STATISTICAL AND ECONOMIC ASPECTS OF RAIL-HIGHWAY GRADE CROSSING SAFETY IMPROVEMENT PROGRAMS IN TEXAS

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The research staff and support staff of several departments within the Texas Transportation Institute contributed to the compilation of data, writing of computer programs, statistical analysis techniques and formulation of methodology used throughout this report.

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ABSTRACT

Texas has approximately 14,000 sites at which railroads intersect public roads and streets. Among these some 800 rail-highway grade crossing accidents occur annually. The accidents result in approximately 100 deaths and 300 injuries to motorists on Texas public roads each year.

In order to reduce the number of accidents that occur at rail-highway intersections, new and improved warning devices at the current train crossbuck installations in Texas would require an initial investment in excess of $120 million. In addition, the estimated annual maintenance outlay would exceed $11 million. Grade separation is considered to be the only sure way to eliminate grade crossing accidents. Based upon the National average of $367,000 per crossing, it would require approximately $4.5 billion to separate all grade crossings in Texas. This sum represents three times the total book value of all railroad property in the state.

A procedure for establishing priorities for grade crossings safety improvement decisions is presented. It provides a framework for the construction of a ranking system or priority index for traffic intersections according to their relative attractiveness as investment alternatives. Given this framework and the rationale implicit within it, those charged with implementation of a safety program may make those changes which best suit their purposes.

SUMMARY

Within the state of Texas there are approximately 14,000 sites at which railroads intersect public roads and streets. At these points a conflict exists between the users of the highway and railway systems. In general, no real problem would exist at these intersections if all warning devices and traffic laws were obeyed. However, for a variety of reasons conflicts in the two traffic streams do occur at these intersections and thus some 800 rail-highway grade crossing accidents occur annually in Texas. These accidents result in approximately 100 deaths and 300 injuries to motorists on Texas public roads each year.

In order to reduce the number of accidents that occur at rail-highway intersections new and improved warning devices at the current train crossbuck installations in Texas would require an initial investment in excess of $120 million. In addition, the estimated annual maintenance outlay would exceed $11 million. Grade separation is considered to be the only sure way to eliminate grade crossing accidents. Based upon the National average of $367,000 per crossing, it would require approximately $4.5 billion to separate all grade crossings in Texas. This sum represents 3 times the total book value of all railroad property in the state.

There are 272 cities and 233 counties in Texas each having at least one public railroad grade crossing. Three major railroads have more than 500 city street and county road grade crossings on their Texas Lines. More than ten thousand railroad grade crossings not under the administration of

the THD are protected only by standard crossbuck signs. This inventory includes 123 non-THD intersections protected by gates and 1256 protected by flashing lights. Although a large portion of the non-THD railroad grade crossings are intersections of single track and one or two traffic lane facilities, the frequency of train operations over these grade crossings may be greater than experienced by THD railroad intersections.

Train speeds over county road-rail intersections is significantly greater than reported for either city street or THD intersection. For example, 73 percent of the county road intersections report train speeds greater than 30 mph while only 36 percent of the city streets and 49 percent of the THD intersections report train speed in this category. The fact that at least 21 percent of the city street intersections and 59 percent of the county road intersections have dirt or gravel roadway approaches suggest that ADT count may be relatively low at many of these intersections.

Data from the Texas Highway Department Log of public rail-highway grade crossings under the administrative responsibility of that agency divulge that more than one-half of these intersections are protected by crossbuck signs only. Although more than one thousand intersections are protected by train actuated warning devices, only 32 have automatic gate installations. Stop signs and flagmen are used very sparingly at THD grade crossings according to the data included in the log.

It is apparent that individual highway districts differ in their criteria for installing rail-highway protective devices. One reason for differing criteria may be the degree of urbanization within a highway district. Data presented in this section show that 60 percent of the THD

Log intersections are located in either urban or incorporated areas. However, more than 75 percent of the actuated protective devices are located in these areas. Individual railroads may also have differing policies toward rail-highway intersection protection. It would appear from data presented in this section of the report that, in general, the larger the railroad company the higher the proportion of actuated vs. non-actuated protective devices installed at the railroad's rail-highway intersection.

When comparison is made between the types of highways most frequently intersected at grade by railroads, it is not surprising that more than 58 percent of the THD grade crossings involve FM roads. However, these intersections have 70 percent of the total crossbuck protected intersections on the state system.

Rail-highway intersections having a) ADT counts of less than one thousand, b) less than five trains per day, c) one or two traffic lanes and d) train speeds less than 50 mph can be expected to have crossbuck sign protective devices only. In general, train actuated warning devices are installed at intersections having a) high ADT count, b) high train volume, c) high volume of trains per day, d) multiple traffic lanes, and e) high train speeds or a combination of these factors.

In an attempt to isolate some of the variables that may contribute to the occurrence of rail-highway accidents, the three principal factors associated with vehicle-train accidents have been discussed in this section of the report, i.e., the driver, the motor vehicle and the train. Although additional information relating to train operations in rail-highway accidents has been presented in other sections of this report, it is sufficient to state that in general the train operation is given and that very little can be done to provide for evasive action on the part of the train, either in its direction or speed of travel. As to the motor vehicle and its driver, several conlcusions may be drawn from the analysis of rail-highway accidents occurring on Texas highways during the period 1962-1966.

a) Tractor-trailer trucks experience a relative higher proportion of the rail-highway accidents than all other classes of motor vehicles.

b) When compared with all other classes of vehicles, tractor-trailer trucks experience a relative higher proportion of rail-highway accidents in urban areas.

c) Most rail-highway accidents occur during day light hours.

d) Approximately thirty percent of the rail-highway accidents occurring on Texas highways were at the intersection of farm-to-market roads and railways within urban areas.

e) The farm product truck may have a higher frequency of rail-highway accident than trucks used in other services.

f) The type of protection installed at rail-highway intersections may not be as effective in the reduction of accidents as often assumed.

g) Drivers over fifty years of age are less aware of hazards at rail-highway intersections than they are of all other types of motor vehicle operation hazards.

h) The condition of the motor vehicle does not appear to be an important factor in the cause of train-vehicle accidents.

i) It does not appear that the use of intoxicants is as significant in rail-highway accidents as generally reported for all motor vehicle accidents.

j) Although failure of a motor vehicle to stop at rail-highway protective devices displaying flashing red lights appears to contribute to these accidents, excessive speed on the approach to the crossings is not reported as a significant contributor to rail-highway accidents.

Each year, approximately 800 rail-highway accidents occur in the state of Texas. Due to reporting requirements, only one-half of these accidents are reported to the Railroad Commission of Texas by the rail carriers. At the time this study was conducted, the research staff only had access to the Railroad Commission accident reports for the period 1965-1967. This section of the report is based upon a summary of 998 accident reports filed by the Texas rail carriers with the Commission during that three-year period.

These 998 accidents resulted in 435 fatalities, 1,093 disabling injuries and 15 permanent disabilities. Accidents on county roads accounted for 10 percent of the accidents, city streets 58 percent, and state highways approximately 32 percent. The higher percent of fatal accidents was experienced by state highways while city streets have the highest percentage of accidents occurring during late evening hours, while county roads have a very low incidence of accidents during late evening and early morning hours. Poor visibility and less than satisfactory driving conditions during the winter months seem to contribute to the increased occurrance of rail-highway accidents during that time of the year.

According to the railroad accident reports, 48 percent of the rail-highway accidents studied were caused by the driver ignoring the protective signal warning. Although only 10 percent of all accidents resulted from drivers braking late, according to the railroad accident reports, over 30 percent of the accidents on county roads were attributed to this cause. This reflects the type of roadway surface and the ability of the driver to view the approaching trains at these intersections.

These reports indicate that almost 73 percent of the accidents involved the simultaneous arrival of the vehicle and train at the interseciton. In more than 18 percent of the accidents, collision occurred after the train occupied the crossing. State highway accidents have a higher percentage of collisions in which the vehicle ran into the side of the train than either county roads or city streets. It is apparent, from data developed during this phase of the study, that considerable improvement in rail-highway safety in Texas may come from improved conditions in the operation of yard engines and local freight trains over public rail-highway intersections.

The procedure for establishing priorities for grade crossing safety improvement decisions as in Chapter 7 of this report should prove quite flexible in practice. Essentially it provides a framework for the construction of a ranking system or priority index for traffic intersections according to their relative attractiveness as investment alternatives. Given this framework and the rationale implicit within it, those charged with implementation of a safety program may make those changes which best suit their purposes.

For example, the components of the accident cost calculation may be changed to reflect the differing weights that might be placed upon the value of a life. Similarly, the cost of protection can be revised to allow for capital recovery factor used in annualizing installation costs. Consideration might also be given to possible delays to vehicles due to a particular type of protection as another cost factor.

The flexibility of the procedure is also evident in the various decision criteria which may be used when employing the priority index. If the funds allocated for the safety program are determined solely on a fixed (legislative or executive) basis, then the problem is one of protecting crossings in descending order of ranking until these funds are exhausted.

However, if the total budget for the program is to be determined on an economic basis, the decision criterion should be to protect all intersections in descending order of ranking until the incremental benefit (marginal reduction in accident cost) equals the incremental cost of added protection (marginal cost). This will insure that net benefits are maximized.

The latter method requires that the cost of accidents include value of future earnings and other indirect costs incurred in both benefit and cost computations.

A third method would be to carry the program to the point that total benefits equal total costs; however, this will not be an optimizing procedure, as is the second method, and may lead to distortions in the allocating of public funds.

It should again be emphasized that the procedure described has not dealt with all of the factors involved in the economic evaluation of safety programs at intersections. Refinements may be made in calculating both the benefits and the costs of increasing the level of protection at such locations. In addition, the effectiveness of the alternative devices and the expected accident rate indices are certainly not perfect measures. Yet it is felt that the procedure described in this paper is sound and that any of the shortcomings mentioned may be easily rectified within this framework.

IMPLEMENTATION REPORT

This report has been prepared at the request of the Texas Highway Department. The purpose of the report is to suggest methods and procedures for implementing the results of the Texas Rail-Highway Grade Crossing study recently submitted to the THD by the Texas Transportation Institute. No attempt has been made to specifically place, within the THD organization, the responsibilities for implementing any of the action programs recommended. However, the projects recommended for implementation are assumed to require THD involvement, either directly or indirectly.

I. Maintain a continuous inventory of all public rail-highway grade crossings under the administrative responsibility of the Texas Highway Department.

Procedure: The Rail-Highway Grade Crossing Log developed during the course of the study would serve as the basis for the inventory. All physical and operational characteristic changes made in THD administered grade crossings would be reflected in the inventory records of each grade crossing. Although sketches, photographs and other hard copy data files may be maintained, the basic data file would be computer adapted.

Activity: It is estimated that 10-20 percent of the THD Log records would require major updating each year. All records would require minimal updating of traffic and train counts.

II. Collect annual data for all rail-highway grade crossing accidents occurring at THD administered grade crossings.

Procedure: The police officer reports of all rail-highway grade crossing accidents are available in the files of the Department of Public Safety. Each accident report would have to be reviewed to determine if the accident occurred on the THD system. Once the accident report is retrieved from DPS records, the Railroad report of that accident could be identified and obtained from the files of the Railroad Commission of Texas. Together these two reports would provide sufficient information to update the accident data required of the overall THD grade crossing program.

Activity: Some 800 railroad grade crossing accidents are reported annually by police officers. Although less than half of these accidents occur on THD facilities, all must be individually reviewed to make this determination. In addition, some 500 records would be required from the files of the Railroad Commission of Texas. Coding, keypunching, and placing accident data with the proper inventory records would require computer staff and facilities.

III. Compute and publish annually a priority rating for all rail-highway intersections under the administration of the THD.

Procedure: The computer program developed by the Texas Transportation Institute and made compatible with Texas Highway Department ADP equipment would serve as the basic tool for computing the annual priority rating. Data developed from updated accident and inventory files would serve as inputs to the priority rating computations.

IV. Install a number-board at each rail-highway intersection on the state system.

Procedure: The number-boards would be fabricated by the THD at a central point and distributed to each district. The railroad company would install the number-board at the grade crossing by attaching it to the warning device located at the crossing. The Department of Public Safety, the Texas Railroad industry, local police officers and Highway Department personnel would be instructed to use the grade crossing identification number in all references to grade crossings on the state system.

V. Update periodically protective device installation and maintenance cost, accident cost, and expected accident equation.

Procedure: Following procedures described in the report each of the items listed above should be updated periodically. It is suggested that this activity be accomplished by special studies assigned to specific personnel within the THD.

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INTRODUCTION

The purpose of this study is to provide the basic information necessary for the improvement of safety conditions at public rail-highway grade crossings in Texas. The primary objectives of the study are:

1. Compile a complete inventory of all public rail-highway grade crossings within the state of Texas.
2. Compile a history and analyze the nature and extent of accidents at Texas rail-highway grade crossings on the state system.
3. Determine methodology and procedures for the development of a predictive model for the assignment of a hazard rating, for various classes of rail-highway grade crossings on the state system.
4. Determination of cost incurred in the installation and maintenance of various types and classes of protective devices.
5. Develop, on the basis of the benefit/cost approach, a priority system for the allocation of public funds for the installation and maintenance of grade crossing protective devices at rail-highway intersections on the state system.
6. Design and adapt to Texas Highway Department Automatic Data Processing equipment a computer routine for the allocation of funds to state and federal grade crossing safety improvement programs.

Background of the Problem

Historically, the cost of providing protective devices at grade crossings has been borne entirely by the railroads. However, the current trend is to finance a part of the improvements from public funds. Justification for this trend is evident as far back as 1935, when the United States Supreme Court stated, in part: ". . . the evidence [thereby] made possible of traffic interruptions incident to crossing at grade is now of far greater importance to the highway users than it is to the railroads crossed."[1] More recently, Henry J. Vinsky, Hearing Examiner, Interstate Commerce Commission, found that:

> . . . highway users are the principal recipients of the benefits flowing from rail-highway grade separations and from special protection at rail-highway grade crossings. For this reason the cost of installing and maintaining such separations and protective devices is a public responsibility and should be financed with public funds the same as highway traffic devices.[2]

The national average for the cost of providing flashing lights at grade crossings is approximately $10,000 to $15,000 for each crossing, and crossing gates require approximately $15,000 to $20,000 for each installation. The maintenance necessary to keep each of these units in proper working order is estimated at $600 to $1,000 per year. It is estimated that in excess of $120 million would be required to install train activated warning devices at the crossbuck installation grade

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[1] Nashville, Chattanooga, and St. Louis Railway v. Walters, Commissioner of Highways, et al., (1935), 55 Sup. Ct., p. 492.

[2] U. S. Interstate Commerce Commission, "Prevention of Rail-Highway Grade-Crossing Accidents Involving Railway Trains and Motor Vehicles," Docket No. 33440, 1963, p. 22.

crossings in Texas. In addition, the estimated annual maintenance outlay would exceed $11 million.

Grade separation is considered to be the only sure way to eliminate grade crossing accidents. Using the national average of $367,000 per crossing, it would require approximately $4.5 billion to separate all grade crossings in Texas. This sum represents 3.1 times the total book value of all railroad property in the state.[3]

Under the Federal Aid Highway Act, federal funds are being made available for the elimination of grade crossing hazards on Federal Aid Highways. Through 1960 the U. S. Bureau of Public Roads had participated in the reconstruction of 1,100 structures, elimination of 7,000 crossings, and the protection of nearly 10,000 crossings at a total cost of $1.45 billion, $1.16 billion of which came from Federal funds. Only about one-quarter of the 2,656,000 miles of this nation's roads and streets, however, are on the Federal Aid Highway System. Consequently, about 75 percent of the highway and street mileage on which grade crossing problems arise are not within the Federal Aid Projects.[4]

Evidence that the cost of providing some of the protection at grade crossings is a responsibility of state and local governments can be noted by the programs undertaken by twenty-nine states including the state of Texas. Although the details of these programs are too varied to categorize, the main points contained in all of them are: (1) A grade crossing fund

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[3] Ibid., p. 4.

[4] Ibid., p. 16.

is established from public monies, and (2) A method is developed for identifying the grade crossings with the greatest accident potential.

Within the state of Texas there are approximately 14,000 sites at which railroads intersect public roads and streets. At these points a conflict arises between highway and railway vehicles, as travel on one system interferes with the other.[5] By law, the right of way is granted to the railroads. If the law was obeyed by the motoring public, no real problem would exist. However, for a variety of reasons, motorists fail to yield the right of way to rail traffic at these intersections; and thus some 800 rail-highway grade crossing accidents occur annually in Texas. The results of these accidents is approximately 100 deaths and 300 injuries to motorists on Texas public roads each year.[6]

Due to the number of accidents, Texas' accident experience at grade corssings is greater than the national average. Figure 1 (Appendix A) shows the ratio of vehicle registrations to the number of accidents occurring at crossings for both Texas and the United States. Not only is the Texas accident rate, per million vehicles registered, greater than the national average, but also the rate of decline in the ratio of accidents to registered vehicles is more significant in the national averages than in the ratios compiled for Texas. Figure 2

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[5]Donald G. Newnan, An Economic Analysis of Railway Grade Crossings on the California State Highway System, Report Engineering-Economic Planning, Number 16 (Palo Alto; Stanford University, 1965), p. 2.

[6]Data compiled from: Texas Department of Public Safety, Motor Vehicle Traffic Accidents, 1964, p. 4; Railroad Commission of Texas, Seventy-Fourth Annual Report, Railroad Statistical Section, Table 13; and U. S. Interstate Commerce Commission, Rail-Highway Grade Crossing Accidents, 1964, p. 3.

shows the decline in this state's railroad train miles as compared to the increase in annual vehicle miles during the period 1954-1965. The increase in annual vehicle miles during this period is approximately 50 percent, while annual train miles have decreased some 23 percent. Figure 3 shows the relationship between annual vehicle registration for the United States as compared with annual train miles. There appears to be a similar relationship between the data presented by this graph and those shown in Figure 2. Although accident rates during this twelve-year period have been rather erratic, the overall trend line indicates only a 3 percent decrease in this measure of accident frequency.

With an increasing number of motor vehicles generating an increasing number of vehicle miles, it is expected that accidents at rail-highway grade crossings would tend to increase. This trend, however, should be offset by reduction in train miles (train frequency). As shown by Figure 4, the Texas grade crossing accident records do not bear out these assumptions. The population in Texas for 1985 has been projected as 51.8 percent above the 1960 level.[7] Although the additional number of automobiles and licensed drivers that will result from this increase is not known, it seems reasonable to expect that the number will be much higher than the present level of 4.4 million automobiles and 5.5 million licensed drivers.[8] Also, indications are that the present accident rate will increase unless an effort is made to eliminate the causes of grade crossing accidents.

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[7] U. S. Bureau of the Census, Current Population Reports, "Illustrative Projections of the Population of States: 1970 to 1985," Table 5, p. 28.

[8] Texas Department of Public Safety, Motor Vehicle Traffic Accidents, op. cit., 1965, p. 4

Significance of the Problem

Past studies have shown that accidents can be reduced at grade crossings by the installation of train activated protective devices and by the elimination of hazardous conditions in the adjacent area.[9] However, in situations where only a limited amount of funds for improvements are allocated, decisions must be made regarding what crossings should be given priority in the program, and how the money should be spent. Hazard ratings have proved valuable in obtaining the maximum protection for a given expenditure.[10] Eighteen states are using formulas for this purpose, and all make provisions for considering the daily volume of vehicular and train movements.[11] The other factors used include such items as weather, topography, and other physical features unique to the specific area. In most of these studies, the values assigned to the different factors are based on the opinions of the various highway departments, and therefore the weights contributed by similar factors are not equal.[12] Because of the lack of information on grade crossings in Texas, highway engineers in this state, prior to the study being reported, did not have a suitable formula for the establishment of a hazard rating index.

In order to provide the Texas Highway Department with a procedure

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[9]Newnan, op. cit., p. 2

[10]L. E. Peabody and T. B. Dimmick, "Accident Hazard at Grade Crossings," Public Roads, XXII (August, 1941), 123.

[11]American Railway Engineering Association, "Methods of Classifying Highway-Railway Crossings with Respect to Public Safety," Proceedings (1949), p. 244.

[12]Ibid., p. 247

for allocating public funds, for the installation and maintenance of rail-highway grade crossing protective devices, several sub-tasks had to be accomplished. The remaining Chapters of this report describe the study procedure developed and implemented to achieve a priority rating system for rail-highway grade crossing protection in Texas.

A review of previous studies conducted by city, state and federal agencies, for the purpose of computing hazard indexes, is provided in Appendix B.

CHAPTER I

INVENTORY OF RAIL-HIGHWAY GRADE CROSSINGS IN TEXAS

In order to provide the basic data for an inventory of all public rail-highway grade crossings within the state of Texas, the Texas Railroad Association was approached with a request for participation in this phase of the study. In late 1966 a meeting of the Association's grade crossing committee and Transportation Institute staff was held in Dallas, Texas. At this meeting the railroad companies agreed to conduct the inventory of grade crossings. Also during the meeting the design of the inventory data card, procedures for conducting the inventory, and railroad contact representatives were agreed upon.

The next step in this phase of the study was to review the design of the inventory data card and procedures for conducting the inventory with members of the Texas Highway Department Project Advisory Committee. As a result of this review some minor changes were made in the basic format of the inventory card and additional items pertaining to the type of material between the tracks were added.

Prior to having the inventory cards printed, instructions for completing each item on the inventory card were prepared. Also the format of the card was arranged so as to allow quick and accurate recovery of the data during keypunch operations.

Figure 1 is a facsimile of the 5 x 7 card that was printed and made available to 27 railroad companies operating within the state of Texas.

FIGURE 1

TEXAS RAIL-HIGHWAY GRADE CROSSING INVENTORY (1) DATE____________

(2) NAME OF RAILROAD____________ (3) SUBDIVISION____________ (Or Branch) (4) MILEPOST____________ Miles Tenths

(5) COUNTY____________ (6) CITY____________ (7) NEAREST CITY____________ Miles

(8) HIGHWAY NUMBER OR STREET NAME____________ (9) NUMBER OF HIGHWAY TRAFFIC LANES____________

(10) TYPE OF HIGHWAY SURFACE

☐ Concrete ☐ Brick
☐ Black Top ☐ Dirt
☐ Gravel ☐ Unknown

(11) TYPE MATERIAL BETWEEN TRACKS

☐ Wood ☐ Steel Rails
☐ Asphalt ☐ Other

(12) NUMBER OF TRACKS

____Main Tracks (No) ____Siding (No)
____Spur (No) ____Wye (No)
____Lead Track (No) ____ ________ (No) (Other)

(13) TYPE & NUMBER OF PROTECTIVE DEVICES

____Crossbucks (No) ____Flashing Lights (No) ____Watchman (No)
____Crossbucks (Reflectorized) (No) ____Bells (No) ____Automatic Gates (No)
____Stop Sign (No) ____Wigwags (No) ____Illumination (No)
____Advanced Highway Flashing Warning Signal (No) (Not Located on Railroad Right of Way)

(14) NUMBER OF TRAINS DAILY ☐

(15) SPEED OF TRAIN AT CROSSING ☐

See Reverse Side for Instructions for Completing this Form

GENERAL INSTRUCTIONS

I. This card is to be completed for each public crossing. A public crossing is defined as a crossing where the city, county, or state maintains the roadway that intersects the railroad.

II. A rail-highway intersection will be defined as a grade crossing where one or more tracks intersect a public roadway and is protected by at least one protective device installation. Where tracks are separated by more than 100 feet, each intersection will be defined as a grade crossing regardless of the location of the protective device.

INSTRUCTIONS FOR COMPLETING REVERSE SIDE

1. Month and year card is completed.
2. Abreviated name of railroad will be sufficient.
3. Full name of subdivision or branch.
4. Give milepost nearest to crossing plus distance to crossing in tenths of mile.
5. Name of county in which crossing is located.
6. Name of city, or nearest city, if crossing is located in a rural or suburban area.
7. Approximate distance to nearest city if crossing is located in a rural or suburban area.
8. Highway number or name of street. Give both if crossing is located on highway within a city.
9. Total number of highway traffic lanes at the crossing.
10. Check in the appropriate space for highway surface approaching the crossing.
11. Check in the appropriate space for type of material between tracks.
12. Indicate total number of tracks in appropriate box for the categories listed.
13. Indicate total number of installations on both sides of the crossing in appropriate box for the categories listed.
14. Average number of trains passing through crossing during any 24 hour period.
15. Posted speed limit for trains at or approaching the crossing.

The number of crossings to be inventoried by these companies ranged from 5, for a small East Texas line, to over 3300 for a Class I carrier with trackage in more than 50 Texas counties.

Texas Rail-Highway Grade Crossings

Figure 1, referred to previously, illustrates the type of information that was collected for completing the inventory. It is noted that all of the information could be obtained by an employee of the railroad either from company records or during a short visit to each of the crossings.

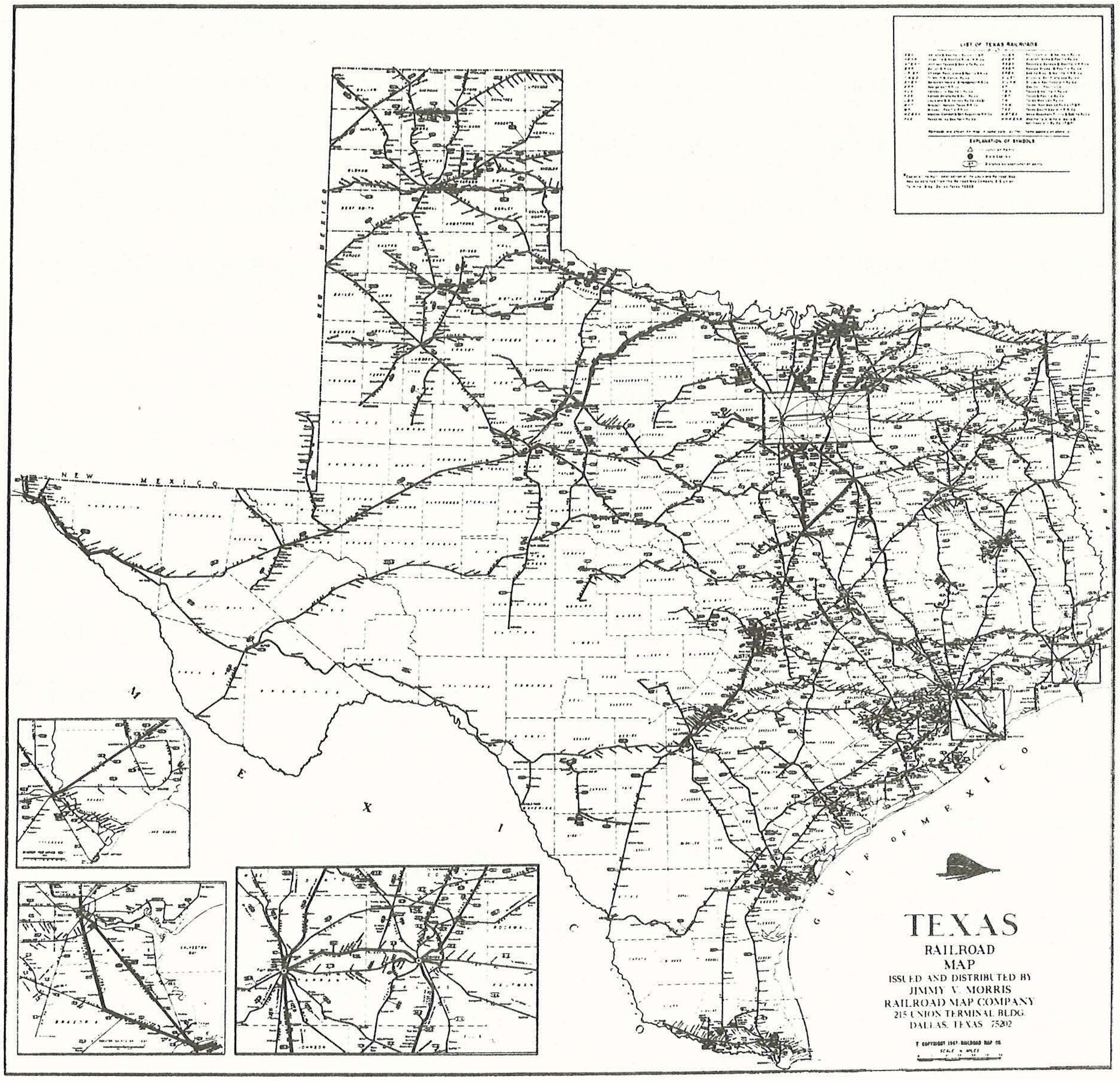
Although tables have been constructed for each of the items included on the inventory card for the purpose of this report, only selected tables are presented. The crossings were first classified according to administrative responsibility, e.g., state, county and city. The next two sections of this Chapter will report inventory data according to the location of the grade crossing, either on or off the state highway system.

Figure 2 is a Texas railroad map indiciating the extent of railroad mileage and the geographic distribution of railroads within the state.

At the time the inventory was completed there were 14,186 public rail-highway crossings in the state of Texas. Of these 2,442 were located on the state highway system, 6,486 on city streets and 5,258 on county roads.*

*Note: These figures represent the final rail-highway crossing inventory. The Highway Department log of grade crossings shows 2,442 crossings on the state highway system. The preliminary inventory, from which the sample presented in Chapter 5 was drawn, showed 1,481 crossings. See page 89 of this report.

FIGURE 2



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Inventory of Texas Highway Department Rail-Highway Grade Crossings

The purpose of this section of the report is to provide information as to physical and operational characteristics of rail-highway grade crossings under the administrative responsibility of the Texas Highway Department. Although the basic data for this section of the report were obtained during the initial inventory of grade crossings, the information reported here is taken from the THD rail-highway grade crossing log.

Table 1 shows the distribution of grade crossings on the state system by THD districts. There are 2,442 rail-highway grade crossings under the administrative responsibility of the THD. District 12, with 7.5 percent of the total, has the most crossings in the state. Districts 22 and 24 each have 1.3 percent of the total for the fewest number of crossings. While the distribution of crossings is relatively constant in most districts, East Texas appears to have a higher percent of crossings than West Texas districts.

Table 1 — Inventory of Public Grade Crossings In Texas By THD Districts

District	Number	Percent	District	Number	Percent
1	137	5.6	13	113	4.6
2	94	3.9	14	101	4.1
3	63	2.6	15	96	3.9
4	111	4.6	16	113	4.6
5	167	6.8	17	91	3.7
6	46	1.9	18	141	5.8
7	41	1.7	19	60	2.4
8	116	4.8	20	134	5.5
9	92	3.8	21	171	7.0
10	106	4.3	22	31	1.3
11	76	3.1	23	53	2.1
12	183	7.5	24	31	1.3
			25	75	3.1
			Total	2442	100.0%

Table 2 shows the distribution of THD grade crossings by type of protective device. Over 55 percent of the crossings are protected by crossbucks only. This type of device has no train activated warning system and basically serves the same purpose as that of a traffic sign. Flashing lights are installed at 41.4 percent of the crossings. Gates are used as protective devices at 1.3 percent of the crossings, while bells, wigwags, stopsigns and flagmen each represent less than 1 percent of the total protective devices. More than one-half of the protective devices place the responsibility of determining approaching trains on the driver, while some 45 percent of the crossings are protected by devices activated by the approaching train.

Table 2 — Distribution of Public Grade Crossings On The State System By Protective Devices

Protective Devices	Number	Percent
Crossbucks	1363	55.8
Flashing Lights	1012	41.4
Bells	4	.2
Wigwags	20	.8
Gates	32	1.3
Stopsign	7	.3
Flagman	4	.2
Total	2442	100.0%

The location of public grade crossings in Texas is shown in Table 3. Urban areas account for 14 percent of the THD grade crossings, thirty-five percent of the crossings are located in rural areas and 51 percent are located in incorporated areas.

Table 3	Distribution of Public Grade Crossings On The State System By Location	
Location	Number	Percent
Urban	336	14.0
Rural	859	35.0
Incorporated	1247	51.0
Total	2442	100.0%

Table 4 shows the distribution of public grade crossings by Average Daily Traffic count. More than 60 percent of the crossings are located on facilities with an ADT count of 2000 or less vehicles with more than 25 percent of the crossings located on facilities with an ADT of between 101 and 500. Only one percent of the crossings are located on highways with an ADT count of over 25,000.

Table 4 — Distribution of Public Grade Crossings On The State System By ADT Count

ADT Count	Number	Percent	ADT Count	Number	Percent
0-100	114	4.7	8001-9000	39	1.6
101-500	615	25.2	9001-10000	37	1.5
501-1000	384	15.7	10001-12000	48	2.0
1001-2000	369	15.1	12001-14000	23	.9
2001-3000	211	8.6	14001-16000	23	.9
3001-4000	137	5.6	16001-18000	17	.7
4001-5000	119	4.9	18001-20000	18	.7
5001-6000	87	3.6	20001-22500	15	.6
6001-7000	87	3.6	22501-25000	4	.2
7001-8000	71	2.9	25001 and over	24	1.0
			Total	2442	100.0%

The type of highway facility on which the public crossings are located is shown in Table 5. The majority of public grade crossings, 57.7 percent are located on Farm to Market roads, while 16.8 percent of the crossings are on state highways, and 16 percent on U. S. Highways. Only 2.1 percent of the crossings are found on the Interstate Highway System. Designated loop highways have 5.6 percent of the grade crossing locations on the state system.

Table 5 — Distribution of Public Grade Crossings On The State System By Type of Highway

Type of Highway	Number	Percent
Farm to Market	1410	57.7
Interstate Highway	50	2.1
Loop	137	5.6
State Highway	410	16.8
U. S. Route	390	16.0
Other	45	1.8
Total	2442	100.0%

Table 6 shows the distribution of public grade crossings by the number of traffic lanes on the facility. More than 85 percent of the crossings are located on one or two lane highways, while some 13 percent are on highways with 3 and 4 traffic lanes.

Table 6 — Distribution of Public Grade Crossings On The State System By Traffic Lanes

Number of Traffic Lanes	Number	Percent
1-2	2081	85.2
3-4	328	13.4
More than 4	33	1.4
Total	2442	100.0%

The distribution of public grade crossings by the number of other tracks is shown in Table 7. Single line tracks represent 53.2 percent of the crossings in Texas. The distribution between single and multiple track grade crossings is significant to current maintenance cost reimbursement policy of the THD.

Table 7 Distribution of Public Grade Crossings On The State System By Number of Tracks

Tracks	Number	Percent
Single	1300	53.2
Multiple	1142	46.8
Total	2442	100.0%

Table 8 shows the distribution of public grade crossings in Texas by material between tracks. Over 75 percent of the crossings have wood between the tracks. Asphalt is used between the tracks at 19.8 percent of the crossings. Steel rails and other material is used at 5 percent of the public grade crossings.

Table 8 Distribution of Public Grade Crossings On The State System By Material Between Tracks

Materials Between Tracks	Number	Percent
Wood	1835	75.1
Asphalt	484	19.8
Steel Rails	5	.2
Others	118	4.8
Total	2442	100.0%

The number of trains per day over public grade crossings is shown in Table 9. Sixty-nine percent have five or less trains per day using the crossing. Over 26 percent of the grade crossings are used by between 6 and 10 trains per day. The remaining 4.8 percent of crossings in the state have more than 10 trains per day passing over them. The high train volume crossings are used primarily for switching traffic.

Table 9 Distribution of Public Grade Crossings On The State System By Number of Trains Per Day

Number of Trains Per Day	Number	Percent
0-5	1679	69.0
6-10	645	26.2
11-15	75	3.0
16-20	22	1.0
More than 20	21	0.8
Total	2442	100.0%

Table 10 shows the distribution of trains speeds over the public grade crossings in the state. At 20.8 percent of the crossings the train speed is 10 mph or less. Trains at speeds of between 11 to 20 mph and 21 to 30 mph travel over 15.5 and 14.3 percent of the crossings. Over 50 percent of the crossings have a train speed of less than 31 mph and at 10 percent of the crossings the train speed is more than 60 mph.

Table 10 — Distribution of Public Grade Crossings On The State System By Train Speed

Train Speed	Number	Percent
0-10	508	20.8
11-20	379	15.5
21-30	350	14.3
31-40	441	18.1
41-50	343	14.1
51-60	176	7.2
61-70	123	5.0
Over 70	122	5.0
Total	2442	100.0%

Inventory of City Street and County Road Railroad Grade Crossings.

The purpose of this section of the report is to provide information as to the number of public railroad grade crossings located at the intersection of city streets and county roads within Texas. Additionally, the physical and operational characteristics of these crossings will be discussed.

The inventory of all public railroad grade crossings in Texas is the sole data source for this section of the report. Since the study of railroad grade crossings not under the administration of the Texas Highway Department was not an objective of the project being reported, these data are presented here for information purposes only. No attempt has been made to analyze the data or draw conclusions from the tabular information included in this section of the report.

There are 272 cities in Texas having at least one public rail-city street intersection. The cities of Houston, Dallas, San Antonio, Fort Worth, Lubbock, Waco and Beaumont each have more than 100 rail-city street intersections under their administrative responsibility. From Table 11 it may be noted that eighteen cities in Texas have more than 50 public grade crossings under their administrative responsibility. The total number of rail-city street intersections in just 18 cities is larger than the total number (2442) of rail-highway intersections under the administrative responsibility of the THD. The varying size of these political sub-divisions involved in grade crossing protection is also evident from Table 11. For example, more than 180 Texas cities each have ten or less rail grade crossings under their administrative responsibility.

Table 11 Cities in Texas With One or More Public Grade Crossings Not on the State System

Number of Crossings	Number
1-5	90
6-10	91
11-25	51
26-50	22
51-75	7
76-99	4
100 or more	7
Total Number of Cities	272

Although not shown in tabular form, the grade crossing inventory records reveal that 233 of the 254 Texas counties have at least one public rail-highway grade crossing. From these data it can be determined that, in addition to the Texas Highway Department (the state), there are more than 500 individual political sub-divisions that the railroads of Texas may become involved with in matters having to do with the installation and maintenance of warning devices at public railroad grade crossings.

Four Texas railroads, AT&SF, MKT, MoPac and the S.P. have more than 500 city street intersections within Texas. Three of these rail carriers have more than 500 intersections with county roads in Texas.

At the time the inventory was completed, there were 6486 city street-rail intersections and 5258 county road-rail intersections within Texas. Table 12 shows the distribution of these intersections by type of protective device installed at the grade crossings. More than <u>ten</u> <u>thousand</u> railroad grade crossings not under the administration of the THD are protected only by the standard crossbuck sign. This represents more than 96 percent of the rail-county road intersections and over 76 percent of the rail-city street intersections. Only 17.6 percent of the city street-rail intersections and 2.2 percent of the county road-rail intersections are protected by flashing lights; however, 119 rail-city streets have gate protection as compared to 32 rail-highway (THD) intersections. Stopsigns, bells, and wigwags are more frequently used at these intersections than reported for THD rail-highway intersections.

Table 12 Distribution of Public Grade Crossings In Texas Not On The State System By Protective Device

Type of Protection Device	City Streets		County Roads		Total	
	Number	Percent	Number	Percent	Number	Percent
Crossbucks (Reflectorized and Standard)	4961	76.5	5054	96.1	10015	85.3
Flashing Lights	114	17.6	115	2.2	1256	10.7
Bells	26	.4	9	.2	35	.3
Wigwags	125	1.9	19	.4	144	1.2
Stop Signs	102	1.6	57	1.0	159	1.3
Gates	119	1.8	4	.1	123	1.1
Flagman*	12	.2	-	-	12	.1
Total	6486	100.0%	5258	100.0%	11744	100.0%

* Protected by member of train crew while train is passing through crossing.

According to the data shown in Table 13, most of the railroad grade crossings are located on one or two traffic lane roadways. More than 36 percent of the rail-county road intersections are single traffic lane facilities. Single track grade crossings account for 56 percent of all rail-city street intersections. However, from Table 14, it will be noted that almost 88 percent of the rail-county road intersections have single track railroad facilities. This compares to 53.2 percent of THD rail-highway intersections having single track facilities.

Table 13 — Distribution of Public Grade Crossings In Texas Not on The State System By Number of Traffic Lanes

Number of Traffic Lanes	City Streets		County Roads		Total	
	Number	Percent	Number	Percent	Number	Percent
1	739	11.4	1922	36.6	2661	22.7
2	4865	75.0	3178	60.4	8043	68.5
3	37	.6			37	.3
4	571	8.8	13	.2	584	5.0
4 or more	66	1.0			66	.5
Unknown	208	3.2	145	2.8	353	3.0
Total	6486	100.0%	5258	100.0%	11744	100.0%

Table 14 — Distribution of Public Grade Crossings In Texas Not on The State System By Multiple or Single Tracks

Number of Tracks	City Streets		County Roads		Total	
	Number	Percent	Number	Percent	Number	Percent
Single	3632	56.0	4611	87.7	8243	70.2
Multiple	2854	44.0	647	12.3	3501	29.8
Total	6486	100.0%	5258	100.0%	11744	100.0%

Although the number of city street and county road rail-grade crossings reporting less than five trains per day operating through the intersection is reported to be 6805 (Table 15), train movements at city street county road crossings may occur relatively more frequently than reported for THD rail-highway intersections. For example, 69 percent of the THD intersections reported less than five trains per day, while less than 5 percent reported more than 10 trains per day. From Table 15 it will be noted that 19 percent of the city street intersections and 18 percent of the county road intersections reported more than 10 train operations each day.

Table 15 Distribution of Public Grade Crossings In Texas Not On The State System By Number of Trains Per Day

Number of Trains Per Day	City Streets		County Roads		Total	
	Number	Percent	Number	Percent	Number	Percent
0-5	3757	58.0	3048	58.0	6805	57.9
6-10	1496	23.0	1265	24.0	2761	23.5
11-15	676	10.4	631	12.0	1307	11.1
16-20	293	4.6	209	4.0	502	4.3
21-25	101	1.6	34	.6	135	1.2
26-40	97	1.4	71	1.4	168	1.4
Over 40	66	1.0	--	--	66	.6
Total	6486	100.0%	5258	100.0%	11744	100.0%

Table 16 provides an excellent account of the difference in train speeds operating over urban vs. rural crossings. Twenty percent of the city street intersections reported train speeds of ten miles an hour or less. Only 194 (3.8 percent) of the county roads reported train speeds in this mph class. Many of these intersections are probably located in urban areas. The difference in train operating speed is more prominent when a comparison is made of percentage of intersections reporting train speeds greater than 30 mph. For example, over 73 percent of the county road intersections fall in this category while only 36.4 percent of the city streets are in this mph class.

Table 16 — Distribution of Public Grade Crossings In Texas Not On The State System By Average Train Speed

Average Train Speed	City Streets		County Roads		Total	
	Number	Percent	Number	Percent	Number	Percent
1-10	1179	20.0	194	3.8	1373	12.3
11-20	1686	27.6	370	7.1	2056	18.3
21-30	961	16.0	835	16.0	1796	16.0
31-40	752	12.4	1268	24.5	2020	18.0
41-50	676	11.2	953	18.4	1629	14.5
51-60	378	6.2	644	12.5	1022	9.1
61-70	175	3.0	409	7.9	584	5.2
71-80	201	3.3	477	9.1	678	6.0
81-90	24	.3	38	.7	62	.6
	6032*	100.0%	5188*	100.0%	11220	100.0%

* Information not available for 454 crossings on City Streets and 70 crossings on County Roads.

The type of roadway surface at the grade crossings located on city streets and county roads is shown in Table 17. At least 21 percent of the city street intersections and 59 percent of the county roady intersections have either gravel or dirt roadway surface on the approach. Although more than 4600 city street intersections report hard surface roadway approaches, only 1225 of the 5258 county road intersections report roadway approaches in this category.

Table 17 — Distribution of Public Grade Crossings In Texas Not On The State System By Type of Roadway Surface

Type of Surface	City Streets		County Roads		Total	
	Number	Percent	Number	Percent	Number	Percent
Concrete	586	9.0	22	.4	608	5.2
Blacktop	4035	62.2	1203	22.9	5238	44.6
Brick	188	2.9	288	5.5	476	4.0
Gravel	975	15.0	1685	32.1	2660	22.7
Dirt	406	6.3	1453	27.6	1859	15.8
Other	209	3.2	212	4.0	421	3.6
Unknown	87	1.4	395	7.5	482	4.1
Total	6486	100.0%	5258	100.0%	11744	100.0%

SUMMARY

A study of city street and county road rail grade crossings not under the administrative responsibility of the Texas Highway Department was not an objective of the project being reported. However, all public grade crossings were included in the original Texas rail-highway grade crossing inventory; therefore, city street and county road intersections may be reported, in the aggregate, for information purposes only.

There are 272 cities and 233 counties in Texas each having at least one public railroad grade crossing. Three major railroads have more than 500 city street and county road grade crossings on their Texas lines. More than ten thousand railroad grade crossings not under the administration of the THD are protected only by standard crossbuck signs. This inventory includes 123 non-THD intersections protected by gates and 1256 protected by flashing lights. Although a large portion of the non-THD railroad grade crossings are intersections of single track and one or two traffic lane facilities, the frequency of train operations over these grade crossings may be greater than experienced by THD railroad intersections.

Train speeds over county road-rail intersections is significantly greater than reported for either city street or THD intersection. For example, 73 percent of the county road intersections report train speeds greater than 30 mph while only 36 percent of the city streets and 49 percent of the THD intersections report train speed in this category. The fact that at least 21 percent of the city street intersections and 59 percent of the county road intersections have dirt or gravel roadway approaches suggest that ADT count may be relatively low at many of these intersections.

CHAPTER 2

THE INSTALLATION OF PROTECTIVE DEVICES AT THD ADMINISTERED RAIL-HIGHWAY INTERSECTIONS

The purpose of this section of the report is to provide information as to the type of protective devices currently installed at rail-highway intersections included in the THD log. The data reported here were derived from the basic inventory records developed by the railroad companies and the THD as an objective of the project. To facilitate data reporting, the protective devices are categorized in the following manner:

Class 1 - Crossbucks

Class 2 - Lights, Bells and Wigwags

Class 3 - Gates

Class 4 - Stop Signs and Flagmen

The distribution of protective device installations according to THD districts is shown in Table 18. More than one-half of the THD administered grade crossings are protected by crossbuck signs only. Although more than one thousand THD grade crossings are protected by train actuated devices, only 32 were protected by automatic gates at the time the inventory was made. As shown in the table, stop signs and flagmen are not frequently used to provide protection at THD rail-highway intersections.

Without constructing each of the 25 THD districts as to vehicular traffic and train operations within each district, only general observations can be made of the data in Table 18. For example, in districts 1, 4, 5, 7,

TABLE 18

Inventory of Protective Devices On
The State System by Highway District

District	Protective Device								Total
	Class 1		Class 2		Class 3		Class 4		
	No.	%	No.	%	No.	%	No.	%	
1	102	7.5	35	3.4					137
2	44	3.2	45	4.3	3	9.3	2	18.2	94
3	44	3.2	19	1.7					63
4	72	5.3	33	3.2	6	18.8			111
5	113	8.3	53	5.1	1	3.1			167
6	19	1.4	24	2.3	2	6.3	1	9.1	46
7	29	2.1	12	1.7					41
8	67	4.9	48	4.6	1	3.1			116
9	55	4.0	36	3.5			1	9.1	92
10	54	4.0	47	4.5	1	3.1	4	36.3	106
11	52	3.8	23	2.2	1	3.1			76
12	72	5.3	109	10.5	2	6.3			183
13	66	4.8	47	4.5					113
14	50	3.7	48	4.6	1	3.1	2	18.2	101
15	46	3.4	44	4.3	6	18.8			96
16	59	4.3	54	5.2					113
17	43	3.2	47	4.5	1	3.1			91
18	76	5.6	63	6.1	1	3.1	1	9.1	141
19	28	2.1	30	2.9	2	6.3			60
20	64	4.7	68	6.6	2	6.3			134
21	93	6.8	77	7.4	1	3.1			171
22	20	1.4	11	1.1					31
23	34	2.5	19	1.7					53
24	5	0.4	25	2.4	1	3.1			31
25	56	4.1	19	1.7					75
Total	1363	100.0	1036	100.0	32	100.0	11	100.0	2442

11, and 25 the number of crossings protected by Class 1 protective devices is at least twice the number of crossings protected by Class 2 devices. However, in districts 2, 6, 12, 15, 17, 19, 20 and 24, the number of train actuated devices is equal to or greater than the number of crossbuck protected crossings in each district. It would appear, from data presented in this table, that there currently exists differing criteria for the protection of rail-highway intersections among THD districts.

It may be seen from Table 19 that 60 percent of the THD administered intersections are located in either urban or incorporated areas. The relative degree of protection at intersections located in these areas differ significantly from those located in rural areas. For example, 75 percent of the Class 2 protected crossings and 87 percent of the crossings protected by gates are located in either urban or incorporated areas. Only 60 percent of the crossbuck protected crossings are located in these areas. The urban area use of stop signs and flagmen for rail-highway intersection protection is also shown in Table 19.

More than 55 percent of all THD administered grade crossings are located on just three railroads; the Southern Pacific, Sante Fe and Missouri Pacific. From Table 20 it will be noted that these three companies also account for almost 64 percent of the Class 2 protected crossings and 75 percent of the crossings protected by gates. Seventeen railroad companies reported 10 or less intersections with THD facilities. Based upon data presented in Table 20, it would appear that the larger railroad companies have a greater than proportionate share of the train actuated protective crossings.

TABLE 19

Inventory of Protective Devices
On the State System in Texas
By Location

	Protective Devices								
	Class 1		Class 2		Class 3		Class 4		Total
Location	No.	%	No.	%	No.	%	No.	%	
Urban and Incorporated	725	60.5	777	75.0	28	87.5	8	80.0	1,538
Rural	638	39.5	259	25.0	4	12.5	3	20.0	904
Total	1,363	100.0	1,036	100.0	32	100.0	11	100.0	2,442

TABLE 20

Inventory of Protective Devices on the State System by Railroad Company

Railroad Company	Protective Device								
	Class 1		Class 2		Class 3		Class 4		Total
	No.	%	No.	%	No.	%	No.	%	
Southern Pacific Company	307	22.5	235	22.6	7	21.9	2	18.2	551
Atchison, Topeka and Santa Fe Railway Company	298	21.8	214	20.7	9	28.1			521
Missouri Pacific Railroad Company	184	13.5	210	20.2	2	6.3	2	18.2	398
Missouri-Kansas-Texas Railroad Company	125	9.2	74	7.1	5	15.6	1	9.1	205
Fort Worth & Denver Railway Company	114	8.4	41	4.0					155
Texas & Pacific Railway Company	58	4.3	81	7.8	8	25.0	3	27.2	150
St. Louis Southwestern Railway Company	66	4.8	48	4.6			2	18.2	116
Chicago, Rock Island and Pacific Railroad Company	47	3.5	20	1.9	1	3.1			68
Louisiana and Arkansas Railway Company	26	1.9	10	1.0					36
Texas Mexican Railway Company	14	1.0	22	2.0					36

Inventory of Protective Devices on the State
System by Railroad Company
(Continued)

Railroad Company	Protective Device: Class 1 No.	Class 1 %	Class 2 No.	Class 2 %	Class 3 No.	Class 3 %	Class 4 No.	Class 4 %	Total
Kansas City Southern Railway Company	17	1.3	12	1.1					29
St. Louis-San Francisco Railway Company	15	1.1	8	0.8					23
Quanah, Acme and Pacific Railway Company	12	0.9	5	0.5					17
Other*	80	5.8	56	5.7			1	9.1	137
Total	1363	100.0	1036	100.0	32	100.0	11	100.0	2442

* All railroad companies having 10 or less rail-highway intersections are included in this category.

Table 21 indicates that approximately 58 percent of the THD rail-highway intersections are located on FM roads. State highways and U. S. highways account for some 33 percent of the intersections leaving less than 10 percent to be distributed among other facilities administered by the THD. Farm-to-Market roads have 70.6 percent of the total crossbuck protected crossings, however, only 41.1 percent of Class 2 and 53.2 percent of Class 3 protective devices are located at FM roads-railroad intersections. On the other hand, U. S. and State highways have 46.2 percent of total Class 2 and 25 percent of total Class 3 protected intersections. Data presented in Table 21 suggest that FM road-railroad grade crossings in Texas have less than their proportionate share of the rail-highway train actuated protective devices.

Table 22 shows the distribution of protective devices by average daily traffic count (ADT). The most relevant observation that can be made from data presented in this table is the fact that beyond the 1000 ADT count group the proportion of actuated protective devices (Class 2 and 3) to crossbuck protected crossings is greater for all ADT count groups. In another comparison, approximately 60 percent of the Class 1 devices are located at intersections with ADT counts less than one thousand. Only 26 percent of the Class 2 devices and 31 percent of the Class 3 devices are located at intersections having less than one thousand ADT count.

The distribution of protective devices on the state system by number of trains per day is shown in Table 23. These data indicate that most of the crossings protected by cross bucks have 10 or less trains per day using the intersection. Additionally, the data suggest that this type of device

TABLE 21

Inventory of Protective Devices On
State System by Type of Highway

Type of Highway	Protective Device: Class 1 No.	%	Class 2 No.	%	Class 3 No.	%	Class 4 No.	%	Total
FM	962	70.6	425	41.1	17	53.2	6	54.5	1410
IH	12	0.9	32	3.1	5	15.6	1	9.1	50
LP	57	4.2	77	7.4	1	3.1	2	18.2	137
SH	149	10.9	255	24.6	5	15.6	1	9.1	410
SP	18	1.3	23	2.2	1	3.1			42
US	163	11.9	224	21.6	3	9.4			390
Other	2	0.2					1	9.1	3
Total	1363	100.0	1036	100.0	32	100.0	11	100.0	2442

TABLE 22

Inventory of Protective Devices
On the State System
by ADT Count

	Protective Devices								
	Class 1		Class 2		Class 3		Class 4		
ADT Count	No.	%	No.	%	No.	%	No.	%	Total
0 - 100	82	6.0	30	2.9	1	3.1	1	9.1	114
101 - 500	501	36.7	109	10.5	2	6.3	3	27.2	615
501 - 1000	242	17.7	135	13.0	7	21.9			384
1001 - 2000	182	13.4	181	17.7	4	12.5	2	18.2	369
2001 - 3000	87	6.4	117	11.2	6	18.8	1	9.1	211
3001 - 4000	55	4.0	79	7.6	3	9.4			137
4001 - 5000	49	3.6	69	6.6	1	3.1			119
5001 - 6000	33	2.4	54	5.1					87
6001 - 7000	34	2.5	52	5.0	1	3.1			87
7001 - 8000	18	1.3	52	5.0			1	9.1	71
8001 - 9000	12	0.9	24	2.3	1	3.1	2	18.2	39
9001 - 10000	12	0.9	23	2.2	2	6.3			37
10001 - 12000	12	0.9	35	3.4	1	3.1			48
12001 - 14000	9	0.7	13	1.3	1	3.1			23
14001 - 16000	6	0.5	16	1.5	1	3.1			23
16001 - 18000	5	0.4	11	1.1			1	9.1	17
18001 - 20000	7	0.5	11	1.1					18
20001 - 22500	6	0.4	9	0.9					15
22501 - 25000	1	0.1	2	0.2	1	3.1			4
25000+	10	0.7	14	1.4					24
Total	1363	100.0	1036	100.0	32	100.0	11	100.0	2442

TABLE 23

Inventory of Protective Devices On
the State System by Number
of Trains Per Day

	Protective Devices								
	Class 1		Class 2		Class 3		Class 4		
No. of Trains Per Day	No.	%	No.	%	No.	%	No.	%	Total
0 - 5	1112	81.6	549	53.0	8	25.0	10	90.9	1679
6 - 10	225	16.5	408	39.4	11	34.3	1	9.1	645
11 - 15	19	1.4	56	5.4					75
16 - 20	4	0.3	15	1.4	3	9.4			22
21 - 25	2	0.1	3	0.3	4	12.5			9
26 - 40			4	0.4	4	12.5			8
40+	1	0.1	1	0.1	2	6.3			4
Total	1363	100.0	1036	100.0	32	100.0	11	100.0	2442

is not used extensively at the high train volume crossing. The use of gates in unique situations is revealed in the distribution of these devices by train volume. For example, almost 60 percent of the gates are located at intersections having less than ten trains per day. With the exception of gates, 90 to 95 percent of the protective devices are located at intersections having less than ten trains per day. The fact that all but one of the intersections having Class 4 protection are in the less than five trains per day category suggests that stop signs and flagmen are used only at intersections having very low train volumes.

Table 24 shows the distribution of protective devices on the state system by train speed. More than 54 percent of the crossbucks are located on crossings where the train speed is less than 31 miles per hour. Only 45.7 percent of the crossings protected by Class 2 devices have train speeds of less than 31 miles per hour. In general, gates are used either at low speed high volume intersections or at high speed low volume crossings. The other determining factor appears to be ADT count. All but two of the stop sign and flagmen protected crossings report train speeds less than 40 mph.

Two lane and single lane highways account for 85 percent of the total state administered rail-highway intersections according to data shown in Table 25. The data also suggest that a higher percent of the multi-lane facilities are protected by train actuated devices than reported for crossbuck protected crossings. From Table 26 it is noted that approximately 78 percent of the rail-highway intersections use wood as a material between the track for the extension of the highway facility between the rails.

TABLE 24

Inventory of Protective Devices On
the State System By Train Speed

Train Speed	Protective Device: Class 1 No.	%	Class 2 No.	%	Class 3 No.	%	Class 4 No.	%	Total
0 - 10	343	25.1	155	14.9	5	15.6	5	45.4	508
11 - 20	209	15.3	166	16.0	3	9.4	1	9.1	379
21 - 30	191	14.0	153	14.8	5	15.6	1	9.1	350
31 - 40	289	21.2	147	14.2	3	9.4	2	18.2	441
41 - 50	191	14.0	147	14.2	4	12.5	1	9.1	343
51 - 60	77	5.7	98	9.5	1	3.1			176
61 - 70	24	1.8	93	8.9	6	18.8			123
70+	39	2.9	77	7.5	5	15.6	1	9.1	122
Total	1363	100.0	1036	100.0	32	100.0	11	100.0	2442

TABLE 25

Inventory of Protective Devices
On the State System
By Traffic Lanes

	Protective Devices								
	Class 1		Class 2		Class 3		Class 4		
No. of Lanes	No.	%	No.	%	No.	%	No.	%	Total
1 - 2	1244	91.4	813	78.5	17	53.1	7	63.6	2081
3 - 4	104	7.6	207	20.0	14	43.8	3	27.3	328
5 - 6	9	0.6	14	1.4	1	3.1	1	9.1	25
7+	6	0.4	2	0.1					8
Total	1363	100.0	1036	100.0	32	100.0	11	100.0	2442

TABLE 26

Inventory of Protective Devices
On the State System by Material
Between Tracks

Material Between Tracks	Protective Devices								
	Class 1		Class 2		Class 3		Class 4		
	No.	%	No.	%	No.	%	No.	%	Total
Wood	983	72.0	819	79.0	29	90.6	4	36.4	1835
Asphalt	302	22.2	173	16.7	3	9.4	6	54.6	484
Steel Rails	2	0.2	3	0.3					5
Other	76	5.6	41	4.0			1	9.0	118
Total	1363	100.0	1036	100.0	32	100.0	11	100.0	2442

SUMMARY

Data from the Texas Highway Department Log of public rail-highway grade crossings under the administrative responsibility of that agency reveal that more than one-half of these intersections are protected by crossbuck signs only. Although more than one thousand intersections are protected by train actuated warning devices, only 32 have automatic gate installations. Stop signs and flagmen are used very sparingly at THD grade crossings according to the data included in the log.

It is apparent that individual highway districts differ in their criteria for installing rail-highway protective devices. One reason for differing criteria may be the degree of urbanization within a highway district. Data presented in this section show that 60 percent of the THD Log intersections are located in either urban or incorporated areas. However, more than 75 percent of the actuated protective devices are located in these areas. Individual railroads may also have differing policies toward rail-highway intersection protection. It would appear from data presented in this section of the report that, in general, the larger the railroad company the higher the proportion of actuated vs. non-actuated protective devices installed at the railroad's rail-highway intersection.

When comparison is made between the types of highways most frequently intersected at grade by railroads, it is not surprising that more than 58 percent of the THD grade crossings involve FM roads. However, these intersections have 70 percent of the total crossbuck protected intersections on the state system.

Rail-highway intersections having a) ADT counts of less than one thousand, b) less than five trains per day, c) one or two traffic lanes and d) train speeds less than 50 mph can be expected to have crossbuck sign protective devices only. In general, train actuated warning devices are installed at intersections having a) high ADT count, b) high train volume, c) high volume of trains per day, d) multiple traffic lanes, and e) high train speeds or a combination of these factors.

CHAPTER 3

DESIGN OF ANALYTICAL PROCEDURES

A review of previous research suggests that there are several approaches to the development of a rail-highway grade crossing hazard rating. (See Appendix B for a listing of the most often referred to hazard ratings) For example Newnan, in his California study, used a "regression model", the Voorhees report develops a "probability of an accident model", while the Indiana study uses both factor analysis and regression analysis in the development of "the index of hazard".

Each of these methods, along with other statistical methods suggested by consulting statisticians from the University's Institute of Statistics, were given careful consideration for adaptation to the data analysis requirements of this project. However, it was obvious from the beginning of the study that the difference between hazard ratings computed for various classes of rail-highway grade crossings would be the result of a number of variables, all acting at the same time. It was decided that the regression model would be the most logical departing point in the design of analytical procedures. Mathematically, the regression model can be expressed in the following manner:

$$X_1 = a + b_2X_2 + b_3X_3 + \ldots + b_mX_m$$

where: X_1 = dependent variable

$X_2 \ldots X_m$ = the several independent variables

The equation is termed the multiple regression equation. The coefficients

b_2 and b_3 are termed the net regression coefficients. An additional term which is significant to the equation is the gross regression coefficient (by x X). This coefficient is a measure of the apparent relation between dependent and independent variables without considering whether the relation is due to the independent variable alone, or partly or wholly due to other independent variables. Allowing for the effect of each of the independent variables, so as to determine the true relation of each one to the dependent variable by adjusting each independent variable separately, is the application of a statistical technique referred to as the method of successive elimination. To determine the closeness of the relationship between the dependent and independent variables, correlation coefficients and standard errors of estimates were to be computed. The F test and t test were to be used as tests of significance.

The dependent variable to be estimated by this approach is a relative measure of the accident potential of a given crossing as expressed by the variables included in the mathematical model. Therefore, the major objective of this phase of the study was to determine crossing characteristics which have a significant relationship with rail-highway grade crossing accident experience. In order to determine those factors (independent variables) that were to be included in the regression analysis, a study of a comparison of variables was undertaken. This chapter reports the details of this study. However, the most significant results of this special study is the fact that thirteen independent variables were identified for inclusion in the regression model. The thirteen rail-highway accident causal variables identified were:

1. Probability of conflict
2. Roadway type
3. Highway width
4. Surface width
5. Angle of intersection
6. Posted speed
7. Number of tracks
8. Crossing slope
9. Approach slope
10. Visibility of sight triangle
11. Visibility of sight channel
12. Type of protective device
13. Number of intersecting roads and streets

In order to implement the regression model in the formulation of an equation for expected accidents at rail-highway grade crossings in Texas, a data system was required. The procedure developed for obtaining these data is described in the following section of this report.

FACTORS WHICH MAY CONTRIBUTE TO ACCIDENTS AT RAIL-HIGHWAY INTERSECTIONS

The principal cause of rail-highway grade crossing accidents can be related to either the driver, the motor vehicle, obstruction to view, type of protection, roadway and railway geometrics, and the train operation. Secondary factors which contribute to these accidents include, but are not limited to, weather, time of day and season of the year.

Because of their mass, trains are unable to accelerate or decelerate rapidly enough to avoid accidents at grade crossings. Due to the fact that the trains path of travel is limited to the rails, its maneuverability is severely limited. However, the fact that motor vehicles are maneuverable, drivers may take evassive actions. Geometric features of the highway are flexible, but a few of the reasons why serious efforts to reduce the incidence of train-vehicle accidents should be directed more toward highway aspects of the problem rather than the railroad related factors.

The remainder of this section of the report will discuss several factors which may contribute to the cause of rail-highway accidents. The purpose of this discussion is to summarize an investigation of train involved vehicle accidents occurring on Texas highways during a five-year period, 1962-1966. The THD accident data tape is the primary data source for this analysis, therefore, the opinions and conclusions drawn from the analysis apply only to the accident data that are included in that data source.

Class of Vehicle

A study of Texas motor vehicle registrations and THD accident records revealed that during the study period tractor-trailer trucks experienced the highest proportion of rail-highway accidents of all vehicular classes. Referring to Table 27, although tractor-trailer trucks represent only one percent of the state's total vehicle registrations, they are involved in more than four percent of all vehicle accidents and almost ten percent of the rail-highway accidents. The proportion of single-unit trucks involved in rail-highway accidents is only slightly higher than their proportional representation in total vehicle registrations. Automobiles account for almost 80 percent of all vehicle registrations in Texas, yet they are involved in slightly less than 70 percent of the rail-highway accidents.

A comparison of accident location (rural or urban) with vehicular class suggests that tractor-trailer trucks are more frequently involved in

TABLE 27

Percentage Distribution of Registrations, Total Accidents And Rail-Highway Accidents By Vehicle Class, 1962-1966

Vehicle Class	Percentage Distribution		
	Vehicle Registration	Total Accidents	Rail-Highway Accidents
Passenger Cars	79.6	77.7	69.3
Single-Unit Trucks	19.4	17.6	20.9
Tractor-Trailer Trucks	1.0	4.7	9.8
Total	100.0%	100.0%	100.0%

train accidents in urban areas than in rural areas. Table 28 shows that during the study period 45 of the 62 tractor-trailer truck-train accidents occurred in urban areas. Although data are not available as to the number of miles operated by tractor-trailer trucks in rural vs. urban areas, the information shown in Table 28 indicates that these vehicles are involved in train accidents more frequently, relative to proportion of registrations, than either automobiles or single-unit trucks.

A study conducted by the Oregon State Highway Department reported that rail-highway grade crossings are considerably more hazardous at night than during day light hours. Although ADT counts for day and night travel were not available from traffic statistics published by the THD, it can be assumed that grade crossings are more frequently used by both rail and highway traffic during day light hours. Data provided in Table 29 reveal that approximately 62 percent of the rail-highway accidents reported during the study period occurred during the day. Although truck accidents may have occurred in proportion to their frequency in the traffic stream, automobile accidents reported at night seem to be disproportionate to their incidence in the traffic stream during that time period.

Type of Highway

The number of rail-highway accidents occurring during the study period on farm-to-market roads, state highways and U. S. highways are reported in Table 30. In an attempt to categorize the rail-highway accident problem one might consider the fact that during the study period approximately three out of ten rail-highway accidents occurred at the intersection of

TABLE 28

Distribution of Rail-Highway Accidents By Vehicle Class And Location of Accident For The Period 1962-1966

Vehicle Class	Location of Accident		Total
	Rural	Urban*	
Passenger Cars	194	232	426
Single-Unit Trucks	59	73	132
Tractor-Trailer Trucks	17	45	62
Total	270	350	620

* Unincorporated towns and incorporated cities less than 5,000 population.

TABLE 29

Percentage Distribution of Rail-Highway Accidents By Time of Day and Vehicle Class for the Period 1962-1966

Vehicle Class	Time of Day		Total
	Day	Night	
Passenger Cars	54.9	45.1	100.0
Single-Unit Trucks	77.7	22.3	100.0
Tractor-Trailer Trucks	81.0	10.0	100.0
All Classes	62.2	37.8	100.0

TABLE 30

Distribution of Rail-Highway Accidents By Type of Highway and Location of Accident for the Period 1962-1966

Highway Type	Location		Total
	Rural	Urban	
Farm-to-Market Roads	167	177	344
State Highways	54	79	133
U. S. Highways	35	82	117
Totals	256	338	594

FM roads and railways within urban areas. Although traffic density is greater in urban areas than rural areas, the relative proportion of rail-highway accidents occurring on U. S. highways in urban areas appears to differ significantly from traffic count proportion of those two areas.

The farm truck, including both single-units and tractor-trailer vehicles, may have a higher frequency of train accident involvements than trucks used in other services. This assumption is supported by data shown in Table 31. For example, approximately 60 percent of the truck-rail accidents occurred on farm-to-market roads. In general, specialized haulers of agricultural commodities operate over this type of highway. Common motor carriers of general commodities have limited authority to serve points over FM facilities. It would also appear from these data that trucks operating in urban areas have a higher potential for train involved accidents than trucks operating over rural highways.

Type of Protection

The type of protection installed at rail-highway intersections should contribute to the accident experience of each crossing. For example, train actuated protective devices should provide a less hazardous environment than static signs. When vehicle class was compared to type of protective device, statistical tests did not support this assumption. From Table 32 it is apparent that some variation in the number of actuated vs. non-actuated crossing accidents by vehicle class does exist. However, a closer review of the data in this table indicates that there is an equal probability of a specific class of vehicle being involved in an accident at a crossing

TABLE 31

Distribution of Rail-Highway Accidents By Type of Highway And Class of Vehicle For The Period 1962-1966

Highway Type	Type of Vehicle*					
	Passenger Cars		Single-Unit Trucks		Tractor-Trailer Trucks	
	Rural	Urban	Rural	Urban	Rural	Urban
Farm-to-Market Roads	121	109	39	47	7	21
State Highways	36	55	13	15	5	9
U. S. Highways	26	60	5	8	4	14
Totals	183	224	57	70	16	44

* Note due to data coding techniques, 26 accidents are excluded from the totals shown in this table.

TABLE 32

Distribution of Rail-Highway Accidents By Type of Vehicle And Type of Protective Device For The Period 1962-1966

Vehicle Class	Protective Device		Total
	Non-Actuated	Actuated	
Passenger Cars	230	199	429
Single-Unit Trucks	78	51	129
Tractor-Trailer Trucks	31	32	63
Totals	339	282	621

protected either by an actuated or non-actuated device. When other factors such as ADT count, sight distance and roadway geometrics are taken into account, the accident potential of these two classes of crossings differs significantly.

Vehicle Drivers

Drivers over fifty years of age are apparently less aware of hazards at rail-highway intersections than they are to all other types of motor vehicle accident hazards. This assumption is based upon a comparison of ages of drivers involved in fatal rail-highway accidents with the ages of drivers involved in all types of fatal motor vehicle accidents. Only data published by the THD for the period 1965-1966 are included in this analysis. A similar comparison of valid license holders by age groups with drivers, by age groups, involved in fatal rail-highway accidents supports the assumption that drivers over the age of fifty are more frequently involved in this type of accident when compared with other age groups.

Vehicle Condition

The condition of the vehicle just prior to the accident is generally assumed to be a contributing factor to the cause of the accident. Except in the operation of commercial vehicles, proper maintenance of the vehicle is the responsibility of the vehicle driver (owner). From Table 33 it is noted that almost 94 percent of all vehicles involved in rail-highway accidents had no obvious defects according to the investigating officers report. A review of the procedures followed in the investigation of motor vehicle accidents, suggest that due to the severity of impacts in most

TABLE 33

Percentage Distribution of Condition of Highway Vehicles Involved in Rail-Highway Accidents For The Period 1962-1966

Defects	Percent of Total
None	93.7
Brakes	3.9
Lights	0.3
Windshield Obstructed	0.3
Tires	0.2
Other	1.6
Total	100.0

vehicle-train accidents it would be difficult for the investigating officer to properly assess the mechanical condition of the vehicle prior to its involvement in the accident.

Driver's Condition

Data from this study indicates that the driver's condition could be defined as "normal" just prior to the rail-highway accident. Table 34 reveals that just less than thirteen percent of the drivers were either intoxicated or "had been drinking" just prior to the accident. Illness and other physical defects accounted for less than three percent of the driver defects. Although reporting procedures may negate a comparison of the data, it does not appear that the use of intoxicants is as significant in rail-highway accidents as reported in total vehicular accidents.

Motor Vehicle Speed

Another often mentioned factor, or a contributor to motor vehicle accidents, is vehicle speed just prior to the accident. It is apparent from Table 35 that any conclusion may be drawn from the data presented. Excessive automobile speed does not appear to be a necessary prerequisite for being in a collision with a train at a rail-highway intersection. For example, these data indicate that approximately 48 percent of the vehicles involved in train accidents were traveling at 30 mph or less just prior to the collision. The significant fact here is that since many of the accidents occurred at intersections protected by actuated warning devices, the vehicle should have been moving at very low rate of speed just prior to

TABLE 34

Percentage Distribution of Driver's Condition Involved In Rail-Highway Accidents For The Period 1962-1966

Drivers Condition	Percent of Total
Normal	84.2
Had Been Drinking	7.1
Intoxicated	5.6
Fatigued	0.5
Ill	0.3
Other Physical Defects	2.3
Total	100.0

TABLE 35

Percentage Distribution of Speed of Motor Vehicle Involved In Rail-Highway Accidents For The Period 1962-1966

Speed Frequency	Percent of Total
Standing Still	7.3
Moving to 10mph	10.7
11-20 mph	14.2
21-30 mph	15.6
31-40 mph	12.8
41-50 mph	15.6
51-60 mph	13.1
61-70 mph	5.9
Over 71 mph	1.2
Unknown	3.6
Total	100.0%

accident, specifically, where a mandatory stop is required at a flashing red light.

SUMMARY

In an attempt to isolate some of the variables that may contribute to the occurrence of rail-highway accidents, the three principal factors associated with vehicle-train accidents have been discussed in this section of the report, i.e., the driver, the motor vehicle and the train. Although additional information relating to train operations in rail-highway accidents has been presented in other sections of this report, it is sufficient to state that in general the train operation is given and that very little can be done to provide for evasive action on the part of the train, either in its direction or speed of travel. As to the motor vehicle and its driver, several conclusions may be drawn from the analysis of rail-highway accidents occurring on Texas highways during the period 1962-1966.

a) Tractor-trailer trucks experience a relative higher proportion of the rail-highway accidents than all other classes of motor vehicles.

b) When compared with all other classes of vehicles, tractor-trailer trucks experience a relative higher proportion of rail-highway accidents in urban areas.

c) Most rail-highway accidents occur during day light hours.

d) Approximately thirty percent of the rail-highway accidents

occurring on Texas highways were at the intersection of farm-to-market roads and railways within urban areas.

e) The farm product truck may have a higher frequency of rail-highway accident than trucks used in other services.

f) The type of protection installed at rail-highway intersections may not be as effective in the reduction of accidents as often assumed.

g) Drivers over fifty years of age are less aware of hazards at rail-highway intersections than they are of all other types of motor vehicle operation hazards.

h) The condition of the motor vehicle does not appear to be an important factor in the cause of train-vehicle accidents.

i) It does not appear that the use of intoxicants is as significant in rail-highway accidents as generally reported for all motor vehicle accidents.

j) Although failure of a motor vehicle to stop at rail-highway protective devices displaying flashing red lights appears to contribute to these accidents, excessive speed on the approach to the crossings is not reported as a significant contributor to rail-highway accidents.

CHAPTER 4
ACCIDENT RECORD RETRIEVAL

The assembly of records of all rail-highway grade crossing accidents occurring in Texas during a specified time is an original objective of the project being reported. Early in the project it was found that there was no single source of information for all rail-highway accidents occurring within the state. For example, the Railroad Commission of Texas collects from rail carriers a duplicate of the Interstate Commerce Commission report of rail-highway accidents occurring on their lines within Texas. ICC reporting requirements include only those accidents involving more than $750 property damage to railroad equipment or resulting in an injury that would require loss of work for more than a 24 hour period. Until very recently, the Texas Highway Department retrieved data for computer application involving rural accidents only. Therefore, rail-highway accidents occurring in the larger urban areas were not included as a part of the THD accident statistics. Police officer reports would include all rail-highway accidents investigated by law enforcement officers. However, these data, until recently, are filed by hard copy and micro film in the massive files of the Department of Public Safety. This method of filing does not lend itself to easy retrieval of rail-highway accident reports.[13/]

Recent computerization of the DPS data files does provide for the review and analysis of all police investigated rail-highway accident reports.

[13/] No reliable estimates of non-train involved rail-highway accidents. The authors on NCHRP 50 state on page 20 of that report, "no data were discovered during the course of this study which indicate the numbers of accidents that occur annually at railroad crossings".

A short summary of the most current year's data relative to these accidents will be included in this section of the report.

Rail-Highway Accident Trends

In order to project a more complete description of Railroad Commission of Texas reports of rail-highway accidents, a considerable amount of effort was expended in reviewing approximately one thousand accident report forms collected from reporting rail carriers during the period 1965-1967. After the individual reports were obtained from the Commission, it was found that some 400 of the reports did not specifically identify the actual location of the rail-highway accident. Due to the lack of information, the accident could not be associated with the recently completed inventory of public rail-highway grade crossings in Texas. Once again the Texas rail carriers were called upon to support the efforts of the study. To complete this very important phase of the accident retrieval effort, the carriers agreed to retrieve, from their confidential files, the necessary information to specifically identify the location of the some 400 previously unidentified accident locations. To accomplish this task, appropriate carriers were mailed the unidentified accident locations. After placing either highway number or street name on the accident report it was returned to the research staff. It should be pointed out that present Railroad Commission of Texas reporting requirements do not include the name of street or highway number at which the accident occurs.

Copies of the accident reports and forms used in this study are provided in Appendix G of this report.

The purpose of this section of the report is to provide information as to the distribution of train-vehicle accidents by selected categories from the historical accident data files. Due to the variation in vehicle operating conditions associated with the different type of roadway facilities, accidents will be categorized according to their location on city streets, county roads or state highways.

Table 36 shows the distribution of train-vehicle accidents for the years 1965, 1966 and 1967. A three year accident experience period was chosen in order to provide sufficient data for evaluation. During this period approximately one thousand accidents occurred at public grade crossings throughout the state. Approximately one-third of the total accidents occurred during each of the study years. The yearly distribution of accidents, by type of facility is also relatively stable. Except for the county road category, each years train-vehicle accident distribution is approximately the same for each of the three classes of roadway. The uniformity of accidents between years suggest that no significant difference in rail-highway accidents occurring at each of the three classes of roadways exist. It should be noted, however, that during the three-year period more than 58 percent of the total accidents occurred on city streets, 10 percent on county roads and almost 32 percent on state highways.

Table 37 shows the distribution of train-vehicle accidents by number of resulting injuries and fatalities. Of the 998 reported accidents, 435 resulted in fatalities, 1,093 disabilities and 15 permanent disabilities.

City streets accounted for over 56 percent of the accidents and 49 percent of the days of disability resulting from injuries. However, a

TABLE 36

DISTRIBUTION OF TRAIN-VEHICLE ACCIDENTS
BY YEAR
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

YEAR	CITY STREETS Number	CITY STREETS Percent	COUNTY ROADS Number	COUNTY ROADS Percent	STATE HIGHWAY Number	STATE HIGHWAY Percent	TOTAL Number	TOTAL Percent
1965	170	(30.0)	38	(37.3)	103	(31.3)	311	(31.1)
1966	202	(35.6)	27	(26.5)	113	(34.4)	342	(34.3)
1967	195	(34.4)	37	(36.2)	113	(34.3)	345	(34.6)
TOTAL	567	(100.0)	102	(100.0)	329	(100.0)	998	(100.0)

TABLE 37

TRAIN-VEHICLE ACCIDENTS
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

	CITY STREETS		COUNTY ROADS		STATE HIGHWAY		TOTAL	
	Number	Percent of Total	Number	Percent of Total	Number	Percent of Total	Number	Percent of Total
Accidents	567	56.8	102	10.2	329	33.0	998	100.0
Fatalities	227	52.2	35	8.0	173	39.8	435	100.0
Injuries	622	56.9	131	12.0	340	31.1	1,093	100.0
Days of Disability	19,377	49.4	5,017	12.8	14,807	37.8	39,201	100.0
Permanent Disability	11	73.3	0	0	4	26.7	15	100.0

larger percent of permanent disability injuries were represented by accidents occurring on city streets than would have otherwise been expected.

Accidents on county roads, while representing 10 percent of the total accidents, accounted for only 8.0 percent of the total fatalities reported. Injuries on county roads represent 12 percent of the total reported injuries, and resulted in 12.8 percent of the total days of disability. No permanent disabilities from accidents occurring on this type of roadway were reported.

Train-vehicle accidents on state highways, while representing 33.0 percent of the total accidents, accounted for 39.8 percent of the fatalities and 31.1 percent of injuries. When compared to other roadway types it appears that accidents on this type have the highest probability for resulting in a fatality. The higher operating speed of both the train and the vehicle at these locations may contribute to their extreme severity.

Table 38 shows the distribution of the number of fatalities in each train-vehicle accident. In 72.8 percent of the reported accidents there were no fatalities. At least one fatality was reported in 21.6 percent of the accidents. Multiple fatalities were experienced in only 5.6 percent of the accidents reported.

The highest percentage of non-fatal accidents occurred on city streets. Single fatality accidents occurred in 18.5 percent of train-vehicle accidents at city street locations. Multiple fatality accidents accounted for slightly more than four percent of the total rail-highway accidents on city streets.

TABLE 38

DISTRIBUTION OF TRAIN-VEHICLE ACCIDENTS
BY FATALITIES IN EACH ACCIDENT
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

FATALITIES	CITY STREETS Number	CITY STREETS Percent	COUNTY ROADS Number	COUNTY ROADS Percent	STATE HIGHWAY Number	STATE HIGHWAY Percent	TOTAL Number	TOTAL Percent
None	439	(77.4)	74	(72.6)	213	(64.7)	726	(72.8)
1	105	(18.5)	22	(21.6)	89	(27.1)	216	(21.6)
2	14	(2.5)	5	(4.9)	15	(4.6)	34	(3.4)
3	5	(0.8)	1	(0.9)	3	(0.9)	9	(0.9)
4	2	(0.4)	0	(0.0)	1	(0.3)	3	(0.3)
5 or more	2	(0.4)	0	(0.0)	8	(2.4)	10	(1.0)
TOTAL	567	(100.0)	102	(100.0)	329	(100.0)	998	(100.0)

No fatalities were reported in 72.6 percent of the accidents on county roads. Single fatality accidents accounted for 21.6 percent of the total accidents at these locations, while only six percent of the train-vehicle accidents involved multiple fatalities.

Train-vehicle accidents occurring at state highways experienced the highest percent of total fatalities. More than one-third of the accidents at these locations resulted in one or more fatalities. Almost 65 percent of these accidents reported no fatalities, while 27.1 percent resulted in at least one death. Multiple fatalities were experienced in 8.2 percent of the rail-highway accidents on state highways. It should be pointed out that fatalities experienced at these intersections is higher than that reported either at city street or county road rail intersections. The apparent larger percent of multiple deaths may be due to higher passenger per vehicle ratio experienced in intercity automobile travel.

Table 39 gives the distribution of train-vehicle accidents by number of resulting injuries. No injuries were reported in 21 percent of the accidents. There was at least one injury in approximately 60 percent of the accidents reported. Accidents on county roads resulted in a greater percent of multiple injuries than accidents at either city street or state highway railway intersections. Even though accidents on county roads accounted for only 10 percent of the total accidents, the percentage of multiple injuries was higher than for other roadway types.

Over 62 percent of the accidents occurring on city streets reported a single injury. In only 19 percent of the accidents were there no injuries reported. Although the injury rate resulting from rail-highway

TABLE 39

DISTRIBUTION OF TRAIN-VEHICLE ACCIDENTS
BY NUMBER OF INJURIES SUSTAINED IN EACH ACCIDENT
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

	CITY STREETS		COUNTY ROADS		STATE HIGHWAY		TOTAL	
INJURIES	Number	Percent	Number	Percent	Number	Percent	Number	Percent
None	107	(18.9)	22	(21.5)	80	(24.3)	209	(21.0)
1	353	(62.3)	52	(50.9)	188	(57.2)	593	(59.4)
2	77	(13.6)	19	(18.6)	44	(13.4)	140	(14.0)
3	19	(3.3)	2	(2.0)	9	(2.7)	30	(3.0)
4	5	(0.8)	4	(4.0)	6	(1.8)	15	(1.5)
5 or more	6	(1.1)	3	(3.0)	2	(0.6)	11	(1.1)
TOTAL	567	(100.0)	102	(100.0)	329	(100.0)	998	(100.0)

accidents is the highest at city street-railway intersections, most of the accidents result in a single injury. Trips to work, shopping and business trips may account for these statistics.

Accidents on state highways had the highest percent of incidents in which no injuries were reported. However, it should be pointed out that this may be due to the higher percentage of fatal injuries in train-vehicle accidents on state highways as shown on Table 37.

Table 40 shows the number of days of disability resulting from train-vehicle accidents. Of the total 998 accidents, 22.3 percent reported no disabling injuries. In accidents on state highways, 26.4 percent of the accidents reported no disabling injuries. Only 20 percent of the train-vehicle accidents at city street locations reported no disabling injuries. It appears from these data that approximately four of every five rail-highway accidents result in injuries producing one or more days of disability.

Train-vehicle accidents on county roads report a larger number of injuries resulting in extended disability of the injured. Almost 17 percent of the accidents at these locations reported 100 days or more of disability, in contrast to 7.9 percent and 12.7 percent of the reported accidents on city streets and state highways.

Table 41 shows the distribution of train-vehicle accidents by time of day. Starting at 1:00 a.m. the percent of accidents on each of the three facilities tend to rise throughout the remainder of the 24-hour period. There are, however, some apparent variations of this pattern by roadway types. State highways, for instance, have a high percent of accidents

TABLE 40

DISTRIBUTION OF TRAIN-VEHICLE ACCIDENTS
BY DAYS OF DISABILITY PER ACCIDENT
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

DAYS OF DISABILITY	CITY STREETS Number	CITY STREETS Percent	COUNTY ROADS Number	COUNTY ROADS Percent	STATE HIGHWAY Number	STATE HIGHWAY Percent	TOTAL Number	TOTAL Percent
None	113	(20.0)	22	(21.6)	87	(26.4)	222	(22.3)
1 - 10	148	(26.1)	24	(23.5)	63	(19.2)	235	(23.6)
11 - 20	65	(11.4)	7	(6.9)	21	(6.4)	93	(9.3)
21 - 40	92	(16.2)	16	(15.7)	40	(12.2)	148	(14.8)
41 - 60	71	(12.5)	12	(11.8)	49	(14.9)	132	(13.2)
61 - 80	11	(2.0)	2	(1.9)	8	(2.4)	21	(2.1)
81 -100	22	(3.9)	2	(1.9)	19	(5.8)	43	(4.3)
101 -120	11	(2.0)	3	(2.9)	13	(3.9)	27	(2.7)
121 -140	2	(0.4)	2	(1.9)	3	(0.9)	7	(0.7)
141 -160	10	(1.7)	2	(1.9)	4	(1.2)	16	(1.6)
161 -180	11	(2.0)	3	(3.0)	12	(3.7)	26	(2.6)
181 -200	1	(0.1)	3	(3.0)	1	(0.3)	5	(0.5)
201 -300	7	(1.2)	2	(2.0)	4	(1.2)	13	(1.3)
Over 300	3	(0.5)	2	(2.0)	5	(1.5)	10	(1.0)
TOTAL	567	(100.0)	102	(100.0)	329	(100.0)	998	(100.0)
Permanent Disability	11		0		4		15	

TABLE 41

DISTRIBUTION OF TRAIN-VEHICLE ACCIDENTS
BY TIME OF DAY
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

TIME OF DAY	CITY STREETS Number	CITY STREETS Percent	COUNTY ROADS Number	COUNTY ROADS Percent	STATE HIGHWAY Number	STATE HIGHWAY Percent	TOTAL Number	TOTAL Percent
1:00 - 2:59 a.m.	28	(4.9)	2	(2.0)	12	(3.6)	42	(4.2)
3:00 - 4:59 a.m.	17	(3.0)	2	(2.0)	19	(5.7)	38	(3.8)
5:00 - 6:59 a.m.	58	(10.2)	5	(4.8)	13	(3.9)	76	(7.6)
7:00 - 8:59 a.m.	49	(8.6)	11	(10.8)	20	(6.0)	80	(8.0)
9:00 -10:59 a.m.	48	(8.5)	14	(13.7)	19	(5.7)	81	(8.1)
11:00 -12:59 p.m.	51	(8.9)	11	(10.7)	30	(9.1)	92	(9.2)
1:00 - 2:59 p.m.	56	(9.8)	10	(9.8)	29	(8.8)	95	(9.5)
3:00 - 4:59 p.m.	56	(9.8)	13	(12.7)	35	(10.6)	104	(10.4)
5:00 - 6:59 p.m.	52	(9.1)	13	(12.7)	38	(11.5)	103	(10.3)
7:00 - 8:59 p.m.	30	(8.8)	11	(10.7)	31	(9.4)	92	(9.2)
9:00 -10:59 p.m.	54	(9.5)	6	(5.8)	42	(12.7)	102	(10.2)
11:00 -12:59 a.m.	48	(8.5)	4	(3.9)	51	(12.5)	93	(9.3)
TOTAL	567	(100.0)	102	(100.0)	329	(100.0)	998	(100.0)

occurring in the late evening. This may be due to factors such as poor visibility and lighting, excessive speed for road conditions, or factors unique to the driver using that type of roadway at that hour of the day. County roads have a much lower incident of accidents during the late evening and early morning hours, which is probably due to a significant reduction in traffic over these facilities during hours of darkness.

Table 42 shows the distribution of train-vehicle accidents by months. The months of January, March and December report the highest percent of total accidents. January alone accounted for 13.0 percent of the train-vehicle accidents reported. The five short day light months of January, February, March, November and December account for over 50 percent of the accidents on each of the three types of roadways. It would appear that poorer visibility and less than satisfactory driving conditions may contribute to the higher percent of accidents occurring during the winter months.

The distribution of train-vehicle accidents by visibility conditions is shown in Table 43. Visibility was reported as clear when 69.7 percent of the total accidents occurred and cloudy when 28.2 percent of the accidents happened. The distribution of accidents is approximately the same regardless of the type of roadway. Although some 70 percent of the accidents occurred during periods of clear visibility it should be noted that clear weather dominates the Texas weather reports.

State highways reported the largest percent of accidents (29.7 percent) occurring during periods of cloudy weather. This higher incidence of accidents, when compared to other roadway types, may be due to the failure of drivers on state highways to reduce speed and exercise caution during periods of poor visibility.

TABLE 42

DISTRIBUTION OF TRAIN-VEHICLE ACCIDENTS
BY MONTH
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

MONTH	CITY STREETS Number	CITY STREETS Percent	COUNTY ROADS Number	COUNTY ROADS Percent	STATE HIGHWAY Number	STATE HIGHWAY Percent	TOTAL Number	TOTAL Percent
January	78	(13.8)	12	(11.8)	40	(12.2)	130	(13.0)
February	54	(9.5)	9	(8.8)	34	(10.3)	97	(9.7)
March	54	(9.5)	15	(14.7)	32	(9.7)	101	(10.1)
April	27	(4.8)	10	(9.8)	25	(7.6)	62	(6.2)
May	29	(5.1)	11	(10.8)	31	(9.4)	71	(7.1)
June	43	(7.6)	4	(4.0)	22	(6.7)	69	(7.0)
July	37	(6.5)	5	(5.0)	29	(8.8)	71	(7.1)
August	38	(6.7)	7	(6.8)	24	(7.3)	69	(7.0)
September	38	(6.7)	3	(3.0)	14	(4.3)	55	(5.5)
October	37	(6.5)	6	(5.8)	18	(5.5)	61	(6.1)
November	57	(10.1)	9	(8.8)	31	(9.4)	97	(9.7)
December	75	(13.2)	11	(10.7)	29	(8.8)	115	(11.5)
TOTAL	567	(100.0)	102	(100.0)	329	(100.0)	998	(100.0)

TABLE 43

DISTRIBUTION OF TRAIN-VEHICLE ACCIDENTS
BY TYPE VISIBILITY AT TIME OF EACH ACCIDENT
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

VISIBILITY	CITY STREETS Number	CITY STREETS Percent	COUNTY ROADS Number	COUNTY ROADS Percent	STATE HIGHWAY Number	STATE HIGHWAY Percent	TOTAL Number	TOTAL Percent
Clear	402	(70.9)	69	(67.6)	225	(68.3)	696	(69.7)
Cloudy	154	(27.1)	29	(28.4)	98	(29.7)	281	(28.2)
Unknown	11	(2.0)	4	(4.0)	6	(2.0)	21	(2.1)
TOTAL	567	(100.0)	102	(100.0)	329	(100.0)	998	(100.0)

Table 44 shows the distribution of train-vehicle accidents by weather conditions at the time of the accident. In over 91 percent of the reported rail-highway accidents the weather conditions were reported to be clear. This corresponds to the data provided in Table 43 where almost 70 percent of the accidents occurred during periods of clear visibility. Rain was reported when 5.6 percent of the accidents occurred, while 2.5 percent of the accidents happened during foggy weather. Few accidents occurred during periods of either snow or sleet; however, both of these conditions are rare in most parts of the state and drivers probably drive with additional precaution during these periods.

Table 45 shows the distribution of train-vehicle accident causes as reported on the railroad accident form. The cause was not reported for 22.6 percent of the accident forms. According to the railroad accident report form, more than 48 percent of the accidents were caused by the drivers ignoring the protective signal. Some ten percent of the accidents were due to the driver braking late.

Drivers ignoring the signal was listed as the cause of 51.5 percent of the accidents occurring on city streets. Braking late was reported to be the cause of 7.8 percent of the accidents at these locations. Six percent of the drivers tried to out run the train. Only 1.6 percent of these accidents on city streets were caused by drunk drivers; however, this is a higher percentage than was reported on either county roads or state highways.

Braking late was the cause of 30.4 percent of the accidents occurring on county roads. Only 25.5 percent of the train-vehicle accidents on this

TABLE 44

DISTRIBUTION OF TRAIN-VEHICLE ACCIDENTS
BY TYPE OF WEATHER AT TIME OF EACH ACCIDENT
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

	CITY STREETS		COUNTY ROADS		STATE HIGHWAY		TOTAL	
WEATHER	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Fog	16	(2.8)	3	(3.0)	6	(1.8)	25	(2.5)
Rain	32	(5.6)	8	(7.8)	16	(4.9)	56	(5.6)
Snow	3	(0.5)	0	(0.0)	1	(0.3)	4	(0.4)
Sleet	2	(0.4)	0	(0.0)	1	(0.3)	3	(0.3)
Clear	514	(90.6)	91	(89.2)	305	(92.7)	910	(91.2)
TOTAL	567	(100.0)	102	(100.0)	329	(100.0)	998	(100.0)

TABLE 45

DISTRIBUTION OF TRAIN-VEHICLE ACCIDENTS
BY CAUSE OF ACCIDENT AS REPORTED BY RAILROAD
ACCIDENT REPORT FORM
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

CAUSE OF ACCIDENT	CITY STREETS Number	CITY STREETS Percent	COUNTY ROADS Number	COUNTY ROADS Percent	STATE HIGHWAY Number	STATE HIGHWAY Percent	TOTAL Number	TOTAL Percent
Not Reported	117	(20.6)	26	(25.5)	82	(25.0)	225	(22.6)
Speed	22	(3.9)	0	(0.0)	31	(9.4)	53	(5.3)
Attempt to Outrun Train	34	(6.0)	8	(7.8)	8	(2.4)	50	(5.0)
Weather	5	(0.9)	1	(1.0)	2	(0.6)	8	(0.8)
Ignored Signal	292	(51.5)	26	(25.5)	162	(49.3)	480	(48.1)
Braking Late	44	(7.8)	31	(30.4)	29	(8.8)	104	(10.4)
Unaware of Train	11	(1.9)	2	(2.0)	5	(1.5)	18	(1.8)
Stopped on Tracks	33	(5.8)	7	(6.9)	6	(1.8)	46	(4.6)
Drunk Driver	9	(1.6)	1	(0.9)	4	(1.2)	14	(1.4)
TOTAL	567	(100.0)	102	(100.0)	329	(100.0)	998	(100.0)

class of roadway were caused because the driver ignored the signal. The comparatively low incidence of this cause factor may be due to the smaller number of signals located on county roads. According to the railroad report, a higher percent, 7.8 percent, of the accidents on county roads were caused when the driver attempted to out run the train.

Failure to obey the signal was the cause of 49.3 percent of the accidents on state highways. Excessive speed was reported as the cause of 9.4 percent of the train-vehicle accidents. This factor accounted for only a small percent on city streets and no accidents on county roads. Braking late was listed as the cause of 8.8 percent of the accidents on state highways.

Table 46 shows the distribution of train-vehicle accidents by type of collision. This information was taken from the reports made by train crews. These reports indicate that 72.8 percent of the total accidents were caused by simultaneous arrival of the vehicle and the train at the crossing. More than 18.0 percent of the collisions occurred after the train had occupied the crossing.

At city street locations 12.7 percent of the accidents occurred when the driver ran into the side of the train. Almost 75 percent of the collisions were classed as simultaneous arrival of vehicle and train at the crossing. The train crews reported that 7.1 percent of the accidents on city streets were due to the driver attempting to out run the train.

The simultaneous arrival of train and vehicle at the crossing represented 74.5 percent of the accidents at county road locations. An additional 11.7 percent of the collisions occurred when the vehicle ran into

TABLE 46

DISTRIBUTION OF TRAIN-VEHICLE ACCIDENTS
ACCORDING TO TRAIN CREW REPORT AS TO NATURE OF COLLISION
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

	CITY STREETS		COUNTY ROADS		STATE HIGHWAY		TOTAL	
TYPE OF COLLISION	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Ran into Side of Train	72	(12.7)	12	(11.7)	98	(29.8)	182	(18.2)
Simultaneous Arrival*	425	(74.9)	76	(74.5)	225	(68.4)	726	(72.8)
Stalled Vehicle	29	(5.1)	3	(3.0)	1	(0.3)	33	(3.3)
Attempted to Outrun Train	40	(7.1)	11	(10.8)	4	(1.2)	55	(5.5)
Pushed onto Crossing	1	(0.2)	0	(0.0)	1	(0.3)	2	(0.2)
TOTAL	567	(100.0)	102	(100.0)	329	(100.0)	998	(100.0)

*The term "Simultaneous Arrivel" indicates that the train crew could not determine clearly which vehicle, highway or railroad, struck the other.

the side of the train. Almost 11 percent of drivers involved in train-vehicle accidents on county roads attempted to out run the train.

On state highways almost 30 percent of the collisions were caused when the driver ran into the side of the train. This type of collision may be due to the higher speeds on highways and the corresponding greater braking distance required. The simultaneous arrival of train and vehicle represented 68.4 percent of the accidents.

Table 47 shows the distribution of train-vehicle accidents by the reported action of the drivers. The driver did not attempt to stop in 50 percent of the accidents. Where included in the report, the railroad form disclosed that only 12.5 percent of the drivers attempted to stop prior to striking the train. This type of information was not provided by the railroad accident form for a large number of the accidents.

It is obvious from the data in Table 47 that in a majority of accidents the vehicle driver made no attempt to stop. This indicates that in many instances the driver is probably unaware that a train is approaching the rail-highway intersection.

Table 48 shows the distribution of train-vehicle accidents by length of train. Trains with over 20 cars were involved in 47.8 percent of the reported accidents. However, on state highways this class of train was involved in 51.1 percent of the accidents. Trains with less than 3 cars were involved in 14.5 percent of the total accidents. More than 18 percent of the accidents on city streets involved the shorter trains while less than 10 percent of the accidents on either county roads or state highways involved the shorter length train. The predominance of switching activities

TABLE 47

DISTRIBUTION OF TRAIN-VEHICLE ACCIDENTS
BY ACTION OF DRIVER UPON APPROACH TO CROSSING AS
REPORTED ON RAILROAD ACCIDENT REPORT FORMS
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

	CITY STREETS		COUNTY ROADS		STATE HIGHWAY		TOTAL	
DRIVER ATTEMPT STOP	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Not observed	213	(37.6)	28	(27.5)	133	(40.4)	374	(37.5)
Yes	59	(10.4)	14	(13.7)	52	(15.8)	125	(12.5)
No	295	(52.0)	60	(58.8)	144	(43.8)	499	(50.0)
TOTAL	567	(100.0)	102	(100.0)	329	(100.0)	998	(100.0)

TABLE 48

DISTRIBUTION OF TRAIN-VEHICLE ACCIDENTS
BY LENGTH OF TRAIN INVOLVED IN EACH ACCIDENT
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

LENGTH OF TRAIN*	CITY STREETS		COUNTY ROADS		STATE HIGHWAY		TOTAL	
(by number of cars)	Number	Percent	Number	Percent	Number	Percent	Number	Percent
0 - 2	105	(18.5)	10	(9.8)	30	(9.1)	145	(14.5)
3 - 6	73	(12.9)	9	(8.8)	46	(14.0)	128	(12.8)
7 -20	128	(22.6)	35	(34.3)	85	(25.8)	248	(24.9)
Over 20	261	(46.0)	48	(47.1)	168	(51.1)	477	(47.8)
TOTAL	567	(100.0)	102	(100.0)	329	(100.0)	998	(100.0)

*Motive Power Units Not Included

over city streets is probably one reason for this difference.

Table 49 shows the distribution of train-vehicle accidents by the speed of the train. It is interesting to note that in 18.2 percent of the accidents, the train was stopped or moving at speeds of less than 5 mph. In only 3.7 percent of the total accidents was the train traveling at more than 60 miles per hour. Table 50 supports the fact that railroad switching activity is the major class of trains involved in rail-highway accidents on city streets. For example, more than 50 percent of these accidents involved the combined class of yard and local freight trains. Over 21 percent of all accidents involved yard trains indicating that considerable improvement in rail-highway safety may come from improved conditions in rail switching operations.

SUMMARY

Rail-highway grade crossing accident reports are on file at two state agencies. The Railroad Commission of Texas has on file, and requires the continuous reporting of certain rail-highway accidents occurring on Texas rail lines. The rail carriers are required to file reports of all grade crossing accidents involving more than $750 property damage to railroad equipment or resulting in an injury that would require loss of work for more than a 24-hour period. Along with all other police officer reports of automobile accidents involving personal property losses in excess of $25, the Department of Public Safety maintains rail-highway grade crossing accident reports.

TABLE 49

DISTRIBUTION OF TRAIN-VEHICLE ACCIDENTS
BY SPEED OF TRAIN INVOLVED IN EACH ACCIDENT
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

SPEED OF TRAIN	CITY STREETS		COUNTY ROADS		STATE HIGHWAY		TOTAL	
(in MPH)	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Standing								
Moving to 5	99	(17.5)	13	(12.7)	70	(21.3)	182	(18.2)
6 - 10	91	(16.1)	10	(9.8)	43	(13.1)	144	(14.4)
11 - 20	116	(20.5)	10	(9.8)	51	(15.5)	177	(17.7)
21 - 30	87	(15.3)	12	(11.8)	52	(15.8)	151	(15.1)
31 - 40	86	(15.1)	20	(19.6)	40	(12.1)	145	(14.6)
41 - 50	48	(8.5)	16	(15.7)	36	(10.9)	100	(10.2)
51 - 60	28	(4.9)	10	(9.8)	23	(7.0)	61	(6.1)
Over 60	12	(2.1)	11	(10.8)	14	(4.3)	37	(3.7)
TOTAL	567	(100.0)	102	(100.0)	329	(100.0)	998	(100.0)

TABLE 50

DISTRIBUTION OF TRAIN-VEHICLE ACCIDENTS
BY TYPE OF TRAIN INVOLVED IN EACH ACCIDENT
FOR THE PERIOD JANUARY 1965 - DECEMBER 1967

TYPE OF TRAIN	CITY STREETS Number	CITY STREETS Percent	COUNTY ROADS Number	COUNTY ROADS Percent	STATE HIGHWAY Number	STATE HIGHWAY Percent	TOTAL Number	TOTAL Percent
Passenger	59	(10.4)	15	(14.7)	28	(8.5)	102	(10.2)
Through Freight	202	(35.6)	38	(37.3)	107	(32.5)	347	(34.8)
Local Freight	146	(25.8)	40	(39.2)	137	(41.7)	323	(32.4)
Yard	156	(27.5)	9	(8.8)	52	(15.8)	217	(21.7)
Work Train	3	(0.5)	0	(0.0)	4	(1.2)	7	(0.7)
Other	1	(0.2)	0	(0.0)	1	(0.3)	2	(0.2)
TOTAL	567	(100.0)	102	(100.0)	329	(100.0)	998	(100.0)

Each year, approximately 800 rail-highway accidents occur in the state of Texas. Due to reporting requirements, only one-half of these accidents are reported to the Railroad Commission of Texas by the rail carriers. At the time this study was conducted, the research staff only had access to the Railroad Commission accident reports for the period 1965-1967. This section of the report is based upon a summary of 998 accident reports filed by the Texas rail carriers with the Commission during that three-year period.

These 998 accidents resulted in 435 fatalities, 1,093 disabling injuries and 15 permanent disabilities. Accidents on county roads accounted for 10 percent of the accidents, city streets 58 percent, and state highways approximately 32 percent. The higher percent of fatal accidents was experienced by state highways while city streets have the highest percentage of non-fatal accidents. State highways also reported a high percentage of accidents occurring during late evening hours, while county roads have a very low incidence of accidents during late evening and early morning hours. Poor visibility and less than satisfactory driving conditions during the winter months seem to contribute to the increased occurrence of rail-highway accidents during that time of the year.

According to the railroad accident reports, 48 percent of the rail-highway accidents studied were caused by the driver ignoring the protective signal warning. Although only 10 percent of all accidents resulted from drivers braking late, according to the railroad accident reports, over 30 percent of the accidents on county roads were attributed to this cause. This reflects the type of roadway surface and the ability of the driver to view the approaching trains at these intersections.

These reports indicate that almost 73 percent of the accidents involved the simultaneous arrival of the vehicle and train at the intersection. In more than 18 percent of the accidents, collision occurred after the train occupied the crossing. State highway accidents have a higher percentage of collisions in which the vehicle ran into the side of the train than either county roads or city streets. It is apparent, from data developed during this phase of the study, that considerable improvement in rail-highway safety in Texas may come from improved conditions in the operation of yard engines and local freight trains over public rail-highway intersections.

CHAPTER 5

THE SAMPLE PLAN AND PROCEDURE

The design of analytical procedures for the development of an "accident predictive model" using regression techniques required data from each rail-highway crossing within the inventory, or a sample of these data based upon accepted sampling criteria. After some consultation with staff statisticians, it was decided that a stratified random sample of a fixed size would be taken of all crossings included in the inventory. The strata to be sampled were established according to the following categories: 1) historical accident records, 2) type of protective device installed at the crossing and 3) the probability of the simultaneous arrival of motor vehicles and trains at a given crossing (probability of conflict). The establishment of these categories resulted in the development of the eight-cell sampling chart shown in Figure 3.

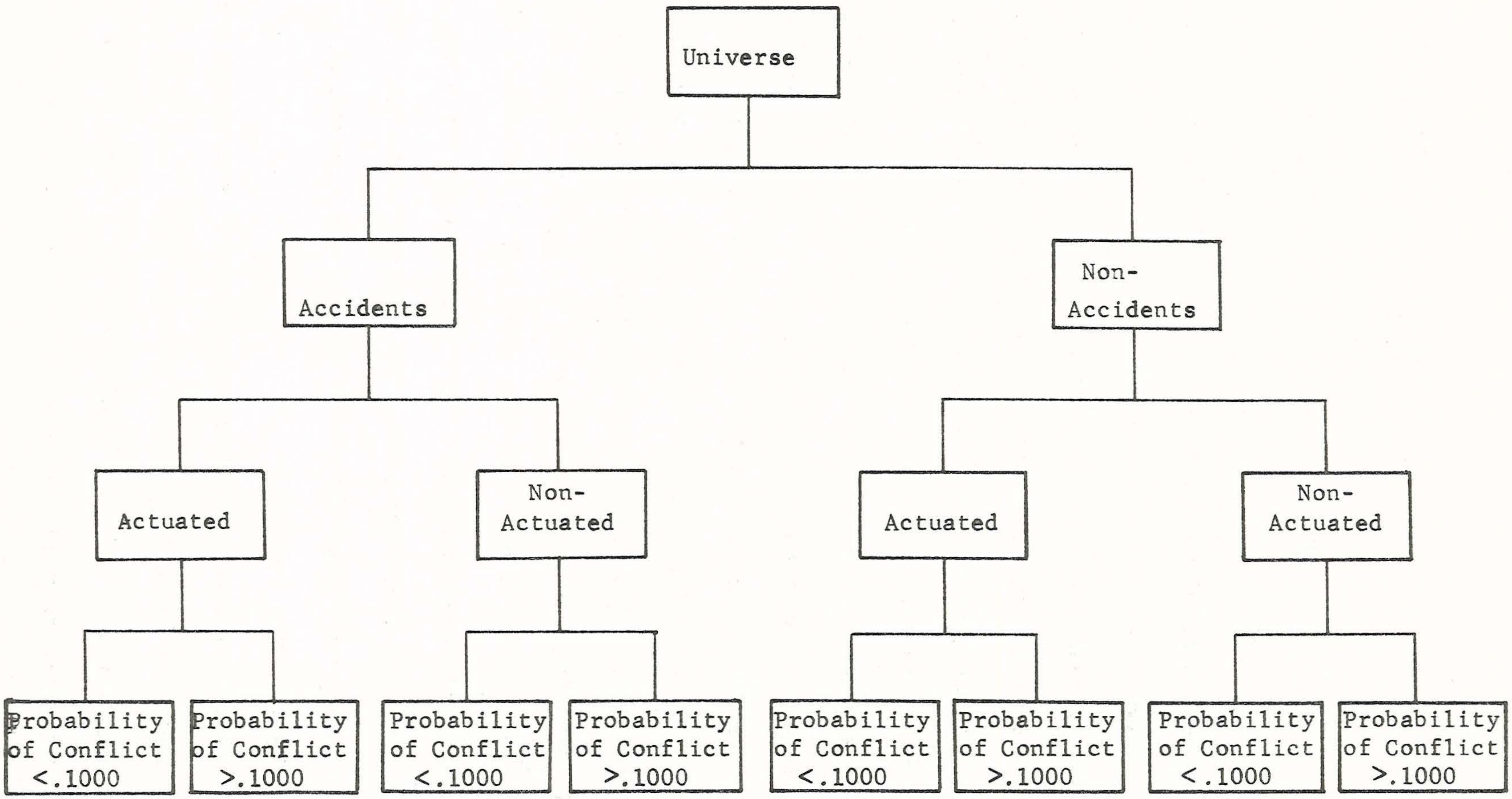
At the time the sample selection was accomplished there were 13,788 crossings in the total Texas rail-highway grade crossing inventory. However, only 1,481 of these crossings were under the administrative responsibility of the Texas Highway Department. These 1,481 crossings are considered to be a part of the records of the THD Planning and Survey Division and are referred to as the Texas Highway Department Rail-Highway Grade Crossing Log throughout this report.*

Considering both the requirements of a large sample (statistically speaking more than 30 observations within each strata) and the minimum

*Note: See page 10.

FIGURE 3

SAMPLING CHART



number of observations within each strata, 35 crossings and two alternates were drawn at random from each of the eight data cells. Additionally seven crossings protected by automatic gates and seven unique crossings without actuated protection were selected for special study.

The Sampling Procedure

The first step in preparing the data for the sampling procedure was to categorize the crossings as to accident and non-accident classes. Crossings that had experienced one or more accidents during the period 1962-1966 were classified as accident crossings.

The records of both the Texas Department of Public Safety and the Railroad Commission of Texas were used in identifying accident crossings. This analysis revealed that 642 accidents occurred at 495 crossings during the five year period 1962-1966.

The next step in the procedure was to categorize the accident and non-accident crossings according to the type of protection installed at the crossing. Due to the variety of protective devices and the lack of a definite effectiveness rating for each type of device, only two categories of devices were considered for sampling purposes. All crossings having protective devices actuated by the approaching train, e.g., automatic flashing lights, automatic gates, wigwags and other electrical operated signals, were placed in the actuated class. Crossings having static protective devices e.g., crossbucks, signs and other markers, were classified as non-actuated crossings.

The final step in stratifying the 1,481 crossings for the purpose of sampling was to determine the relationship between the vehicular and train traffic that moved over the crossing. Since it was not sufficient to consider only the number of vehicles and trains that moved over the crossing during a twenty-four hour day but rather to estimate the probability that a vehicle and train would arrive at the crossing simultaneously, other factors had to be considered. Train length and train speed were two additional variables required for computing the probability of conflict.[14/] Except for the average length of trains, the required information was available from the THD Log. From a special study of railroad annual reports to the Railroad Commission of Texas it was determined that the average length of trains in Texas is approximately seventy cars.

Using the following mathematical expression:

$$\text{Probability of Conflict} = 1 - e^{-am}$$

where: $$am = ADT \frac{\dfrac{\text{train length in feet}}{\text{Train speed in ft/sec} + 10\text{ mph}} \text{ (number of trains/day)}}{\text{seconds/day}}$$

the probability of conflict was computed for each of the 1,481 crossings included in the THD Log. The results of these calculations were studies to determine if there were significant differences in the range of values computed. It was found that a continuous array of probabilities of conflict from a value of 0.0047 to unity existed. Consequently, an arbitrary decision was made to categorize the crossings in two classes, those having a probability of conflict value below 0.100 in one class and those having a value greater than 0.100 in another class.

[14/] The probability of conflict is derived from a special case of poisson distribution. It assumes the random arrival of vehicles given the amount of time the intersection is blocked by rail traffic. Chapter 7 of Traffic Flow Theory & Control by Drew provides a general discussion of the application of the poisson law. Page 76, NCHRP 50 gives another version of the use of this approach in the design of an index of hazard by Contra Costa County, California.

The next step in the sampling procedure was to sort data cards representing each of the 1,481 crossings included in the THD Log according to the categories previously described. Referring again to the sampling chart, eight unique data cells were constructed from the categories described. The number of observations (crossings) in each of these cells ranged from less than 50 to more than 100 per cell.

Following the physical placement of each crossing (represented by a data card) in one of the eight cells a table of random numbers was used to draw 35 observations and two alternates from each of the data cells.

As a result of this sampling procedure a stratified random sample of 280 rail-highway grade crossings located at the intersection of railroad and highways were selected for analysis. Although geographical distribution was not a criterion for sample selection, Figure 4 shows that geographic distribution was achieved in the process of sample selection. More significant is the fact that population, climate, topography and urban-rural considerations are also given representation in the resulting sample crossings.

Collection of the Sample Data

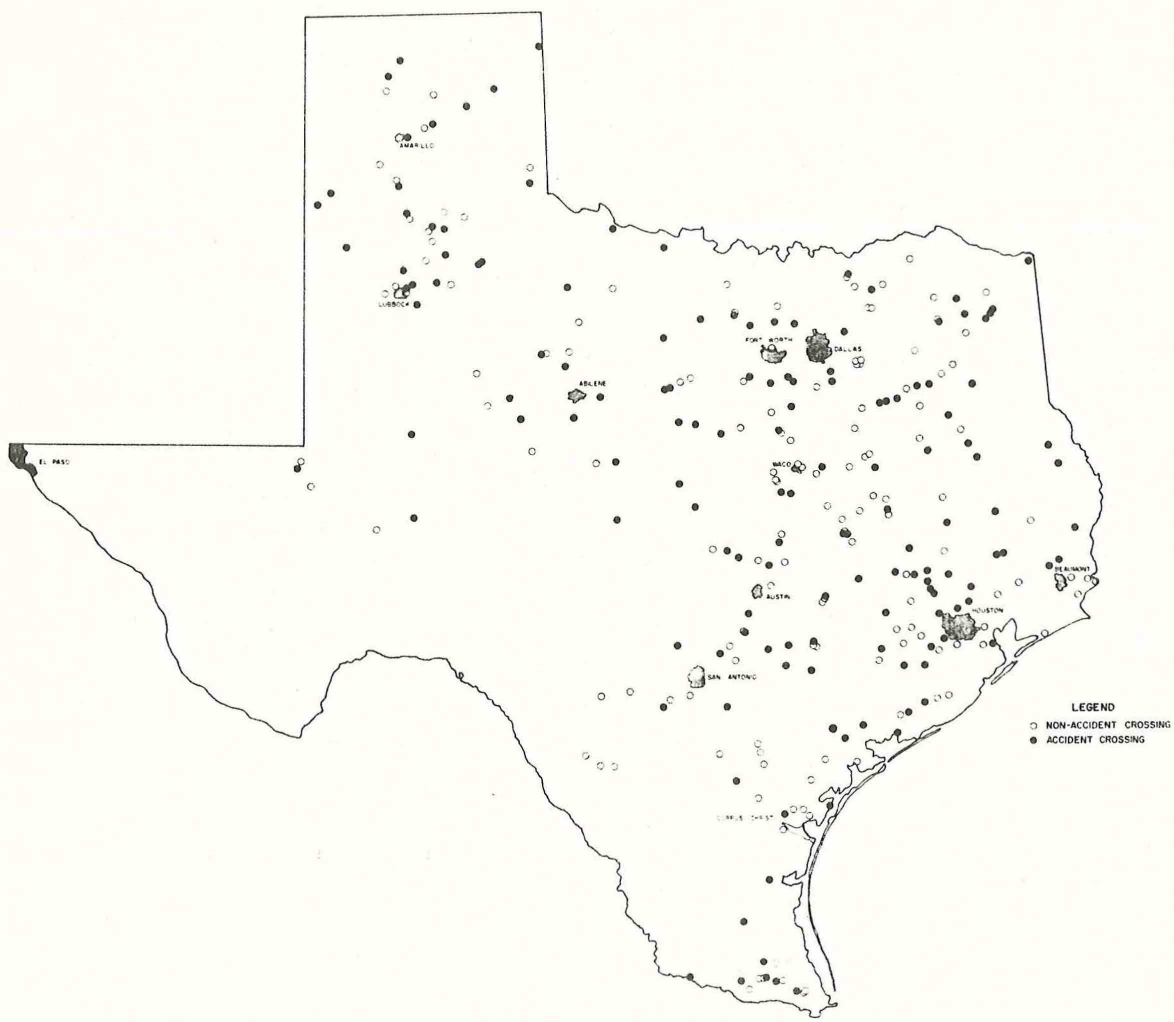
A field investigation was made of the 280 sample rail-highway grade crossings. The variables to be included in the collection of the sample data were selected on the basis of the information developed during that phase of the study reported in Chapter 3. Traffic and highway design engineers were consulted prior to the implementation of the field studies.

The variables included in the collection of the sample data may be described as follows:

1. Roadway type - number of highway lanes and direction of traffic.

FIGURE 4

LOCATION OF SAMPLE CROSSING



2. Highway width (feet) - width of surface used by traffic plus width of shoulders.

3. Highway surface width (feet) - width of surface used by traffic.

4. Surface type - cement, blacktop, gravel, or other.

5. Shoulder type - same as surface type.

6. Shoulder width (feet) - highway width minus surface width, divided by two.

7. Highway direction - reference to compass direction (N, NE, S, SW).

8. Approach grade (percent) - average change in elevation of highway roadbed within 400 feet of crossing.

9. Angle of intersection (degree) - acute angle formed by the intersection of the center-line of the highway and the rails on the railroad bed, estimated to the nearest 15 degrees.

10. Highway curvature (degree) - radius of the highway curve within 400 feet of the railroad crossing.

11. Highway speed (MPH) - posted speed or subjective appraisal by observer if posted speed did not appear to be realistic.

12. Number of tracks (actual number) - each track is composed of two rails.

13. Crossing slope (percent) - the difference in elevation of the highway surface with respect to the railroad bed within 100 feet of crossing.

14. Driver visibility - the degree of visibility afforded the driver at each intersection. The visibility is determined by the obstructions located in the sight channel and the secondary sight triangle of each quadrant.

15. Number and type of protective devices - the actual number of installations of the different types of protective devices at a crossing.

16. Number of intersecting streets and highways - within 400 feet of the rail-highway intersection.

A sample form for collecting the field data and a copy of the instructions to field crews are included in Appendix C of this report.

Data concerning changes that occurred in physical features of the sample crossings during the study period (such as type of protective device, elevation of road bed, or angle of intersection) were secured from the highway district engineers. These additions permitted yearly status for each of the five years of the study period to be reflected.

To account for the changes in motor-vehicle traffic that occurred during the five-year period for each of the sample crossings, annual traffic maps were secured from the Planning and Survey Division of the Texas Highway Department. These maps are published annually by that division and are the most accurate traffic data available. Some extrapolation was required in cases where traffic count was not available to coincide with the exact location of the crossing.

Accident Data

One or more accidents occurred at 146 of the sample crossings during period 1962-1966. Accident reports were retrieved for each of these accidents. Information obtained from the police officers reports and the railroad T-Form report included the following items:

Crossing ID number	Type of train
Time of Accident (year, month day and hour)	Number of cars in train
Visibility condition	Speed of train
Weather condition	Type of highway vehicle
Cause of accident	Estimated train damage ($)
Number killed and injured	Type of roadway
Days of disability to injured	

These data were used both in the development of the expected accident equation and in the establishment of accident cost coefficients for the priority section of this report.

CHAPTER 6

DEVELOPMENT OF THE EXPECTED ACCIDENT RATE EQUATION

The data used in the development of the expected accident formula were collected at 140 sample crossings that experienced one or more accidents during the years 1962-1966 and at 140 sample crossings where no accidents were recorded during this period. Data collecting procedure and forms used in obtaining field data at the sample crossings are provided in Appendix C of this report.

The model was derived by adopting a multiple regression and correlation analysis program for use on the IBM 7094 computer. The program possessed the feature of eliminating the variable with the least non-significant t-value after the calculation of an equation and of computing a new equation with the remaining variables. This process continued until all of the remaining variables were significant at the 5 percent level.

The following statistics were computed for each equation:

Multiple correlation coefficient
Regression line intercept
F-value for multiple regression
Standard error of estimate
Sums
Sum of squares

For each independent variable the following statistics were computed:

Regression coefficient
t-value
Partial regression coefficient
Standard error of regression coefficient

Thirteen independent variables were used in the first analysis.

These were:

A.* Probability of conflict
B. Roadway type
C. Highway width
D. Surface width
E. Angle of intersection
F. Posted roadway speed
G. Number of tracks
H. Crossing slope
I. Approach slope
J. Visibility of sight triangle
K. Visibility of sight channel
L. Type of protective device
M. Number of intersecting roads and streets

By eliminating the variable with the least non-significant t-value, it was found that probability of conflict and types of protective device were the only two variables that were significant at the five percent level. The order in which the other eleven variables were eliminated is as follows:

1. Number of roads
2. Visibility of sight channel
3. Roadway type
4. Number of tracks
5. Angle of intersection
6. Surface width
7. Highway width
8. Posted speed
9. Visibility of sight triangle
10. Crossing slope
11. Approach slope

A total of twelve equations was derived. The analysis for eleven of the equations is presented in abbreviated form in Appendix D. The analysis for the final equation,

$$EAR = 0.02091 + 0.26689A - 0.03996L$$

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*The letter designations are for use in formulas and tables presented in this section and in Appendix D.

where:

EAR = Expected accident rate

A = Probability of conflict

L = Type of protective device

1 = Crossbuck; 2 = Flashing light

is presented in Tables 51 and 52. The equation has a multiple correlation coefficient of 0.1042 and a standard error of estimate of 0.4382.

Table 51 Multiple Regression Analysis For Expected Accident Rate Formula

Variable	Regression Coefficient	Std. Error Regression Coefficient	Partial Correlation Coefficient	t-value
A Probability of Conflict	.26689	.10837	.06968	3.83*
B Protective Device	.03996	-.04721	.02395	-1.67*

*Significant at .05 level

Table 52 Analysis of Variance For Expected Accident Rate Formula

Source	DF	SS	MS	F
Total	1364	264.45		
Due to Regression	2	2.87	1.435	7.47*
Error	1362	261.57	.1921	

*Significant at .05 level

The various terms associated with the analysis are explained as follows:

Mean: A measure of central tendency, is often termed the "average" for an array of values.

Regression Coefficient: Expresses the functional relationship that exists between the dependent variables and the various independent variables. The standard error of the regression coefficient indicates how much the regression coefficient may vary from the true coefficient.

Partial Correlation Coefficient: A measure of the importance of each independent variable, while simultaneously allowing for the variation associated with the other independent variables.

t-test: A test used to determine the significance of a regression coefficient. The null hypothesis tested was that:

(1) The regression coefficient is zero.

The basic ratio for the t-test is:

$$t = \frac{\text{Regression coefficient}}{\text{Standard error of the regression coefficient}}$$

Where the tabulated value exceeded the calculated value, the null hypothesis was accepted.

F-test: A test that was applied to each equation and was used to test the hypothesis that the equation does not contribute significantly to an explanation of the variance of the data about the mean. To determine the value of F, the sum of the squares of the deviation from the mean was separated into two components: sum of squares due to regression and sum of squares about regression. Each of these components was further divided by its number of degrees of freedom to obtain a mean sum of squares.

The value for F was obtained by the ratio:

$$\frac{\text{Mean square due to regression}}{\text{Mean square about regression}}$$

Where the tabulated value exceeded the calculated value, the null hypothesis was accepted.

Correlation Coefficient: May be defined as the square root of the proportion of the variation in the dependent variable (accidents) explained by its association with the independent variables. If the independent variable accounted for all the variation in the dependent variables, the correlation coefficient should have a value of one. The value for the correlation coefficient for the twelve equations in this analysis ranged from 0.1042 to 0.1414.

Standard Error of Estimate: A measure of the relationship between the dependent variable and the independent variables. It estimates the closeness with which the values of the dependent variable may be estimated from values of the independent variables. A range of 0.4374 to 0.4381 was obtained for the standard error of estimates for the twelve equations derived in this analysis.

Discussion of the Analysis

A close review of the analysis associated with deriving the accident rate formula will reveal that the relationship between the independent variables and accidents is not strong. This fact is revealed by both the multiple correlation coefficient, and standard error estimate for each equation. The value for the multiple correlation coefficient in the first equation, in which all thirteen variables are considered, is 0.1414. (Table 1, Appendix D) This accounts for approximately two percent of the total variation in the dependent variable. This value, however, dropped to slightly more than one percent in the final equation in which probability of conflict and type of protective device are the only two independent factors.

The standard error of estimate, on the other hand, reached the minimum value with the elimination of the variable, number of tracks (Table 2, Appendix D). It will be observed that the elimination of Variable E, angle of intersection (Table 3, Appendix D) did not affect the standard error; but, as the elimination of variables continued from that point, an increase in the value for the standard error will be noted.

An accident rate is a relative measure of the accident potential of a crossing as expressed by the variables included in the equation. The task in this study, therefore, was to discover crossing characteristics that had a significant relationship with accidents. As revealed by the t-test the analysis indicated that only two variables, probability of conflict and type of protective device, have a significant relationship.

The F-values that were determined for each equation were found to be significant at the 5 percent level in all instances. However, the value became progressively larger as the variables were eliminated in each successive equation.

The simple correlation coefficients for the variables associated with deriving the model are presented in Table 9, Appendix D. It will be observed that many of the independent variables have a high correlation with each other, but all have a rather low relationship with accidents. Ideally, independent variables selected for predictive purposes should have a high correlation with the criterion, but a low correlation with each other. This means that both measure different aspects of the criterion, and both will contribute substantially to prediction.

The final equation indicates that accident experience is associated with the number of opportunities for collisions. This conclusion is warranted by the inclusion in the equation of variable A, probability of conflict, which considers the average daily traffic and the length of time that a crossing is occupied by a train. Variable L, type of protective device, is a measure of the advance warning provided to the motorist of the presence of a train, and is less closely associated with accident experience.

CHAPTER 7

ESTABLISHING PRIORITIES FOR GRADE CROSSING SAFETY IMPROVEMENT DECISIONS

This section of the report has a two-fold purpose: (1) to develop a procedure for the economic evaluation of alternative types and locations of traffic safety devices and (2) to apply this procedure to the Texas rail-highway grade crossing example. The example represents a specific application of the more general procedures discussed later in this section of the report. It will be assumed that the rail-highway grade crossing is similar in many respects to highway and street intersections; therefore, the procedure described should be of use to city, county, and state traffic engineers in establishing priority ratings for the installation of traffic control devices at highway and street intersections as well as at rail-highway intersections.

Economic theory is concerned with the efficient allocation of scarce resources so as to insure the maximization of social welfare. Without going into the details of the general equilibrium theory, it must be emphasized that this concept of economic efficiency requires that the expenditure decisions of all economic units be evaluated at the margin; in other words, the marginal (incremental) returns must equal the marginal (incremental) costs of the transaction or investment. This will insure the maximization of net returns.

Ideally, therefore, the investment and expenditure decisions of governments should also be made at the margin with each alternative forced to compete for funds on the basis of their respective costs and returns. Of course, this is often not the case in the "real world" where economic criteria are usually secondary to social criteria. It is with full awareness of this fact that a procedure is presented for allocating limited funds over alternative installations on the basis of marginal benefit-cost calcualtions.

In recent years, the public has become increasingly concerned with safety, particularly on the highways; however, it must be recognized that highway accidents are only one of many causes of death, injury, and property loss. The logical goal of society would seem to be to reduce these losses of life and property regardless of the cause. Then, assuming limited resources, funds should be allocated among alternative programs concerned with health and safety according to the expected costs and benefits of each.

Assuming all benefits and costs are properly identified and measured, the use of marginal benefit-cost analysis will determine the funds required to maximize the returns from some specific safety program such as reducing accident losses at rail-highway grade crossings. This program must then compete with others designed to reduce the losses due to accident and health hazards. Thus, given the goal of reducing losses of life and property, funds are allocated such that <u>each</u> program is carried out to the point where the extra benefit from further investment equals the extra costs incurred. The net returns from the entire program will be maximized when the marginal values of all programs are equated.

This procedure to be described in this section of the report, then, should be considered as an application of the above scheme to a particular program of accident reduction. Essentially, it consists of the ranking of alternatives in descending order of their marginal (incremental) benefit-cost ratio values and carrying the program to the point where (a) the marginal (incremental) benefits and costs are equal, or (b) the given funds are exhausted. Decision criterion (b) is, or course, the usual situation faced by the traffic engineers. This example will assume the funds available for the program are given. This is merely a recognition of reality and does not represent advocacy of this procedure; on the contrary, it is believed that the funds for a specified program, e.g., rail-highway grade crossing safety, should be determined by the general procedure outlined above.

Economic Cost of Traffic Accidents

In this example economic losses due to traffic accidents will be treated as social costs rather than as private costs. The assumption that resources are scarce and that they have alternative uses is fundamental to the costing of accidents, especially when one must deal with injuries and deaths. In essence, such costing attempts to measure the net loss to society of productive resources.

Property damage resulting from traffic accidents presents the least difficutly in that market values are available for repair or replacement of vehicles and equipment. However, conceptual and even moral complications arise when attempts are made to estimate the loss due to injury and death. Direct expenditures for medical services and loss of earnings by fatalities or injured persons are also market values, although the later is less indicative of the losses they purport to measure. For deaths, consideration should be given to the inclusion of burial costs and the loss of future earnings. One may counter the contention that "everyone must die some time" with the argument that the premature burial costs represent an opportunity cost.[15] Similarly, the present value of future earnings (including consumption expenditures) must also be added to the estimate of premature losses to society.[16] It is interesting to note in this regard that these categories have often been excluded from accident cost studies tabulations.

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[15]The money could have been invested during the period.

[16]Consumption expenditures are included because persons are considered members of society and not capital in the usual sense.

It is assumed here that the value of earnings lost may be omitted only when the problem is one of allocating a given sum of money among alternative projects designed to serve the same purpose with varying degrees of effectiveness and cost; furthermore, it must be assumed that fatalities are not expected to vary in proportion among the alternatives and that the income distribution of the population "at risk" is relatively uniform. It should be emphasized, however, that these costs must not be omitted if the problem includes the determination of the amount of money to be allocated especially when there are alternative programs competing for public funds. Although the omission will not affect the relative ranking of alternatives given the above assumptions, it will most certainly affect the total economic loss estimate which is intended to be reflective of the overall accident problem.

Secondary benefits from accident reduction programs may include reduced delay time to traffic, reduced repair and replacement costs of property other than the vehicles, insurance, overhead costs (excluding transfer payments), and legal and governmental administrative costs.

Full recognition must be made of the fact that this discussion has omitted private intangible losses incurred by the persons directly and indirectly involved. Although these losses (pain, grief, etc) are not amendable to measurement, it is generally assumed that the sum of private losses exceeds the social cost of accidents; thus, one might consider the social costs outlined above to represent a "lower bound on the amount society would spend to prevent accidents.....".[17]

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[17] Arthur D. Little, Inc., Final Report on Cost Effectiveness in Traffic Safety, p. 127.

TABLE 53

ACCIDENT COST FACTORS TO BE USED IN

ESTABLISHING ALTERNATIVE PRIORITY RATINGS

	AVERAGE COST	COMPOSITE ACCIDENT[3]	COMPOSITE ACCIDENT COST
PERSONAL INJURY			
FATAL INJURY[1]	$109,807	0.51	$56,001.57
NON-FATAL INJURY[1]	23,864	1.04	24,818,56
A DAY OF DISABILITY[2]	12	--	--
PROPERTY DAMAGE			
AUTOMOBILE			
FATAL INJURY ACCIDENT[1]	996	0.34	338.64
NON-FATAL INJURY ACCIDENT[1]	427	0.65	277.55
NON-INJURY ACCIDENT[1]	197	--	--
RAILWAY			
ALL ACCIDENTS[2]	771	1.00	771.00
			$82,207.32

1/ Includes direct costs incurred by persons e.g., medical, funeral, legal, value of time lost, and loss of future earnings. SOURCE: Wilbur Smith and Associates, Motor Vehicle Accident Costs: Bureau of Public Roads, 1966, Tables 9-A, B, C, and 10-A, B.

2/ Data developed in TTI Study from railroad T-Form information on file with the Texas Railroad Commission.

3/ Composite accident computed from actual accident experience of study intersections.

Although this example treats the evaluation of rail-highway grade crossing safety devices, insufficient data for this accident category necessitated the use of general highway accident cost estimates. Only railway equipment and facility property loss resulting from rail-highway accidents occurring during a three-year period in Texas were developed for specific use in this study. After an examination of a number of highway accident cost studies, it was determined that the recent Washington, D. C. area study best suited the purposes of this paper.[18]

Data extracted included the direct economic cost of fatalities, non-fatal injuries, and vehicle property damage according to accident severity. The estimates include medical, burial, legal, value of time costs in addition to the value of loss of future earnings. Additional cost data from railroad sources provided an estimate of the average direct costs incurred by railroads in crossing accidents. No attempt was made to determine the indirect costs suggested earlier such as commerical vehicle delays. Therefore, it may be assumed that the loss estimates used in this paper are understated. Table 53 provided the accident cost factors used in establishing alternative priority rating procedures developed in this paper.

Column two gives the percentage each accident category made up of all grade crossing accidents in Texas over the three-year period, 1965-67. Multiplying columns one and two gives the estimates of accident cost by

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[18] Wilbur Smith and Associates, Motor Vehicle Accident Costs: Bureau of Public Roads, 1966.

category of accident severity. The column total then gives an estimate of the cost of the average accident or the composite accident cost.

This composite value represents the cost of the average accident experience as recorded in the grade crossing accident statistics for Texas. It may be written:

$$CAC = (FR \times CF) + (IR \times CI) + PL$$

where:

CAC = composite accident cost	CF = cost of a fatality
FR = fatality rate per accident*	CI = cost of an injury
IR = injury rate per accident**	PL = property loss

* fatality rate per accident-average number of fatalities occurring in each accident.

**injury rate per accident-average number of injuries occurring in each accident.

Source of Data For Priority Rating Analysis

The rail-highway intersections selected for the application of alternative priority rating procedures developed in this example are all located in one of the 25 highway districts of the state of Texas. The 138 crossings represent all rail-highway intersections within the district under the administrative responsibility of the Texas Highway Department.

A detailed inventory of the physical and operational characteristics of these intersections reveals that 58 of the 138 intersections are not protected by actuated traffic control devices. It is estimated that replacement cost of the actuated devices installed at the 70 protected crossings is approximately $816,000.

An analysis of accident records discloses that during the three year period 1965-1967, 27 accidents occurred at these intersections. These accidents resulted in 19 fatalities and 30 injuries. Applying accident costs reported in this paper these 27 accidents are estimated to have a total cost of $2,563,613.

A determination of which intersections are to be improved and in what order of priority provides the basis for developing a procedure to rank each of the 138 intersections within the highway district. In general, the objective is to obtain maximum beneifts from limited funds available for rail-highway intersections safety improvement.

Installation Cost of Protective Devices

In order to establish current estimates of installation cost for providing either new or additional protection at rail-highway intersections two sub-studies were necessary. The objective of the first study was to determine the average number of Association of American Railroads (AAR)[19] units required at grade crossings protected by either flashers (single track), flashers (multiple track) or gates. Ten major Texas railroads provided data for this study.

The objective of the second study was to determine the cost of providing protection at a specific crossing given a specified protective device. In this study data were obtained from estimates of installation costs for 89 crossings geographically distributed over the state of Texas

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[19]Railroad signal systems are comprised of more than 60 component parts, each of which (individually or in combinations) have been assigned relative unit values by Signal Division of Association of American Railroads. These relative unit values, designated as AAR units, were developed for accounting and recordation purposes directed toward determining installation, replacement, and maintenance and operating costs on an industry-wide uniform basis.

and involving 14 different railroad companies. Only four estimates of installation costs were made at crossings that were located on railroads not included in the first study. In these instances, the average number of AAR units developed for the ten study railroads was applied.

A computer program was developed to apply these costs to both protected and not-protected intersections according to the railroad involved. In general, the results of this analysis is as follows:

AVERAGE INSTALLATION COST OF FLASHERS (SINGLE TRACK)		$11,900
COST PER AAR UNIT	$868.32	
AVERAGE INSTALLATION COST OF FLASHERS (MULTIPLE TRACK)		16,950
COST PER AAR UNIT	887.52	
AVERAGE INSTALLATION COST OF GATES		21,016
COST PER AAR UNIT	913.76	

Maintenance Cost of Protective Devices

The information provided by the ten railroad companies reveals that in addition to the use of AAR units to determine the relative amount of equipment necessary to the installation of various types of protective devices at rail-highway intersections, these units are significant to estimating maintenance cost of these devices. From a descriptive list of AAR units required in the installation and operation of these various devices, annual maintenance cost for each installation may be computed. In general the average cost per AAR unit is estimated by the allocation of each railroad company's total maintenance cost to the total number of AAR units maintained by the company. It was found that these cost differ between railroad companies due to geographic location, labor cost, operating cost, etc.

Maintenance cost applicable to the alternative priority rating procedures developed in this paper include data from each of the ten railroads participating in the study. An averaging of these cost provided the following results:

AVERAGE ANNUAL MAINTENANCE COST OF FLASHERS (SINGLE TRACK)		$ 571
AVERAGE AAR UNITS PER LOCATION	13.7	
AVERAGE ANNUAL MAINTENANCE COST OF FLASHERS (MULTIPLE TRACK)		827
AVERAGE AAR UNITS PER LOCATION	19.9	
AVERAGE ANNUAL MAINTENANCE COST OF GATES		1,105
AVERAGE AAR UNITS PER LOCATION	26.0	

Incremental Benefit Cost Procedure

For each incremental improvement in protection at each crossing location an incremental (or marginal) benefit-cost ratio is computed for use in the priority index to be described later. The benefits are the expected annual reduction in accident costs attributed to each increment of protection. These accident costs are discussed in the section on the economic cost of accidents. Costs include annualized initial installation cost and annual maintenance expenses incurred for each incremental improvement in protection.

The procedure may be more easily described by the use of the following equations:

BENEFITS:

(1.1) $EAB_{ijk} = ER_i \times CAC_j \times EAR_k$

where:

EAB = expected annual accident cost reduction

ER_i = relative effectiveness rating for an increment of protection

CAC_j = composite accident cost

EAR_k = expected annual accident rate for a given crossing location

COSTS:

(1.2) $TAC_{ik} = (CRF \times IC_{ik}) + MC_{ik}$

where:

TAC = total annual cost of an increment of protection

CRF = capital recovery factor $r(1+r)^m \; / \; (1+r)^m - 1$

where:

r = interest rate

m = useful life of device

IC = total installation cost of improvement

MC = annual maintenance cost

INCREMENTAL BENEFIT-COST CALCULATION:

(1.3) $PI_{ijk} = EAB_{ijk} \; / \; TAC_{ik}$

In the evaluation procedure the incremental benefit-cost ratio may be thought of as a priority index value to be used in ranking projects. The key point is that the choices of level of protection and location of protection are made simultaneously; thus, the index value (benefit-cost ratio) corresponding to each feasible increment of protection for each location is ranked in descending order. The decision rule is to carry the project to the point where incremental benefits equal the incremental costs (thereby maximizing net benefits) or, if the level of expenditure is given, until funds are exhausted at some point above this. Additional investment beyond this point will contribute more to costs than to benefits.

Procedures for Computing Priority Ratings

From an inventory of physical and operational characteristics of the 138 rail-highway intersections and the installation and maintenance cost factors reported in this paper, the annualized cost of improving protection at each of the intersections may be computed. The following assumptions are made regarding these costs:

a) Protective devices to be evaluated are limited to crossbucks (signs), flashing lights and gates.

b) A 30 year useful life is assumed for each class of protective device with zero salvage value at the end of the period.

c) A six percent interest rate is applied to the annualized installation cost computation.

d) Protective devices may be upgraded by the addition of AAR units.

Equation (1.2) is applicable to the computation of total annual protection (TAC) cost for both protected and unprotected intersections. The only difference being that two computations are required for unprotected intersections while only one is required for protected intersections.

For example, given an unprotected intersection, TAC costs are estimated for flashers, gates and the increment between flashers and gates. From equation (1.2) the following results are obtained:

Improvement Alternative	Annual Cost Installation	Annual Cost Maintenance	Total (TAC)
a. Crossbucks to Flashing lights	$1066.71	$563.92	$1,630.63
b. Crossbucks to gates	1604.98	850.96	2,455.94
c. Flashing lights to gates	538.27	287.04	825.31

On the other hand, if the example intersection is protected with flashing lights; thus, the only improvement alternative, given the above assumptions, is the addition of gates. From equation (1.2) the following results are obtained:

Improvement Alternative	Annual Cost Installation	Annual Cost Maintenance	Total (TAC)
Flashing lights to gates	$456.27	$313.37	$769.64

These examples are representative of the two levels of protection exhibited by the grade crossings included in this study.

The second step is the composite accident cost calculation as shown in Table 53. This cost estimate may be computed for the state; for each highway district; by rural and urban intersections; or in other categories as warranted by the data. In this example, the composite accident cost estimate of $82,207.32 is based on state-wide accident data.

The third step in the procedure is the calculation of the expected reduction in accident costs for a given increment of improvement. From data published in NCHRP Report 50[20], the following relative effectiveness ratings for protective devices have been utilized in this paper:

Type of Protection	Relative Hazard
Crossbucks	1.00
Flashing lights	.20
Gates and lights	.11

From these data it may be seen that the addition of flashing lights to an unprotected crossing should reduce the hazard by 80 percent and the addition of gates should contribute an additional 9 percent reduction in the relative hazard rating.

The expected accident rate for the existing protection is calculated as follows:

$$EAR_k = 0.02091 + 0.26689(PF) - 0.03996\ (PD)$$ [21]

where:

EAR_k = Expected accident rate

PF = Probability of conflict = $1 - e^{-am}$

PD = Type of protective device
1 = non-actuated
2 = actuated

and:

$$am = ADT\ \frac{\frac{\text{train length in ft.}}{\text{train speed in ft./sec.}} + 10\ \text{sec. (trains/day)}}{86{,}400\ \text{sec./day}}$$

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[20] Factors Influencing Safety at Highway-Rail Grade Crossings, (NCHRP Report 50), 1968.

[21] The development of the Accident Rate Equation is described in a previous section of this report.

ADT - Average Daily Vehicular Traffic

Now, using equation (1.1), the expected annual benefit for installing flashing lights is computed:

$$EAB_i = ER_i \times CAC_j \times EAR_k$$

$$= 0.80 \times \$82,207.32 \times 0.24784$$

$$= \$16,299.41$$

and, using equation (1.2), the total annual cost of protection is:

$$TAC_{ik} = \$1,630.63$$

Giving the following priority index value:

$$EAB/TAC = 9.99$$

Similar computations give the priority index value for the addition of gates to the flashing lights.

$$EAB = 0.09 \times \$82,207.32 \times 0.24784$$

$$= \$1,833.68$$

$$TAC = \$\ 825.31$$

$$PI = \$\ 2.22$$

On the other hand, raising the level of protection from crossbucks to gates initially will produce the following results:

$$EAB = \$18,130.64$$

$$TAC = \$\ 2,455.94$$

$$PI = \$\ 7.38$$

Were each crossing to be evaluated individually, it would seem appropriate to install only flashing lights; however, when all crossings are evaluated simultaneously, the additional increment of protection provided by gates may be justified if the priority index value of 2.22 exceeds the value for the addition of lights to another crossing further down the list. This example clearly shows that adding gates contributes more to costs than to benefits; again, however, it should be emphasized that when all crossings are evaluated simultaneously neither a policy of always adding flashing lights and gates nor one of omitting all gates is necessarily desirable. In ranking the crossings the third "alternative" shown above is not included since only increments of protection are of interest in this analysis.

Application of the General Procedure

Tables 54 and 55 present the results of the application of the general procedure developed in this example for allocating funds for rail-highway grade crossing protection devices within the example highway district. The tables are based upon two criteria alternatives. Table 54 assumes that the program is to be carried to the point at which the incremental cost of improvement equals the incremental benefit from improvement. Stated another way, the program is carried to a point at which the incremental benefit-cost (B-C) ratio has a value of 1.0. This criterion not only determines which crossing locations are selected and what level of protection is required, but also determines the total investment expenditure required to maximize net benefits. The improvement decision for each rail-highway intersection is shown in columns 4, 5, and 6. Accumulated investment totals are given in column 7. Based upon this analysis, 118 of the example highway districts' 138 rail-highway intersections would be included in the program if the objective were to maximize net benefits. From column 7, it is estimated that an initial investment of approximately 1.14 million dollars is required in the program.

An alternative approach is demonstrated in Table 55. The purpose of this table is to provide an analysis of data based upon a decision criterion in which the total budget is given and fixed. Therefore, the procedure to be followed is the allocation of the fixed (appropriated) funds among the competing rail-highway intersections and levels of protection. As in Table 54, incremental B-C ratios are ranked; however, in this analysis the intersections to be included in the program are dependent upon that point in the priority ranking at which total initial investment exhausts the given budget (provided no increments are included having a B-C ratio less than 1.0).

The fixed fund assumed for the example program demonstrated in Table 55 is $950,000. The intersections to be included in this program appear above a line drawn at the point at which accumulated initial investment exceeds $950,000. Improvement decisions for each increment are shown in columns 4, 5, and 6. In this example intersections are repeated in the analysis and become a part of the program when warranted by incremental B-C ratios.

In comparing Tables 54 and 55, it should be observed that the accumulated initial investment is the same for both tables. The two alternative programs differ in that Table 54 demonstrates the results of improvement decision determined on an economic basis while Table 55 demonstrates the results of an improvement decision based upon fixed funds.

TABLE 54- OPTIMUM ALLOCATION

Crossing Number	Current Protection	Priority Index	IMPROVEMENT DECISIONS Flashers	Gates	Flashers & Gates	Initial Investment*
8771	Flasher	22.81	--	X	--	$ 3,396
8666	Flasher	22.81	--	X	--	6,792
50417	Flasher	22.81	--	X	--	10,188
50199	Flasher	22.80	--	X	--	13,584
5820	Flasher	22.72	--	X	--	16,980
5823	Flasher	22.45	--	X	--	20,376
12363	Flasher	21.96	--	X	--	23,986
5826	Flasher	20.13	--	X	--	27,382
5835	Flasher	20.13	--	X	--	30,778
5874	Flasher	20.13	--	X	--	34,174
5880	Flasher	20.13	--	X	--	37,570
5882	Flasher	20.13	--	X	--	40,966
5903	Flasher	20.13	--	X	--	44,362
7804	Flasher	20.13	--	X	--	47,758
8775	Flasher	20.13	--	X	--	51,154
50128	Flasher	20.13	--	X	--	54,550
50414	Flasher	20.13	--	X	--	57,946
50415	Flasher	20.13	--	X	--	61,342
5888	Flasher	20.12	--	X	--	64,738
50413	Flasher	20.12	--	X	--	68,134
7286	Flasher	20.12	--	X	--	71,530
5856	Flasher	20.01	--	X	--	74,926
8669	Flasher	20.01	--	X	--	78,322
8680	Flasher	19.73	--	X	--	81,718
5853	Flasher	19.16	--	X	--	85,114
5851	Flasher	18.11	--	X	--	88,510
5845	Flasher	17.66	--	X	--	91,906
50416	Flasher	17.33	--	X	--	95,302
50402	Flasher	14.52	--	X	--	100,948
143	Flasher	13.46	--	X	--	106,780
151	Flasher	13.45	--	X	--	112,612
152	Flasher	13.44	--	X	--	118,444
12296	X Buck	12.59	--	--	X	134,227
50132	X Buck	12.59	--	--	X	150,010
50270	X Buck	12.59	--	--	X	165,793
50271	X Buck	12.59	--	--	X	181,576
5821	Flasher	12.58	--	X	--	184,972
12305	Flasher	12.21	--	X	--	191,335
50406	Flasher	11.90	--	X	--	196,981
138	Flasher	11.87	--	X	--	202,813

TABLE 54 (Continued)

Crossing Number	Current Protection	Priority Index	IMPROVEMENT DECISIONS Flashers	Gates	Flashers & Gates	Initial Investment*
146	Flasher	11.87	--	X	--	$208,645
150	Flasher	11.86	--	X	--	214,477
749	Flasher	11.85	--	X	--	220,309
739	Flasher	11.52	--	X	--	226,141
137	Flasher	11.49	--	X	--	231,973
2148	Flasher	11.12	--	X	--	238,854
2179	Flasher	11.12	--	X	--	245,735
2962	Flasher	11.12	--	X	--	252,616
12350	X Buck	11.11	--	--	X	268,399
12389	X Buck	11.11	--	--	X	284,182
12391	X Buck	11.11	--	--	X	299,965
12410	X Buck	11.11	--	--	X	315,748
50124	X Buck	11.11	--	--	X	331,531
50130	X Buck	11.11	--	--	X	347,314
50131	X Buck	11.11	--	--	X	363,097
50268	X Buck	11.11	--	--	X	378,880
12421	X Buck	11.09	--	--	X	394,663
2971	Flasher	11.08	--	X	--	401,544
12298	Flasher	10.99	--	X	--	407,907
12299	Flasher	10.99	--	X	--	414,270
12354	Flasher	10.99	--	X	--	420,633
12367	Flasher	10.99	--	X	--	426,996
50129	Flasher	10.99	--	X	--	433,359
12318	Flasher	10.97	--	X	--	439,722
730	Flasher	10.96	--	X	--	445,554
3732	Flasher	10.87	--	X	--	452,435
12355	Flasher	10.82	--	X	--	458,798
2071	Flasher	10.81	--	X	--	465,679
3720	Flasher	10.80	--	X	--	472,560
50276	X Buck	10.48	--	--	X	486,336
742	Flasher	10.32	--	X	--	492,168
8681	Flasher	10.23	--	X	--	495,564
7287	X Buck	9.87	--	--	X	509,340
8663	X Buck	9.85	--	--	X	523,116
8664	X Buck	9.85	--	--	X	536,892
50266	X Buck	9.85	--	--	X	550,668
50267	X Buck	9.85	--	--	X	564,444
50273	X Buck	9.85	--	--	X	578,220
5881	X Buck	9.84	--	--	X	591,996
157	X Buck	9.49	--	--	X	608,744

TABLE 54 (Continued)

Crossing Number	Current Protection	Priority Index	IMPROVEMENT DECISIONS Flashers	Gates	Flashers & Gates	Initial Investment*
159	X Buck	9.49	--	--	X	$625,492
160	X Buck	9.49	--	--	X	642,240
708	X Buck	9.49	--	--	X	658,988
5885	X Buck	9.43	--	--	X	672,764
50275	X Buck	9.03	--	--	X	686,540
2986	Flasher	8.63	--	X	--	693,421
2164	Flasher	8.42	--	X	--	700,302
50127	X Buck	8.39	--	--	X	720,816
2069	X Buck	8.39			X	741,334
2957	X Buck	8.39	--	--	X	761,850
12309	Flasher	8.17	--	X	--	768,213
2982	X Buck	8.02	--	--	X	788,729
2963	Flasher	7.82	--	X	--	795,610
2956	X Buck	7.06	--	--	X	816,126
12314	Flasher	6.76	--	X	--	822,489
2156	X Buck	6.38	--	--	X	843,005
735	Flasher	5.80	--	X	--	848,837
736	Flasher	5.80	--	X	--	854,669
50274	X Buck	5.17	--	--	X	875,185
2146	X Buck	4.94	--	--	X	895,701
3749	X Buck	4.89	--	--	X	916,217
3740	X Buck	4.82	--	--	X	936,733
8674	X Buck	4.73	--	--	X	950,509
8679	X Buck	4.48	--	--	X	964,284
4996	X Buck	4.39	X	--	--	977,921
140	X Buck	4.27	X	--	--	988,837
8678	X Buck	4.18	--	--	X	1,002,613
50405	X Buck	4.10	X	--	--	1,014,391
50403	X Buck	3.97	X	--	--	1,026,169
2979	X Buck	3.38	X	--	--	1,039,805
7289	X Buck	3.20	--	--	X	1,053,581
2173	X Buck	2.64	X	--	--	1,074,097
5001	X Buck	2.48	X	--	--	1,087,733
2159	X Buck	2.00	X	--	--	1,101,369
50440	Flasher	1.97	--	X	--	1,107,015
50441	Flasher	1.97	--	X	--	1,112,661
50001	X Buck	1.37	X	--	--	1,126,297
8667	X Buck	1.25	X	--	--	1,136,677

*Accumulated Totals

TABLE 55 - FIXED FUND ALLOCATION

Crossing Number A[1/]	Crossing Number B[2/]	Priority Index	IMPROVEMENT DECISIONS Flashers	IMPROVEMENT DECISIONS Gates	IMPROVEMENT DECISIONS Flashers & Gates	Initial Investment**
8771		22.81	--	X	--	$ 3,396
8666		22.81	--	X	--	6,792
50417		22.81	--	X	--	10,188
50199		22.80	--	X	--	13,584
5820		22.72	--	X	--	16,980
5823		22.45	--	X	--	20,376
12363		21.96	--	X	--	23,986
5826		20.13	--	X	--	30,778
5874		20.13	--	X	--	34,174
5880		20.13	--	X	--	37,570
5882		20.13	--	X	--	40,966
5903		20.13	--	X	--	44,362
7804		20.13	--	X	--	47,758
8775		20.13	--	X	--	51,154
50128		20.13	--	X	--	54,550
50414		20.13	--	X	--	57,946
50415		20.13	--	X	--	61,342
5888		20.12	--	X	--	64,738
50413		20.12	--	X	--	68,134
7286		20.12	--	X	--	71,530
5856		20.01	--	X	--	74,926
8669		20.01	--	X	--	78,322
8680		19.73	--	X	--	81,718
5853		19.16	--	X	--	85,114
5851		18.11	--	X	--	88,510
5854		17.66	--	X	--	91,906
50416		17.33	--	X	--	95,302
50402		14.52	--	X	--	100,948
143		13.46	--	X	--	106,780
151		13.45	--	X	--	112,612
152		13.44	--	X	--	118,444
	12296	12.59	X	--	--	127,864
	50132	12.59	X	--	--	137,284
	50270	12.59	X	--	--	146,704
	50271	12.59	X	--	--	156,124
5821		12.58	--	X	--	159,520
12305		12.21	--	X	--	165,883
50406		11.90	--	X	--	171,529
138		11.87	--	X	--	177,361
146		11.87	--	X	--	183,193

TABLE 55 (Continued)

Crossing A[1/]	Number B[2/]	Priority Index	IMPROVEMENT DECISIONS Flashers	Gates	Flashers & Gates	Initial Investment**
150		11.86	--	X	--	$189,025
749		11.85	--	X	--	194,857
739		11.52	--	X	--	200,689
137		11.49	--	X	--	206,521
2148		11.12	--	X	--	213,402
2179		11.12	--	X	--	220,283
2962		11.12	--	X	--	227,164
	12350*	11.11	X	--	--	236,584
	12389*	11.11	X	--	--	246,004
	12391*	11.11	X	--	--	255,424
	12410*	11.11	X	--	--	264,844
	50124*	11.11	X	--	--	274,264
	50130*	11.11	X	--	--	283,684
	50131*	11.11	X	--	--	293,104
	50268*	11.11	X	--	--	302,524
	12421*	11.09	X	--	--	311,944
2971		11.08	--	X	--	318,825
12298		10.99	--	X	--	325,188
12299		10.99	--	X	--	331,551
12354		10.99	--	X	--	337,914
12367		10.99	--	X	--	344,277
50129		10.99	--	X	--	350,640
12318		10.97	--	X	--	357,003
730		10.96	--	X	--	362,835
3732		10.87	--	X	--	369,716
12355		10.82	--	X	--	376,079
2071		10.81	--	X	--	382,960
3720		10.80	--	X	--	389,841
	50276	10.48	X	--	--	400,221
742		10.32	--	X	--	406,053
8681		10.23	--	X	--	409,449
	7287	9.87	X	--	--	419,829
	8663	9.85	X	--	--	430,209
	8664	9.85	X	--	--	440,589
	50266	9.85	X	--	--	450,969
	50267	9.85	X	--	--	461,349
	50273	9.85	X	--	--	471,729
	5881	9.84	X	--	--	482,109
	157	9.49	X	--	--	493,025
	159	9.49	X	--	--	503,941

TABLE 55 (Continued)

Crossing A[1]	Number B[2]	Priority Index	IMPROVEMENT DECISIONS Flashers	Gates	Flashers & Gates	Initial Investment**
	160	9.49	X	--	--	$514,857
	708*	9.49	X	--	--	525,773
	5885	9.43	X	--	--	536,153
	50275	9.03	X	--	--	546,533
2986		8.68	--	X	--	553,414
2164		8.42	--	X	--	560,295
	50127*	8.39	X	--	--	573,931
	2069*	8.39	X	--	--	587,567
	2957*	8.39	X	--	--	601,203
12309		8.17	--	X	--	607,566
	2982*	8.02	X	--	--	621,202
2963		7.82	--	X	--	628,083
	2956*	7.06	X	--	--	641,719
12314		6.76	--	X	--	648,082
	2156*	6.38	X	--	--	661,718
735		5.80	--	X	--	667,550
736		5.80	--	X	--	673,382
	50274*	5.17	X	--	--	687,018
	2146*	4.94	X	--	--	700,654
	3749*	4.89	X	--	--	714,290
	3740*	4.82	X	--	--	727,926
	8674*	4.73	X	--	--	738,306
	8679*	4.48	X	--	--	748,686
4996		4.39	--	X	--	762,322
140		4.27	--	X	--	772,702
	8678*	4.18	X	--	--	786,478
50405		4.10	--	X	--	798,256
50403		3.97	--	X	--	810,034
	50276	3.59	--	--	X	813,430
	7287	3.38	--	--	X	816,826
2979		3.38	--	X	--	830,462
	8663	3.38	--	--	X	833,858
	8664	3.38	--	--	X	837,254
	50266	3.38	--	--	X	840,650
	50267	3.38	--	--	X	844,046
	50273	3.38	--	--	X	847,442
	5881	3.38	--	--	X	850,838
	5885	3.23	--	--	X	854,234
	7289*	3.20	X	--	--	864,614
	50275	3.09	--	--	X	868,010

TABLE 55 (Continued)

Crossing A1/	Number B2/	Priority Index	IMPROVEMENT DECISIONS Flashers	Gates	Flashers & Gates	Initial Investment**
2173		2.64	--	X	--	$888,526
5001		2.48	--	X	--	902,162
	12296	2.09	--	--	X	908,525
	50132	2.09	--	--	X	914,888
	50270	2.09	--	--	X	921,251
	50271	2.09	--	--	X	926,614
	157	2.00	--	--	X	933,446
	159	2.00	--	--	X	939,278
	160	2.00	--	--	X	945,110
	708	2.00	--	--	X	950,942
2159		2.00	--	X	--	964,578
50440		1.97	--	X	--	970,224
50441		1.97	--	X	--	975,870
	50127	1.87	--	--	X	982,751
	2069	1.87	--	--	X	989,632
	2957	1.86	--	--	X	996,513
	12350	1.84	--	--	X	1,001,876
	12389	1.84	--	--	X	1,009,239
	12391	1.84	--	--	X	1,015,602
	12410	1.84	--	--	X	1,021,965
	50124	1.84	--	--	X	1,028,328
	50130	1.84	--	--	X	1,034,691
	50131	1.84	--	--	X	1,041,054
	50268	1.84	--	--	X	1,047,417
	12421	1.84	--	--	X	1,053,780
	2982	1.78	--	--	X	1,060,661
	8674	1.61	--	--	X	1,064,057
	2956	1.56	--	--	X	1,070,938
	8679	1.54	--	--	X	1,074,334
	8678	1.43	--	--	X	1,077,730
	2156	1.42	--	--	X	1,084,611
50001		1.37	--	X	--	1,098,247
8667		1.25	--	X	--	1,108,627
	50274	1.15	--	--	X	1,115,508
	2146	1.10	--	--	X	1,122,389
	7289	1.10	--	--	X	1,125,785
	3749	1.09	--	--	X	1,132,666
	3740	1.07	--	--	X	1,136,677

1/Intersections identified in this column appear only once in the analysis.

2/Intersections identified in this column appear twice in the analysis. Each italicized crossing number is matched with a script number.

* Indicates that the script matching number appears below the program decision line.

** Accumulated Totals

Expected Accidents And Their Resulting Cost

It should be pointed out that the procedure described in the preceding pages does not imply rigid compliance to a specific method for computing priority ratings. For example, the lack of statistical validity of the expected accident equation may result in the decision to use actual historical accident experience at individual crossings. Also, due to the fact that rail-highway accident cost experienced by individual crossings differ considerably, the use of actual accident cost rather than average cost in the procedure may have greater appeal to the decision maker.

The purpose of this section of the report is not to describe a fixed operational plan for computing priority ratings for the allocation of public funds to rail-highway safety improvements at specific intersections but rather one of describing a flexible procedure that may be adjusted to the specific requirement of the decision maker for such a continuous operational plan.

SUMMARY

The procedure outlined in this example should prove quite flexible in practice. Essentially it provides a framework for the construction of a ranking system or priority index for traffic intersections according to their relative attractiveness as investment alternatives. Given this framework and the rationale implicit within it, those charged with implementation of a safety program may make those changes which best suit their purposes.

For example, the components of the accident cost calculation may be changed to reflect the differing weights that might be placed upon the value of a life. Similarly, the cost of protection can be revised to allow for salvage values and for different discount rates in computing the capital recovery factor used in annualizing installation costs. Consideration might also be given to possible delays to vehicles due to a particular type of protection as another cost factor.

The flexibility of the procedure is also evident in the various decision criteria which may be used when employing the priority index. If the funds allocated for the safety program are determined solely on a fixed (legislative or executive) basis, then the problem is one of protecting crossings in descending order of ranking until these funds are exhausted.

However, if the total budget for the program is to be determined on an economic basis, the decision criterion should be to protect all intersections in descending order of ranking until the incremental benefit (marginal reduction in accident cost) equals the incremental cost of added protection (marginal cost). This will insure that net benefits are maximized.

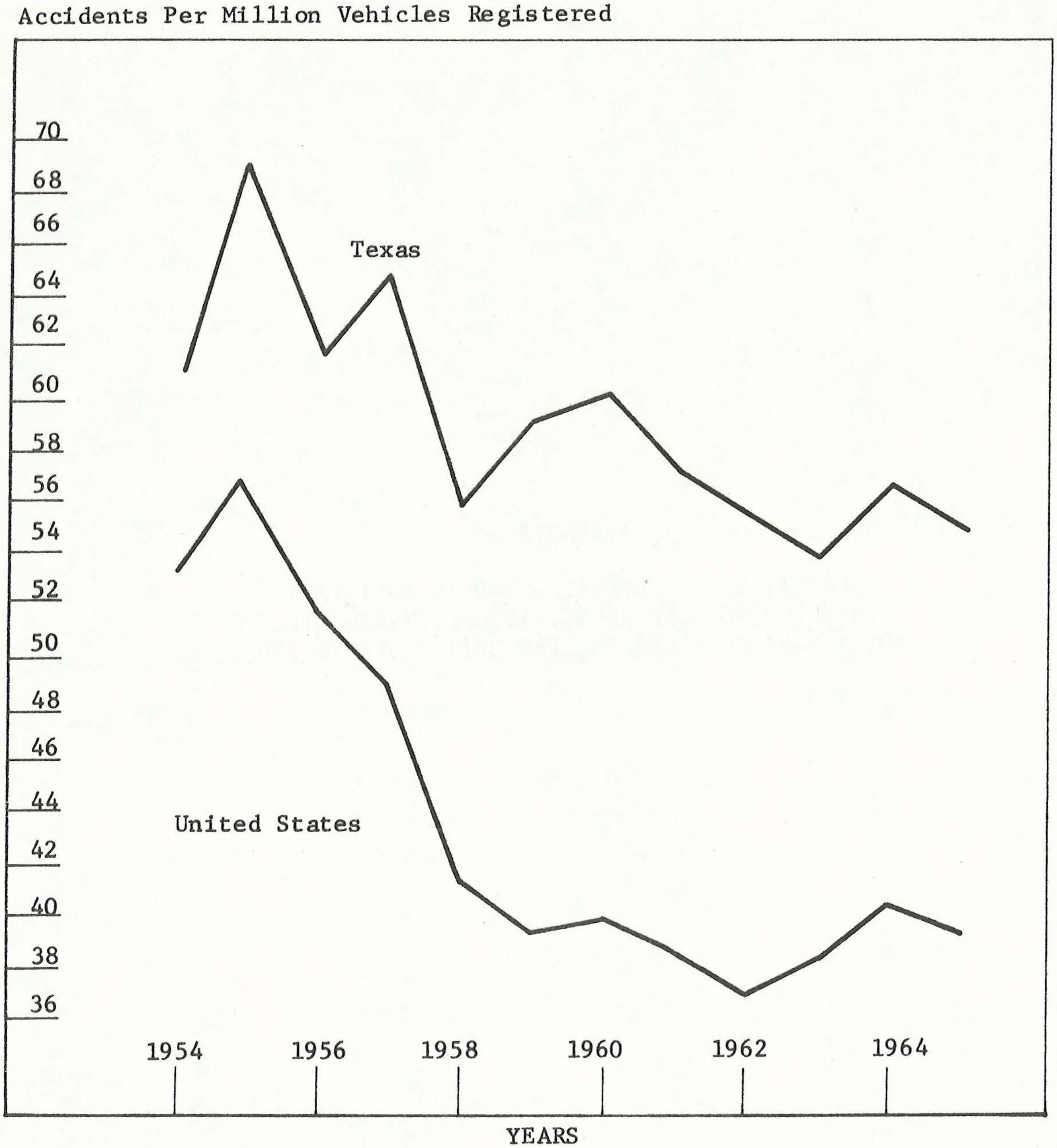
The latter method requires that the cost of accidents include value of future earnings and other indirect costs incurred in both benefit and cost computations.

A third method would be to carry the program to the point that total benefits equal total costs; however, this will not be an optimizing procedure, as is the second method, and may lead to distortions in the allocating of public funds.

It should again be emphasized that the procedure described has not dealt with all of the factors involved in the economic evaluation of safety programs at intersections. Refinements may be made in calculating both the benefits and the costs of increasing the level of protection at such locations. In addition, the effectiveness of the alternative devices and the expected accident rate indices are certainly not perfect measures. Yet it is felt that the procedure described in this paper is sound and that any of the shortcomings mentioned may be easily rectified within this framework.

FIGURE 1

RAIL-HIGHWAY GRADE CROSSING ACCIDENTS PER MILLION VEHICLES REGISTERED IN THE UNITED STATES AND TEXAS FOR THE PERIOD 1954-1965



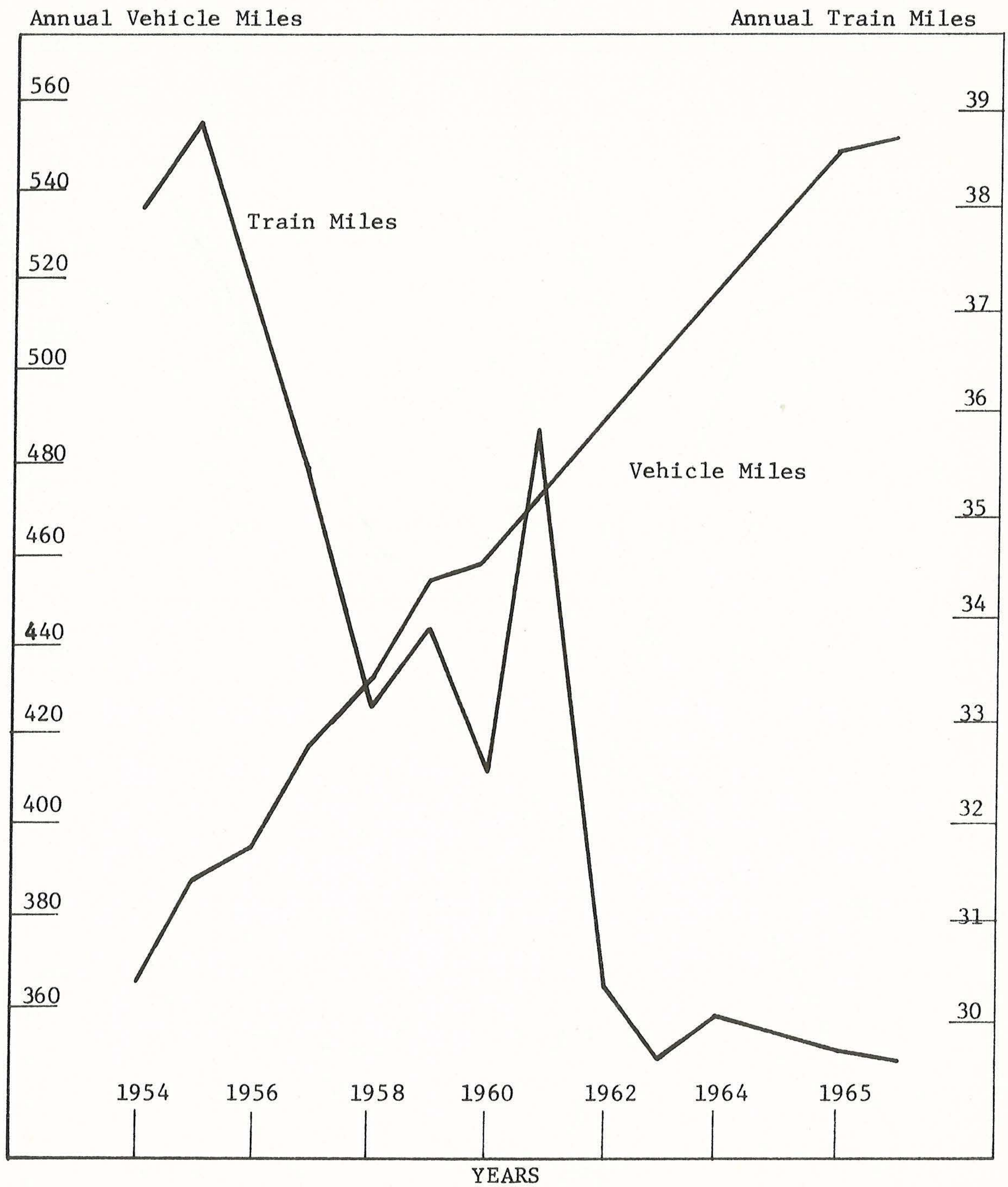
SOURCE: Seventy Fourth Annual Report, Railroad Statistical Section. Railroad Commission of Texas, and Rail-Highway Grade Crossing Accidents, ICC Statement 6305.

APPENDIX A

RELATIONSHIP OF RAIL-HIGHWAY ACCIDENTS TO MOTOR VEHICLE REGISTRATIONS, TRAIN MILES, AND MOTOR VEHICLE MILES FOR THE UNITED STATES AND TEXAS

FIGURE 2

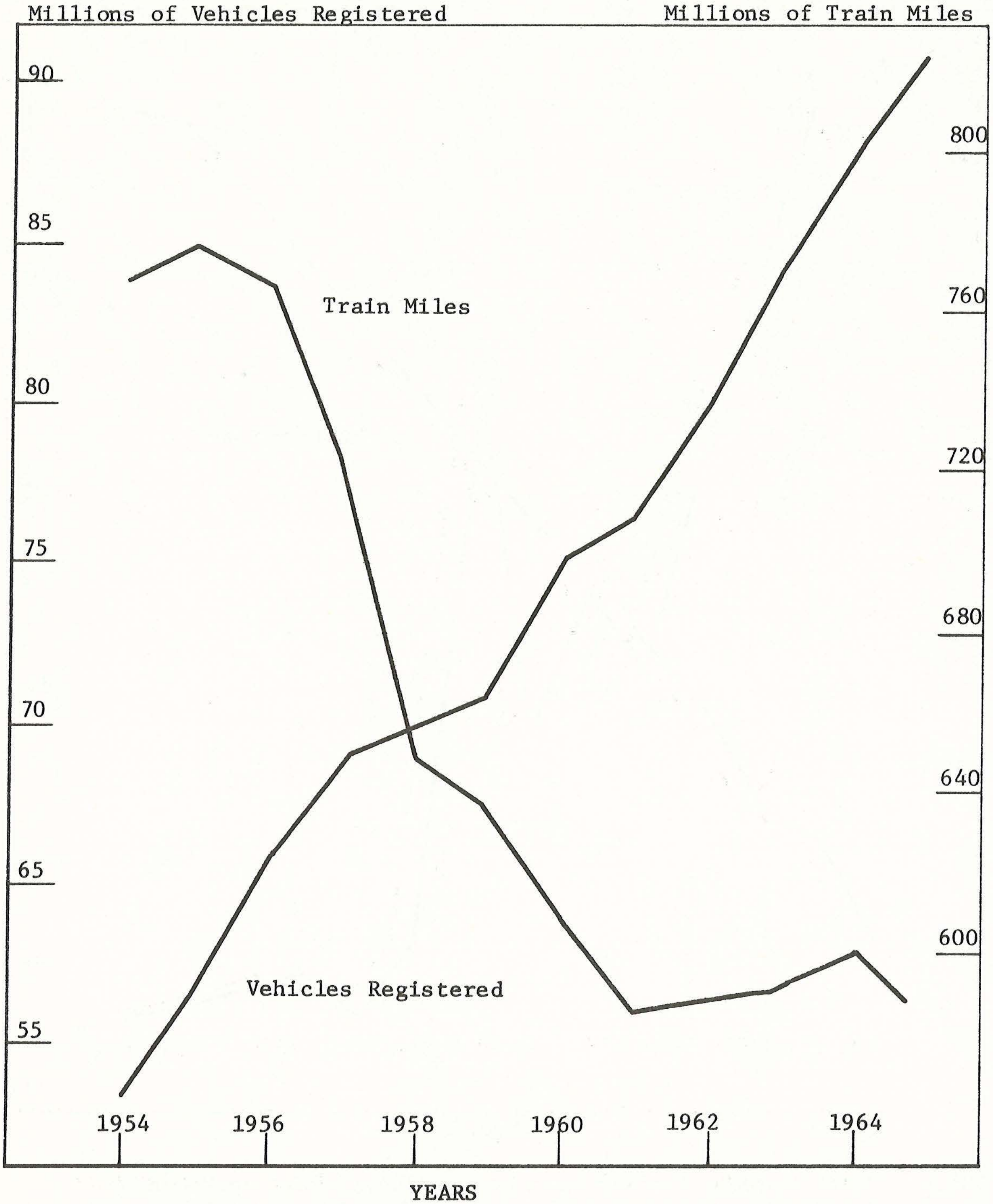
TEXAS VEHICLE MILES OPERATED ANNUALLY AS COMPARED TO ANNUAL TRAIN MILES OF TEXAS RAILROADS FOR THE PERIOD 1954-1965
(In Millions)



SOURCE: Motor Vehicle Traffic Accidents, 1964, Texas Department of Public Safety, and Seventy Second Annual Report, Railroad Statistical Section, Railroad Commission of Texas.

FIGURE 3

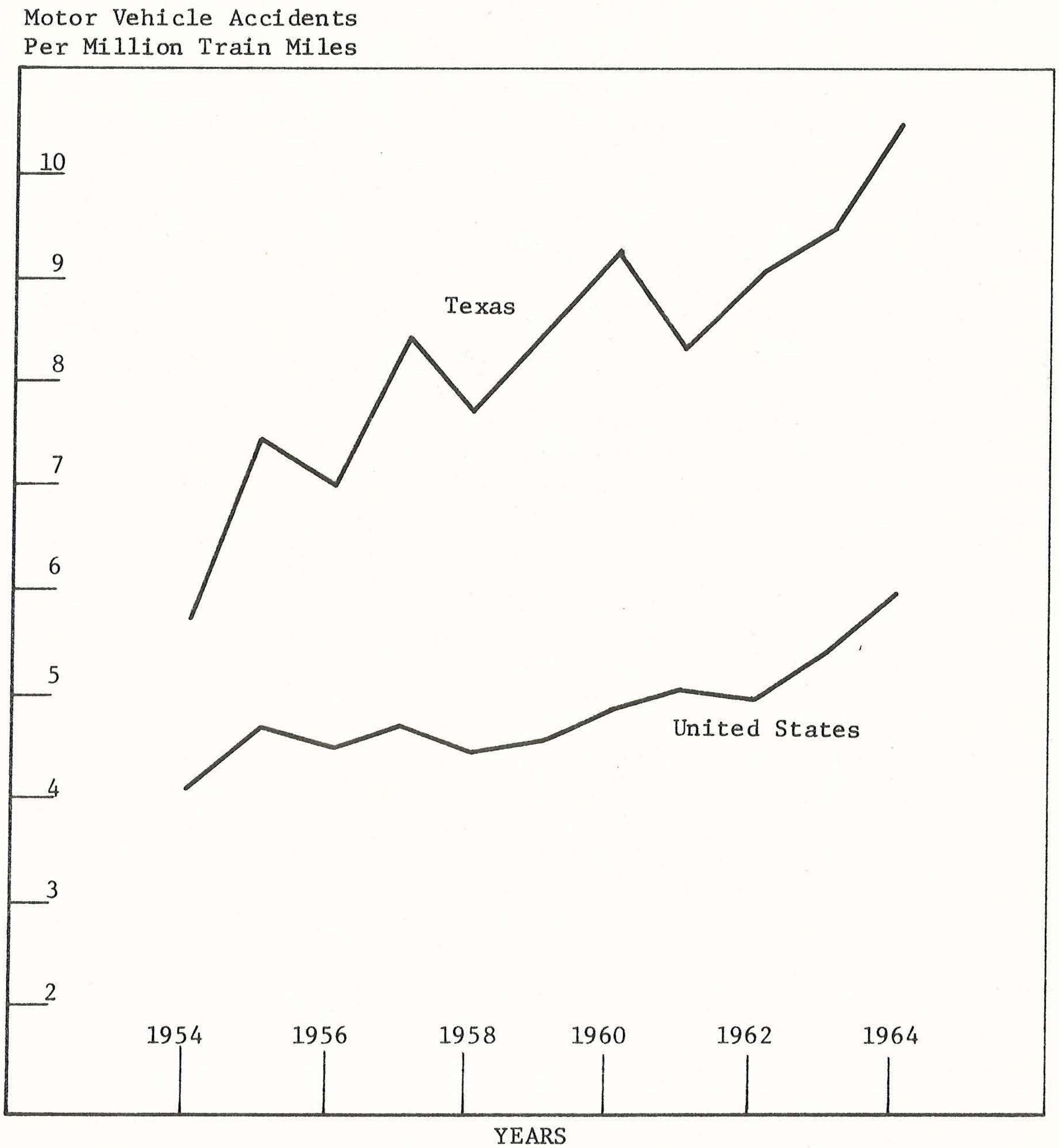
UNITED STATES TRENDS IN ANNUAL TRAIN MILES AND MOTOR VEHICLES REGISTERED FOR THE PERIOD 1954-1965



SOURCE: Rail-Highway Grade Crossings Accidents, ICC Statement 6305, and Table 155, Part 1, Transport Statistics in the United States Year Ended December 31, 1964.

FIGURE 4

RAIL-HIGHWAY GRADE CROSSING ACCIDENTS TO MOTOR VEHICLES
PER MILLIONS OF TRAIN MILES OPERATED IN THE
UNITED STATES AND TEXAS FOR THE PERIOD 1954-1964



SOURCE: Seventy Fourth Annual Report, Railroad Statistical Section. Railroad Commission of Texas, and Rail-Highway Grade Crossing Accidents, ICC Statement 6305, and Table 155, Part 1, Transport Statistics in the United States Year Ended December 31, 1964.

APPENDIX B

REVIEW OF PREVIOUS STUDIES

REVIEW OF PREVIOUS STUDIES

The approach to previous investigations of hazards at grade crossings has varied according to the type of agency performing the study. For the purposes of this review, the types of studies have been classified as follows:

1. State Highway and City Investigations
2. Railway Investigations.

State Highway and City Investigations

An early study on a multi-state level was reported by Peabody and Dimmick in 1941.[1] They collected data from 3,563 rural crossings distributed over twenty-nine states. These data were collected by officials of the various state highway departments and included only crossings in which one or more accidents had occurred during the years 1932 thru 1936. The information furnished for each crossing included: (1) a description or sketch of the crossing, (2) highway and railway traffic volume, and (3) a description of each accident that had occurred during the five-year study period.

The multiple regression analysis technique was used to determine the significant relationships between several factors associated with grade crossings and the accidents that occurred at these crossings. The study concluded that expected accidents could be calculated by the equation:

$$I = 1.28 \frac{ADT^{0.170} + T^{0.151}}{P^{0.171}} + K ,$$

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[1]L. E. Peabody and T. B. Dimmick, "Accident Hazard at Grade Crossings," Public Roads, XXII (August, 1941).

where,

I = Expected number of accidents in a five-year period.
ADT = Average daily traffic count.
T = Trains per day.
P = Protection type coefficient.
K = Smoothing factor, reported in a graphical form without a defining equation.

This particular investigation is considered by many to be the most ambitious study ever undertaken on this subject.[2] The results are still used and are often considered the most "authoritative work to date."[3] However, the study has received some criticism, due to the fact that the degree of correlation and the extent of variability associated with the accident equation were not made available by the researchers.[4]

Two recent investigations of hazards at state highway railroad grade crossings were conducted in Oregon and California.[5] As in the Peabody-Dimmick study, these investigations used a multiple regression analysis to determine the relationship between features of a grade crossing, and accidents. The Oregon study concluded that a multiple curve-linear regression technique was the preferred solution, while the California study

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[2]Donald G. Newnan, An Economic Analysis of Railway Grade Crossings on the California State Highway System, Report, Engineering-Economic Planning, Number 16 (Palo Alto: Stanford University, 1965), p. 6.

[3]Ibid.

[4]Ibid.

[5]Oregon State Highway Department, Relative Hazards at Railroad Grade Crossings on State and Federal Aid Highway Systems, (1954); and Newnan, op. cit.

found that a multiple linear regression technique was the best expression of the relationship between accident and railroad grade crossing characteristics.

The crossings in the Oregon investigation consisted of those located on the State and Federal-Aid Highway System and included both accident and non-accident sites. The study covered a period of five years from January 1, 1946, to December 31, 1950. The accident expression developed from this study,

$$A:VT$$

where,

A = Accidents
V = Average daily traffic
T = Train traffic

has a correlation coefficient of 0.6505. A standard error of estimate was not reported in the original study, but Newnan analyzed the data for 361 of the Oregon crossings in 1965 and found that they yielded,

$$A = 0.7047 + 2(10^{-5})VT.$$

Newnan reported that his equation had a standard error of estimate of 2.16 and a correlation coefficient of 0.55.[6]

The report showed that the preferred solution was curve-linear:

$$A_2 = 40 + 7.53(10^{-5})V - 8.72(10^{-11})\ V^2$$

where,

$$V = P(V_{night} + t_{night}d + V_{day} + t_{day})$$

---

[6]Newnan, op. cit., p. 7

$V = V_{night} + V_{day}$

$t = t_{night} + t_{day}$

P = Protection factor

d = Darkness factor

The correlation coefficient for this last equation is 0.7202.

In 1965, Donald G. Newnan reported a study that he had conducted of 617 crossings located on the California State Highway System.[7] The development of a model for predicting accidents at grade crossings was not the total objective in this investigation. Newnan's study was unique, however, in that it developed a predictive equation for crossings using five different types of protective devices. This investigation determined that the number of accidents in a two-year period for each type of protective device could be predicted from:

Device	Equation
Crossbucks Accidents =	-0.1956+0.0028(A)+0.0037(C)+0.0329(D)+0.0193(E)+0.0307(G)
Standard Wigwag Accidents =	0.1315+0.0042(A)+0.0569(B)+0.0373(D)-0.0897(F)
Other wigwag, rotating, and flashing lights Accidents =	-0.4634-0.0022(A)+0.0357(C)+0.0139(D)+0.1897(G)
Flashing lights Accidents =	0.0262+0.0018(A)+0.0290(B)+0.0217(D)+0.0356(F)+0.0302(G)
Automatic gates Accidents =	-0.4938-0.0037(A)-0.0843(B)+0.0186(C)+0.0192(D)+0.1625(G)

where,

A = Annual ADT

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[7] *Ibid.*

B = Total number of tracks
C = Weather (horizontal visibility)
D = Average number of trains daily
E = Crossing angle
F = Highway approach grade
G = Crossing corner visibility

Newnan's investigation covered a period of from 1946 thru 1963 and was based on data obtained from the records of the California Public Utilities Commission.

Traffic engineering departments in Detroit and Houston have conducted studies of railroad grade crossings located in their respective cities.[8] The Detroit study was quite comprehensive in that an accident potential rating was determined for each crossing, and detailed information for improvements was compiled. The Houston study considered only train and vehicular movements in determining an exposure rating for each major crossing within the city.

Separate investigations on rural and urban crossings were recently completed in Indiana by Berg[9] and Schultz[10]. The objective in both of these studies was to determine the relative effects of those factors which significantly influence the accident pattern at urban and rural crossings,

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[8]City of Detroit, Traffic Engineering Bureau, Report on Railroad Grade Crossings (Vol. 11), 1953, and Houston, Department of Traffic Engineering, Study of Railroad Grade Crossing Protection in Houston, 1963.

[9]W. D. Berg, "Evaluation of Safety at Railroad-Highway Grade Crossings in Urban Areas," Joint Highway Research Project No. 16, (Lafayette, Indiana: Purdue University, 1966).

[10]T. G. Schultz, "Evaluation of Safety at Railroad-Highway Grade Crossings," Joint Highway Research Project No. 9, (Lafayette, Indiana: Purdue University, 1965).

and then to develop models that could be used for establishing a priority rating system. Both accident and non-accident crossings were used in these two investigations. Schultz, in his investigation of rural crossings, derived a predictive formula by both factorial and regression analysis. He concluded that each technique proved the results of the other, but the simplicity of the regression model made it preferable to the one developed by factorial analysis. Twenty-eight variables were included in his regression analysis, but only nine proved significant. The equation is expressed in the following manner:

$$IH = 0.149 - 0.376X_1 - 0.300X_2 - 0.383X_3 - 0.331X_4 + 0.082X_5 + 0.0223X_6 + 0.011X_7 + 0.0143X_8 + 0.024X_9$$

where,

IH = Index of hazard
X_1 = Presence of a painted crossbuck (0,1)
X_2 = Presence of a reflectorized crossbuck (0,1)
X_3 = Presence of a flasher (0,1)
X_4 = Presence of a gate (0,1)
X_5 = Number of track pairs
X_6 = Pavement width in feet
X_7 = Trains per day
X_8 = ADT/1000
X_9 = Sum of distraction (Houses, businesses, and signs).

The equation has a correlation coefficient of 0.193 and a standard error of estimate of 0.484.

Because the values of the coefficients for the different protective devices were approximately equal, a formula, excluding these variables, was developed. This equation,

$$IH = 0.185 + 079X_5 + 0.21X_6 + 0.11X_7 + 013X_8 + 024X_9 ,$$

has a multiple correlation coefficient of 0.183 and standard error of estimate of 0.486.

Although the hypothesis that the protection coefficients are equal to zero could not be rejected, Schultz stated that this test did not warrant the conclusion that protective devices have no influence on reducing hazards. He suggested a before-and-after analysis of locations where changes in protective devices are made, to ascertain their relative contributions.

In his investigation of urban crossings in Indiana, Berg developed a model for discriminating between accident and non-accident crossings. The mechanics of regression analysis were used in the development of the formulas, and the most discriminant formula was seventy-four percent successful in classifying the crossings in the study as either accident prone or non-accident prone. The model,

$$\begin{aligned} F = 0.41227 - 0.03276X_1 + 0.02384X_2 + 0.00728X_3 \\ - 0.02109X_4 - 0.19494X_5 - 0.52512X_6 = 0.01281X_7 \end{aligned}$$

where,

F = Discriminant score
X_1 = Line of sight ratio
X_2 = ADT/1000
X_3 = Trains per day
X_4 = Presence of a reflectorized crossbuck (0,1)
X_5 = Presence of a flasher (0,1)
X_6 = Presence of a gate (0,1)

X_7 = Sum of distractions (number of businesses or advertising signs, on both sides of the roadway, along a section extending 500 ft. from the crossing to 200 ft. beyond the crossing for one approach direction),

must be used under the following constraint:

Pr. (observation is from accident prone group) +

$$\begin{aligned} &0, \text{ if } F < 0 \\ &F, \text{ if } 0 < F < 1 \\ &1, \text{ if } 1 < F \end{aligned}$$

Railway Investigations

The investigations that were reviewed under this classification have been concerned primarily with determining the relative effectiveness of the different types of protective devices at rail-highway grade crossings. Two studies used statistics that covered more than twenty years,[11] while a third investigator collected data for a ten-year period.[12] All of the investigations found that automatic gates provided the greatest amount of protection for motorists at railroad grade crossings. A brief summary of each of these investigations is outlined below.

Wabash Study. One of the most thorough investigations to determine the relative effectiveness of protective devices at grade crossings was

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[11] W. J. Hedley, "The Achievement of Grade Crossing Protection," _AREA Proceedings_, (1949), pp. 849-864; and Southern Pacific Company, Office of Chief Engineer, _A Study of the Protection and Accident Records of 77 Main Track Railroad-Highway Grade Crossings on the San Francisco Peninsula, 1942 through 1964_, (San Francisco, California, August 23, 1965).

[12] California Public Utilities Commission, Transportation Division, _Effectiveness of Automatic Crossing Gates in Northern California, 1954 through 1964_, (San Francisco, California, March, 1965).

reported in 1949 by W. J. Hedley.[13] His report covered the period from January 1, 1929, to December 31, 1948. It was concerned exclusively with the rail-highway accident experience of the Wabash Railroad. Using data developed from physical and operational characteristics of various classes of grade crossings and accidents of these crossing classes, Hedley developed an accident quotient for each type of protection. (See Table 1 for the results of this analysis) The report was updated in 1952 and again in 1954, but the results were substantially the same as reported in the original study.

Southern Pacific. This study covered a twenty-three year period from 1942 through 1964.[14] The rail-highway grade crossings included in this study were located on the high-speed, double-track main line of the Southern Pacific Company between San Francisco and San Jose, California. There were 27 crossings having train speeds of 50 to 79 miles per hour over a majority of the crossings. The number of trains varied between 65 and 100 movements per day. Eleven of the crossings were closed or eliminated during the study period. Table 2 shows the effectiveness of different types of protective devices at sixty-six of the crossings. The conclusions reached from this investigation were:

1. The physical barrier of crossing gates and their automatic operation tend to eliminate the human failures which contribute to crossing accidents.

2. Automatic gate installations have materially reduced both

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[13] Hedley, *op. cit.*

[14] Southern Pacific, *op. cit.*

TABLE 1

FINAL ACCIDENT QUOTIENTS

Type of Protection	Experience Factor (Years)	Final Accident Quotient
Automatic gates	527.3	0.0815
Painted crossbuck signs	1825.9	0.5680
Reflector signs--AREA	419.4	0.4771
Reflector signs--Michigan	611.0	0.5373
Automatic bell	242.1	0.5036
Wig-way	114.5	0.4995
Flashing lights--old, single track	12.8	0.5695
Flashing lights--old, multiple track	365.2	0.4176
Flashing lights--modern, single track	538.9	0.1374
Flashing lights--modern, multiple track . .	776.5	0.2836
Watchman--part time	197.6	0.5108
Watchman--24 hours	144.1	0.4819
Manual gates--part time	146.2	0.4206
Manual gates--24 hours	158.1	0.2560

Source: Address by W. J. Hedley, Table 16, AREA Proceedings, 1949, op. cit.

TABLE 2. EFFECTIVENESS OF DIFFERENT TYPES OF PROTECTIVE DEVICES

Type of Previous Protection	Number of Crossings	Crossing Years in Operation	Total Number			Per Crossing Year		
			Accidents	Fatalities	Injuries	Accidents	Fatalities	Injuries
Fixed Signs-Standard No. 1	5	37.8	21	6	5	0.56	0.16	0.13
Automatic Signals (#3, #4, #5, or #8)	48	624.9	273	91	91	0.44	0.15	0.15
Crossing Watchman	4#	34.9	17	2	8	0.49	0.06	0.23
Manual Gates	12	145.7	17	3	7	0.12	0.02	0.05
Before Installation of Automatic Gates	66*	843.3	328	102	111	0.39	0.12	0.13
After Installation of Automatic Gates	66**	651.9	90	7	15	0.14	0.01	0.02

* Above figures in column "Number of Crossings" will not equal the total of 66 as in some cases crossings had more than one type of protection during the period studied.

** Total of 66 crossings with automatic gates does not include E-12,8, Center St., Millbrae, or E-24.1, Howard Ave., San Carlos, both of which were newly established since 1942, or E-31.0, Churchill Ave., Palo Alto, which had automatic gates prior to 1942.

\# Crossings E-28.8, Oak Grove Ave., Menlo Park, and E-29.8, Palo Alto Ave., Palo Alto, are listed under "Crossing Watchman" only, although Automatic Signals were in place at same time.

the accident rates and the number of casualties, in spite of the tremendous increases in the number of motor vehicles in operation.

3. Automatic gates provide the safest type of grade crossing protection.[15]

Northern California. This was a study of the accident experience over a ten-year period, July 1, 1954, through June 30, 1964, at 168 railroad grade crossings in Northern California.[16] Automatic gates were installed at 113 crossings during the study period. The investigation, therefore, consisted of a comparison of the accident experience before and after the installation of automatic gates. Fifty-five of the crossings had automatic gates during the entire study period. The results of this investigation are summarized in Tables 3 and 4.

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[15] Southern Pacific, op. cit.

[16] California Public Utilities Commission, op. cit.

Table 3
Summary of Results on a "Crossing-Year" Basis

Line No. (1)	NO. of Points (2)	Type of Crossing Protection IMMEDIATELY Automatic Gate Installation (3)	Results on a "Crossing-Year" Basis: BEFORE Auto.Gate Installation: Accidents (4)	Deaths (5)	Injuries (6)	AFTER Auto.Gate Installation: Accidents (7)	Deaths (8)	Injuries (9)
1	55	Auto. Gates Only June 1954 - June 1964	-	-	-	0.166	0.014	0.019
2	13	Fixed Signs	0.267	0.015	0.148	0.160	0	0.032
3	10	Crossing Watchman	1.021	0.048	0.451	0.155	0	0.052
4	37	Auto. Signals #3, 4, and 5	0.649	0.147	0.239	0.111	0.005	0.024
5	42	Auto. Signals #8	0.658	0.111	0.282	0.151	0.011	0.027
6	11	Manual Gates	0.344	0.012	0.154	0.039	0	0
7	168	All Types, Lines 1 - 6	0.592	0.091	0.249	0.148	0.010	0.024
8	113	All types, Lines 2 - 6 (exclusive Line 2 at which no experience BEFORE auto. gate installation is shown).	0.592	0.091	0.249	0.132	0.006	0.028

Table 4
Summary of Effectiveness of Automatic Crossing Gate Installation

Line No. (1)	Description (2)	Accidents (3)	Deaths (4)	Injuries (5)
1	Results on a "Crossing-Year" Basis at 113 points BEFORE Automatic Crossing Gate Installation (Line 6, Table II)	0.592	0.091	0.249
2	Results on a "Crossing-Year" Basis at 113 points AFTER Automatic Crossing Gate Installation (Line 6, Table II)	0.132	0.006	0.028
3	Decrease per "Crossing-Year" AFTER Automatic Gate Installation (Line 1 minus Line 2)	0.460	0.085	0.221
4	Percent decrease per "Crossing-Year" AFTER Automatic Gate Installation (Line 3 divided by Line 1)	78%	93%	89%
5	Estimated Decrease per CALENDAR YEAR for the 113 points studied AFTER Automatic Gate Installation (line 3 times 113)	52	10	25

APPENDIX C

FORM, PROCEDURE, AND CODING SYSTEM FOR FIELD DATA

PROCEDURE FOR COLLECTING FIELD DATA

Each crossing will require a separate form. The portion of the form concerning district, county, route, railroad, and crossing number will be filled out before leaving the office. Also, train speed will be recorded on the form in the office and is to be secured from the railroad inventory form.

Before leaving the office to collect field data, each field crew will ascertain that they have the following items:

a. A marked map indicating itinerary of crossings to be visited.

b. A form for each crossing on itinerary.

c. Set of tables for determining primary sight channels.

d. A roto-meter wheel for measuring sight distances.

e. A set of short-wave radios with a set of spare batteries.

f. A copy of the coding manual.

g. Two clip boards.

h. Note pad and pencils.

i. A set of these instructions.

The data should be collected on each item in accordance with the following instructions:

Roadway type--Number of lanes and direction of travel.

Highway width--(feet) Includes highway surface and shoulders.

Surface width--(feet) Highway width minus shoulder width.

Surface type--Cement, blacktop, gravel, or other.

Shoulder type--Same as surface type.

Shoulder width--(feet) Highway width minus surface width, divided by two.

Highway direction--Will be referenced to compass direction (N, NE, S, SW).

Angle of intersection--Estimate to the nearest 15 degrees.

Speed--posted speed limit, or the observer will make a subjective appraisal if posted speed does not appear realistic.

Number of tracks--actual number--each track is composed of two rails.

Crossing Slope (percent)--The difference in elevation of the highway surface with respect to railroad bed within 100 feet of crossing. The observer will measure 100 feet down highway from nearest rail and estimate the rise or fall in the highway for this distance. See illustration in Figure 25.

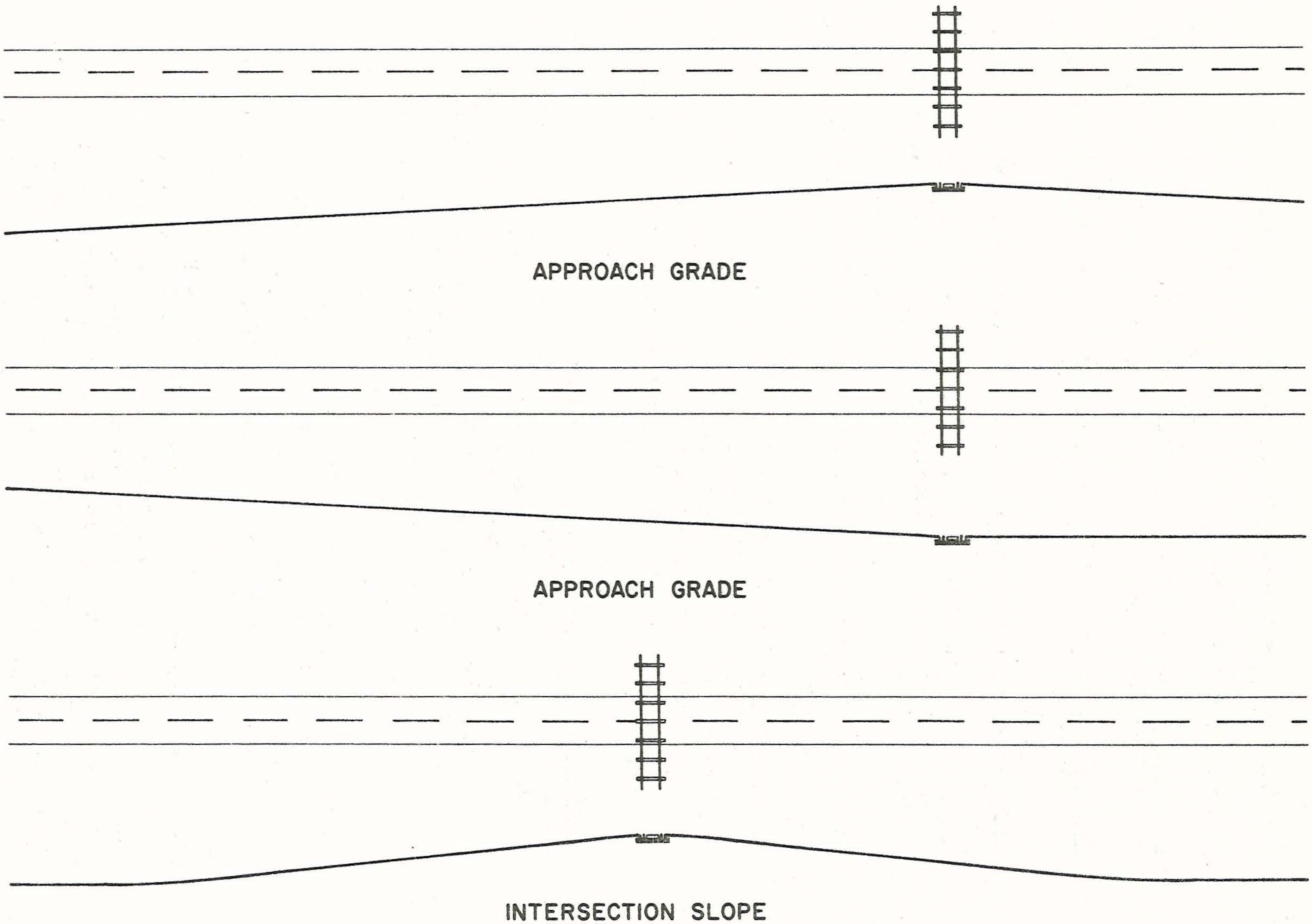
Level of track with respect to ground--The observer will note if the natural topography has been altered to accommodate the railroad bed. An example of this would be of the railroad running through a cut just before intersecting the highway. If the situation is not uniform on both sides of the highway, the observer is to make a determination of the most hazardous condition and indicate accordingly on the form.

Primary sight channel--The following narrative defines the primary sight channel. The procedure for determining this variable at each crossing will follow. The illustration in Figure 3 should be used for additional clarity.

The primary sight channel is defined by two points along the highway and two points along the railroad in each quadrant of the highway-railroad intersection. The most distant point along the highway is defined as the think-reaction time of the driver plus braking distance on wet pavement, plus twenty feet of clearance from the first track at the crossing. The second highway point is defined as the commitment point and excludes the think-reaction time. In other words, at the second point the driver must be engaging either his brakes

FIGURE 1

TYPE OF CROSSING GRADIENT



or accelerator. At this time the driver is committed to a course of action to either stop or go. Note that each of the points are defined only by vehicle speed and friction on the highway. The most distant point along the railroad is defined as a point where a train traveling at the posted speed limits could be beaten to the intersection by a vehicle at the most distant point along the highway defined above. The highway vehicle is assumed to travel at a constant speed between the two highway points and take on truck acceleration rates at the second highway point. (At speeds above 50 mph no acceleration was assumed.) The second railroad point is the position of the train under the same conditions but with the vehicle at its second point.

In any one quadrant these four points define a path or channel that includes the paths of both the highway vehicle and the train during the driver's think-reaction time. This study assumes a three second think-reaction time which is sufficiently long to include more than ninety percent of drivers. The study assumes that the driver must have clear visibility of the train all during the think-reaction time to assess his situation adequately. Note that if the train is just entering the sight channel, either decision the driver makes, to stop or go, is correct. Of course, if the train is within or through this channel, the driver has only one correct choice, to stop.

Procedure: Upon arrival at the crossing, the observer will note the appropriate automobile speed; and from the form the speed of the fastest train can be obtained for that crossing. With these two speeds, the appropriate distances can be determined for the primary sight channels from the set of tables provided for this purpose. One observer will walk to the minimum distance down the railroad track, while the other observer stations himself at the minimum point on the highway. Confirmation that each observer is at the minimum point, each shall start walking toward the maximum point, or until some obstruction is encountered in the channel that would restrict the visibility of a driver from seeing a train. The process shall be repeated for all four quadrants.

Secondary sight triangle. After the train and the highway vehicle are within the near points defined above, the vehicle is completely committed to his decision; he can no longer change his mind unless he has superior brakes or acceleration ability. In this secondary sight triangle, which is formed by the highway, the railroad, and the inside line of the primary sight channel, it is not as critical for the driver to maintain view of the train.

However, this area should be as clear as possible in order that the driver maintain a continuous path of vision. It would be most desirable to maintain this triangle free of any large, solid objects, such as buildings or large signs; however, light vegetation, scattered trees or small signs may be acceptable in this portion of the sight triangle. Because of the severity of auto-train accidents, even accidents which result from engaging in evasive action are usually preferable to these accidents. A continuity of vision in the secondary sight triangle is recommended in order that the driver has an opportunity to re-evaluate his decision in light of the dynamic conditions which are encountered in the interval between his decision and the completion of the decision.

Procedure: While going from the center of the intersection to the minimum distance for the primary sight channel, each observer shall note the degree of obstruction from his view point. When the minimum distances are reached, a decision will be made on the degree of visibility restriction within the triangle. Four increments of visibility restriction shall be used: 0.25 percent, 25 to 50 percent, 50 to 75 percent, and 75 to 100 percent.

Number and types of protective devices. The actual number of installations of the different protective devices at a crossing should be entered in the appropriate place. A zero will indicate the absence of a protective device at a crossing.

Number of intersecting streets and highways. Enter actual number in the appropriate blank. The following definitions shall apply:

Primary streets--all hard-surfaced streets.

Secondary streets--all graveled roads and streets.

Primary highway--all U. S. and State highways.

Secondary highway--all farm-to-market roads.

Zero points for the purpose of recording distances will be:

a. On the right side pavement edge for measurements to the right.

b. On the railroad,

1. On the right side pavement edge for measurements to the right.

2. On the left side pavement edge for measurements to the left.

It is the responsibility of each crew member to see that the form is completed prior to leaving the intersection.

Date________________

FORM FOR FIELD DATA
Sample Crossings

(1-2) Card Number__________

(3-7) I.D. Number__________

(8-11) Highway Control__________

(12-13) Highway Section__________

(14-16) Highway Milepost__________

(17) Roadway Type__________

(18-19) Highway Width__________

(20-21) Surface Width__________

(22) Surface Type__________

(23) Shoulder Type__________

(24-25) Shoulder Width__________

(26) Highway Direction__________
(N, E, NE or NW)

(27) Approach Grade__________
(N, E, NE or NW)

(28) Approach Grade__________
(S, W, SW or SE)

(29-30) Angle of__________
Intersection

(31-32) Highway Curvature
(N,E,NE or NW)__________

(33-34) Highway Curvature
(S,W,SW or SE)__________

(35-36) Posted Speed__________

(37-38) Number Tracks__________

(39-40) Crossing Slope
Vertical__________
Horizontal__________

City__________

County__________

Highway No.__________

District No.__________

Railroad Co.__________

Railroad Subdivision__________

Railroad Milepost__________

Visibility Triangle Quadrant

__________42NE__________

__________43NW__________

__________44SE__________

__________45SW__________

Visibility Sight Channel Quadrant

__________46NE__________

__________47NW__________

__________48SE__________

__________49SW__________

(41) Track Level with Respect to Natural Ground Level____________________

Below____________________
Above____________________
Same____________________

Number and Type of Protective Devices

(50) Crossbuck__________

(51) R. Crossbuck__________

(52) Stop Signs__________

(53) Flashing Lights__________

(54) Bells__________

(55) Wigwags__________

(56) Watchmen__________

(57) Automatic Gates__________

(58) Illumination__________

(59) Advanced Warning__________

(60) RR__________

(61) Highway__________

(62) Signal__________

(63) Other__________

(64) Class of Protection

____

Number of Intersecting Streets and Highways

		( )	( )	( )	( )
		Primary Street	Secondary Street	Primary Highway	Secondary Highway
(65-68)	0-100 ft.	( )	( )	( )	( )
(69-72)	100-200 ft.	( )	( )	( )	( )
(73-76)	200-300 ft.	( )	( )	( )	( )
(77-80)	300-400 ft.	( )	( )	( )	( )

COMMENTS:

APPENDIX D

SUMMARY OF ANALYSES FOR PREDICTIVE MODEL

TABLE 1

SUMMARY OF ANALYSIS

WITH ALL THIRTEEN VARIABLES

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
A. Probability of Conflict	0.89	0.260	7.48	0.106	3.48
B. Roadway Type	1.29	0.010	2.09	1.999	0.49
C. Highway Width	34.92	0.003	0.003	8.274	1.66
D. Surface Width	27.48	-0.003	0.002	-7.711	-1.37
E. Angle of Intersection	80.92	0.0005	0.0008	1.943	0.65
F. Posted Speed	38.09	-0.0006	0.0007	-2.740	-0.82
G. Number of Tracks	1.59	0.0060	1.45	1.347	0.41
H. Crossing Slope	0.81	-0.0140	91.70	-4.413	-1.53

TABLE 1 (CONTINUED)

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
I. Approach Slope	2.27	-0.0314	1.93	-4.722	-1.63
J. Visibility of Sight Triangle	6.48	19.38	40.55	2.342	0.48
K. Visibility of Sight Channel	2.30	48.69	1.48	1.616	0.33
L. Type of Protective Device	1.51	-0.055	2.56	-6.478	-2.14
M. Number of Roads	1.87	0.002	97.41	90.23	0.25

Intercept	-0.00376
Multiple Correlation Coefficient	-0.1414
Standard Error of Estimate	0.4380
Analysis of Variance: F Value	2.12

TABLE 2

SUMMARY OF ANALYSIS WITH VARIABLE M (NUMBER OF ROADS) ELIMINATED

ON THE BASIS OF LOWEST REMAINING NON-SIGNIFICANT T-VALUE

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
A. Probability of Conflict	0.8921	0.261	0.075	0.106	3.50
B. Roadway Type	1.29	0.010	0.0021	0.020	0.49
C. Highway Width	34.92	0.003	0.002	0.082	1.66
D. Surface Width	27.48	0.003	0.002	-0.075	-1.35
E. Angle of Intersection	80.92	0.0006	0.0008	0.020	0.67
F. Posted Speed	38.09	-0.0007	0.0006	-0.031	-1.07
G. Number of Tracks	1.59	0.007	0.012	0.016	0.51
H. Crossing Slope	0.81	-0.014	0.009	-0.043	-1.51
I. Approach Slope	2.27	-0.031	0.019	-0.047	-1.63

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TABLE 2 (CONTINUED)

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
J. Visibility of Sight Triangle	6.48	0.002	0.004	0.024	0.48
K. Visibility of Sight Channel	2.30	0.005	0.015	0.016	0.34
L. Type of Protective Device	1.51	-0.054	0.025	-0.064	2.12

Intercept	-0.00508
Multiple Correlation Coefficient	0.1413
Standard Error of Estimate	0.4378
Analysis of Variance: F Value	2.29

TABLE 3

SUMMARY OF ANALYSIS WITH VARIABLE K (VISIBILITY OF SIGHT CHANNEL) ELIMINATED ON THE BASIS OF LOWEST REMAINING NON-SIGNIFICANT T-VALUE

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
A. Probability of Conflict	0.89	0.262	0.075	0.106	3.51
B. Roadway Type	1.29	0.009	0.020	0.017	0.43
C. Highway Width	34.92	0.003	0.002	0.083	1.66
D. Surface Width	27.48	-0.003	0.002	-0.074	-1.32
E. Angle of Intersection	80.92	0.0006	0.0008	0.021	0.71
F. Posted Speed	38.09	-0.0007	0.0006	-0.032	-1.10
G. Number of Tracks	1.59	0.008	0.012	0.017	0.55
H. Crossing Slope	0.81	-0.014	0.009	-0.044	-1.55
I. Approach Slope	2.27	-0.032	0.019	-0.047	1.64

TABLE 3 (CONTINUED)

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
J. Visibility of Sight Triangle	6.48	0.003	0.002	0.037	1.28
L. Type of Protective Device	1.51	0.055	0.025	-0.064	-2.14

Intercept	-0.00764
Multiple Correlation Coefficient	0.1408
Standard Error of Estimate	0.4377
Analysis of Variance: F Value	2.49

TABLE 4

SUMMARY OF ANALYSIS WITH VARIABLE B (ROADWAY TYPE) ELIMINATED

ON THE BASIS OF LOWEST REMAINING NON-SIGNIFICANT T-VALUE

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
A. Probability of Conflict	0.89	0.265	0.074	0.107	3.56
C. Highway Width	34.92	0.003	0.002	0.084	1.70
D. Surface Width	27.48	-0.002	0.002	-0.062	-1.28
E. Angle of Intersection	80.92	0.0006	0.0008	0.022	0.73
F. Posted Speed	38.09	-0.0007	0.0006	-0.033	-1.13
G. Number of Tracks	1.59	0.007	0.014	0.016	0.50
H. Crossing Slope	0.81	-0.014	0.009	-0.045	-1.56
I. Approach Slope	2.27	-0.032	0.019	-0.048	-1.66
J. Visibility of Sight Triangle	6.48	0.003	0.002	0.037	1.29

TABLE 4 (CONTINUED)

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
L. Type of Protective Device	1.51	-0.055	0.025	-0.065	2.17

Intercept	-0.00579
Multiple Correlation Coefficient	0.1405
Standard Error of Estimate	0.4376
Analysis of Variance: F Value	2.73

TABLE 5

SUMMARY OF ANALYSIS WITH VARIABLE G (NUMBER OF TRACKS) ELIMINATED

ON THE BASIS OF LOWEST REMAINING NON-SIGNIFICANT T-VALUE

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
A. Probability of Conflict	0.89	0.267	0.074	0.108	3.60
C. Highway Width	34.92	0.003	0.002	0.088	1.79
D. Surface Width	27.48	-0.002	0.002	-0.064	-1.30
E. Angle of Intersection	80.92	0.0007	0.0008	0.026	0.91
F. Posted Speed	38.09	-0.0008	0.0006	-0.035	-1.23
H. Crossing Slope	0.81	-0.014	0.009	-0.045	-1.56
I. Approach Slope	2.27	-0.031	0.019	-0.046	-1.62
J. Visibility of Sight Triangle	6.48	0.003	0.002	0.039	1.37

TABLE 5 (CONTINUED)

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
L. Type of Protective Device	1.51	-0.051	0.025	-0.063	-2.11

Intercept	-0.00206
Multiple Correlation Coefficient	0.1399
Standard Error of Estimate	0.4374
Analysis of Variance: F Value	3.00

TABLE 6

SUMMARY OF ANALYSIS WITH VARIABLE E (ANGLE OF INTERSECTION) ELIMINATED ON THE BASIS OF LOWEST REMAINING NON-SIGNIFICANT T-VALUE

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
A. Probability of Conflict	0.89	0.262	0.074	0.106	3.54
C. Highway Width	34.92	0.003	0.002	0.085	1.75
D. Surface Width	27.48	-0.002	0.002	-0.062	-1.28
F. Posted Speed	38.09	-0.0009	0.0006	-0.042	-1.50
H. Crossing Slope	0.81	-0.014	0.009	-0.045	-1.59
I. Approach Slope	2.27	-0.003	0.019	-0.046	-1.62
J. Visibility of Sight Triangle	6.48	0.004	0.002	0.049	1.61
L. Type of Protective Device	1.51	-0.052	0.003	-0.062	-2.01

Intercept	0.06322	Standard Error of Estimate	0.4374
Multiple Correlation Coefficient	0.1377	Analysis of Variance: F Value	3.28

TABLE 7

SUMMARY OF ANALYSIS WITH VARIABLE D (SURFACE WIDTH) ELIMINATED

ON THE BASIS OF LOWEST REMAINING NON-SIGNIFICANT T-VALUE

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
A. Probability of Conflict	0.89	0.261	0.074	0.106	3.52
C. Highway Width	27.48	0.001	0.0009	0.035	1.23
F. Posted Speed	38.09	-0.0009	0.0006	-0.041	-1.48
H. Crossing Slope	0.81	-0.014	0.009	-0.045	-1.58
I. Approach Slope	2.27	-0.034	0.019	-0.051	-1.78
J. Visibility of Sight Triangle	6.48	0.003	0.002	0.041	1.49
L. Type of Protective Device	1.51	-0.053	0.025	0.063	-2.11

Intercept	0.06711	Standard Error of Estimate	0.4375
Multiple Correlation Coefficient	0.1333	Analysis of Variance: F Value	3.51

TABLE 8

SUMMARY OF ANALYSIS WITH VARIABLE C (HIGHWAY WIDTH) ELIMINATED

ON THE BASIS OF LOWEST REMAINING NON-SIGNIFICANT T-VALUE

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
A. Probability of Conflict	0.89	0.283	0.072	0.115	3.96
F. Posted Speed	38.09	-0.0009	0.006	-0.041	-1.47
H. Crossing Slope	0.81	-0.016	0.009	-0.051	-1.80
I. Approach Slope	2.27	-0.033	0.019	-0.050	-1.75
J. Visibility of Sight Triangle	6.48	0.004	0.002	0.043	1.54
L. Type of Protective Device	1.51	-0.052	0.025	-0.062	-2.09

Intercept	0.09269	Standard Error of Estimate	0.4376
Multiple Correlation Coefficient	0.1292	Analysis of Variance: F Value	3.84

TABLE 9

SUMMARY OF ANALYSIS WITH VARIABLE F (POSTED SPEED) ELIMINATED

ON THE BASIS OF LOWEST REMAINING NON-SIGNIFICANT T-VALUE

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
A. Probability of Conflict	0.89	0.288	0.072	0.117	4.03
H. Crossing Slope	0.81	-0.014	0.009	-0.043	-1.54
I. Approach Slope	2.27	-0.030	0.019	-0.046	-1.60
J. Visibility of Sight Triangle	6.48	0.003	0.002	0.373	1.36
L. Type of Protective Device	1.51	-0.049	0.025	-0.058	-1.98

Intercept	0.03433	Standard Error of Estimate	0.4378
Multiple Correlation Coefficient	0.1230	Analysis of Variance: F Value	4.18

TABLE 10

SUMMARY OF ANALYSIS WITH VARIABLE J (VISIBILITY OF SIGHT TRIANGLE) ELIMINATED

ON THE BASIS OF LOWEST REMAINING NON-SIGNIFICANT T-VALUE

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
A. Probability of Conflict	0.89	0.284	0.072	0.115	3.97
H. Crossing Slope	0.81	-0.014	0.009	-0.043	-1.54
I. Approach Slope	2.27	-0.030	0.019	-0.044	-1.56
L. Type of Protective Device	1.51	-0.043	0.024	-0.050	-1.75

Intercept	0.04615	Standard Error of Estimate	0.4379
Multiple Correlation Coefficient	0.1175	Analysis of Variance: F Value	4.76

TABLE 11

SUMMARY OF ANALYSIS WITH VARIABLE H (CROSSING SLOPE) ELIMINATED

ON THE BASIS OF LOWEST REMAINING NON-SIGNIFICANT T-VALUE

Variable	Mean	Regression Coefficient	Standard Deviation Regression Coefficient	Partial Correlation Coefficient	t-value
A. Probability of Conflict	0.89	0.288	0.071	0.117	4.02
I. Approach Slope	2.27	-0.024	0.019	-0.036	-1.30
L. Type of Protective Device	1.51	-0.046	0.024	-0.054	-1.89

Intercept	0.02416	Standard Error of Estimate	0.4381
Multiple Correlation Coefficient	0.1099	Analysis of Variance: F Value	5.55

TABLE 12

SIMPLE CORRELATION VALUES
(of all variables)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
A. Probability of Conflict	1.00													
B. Roadway Type	.23	1.00												
C. Highway Type	.28	.63	1.00											
D. Surface Width	.25	.73	.83	1.00										
E. Crossing Slope	-.05	.02	-.03	.01	1.00									
F. Posted Speed	.08	-.01	.02	.004	-.22	1.00								
G. Number Tracks	.17	.06	.20	.17	.33	-.23	1.00							
H. Crossing Slope	-.04	-.13	-.17	-.15	.03	-.18	.01	1.00						
I. Approach Slope	.18	.08	.10	.15	.01	.06	.11	-.21	1.00					
J. Visibility of Sight Triangle	.02	.08	.05	.10	.20	.11	.19	.02	-.004	1.00				
K. Visibility of Sight Channel	.03	-.004	.07	.11	.24	.02	.27	-.02	.01	.82	1.00			
L. Type Protection	.30	.04	.08	.09	.06	-.08	.24	.10	-.13	.20	.16	1.00		
M. Number Roads	.16	.11	.14	.18	.28	-.54	.45	.16	.06	.08	.16	.23	1.00	
N. Accidents	.09	.04	.06	.03	.03	-.03	.04	-.04	-.01	.03	.04	-.01	.03	1.0

APPENDIX E

RECOMMENDED DESIGN FOR SIGNING RAIL-HIGHWAY GRADE CROSSINGS

RECOMMENDED DESIGN FOR SIGNING RAIL-HIGHWAY GRADE CROSSINGS

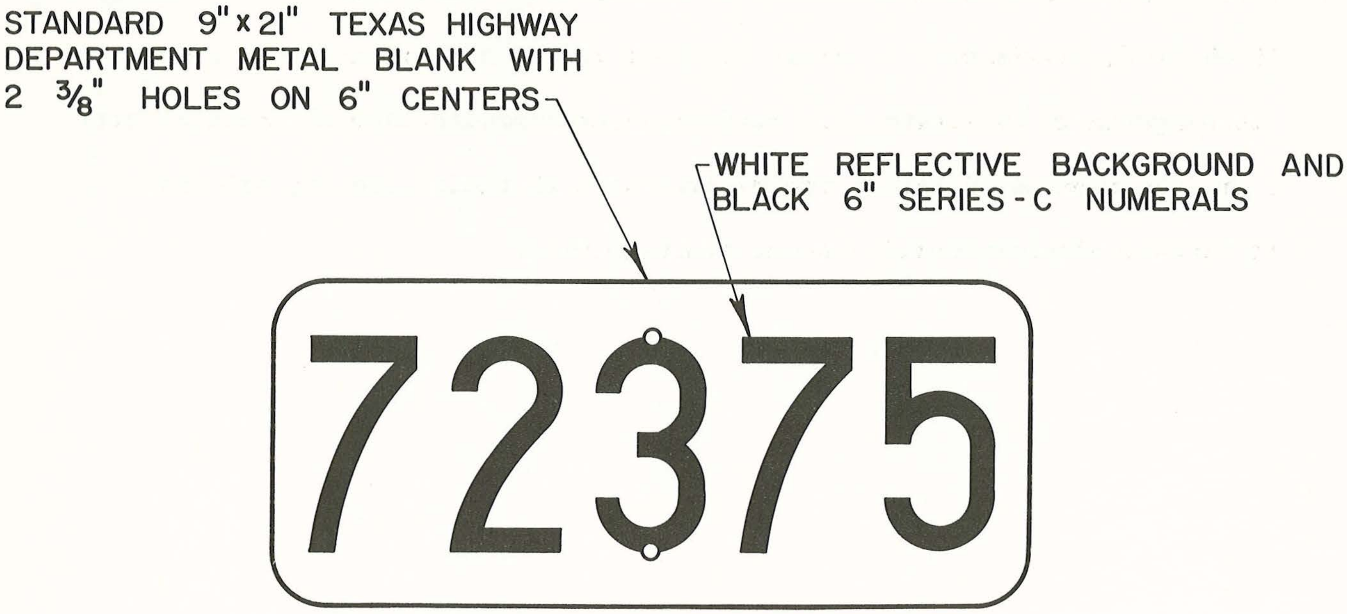
It is recommended that each Texas rail-highway grade crossing be identified with some form of number-board placed on the crossing's protective device. This section is to provide details of the recommended crossing identification system, to establish the feasibility of such a plan, and to briefly suggest a method of implementation.

After consulting with the Texas Highway Department officials, the type of number-board shown in the accompaning figure was decided upon. There should be one number-board per crossing mounted on one of the railroad protective device or crossbucks as illustrated in the attached sketch; i.e., a standard railroad clamp on the metal protective devices and leg bolts on wodden crossbucks.

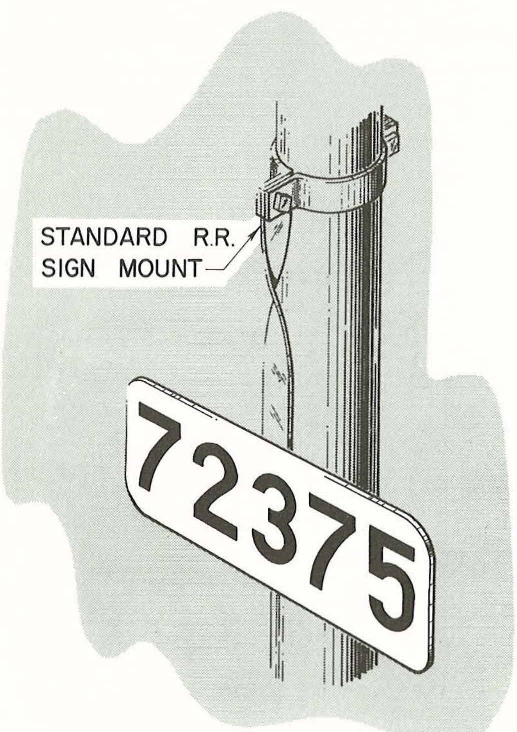
Several factors contribute to the efficiency of this design for keeping the cost of the program relatively low. Among them are the use of only one identification board per crossing; standard highway department 9" x 21" blanks painted with common white reflective background; standard class black numerals; and, the already widely used and inexpensive mounted system. Because small items are now done in batched jobs and given unit prices, actual cost estimates are difficult. However, according to highway department officials, each completed identification board should cost approximately either $2.00 or $4.00 depending on whether reclaimed or new blanks are used.

To keep from interrupting the work schedule of any one district, it is recommended that each district make the signs for its own rail-highway crossings. The minimum number of crossings per district is approximately 50 while the maximum is about 200 for a total of approximately 2,500 crossings in the state. It is further recommended that the identification boards be made available by the districts to the railroads, and that railroad employees install and maintain them.

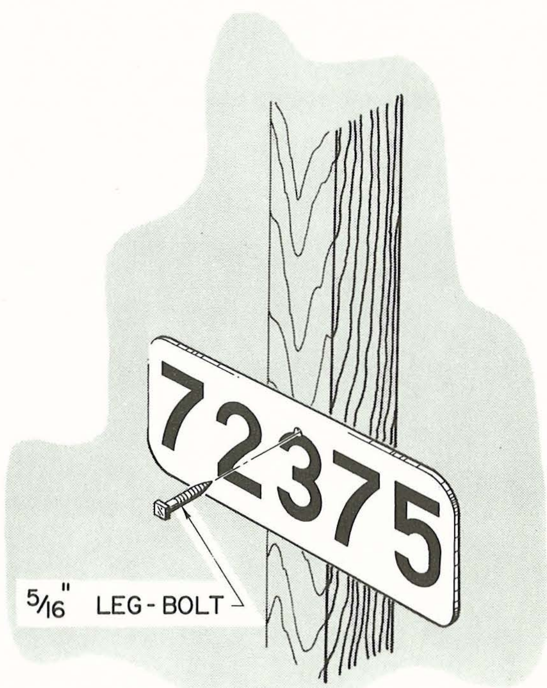
SUGGESTED DESIGN FOR SIGNING RAIL-HIGHWAY GRADE CROSSINGS BY IDENTIFICATION NUMBER



TYPICAL IDENTIFICATION BOARD



ON METAL POLES



ON WOODEN POSTS

MOUNTING TECHNIQUES

APPENDIX F

ACCIDENT REPORT FORMS

1962 Revision

Form Approved
Budget Bureau No. 60 R273 11

INTERSTATE COMMERCE COMMISSION
BUREAU OF TRANSPORT ECONOMICS AND STATISTICS

MONTHLY REPORT
ACCIDENT AT HIGHWAY GRADE CROSSING

Supplemental to T Sheet No.______

1. Reporting Carrier	2. Date of Accident	3. Reporting Month

I. ACCIDENT

4. Cause of Accident
   - ☐ Struck by Train
   - ☐ Ran into side of Train

5. Part of Train Struck
   - ☐ Engine pulling
   - ☐ _____ Quarter
   - ☐ Lead car
   - ☐ Last car or unit pushing

6. Object Struck, or Striking
   - ☐ Auto
   - ☐ Bus
   - ☐ Truck
   - ☐ Motorcycle
   - ☐ Other

7. Vehicle was
   - ☐ Stalled on crossing
   - ☐ Stopped on crossing

   Estimated speed of vehicle (if moving) _____mph

8. If vehicle subject to Motor Carrier Act, give name and address of operating company.

   Name: Address:

9. If vehicle carried dangerous commodity* (i.e., explosives, petroleum, etc.) name commodity carried.

II. CROSSING PROTECTION

10. Type of Protection
    - ☐ Gates, Automatic
    - ☐ Gates, Manual
    - ☐ Watchman
    - ☐ Other employee
    - ☐ Audible and Visual
    - ☐ Audible Signal
    - ☐ Visual Signal
    - ☐ Crossbuck
    - **☐ Other
    - ☐ Unprotected

11. Protection was located on
    - ☐ Both sides of crossing
    - ☐ Side from which vehicle approached
    - ☐ Side opposite

12. Was protection operating? ☐ Yes ☐ No

    State any factor impairing effective operation.

13. Was view of track obscured by
    - ☐ Permanent structure
    - ☐ Standing RR equipment
    - ☐ Passing train
    - ☐ Topography
    - ☐ Vegetation
    - ☐ Vehicle
    - ☐ Other, explain

14. Did person or object struck, or striking go *over*, *around*, *under* or *through* gates?

    ☐ Yes ☐ No

15. If accident occurred at night (one-half hour after sunset to one-half hour before sunrise) was crossing illuminated?

    ☐ Yes ☐ No

16. Signature Title

*Dangerous commodities: Liquid petroleum, and liquid petroleum products, explosives, flammable or poisonous compressed gases, volatile liquids and solids which emit poisonous fumes, corrosive liquids, and radioactive materials, etc.

**Explain whether State signs, advance warning signs, etc.

☆ U S GOVERNMENT PRINTING OFFICE : 1962 OF—658262

1962 REVISION

INTERSTATE COMMERCE COMMISSION
BUREAU OF TRANSPORT ECONOMICS AND STATISTICS

Form Approved
Budget Bureau No. 60-R263.13

MONTHLY REPORT OF RAILROAD ACCIDENT

(See instructions on reverse side.)

FORM T

SHEET NO.

1. REPORTING CARRIER
2. CARRIER'S FILE NO.
3. FOR THE MONTH OF

4. IF "JOINT OPERATION" OR CROSSING COLLISION NAME ROADS INVOLVED.
5. IF "JOINT OPERATION" NAME ROAD WHOSE SUPERINTENDENT IS IN CHARGE OF TRACK.

6. KIND OF ACCIDENT
☐ TRAIN ☐ TRAIN-SERVICE ☐ NONTRAIN
7. ICC CLASS & SUB CLASS *(§125.22, 125.23, 125.24)*

8. NEAREST STATION AND NAME OF STATE WHERE ACCIDENT OCCURRED.
9. DATE OF ACCIDENT
10. TIME *(Use standard)* ..........A.M. ....P.M.

11. VISIBILITY AND WEATHER (CHECK APPROPRIATE BOXES)

	DAYLIGHT		FOGGY
	DARK		RAINING
	CLEAR		SNOWING
	CLOUDY		SLEETING

12. DAMAGE IN DOLLARS *(Train accidents only)*

NAME OF ROAD	EQUIPMENT	TRACK	TOTAL
	$	$	$
TOTAL			

13. CAUSE *(Briefly)*

14. KIND OF TRACK

	MAIN
	BRANCH
	YARD

15. METHOD OF OPERATION AND SIGNALLING

	MANUAL BLOCK		AUTO. BLOCK SIG.		AUTO. TRAIN STOP
	CONT. MANUAL		INTERLOCKING		AUTO. TRAIN CONT.
	TRAIN ORDER		CENT. TRAF. CONT.		CAB SIGNAL

16. KIND OF EQUIPMENT

	LOCOMOTIVE
	FREIGHT TRAIN CAR
	PASS. TRAIN CAR

17. KIND OF TRAIN

P	TF	LF	Y	W	O
☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	☐	☐

18. MOTIVE POWER

D	E	RMC	O
☐	☐	☐	☐
☐	☐	☐	☐

19. NO. OF CARS

20. TIMETABLE DIRECTION

N	S	E	W

21. SPEED
____ MPH
____ MPH

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45

I.C.C. use only

22. DETAILS OF CASUALTIES TO PERSONS

Class of person *(a)* (§125.50)	Age in case of employee *(b)*	I.C.C. use only 29	30	31	32	33	Killed or nature and extent of injuries *(c)* [§125.14(a), 125.47(a), 125.47(c)]	I.C.C. use only 34	35	36	Days disability A=Actual P=Probable *(d)* [§125.47(b)]

23. FULL DETAILS OF CAUSE, NATURE, AND CIRCUMSTANCES OF ACCIDENT

CONTINUE ON REVERSE SIDE OF SHEET IF NECESSARY

SIGNATURE
TITLE

TEXAS POLICE OFFICERS' CONFIDENTIAL ACC NT REPORT MAIL TO: Texas Department blic Safety, No. Austin Sta., Austin, Texas. 78751

LOCATION

PLACE WHERE ACCIDENT OCCURRED County .... City or town ....

If accident was outside city limits, indicate distance from nearest town .... miles ☐ North ☐ S ☐ E ☐ W of .... City or Town

ROAD ON WHICH ACCIDENT OCCURRED .... Give name of street or highway number (U.S. or State). If no highway number, identify by name. Under Construction? ☐ Yes ☐ No

Check and complete one only
- AT ITS INTERSECTION WITH .... Name of intersecting street or highway number
- IF NOT AT INTERSECTION .... feet ☐ North ☐ S ☐ E ☐ W of .... Show nearest intersecting street or highway, house no., bridge, RR crossing, alley, driveway, culvert, milepost, underpass, or other landmark

DO NOT WRITE IN THIS SPACE
Local No.
DPS No.
Loc.
S.R.
Fat. rec.
Dr. rec.
Code
Type
FAT. P.I. P.D.

TIME

Date of Accident .... 19 .... Day of Week .... Hour .... ☐ A.M. ☐ P.M. If exactly noon or midnight, so state

VEHICLES

For Other Vehicles Use Another Form

Total Vehicles Involved

VEHICLE NO. 1

Year Model .... Make and Type of Vehicle .... Sedan, tractor-semi-trailer, taxi, etc. Vehicle Registration .... Year State Number Commodity Carried .... Butane, mixed freight, etc. Had Seat Belts ☐ Yes ☐ No

DRIVER .... Name Address City and State Sex .... Drinking?* ☐ Yes ☐ No

Race of Driver .... Driver's Occupation .... Carpenter, doctor, sales clerk, etc. Date of Birth .... Month, Day, Year Driver's License .... State Number ☐ Chauffeur ☐ Operator ☐ Com. Op.

Speed Before Accident* .... m.p.h. Legal Speed Limit .... m.p.h. Maximum Safe Speed* .... m.p.h. Physical Condition* .... Approximate cost to repair vehicle* $ ....

OWNER .... Name Address Vehicle Removed To .... Name of garage, home by owner, driven away, etc.

VEHICLE NO. 2

Year Model .... Make and Type of Vehicle .... Sedan, tractor-semi-trailer, taxi, etc. Vehicle Registration .... Year State Number Commodity Carried .... Butane, mixed freight, etc. Had Seat Belts ☐ Yes ☐ No

DRIVER .... Name Address City and State Sex .... Drinking?* ☐ Yes ☐ No

Race of Driver .... Driver's Occupation .... Carpenter, doctor, sales clerk, etc. Date of Birth .... Month, Day, Year Driver's License .... State Number ☐ Chauffeur ☐ Operator ☐ Com. Op.

Speed Before Accident* .... m.p.h. Legal Speed Limit .... m.p.h. Maximum Safe Speed* .... m.p.h. Physical Condition* .... Approximate cost to repair vehicle* $ ....

OWNER .... Name Address Vehicle Removed To .... Name of garage, home by owner, driven away, etc.

DAMAGE TO PROPERTY OTHER THAN VEHICLES .... Name object and state nature of damage $ .... Estimated Cost*

Name and address of owner of damaged property ....

CODE FOR INJURY SEVERITY
(Use only the most serious one in each space for injury.)
A – Serious visible injury, as deep, bleeding wound, distorted member, etc.
B – Minor visible injury, as bruises, abrasions, swelling, limping, etc.
C – No visible injury but complaint of pain or momentary unconsciousness.

CASUALTIES

Total

NO. 1

Name .... Address ....

Age .... Sex .... Race .... Was person killed? .... Date of Death ....

Taken to .... By ....

☐ Driver ☐ Passenger In veh. No. .... ☐ Pedestrian

Severity ☐ A ☐ B ☐ C

Seat Belt ☐ Used ☐ Not Used

NO. 2

Name .... Address ....

Age .... Sex .... Race .... Was person killed? .... Date of Death ....

Taken to .... By ....

☐ Driver ☐ Passenger In veh. No. .... ☐ Pedestrian

Severity ☐ A ☐ B ☐ C

Seat Belt ☐ Used ☐ Not Used

PASSENGERS AND/OR WITNESSES

Name .... Address .... Location .... In veh. 2 RF, ped. 60 ft. east, etc.
Name .... Address .... Location ....
Name .... Address .... Location ....
Name .... Address .... Location ....
Name .... Address .... Location ....
Name .... Address .... Location ....
Name .... Address .... Location ....
Name .... Address .... Location ....

FORM ST-3 *THESE ITEMS REFLECT THE INVESTIGATOR'S OPINIONS. REV. 1-1-64

KIND OF LOCALITY
(Check one)
1. ☐ Apartments, Stores Factories, Schools
2. ☐ One-family homes
3. ☐ Farms, Fields
4. ☐ No marginal development

ROAD LANES (TOTAL)
(Check lanes on road used by each driver.)
Driver 1 2
1. ☐ ☐ 1 lane
2. ☐ ☐ 2 lanes
3. ☐ ☐ 3 lanes
4. ☐ ☐ 4 or more lanes
☐ ☐ Divided roadway
☐ ☐ Expressway, freeway, toll road, etc.

W... DRIVERS WERE GOING TO DO BEFORE ACCIDENT
(Check one for each driver)
Driver 1 2
1. ☐ ☐ Go straight ahead
2. ☐ ☐ Overtake and pass
3. ☐ ☐ Make right turn
4. ☐ ☐ Make left turn
5. ☐ ☐ Make U turn
6. ☐ ☐ Slow or stop
7. ☐ ☐ Start in traffic lane
8. ☐ ☐ Start from Parked position
9. ☐ ☐ Back
10. ☐ ☐ Remain stopped in traffic lane
11. ☐ ☐ Remain parked

TRAFFIC CONTROL
(Check one or more)
1. ☐ Stop sign
2. ☐ Stop-and-go signal
3. ☐ Officer or watchman
4. ☐ R.R. gates or signals
5. ☐ .... Specify other
6. ☐ No traffic control

WHAT PEDESTRIAN WAS DOING
Pedestrian was going ☐ N ☐ S ☐ E ☐ W ☐ Along ☐ Across or into .... (Street name, highway No.) From .... To .... (N.E. corner to S.E. corner, or west to east side, etc.)
1. ☐ Crossing or entering at intersection
2. ☐ Crossing or entering not at intersection
3. ☐ Getting on or off vehicle
4. ☐ Walking in roadway – with traffic
5. ☐ Walking in roadway – against traffic
6. ☐ Standing in roadway
7. ☐ Pushing or working on vehicle
8. ☐ Other working in roadway
9. ☐ Playing in roadway
10. ☐ Other in roadway
11. ☐ Not in roadway
12. ☐ Had been Drinking *

ROAD SURFACE
(Check one)
1. ☐ Dry
2. ☐ Wet
3. ☐ Snowy or Icy
4. ☐ .... Specify other

LIGHT CONDITIONS
(Check one)
1. ☐ Daylight 3. ☐ Darkness
2. ☐ Dawn 4. ☐ Dusk

ROAD CHARACTER
(Check two)
1. ☐ Straight road
2. ☐ Curve
3. ☐ Level
4. ☐ On grade
5. ☐ Hillcrest

WEATHER
(Check one)
1. ☐ Clear 3. ☐ Snowing
2. ☐ Raining 4. ☐ Fog
5. ☐ .... Specify other

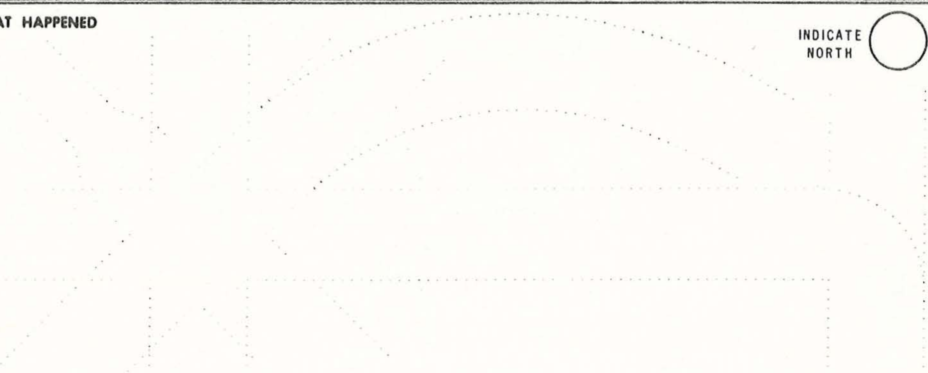
VIOLATIONS CONTRIBUTING TO ACCIDENT
(Check one or more for each driver)
Driver 1 2
1. ☐ ☐ Speeding – over limit
2. ☐ ☐ Speed – under limit–unsafe
3. ☐ ☐ Fail to Yield ROW to Vehicle
4. ☐ ☐ Disregard Stop Sign or light
5. ☐ ☐ Disregard Stop and Go Signal
6. ☐ ☐ Disregard Flashing Yellow Signal
7. ☐ ☐ Improper turn – wide right
8. ☐ ☐ Improper turn – cut corner on left
9. ☐ ☐ Improper turn – wrong lane
10. ☐ ☐ Wrong side – not passing
11. ☐ ☐ Wrong way 1 way road
12. ☐ ☐ Following too closely
13. ☐ ☐ Overtake and pass – insufficient clearance
14. ☐ ☐ Pass in No Passing Zone
15. ☐ ☐ All other illegal passing
16. ☐ ☐ No signal or wrong signal of intention
17. ☐ ☐ Improper start from parked position
18. ☐ ☐ Fail to yield ROW to pedestrian
19. ☐ ☐ Improper parking
20. ☐ ☐ Driving under influence (liquor or drugs)
21. ☐ ☐ Defective Brakes
22. ☐ ☐ Defective lights
23. ☐ ☐ Other Defective equipment
24. ☐ ☐ Other Violations ....
25. ☐ ☐ No violation as accident cause

INDICATE ON THIS DIAGRAM WHAT HAPPENED

INSTRUCTIONS

1. Follow dotted lines to draw outline of roadway at place of accident.
2. Number each vehicle and show direction of travel by arrow: —[1]X[2]—
3. Use solid line to show path before accident ——[2>
   dotted line after accident: - - - -[2>
4. Show pedestrian by: ——O
5. Show railroad by: -++++++++-
6. Show distance and direction to landmarks; identify landmarks by name or number.

INDICATE NORTH ◯



DESCRIBE WHAT HAPPENED
(Refer to vehicles by number) ....

POLICE ACTIVITY

SHOW ARRESTS AND CHARGES
Name .... Charge .... Ticket No. ....
Name .... Charge .... Ticket No. ....

Time notified of accident .... M (Date, Hour) Time arrived at scene of accident .... M (Date, Hour) Was investigation made at scene of accident? ☐ Yes ☐ No Driver report form furnished to ☐ Driver 1 ☐ Driver 2

Where else was investigation made? .... Were photographs taken? ☐ Yes ☐ No Is investigation complete? ....

SIGNATURE .... (Investigator's name and rank or number) (Department) Date of report ....

IMPORTANT! Drivers must also submit a report to DPS if there were casualties and/or total damage of $25 or more. Drivers accident report forms are available at all state, county, and city police offices.

APPENDIX G

COMPUTATION OF RAIL-HIGHWAY GRADE CROSSING PRIORITY INDEX:

THE COMPUTER APPLICATION

COMPUTATION OF RAIL-HIGHWAY GRADE CROSSING PRIORITY INDEX: THE COMPUTER APPLICATION

PART A: SYSTEM DESCRIPTION

This section of the report describes the computer processes devised to facilitate the computation and listing of priority indexes for rail-highway grade crossings under the administration of the Texas Highway Department. Included in this section are descriptions of the two main programs in the system.

1) Phase 1: Index Computation Program

This FORTRAN program (P1111901) developed for implementation of this phase of the system consists of two parts. The first part matches the T-form accident records with the Texas Highway Department grade crossing log records. Those log records having a matching accident card are used to compile a composite 112 byte record. Log records that are not matched are used to develop a composite record even though the accident field of that record remains blank. Crossings that have more than one accident create separate records, therefore in some instances a log record may be used more than once in the development of the composite record. The primary purpose of the individual composite records is to provide an input for proper costing of each of the accidents.

As the accident records are matched, composite averages are computed in the following four categories of crossings:

1. The Total State

2. Urban and rural locations

3. THD District

4. Railroad Company

The averages include coefficients for fatalities, personal injury, vehicular property damage, and railway damage. These coefficients are necessary to the computation of individual priority indexes for each grade crossing included in the THD log.

Key fields in the log record are checked to insure that they are properly coded. Where coded data are missing the records are identified and printed in an error listing. To provide for a complete error check of the input records with a single pass of the data, predetermined values are inserted in blank fields where appropriate.

The final step in the matching routine is the printing of control tabulations which are used to further edit input records.

Control tabulation include the following information:

a) Number of log records read.

b) Number of accident cards read.

c) Number of accident cards not matched to log records.

d) Number of composite records written with accident data.

e) Number of composite records written without accident data.

f) Total number of composite records written.

g) Number of accident crossings.

h) Number of fatalities.

i) Number of injuries.

j) Number of fatal accidents.

k) Number of non-fatal accidents.

l) Annualizing factor in computing protective device depreciation.

At this point in the computer processing, the composite record file has been prepared. The data tape is rewound and then passed to calculate the priority indexes from the coefficients which were compiled during the initial processing phase. A control card is used to select the appropriate coefficient to be used in the calculation of the indexes. A description of the control card is shown in Part B, section 4, subheading a of this report. In the second phase of the program, the priority indexes are computed by each of the three procedures developed during the study. The program then prints a worksheet record and writes an output record for each unique log record. Duplicate log records created during the first part are regrouped to form one output record. This output record consists of the grade crossing identification number, the priority index, annual installation and maintenance cost, and initial installation cost for each alternative procedure for computing the priority index.

Additionally the worksheet provides selected data used in the intermediate calculations of the index. For each unit record the worksheet provides the following coded information.

SER - Grade Crossing identification number
RR - Railroad company code
S - Description of area in which the crossing is located
 R = Rural
 U = Urban
 I = Incorporated
C - Type of protection
 1 = Cross-bucks
 2 = Flasher, wig ways and bells
 3 = Gates
CACI - Composite accident cost (Procedure I)

EA - Expected accident rate (Procedure III)
IF - Cost of installing flashers
IG - Cost of installing gates
IFG - Cost of installing gates at flasher locations
MF - Cost of annual maintenance of flashers
MG - Cost of annual maintenance of gates
MFG' - Cost of annual maintenance of gates and flashers
PI3 - Priority index using expected accidents (Procedure III)
PI2 - Priority index using average accidents (Procedure II)
PI1 - Priority index using actual accidents (Procedure I)
EAB3 - Expected annual benefits (Procedure III)
EAB2 - Expected annual benefits (Procedure II)
EAB1 - Expected annual benefits (Procedure I)
INST3 - Cost of installing additional protection (Procedure III)
INST2 - Cost of installing additional protection (Procedure II)
INST1 - Cost of installing additional protection (Procedure I)
MAT3 - Annual maintenance costs of additional protection (Procedure III)
MAT2 - Annual maintenance costs of additional protection (Procedure II)
MAT1 - Annual maintenance costs of additional protection (Procedure I)

Depending upon the procedure used, some of the above categories will develop a zero vaule. For example, those that pertain to Procedure I (actual accidents) will be zero due to the fact that during the study period an accident did not occur at the grade crossing. Occasionally, the formula for expected accidents develops a negative value. In this instance the values applicable to Procedure III are set to zero. Except in the case where the intersection cannot be improved, Procedure II will always develop some non-zero data. When the intersection protection cannot be improved, all cost and priority fields are set to zero.

The output from this program is a file which contains all the information necessary to publish the list of priority indexes. The record layout for this file and the input files for this procedure are described in Part B, section 2 of this section.

PHASE 2: SORT AND REPORT GENERATOR PROGRAM

This COBOL program (P1111902) reads the data generated by the Phase I program (P1111901), sorts the data into the order instructed by the control cards, and prints tables showing the priority rank of each grade crossing (by ID number) included in the THD log.

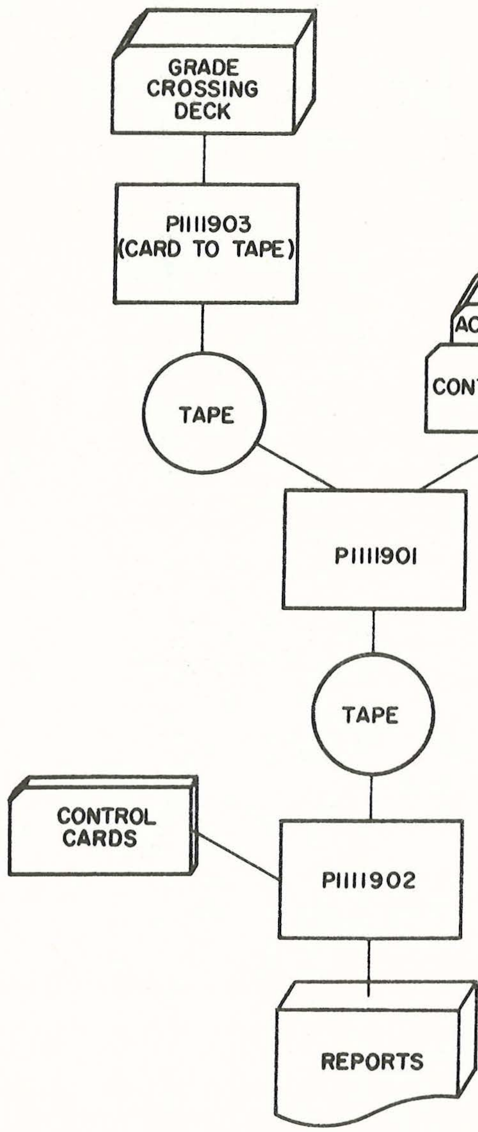
Listings are provided in the following categories: a) by railroad company, b) by location (rural-urban), c) by THD district, and d) for the state (all grade crossings). With appropriate control cards any or all of the three priority indexes may be printed for each of the four categories. Proper punches in the control cards determines whether the data to be listed will be separated according to protected and non-protected groups.

The control card documentation for this program is shown in Part B, section 4, subheading b of this section of the report.

PART B: SYSTEM DOCUMENTATION

This section of the report documents the system described in Part A. Included in this section are: system diagram, individual input and output record formats, input card codes, control card instructions, and a detailed flowchart of the index computation program, P1111901.

SYSTEM FLOW CHART



RGCPIIS PHASE I INVENTORY CARD AND LOG TAPE LAYOUT

1	SERIAL NUMBER	
2		
3		
4		
5		
6	NUMBER	RAILROAD
7		
8		
9	SUB-DIVISION	
10		
11		
12		
13	MILEPOST	
14		
15		
16		
17		
18	COUNTY	
19		
20		
21	DISTRICT	
22		
23	CITY NAME	
24		
25		
26		
27		
28		
29		
30		
31		
32		
33	HIGHWAY SYSTEM	HIGHWAY
34		
35	HIGHWAY	
36		
37		
38		
39	FA	
40	URBAN - RURAL - INC	
41	CONTROL	
42		
43		
44		
45	SHD	
46		
47	SECTION	
48		
49		
50	MILEPOST	
51		
52		
53		
54		
55	NUMBER OF LANES	
56	MATERIAL BETWEEN TRACKS	
57	NUMBER OF MAIN TRACKS	
58	NUMBER OF OTHER TRACKS	
59	CROSSBUCKS	
60	REFLECTIVE CROSSBUCKS	
61	STOP SIGN	DEVICES
62	FLASHERS	
63	BELLS	
64	WI	
65	FLAGMEN	
66	GATES	
67	IL	
68	ACT	
69	OTHER	
70	CO	
71	TRAINS PER DAY	
72		
73	TRAIN SPEED	
74		
75	ADT	
76		
77		
78		
79		
80	BLANK	

TAPE
80 BYTES/RECORD
1600 BYTES/BLOCK

RGCPIIS PHASE I T-FORM ACCIDENT CARD LAYOUT

1	SERIAL NUMBER		61	
2			62	
3			63	
4			64	
5			65	
6	MONTH	DATE	66	
7			67	
8	DAY		68	
9			69	
10	YEAR		70	
11	HOUR	TIME	71	
12			72	
13	MINUTE		73	
14			74	ACCIDENT COST
15	1 = AM 2 = PM		75	
16	VISIBILITY		76	
17	WEATHER		77	
18	CAUSE		78	
19	KIND OF TRAIN		79	
20	NUMBER OF CARS		80	SYSTEM
21				
22				
23	SPEED			
24				
25	KILLED			
26				
27	INJURED			
28				
29	DAYS OF DISABILITY			
30				
31				
32	ESTIMATE OF CAUSE			
33	ATTEMPT TO STOP			
34	PERMANENT INJURIES			
35	TYPE OF VEHICLE			
36				
37				
38				
39				
40				
41				
42				
43				
44				
45				
46				
47				
48				
49				
50				
51				
52				
53				
54				
55				
56				
57				
58				
59				
60				

RGCPIIS PHASE I COMPOSITE TAPE LAYOUT

1–5	SERIAL NUMBER	
6–8	NUMBER	RAILROAD
9–12	SUB-DIVISION	RAILROAD
13–17	MILEPOST	RAILROAD
18–20	COUNTY	
21–22	DISTRICT	
23–32	CITY NAME	
33–34	HIGHWAY SYSTEM	HIGHWAY
35–38	HIGHWAY	HIGHWAY
39	FA	HIGHWAY
40	URBAN-RURAL-INC	HIGHWAY
41–44	CONTROL	HIGHWAY
45–46	SHD	HIGHWAY
47–49	SECTION	HIGHWAY
50–54	MILEPOST	HIGHWAY
55	NUMBER OF LANES	
56	MATERIAL BETWEEN TRACKS	
57	NUMBER OF MAIN TRACKS	
58	NUMBER OF OTHER TRACKS	
59	CROSSBUCKS	
60	REFLECTIVE CROSSBUCKS	
61	STOP SIGN	DEVICES
62	FLASHERS	DEVICES
63	BELLS	DEVICES
64	WI	DEVICES
65	FLAGMEN	DEVICES
66	GATES	DEVICES
67	IL	DEVICES
68	ACT	DEVICES
69	OTHER	DEVICES
70	CO	DEVICES
71–72	TRAINS PER DAY	
73–74	TRAIN SPEED	
75–79	ADT	
80	1 = ACCIDENT 2 = NON-ACCIDENT	
81–82	MONTH	DATE
83–84	DAY	DATE
85	YEAR	DATE
86–87	HOURS	TIME
88–89	MINUTES	TIME
90	1 = AM 2 = PM	
91	VISIBILITY	
92	WEATHER	
93	CAUSE	
94	KIND OF TRAIN	
95–97	NUMBER OF CARS	
98–99	SPEED	
100–101	KILLED	
102–103	INJURED	
104–106	TOTAL DAYS OF DISABILITY	
107	ESTIMATE OF CAUSE	
108	ATTEMPT TO STOP	
109	PERMANENT INJURIES	
110	SYSTEM	
111–112	BLANK	

TAPE
112 BYTES/RECORD
2240 BYTES/BLOCK

PART B, SECTION 3, SUBHEADING a:

GRADE CORSSING INVENTORY CARD CODES

ITEM	COLUMN	CODE
Month	1 - 2	Actual Month
Year	3 - 4	Actual Year
Name of Railroad	5 - 7	000. Railroad Abandoned
		001. Belton Railroad
		002. Georgetown Railroad
		003. Dallas Terminal Ry. & Union Depot Co.
		007. Missouri Pacific Railroad
		015. Atchison, Topeka & Santa Fe Ry. Co.
		016. Beaumont Wharf & Terminal Co.
		017. Port Arthur Canal & Dock Co.
		018. San Antonio Bell & Terminal Ry. Co.
		019. Texas & Northern Ry. Co.
		020. Point Comfort & Northern Ry. Co.
		026. Panhandle & Santa Fe Ry. Co.
		036. Texas & Pacific Ry. Co.
		037. Abilene & Southern Ry. Co.
		039. Denison & Pacific Suburban Ry. Co. (Abandoned)
		040. Fort Worth Belt Ry. Co.

ITEM	COLUMN	CODE
		041. Pecos Valley Southern Ry. Co.
		042. Texas-New Mexico Ry. Co.
		043. Texas Short Line Ry. Co.
		044. Weatherford, Mineral Wells & Northwestern Ry. Co.
		045. Texas & New Orleans RR. Co. (Abandoned)
		048. Southern Pacific Co.
		049. Southern Pacific Terminal Co.
		051. Fort Worth & Denver Ry. Co
		056. Wichita Valley Ry. Co.
		061. Chicago-Rock Island & Pacific RR. Co.
		064. Missouri-Kansas-Texas RR. Co.
		070. Wichita Falls & Southern RR. Co.
		073. St. Louis Southwestern Ry. Co.
		076. St. Louis San Francisco Ry. Co.
		078. Quanah Acme & Pacific Ry. Co.
		079. Kansas City Southern Ry. Co.
		082. Angelina & Neches River RR. Co.
		086. El Paso Southern Ry. Co.
		087. El Paso Southwestern RR. Co.
		089. Galveston, Houston & Henderson RR. Co.
		090. Galveston Wharf Co.
		091. Galveston Terminal Ry. Co.

ITEM	COLUMN	CODE
		092. Hamlin & Northwestern Ry. Co.
		093. Houston Belt & Terminal Ry. Co.
		095. Kansas, Oklahoma & Gulf Ry. Co. (Abandoned)
		096. Louisiana & Arkansas Ry. Co.
		099. Moscow, Camden & San Augustine RR. Co.
		106. Rockdale, Sandow & Southern RR. Co.
		107. Roscoe, Snyder & Pacific Ry. Co.
		109. Texas City Terminal Ry. Co.
		110. Texas-Mexican Ry. Co.
		111. Texas-Southeastern RR. Co.
		112. Texas Transportation Co.
		113. Union Terminal Co.
		115. Waco, Beaumont, Trinity & Sabine Ry. Co.
		117. Great Southwest Railroad
		118. Port Terminal Ry. Assn.
		121. Joint Texas Division (Fort Worth & Denver RR. Co.)
RR. Subdivision	8 - 11	Code by cities as compiled by Texas Research Board (where not available by city code refer to "Supplemental Code For Railroad Subdivisions," enclosed in this code book).
Milepost	12 - 15 16	Miles Tenths
County	17 - 19	Code by counties as compiled by Texas Research Bureau.

ITEM	COLUMN	CODE
City	20 - 23	Code by cities as compiled by Research Bureau.
Distance to	24 - 25	Actual Distance
city type highway	26	Code as follows:
		1. = IHS
		2. = U.S. Highway
		3. = State Highway
		4. = F.M. Road or F.M. Spur
		5. = Loop
		6. = Spur
		7. = Park Road
		8. = County Road
		9. = City Street
		0. = No Road
Highway number	27 - 30	Actual designated highway number
Name of Street	31 - 50	Full name if it does not exceed twenty letters. Abbreviate if name exceeds twenty characters.
No. of highway lanes	51	Actual number or code as 9 if the number of total lanes exceed 9.
Type of highway surface	52	Should be coded as follows:
		1. = Concrete
		2. = Blocktop
		3. = Brick
		4. = Gravel
		5. = Dirt
		6. = Unknown

ITEM	COLUMN	CODE
Type of material	53	Code as follows:
		1. = Wood
		2. = Asphalt
		3. = Steel Rails
		4. = Other
No. of Main Track	54)	
No. of Spur Track	55)	
No. of Lead Track	56)	
No. of Siding Track	57)	Actual Number or code as 9 if the number exceeds 9.
No. of Wye Track	58)	
No. of Other Track	59)	
Other Identified	60	1. = House Track
		2. = Interchange Track
		3. = Yard
		4. = PTRA
		5. = Team
		6. = Hold Track
	61 - 62	Blank
No. of protective devices		
Crossbuck	63	Actual No.
R. Crossbuck	64	Actual No.
Stop Sign	65	Actual No.
Flashing Lights	66	Actual No.

ITEM	COLUMN	CODE
Bells	67	Actual No.
Wigways	68	Actual No.
Watchman	69	Actual No.
Automatic Gates	70	Actual No.
Illumination	71	Actual No.
Advanced Warning	72	Actual No.
Other	73	Actual
Other Identified	74	1. = Traffic Lights
Number of trains daily	75 - 76	Actual No.
Speed of train at crossing	77 - 78	Actual Speed - if greater than 99 code as 99.
	79	Blank
Administrative Control	80	1. = State Highway System
		2. = City System
		3. = County System

PART B, SECTION 3, SUBHEADING b:

ACCIDENT CARD CODE SHEET

Item	Col.	
1	1-5	Id from Inventory
2	6-10	Date month-day-last digit of year
3	11-14	Time of accident hours and minutes
	15	1. AM 2. PM
4	16	Visibility 1. Clear 2. Cloudy
5	17	Weather 1. Fog 2. Rain 3. Snow 4. Sleet
6	18	Cause 1. Car hit side of train 2. Collision 3. Car stalled 4. Car tried to beat train 5. Car tried to avoid train
7	19	Kind of train 1. P 2. TF 3. LF 4. Y 5. W 6. O
8	20-22	No. of cars 0 when not given
9	23-24	Speed
10	25-26	Number Killed
11	27-28	Injured
12	29-31	Total days disability

13	32	R. R. estimate of cause of accident 1. not sufficient on T-form 2. no obvious reason 3. high rate of speed 4. car tried to beat train 5. weather 6. disregard of warning signals 7. failure to apply brakes in time 8. unaware of train 9. stopped on tracks 0. intoxicated
14	33	Attempt to stop 1. not answered 2. yes 3. no
15	34	Permanent or undetermined injuries
16	35	Type of vehicle 1. Auto 2. Pickup 3. Other truck 4. Passenger vehicle 5. Farm 6. One auto and one pickup
17	80	System 1. city 2. county 3. state

Part B: System Documentation

Section 4: Control Card Instructions

Subheading a: P1111901 Index Computation Program

This program uses only one control card. This card selects which set of averages are to be used in calculating the priority indices that are printed in Phase 2.

cc	Code
1	1 = Texas Averages
	2 = System Averages (urban-rural)
	3 = Railroad Averages
	4 = Highway District Averages

This card is placed ahead of the accident cards that are read by this program.

PART B, SECTION 4, SUBHEADING b:

P1111902 SORT AND REPORT GENERATOR PROGRAM

Four control cards comprise a "set" and are required with one exception. The exception is when all four classifications or divisions (Texas, System, District, Railroad) are to be sorted (12 sorts) and each listed. In this case only one (1) control card need be used and this card must contain a "5" in Column 4.

For all other conditions a complete set of four (4) control cards must be used.

(b = blank)

CONTROL CARD #1

This card is for the Texas Division.

Cols. 1-2 SEMAFOR = A control for selecting priority index. The method is:

00 = All 3 priority indices (1, 2, 3) for all data will be sorted and listed.

01 = Priority index #1 for all data will be sorted and listed.

02 = Priority index #2 for all data will be sorted and listed.

03 = Priority index #3 for all data will be sorted and listed.

RUNN = tells the computer this division will be run or will not be run.

The method is:

b = Run

1 = Do not run

Col. 4 GATE = Used in first control card only. A "5" indicates all four divisions are to be run on all three priority indices, a total of 12 sorts in all. If a "5" appears in this column, no other control cards are required.

Col. 5 SPLIT = Determines whether listing will be broken down by protected and non-protected

S = List seperately

b = List together

CONTROL CARD #2

This card is for the System Division. It selects on system only. 1 = Urban; 2 = Rural.

Cols. 1 - 2 SEMAFOR = Same system as for "Texas"

Col. 3 RUNN = Same as above

Col. 4 Leave blank

Col. 5 SPLIT

CONTROL CARD #3

This card selects for the Districts only. A maximum of 25 districts is assumed.

Cols. 1 - 2 SEMAFOR = Same system as for "Texas"

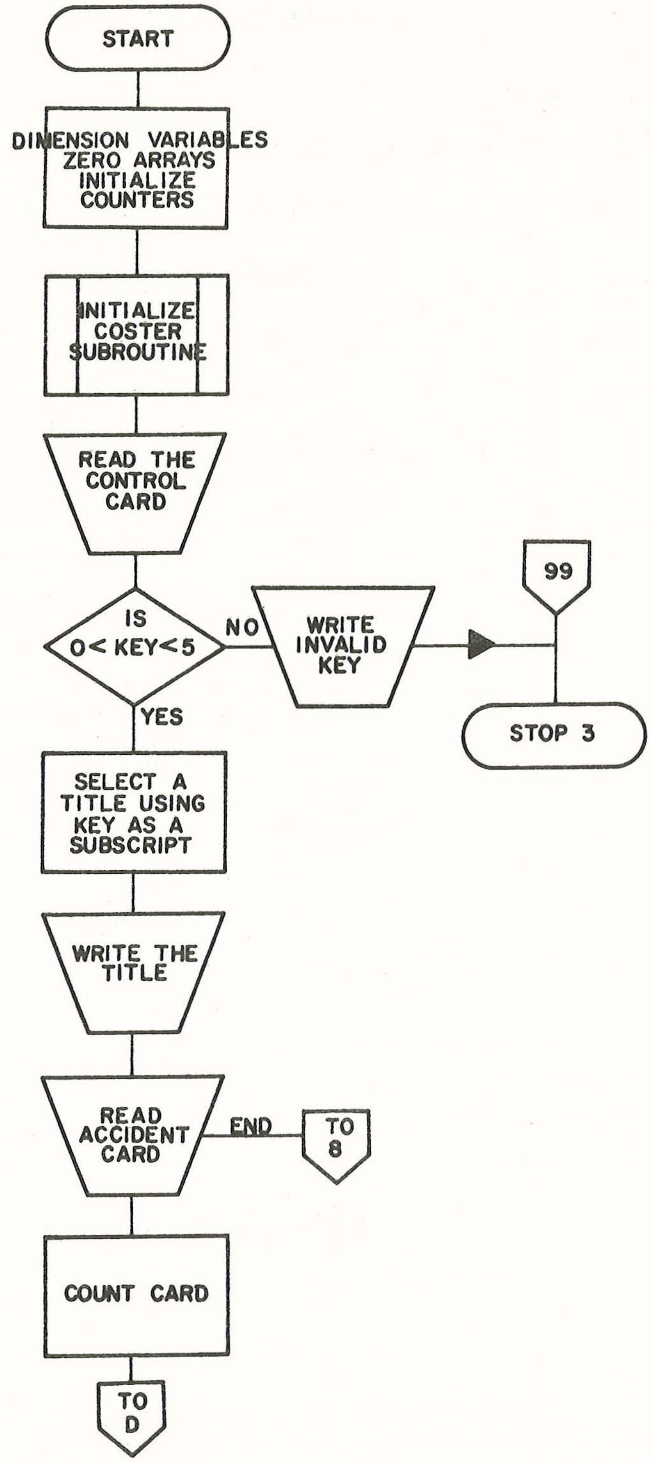
Col. 3	RUNN = Same as above
Col. 4	Leave blank
Col. 5	SPLIT

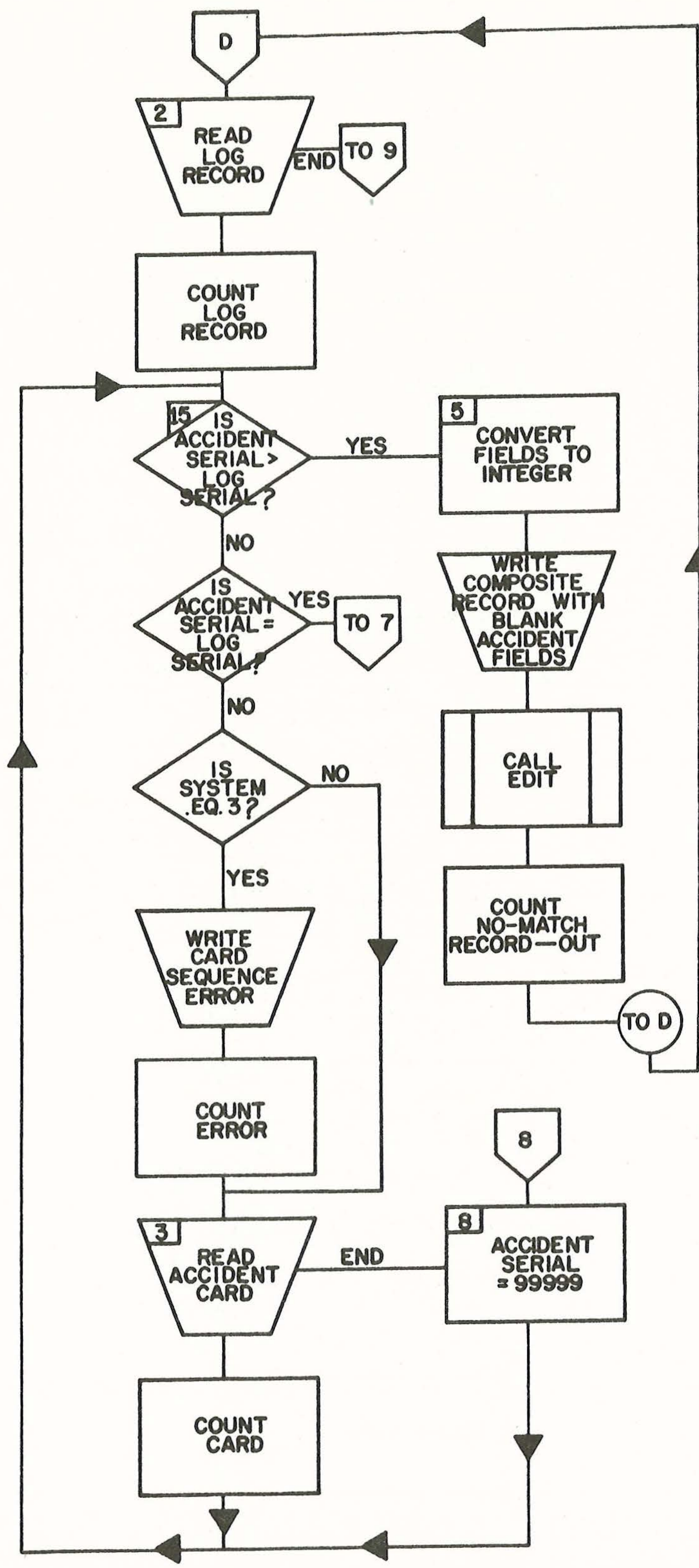
CONTROL CARD #4

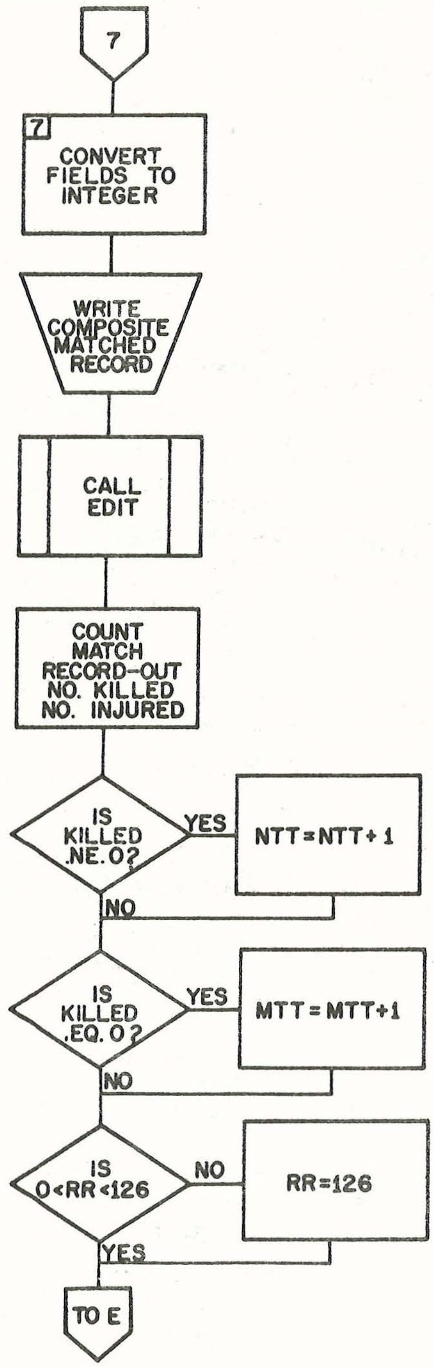
This card selects for the Railroads only.

Cols. 1 - 2	SEMAFOR = Same system as for "Texas"
Col. 3	RUNN = Same as above
Col. 4	Leave blank
Col. 5	SPLIT

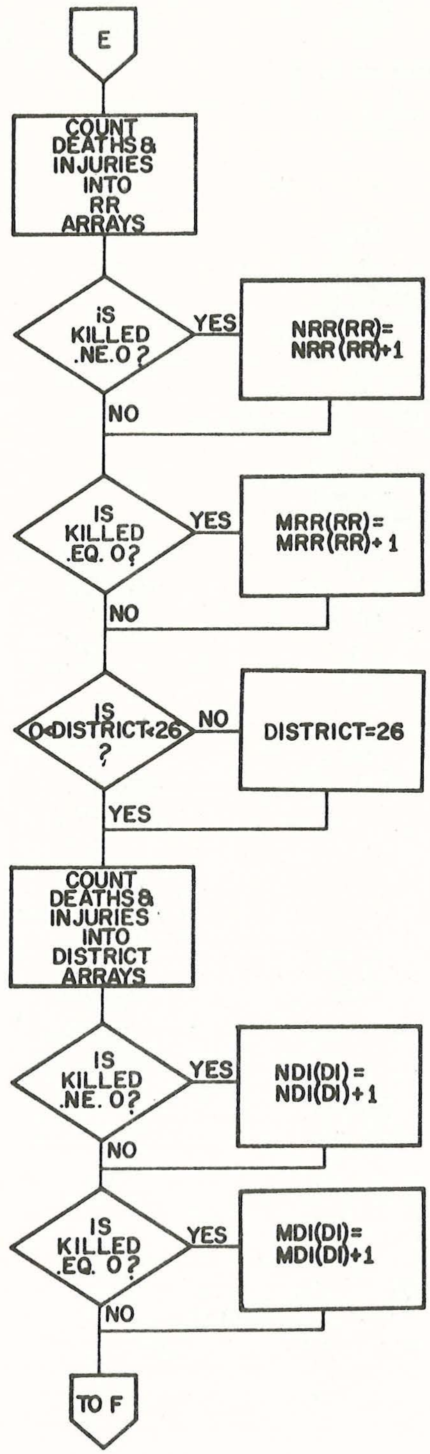
SYSTEM DOCUMENTATION FLOW CHART - PIIII901

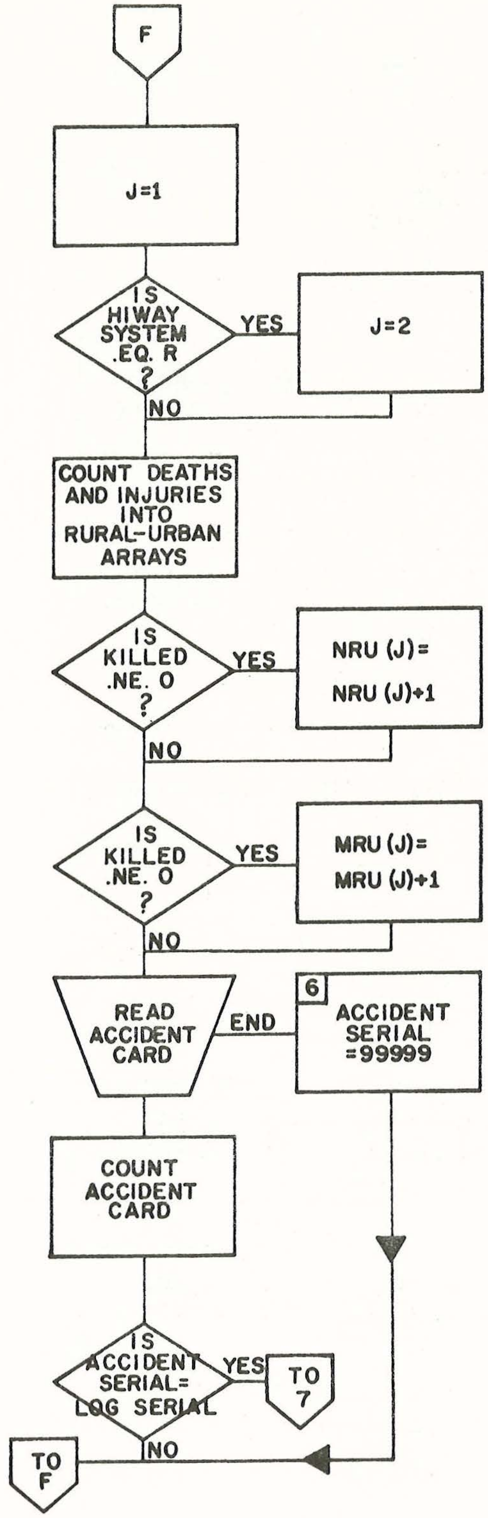


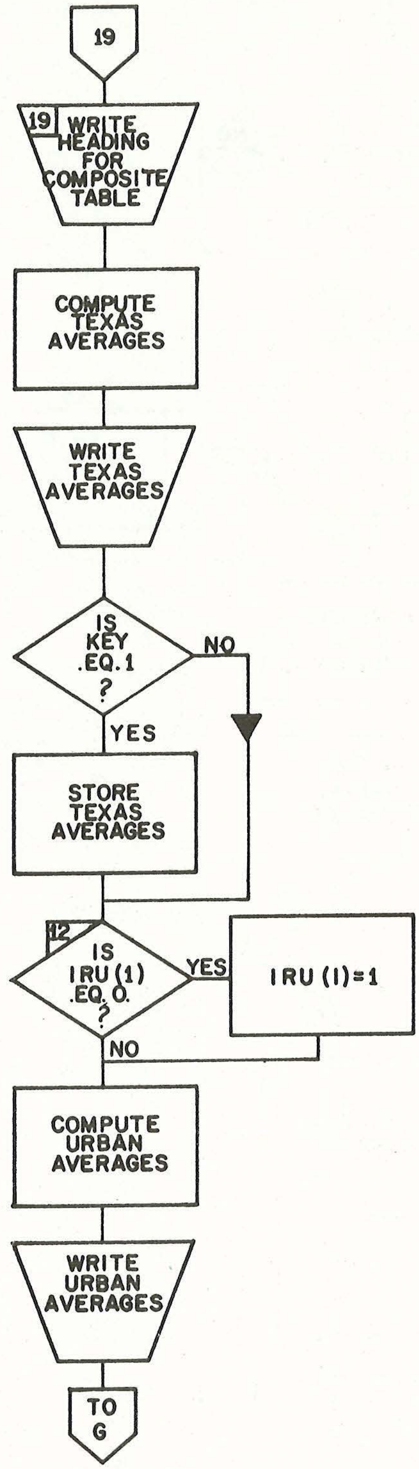

D
2
READ LOG RECORD
END
TO 9
COUNT LOG RECORD
15
IS ACCIDENT SERIAL > LOG SERIAL?
YES
NO
5
CONVERT FIELDS TO INTEGER
WRITE COMPOSITE RECORD WITH BLANK ACCIDENT FIELDS
CALL EDIT
COUNT NO-MATCH RECORD—OUT
TO D
IS ACCIDENT SERIAL = LOG SERIAL?
YES
TO 7
NO
IS SYSTEM .EQ. 3?
NO
YES
WRITE CARD SEQUENCE ERROR
COUNT ERROR
8
3
READ ACCIDENT CARD
END
8
ACCIDENT SERIAL = 99999
COUNT CARD

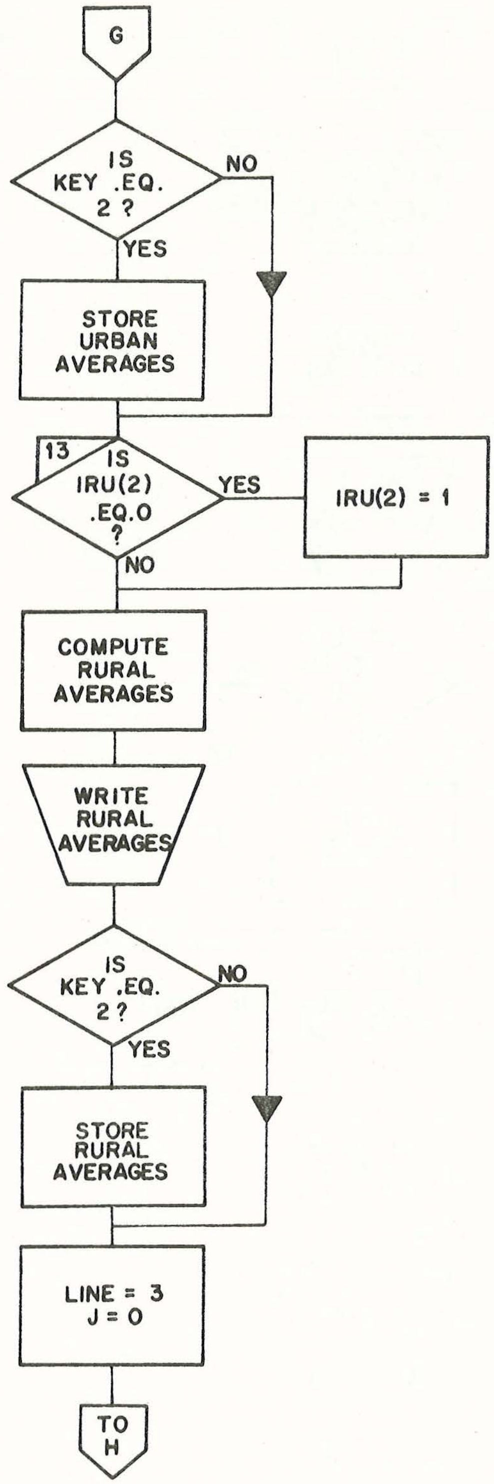


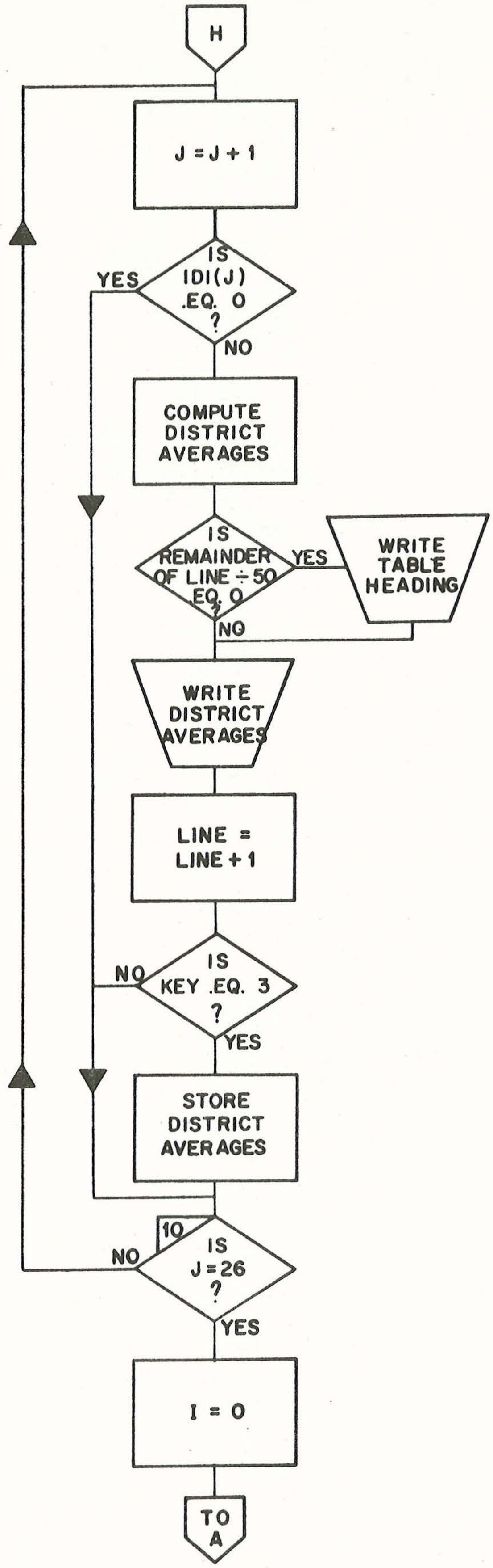
7
7
CONVERT FIELDS TO INTEGER
WRITE COMPOSITE MATCHED RECORD
CALL EDIT
COUNT MATCH RECORD-OUT NO. KILLED NO. INJURED
IS KILLED .NE. 0?
YES
NTT = NTT + 1
NO
IS KILLED .EQ. 0?
YES
MTT = MTT+1
NO
IS 0<RR<126
NO
RR=126
YES
TO E


E
COUNT DEATHS & INJURIES INTO RR ARRAYS
IS KILLED .NE. 0 ?
YES
NRR(RR)= NRR(RR)+1
NO
IS KILLED .EQ. 0?
YES
MRR(RR)= MRR(RR)+1
NO
IS 0<DISTRICT<26 ?
NO
DISTRICT=26
YES
COUNT DEATHS & INJURIES INTO DISTRICT ARRAYS
IS KILLED .NE. 0?
YES
NDI(DI) = NDI(DI)+1
NO
IS KILLED .EQ. 0?
YES
MDI(DI)= MDI(DI)+1
NO
TO F

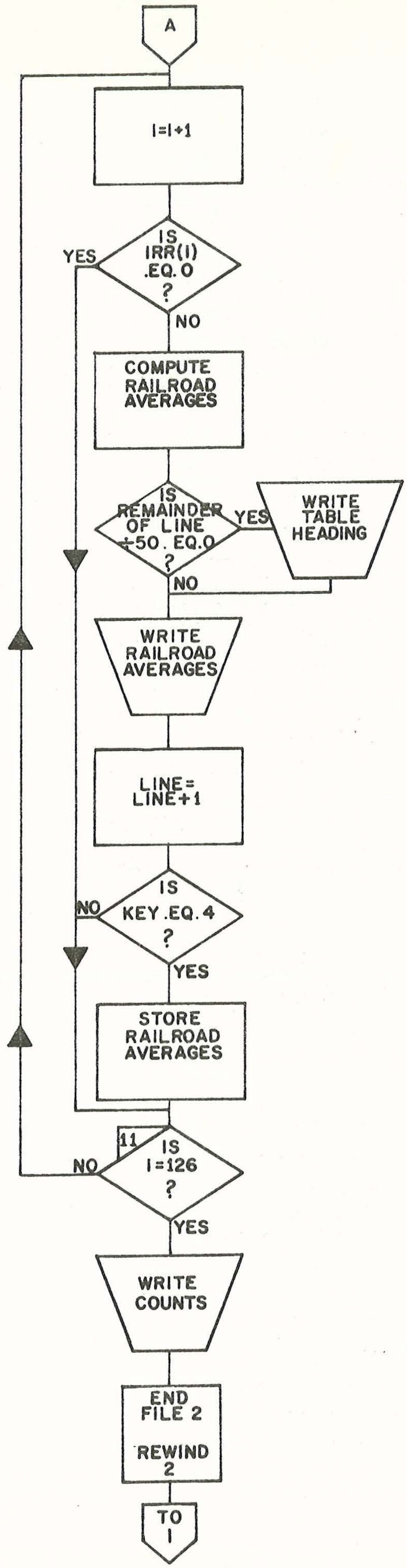

F
J=1
IS HIWAY SYSTEM .EQ. R ?
YES
J=2
NO
COUNT DEATHS AND INJURIES INTO RURAL-URBAN ARRAYS
IS KILLED .NE. 0 ?
YES
NRU (J)= NRU (J)+1
NO
IS KILLED .NE. 0 ?
YES
MRU (J)= MRU (J)+1
NO
READ ACCIDENT CARD
END
6
ACCIDENT SERIAL =99999
COUNT ACCIDENT CARD
IS ACCIDENT SERIAL= LOG SERIAL
YES
TO 7
NO
TO F

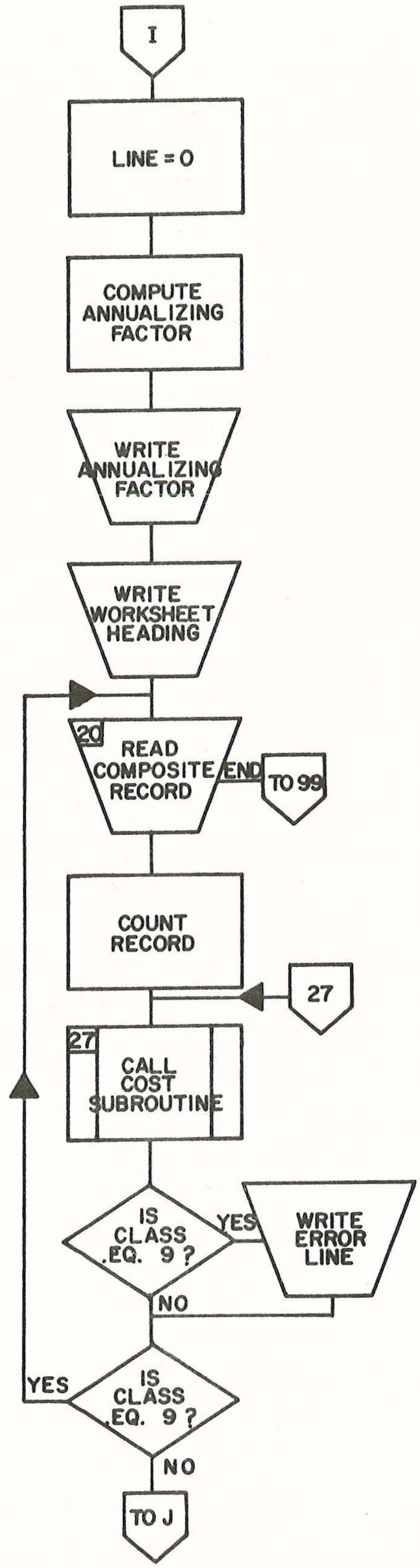

19
19 WRITE HEADING FOR COMPOSITE TABLE
COMPUTE TEXAS AVERAGES
WRITE TEXAS AVERAGES
IS KEY .EQ.1 ?
NO
YES
STORE TEXAS AVERAGES
12 IS IRU(1) .EQ.0 ?
YES
IRU(I)=1
NO
COMPUTE URBAN AVERAGES
WRITE URBAN AVERAGES
TO G

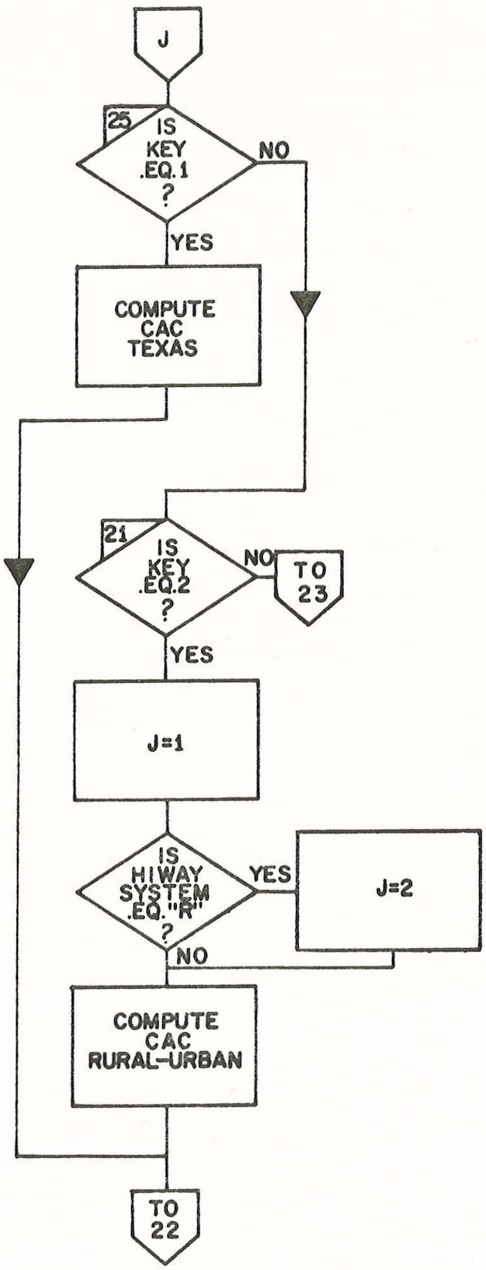

G
IS
KEY .EQ.
2 ?
NO
YES
STORE
URBAN
AVERAGES
13
IS
IRU(2)
.EQ.O
?
YES
IRU(2) = 1
NO
COMPUTE
RURAL
AVERAGES
WRITE
RURAL
AVERAGES
IS
KEY .EQ.
2 ?
NO
YES
STORE
RURAL
AVERAGES
LINE = 3
J = O
TO
H



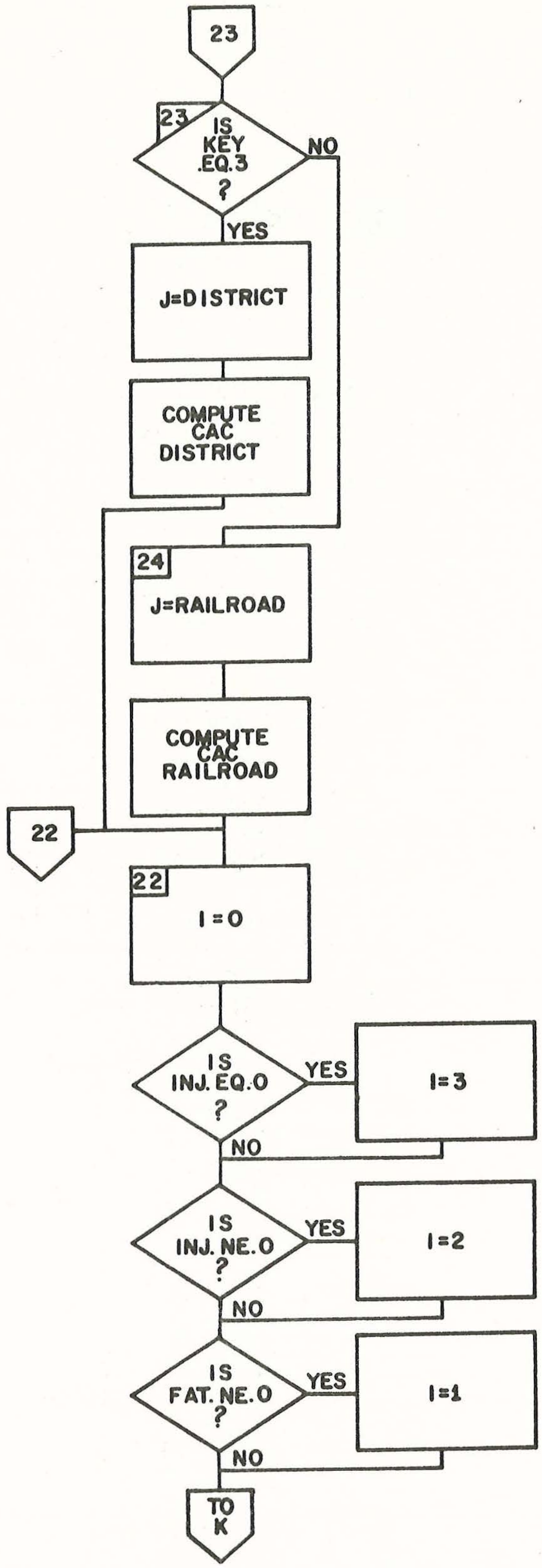
H
J = J + 1
IS IDI(J) .EQ. 0 ?
YES
NO
COMPUTE DISTRICT AVERAGES
IS REMAINDER OF LINE ÷ 50 .EQ. 0 ?
YES
WRITE TABLE HEADING
NO
WRITE DISTRICT AVERAGES
LINE = LINE + 1
IS KEY .EQ. 3 ?
NO
YES
STORE DISTRICT AVERAGES
10
IS J = 26 ?
NO
YES
I = 0
TO A

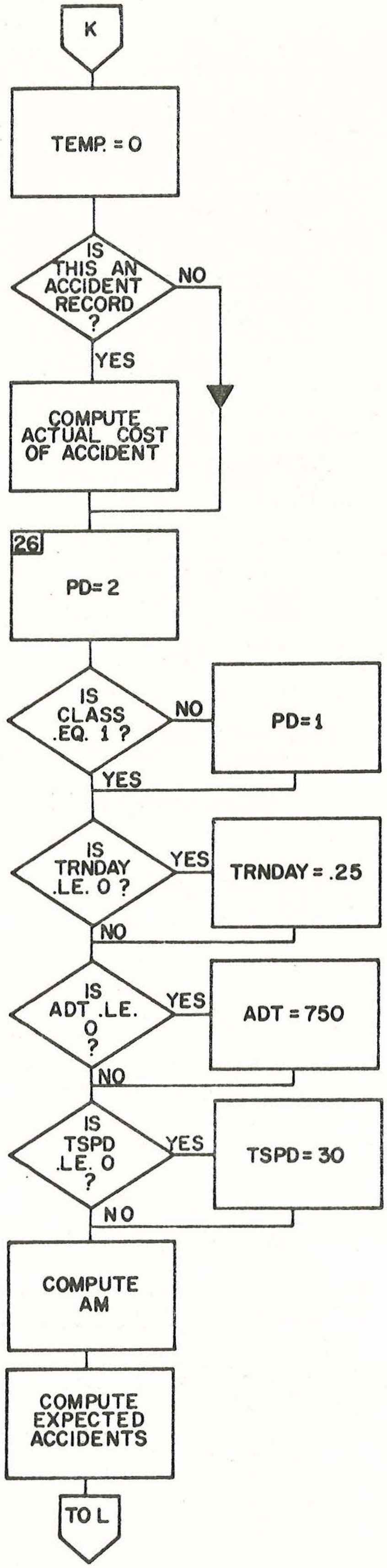

A
I=I+1
IS IRR(I) .EQ.0 ?
YES
NO
COMPUTE RAILROAD AVERAGES
IS REMAINDER OF LINE ÷50. EQ.0 ?
YES
WRITE TABLE HEADING
NO
WRITE RAILROAD AVERAGES
LINE= LINE+1
IS KEY .EQ. 4 ?
NO
YES
STORE RAILROAD AVERAGES
11
IS I=126 ?
NO
YES
WRITE COUNTS
END FILE 2
REWIND 2
TO I

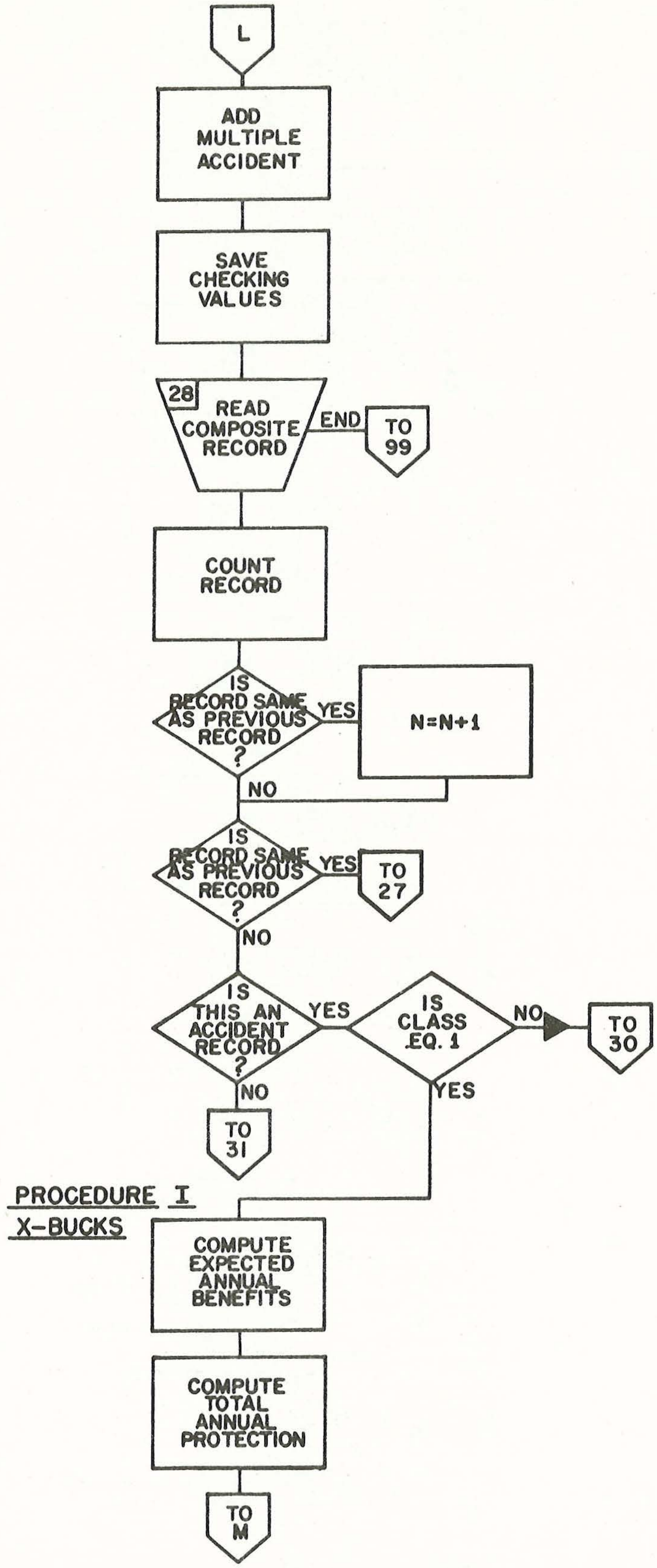

I
LINE = O
COMPUTE ANNUALIZING FACTOR
WRITE ANNUALIZING FACTOR
WRITE WORKSHEET HEADING
20
READ COMPOSITE RECORD
END
TO 99
COUNT RECORD
27
27
CALL COST SUBROUTINE
IS CLASS .EQ. 9 ?
YES
WRITE ERROR LINE
NO
YES
IS CLASS .EQ. 9 ?
NO
TO J

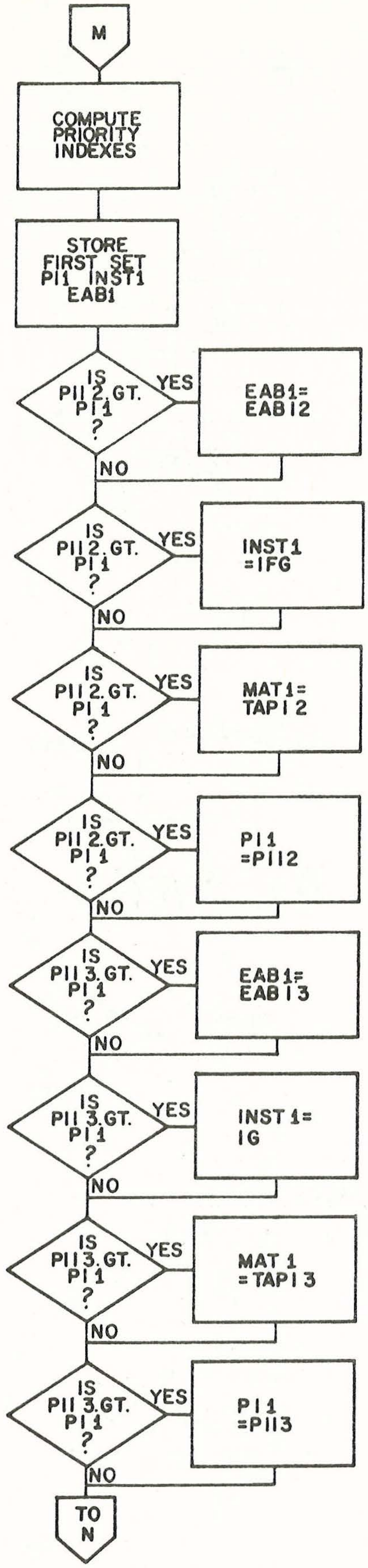


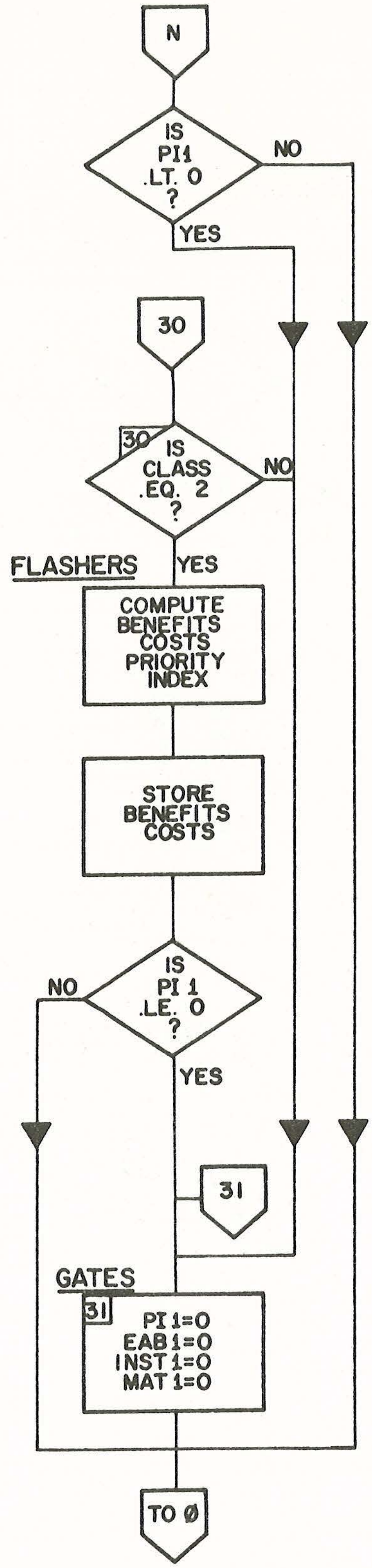
J
25
IS
KEY
.EQ.1
?
NO
YES
COMPUTE
CAC
TEXAS
21
IS
KEY
.EQ.2
?
NO
TO
23
YES
J=1
IS
HIWAY
SYSTEM
.EQ."R"
?
YES
J=2
NO
COMPUTE
CAC
RURAL-URBAN
TO
22


23
23
IS KEY .EQ.3 ?
NO
YES
J=DISTRICT
COMPUTE CAC DISTRICT
24
J=RAILROAD
COMPUTE CAC RAILROAD
22
22
I=0
IS INJ. EQ.O ?
YES
I=3
NO
IS INJ. NE.O ?
YES
I=2
NO
IS FAT. NE.O ?
YES
I=1
NO
TO K

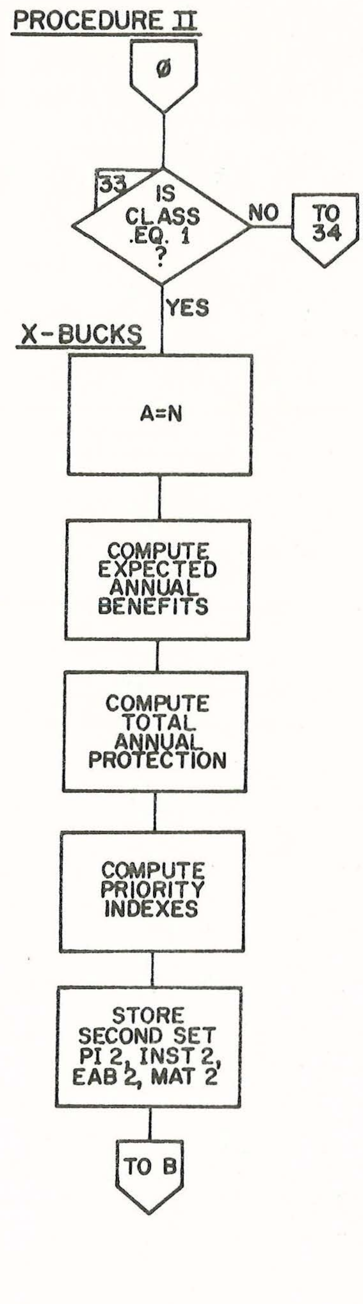

K
TEMP. = O
IS THIS AN ACCIDENT RECORD ?
NO
YES
COMPUTE ACTUAL COST OF ACCIDENT
26
PD= 2
IS CLASS .EQ. 1 ?
NO
PD= 1
YES
IS TRNDAY .LE. O ?
YES
TRNDAY = .25
NO
IS ADT .LE. O ?
YES
ADT = 750
NO
IS TSPD .LE. O ?
YES
TSPD= 30
NO
COMPUTE AM
COMPUTE EXPECTED ACCIDENTS
TO L

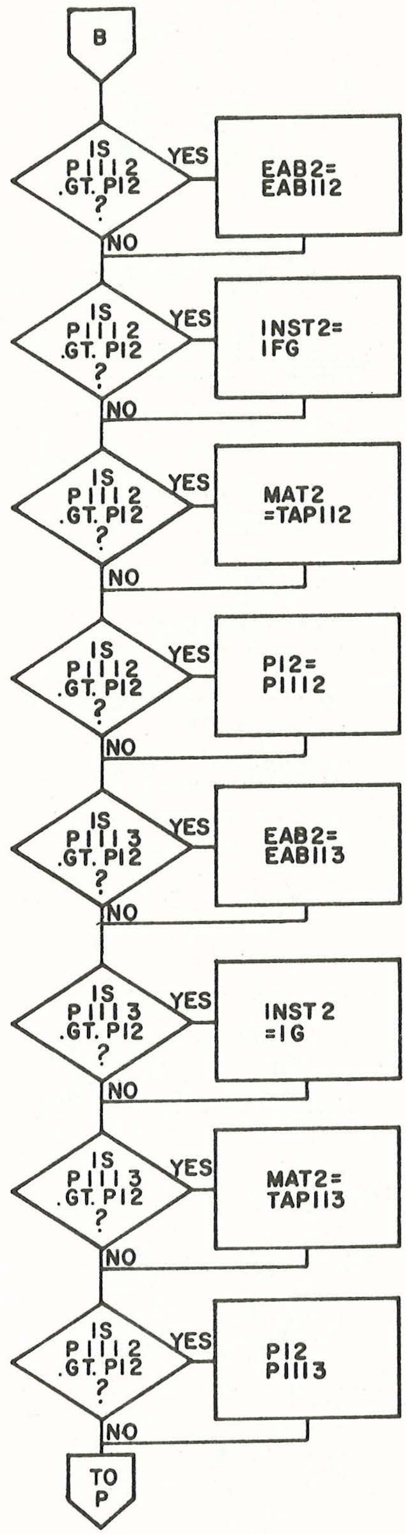

L
ADD MULTIPLE ACCIDENT
SAVE CHECKING VALUES
28
READ COMPOSITE RECORD
END
TO 99
COUNT RECORD
IS RECORD SAME AS PREVIOUS RECORD ?
YES
N=N+1
NO
IS RECORD SAME AS PREVIOUS RECORD ?
YES
TO 27
NO
IS THIS AN ACCIDENT RECORD ?
YES
IS CLASS EQ. 1
NO
TO 30
YES
NO
TO 31
PROCEDURE I
X-BUCKS
COMPUTE EXPECTED ANNUAL BENEFITS
COMPUTE TOTAL ANNUAL PROTECTION
TO M

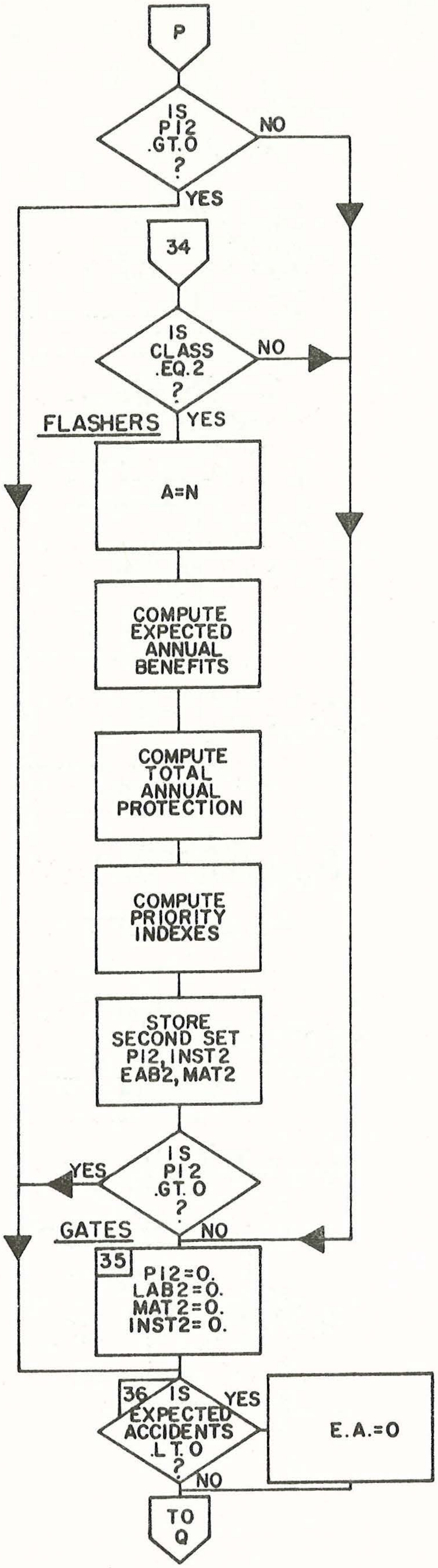

M
COMPUTE PRIORITY INDEXES
STORE FIRST SET PI1 INST1 EAB1
IS PI I 2.GT. PI 1 ?
YES
EAB1= EAB I2
NO
IS PI I 2.GT. PI 1 ?
YES
INST1 =IFG
NO
IS PI I 2.GT. PI 1 ?
YES
MAT 1= TAP I 2
NO
IS PI I 2.GT. PI 1 ?
YES
PI 1 =PI I2
NO
IS PI I 3.GT. PI 1 ?
YES
EAB1= EAB I 3
NO
IS PI I 3.GT. PI 1 ?
YES
INST 1= IG
NO
IS PI I 3.GT. PI 1 ?
YES
MAT 1 =TAP I 3
NO
IS PI I 3.GT. PI 1 ?
YES
PI 1 =PI I3
NO
TO N

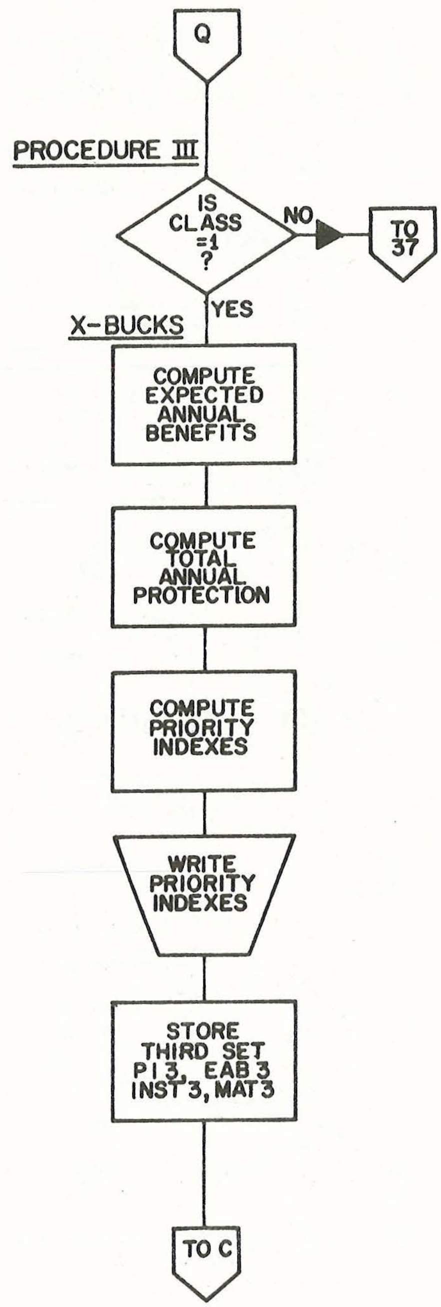


N
IS
PI1
.LT. 0
?
NO
YES
30
30
IS
CLASS
.EQ. 2
?
NO
FLASHERS
YES
COMPUTE
BENEFITS
COSTS
PRIORITY
INDEX
STORE
BENEFITS
COSTS
IS
PI 1
.LE. 0
?
NO
YES
31
GATES
31
PI 1=0
EAB 1=0
INST 1=0
MAT 1=0
TO Ø

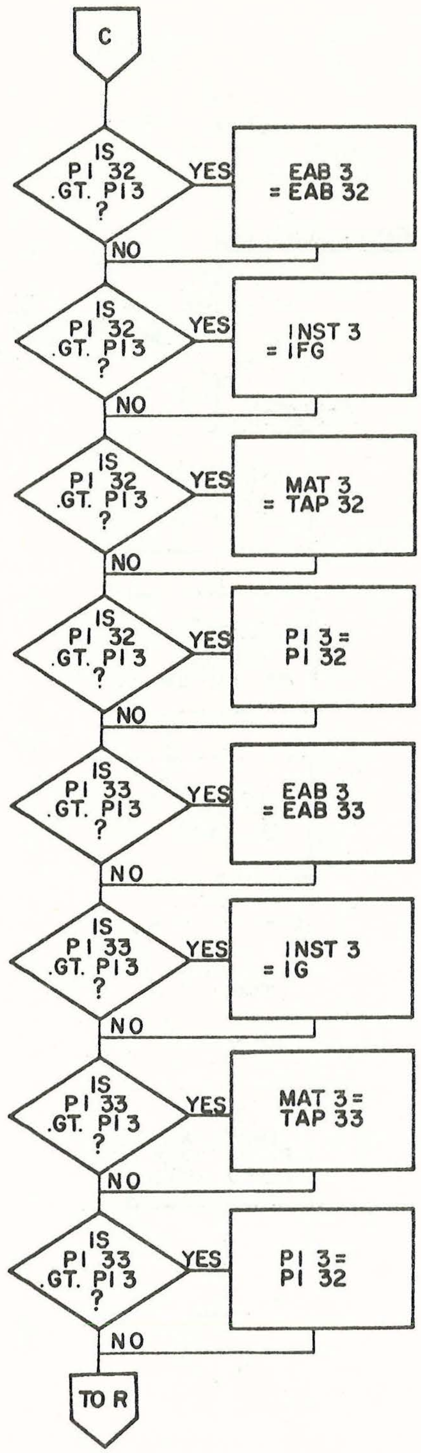

PROCEDURE II
Ø
33
IS CLASS .EQ. 1 ?
NO
TO 34
YES
X-BUCKS
A=N
COMPUTE EXPECTED ANNUAL BENEFITS
COMPUTE TOTAL ANNUAL PROTECTION
COMPUTE PRIORITY INDEXES
STORE SECOND SET PI 2, INST 2, EAB 2, MAT 2
TO B

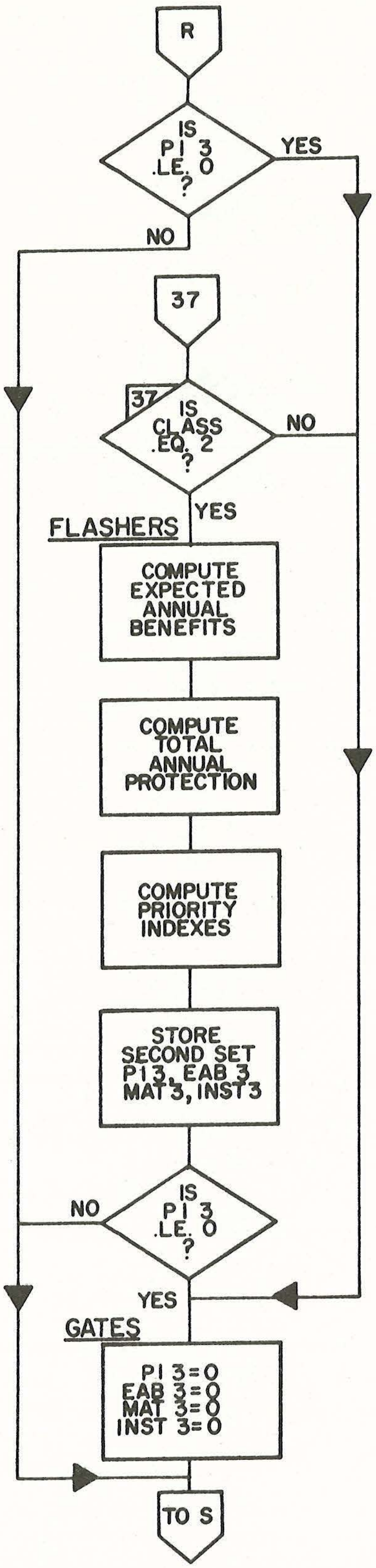

B
IS P1112 .GT. P12 ?
YES
EAB2= EAB112
NO
IS P1112 .GT. P12 ?
YES
INST2= IFG
NO
IS P1112 .GT. P12 ?
YES
MAT2 =TAP112
NO
IS P1112 .GT. P12 ?
YES
P12= P1112
NO
IS P1113 .GT. P12 ?
YES
EAB2= EAB113
NO
IS P1113 .GT. P12 ?
YES
INST2 =IG
NO
IS P1113 .GT. P12 ?
YES
MAT2= TAP113
NO
IS P1112 .GT. P12 ?
YES
P12 P1113
NO
TO P

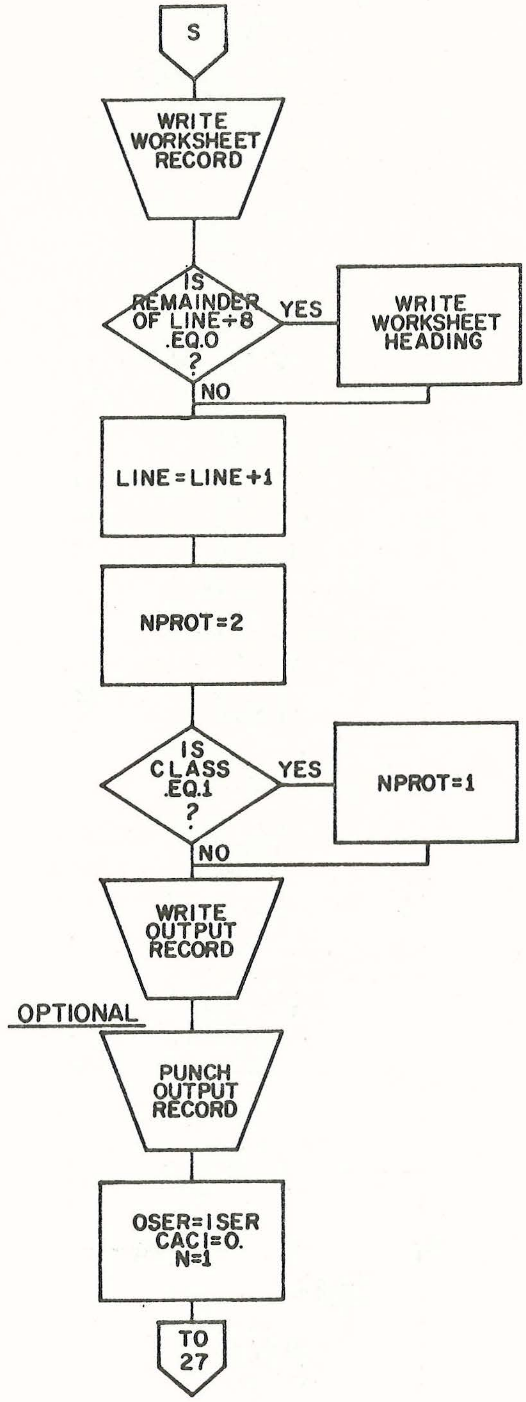

P
IS PI2 .GT.0 ?
NO
YES
34
IS CLASS .EQ.2 ?
NO
FLASHERS
YES
A=N
COMPUTE EXPECTED ANNUAL BENEFITS
COMPUTE TOTAL ANNUAL PROTECTION
COMPUTE PRIORITY INDEXES
STORE SECOND SET PI2, INST2 EAB2, MAT2
IS PI2 .GT. 0 ?
YES
GATES
NO
35
PI2=0.
LAB2=0.
MAT2=0.
INST2=0.
36
IS EXPECTED ACCIDENTS .LT.0 ?
YES
E.A.=0
NO
TO Q

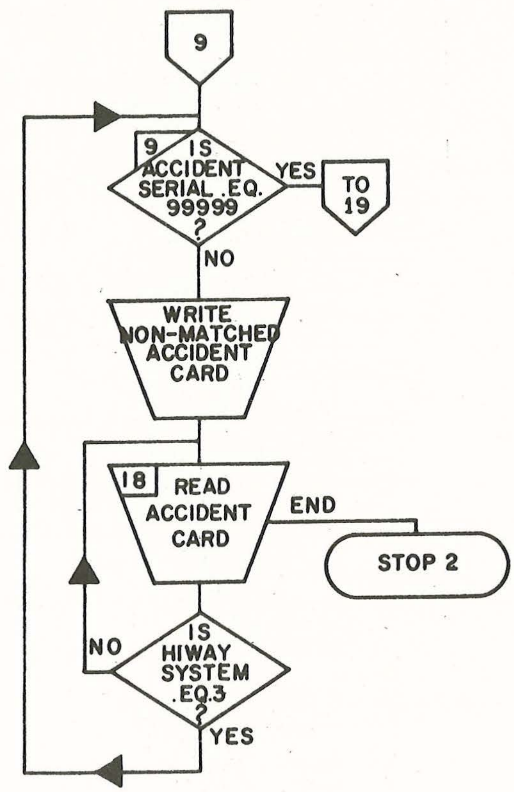


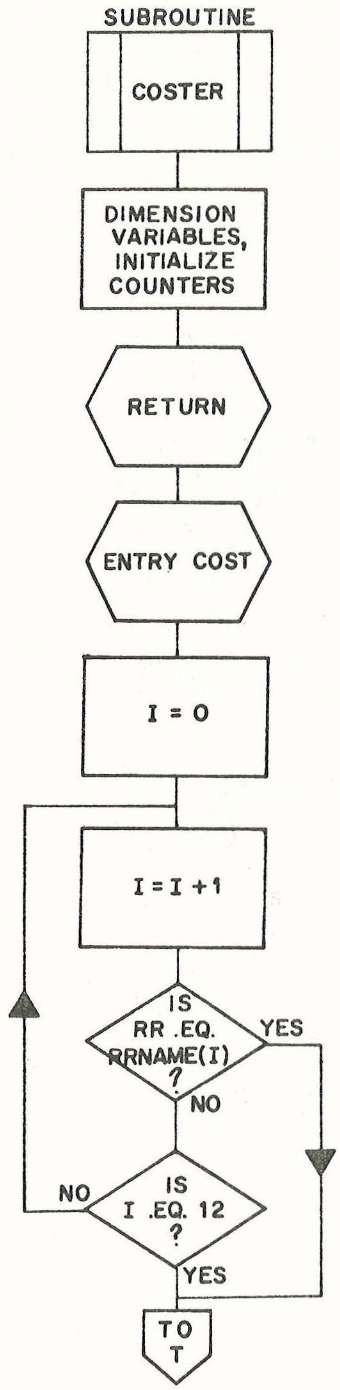
Q
PROCEDURE III
IS CLASS =1 ?
NO
TO 37
YES
X-BUCKS
COMPUTE EXPECTED ANNUAL BENEFITS
COMPUTE TOTAL ANNUAL PROTECTION
COMPUTE PRIORITY INDEXES
WRITE PRIORITY INDEXES
STORE THIRD SET PI 3, EAB 3 INST 3, MAT 3
TO C

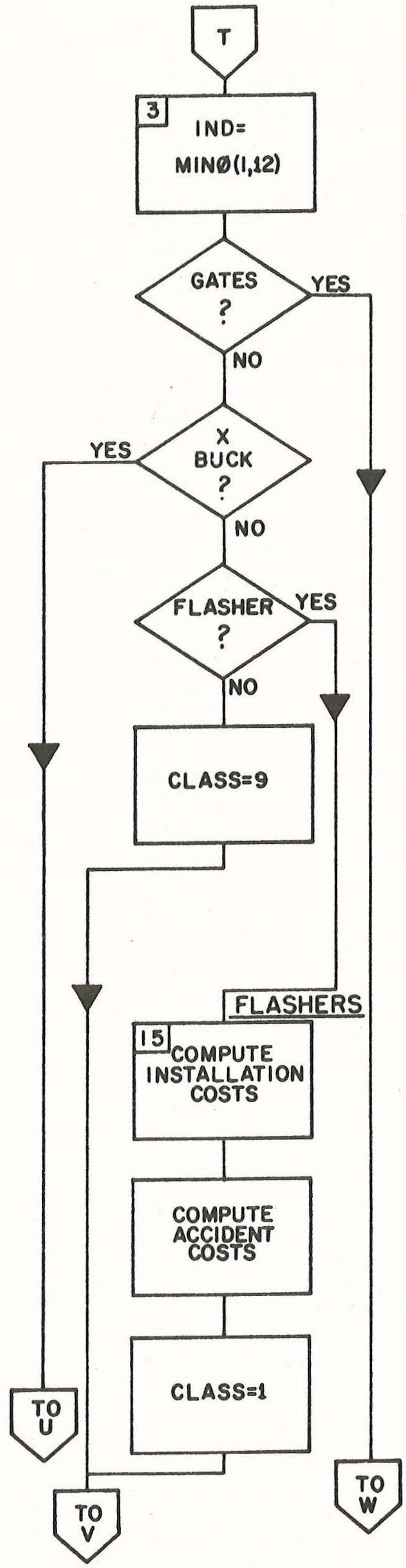

C
IS PI 32 .GT. PI 3 ?
YES
EAB 3 = EAB 32
NO
IS PI 32 .GT. PI 3 ?
YES
INST 3 = IFG
NO
IS PI 32 .GT. PI 3 ?
YES
MAT 3 = TAP 32
NO
IS PI 32 .GT. PI 3 ?
YES
PI 3 = PI 32
NO
IS PI 33 .GT. PI 3 ?
YES
EAB 3 = EAB 33
NO
IS PI 33 .GT. PI 3 ?
YES
INST 3 = IG
NO
IS PI 33 .GT. PI 3 ?
YES
MAT 3 = TAP 33
NO
IS PI 33 .GT. PI 3 ?
YES
PI 3 = PI 32
NO
TO R

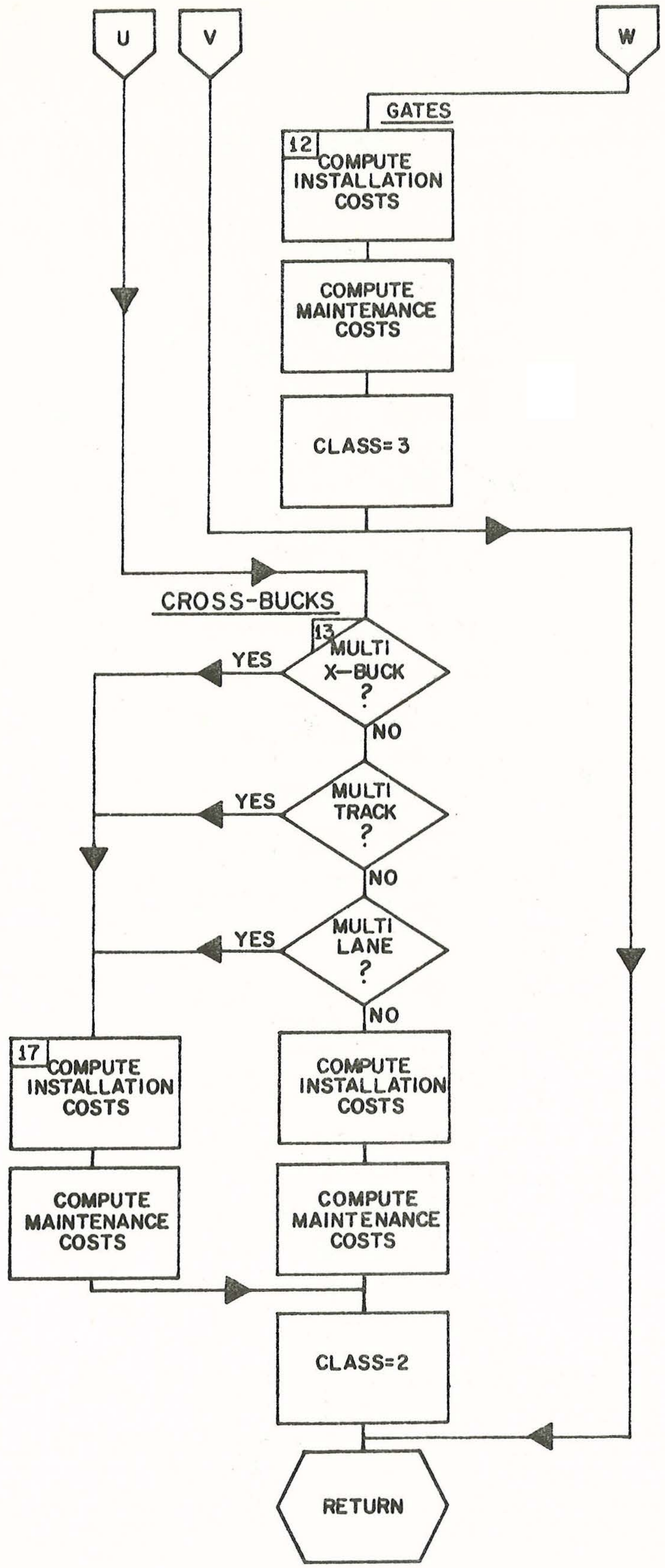

R
IS
PI 3
.LE. 0
?
YES
NO
37
37
IS
CLASS
.EQ. 2
?
NO
YES
FLASHERS
COMPUTE
EXPECTED
ANNUAL
BENEFITS
COMPUTE
TOTAL
ANNUAL
PROTECTION
COMPUTE
PRIORITY
INDEXES
STORE
SECOND SET
PI 3, EAB 3
MAT 3, INST 3
IS
PI 3
.LE. 0
?
NO
YES
GATES
PI 3=0
EAB 3=0
MAT 3=0
INST 3=0
TO S


S
WRITE WORKSHEET RECORD
IS REMAINDER OF LINE÷8 .EQ.0 ?
YES
WRITE WORKSHEET HEADING
NO
LINE=LINE+1
NPROT=2
IS CLASS .EQ.1 ?
YES
NPROT=1
NO
WRITE OUTPUT RECORD
OPTIONAL
PUNCH OUTPUT RECORD
OSER=ISER
CACI=0.
N=1
TO 27

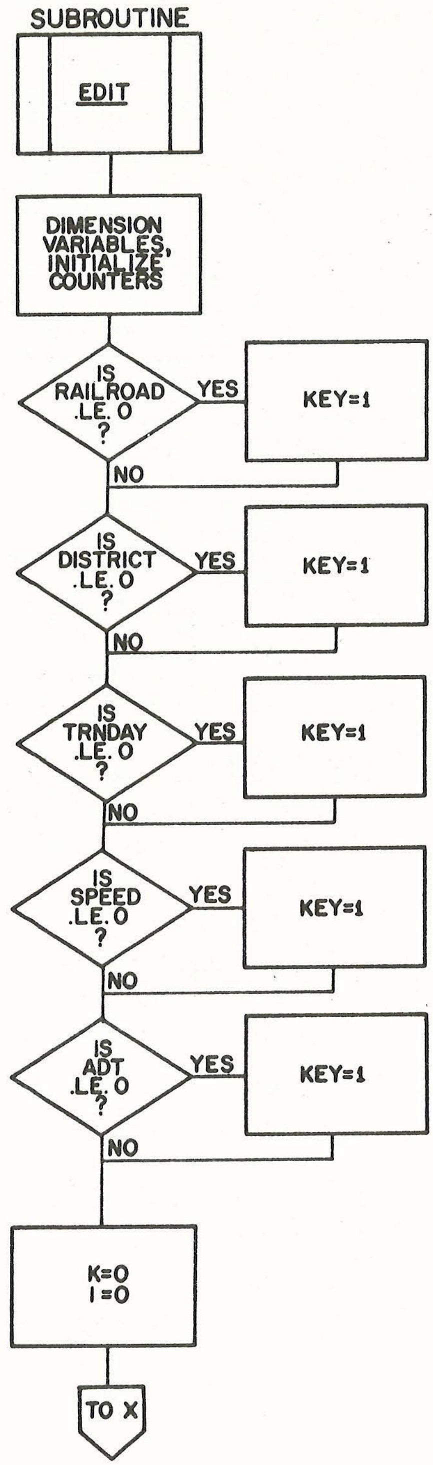

9
9 IS ACCIDENT SERIAL .EQ. 99999 ?
YES
TO 19
NO
WRITE NON-MATCHED ACCIDENT CARD
18 READ ACCIDENT CARD
END
STOP 2
IS HIWAY SYSTEM .EQ.3 ?
NO
YES

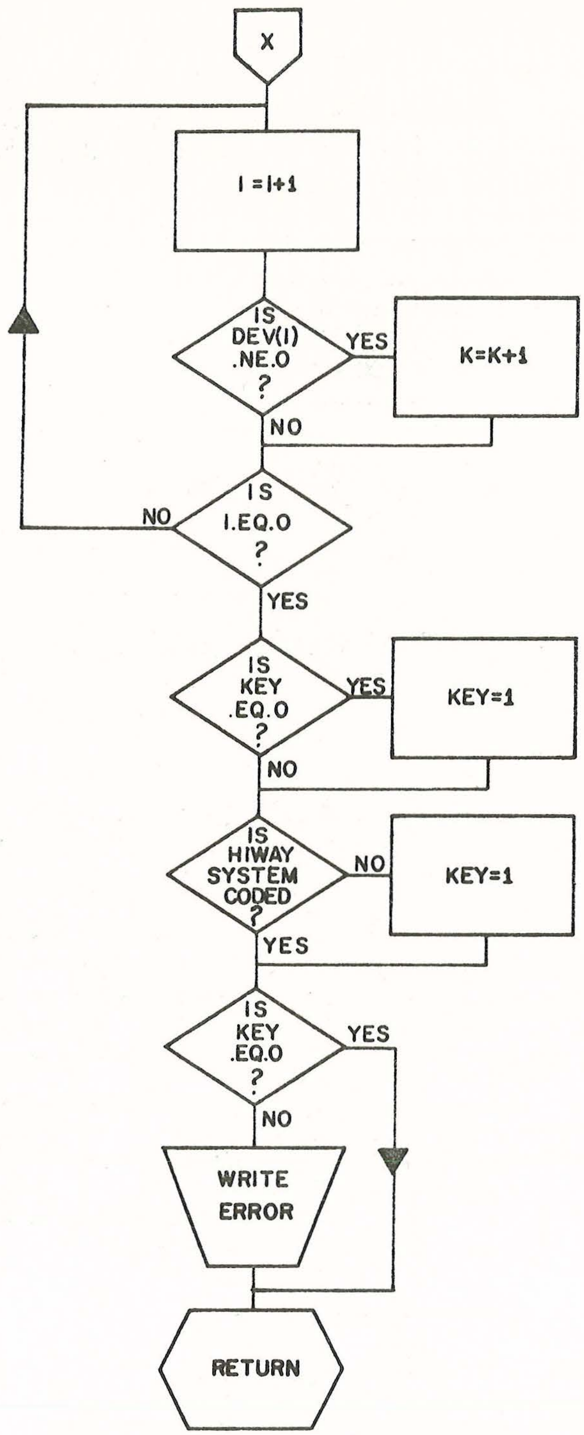

SUBROUTINE
COSTER
DIMENSION VARIABLES, INITIALIZE COUNTERS
RETURN
ENTRY COST
I = 0
I = I + 1
IS RR .EQ. RRNAME(I) ?
YES
NO
IS I .EQ. 12 ?
NO
YES
TO T


T
3
IND=
MINØ(I,12)
GATES
?
YES
NO
X
BUCK
?
YES
NO
FLASHER
?
YES
NO
CLASS=9
FLASHERS
15
COMPUTE
INSTALLATION
COSTS
COMPUTE
ACCIDENT
COSTS
CLASS=1
TO
U
TO
V
TO
W



U
V
W
GATES
12 COMPUTE INSTALLATION COSTS
COMPUTE MAINTENANCE COSTS
CLASS=3
CROSS-BUCKS
13 MULTI X-BUCK ?
YES
NO
MULTI TRACK ?
YES
NO
MULTI LANE ?
YES
NO
17 COMPUTE INSTALLATION COSTS
COMPUTE MAINTENANCE COSTS
COMPUTE INSTALLATION COSTS
COMPUTE MAINTENANCE COSTS
CLASS=2
RETURN


SUBROUTINE
EDIT
DIMENSION VARIABLES, INITIALIZE COUNTERS
IS RAILROAD .LE. 0 ?
YES
KEY=1
NO
IS DISTRICT .LE. 0 ?
YES
KEY=1
NO
IS TRNDAY .LE. 0 ?
YES
KEY=1
NO
IS SPEED .LE. 0 ?
YES
KEY=1
NO
IS ADT .LE. 0 ?
YES
KEY=1
NO
K=0
I=0
TO X


X
I = I+1
IS DEV(I) .NE.O ?
YES
K=K+1
NO
IS I.EQ.O ?
NO
YES
IS KEY .EQ.O ?
YES
KEY=1
NO
IS HIWAY SYSTEM CODED ?
NO
KEY=1
YES
IS KEY .EQ.O ?
YES
NO
WRITE ERROR
RETURN