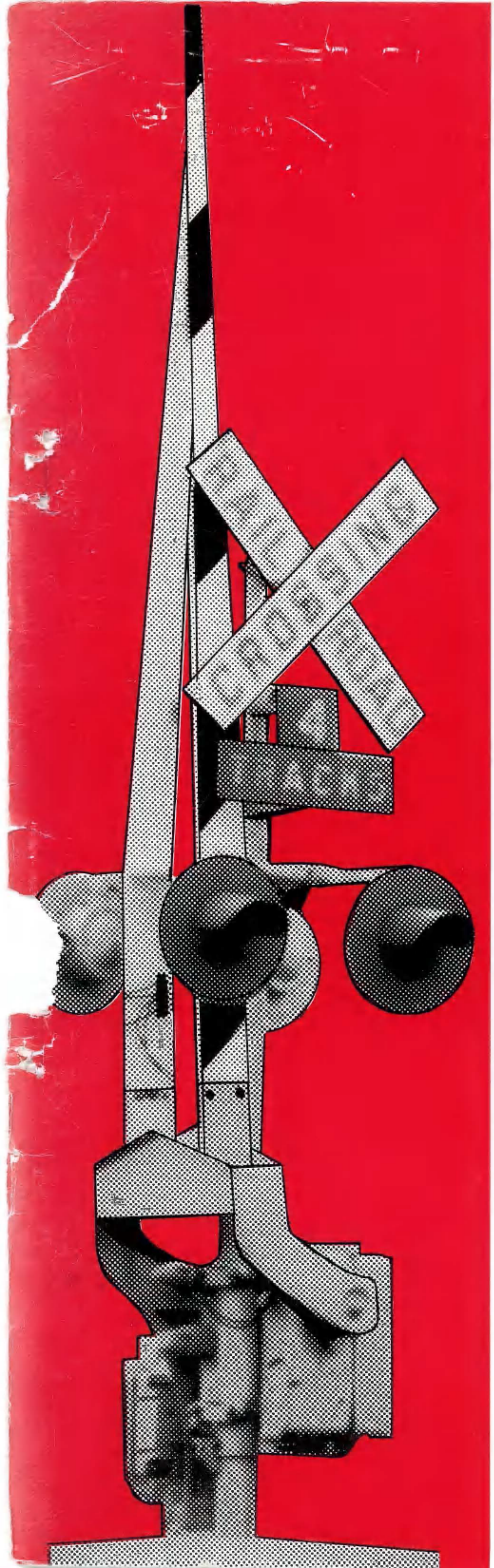
Robert C. Hunter

Proceedings

1972 NATIONAL CONFERENCE ON

Railroad-Highway Grade Crossing Safety

AUGUST 29 - 31, 1972



Sponsored By

U.S. Department of Transportation

Highway Research Board

National Safety Council

Held at

The Ohio State University

Columbus, Ohio

Objective of Symposium

"To bring together key interest groups to discuss new ways and means to insure increased safety and to achieve optimum efficiency in the use of both highway and railroad facilities."

U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

SUBJECT Proceedings of 1972 National Conference On Railroad-Highway Grade Crossing Safety	FHWA NOTICE

January 26, 1973

HNG-14

The proceedings of the 1972 National Conference on Railroad-Highway Grade Crossing Safety held at Ohio State University on August 29-31, 1972, have just been received and are being distributed for your information and use. The conference was jointly sponsored by the Department of Transportation (Federal Highway Administration and Federal Railroad Administration), the Highway Research Board, and the National Safety Council.

Secretary Volpe, as the keynote speaker at the conference, reported on the significant findings contained in Part II of the Report to Congress on Railroad-Highway Safety (transmitted with our FHWA Notice of September 5, 1972). The Secretary also outlined other elements of the Department's emphasis on grade crossing safety and asked the support of other involved parties in furthering the advancement of grade crossing safety.

The paper entitled, "Implementation Problems Relating to a Rail-Highway Grade Crossing Safety Program," should be of particular interest to State highway departments and others embarking on grade crossing improvement programs. The paper entitled, "Warrants for Safety Improvements at Railroad-Highway Grade Crossings," represents the interim results of an ongoing effort. Nevertheless, the discussion and the results, particularly for rural crossings, may be of immediate value to States and localities in developing grade crossing improvement programs.

The paper entitled, "Passive Devices at Railroad-Highway Grade Crossings," presents new passive devices for consideration. Although these non-standard devices are not to be installed except as experimental devices under the provisions of Section 1A-5 of the Manual On Uniform Traffic Control Devices, it is quite possible that this paper will provide input to a multi-State research project on passive devices to be initiated by FHWA and the States in the very near future.

The increasing problem of railroads in urban areas and railroad relocation as a solution is also presented.

-more-

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Highlights of the Report to Congress are included, as well as a critique of the Report.

Sufficient copies are being distributed to provide one copy for each regional office, division office, and State highway department. Additional copies, as may be desired by others such as in any of the above; members of diagnostic teams, or other State and local agencies, may be obtained from Mr. J. E. Kirk, Chief, Railroads and Utilities Branch, HNG-14, (telephone: (202) 426-0104).

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Opening Session

Douglas M. Fergusson, *Moderator*
Director of Safety Services
Nationwide Insurance Company

Welcome to the 1972 National Conference on Railroad-Highway Grade Crossing Safety. On behalf of the Joint Planning and the co-sponsors—National Safety Council, Highway Research Board and Department of Transportation—I sincerely wish everyone an enjoyable and profitable stay in Columbus, Ohio. We are grateful to Ohio State University for being our host and particularly to Professor E. A. Whitehurst for his role in coordinating the outstanding services of this fine institution.

This 1972 Conference represents the fourth national conclave since 1967 on railroad-grade crossing safety. The objective of the conference, as prepared by the Joint Planning Group, is stated as follows:

> *"The nature of the rail-highway grade crossing safety problem is changing. The objective is to bring together key interest groups to discuss new ways and means to insure increased safety and to achieve optimum efficiency in the use of both highway and railroad facilities."*

The program has been designed, with specific interest groups in mind, to achieve this objective. Preceding conferences have naturally had different objectives lending themselves to greater participation by other groups. Lest you be surprised, there will be some subjects that have intentionally been omitted from the program and will not be discussed.

Finally, the program format is so designed that questions will not be entertained during the morning general sessions. Each afternoon has been planned for free and open discussion, and you are urged to utilize this time to engage our speakers, and other resource personnel, in meaningful dialogue.

Welcome to The Ohio State University

Harold A. Bolz
Dean
College of Engineering
The Ohio State University

Ladies and Gentlemen of the Conference on Railroad-Highway Grade Crossing Safety, Welcome to The Ohio State University campus.

I am particularly glad to express in behalf of my faculty associates in the College of Engineering and for myself our appreciation that you have chosen to meet here on our campus. We are very glad to have you here and have several very good reasons for feeling this way.

You are important persons representing important organizations. We are glad to have you here because we like to be associated with important people. We recognize the Highway Research Board, the National Safety Council, the U.S. Department of Transportation, and the various organizations and agencies related to transportation safety represented here at this conference as significant groups at work in the improvement of living for our fellow citizens.

You are here to discuss critical safety problems related to transportation. We are glad to have you here because transportation is one of our major areas of teaching and research.

You came here to learn together. We are glad that you are here because we are in the business of trying to help people to learn. We welcome this opportunity of working with you and we hope that the campus environment will be conductive to our learning together.

You are interested in new knowledge. Research is the process by which new knowledge is disclosed and discovered. We are glad to have you here because research is a foremost activity in our College of Engineering. We hope that this Conference may lead to new ways by which we at the University may serve your organizations through our research capabilities.

You are interested in solving problems and not in just talking about them. We are glad to be associated with you because our major mission is to prepare young engineers to attack problems in productive ways. We hope that you will consider employing our graduates for engineering careers in your organizations. We hope also that you will do whatever you can to encourage high school students to consider engineering careers and of course to prepare for these careers here at Ohio State.

We also have a rather selfish reason to be happy about your presence here with us. We, as teachers of engineers, are expected to keep abreast of engineering problems as they are faced in your organizations today as well as those which may be facing you in the future. As we participate with you in these meetings and hear the discussions of your problems we enhance our abilities as teachers to bring live and up-to-date information to our students and to give them an insight into the challenges that lie ahead of them in the profession. As you leave this Conference, we hope you will take with you new information, ideas, and friendships. We hope at the same time that you will leave with a feeling of satisfaction in having contributed to the enrichment of our teaching program by helping us to be better informed teachers.

Again, welcome to our campus. We hope that in the next two and one-half days you will feel our welcome as well as hear it and that you will find your experiences and associations in the Conference both rewarding and enjoyable.

Opening Remarks

John D. Lawlor
Executive Vice President
National Safety Council

May I start by saying we're proud as punch to see such a good turn out and welcome on behalf of the National Safety Council, a co-sponsor of the conference.

I realize there are in the audience people who are quite knowledgeable in the area. I'm reminded of the football coach, I'd better call him Woody Hayes in this town, who was disgusted after the first hour's practice of the first day. He called the squad together and said, "Now we're going back to fundamentals." Holding up the pigskin he said, "Gentlemen, this is a football." One big hulking lineman standing in the rear didn't hesitate a minute. He shouted, "Hey coach, not so fast."

More than 70,000 people lost their lives at rail-highway grade crossings in the last 50 years. In the last decade more than 15,000 have been killed. But the bald fact remains this type of traffic accident accounts for less than 3 per cent of the total traffic fatalities in the nation.

Why all the concern for what is a minor part of the problem?

One answer of course is that the type of accident is so darn needless, or to use the jargon of the trade, so preventable.

Another answer is in the pay off—the cost benefit exercise that we all go thru these days.

A 1969 study estimated that one dollar spent on certain grade crossings would produce net benefits to the public by tenfold and at the same time would facilitate the movement of freight and people over our surface transportation net work. Last year, DOT's estimate was that if 15,000 crossings were provided with improved protection, accident costs would be reduced by nearly 3 times the installation and maintenance cost of the equipment.

So its pretty clear we know the answers—we don't really have to doubt that the corrective measures if applied will be beneficial. Certainly, we are not so certain of our solutions to many of the central issues that face the nation today and on which we spend large sums of money.

Who's to Blame? Originally the railroads were charged with total responsibility for grade crossing safety. Just before the turn of the century however, the Supreme Court held that the obligations of the railroad and those of the driver and the pedestrian were mutual. In 1935 Justice Brandeis indicated, "It is the railroad which now requires protection from the dangers incident to motor transportation." In studies conducted on the problem in the past, it has been determined that the driver was at fault in the majority of rail highway grade crossing accidents. This lends further emphasis to the now generally accepted view that the public ought to bear prime responsibility for rail highway grade crossing protection. It would certainly be in the public interest if all crossings were adequately protected.

The National Council has given attention to this problem for the past 57 years. In 1915 a committee was formed in the Industrial Department to attack the problem.

In the ensuing years much was accomplished in education, engineering, and enforcement. In 1916 the committee recommended the development and use of a uniform protection device. The development of a traffic code was consummated in 1924. In 1947 the now widely known "Signs of Life" program was begun.

In 1960 in order to further emphasize the importance of the activities of the committee of the Industrial Conference, an additional committee on MV Traffic Safety at railroad grade crossings was created in the Traffic Conference. This new committee has continued to expand its activities through the issuance of press kits, TV spots, and in the cooperation of the production of educational films.

We have also been active in the enforcement area in recent years thru the "Near Miss" program, a simple means whereby violations noted by the train engineers are passed on to responsible authorities.

As in most safety problems however, it is the engineering solution that seems to be the surest—certainly it can't talk back and can't get drunk. Unfortunately, this solution is also quite expensive—it is time consuming and often frustrating since it involves the engendering of public support if we are to assume this to be a public responsibility.

The problem is that a train can't stop on a dime and we can't stop railroad grade crossing accidents on a dime.

As for the future—as the suburbs grow, unless we repeal the laws of population growth, we are going to have more and more strip cities—more commuters—longer and faster trains.

Unless we repeal the laws of physics, the trains will be harder to stop quickly.

So let us disabuse ourselves of any thought that this is not a forward looking 21st century project. It is.

May I say again how pleased the National Safety Council is to be able to participate in the proceedings over the next three days.

We are confident that the discussions will benefit the conferee, the speakers, and above all, the nation as a whole.

Welcoming Remarks

W. N. Carey, Jr.,
Executive Director
Highway Research Board

It is my pleasure this morning to welcome you to this Conference on behalf of the Highway Research Board. The subject of safety at the grade crossing interface between highway and rail traffic is not a newcomer to HRB. I find, for example, that the published Proceedings of our 1927 Annual Meeting contained a paper in which the author tried to assess the true extent of the accident picture at rural grade crossings; was it really 4% of the fatalities as some claimed, or more nearly the 16% which his study of sparse records indicated? Today's accident statistics allow us to make much better appraisals of the relative extent of the problem, but unfortunately continue to fall short in directing us to the most cost-effective solutions for this facet of the accident picture which still claims some 1500 lives each year.

Through the efforts of its Committee on Highway-Railroad Grade Crossings and its predecessors in Highway Safety, the Board has played a role in all of the three conferences which have preceded this one. As the Board's traditional base of support is broadening into transportation modes in addition to highways and including rail transit, our concern for rail-highway grade crossing safety can be expected to become stronger.

One of our prime purposes is to disseminate research findings to operations authorities, and these National Conferences have served this purpose well. The earlier conferences in Texas, Illinois and Georgia provided attendees many ideas which could be put into immediate practice to reduce the toll at individual crossings, and I am sure that the program for this conference will produce similar benefits to you.

Another primary mission of HRB is the stimulation of research. The format for this conference has been devised by the planning committee to maximize your opportunity to discuss the seven sub-divisions of the problem which they judged to be of major importance. I urge you to actively participate in the afternoon discussion sessions today and tomorrow, for by doing so you will enrich the conference with your own professional experiences. By taking part in the discussions, you, the leaders in the field, can focus attention on technical and administrative improvements which are needed by you, as well as to pass on your successful techniques to others. The discussions will be attended carefully as a means of identifying the emphasis which research programs ought to have in order to be most responsive to your most urgent needs.

The sponsorship of this series of conferences has varied from year to year, and I am pleased that the Board shares it again this year with our good friends in the National Safety Council. We owe special thanks to the Department of Transportation for the financial support which has made the conference possible, and which will support publication of a Conference Proceedings as well. Each of the conferences has enjoyed staff support from a major university, and we greatly appreciate the fine cooperation extended by the Ohio State University this year.

I wish also to extend appreciation to Mr. Hoy Richards, Chairman of our Grade Crossing Committee, and to Neill Darmstadter of the American Trucking Association, for their excellent effort in leading the planning committee in developing this program. The work of such volunteers, along with those who serve with them, goes largely unrewarded but I am sure it will be recognized by each of you as the conference proceeds.

Lastly, by your continuing support, attendance and participation, you tell us that we are doing something which needs doing very badly, that is, to contribute to the relief of human suffering and loss occasioned by tragic accidents at grade crossings. Your deliberations here this week will surely be helpful in delineating future courses which can be followed by all of us interested in further reducing the toll, and we thank you for coming.

Keynote

Honorable John A. Volpe
Secretary
U.S. Department of Transportation

Introduction

R. R. Bartelsmeyer
Acting Administrator
Federal Highway Administration

I am delighted to be here today and to have the opportunity to participate in this most worthwhile conference.

For safety is a paramount consideration with the Federal Highway Administration—and the Department of Transportation. There is, simply put, no higher priority. And a major safety problem which must be resolved is that of railroad-highway grade crossings. I am sure that the deliberations at this conference will contribute much toward attaining this goal.

I am particularly pleased to have been asked to introduce the keynote speaker, for he is a man who shares completely your keen concern with eliminating the hazard posed by railroad-highway grade crossings. And as a man of action, I know he will not be satisfied until the problem is solved—and as speedily as is humanly possible.

As a former Commissioner of Public Works and three-term Governor of the Commonwealth of Massachusetts, he is the man who knows first-hand problems such as these, as encountered on the State and local levels. As the first Federal Highway Administrator some 16 years ago, he is well versed in the Federal-aid highway program, and is a staunch supporter of the longstanding Federal-State partnership in highway matters.

As secretary of Transportation, he has brought vitality and cohesiveness to the Department of Transportation, of which the Federal Highway Administration is proud to be one of the seven operating agencies. He has provided firm and farseeing leadership, and his purpose unwaveringly has been to provide all Americans with the most efficient and safest transportation systems the world has ever known. And in striving energetically toward that lofty goal, he has compiled a tremendously effective record.

Ladies and gentlemen, it is my great pleasure and privilege to present to you a man who is determined to make travel safer in all modes of transportation and who works tirelessly toward that objective—the United States Secretary of Transportation, John A. Volpe.

Keynote Address

Honorable John A. Volpe

The facts of the railroad-highway grade crossing challenge are stark and dramatic. There are more than 220,000 public grade crossings in the United States today. That's where some 12,000 motor vehicle-train collisions occur annually. These collisions—averaging about 32 a day—result in some 1,500 deaths and 7,000 injuries. This must stop.

I am sure all of us have the same reaction when we hear of an accident between a motor vehicle and a railroad train, "Why, in this period of such advanced technology must such primitive kinds of accidents occur?" Like you, I have asked myself that question many times, and, frankly, gentlemen, I am not satisfied with the answers I get. There is no excuse for these kind of accidents. They must not be allowed to continue. And they will not continue.

The technological answers to the grade crossing problem may not seem complex, but technology is only part of the answer. The obvious solution is universal grade separation, but the cost for this would be about $100 billion—or about four times the net total investment of all our railroads combined. So the sheer size of the problem is our first obstacle.

Another complexity is the number of people and organizations involved. The railroads, the highway system and the millions of drivers are all independent of each other. Moreover, among the public agencies involved there are various degrees of authority and responsibility. No one person or group has complete responsibility.

Another important fact is the very large number of crossings which carry low volumes of both vehicular traffic and railroad movements. More than 70,000 of these—almost one third of the total—have two or less train movements per day and vehicular traffic of 500 or less per day. Very few of these lightly used crossings have sufficient accident potential to economically justify the cost of train-activated crossing protection. In only the most unusual circumstances would they warrant the expenditure required for grade separation.

So obviously, there is more than one facet to this problem.

In 1970, the Congress directed our Department to prepare a comprehensive report on the grade crossing problem. The first part of this report was sent to the Congress last year. I am happy to report the second part was submitted a little more than a week ago.

The two-part report is the culmination of an intensive two-year study carried out jointly by the staffs of the Federal Highway and the Federal Railroad Administrations, with assistance from the National Highway Traffic Safety Administration, the American Association of State Highway Officials, the Association of American Railroads, and the American Short Line Railroad Association, and all of the State Highway Departments. All parties are to be congratulated for a fine job.

The new Part Two which we just sent to the Congress calls for a substantial increase—during the next 10 years—in grade crossing protection. At the same time it recommends continuance of the existing program of eliminating potential crossings by building grade separations and relocating and consolidating railroads and highways.

We began our study with an economic analysis of the benefits to be secured by improvements such as flashing lights, automatic gates and the total benefits from grade separating structures. It was soon apparent that improved protection at many crossings will give a greater pay-off than grade separation at a lesser number.

The program we are recommending, consequently, calls for protection at 30,000 grade crossings at a cost of about $750 million. We envision that this program would run for 10 years upgrading some 3,000 crossings a year at an annual cost of $75 million.

This would be about three times the current rate of installation. The completion of this program would eliminate nearly 4,000 motor vehicle-train collisions annually and would result in saving 500 lives a year. We believe this is a most worthwhile program.

I want to point out that about half the motor vehicle-train collisions now occur at crossings off the Federal highway system—crossings that are not eligible for Federal funds. That's why we recommend that Federal assistance be expanded to improve safety at all locations.

We believe our report provides the Congress with sufficient information, and we are optimistic that the members will approve our program and give us the go ahead.

This report to Congress is, of course, but one element in our grade crossing program. We are regularly spending about $100 million a year separating highway and railroad traffic on new construction on the Interstate System. This is an on-going part of the interstate building program.

This past year, however, we launched a new attack. We secured a special release of Federal Aid Highway

Funds for the purpose of financing grade crossing safety projects on highways other than those on the Interstate System. I then wrote to each Governor telling him about the new funds and asking his cooperation, and the response was extremely gratifying. Our original plan was to set aside $100 million. I am very happy to announce that we passed that goal and obligated a total of $112 for grade crossing safety projects in the Fiscal Year ending June 30 of this year.

This special project comes on top of two on-going grade crossing demonstration projects. These programs are designed to show the states and municipalities what can be done.

The first project aims for elimination of all public grade crossings along the route of the high speed rail line between Washington, D.C. and Boston, Massachusetts. We are adapting to railroads the design concept of no intersections that is part of our Interstate Freeways System. We shall eliminate 50 public road crossings, and the end result will be the Nation's first rail freeway.

In Greenwood, South Carolina, we are showing how railroads can be integrated into an urban environment to the advantages of all parties. This project, involving two railroads, will relocate and consolidate several miles of track. At the same time, several grade crossings will be protected and others will be eliminated. In all, eight miles of track will be eliminated. The net results will be, (1) An improvement in the appearance and cohesiveness of the downtown area; (2) Increased highway safety and mobility and; (3) Improved railroad operations.

We are also carefully examining every phase of the grade crossing safety effort to determine where new technology can be helpful and we are conducting a vigorous research and development program to improve that technology. We have introduced several technological innovations into train-activated crossing protection devices. We are also seeking ways to improve the passive warning devices—both signs and pavement markings—and we are working on methods for making trains more visible.

We have zeroed in on the driver, too, to learn what human factors are involved in improving grade crossing safety.

One of our major studies is a complete inventory of all grade crossings in the country. We are convinced that this is the only feasible way for a sound understanding of all the problems. This inventory moreover, will also help us direct available resources to suitable improvement techniques.

All these approaches, however, will not solve the problem unless we can add one more very important ingredient. And we are counting on this Conference to help us supply this catalyst.

I spoke earlier of the many organizations, the many individuals, and the many authorities that are involved in and have responsibility for improving grade crossing safety. To move forward on this problem, it is vitally necessary that all parties concerned are aware of the seriousness of the problem and are willing to volunteer resources to help meet it. We shall avail ourselves nothing if our only contribution is to assign blame or fix responsibility. And so I ask all of you here to work with us at this Conference and then, on your return home, spread the word to your organizations.

Now I am optimistic we shall get a strong Federal program underway. When President Nixon first gave me my marching orders, he told me to put safety at the top of my list. He was not satisfied that safety was receiving enough attention. Because of the President's insistence I set up the new National Highway Traffic Safety Administration and made it part of my own staff.

In addition, we are getting tremendous cooperation from our Bureau of Motor Carrier Safety. They recognize full well that rail crossings are not exclusively a rail problem and they make sure that the Nation's professional truck and bus drivers treat grade crossings with the highest respect and regard.

And at the policy level, we now have an Assistant Secretary for Safety and Consumer Affairs—who has an overview of the entire transportation safety spectrum. So as you can see, the Department of Transportation is most definitely in a position to play a meaningful role in meeting this challenge. I do not expect the President's interest to slacken and I am convinced he will make a strong case for our new grade crossing program with the next Congress and I am convinced President Nixon will be successful. Then we shall need your help. By ourselves, we in Washington cannot be fully effective. But working together with you—with local authorities and local organizations—we can win and win big. I remind you, gentlemen, the purpose of our efforts is to save lives. Can there be anything more important?

Urban Railroad Problems
A Panel

William E. Loftus, *Moderator*
Chief
Policy Division
Federal Railroad Administration

Many communities are becoming increasingly concerned with the presence of multiple railroad lines within their boundaries. Some 30 urban areas have undertaken special planning studies to develop practical solutions to their particular type of problem. At the Federal level, the Federal Railroad Administration and the Federal Highway Administration have jointly retained a consultant to undertake a study of the national magnitude of this problem and the costs and benefits to be obtained from various solutions.

This morning, we have a three-member panel consisting of a representative of this consulting firm and representatives from two cities which are moving to solve their particular problem. We will then have comments on this subject by the Federal Railroad Administrator.

Urban Railroad Relocation: Benefits and Problems

Albert E. Moon
Senior Transportation Systems Analyst
Stanford Research Institute

In recent years, a number of communities have proposed changes in their rail service that primarily require consolidation of rail traffic from two or more rail lines into a single corridor. It is our feeling that similar changes and proposals for other types of railroad relocation or redevelopment will be numerous in the next few years because of such factors as: (1) increased delays at urban railroad-highway intersections resulting from more roads, increased motor vehicle traffic, and longer freight trains then existed previously; (2) search by city governments for reduction of barriers to traffic and urban redevelopment, and (3) increasing availability of surplus railroad property that stems from surpluses of rail facilities, prospective consolidation of underutilized lines and yards, and line abandonments.

Relocation of active rail facilities is a complex problem because many parties in the community are affected and the cost may be substantial. Despite the complexities, the benefits from successful relocation can also be substantial. To take into account the needs of those affected and to achieve these benefits at reasonable cost while avoiding undesirable side effects, planning is needed. And for the planning a planning framework must be developed. Even with the best planning there are problems and obstacles that must be overcome to implement the plans.

The Department of Transportation has recently initiated a study of Urban Railroad Relocation to determine the magnitude of the opportunity for beneficially relocating rail lines in urban areas and to develop methods for planning and implementing rail relocation projects. To accomplish these objectives, the Department selected a team of consultants led by Stanford Research Institute to conduct a year-long analysis. The study has been in process for about six weeks.

This paper will describe the benefits of urban rail relocation that have been identified, discuss planning requirements, and identify some of the problems that have been encountered in rail relocation proposals.

The material presented here results largely from an analysis of proposals for relocating rail facilities in over 30 North American cities.

Benefits

The benefits that proponents of rail relocation projects hope to achieve for their communities include:

- Reduction of railroad-highway interference.
- Availability of land for public, commercial or industrial use.
- Removal of barriers to expand or redevelop central city areas.

While achieving these benefits for the community, the relocation proposals would also achieve reductions in railroad operating and maintenance costs.

Restructuring the rail facilities has been considered as an alternative to building grade separations for reducing both delay to highway vehicles and the number of accidents. Restructuring appears to be especially applicable where the railroad traverses a number of principal streets and the cost of building multiple grade crossings exceeds the cost of trackwork needed for relocation, or where parallel tracks are spaced so that long spans or undesirable geometrics are needed for separation, resulting in expensive structures.

The benefits derived from reducting interference with highway traffic are substantial. Because railroad crossings are rough and represent a potential hazard, many motorists slow down at grade crossings, even when there is no train or train warning. The cost of slowing and accelerating the vehicle and of the motorist's time consumed in this delay is estimated at $4,250 per year per 1,000 daily vehicular crossings. This is a cost of having the tracks across the road with no trains on them. On the basis of data collected by the Federal Highway Administration, the annual cost to highway users at all urban grade crossings, including the delays caused by the trains and the costs of accidents and of slowing down, is about $1.5 billion. Of this amount, almost $1.4 billion results from crossings traversed by more than 1,000 vehicles per day.

Less readily quantifiable, but still very important, is the conversion to other uses of the land now being occupied by the tracks. Because of the need to change elevation of the railroad or highway, grade separations occupy land, and sometimes this land must be taken from residential, commercial, or industrial use. On the other hand, relocation of the railroads may make land available for other than railroad uses, sometimes in substantial or dramatic amounts. Where railroads can be completely abandoned, the land has been used for streets, parks, public buildings, or development for residential, commercial, or industrial uses.

Some communities seek to remove the railroads because they act as barriers to expansion of the central business district or other specialized areas. Such areas require automobile access over a number of streets and pedestrian access at every block. The railroad acts as a barrier to such access. The provision of grade separations and intermediate street closures tends to reinforce the barrier. The separation also concentrates traffic on the remaining streets, creating high volume arterials that may be another barrier.

The railroads may benefit more from relocation than from isolated grade separations. Where there are still highway crossings at grade, the railroads must slow their operations to safe limits and observe signalling procedures; thus, until all the crossings are removed, the noise and slow train operations will remain. The cost of slowing and accelerating the trains is estimated at $70 million per year in urban areas. In addition, elimination of a grade crossing will result in elimination of maintenance costs for active signalling devices at crossings, a cost estimated at $43 million annually for all crossings.

Need for Overall Planning

Since the costs and impacts of relocation may significantly affect the community, the highway users, and the railroads, it is clear that careful planning and imaginative study of alternatives are needed to produce plans that will capture the benefits that are potentially available. The kind of planning that is needed falls in a gap between existing urban planning and highway planning programs and at the same time overlaps them. The planning is complicated by the requirements of railroad alignment that restrict grades and curvature.

These technical complications have resulted in the concentration of many studies on engineering problems, and a large portion of the project funds has been expended in defining a few technically acceptable alternatives. This situation restricts the number of alternatives examined because of the expense of defining each one in detail. It probably also contributes to the uneven consideration of urban planning and highway, social, environmental, and economic factors in analyses that we have reviewed. This uneveness extends to the presentation of results—in a few of the reports neither the problem nor the recommended solution was clearly stated. Thus, an overall planning methodology that will standardize the scope of consideration and the details available to urban planners and highway planners is needed.

An apparent gap in the planning process appears to be the failure of planners to take advantage of urban rail relocation as a joint development with highway construction. At the present time there is increasing federal, state, and local emphasis on joint development along highway rights-of-way, and such joint development would offer a significant opportunity for relocating rail lines. However, cooperative freeway and railroad planning does not appear to have been widely undertaken to date.

Problems of Railroad Relocation

Rail relocation has a number of inherent problems, and planning alone will not obviate all these problems. From the community viewpoint, moving a rail line to another area means that some of its undesirable features are moved with it—especially the noise and the visual intrusion. Because of these community effects, the requirements for approval of rail relocation projects may be similar to those for new highway construction, and the planning will have to consider these effects.

Another community problem is that, along with railroad relocation, there could also be displacement of businesses and consequent loss of jobs in the central areas. At a time when efforts are being made to keep jobs for central city residents, forcing an industry out of the area by disrupting its rail service would not be likely. Thus, efforts are being made to keep rail connections to industries until they can be relocated.

The problems of the railroads also need to be considered in relocation planning. In many of the proposals for consolidation, consolidation of tracks into a single right-of-way or consolidation of operations over a single set of tracks is required. The railroads must conclude legal agreements to implement such plans, and these legal agreements must result from negotiations among the railroads. If one of the railroads is put to a disadvantage in the negotiations—or position likely to be occupied by the railroad whose operations are being relocated—these negotiations are difficult. The displaced railroad is also likely to suffer a disadvantage in joint operations, where control of its train movements is governed by some other railroad.

The railroads also have to negotiate with the community. In many cases the amount of the financial obligation that the railroad must bear is not defined. Railroad earnings are such that capital expenditures are difficult to justify for projects that do not result in increased income or reduced costs. At the same time, increased distances over relocated lines may partially offset economies gained from the consolidation in the form of reduced maintenance and higher operating speeds.

Another problem facing the railroads is maintaining their market share in the face of competition from other railroads. Proposals that upset this balance are likely to be difficult to implement.

Financing

Perhaps the most important community problem is that of financing. Although the community may benefit from railroad relocation by a factor of many times the cost, some means must be found to provide the funds that will generate the future stream of benefits. In several communities, grade separations have been selected rather than relocation, even though relocation appeared to offer more benefits and be less costly, because federal and state highway funds were available for the grade separations. Such a situation is clearly undesirable.

Local agencies with relocation projects have had to finance them using highway and urban planning funds from existing programs. Federal financing would provide a convenient source of the funds, both for studies and implementation of railroad relocation projects, but relocation would obviously have to compete with many other programs for funds and, at the present time, the total amount needed by such a program is not known. However, the costs to motor vehicle users and the railroads caused by urban grade crossings may provide an indication of the order of magnitude. Complete elimination of all urban grade crossings would result in user cost savings of approximately $1.5 billion per year, thus an investment of $15 billion would be justified (using a 10-percent discount rate) if all these costs could be eliminated. Clearly, complete elimination would not be warranted or even desirable; consequently, this figure should be considered as something beyond the upper limit of justified expenditures. Additional investment would be justified by other benefits, such as the increase in the value of redeveloped land.

The financing program should be based on the type of benefits and the identification of those who will benefit from relocation programs. The study now under way is designed to produce better estimates of the total costs, the total benefits, and the distribution of the benefits.

The Urban Railroad Relocation Study

In the Urban Railroad Relocation Study, SRI plans to use its extensive experience in highway planning and evaluation to develop the planning methodology, with assistance from noted engineering, and railroad-operating companies and urban planners. The planning methodology will describe planning procedures, identify benefits or estimate their magnitude, and describe appropriate benefit/cost methodology for analysis of alternatives.

In determining the national potential for relocation, all urban places will be classified according to such characteristics as size, railroad service, geographical region, and others yet to be determined. Costs and benefits related to the classifications will be extended over the number of locations in each class to determine the national totals. Field work in local communities with rail relocation proposals is planned to help the project team develop methods that are practical and relevant to the problems. Extensive questionnaires are planned to supplement the field work.

The results of the study should provide the Administration, the Congress, and local planners with needed information on which to make a decision regarding rail relocation plans and programs.

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Status of Urban Railroad Problem in Lincoln, Nebraska

Marvin Nuernberger
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Lincoln-Lancaster Railroad Transportation Safety District

Transportation corridors are the means of relocating an area from the middle of nowhere to the middle of everywhere, and accordingly, they have always been and always will be the lifelines of community growth and prosperity, regardless of the political controversy that their planning and funding may sometimes provoke.

Last summer I traveled extensively in Jordan, a land of antiquities, and it was a significant and sobering experience to wander into a restored amphitheater amongst the ruins of an ancient city and sit down by myself and have centuries whirl back to a point in time when the city was alive and thriving and recognize that what gave it life and prosperity was its location astride a major caravan route of that time.

Jordan, for centuries and centuries, was coveted by every empire of ancient history because as a land bridge connecting Asia and Africa, it was the middle link of an important transportation corridor, but eventually, when trade routes shifted and communities returned to the middle of nowhere, growth and prosperity vanished and decadence and ruin followed.

Nebraska, my home state, is also a land bridge, and the community growth and prosperity of which I as a resident of Lincoln am living a part of today, is a product of railroad locations which were the first important transportation corridors into the community.

When Nebraska was admitted to the Union in 1867 as the 37th state, the Oregon Trail, the Mormon Trail and the Denver Trail were active transportation corridors across the state, but none of them passed through the designated capital city, a community of 500, in the middle of nowhere, which had its hopes for growth and prosperity riding on a new mode of transportation, the railroad, when and if it came to town.

In 1868 hopes were reinforced with hard cash when Lincoln voters approved a $100,000 bond issue to fund a bonus payment to any and all railroads that would bring service into the community.

It was one year later when the Atlantic and Pacific coasts were united by two bands of steel, a transcontinental railroad, and in 1870 the Burlington and Missouri Railroad reached Lincoln and claimed the first $50,000 bonus, and provided the community with a vital artery to the rest of the world and with a heartbeat that grew stronger and stronger as other railroads brought service to the community. By 1892 nine railroads were running through the city in most every conceivable direction and Lincoln was growing and prospering because she was an integral part of the greatest nation on earth, the United States of America.

In those first 25 years, 1867 to 1892, Lincoln's population increased more than 1,000 times because the transportation corridors were working and they were being used 24 hours a day, and were being supplemented by walking horse and horse drawn vehicles and there was very little, if any, conflict. But things were continuously changing and as time passed the tempo of change increased, as it always has and always will.

In the next 40 years, 1892 to 1932, Lincoln's population appeared to level off at something less than double of what it was when the last of the railroad transportation corridors was established through the community. But changes were complicating the serviceability and the desirability of the railroad transportation corridors within the city because the diesel locomotive and the automobile had increased community mobility and there were more homes, more businesses, more public buildings, and more churches and there were more plans for the future based on hopes and agitation.

The University had hopes for the relocation of a railroad so that the eastern edge of the campus could become a system of radiating boulevards and there was agitation within the community to relocate the railroads, to force the use of a union station, but the question was "Who Pays?" and the only agreement was that postponing the relocations would bring additional complications and added costs, but there was also a depression and then there was World War II and the railroads remained in their original locations.

The Bureau of Public Roads introduced comprehensive planning to Lincoln in 1950 and Lincoln complied and remained eligible for federal funding and the relocation of the Rock Island Railroad was a high priority goal in the first comprehensive plan and there was a committee report with an estimated cost of $8,886,000 which scared the hell out of the planners and railroads relocations became a passive issue in updated comprehensive plans but other community planning proceeded although the feasibility of much of it was dependent on the relocation of the railroads.

The National System of Interstate and Defense Highways, the most massive system of transportation corridors ever envisioned by man, was created by an act of Congress in 1956, and Interstate 80 passed through Nebraska and Lincoln was connected to it by a spur route providing further stimulus for community growth and prosperity which was verified by a 40 per cent increase in population between 1956 and 1966.

By 1960 it was apparent that the railroads had lost to the automobile and the airplane as passenger carriers in bridge states like Nebraska. But innovations in freight service, such as piggyback, were introduced which provided a competitive position for the railroads in long distance freight hauling assuring that freight trains would roll on and on into the future and continue to contribute to the growth and prosperity of Lincoln. But with 5 Class 1 railroads and a local switching railroad running on independent trackage within the city the grade crossing protection problem was increasing and increasing and there were mounting involvements in the planning of highways, arterials, flood protection, campus expansion, subdivisions, and ad infinitum.

In 1966 the Chamber of Commerce laid a foundation for action by reinforcing hope and expectation with hard cash when it sponsored a $100,000 study by a qualified consultant with financial participation by all of the railroads, and numerous governmental agencies, to analyze the problems inherent in leaving yesterday's railroad locations in tomorrow's urban areas and to propose logical solutions.

The Lincoln-Lancaster railroad transportation study, a nationally recognized study, was completed in September of 1970, by Sverdrup and Parcel, and the 1971 session of the Unicameral provided enabling legislation which permitted the creation of railroad transportation safety districts in Nebraska counties with a city of the primary class with authority to enter into contracts with persons, railroads and other corporations, and any and all agencies of federal, state and local governments and to issue general obligation bonds during the first 10 years of its scheduled 15 years of existence which may only be extended for the purpose of payment of debts, obligations and bonds.

Lancaster county, and the city of Lincoln, immediately passed the necessary resolutions of formation and the board of directors restricted by law to a maximum county levy of ¾ mil, prepared a fiscal 1972 budget of $230,000, or ½ mil.

Currently the district is finalizing negotiations with the Union Pacific and Burlington Northern railroads for the operation of a joint-use line which will provide inproved flood protection for the municipal airport, the state fairgrounds, a city park, and a growing residential area of the community, but because of apparent current Federal Highway Administration regulations, the district is negotiating for the relocation of the Union Pacific through the area of two ultimate federal aid projects in lieu of extending the joint-use line operation and this could be a proper subject for detailed discussion this afternoon.

The district has successfully sponsored legislation providing for $30,000 of highway user's revenue to be credited monthly to the grade crossing protection fund for crossing signalization with the fund paying 65 per cent of the cost and the Railroad Transportation Safety district 25 per cent and the involved railroad 10 per cent and an amendment is being drafted for a lump sum payment from the fund to a specified political entity when roads or streets are closed or an operating railroad is relocated which eliminates a railroad grade crossing on the non-federal aid system, and we might discuss the feasibility of lump sum payment by FHWA for the elimination of grade crossings on the federal aid system where operating railroads are relocated.

Upon finalization of benefits and costs and execution of the referenced current contracts, the district will initiate negotiations with the Rock Island for a major railroad relocation which will also involve the Burlington Northern and Union Pacific and numerous public and private agencies.

The federal study, awarded to the Stanford Research Institute, is a basis for hope for a long over due solution to urban railroad relocation problems but hopes don't go far until they are reinforced with hard cash and so we would direct your attention to an amendment to the 1972 Federal Aid Highway Act introduced by Nebraska's Senators, which directs the Secretary of Transportation to select a pilot city to test the methodology developed in the referenced study and we would ask your support of the amendment.

Before I close I would like for you to wander into a restored palatial home of the past which is Lincoln's oldest building and has been designated as a historical landmark by the Nebraska legislature. It was built by the Chairman of Nebraska's first capitol commission, to instill confidence in the future, of the community.

As you stand on the porch, let time whirl back, not through centuries, only decades, to a time when this house was nearing completion, from the middle of nowhere to the middle of everywhere, by railroad transportation corridors in use, under construction, and planned.

Now recognize the changes that lie ahead and establish the fact that this house, and the railroad locations, will be sealed in a glass case so to speak because they will be the only things that will not change.

It should be a significant and sobering experience to observe that as the tempo of change increases and competing modes establish additional corridors within the community that efficient transportation operations become increasingly impeded and that orderly community planning and growth are strangled in the areas of transportation conflicts.

Certainly if this community is to have future, continuing, orderly growth and prosperity and if the various transportation corridors are to have efficient operations, there must be integration of the community's future, major transportation corridors, rail, highway and air, and it must be in the best interest of all concerned and it must be accomplished now, because the tempo of change will not permit further procrastination.

Railroad Relocation

Dan W. Bannister
Chairman
Capital City Railroad Relocation Authority
Springfield, Illinois

Ladies and Gentlemen: It is a pleasure for me to appear here on behalf of the Capital City Railroad Relocation Authority of Springfield, Illinois, and to describe to you in some brief detail as to how this Authority has progressed so far in its railroad relocation plans and how it intends to accomplish its purposes.

Springfield was founded in 1817 by some hunters and trappers from North Carolina who built a village beside a stream. They were attracted by the woods which abounded in wild game. In 1835 at a public auction of town lots a young man named A. Lincoln who resided in New Salem bought a couple of lots. Two years later when the question of moving the State Capitol north from Vandalia came before the legislation, Lincoln took leadership in the selection of Springfield. After the State Capitol had been moved to Springfield, Lincoln decided that he should also move there and he did in the same year.

At that time the only mode of transportation to Springfield was by ox team, horse or mule drawn wagons or horseback or foot. There was no waterway that was navigable. Immediately the towns people saw the need for a railroad to Alton, Illinois, where the produce of the Central Illinois Area could be loaded on ships on the navigable waters of the Mississippi. The legislature assisted in financing the railroad and a railroad was commenced about 1845, and by 1850 was in operation. In 1850 the City of Springfield granted an easement through what is now the center of Springfield along Third Street to the Alton & Sangamon Railroad. This easement right-of-way is now used by the Gulf, Mobile & Ohio Railroad and has the effect of a physical barrier between two halves of our City, aggrevated by the presence of our Capitol Complex on one side and our downtown area immediately on the other.

Five railroads now serve Springfield, including the main lines of three class one railroads. Twenty-five major trucking firms provide interstate service and sixteen provide intrastate service. Interstate Route #55 between St. Louis and Chicago and two major east-west highways, U.S. 54 and 36, pass through Springfield.

Although Sangamon County is urban in character, Springfield's surrounding trade areas are oriented toward agriculture. This is one of the world's richest agricultural areas, with principal products being corn, soy beans and livestock. Springfield lies approximately 7 miles from the Sangamon River and 45 miles from the commercially navigable Illinois River. Springfield has an urban area with a population of approximately 116,000 and a forecast 1985 population of 156,-000 urban area and 195,000 in the county. The problems of the railroads crossing downtown Springfield were first recognized by Myron West in developing the West Plan for Springfield in 1928. The West Plan indicated that the railroads should be elevated and the cost projected by Mr. West for the elevation of the railroads at that time was about two and one half million.

In 1958 another railroad study was made by the University of Illinois and a plan was projected. This plan laid in the offices of the Springfield Sangamon County Regional Plan Commission for some ten years, as the problem of highway safety blockages of vehicular traffic and the commercial blight that the railroads cast on downtown Springfield became more tense. Finally in 1966, the Mayor and the City Council appointed a Springfield Railroad Commission of some 24 business, industry, and labor leaders in the community to see if something could be done.

The Commission met in the fall of 1966 and in the spring of 1967, and from these meetings evolved a draft of a Capital City Railroad Relocation Authority Act which was introduced in the Illinois General Assembly in April 1967. After some amendments, the Act was passed by the Assembly and the Governor signed it into law in the fall of 1967. During the next several months the appointments to the newly created Authority were made and its initial meeting was held in January 1968.

There are three principal aspects of this Act which I should mention. First, it creates a ten-man Authority of which six are appointed by the Governor, with three being designated by the three major railroads; three by the City of Springfield; and one by the County of Sangamon. Secondly, the Act gives the Authority the power of eminent domain and bonding power. Third, the Act does not give the Authority any taxing power, therefore the Authority has necessarily been financed by appropriations from the State of Illinois, City of Spring, the County of Sangamon, and some substantial donations from private business and private industry from the City of Springfield.

We have prepared an amendment to the Railroad Relocation Authority Act which would do three things—shorten its name, make the physical boundaries of the Authority slightly larger, and give it taxing power. This amendment has been offered in the Illinois legislature but no action has been taken on it.

The basic philosophy of our Railroad Authority has been from the beginning to cooperate with the railroads. Without this our difficult project would be impossible. We wish to develop a plan that they would find economically desirable and could endorse with as much enthusiasm as the rest of community. One of our problems has been to try to retain this philosophy throughout all of the stages when local governments have disagreements with railroads, particularly relating to grade crossing maintenance and supervision. Our Authority has taken no position in these, preferring to concentrate on the big picture. Railroads have seen these plans proposed before in our community and would have been justified to assume our initial efforts were an academic exercise, but with the aid of the excellent railroad men who were designated by the three major railroads to sit on our Authority, we now have a plan with which each railroad has indicated general agreement.

One of the problems for our Authority involves the difference between "railroad relocation" as opposed to "grade separation."

It seems inconsistent that there are funds available for grade separations, but none for rail relocation when in fact in our community by placing all the railroads into one corridor we can eliminate 101 grade crossings with the construction of eleven additional grade separations. I know it can easily be proved that the cost of our Plan would be significantly less then the cost of grade separating all the existing protected crossings in our town.

It has been pleasant being here with you this morning and perhaps we can look a little deeper into our program in the session scheduled for this afternoon. Thank you very much.

The FRA Rule In Urban Rail Planning

John W. Ingram
Administrator
Federal Railroad Administration

Good morning, it is indeed a pleasure to be here and particularly to be involved as one of the sponsors of this Conference. I want to thank you for attending and I know that all of us will benefit from our participation in the workshop sessions where an informal atmosphere will prevail.

As the panel members have clearly shown, and as we have illustrated in Chapter 5 of our Report to Congress, the urban railroad problem is a complex one. Approximately one-third of the Nation's public grade crossings are located on urban highway mileage and about 50 percent of the Nation's traffic moves on these urban roads and streets. Most urban areas have large numbers of closely spaced grade crossings, and there are generally a greater number of rail movements as well as commercial and private motor vehicle activity over these crossings. In addition to through trains, rail movements include local industry service, switching operations at yards and terminals, and interchange movements between railroads.

Fortunately, as the various levels of Government, particularly the Federal level, direct attention to the plight of our urban communities, more attention is also focused on the rail industry's relationship to community development. This greater emphasis on rail facilities occurs not only because of motor vehicle delays at grade crossings but also because of a less than altruistic realization that railroad's rights-of-way are of great developmental value to the community. Relocation proposals are now originating from a community's desire to provide a unified and balanced transportation system, consistent with the goals of President Nixon's Administration.

It is interesting to note that the entire subject of "rail relocation" began with public insistence upon either improvement or removal of rail-highway crossings. For example, in Greenwood, South Carolina, where the Department of Transportation is conducting a rail relocation demonstration, the city is currently divided into four parts by four separate rail lines. The city's highway traffic was restricted in its movement from one side of town to the other. Schools, hospitals, fire stations, and other essential city services are on what could be called a "rail island." These factors spurred the city to seek outside help. And what started out as a grade crossing problem, found its solution in a community redevelopment plan—the urban railroad problem is, in many areas, a critical part of the overall urban problem.

Each week we receive letters, and in some cases actual preliminary engineering studies, from both large and small cities across the country seeking Federal assistance to relocate their friendly local railroad. They ask two questions, both involving money: Is there any money available for development of a rail relocation plan? And, is there any money available for implementation of these plans? Unfortunately, my answer has had to be that no direct rail planning funds are available.

We are looking at the urban problem in two ways: First, we are making a nationwide assessment of the degree to which community development plans are hampered by existing rail facilities. This will give us a dollar and cents understanding of the magnitude of the problem.

Secondly, we are trying to assist cities in developing techniques to measure costs and benefits. It is clear that most communities interested in this project need more than a good engineering plan to support bond issues or other special public funding. They need to be able to relate public costs to public benefit before they seek new funding.

In most plans I've seen, the improvement or elimination of grade crossings is a major consideration. This is as it should be. It doesn't make sense for a city to renovate or rebuild an area without giving attention to a nearby grade crossing which may inhibit easy access to the newly developed area.

When the results of our research efforts become available, and I assure you we do not intend to study the problem to death, we will have a better perspective on the priorities to place on any given proposal. What is neglected in many proposals is a consideration which I personally feel should be given close scrutiny—wherever rails are relocated, the layout should be operationally equal to or better than the original. Thus, the consuming public should be able to realize benefits in service and cost, and the efficiency of the railroad should be increased.

I want to leave with the thought that rail crossing safety and urban rail relocation are equally important to the Federal Railroad Administration. Both efforts fit into the FRA objective of improving safety as well as railroad performance.

Train Activated Rail Highway Protection

James Moe
Assistant General Manager
Marquardt Industrial Products

Basically, train activated grade crossing protection involves two areas of concern: Determining when a train movement across the roadway is imminent, and conveying this information to the motorist.

Development of both started as early as 1890 and has progressed with constant development. Today, electronic controls are standard and account for most all crossing protection installed. Flashing lights have become highly efficient as have gates and other warning devices.

Signal equipment is marketed to the railroads by technically trained people and suppliers work closely with the railroads who, in turn, work closely with the states.

The AAR has actively progressed grade crossing protection and acts as a coordinating body, working both with railroads, suppliers and the states.

Here to address us on "Train Activated Protective Devices" is James Moe, Assistant General Manager, Chief Engineer, Marquardt Industrial Products Division of Safetran Systems, Inc. (D. M. Fergusson)

Introduction

Recently an engineer with a background in aerospace techniques was discussing grade crossing protection with me. We were talking about train detection and he made the statement, "Something that creates the general disturbances that a train creates ought to be hard to miss." I guess that is true if you have eyes and ears and are attentive at that moment or if you can rely on automatic equipment that never misses or detects a train when one is not there. However, to do it inexpensively, reliably and without fail has required many more years of attention. When it wasn't accomplished we have seen the statistics on what happens. We still are giving the problem attention.

In providing protection at the grade crossing we must convey the information from the "general disturbance" to the person driving the car, bus or truck. This is the part of the grade crossing protection the motorist sees—the flashes or gate. We also require a means of determining, positively, that the train is coming. This he doesn't see, but must depend on.

History

When grade crossing protection started because a road came along and crossed the tracks, both train detection and information to the road user were vested in one place, a flagman. He saw and heard the train and waved a flag or lantern and warned the road traffic. He was generally pretty reliable. The locomotive engineer aided this by blowing his whistle or ringing his bell when moving slowly—a practice carried on today.

As early as 1870 our flagman was given a gate to manually lower to improve his attention getting!

In 1889 an important distinction was made in that an automatic train detection system was used. This was an electrical switch, operated by the weight of the train, which connected a battery to a bell at the crossing. The bell alone was suitable for pedestrians and horsedrawn vehicles which could be stopped in the distance a person could hear. It is still used as an adjunct to modern visual warnings.

In 1890 a visual signal was added in the form of a "wig wag." This, of course, was a means of duplicating the watchman's waving his lantern. This had evolved by 1920 to the flashing lamps we accept as standard today. The lantern concept was kept without moving parts.

Meanwhile, the detection of the train was improved by incorporation of a track circuit in 1914.

This original and reliable means of detection was to place a battery across the pair of rails where we wanted to detect a train. We insulated the section where we wanted the detection so we knew where the train was. We then connected a relay coil to the other end. If everything was intact and a train wasn't there to short out our track, the relay stayed energized. A train shorting the tracks or anything which disturbed or broke the circuit, resulted in the track relay de-energizing. When the relay de-energized, the warning device started.

Thus, the track circuit was always failsafe and we had a positive means of detecting the train or, if a failure occurred because of broken wires or short circuit, we would activate the warning devices. This same track circuit concept is in use today.

In 1936 automatic gates were added so that our relays which operated lights and bells could better convey train presence information to motorists traveling at higher speeds and greater density. These, again, are designed on the failsafe principle. They are driven up and locked up by electrical energy. They release and drop by gravity.

When we had these warning devices such as gates and flashing lights, it became essential that they operate only when actually required. Consequently several track circuits were used with specially designed interlocking relays and relay logic circuits. Approach warning was given but the protection was deactivated when the train cleared the actual roadway.

This logic required three track circuits—two approaches and an "island" circuit. The approaches had to be long enough so that the highest speed train would provide 20 seconds warning time. This can mean track circuit as long as 3000' or over 6000' for a complete crossing. It also meant additional relays to perform the logic functions.

This brings up another important factor in grade crossing protection—credibility.

If we are to convince the driver that there is a train coming, we must operate the crossing signal only where it is necessary. The three track circuit logic prevents an "overring" after the train has passed.

Other developments carried on subsequently in grade crossing protection have been aimed at providing this credibility. Several track circuits have been used on approaches with timers to determine whether we had a fast or slow train coming. Cutouts have been provided so that train crews could deactivate signals if they stopped and track circuits have been altered by electrical switches operated when a track switch is thrown and the train was diverted from the crossing.

As will be covered later, electronic means are now available to operate the protection devices only when they are specifically necessary.

However, where uniform train speeds and through train moves are normal, this three track circuit system is installed today and provides a simple and reliable control.

Design

Note the dates cited here. Manual gates in 1870, bells, wigwag signals and automatic train detection by 1890, continuous failsafe track circuits by 1914, flashing lamps by 1920 and automatic gates by 1936. This made grade crossing protection probably one of the first in reliable automatic control. Some of the relay logic, now basic with computer-type controls, was in use years before it was common anywhere else. As reliability and failsafe operation were essential, equipment was specially designed to provide this. Railroad signal equipment has carried this principle to the highest level known today.

By the 1950's electronics were developed to a degree where they could be applied to railroad signaling.

This was attractive because it was possible to use an audio frequency overlay or AFO on the tracks to provide a track circuit. As this eliminated the need for insulated joints, always a maintenance problem, and eliminated intervention in the railroad's wayside signal systems, its development was encouraged and the audio type track circuit now accounts for most of the grade crossing train detection now installed.

By 1960 some railroads saw the need for train detection which related to the speed or motion of the train and not only its presence. As a result, track circuit equipment has been designed and is currently in use which starts the flashers or drops the gates when the train approaches the crossing and stops them when the train stops or backs away. Other equipment is available in the form of a small analog computer which is able to predict the time of arrival of the train at the crossing and provide the same warning time for fast or slow trains. This substantially improves credibility.

Applying these electronic concepts while maintaining the reliability and failsafe operation of the battery track circuit has been a large task. Because of this requirement it has been said that 10% of the design efforts is making it work and 90% is making it failsafe and keep working. The railroad environment, both because of natural causes and vandalism, is acknowledged to be one of the most difficult in which to work.

While the train detection portion of the grade crossing was undergoing development, the informational devices were also. The flashing lamp started with an 11 watt bulb as standard. This low wattage was dictated by the requirement for battery standby; the signal has to work even if the power is off. Present day practice is to use an 18 or 25 watt lamp.

With the small wattage available, the lamp has to be efficient. A shallow bowl precision parabolic reflector is normally used. The light distributing roundel must be designed and precision molded to put the available light exactly where it is needed with none wasted. Even with this wattage limitation, the present grade crossing lamp is the equal of traffic lamps requiring 100 watts, 150 watts or more.

Gate mechanisms have undergone changes and updates in design since their introduction. We, of course, must use battery power here requiring special motor and power train design for maximum efficiency. We have to build it so it will withstand onslaughts of children and even operate with them hanging on the arms. Presently available gates utilize such things as electrohydraulic mechanisms similar to aerospace type actuators and lightweight fiberglass arms which better withstand collision from cars.

Also, gates are being used more extensively as it has been learned that they dramatically reduce accidents at the crossing. Lightweight and thus less expensive gates are now available for adding to present flasher locations. Some railroads now utilize gates for all but the most lightly traveled crossings.

Cantilevers have been developed and are in general use to get the flashing lamps where they can be seen on today's wider roads with wider shoulders. Standards for highway adjacent appurtenances are ever more requiring that cantilevers be used. For railroad signal use, they must be made so that they can be serviced without interrupting traffic. Unlike the highway department, the signal maintainer cannot put up barricades for traffic. This has led to the rotatable cantilever and a fixed cantilever equipped with a catwalk.

With these design requirements, both the railroads and the suppliers have incorporated qualified technical staffs. These people have had to both follow the latest technology and hold to the basic failsafe principle of the battery track circuit.

In the design of satisfactory crossing protection all disciplines of engineering are involved—human and psychological, electrical, electronic, mechanical, optical. Consequently, the supply companies have had to become proficient in all these fields. Moreover, a thorough knowledge of where and how the equipment would be used is necessary.

As so many of the considerations in signal system design are peculiar to the railroad environment, design engineers must have or be properly directed in the restriction of that environment. Railroad experience is certainly helpful here.

The 90% of the design effort for failsafe and reliable operation show up here, too. Testing and re-testing, tight quality control, high specifications have to become normal. Self-check circuits must be used as well as design having intrinsic failsafe features. Single component failures must never result in an unsafe system failure.

Electrical surge protection of a degree unknown elsewhere must be used. Railroad signal lightning arresters, for instance, have required a many year long development and refinement.

Marketing

Of course, when we have devices and systems designed, manufactured, and used we require a method of marketing. In the railroad signal business, this takes a somewhat different form than in the marketing of other technically oriented industrial equipment. This is true for several reasons.

First, the market is small and highly specialized. At present there are but a handful of companies manufacturing the essential ingredients of grade crossing protection. With this small market, by any standards of industrial control markets, it is not possible to have many companies involved. If there were, none would have the capability for engineering and development investment, flexibility in production volume and so forth.

Another reason is that the differences in grade crossing make a "custom" installation out of most every installation. We have vehicular traffic ranging from 20 MPH on a city street to 60+ MPH on an expressway. We have train traffic from 5 MPH switching to 80 MPH limiteds. Railroads, highway people, and suppliers all shudder a little when they see a three street intersection over several railroad tracks requiring protection, but that happens too.

As a result of these factors, most all marketing is done directly to the railroad and is done by technically trained people. In fact, the predominant source of signal marketing people is from the signal department of a railroad. That is virtually the only place where a training ground exists.

Also, the signal equipment supplier usually participates in the application engineering to some degree. This can range from a suggestion to an engineer of a railroad having a large signal department to a "turnkey" installation for a 25 mile switching line. All, of course, must be done to the exacting standards of the state and the AAR.

While these factors do not develop the marketing sutuation we are used to, they do develop a close working relationship between the railroad and the supplier. Virtually no need seen by a railroad signal engineer goes unheeded by some supplier. The railroad is working with the state and AAR so we have a fairly efficient communication path.

Another effect of this arrangement is that new products of any supplier are subjected to an intense screening before being accepted for general use. The supplier and the railroad remain keenly aware of the need for failsafe and reliable operation. The requirements of the state and AAR, and thus the public, are met.

Of course, what hasn't been mentioned is competition in the marketplace. This certainly exists. The lower cost system, the one that does more, the one that comes with better application assistance is the one that will be bought. Salesmen are required to be astute in the technicalities of both their product and its application, but they have to sell it.

AAR

One highly important factor in grade crossing protection is the AAR. Long before it became standard practice to have regulatory agencies for just about everything, it was recognized that there must be a standard for railroad signaling and grade crossing protection. To this end, the AAR set up a system of standard which is revised and updated every year. There is a Signal Manual of Recommended Practice which is considered the basic guide for all current crossing installations. An excerpt from this, Bulletin 6, is cited as the standard by many states for crossing protection.

AAR Communication and Signal Committee "D" has the responsibility for the annual update of the Manual. While composed of railroad signal people, both suppliers of signal equipment and state and highway people are invited and encouraged as consultants. Consequently, this has become a highly effective forum for discussion of and specifications for improvements in rail/highway safety equipment.

Conclusion

From the foregoing it is apparent that grade crossing protection systems have been with us for a long time. They have stayed abreast of technology and, in fact, have been leaders in technology.

Suppliers, railroads and those setting standards have found it necessary and have complied to provide a highly reliable system and one that is as failsafe as any control system used anywhere.

We anticipate the same trend in the future. Speaking both as a supplier and for the railroads, I'm convinced this will be the case.

Safety Responsibilities Statutory and Otherwise

Jack L. Sollis
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Based on his years of experience in the handling of grade crossing situations, our next speaker has prepared a paper outlining facts, considerations, and conclusions having to do with the important and ever-evident matter of responsibility for safety at crossings of railroads by streets and highways at grade.

Here to address us on the subject of "Safety Responsibilities: Statutory and Otherwise" is Jack L. Sollis, Assistant Attorney General, Department of Justice, State of Oregon. (D. M. Fergusson)

The definition of the word "responsible" is as follows:

> *"Expected or obligated to account (for something to someone); answerable; accountable; Involving accountability, obligation, or duties, able to distinguish between right and wrong, and to think and act rationally, and hence, accountable for one's behavior; trustworthy; dependable; reliable, synonym answerable, which implies a legal or moral obligation for which one must answer to someone sitting in judgment. Accountable implies his liability for something of value or responsibility for one's own actions for which one may be called to account."*

The definition of a word may sound like a strange way to start a paper on this particular subject, but the purpose of it was to point up the fact that, as the word "responsible" has many connotations and can be interpreted in many ways, so can its application to safety at railroad-highway grade crossings.

The purpose of this paper will be to explore the basic responsibilities for safety at highway-railroad grade crossings, this will include liability to persons for injury or property damage because of collisions between motor vehicles and trains at grade crossings, the responsibility for maintaining a safe grade crossing, and also to propose a method of meeting these responsibilities that is perhaps a bit different than those presently being considered.

Historically, the responsibility for providing a safe situation at the railroad-highway grade crossing has rested with the railroad where it is concerned with the physical attributes of the actual crossing itself. This was not too much of a problem in the olden days when the mode of transportation was by four-footed animals, and the cow-catcher took care of any animal, riderless or not, that decided to stop on the tracks. The train usually had a slight advantage over the buffalo who tried to take them on, and things were not too rough then. In the ensuing years, things have changed considerably, and there is a tremendous amount of liability that attaches itself to an accident that occurs at a grade crossing. The mode of transportation, the speed of the trains, the speed of the vehicles and the number of vehicles have complicated this problem to a tremendously increasing degree. While highway traffic and miles of highways are increasing at a pretty rapid pace, the mileage of the railroads is decreasing at a very steady rate each year.

To open the discussion on the liability that a railroad has with respect to a grade crossing, I would like to quote from cases, the names of which I will omit, to give you the benefit of some of the language the Courts have used when describing the liability of a railroad at a grade crossing.

> *"Such precaution as prudent management with respect to public safety requires."*
>
> *"The railroad company is not an insurer of the safety of a traveler at its highway crossing, and is not required to exercise extraordinary care or vigilance in the operation of its trains over such crossings."*
>
> *"As liability is based upon violation of some duty owed, there is no liability in the absence of a violation of a duty to guard the injured person against foreseeable injuries."*
>
> *"What constitutes ordinary and reasonable care on the part the railroad company and the maintenance of its public crossings, and the operation of trains over them, is determined in the light of all of the surrounding facts and circumstances."*
>
> *"The care required to prevent the infliction of injury is always proportinate to the danger and chances of injuries."*
>
> *"What may be due care in one locality, or with reference to a particular crossing, may be negligence with respect to other crossings."*

To sum up the holdings in cases throughout the United States, the Court is going to look at the crossing, the circumstances, and determine what degree of care was necessary by the railroad and what degree of care was necessary by the traveler. The traveler does not have the right to expect to be able to whip across every crossing without taking any precaution on his part. The cases dealing with contributory negligence in accidents at grade crossings go from one extreme to the other. Some say that the man has to use reasonable care under the circumstances. One case in which Justice Holmes wrote the decision indicated that the driver was contributory negligent if he didn't stop and get out of his car and look up and down the track. This might be a little inconvenient today on some crossing that has 40,000 vehicles a day going over it.

It is interesting to note that some of the Courts have said that while the duties of the railroad company at crossings may be prescribed by statute, no statute is necessary to make a railroad company liable for injuries or damages caused by failure to exercise ordinary care at a highway crossing. The fact that a statute does not provide for certain precautions at a railroad crossing does not relieve a railroad company from adopting such other measures as public safety and common prudence dictate.

In light of the fact that many states now have a Tort Claims Act which allows the state to be sued for any negligence on the part of its officers or employees, and this usually includes acts of omission as well as commission, and errors in judgment, there is a distinct possibility that a new field of law may develop in the liability of the state with respect to accidents at crossings. This is expecially true where the state has a governmental agency that is responsible for determining whether crossings are properly signalized and determining the type of signalization to be used at various crossings.

For instance, in Oregon right now, there is a case pending in which one person was injured at a unsignalized (cross bucks only) grade crossing, where, as a result of the collision, the injured party is not only suing the railroad company, but the Highway Division and the Public Utility Commissioner. The basis of his law suit is that the crossing was not signalized and three quadrants of the crossing had extremely limited visibility. The contention is that a reasonably prudent person, in the exercise of due caution, would have seen that the crossing was signalized. The complaint alleges that the railroad was negligent for not seeing that the crossing was signalized, the Highway Division was negligent for not seeing that the crossing was signalized, and so was the Public Utility Commissioner. In Oregon, all three of these listed parties had the authority to apply for or to require that the crossing be signalized. The outcome of this case will undoubtedly be of extreme interest to states, highway divisions and railroads all over the United States. This will be especially true in states where they have a Public Utility Commissioner, or some other state agency that has the responsibility for supervising and ordering the signalization of grade crossings. The failure to signalize a crossing could be the basis for a jury to decide that the state was negligent and could be held to account in damages for injuries at that crossing. This would involve the agency in charge of regulating the signalization as well as the governmental agency in charge of the highway, as well as the railroad. With this thought in mind, perhaps more impetus will be given by states to signalizing and/or eliminating grade crossings, or at least improving them.

The proposition that if a railroad follows a statutory direction as to giving of signals, sounding its horn, etc., as the train approaches the crossing, that it is discharged of all its duty, has not been followed in all the Courts. Some Courts have said that the statutes merely prescribe a minimum that the railroads must follow and that if, under the particular circumstances of a particular crossing, warnings in excess of the minimum are required, then the railroad could possibly be guilty of negligence if these were not used. The basis for this is that neither the legislature nor the Railroad Commissioners (in Oregon, the Public Utility Commissioner) can arbitrarily determine in advance what shall constitute ordinary care or reasonable prudence in the actions of a railroad company at a particular grade crossing, but that each case must stand upon its own merits and be decided upon its own facts and circumstances. Whether this reasoning would follow today is hard to determine. If a railroad has done all that is possible in the signalization of the crossing and nothing more can be done short of building an overcrossing or an undercrossing, would the question of negligence ever get to the jury. One of the railroads that has a great deal of track mileage in Oregon has a policy that when the crossing is signalized, that it be signalized with gates as well as lights. The philosophy behind this is that if there is a collision at the crossing and a portion of the gate is embedded in the front end of the vehicle before it collides with the train, there isn't too much of a question as to who was at fault and the signal has paid for itself several times over.

The liability of railroads at grade crossings is clearly established in the various jurisdictions. However, in the next five to ten years, because of the tremendous increase in automobile traffic and because of the advent of the Tort Claims Act in an increasing number of states, there may be a change in this liability. The Governmental agencies may find themselves involved in law suits where there are injuries at a crossing. They may find themselves involved in the law suit because the signals were either inadequate, because the crossing was not signalized, or because the crossing was unsafe because of limited visibility or other factors. The governmental agencies will then, be in the same boat (with a hole in it) as the railroads and discover that they are going to have to bail together to get out of it.

Another question that arises in this field is "who owns the signals?" In Oregon, regardless of who contributes how much for the installation of signals at the crossing, the railroad purchases and installs the signals. The railroad is reimbursed by the public agency who controls the highway, whether it be the City, County, or State, for their proportionate share of the cost of the installation. The Public Utility Commissioner has ruled that the public agency has an equitable interest in the signals to the extent that they have contributed toward their original cost, and if the signals are later taken out, they are entitled to a proportionate share of the salvage value of the signals. This would seem to be a simple way to handle the ownership of the signals inasmuch as they are purchased by the railroad, located on the railroad right of way, and maintained by the railroad.

Another question that comes up is "Should the public agencies own and maintain the grade crossing protection devices?" Unless the states are willing to agree to hold the railroads harmless and assume all of the liability for accidents at grade crossings that have signals, then the installation and maintenance should be handled by the railroads. If you were to try to have the governmental agency install the signals and still have the railroad liable for accidents at crossings with Government owned signals, without the guarantee of who would assume the liability, this would be a totally unworkable situation. The procedure in Oregon now is that the Public Utility Commissioner approves the signalization of a crossing and the allocation of costs, the railroad purchases the signals, installs the signals, hooks them up, they become operational, they send the governmental agency who is sharing the cost, the bill. The bill is paid and the railroad, in most cases, provides the maintenance for the signals and stands the liability for any accidents at the crossing. If the railroad signals are interconnected with highway signals, the railroad maintains the railroad signals. We have one recent order published in Oregon in which the Public Utility Commissioner ruled that it would be impossible, safety wise, to signalize a crossing without also signalizing an intersection that was extremely close to the crossing, and he directed that the total cost of signalizing the intersection and the crossing be split 50-50 and that the railroad maintain the railroad signals and the County and State maintain the traffic signals. This case is on appeal and the outcome will certainly be of interest to many states. This was a factual situation in which the signalization of one, without signalizing the other would very likely have made the condition worse, rather than have helped it.

In dealing with the responsibilities at grade crossings, the question arises as to the quality of the existing signals we have at railroad grade crossings. Are these of the sufficient quality that they adequately fulfill the responsibility that is becoming more and more a joint responsibility between the governmental agency and the railroad for the proper protection of a grade crossing. At the crossings in Oregon, the power is fed through batteries and as a result, the wattage of the signal lights are extremely low and the cone of vision from a railroad signal light, due to outdated optical systems, is extremely limited. They are not nearly as bright as the regular highway traffic signal. The philosophy that a railroad crossing must be signalized different from a regular traffic intersection has prevailed for many years, and I frankly wonder if the time has not come to investigate the possibility that a great many grade crossings could be signalized with vehicular traffic signals and that they would be just as effective and efficient as the present type of railroad signals. The philosophy that a grade crossing has to have sixteen flashing lights, eight in each direction, to adequately warn the traveling public, is possibly a bit outmoded. Four flashing lights that were four or five times as bright, maybe twice as big and located in a different spot would probably do as good, or a better job. The Public Utility Commissioner in Oregon, in adopting the rules that supplement the statutes, has adopted a new standard Number 5, which looks like a vehicular traffic signal, except that it has double flashing red lights at the top, a yellow and a green. This could be used in place of the conventional railroad signal. This is a mast arm mounted signal that would be powered by 110 AC and would provide the same illumination that a regular traffic signal provides. There would also be a backup power supply. In Oregon, presently, there are three different crossings that are controlled with vehicular traffic signals now on an experimental basis, and so far, there have not been any problems. This is another field that should be looked into in the next few years with the possibility that the cost of signalizing grade crossings as well as the cost of maintenance could be greatly reduced. I would also hope that some improvement could be made in the power supply, optical systems and light sources for grade crossing signals so that they would produce more illumination and thus be visable at a greater distance. It can only be done if they are connected up to a direct 110AC with a standby power in the event the regular power goes off. The railroads seemed concerned about having one level of illumination when regular power is functioning and a lesser level of illumination when the power goes off. Is this a valid reason for avoiding a new procedure inasmuch as power failures are of generally short duration. Would a Court hold the railroad negligent for a power failure if they had another substitute mechanism that worked, even though it might not be as bright as the signals when powered by a regular 110 volt AC.

Some investigation should be given to the maintenance program in future years with the railroads co-operating in the maintenance of each others signals. While I am aware that this does raise the questions of liability between the railroads, I am sure that this could be worked out by agreement and would result in a much reduced cost of maintenance. I am also curious as to whether or not maintenance agreements could not be entered into with local power companies to have people trained in the maintenance of railroad signals. We have a situation in Oregon now where one maintenance man for a railroad covers a large portion of the state and if a signal malfunctions in the South part of his district, it is a considerable length of time before he can get there and fix it, and if one malfunctions at the same time in the Northern part of his district, there isn't any way he can be at two places at once.

This is another area in which I think the Federal Government could wisely spend some money on research. The industry that manufactures railroad signals is not sufficiently large that it can stand the cost of research and experimentation in new types of signal devices, track circuitry and such. Inasmuch as this is a joint problem, I do not feel that the railroads should stand this burden alone. I think it would certainly behoove the Federal Government to earmark some of its funds for special research projects in the development of new signals with better illumination, different methods of track circuitry, different component parts that last longer, are more efficient and cost less. Before millions of dollars are spent utilizing signals that are not as efficient as they could be, perhaps it would be better to see if it is not possible to develop the ultimate in signalization. With the technology that has been landing men on the moon available, they certainly should be able to apply it to the circuitry and signal mechanisms needed for better crossing signalization.

It is estimated that the increase of the number of motor vehicle miles of travel has been 2400% since 1920. Most of this has been over the last twenty years. However, during the last twenty years, the street and highway mileage has gone up only about 5% per year, which would give it a 100% increase. Over the last fifty years period, railroad mileage has gone down about 20% and is now going down at the rate of about 4% per year.

It is quite obvious, not only from these figures, but from the fact that the large cities are choking in their auto exhaust, that the increase in the number of motor vehicle miles of travel per year has had a tremendous impact on the grade crossing problem.

Now to discuss for a few moments, the magnitude of the problem of grade crossings. A summation of figures picked up from the draft of Chapter 3 of Part II of the Railroad-Highway Grade Crossing Safety Report to Congress which was to be completed by July 1, 1972, indicates that there are approximately 223,000 grade crossings in this country, and about 35,000 grade separations. Of the 223,000, 174,715 have passive portection and 48,528 have active protection. Passive protection being defined as advance warning signs and cross bucks, or nothing. Active devices being lights and/or lights and gates. Of the 174,715 that have passive signalization, 147,616 are on non-federal aid systems, and 27,099 are on federal aid systems. Of the crossings that have active protection, 26,755 are on non-federal aid systems and 21,773 are on federal aid systems. The interesting part of this statistic is the fact that most of the crossings that have passive signalization are not on the federal aid system, and of the crossings that have active signalization, there are only 5,000 more off the federal aid system that are protected than are on it. This indicates that the crossings off the federal aid system are not getting their proportionate share of active signalization.

In classifying the various grade crossings, the following table, from the same report, brings to light an interesting point.

CLASS	TRAINS	CARS
I	0—2	0—500
II	3—5	500—1,000
III	6—10	1,001—5,000
IV	11—20	5,001—10,000
V	21—40	10,001—20,000
VI	Over 40	Over 20,000

This table indicates trains per day and vehicles per day. In applying this table to the grade crossings in the United States, we find that 63% of the crossings will lie in the minimum highway volume class and about 47% in the minimum train volume class. Thus, it is quite obvious that there is a tremendous amount of grade crossings in this country that have a very small volume of traffic and very limited use by trains.

In most of the publications by governmental agencies, research agencies, highway associations, railroad associations, there are a great many articles on the grade crossing problem and what type of signals, how much money, so on and so forth, it will take to reduce the number of fatilities at grade crossings. To me, they're starting at the wrong point. Before they attempt to use the typical bureaucratic method of solving a problem (beat it to death from all sides with money), perhaps they should take a small amount of money (in proportion to what it would take to signalize many of these crossings) and require each state to make a comphrehensive study of all of the grade crossings in the state and come up with the following categories of grade crossings:

1. Crossings that can be closed because they are unnecessary. (There are many crossings where they may be desirable, convenient and look pretty, but are totally unnecessary to convenient travel in today's society).
2. Crossings that can be eliminated in conjunction with the signalization with other crossings in the vicinity.
3. Crossings that could be eliminated by the construction of overcrossings or undercrossings in the general vicinity.
4. Crossings that must remain and are in a area where no other crossings are related to them and establish a priority of signalization of these crossings.

As noted from the previous statistics, the lion's share of the unsignalized crossings are not on the Federal Aid Highway System. If the Federal Government is going to put some money into this area, it should be given to the states to spend on those crossings that need signalization, whether they are on the Federal Aid System or not. The requirement for the allocation of the money should be (1) an agency that has the authority to supervise the signalization, safety aspects and construction details of grade crossings and grade separations, (2) a comprehensive study of all the crossings in the state and a definite program of eliminating unnecessary crossings as well as a well delineated priority for the signalization of crossings, or the separation of crossings for the entire state. It is important that the state be allowed to distribute this money on the basis of its own priority system, because there are some counties and cities that do not have any crossings in them, and others that have so many that they could not possibly do it with any other type of funds. To merely allocate the state so many hundred thousand, or so many million dollars for grade crossing protection without requiring a definite plan, or unless they have an agency other than the highway division to be responsible for proper signalization, then the grade crossings that really need signalization may not get it.

In Oregon, we have a very workable situation in that there is an independant agency that has the authority to provide for the signalization of crossings in the state, and has the machinery and staff to implement a program of closing crossings, setting up a priority system on the signalization of crossings and see to it that the money is spent where it is most needed. In states that do not have a setup such as this, where the money would be allocated solely to the highway division to use as they see fit, you might have an efficient highway division, but when you get to allocating the money to crossings in various areas of the state, you immediately become deeply involved in politics and many of these types of problems are less likely to develop if there is an independant agency that determines the priority and has the authority under law to see that grade crossings are signalized in accordance with the uniform priority system and that the parties affected (railroads, highway divisions, etc.) still have recourse to Courts in the event they feel the agency with the authority over crossings has been arbitrary or capricious. If a crossing signalization fund is set up in a state, it would be desirable that the language of the statute is such that federal monies could be channeled through that fund and disbursed by the agency that has control of that fund for signalization of grade crossings.

The basic problem of funding grade crossing protection, elimination and improvement, has plagued all levels of state government. At the present time, the Federal Government is commencing a program to move more money into this field and some states have already set up special funds that are earmarked for these purposes. California has a Grade Separation Fund of $5,000,000 and a Grade Crossing Protection Fund of $1,100,000; Colorado has $120,000; Florida has $1,000,000; Illinois has $1,200,000; Iowa has $240,000; Minnesota has $360,000; Nebraska has $180,000; North Dakota has $15,000; Texas has $1,500,000; Washington has $180,000; Wisconsin has $400,000 and Wyoming has $60,000. I understand that Kansas now has a fund and administrator to supervise the allocation of the money and there are probably some I have overlooked. In Oregon, a bill was presented at the last Legislature and failed because the money was to come from the General Fund rather than the Highway Fund. It would have provided 50% matching funds for the signalization of crossings, with the remaining 50% to be split between the Government agency and the railroad, as determined by the Public Utility Commissioner, with the railroad to bear the maintenance by statute. The governmental agency that had jurisdiction over the road on which the signalization was being done would be given a 10% bonus from the Fund for every additional grade crossing that was closed over and above the one that was signalized, or the one that was opened. As an example, if Podunk decided to signalize a crossing, and in the process, close three other crossings, they would get a 30% bonus from the Fund, which would mean that the Fund would pay 80% and the remaining 20% would be paid by the town and the railroad, as determined by the Public Utility Commissioner. If they opened a new crossing and closed three crossings, they would get a 20% bonus, as there was a net loss of only two crossings. A bill with slightly different provisions is being prepared for the Legislature in 1973, and I believe that it will have a strong chance of passage.

Some states have developed formulas for determining the priority of signalizing grade crossings which deal with many variables. The purpose of this is to determine the priority in which crossings should be signalized and the purpose of the formula is to determine what the odds are that somebody is going to get killed or injured at a crossing. One variable which some formulas leave out is if a car is hit at a crossing, what are the odds going to be that the occupants are going to be killed or just shaken up. Adding this variable, you might get a little different answer than you would get with a normal formula. There are some crossings where the odds are a thousand to one that you are going to get hit, but the odds are also a million to one that if you do, you are going to get killed. There are other crossings where the odds are twenty to one that you are going to get hit, but the odds are a million to one against getting killed, and you probably get just shaken up, because the train is only moving five miles per hour.

The first thing to be done is to make a comprehensive study in each state and have an agency that can take this study and do something with it.

The Oregon statutes that give the Public Utility Commissioner the authority to deal with grade crossings, overcrossings and undercrossings in the State of Oregan, which I am sure you will agree, are pretty strong and give him a great deal of authority to do whatever is necessary.

There are some diagrams of grade crossing situations in some cities in Oregon in which the cities have too many crossings. The crossings designated by the circles could be closed and those designated by the squares could be left open, and in a couple instances, signalized. This would reduce the hazard to almost zero as far as these small towns are concerned.

As you will note from Exhibit "A", in the town of Milton-Freewater in Oregon, there are a large number of grade crossings because of the particular way the railroad track is located through the town. You will note that of eight crossings of the railroad, it would be possible to close five, leave three open and still adequately serve the area inasmuch as the area served on each side of the railroad is a relatively narrow area. This is the example of the closure system that I am speaking of. There are other crossings in the town that could possibly be closed. These would be on Third and Second Streets in which the area served on each side of the crossing is relatively minor.

On Exhibit "B", the town of Canby, there are now three crossings and one of those could be closed with traffic routed over the other two crossings and this would easily eliminate what is now a rather hazardous crossing.

Referring to Exhibit "C", this is over in Central Oregon. It involves the small town of Redmond. You will note there are seven crossings involved, three of which could be closed and four of which would be left open. The crossing which is covered by the second square from the top is a very complicated crossing involving about six or seven tracks and a 90° turn, and is presently lit up like Dodger Stadium and controlled with advance warning signs and stop signs. One of the other crossings that would be left in, the bottom one, is already signalized. This would eliminate three crossings that do not serve a particularly large area and are unsignalized. They are not particularly safe crossings and because of the small area they serve and the fact that there are other routes available for the people to cross the tracks, safety is served by going a little bit further. This is a typical example of how the large number of unprotected grade crossings in this country could be very effectively eliminated.

Referring to Exhibit "D", which is the City of Dundee. There are four crossings there now. At one time, they asked for a fifth, which was turned down. Two of these crossings could be closed and the two marked in black squares be left open, signalized and the hazard, for all intents and purposes, be eliminated, as far as the City of Dundee goes. The other streets that are not marked are not open to traffic at this time, and there are no grade crossings at those locations.

I believe that advance planning in the opening of new grade crossings which would require that old grade crossings be closed, or that in lieu of opening new ones, old ones be used and a street system worked into the old crossings, is a far better way to approach the problem than attempt to just signalize whatever is there. In Oregon recently, the Public Utility Commissioner refused to authorize a new crossing on the basis that the public necessity did not require it. It would have been nice and convenient for a few people, but it was not necessary. This will probably happen more frequently in the future. As a result, cities and counties, as well as the State, will realize that prior planning of the street system in conjunction with the railroads will result in the opening of fewer new grade crossings and certainly result in the closure of many that do exist today. If the Federal Government wants to spend some money wisely in working on the grade crossing problem, one way where they could really get their money's worth, is to give the states some money and set the guidelines for the study that they would be required to make. This comprehensive plan would be of tremendous help to the cities and counties as well as the state highway departments in planning their road building budgets over the next five or ten years. Over that period of time, they could phase out old crossings, develop new ones and in the long run, minimize the number of necessary grade crossings. It would appear that this would be by far the cheapest method to deal with this problem and I would a guess that 25% of the crossings in this country could be closed and would never be missed. The railroads would certainly not be brokenhearted by not having so many crossings to maintain.

In conclusion, I am slightly partial to the way it is done in Oregon, because it seems to work and it is efficient. We have a good working relationship between the Public Utility Commissioner, the Highway Division, the counties, the cities, and the railroads. We don't always agree, but we do have a very good line of communication open and most of the problems that do arise concerning crossings are solved short of going to a hearing before the Public Utility Commissioner. I am sure that the regulatory powers that he has, with respect to grade crossings, is a very definite asset in setting up a comprehensive plan. His orders are subject to review by the Courts in case he gets over eager, and in the opinion of a governmental agency or railroad, is getting out of line. If Oregon were to get a federal grant to make such a comprehensive study as I have outlined, I am sure that they would jump eagerly at the chance, and a result of such a comprehensive statewide plan for the elimination, alteration, improvements and signalization of grade crossings would certainly provide Oregon with a definite course of action over the next ten years and a pretty good idea of what it would cost the State, each county and city. By doing it this way, a great deal of money would be saved by not signalizing crossings that could be closed, and that would save a great many lives.

In the final analysis, the application of the word "responsible" to grade crossings rests with everybody, and by that I mean the states, the cities, the counties, the railroads, the Federal Highway Administration. Everybody concerned with this problem wants to cut down the number of accidents and the number of fatalities at grade crossings. I think this responsibility also extends to doing it in the most efficient and most economical manner that it can be done. I firmly believe that this responsibility can be most adequately met by a comprehensive statewide study for the elimination of as many crossings as possible before a massive program of signalization and construction of grade separations is commenced. While all of the articles I have read that refer to crossing elimination

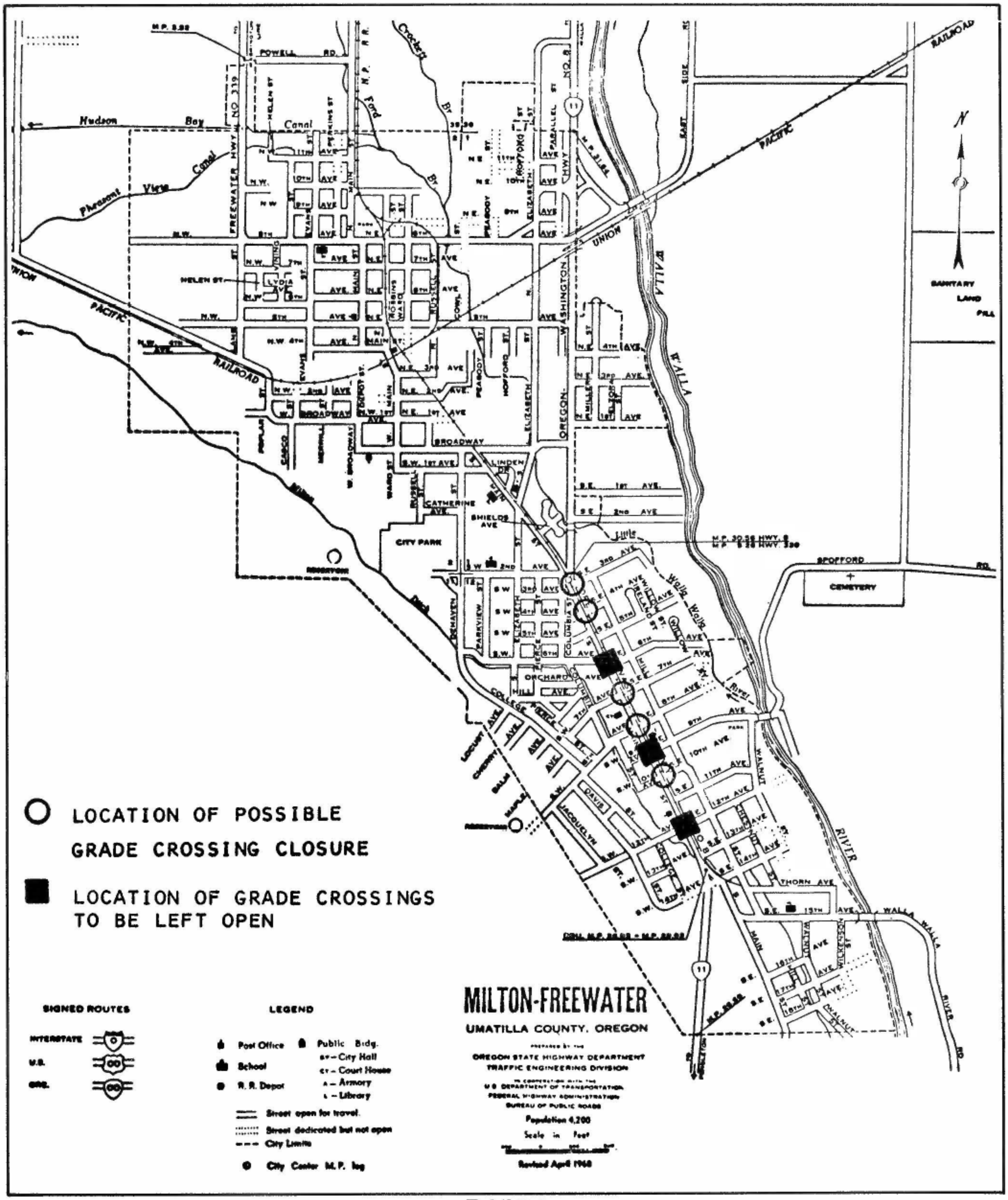

Exhibit A

and the construction of overcrossings as being synonymous and the ultimate in the elimination of hazards where highways and railroads cross, I feel the ultimate is where highways and railroads don't cross, and by eliminating a lot of unnecessary grade crossings, you reach the ultimate very very cheaply.

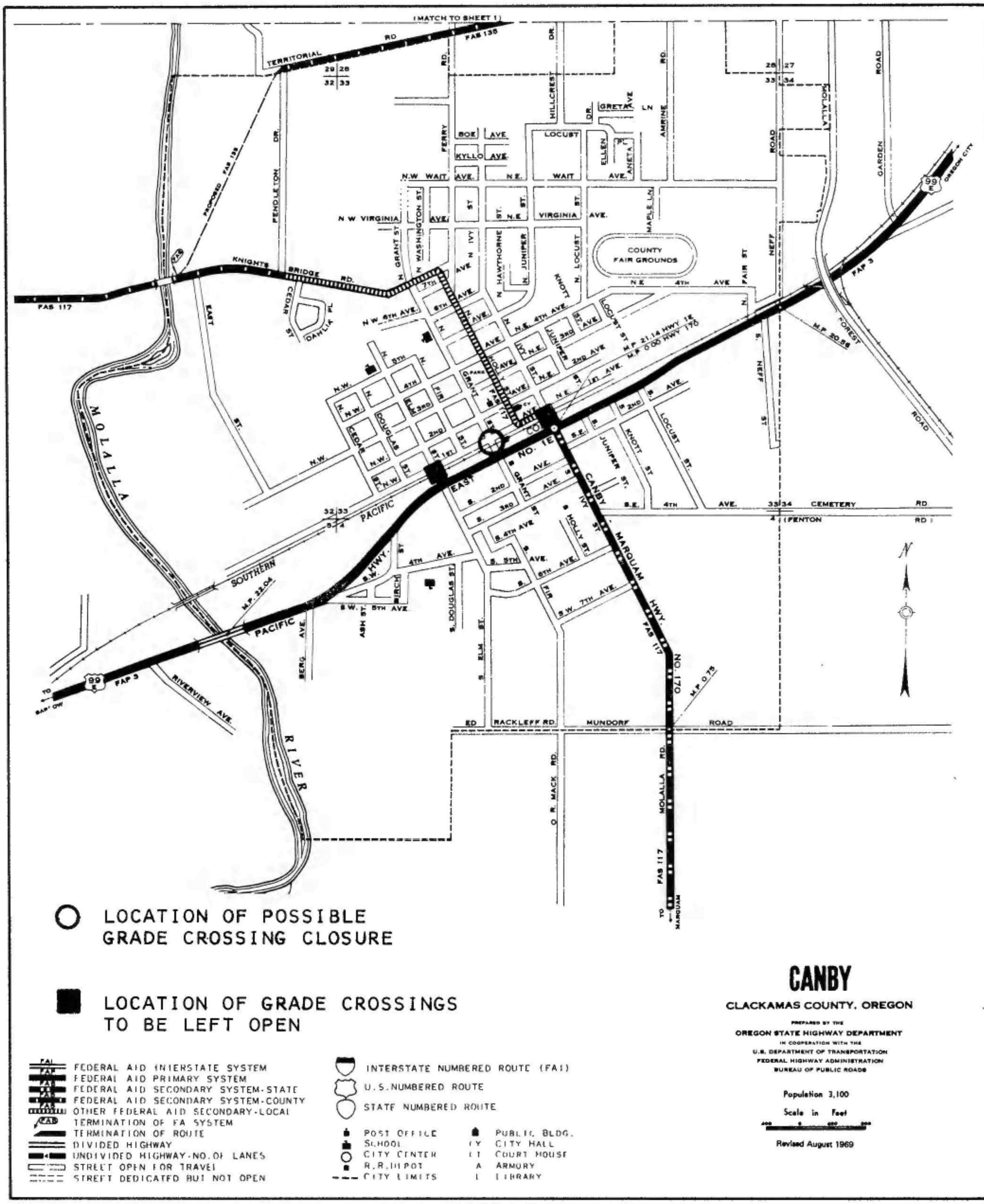

Exhibit B

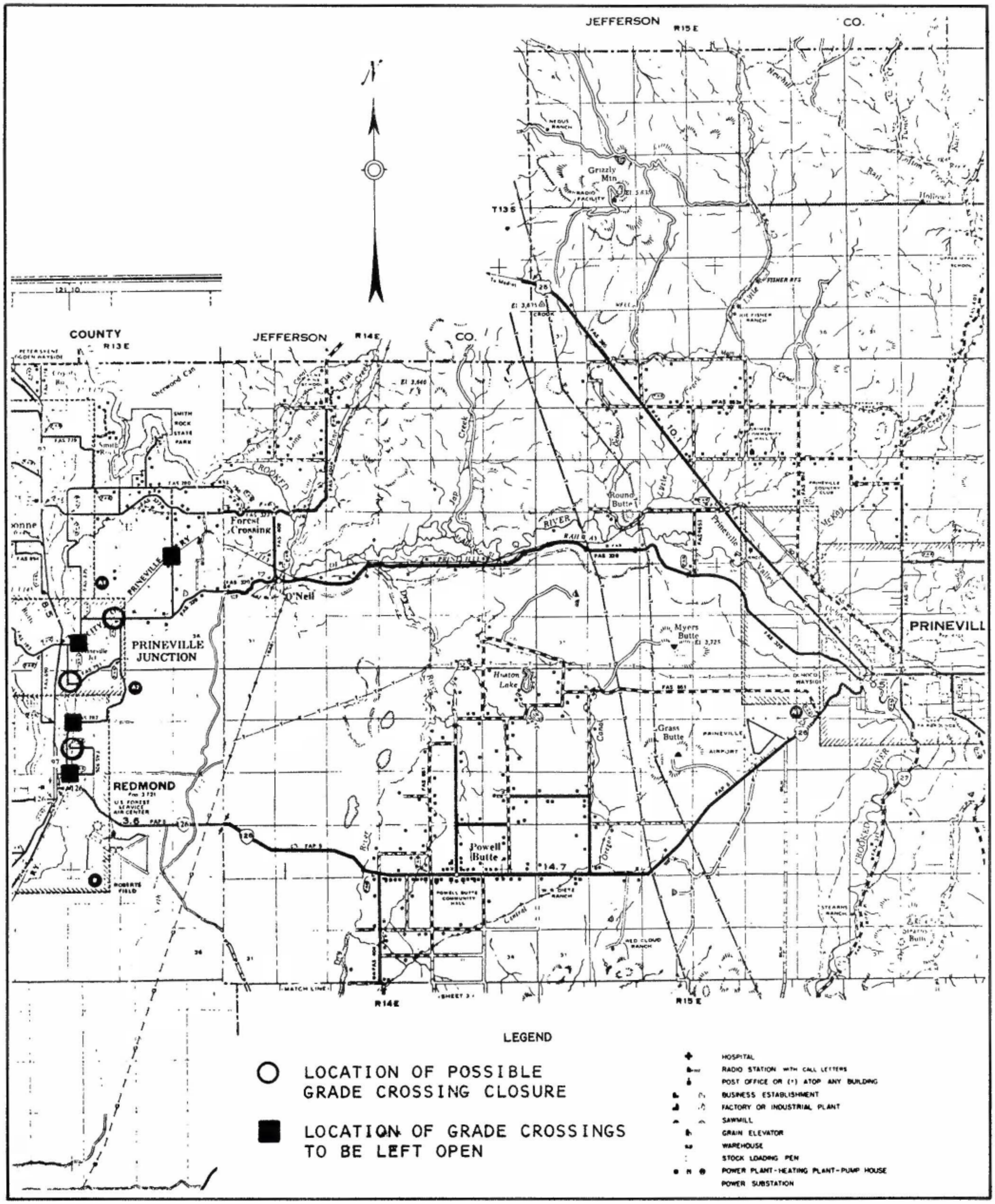
JEFFERSON
R15E
CO.
N
T13S
COUNTY
R13E
JEFFERSON
R14E
CO.
Grizzly Mtn
SMITH ROCK STATE PARK
Forest Crossing
O'Neil
PRINEVILLE RY.
PRINEVILLE JUNCTION
REDMOND
U.S. FOREST SERVICE AIR CENTER
ROBERTS FIELD
Round Butte
RIVER
Myers Butte
Grass Butte
PRINEVILLE AIRPORT
Powell Butte
POWELL BUTTE COMMUNITY HALL
RED CLOUD RANCH
STEARNS RANCH
PRINEVILL
CROOKED RIVER
10.1
14.7
3.6
8.5
MATCH LINE
SHEET 3
R14E
R15E
LEGEND
LOCATION OF POSSIBLE GRADE CROSSING CLOSURE
LOCATION OF GRADE CROSSINGS TO BE LEFT OPEN
HOSPITAL
RADIO STATION WITH CALL LETTERS
POST OFFICE OR (*) ATOP ANY BUILDING
BUSINESS ESTABLISHMENT
FACTORY OR INDUSTRIAL PLANT
SAWMILL
GRAIN ELEVATOR
WAREHOUSE
STOCK LOADING PEN
POWER PLANT - HEATING PLANT - PUMP HOUSE
POWER SUBSTATION

Exhibit C

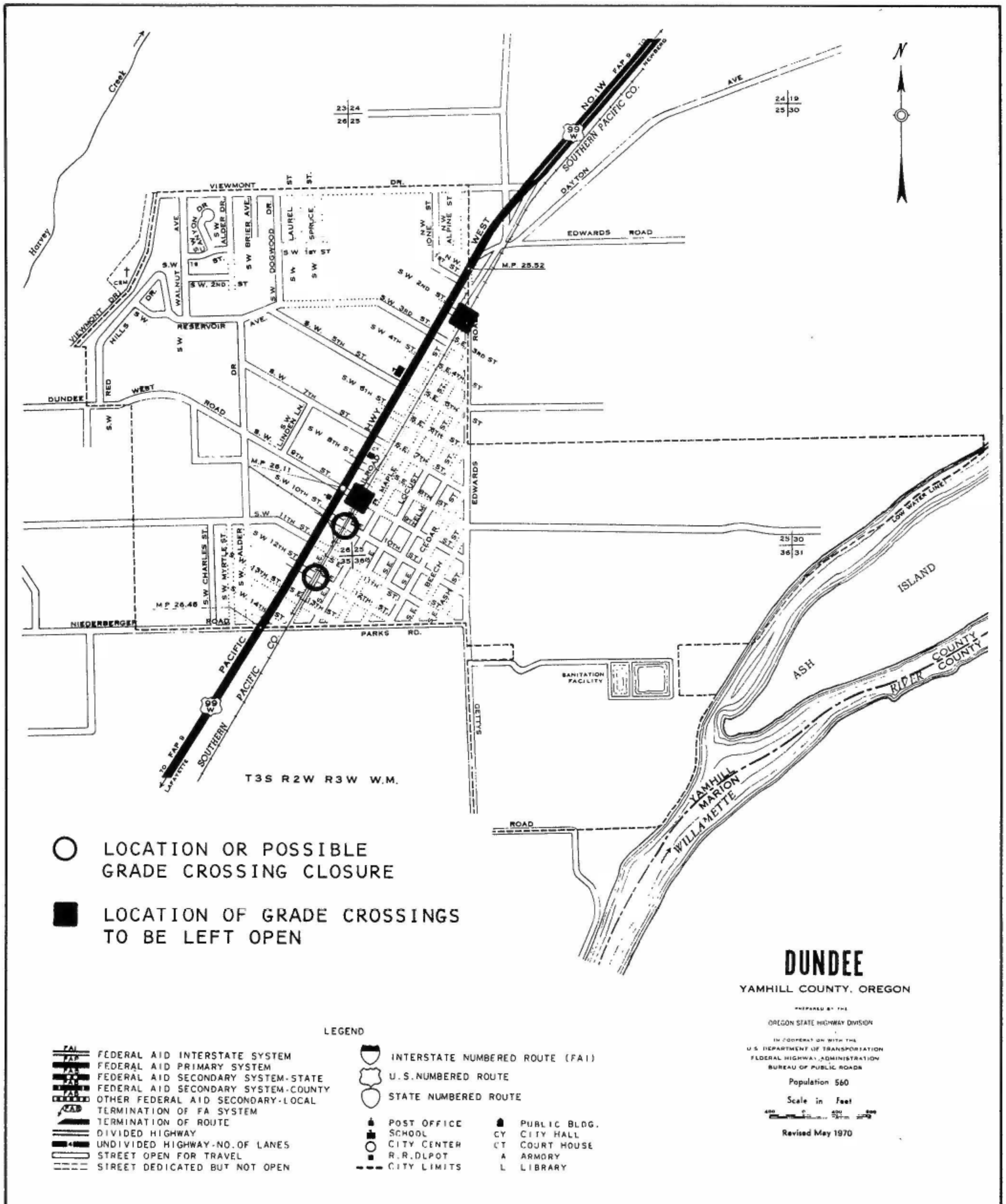
LOCATION OR POSSIBLE GRADE CROSSING CLOSURE
LOCATION OF GRADE CROSSINGS TO BE LEFT OPEN
DUNDEE
YAMHILL COUNTY, OREGON
OREGON STATE HIGHWAY DIVISION
Population 560
Scale in Feet
Revised May 1970
LEGEND
FEDERAL AID INTERSTATE SYSTEM
FEDERAL AID PRIMARY SYSTEM
FEDERAL AID SECONDARY SYSTEM-STATE
FEDERAL AID SECONDARY SYSTEM-COUNTY
OTHER FEDERAL AID SECONDARY-LOCAL
TERMINATION OF FA SYSTEM
TERMINATION OF ROUTE
DIVIDED HIGHWAY
UNDIVIDED HIGHWAY-NO. OF LANES
STREET OPEN FOR TRAVEL
STREET DEDICATED BUT NOT OPEN
INTERSTATE NUMBERED ROUTE (FAI)
U.S. NUMBERED ROUTE
STATE NUMBERED ROUTE
POST OFFICE
SCHOOL
CITY CENTER
R.R. DEPOT
CITY LIMITS
PUBLIC BLDG.
CY CITY HALL
CT COURT HOUSE
A ARMORY
L LIBRARY
T3S R2W R3W W.M.
SOUTHERN PACIFIC CO.
EDWARDS ROAD
VIEWMONT DR.
DUNDEE WEST ROAD
NIEDERBERGER ROAD
PARKS RD.
SANITATION FACILITY
ASH ISLAND
WILLAMETTE RIVER
YAMHILL COUNTY
MARION COUNTY
Harvey Creek
M.P. 25.52
M.P. 26.11
M.P. 26.46

Exhibit D

Passive Devices at Railroad–Highway Grade Crossings

Slade F. Hulbert
Research Psychologist
University of California at Los Angeles

and

R. C. Vanstrum
3 M Company

The paper will explore the driving task as related to grade crossings and principles to make traffic control devices effective. These principles give us to two distinct passive signing systems—one for crossings which have active device protection and the other for so-called "unprotected" crossings. Colors, costs and other passive device improvements including crossbuck variations will now be discussed by Dr. Hulbert—assisted by Robert Vanstrum, committee member. (D. M. Fergusson)

Introduction

This paper will deal only with traffic signs as the "passive" traffic control devices for railroad crossings. Other devices such as illumination and pavement markings certainly have much to offer in conveying information to drivers but they are not as universally available as signs and should be the subject of regional studies and local consideration by traffic authorities where they are feasible to install.

Passive devices (signs) are important for all crossings both the so-called "protected" and "unprotected" because both have advance warning signs, and signs at the crossing. Even protected crossings with active devices such as gates and flashing lights provide a passive display when they are not actuated. The raised gate, the unlit flashers and stationary wigwags all contribute visible cues to drivers to help inform them they are near a crossing. All such devices have a common purpose, namely, to improve the accuracy of each driver's expectation of what lies on the road ahead. This expectation is the essence of successful driving. If I can accurately predict what traffic situations to expect, I can more successfully cope with them.

At crossings, the motorist must be assisted so that he expects to encounter trains; moving trains, stationary trains and approaching trains. At protected crossings where active devices are present, the driver is given a positive signal that trains are present or near the crossing. However at unprotected crossings where only passive devices are present, the motorist has the entire unassisted burden of determining whether or not a train is near. This important difference in burden on the driver is a main theme of this paper.

Several pieces of information will be described that are related to this major theme of distinction between protected and unprotected crossings. First, the driving task in general and while approaching crossings; second, cost and relative risk; and finally proposed improvements that might increase the safety of railroad and highway operation. Proposed improvements will include two different passive systems, one for protected and one for unprotected crossings; the use of color and in particular a new color; and some possibilities for making passive signs much more effective thus providing a low cost opportunity for up-grading crossing protection.

Driving task—General

Each driver must learn to anticipate what lies ahead of his vehicle. As speed increases this anticipation must reach increasingly farther ahead. Hulbert and Burg [1] [2] have dealt with this concept and have diagrammed it as a fan-shaped zone of relatively "committed" space extending in front of each moving vehicle including in this case the train which at high speeds has an extraordinary committed zone which may extend a mile or more along the track ahead of the first unit. When these committed zones overlap, there is a potential collision of disastrous consequence to the automobile, bus or truck and its occupants. Vanstrum and Caples [3] built upon this concept and related it to driver decision making as diagrammed in Figure No. 1* where the general shape of the committed zone is shown. The precise shape of this zone will of course vary with each vehicle and with speed and steering system and stability afforded by the interaction between the vehicle and the roadway. As the time-frame of this commitment increases the commitment becomes more and more provisional because the driver has more time to receive new up-dated information and change his path or speed accordingly. Also shown are band 1 which represents the distance traveled during minimum perception time; band 2 is distance traveled during minimum decision time and band 3 distance traveled during minimum reaction time. Band 4 is the minimum committed motion area of the vehicle after activation has been made to turn or stop. On the right is a hazard (the train) designated by the box marked X. It can also represent a potential hazard such as at crossings. In this diagram, T is the "true point" or last point at which successful evasive action can be initiated. It is a point of no return and is determined by the zone of committed motion and the laws of physics. Point M is the "mental point" which is the driver's perception of the true point 'T'. Point A is the "action point" where the driver actually does take action. This diagram represents only one single moment in time. In actuality these are dynamic points changing with every passing second as the vehicle approaches the crossing or other hazard.

**Please turn to the unnumbered center section for the illustrations referred to in this paper.*

Driving task—at Crossings

At crossings there must be a safe blending of these expectancy aspects of the driving task. As Schoppert (4) has pointed out, there are on public roads about 225,000 thousand crossings at grade only 45,000 thousand (or 20%) of which may be protected by active devices and about 11,000 crossings have no signs at all. At these unprotected crossings the driver's task can be described as follows:

Tasks

(1) He must realize that he is nearing a crossing.
(2) He must realize that it is his entire burden to decide whether or not a train is near.
(3) He must begin to look for the crossing and begin to expect to encounter trains.
(4) He must adjust his speed according to his ability to maintain a safe balance between his committed space and his ability to predict that a train will not also be in that space.
(5) He must detect the location of the crossing.
(6) He must determine the size, shape and nature of the crossing in terms of his exposure to conflict with trains. Such things as the visibility cone described by Richards (5), the number of tracks, frequency of train arrivals, alignment of tracks with the roadway which tells him to look, and condition of the roadway all enter into his decision to cross or not to cross.

At protected crossings, these same tasks apply except that while the driver still has responsibility to look for trains, he can expect assistance from a signal system. He therefore has an added task, namely, to detect the nature, location and status of whatever signals are used. When they are not in their action status, the only cues they afford him are their passive aspects.

Costs of Traffic Control

If there were no practical considerations involved, it would be relatively simple to provide the motorist with all the information he needs to make the decisions listed above at each and every one of the 225,000 crossings. However, it clearly is not feasible to do so. Also, we must take account of such factors as impedance to traffic flow and resultant turbulance and accidents if, for example, all traffic is required to halt at all crossings by placing of stop signs. We must take a practical look at costs compared with relative risk. The work of Schoppert (4) and Richards (6) provides a basis for the information presented in Figure No. 2.

The main purpose of this graph is to show the wide gap existing between present day passive systems and active systems, in terms of both protection and costs. In the graph, costs are shown along the vertical on the left in logarithmic fashion \$100, 1000, 10,000, 100,000 and \$1 million. A relative hazard factor is shown along the horizontal on the bottom. The scale on the bottom is arithmetic, so this is a semilog plot. The relative hazard factors shown are 1.0 for a simple crossbuck system, 0.2 for flashing lights, about 0.1 for lights and gates and extremely low number for grade separation. The lower the number, the safer the protection system in question.

The upper curve in red shows the initial installation costs of each type of protection. The bottom curve in blue shows the total annual costs including depreciation and maintenance. The numbers used to construct these graphs come from recent reports and represent ballpark figures perhaps a bit on the low side. There is, of course, a wide variation. As you can see there is a wide gap where an intermediate type of crossing protection might fit. Costs for the intermediate system might range from \$500—\$2,000. There is a need for intermediate protection for upgrading crossings that warrant more than the bare minimum but which do not have enough train or vehicle volume to warrant automatic protection. Passive sign systems could well fit in here. Lower cost automatic devices at this time do not show promise of being low enough in cost to fill the intermediate need.

Improvements

It seems clear that there is need for relatively low-cost improvements in passive traffic control devices (signs) at railroad crossings. We have considered that there are several guiding principles for meeting this need:

Principles

(1) Distinction between protected versus unprotected crossings to inform the motorist that it is his entire burden to detect trains.
(2) Redundant display of cues, i.e., distinctions in as many aspects as possible, e.g., color, shape, symbols, etc.
(3) Recognition of the crossbuck symbol's utility and its use in foreign countries.
(4) The need for symbology plus words at least during an introductory initial period.
(5) Cost and technology constraints.
(6) Acknowledgement of the Manual of Uniform Traffic Control Devices (MUTCD) principles of color, shape, size and location of warning devices.

These principles as they regard color are shown in Figure 3. This figure represents our interpretation of the hazards encountered on all of the roadway (not just crossings) and the sign colors which are used. It divides hazards into two measures—the *frequency* of accidents at any given location shown along the bottom and the *severity* of accidents, shown along the vertical. The lower left corner represents the safest part of the roadway, the upper right corner the most hazardous. The lower right corner represents where frequent but non-severe, "fender-bender" accidents occur. The upper left represents where infrequent but severe accidents occur.....Starting with the upper right we encounter an area where traffic control devices cannot do the job and physical separation is needed such as grade separation at crossing. Then in progressively less severe situations, the color red is used, followed by the new intermediate color, orange (now used for construction and maintenance signs) and the familiar yellow used for warning signs. In the low hazard part of the roadway other types of signs such as guide signs and informational signs of blue, green and brown, can be used and they should be used there only.

We propose that where an unusually severe type of accident may result at low or medium frequency risk, that brilliant yellow green be used as a warning color. This fits for example the rural grade crossing situation where there may be 10-15 years between accidents but where fatalities occur with each accident. The diagram shows where we propose that brilliant yellow green might fit, in the high severity area where red is not called for. BYG is a reserve color approved by the National Joint Committee but is not in current use. All the other colors shown are in current use. As an alternative to BYG, yellow together with red for greater emphasis might be used.

Proposed Signs

A. Protected Crossings

The principle (1) of clearly distinguishing protected from unprotected crossings led us to choose a unique shape, namely, the familiar circular disc which agrees with principle (6). It also led us to choose the color yellow mixed with the color red. This mixture of colors was chosen to indicate the high degree of risk and severity associated with train-vehicle collisions at well traveled crossings. The disc shape and yellow warning color were carried through to the back plate we advocate be placed on the flashing lights in order to increase their passive target value and assist the driver in task 5 "locating the crossing."

Figure (s) 4, 5 & 6 show the proposed set of warning signs of protected crossings.

Figure 4— (36" yellow RxR disc with red quadrants) This sign helps with task 1 and agrees with all 6 principles.

Figure 5 — (36" yellow disc with red flashing light symbol) Helps with the added task of realizing he must look for flashers, agrees with four principles. The words "signal ahead" were put on the sign instead of on a separate plaque for economy reasons, possible in this case because they do not distort the symbol.
(Figure 5A). They would be removed on replacement signs after a period of driver education. *(Figure 5B)* Note—an appropriately different symbol could be used where only wig-wags or gates are installed.

Figure 6— (large 48" yellow disc fitted over lights) Helps with task 5 and task 6.
Note—This can be augmented with crossbucks, preferably yellow. Also it may be desirable to include a 4" wide ring of black around each light.

B. Unprotected Crossings

Principles number 1, 2 and 6 led us to choose the diamond shape. The color brilliant-yellow-green (BYG) is recognized by the National Advisory Committee on Traffic Control Devices (NACTCD) as having the highest target value. Since the NACTCD has not yet assigned a meaning for BYG we are proposing its use for high severity hazards of low to medium accident frequency including these important passive unprotected crossing traffic control devices in order to satisfy principles 1, 2 and 6.

Figures 7, 8 and 9 show the warning signs proposed for unprotected crossings.

Figure 7 (36" BYG diamond-crossing symbol) Helps with tasks 1 and 2 and 3—agrees with principles 1, 2 and 4 and 6. Here again the word "ahead" was incorporated on the sign instead of a plaque (Figure 7a) but could be omitted after a period of time on replacement signs (Figure 7B).
Note—if symbol also shows track alignment, such as the tracks crossing at an angle, it can help task 6.

Figure 8—(36" BYG diamond—"Trains?" symbol) Helps with tasks 1, 2 and 3—agrees with principles 1, 2, 4 and 6. The educational plaque would eventually be eliminated. A variation would show the train symbol at the top with the question mark below.

Figure 9—(48" BYG crossbuck) Helps with tasks 5 and 6—agrees with principles 1, 2, 3 and 6.

These two sets of signs are recommended for consideration and inclusion in reaserch evaluations of various improvements in warning systems at railroad-highway crossings. We consider these to be relatively low cost and therefore in agreement with principle 5 and with the ideas set forth in Figure 2 where a clear-cut need is shown for such devices. Driver reaction will of course be the deciding factor and due care must be exercised to experimentally control for the "novelty effect" such new signs will engender.

Another area which can be considered *independently* of the above two proposed systems is that of providing a different colored crossbuck. Figure 10 shows the yellow crossbuck without the familiar "Rail-Road Crossing" legend. Figures 11 and 12 show the Swiss version of the St. Andrews cross for single and multiple tracks, in use in Europe. The use of either yellow or red gives greater contrast with the background and provides for greater hazard warning. These signs could also be used with the "Yield" sign, Figures 13, 14 & 15 to show that the train always has the right-of-way and imply *some* slowing action (not stopping or excessive slowing) as the safest procedure at a crossing.

Along with the two basic sets of signs and the crossbuck series we also recommend consideration of the potential use of several additional relatively low-cost traffic control devices at those special locations where added warning is judged by the traffic engineer to be required. Several such devices and techniques are briefly described below:

(1) The use of oversize signs.
(2) The use of backshields to provide added target value against particular backgrounds.
(3) Signs installed on both sides of the roadway.
(4) Repetition of signs as needed.
(5) Use of advisory speed plates on same post.
(6) Use of several advisory speed plate mounted singly and in various patterns to influence speed awareness on the part of the motorist (e.g., a "funnel" effect where a number of speed plates are used as delineators, the distance between

each becoming progressively less as the crossing is approached.)

(7) Pavement markings standard and novel as may be approved in future deliberations of the NACTCD.

(8) Raised pavement markers both reflectorized and non-reflectorized. These can be placed to create a rumble effect.

(9) Rumble strips and rough pavement (or smooth) to alert driver's attention.

(10) So-called "click sticks" (highly visible reflective panels) placed on the far side of the crossing to help detect the fact that a moving train is already occupying the crossing.

These and many other potential devices should be available (but not mandatory) for exercise of traffic engineering judgement at each particular crossing. We believe strongly that it is important to provide the traffic engineer with this ability to create added "punch" to those crossings where his professional experience causes him to feel it is necessary. Great care and restraint, however, must be exercised in order to resist the pressures that will be brought to add these "extras" at all crossings. If these (or other) extras are judiciously used, they can help to comply with public pressure for "immediate action" at those crossings where an accident has occurred and thus not only improve the level of protection but also reduce the tendency to install active devices or separation where it really is not warranted.

Summary and Conclusions

In this paper we have presented three analyses as follows: first, we have carefully studied the driving task and selected six items as being important at crossings; second, we have examined the literature and developed six guiding principles of traffic control device design and placement that we feel apply to improvement of warnings at crossings; and third, we recommend these for consideration along with our analysis of the cost vs. relative risk information available concerning grade crossing protection.

By way of example of an application of these three analyses we have presented two candidate sets of signs; one for protected and another set for unprotected crossings. We find that these carefully chosen signs are consistent with the driving task and the guiding principles. There are of course other configurations that also would be more or less consistent with the tasks and principles. We urge consideration of the proposed signs from two standpoints. First as being a tangible means of visualizing the principles upon which they were chosen, and second as a serious and practical possibility for installation and evaluation of motorist response.

Finally we plea for policies that will allow traffic engineers to fully utilize their professional judgement in designing traffic control systems for railroad-highway crossings at grade and we have presented ten candidate optional treatments for consideration as offering potential for immediate upgrading of passive device controls.

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4. *Schoppert, D. W. "A Program Definition Study for Rail-Highway Grade Crossing Improvement" PB 190401.*
5. *Richards, O. W. "Visual Needs and Possibilities for Night Automobile Driving" PB 176566.*
6. *Richards, H. A. and Bridges, G. S. "Traffic Control and Roadway Elements (Revised) Chapter 1 "Railroad Grade Crossings" Automotive Safety Foundation.*

Implementation Problems Relating to a Rail-Highway Grade Crossing Safety Program

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Florida Department of Transportation

Rail-Highway safety improvement projects require the involvement of a multitude of private and public agencies and interest groups. The coordination of fragmented fundings policies, railroad construction schedules, state and local government project coordination and the supply of a technical work force are just a few of the factors to be considered in any expanded grade crossing safety improvement programs.

We have asked a representative of a state department of transportation to discuss with us the type of problems (and possibly their solutions) that can be anticipated in an expanded safety program.

Mr. Ed Mueller, Senior Engineering Advisor to the Secretary of the State of Florida Department of Transportation will now address the conference on the subject "Program Implementation Problems." (D. M. Fergusson)

Last year in Florida, 67 persons died violently in rail-highway grade crossing accidents. Three hundred more suffered serious or permanent injury in train collisions. Economic loss was more than $5 million. Tragically, the majority of these accidents could have been prevented. Statistically, we know that the installation of automatic warning devices at all crossings could reduce the accident rate by 60 to 90%.

However, simply stating that signalization would solve the problem is very misleading. It's very much like my favorite statistical analysis of the problem of overpopulation. Confronted with the statistical fact that somewhere in the world a woman is having a baby every second, my statistician formulated a simple plan for population control; find that woman and stop her.

Statisticians have the answer to every problem. Recently, in planning a trip I was very concerned because I had been reading about the problem of bombs being smuggled aboard and exploding on airliners. Even though the odds were 10,000 to one against my being on a plane when it happened, I didn't want to take any chances so I asked my statistician how I could improve my odds. He thought about it for a couple of days and came up with a perfect solution. He planted a bomb in my briefcase and told me to carry it aboard. The odds against two on the same plane were 100 million to one.

Likewise, the simple solution of signalizing all crossings may sound good to the statistician but from a management standpoint it's probably a poor investment. We have thousands of crossings that have never experienced an accident. Is it a wise policy then to spend $20,000 or more to install automatic warning devices at each location to further reduce accident probability? On a general basis—no. On the other hand, many crossings desperately need improvements, including signalization.

The questions to be answered, then, are what protective devices are needed and justified at rail-highway grade crossings and what kind of program is needed to provide adequate protection for the traveling public.

I don't have all the answers but I do have a number of ideas to offer you for consideration. Florida DOT has an active program in rail-highway safety. We've encountered many problems. We have developed *some* workable solutions. This morning I'd like to discuss our program with you, share our approaches to some of the problems encountered and present enough unsolved problems to keep all of us busy in the Workshops this afternoon.

In discussing the Florida DOT program, I'll comment on items such as planning and budgeting, design, railroad contacts and agreements, setting priorities and construction and special programs and experiments.

Planning and Budgeting

The planning and budgeting process involves the inventory of crossings, determination of deficiencies and remedial actions necessary, the estimation of improvement costs and benefits, and the establishment of priorities for budgeting.

Like many highway departments, the former Florida Road Department had a hazard index formula back in 1966. An inventory was made of all state road crossings. A "Hazard Index" computed, and a list of priorities generated according to the relative hazard of each crossing. This system was deficient because:

1. No source of funds was set aside specifically for installation of recommended devices.
2. There was no scientific evidence correlating accidents with the geometric features measured or for assigning weights to factors in the "Hazard" formula.
3. There was no economic analysis associated with the determination of protective devices warranted by the formula. Arbitrary cutoff points were established to determine whether a crossing required passive protection, flashing lights, gates or a more sophisticated installation.
4. The inventory was limited to state road crossings—less than 20% of the crossings in Florida.

Our current program is a far cry from this initial attempt at rail-highway safety.

To fund improvements at dangerous crossings, Florida DOT set aside $1 million in state funds in its 1971 construction budget. In October, 1971, Florida's concern for rail crossing safety was echoed by the U.S. Department of Transportation when they announced the release of special Federal safety funds for highway improvements. U.S. DOT identified rail-highway crossings as the number one safety problem in the country and gave top priority to their protection for expenditure of funds, which were made available on a first come-first served basis.

Florida's early involvement in this area enabled the Department to immediately capture $3-½ million of the Federal funds—more than 1/3 of the total amount obligated nationwide. An additional $1 million was obligated under the TOPICS Program for rail crossing improvements.

Having this amount in this special safety program was no accident—it was the result of careful preparation. Obligation of the Federal funds required prior submission of engineering plans, cost estimates, and legal agreements with the individual railroads to perform the signal installation work. Florida was in a good position to make such a submission.

The Department of Transportation had available a complete listing of all crossings on the state maintained highway system and an analysis of the signal needs at each location. Furthermore, as a result of our ongoing program; plans, cost estimates and agreements were complete or in process for many crossings. Procedures and responsibilities were well-defined and the additional work necessary to obligate the federal funds was performed quickly and without undue disruption of the Department's normal operations.

A recent modification of our program involved the development of a new accident probability formula to replace the old hazard index. Our computer now forecasts the accident potential at each crossing, calculates the expected economic loss due to train-vehicle collisions over a period of time, and using cost effectiveness analysis, determines the best way to distribute funds to save lives.

Finally, in order to deal with the problem of limited jurisdiction, the DOT proposed legislation which would give the Department legal authority to regulate crossing protection and train speeds throughout the state. With support from the Governor's Office and the Highway Safety Commission, the bill was adopted by the State Legislature and signed into law. Florida is now in a position to implement the comprehensive programs necessary to develop a modern rail-transit system with adequate protection of the safety of the traveling public on the highway—and on the track.

By this act, the DOT acquired jurisdiction over the 5000+ locations where the railroad intersects with city streets and country roads not maintained by the state. Local governments, formerly responsible for the crossings, were hampered by limited funds and a lack of comprehensive engineering programs for rail-highway safety. Consequently, little was done.

DOT is now in the process of inventorying all of these crossings to determine signal requirements. At the same time, we are developing preliminary recommendations for crossings to be closed. We consider closing crossings an integral part of the overall plan to provide adequate protection throughout the state.

Economically, it is not feasible to install signals at all crossings, Furthermore, it is seriously doubtful that the continued existence of certain crossings is justified. There are many crossings where traffic is so light and alternate access so convenient that closing is the only reasonable recommendation.

Of course, any plan to close crossings must be developed cooperatively with the local governments, the railroads, and the citizens involved. State law makes adequate provision for local participation through public hearing procedures which must precede any closing by the Department.

One final revision in the planning and budgeting process was made to extend the rail-highway safety program. Every project listed in our 5-year work program is examined for railroad crossings. All crossings are evaluated in terms of the types of protective devices necessary for the conditions anticipated on the completed project. This evaluation applies to *all* new construction, reconstruction, widening and resurfacing projects. The necessary crossing improvements (including signals) are budgeted as part of the proposed construction project.

We believe this addition to our program is significant because every improvement in roadway conditions, whether it be new construction or resurfacing, encourages increased traffic volumes, higher speeds, and a generally less cautious attitude on the part of the driver. Any of these conditions increase the potential hazard of an unprotected or an inadequately protected railroad crossing. Consequently, the Florida DOT will not allow partial roadway improvements that call for "feathering down" or "tapering" of the approach pavement to a crossing.

Design

Once crossing improvement were programmed, two design operations took place. First, the roadway agency scheduled field surveys and prepared crossing site plans. Synchronization plans were also prepared for those projects requiring pre-emption of traffic signals. Following preparation and submission of these plans, detailed signal plans must be prepared by the railroad company involved.

In Florida, we encountered serious problems in the the development of both the roadway plans and the signal plans.

Rail crossing site plans have traditionally been treated as between-job "fillers" in the design offices. Because of their simplicity, they were not properly scheduled as were more complex jobs. We now require that all railroad site plans be prepared at the *beginning* of each budget year.

One additional benefit of this new procedure is that it allows early negotiation of legal agreements and this reduces some of the time lost in the agreement process.

The second problem relating to the design stage occurs in the railroad office and is not so easily solved. Each railroad signal installation is individually designed. The standardization of signal components now widespread in roadway traffic signals is virtually nonexistent in the design of railroad signals. As a result, serious delays occur in the design, manufacture, and delivery of railroad signal equipment. In Florida, the average time lapse in this process exceeds one year. We believe this area of signal design could greatly benefit from application of recent technological advances and feel that signal prepackaging could revolutionize the industry.

Railroad Contacts and Agreements

Completion of the initial crossing site plans is the normal signal for initiation of contact with the railroad and for negotiation of the legal agreements necessary to authorize signal installations. This process also involves serious delays. The Florida DOT has taken two steps to expedite negotiations. First, a permanent, full-time liaison position was established within the Department. This man is specifically assigned to follow-through on individual projects after their initial submission to the railroads, and to follow-through on the construction of individual crossing projects after completion of agreements. Benefits resulting from establishment of this position included a noticeable improvement of the Department's "credibility" with the railroads and markedly improved communications between the DOT and the railroad companies.

Our second approach to expediting the agreement process has proven to be our most productive and most successful innovation in the rail-highway safety program. This step was the establishment of quarterly meetings between the Secretary of Transportation and railroad company key executives. This top level communication has been effective for a number of reasons. First of all, the sincerity of all parties and their willingness to work toward a common goal was immediately apparent. The resulting atmosphere of trust and friendship led to gratifyingly straightforward communication of ideas and criticisms. This in turn, led to many of the innovative changes I've discussed here today. Additionally, the DOT:

-Accepted the financial responsibility for 50% of the maintenance cost for signals on the state system. This relieved a heavy financial burden from the railroads and removed a serious obstacle to progress in the program;

-Altered its policy for the installation of automatic gates, thus allowing a more widespread application of these devices in urban areas.

-Initiated research leading to application of additional forms of passive protection at crossings, including improved signing and pavement markings and illumination at selected locations;

-Established the full-time liaision position described above.

The railroads, in turn:

-Accepted the DOT's hazard criteria (Accident prediction formula) as the official basis for project site selection;

-Agreed to allow DOT to establish priorities for signal installations, thereby scheduling the railroad's construction programs;

-Agreed to bring in additional crews to accelerate their construction program in areas where safety or TOPICS programs resulted in a concentration of signal projects in a particular area.

-Agreed to accept a master agreement enabling the Department and the railroads to negotiate on a "mass" rather than an individual basis. Despite the legal complications encountered in the development of the master agreement, it is now accepted by Legal and Fiscal Offices of the state, the railroads, and the Federal Highway Administration. This document has contributed enormously to the success of Florida's program and was a significant factor in obligating Federal funds for rail-highway safety inprovements.

Setting Priorities and Construction

Once the legal agreements have been approved, priorities must be established and signals and equipment must be installed. As mentioned earlier, the DOT sets construction priorities. However, signal installations must be performed by crews employed by the railroad companies. As a consequence, serious problems and delays have occurred in the implementation of safety projects. Historically, the railroad crews have not been able to keep pace with their ever-increasing work load. Florida crews are now able to handle signal installations and relocations which must be performed in conjunction with new construction and reconstruction projects. Beyond this they are able to do little or none of the installation work programmed as separate safety projects.

Three hundred fourteen (314) installation agreements between DOT and railroads operating in Florida are currently pending. At the traditional installation pace, this represents a construction backlog of almost seven years work. The construction bottleneck represents a serious threat to the success of the entire rail-highway safety program and the problem will be greatly accentuated by the DOT's commitment of additional millions of dollars (over and above the $4-½ million already committed) to the rail crossing safety program in the years to come.

Although the employment of additional crews by the railroads would afford some relief, the railroads are reluctant to appreciably expand their crews for a number of reasons. In the long run, it appears that the most effective solution to the construction problem is a change in procedures to allow the states to contract the work to independent firms. This proposal has not met with overwhelming success in Florida, or anywhere else, for that matter. Strong support at high governmental levels will be necessary to bring about any change.

The Florida DOT has initiated attempts to contract signal installation work on a limited basis with a non-unionized railroad to test the merits of this proposal. However, to date, no signal installations have been made by independent contractors.

We are also investigating the feasibility and desirability of purchasing and warehousing signal equipment. Hardware would be provided to the railroads on a job by job basis under this arrangement. The possibilities of quantity discounts and uniform specifications led to our interest in this proposal. Initially, only common equipment would be purchased due to the lack of uniform specifications. However, we regard this as a first step toward the eventual development of signal control packages.

Special programs and Experiments

In addition to our regular rail-highway safety program, the Department has underway a number of special programs and experiments which merit discussion. Our most important special program is an on-going study of certain high-speed corridors potentially suitable for rapid rail passenger service. Passage of legislation authorizing the DOT to control train speeds and crossing protection provided added incentive to pursue this program. Detailed analyses of the Tampa-Orlando (Disneyworld) and Orlando-Miami corridors have shown the feasibility of high speed train operations and market surveys have shown the need. Implementation funds have not been made available, although the Federal Government has shown interest in the projects.

The TOPICS program has also been used to augment our regular rail safety program. Under a recent TOPICS contract 28 crossings were signalized in Orlando. Thirty-one additional crossings are programmed for TOPICS funds in the Miami area. The chief limitation on TOPICS funds is that they can only be spent in urban areas.

Experimental projects currently underway in the State of Florida include the following:

1. A number of unsignalized crossings where slow freights or switching movements create a night-time hazard are being illuminated to prevent motorists from hitting the sides of trains. This is a significant problem since it represents roughly one-third of all train-vehicle collisions. The problem was emphasized last week when a Florida Highway Patrolman, leaving the scene of an accident, crashed into the side of a freight train. Fortunately, the trooper was able to crawl from his car seconds before the ruptured gas tank exploded.
2. Improved signs and pavement markings are being tested in advance of railroad crossings. The most

recent experimental design utilized raised reflectors embedded in thermo-plastic tape to provide a "rumble" effect in addition to excellent day and nighttime visibility.

3. Programmed traffic signals are being interconnected with automatic railroad warning flashers. The new programmed lights can be seen by drivers unaffected by the train movements.
4. Advance warning flashers are being interconnected with automatic flashing lights at crossings where sight obstructions or road alignment restrict the driver's view of trackside signals.
5. A task force comprising railroad and DOT personnel has been established to develop recommendations for achieving uniform specifications for traffic and railroad signal equipment. An experimental device utilizing Strobe Lights (Xenon Tubes) in a standard railroad flasher has been developed and is being demonstrated here this week.

Conclusion

In closing, I would simply like to say that every step in the path to success in rail-highway safety is strewn with pitfalls, but the problems are not insurmountable. The cost of providing adequate protection at all crossings is considerable. But, by comparison, so is the continuing cost in lives, injuries and property damage sustained in train-vehicle accidents. The Federal Government has clearly shown its interest in the program and its determination to make funds available for this purpose.

Clearly, the protection of the public is a matter of great concern at the local and national levels. Support from concerned individuals and citizens groups increases every day. The force is irresistable. I, for one, believe that the subject is not immovable.

Warrants for Safety Improvements at Railroad-Highway Grade Crossings

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The function of the rail-highway grade crossing warning system is to advise and warn the driver of the potential or actual hazard and the responsibilities and actions required of him. In order to provide a standard warning system on a "where needed" basis, certain uniformity for the selection and location of the protective devices is required.

We have asked representatives of the Federal Highway Administration to discuss for us engineering and economic warrants for the installation of protective devices. The paper is to be presented by Mrs. Phyllis Huntington, FHWA. (D. M. Fergusson)

Introduction

This paper briefly reviews existing warrants for grade crossing protection. It presents the results of a new method for estimating train-involved accidents, using the largest data base ever assembled for a grade crossing study. The paper also suggests further steps to translate expected accidents into warrants.

Background

By definition, a warrant is a justification for a decision. Warrants are developed for making changes to an existing condition leading to an improvement. A warrant should be determined through analytical or engineering studies; it should not be a matter for subjective opinion. At rail-highway grade crossings, an improvement is defined as a measurable reduction in hazardous conditions effected by a modification at or approaching the crossing.

Warrants provide the decision maker with guides and measures for his use in deciding whether or not to undertake a grade crossing improvement or to direct his resources to another improvement project. When considering grade crossing improvements only, warrants assist in the development of an orderly systematic program of improvements. They may be used to determine (1) the crossings to be improved, (2) the nature of the improvement, and (3) the priorities for their improvement. Existing warrants for grade crossing protection are shown in Table 1.

It may be noted that none of these warrants includes a specific number for any of the factors which appear to be related to accident potential such as highway volume, train volume, or accident experience.

Further, the general warrant for installation of active protection in the MUTCD[1] is simply "where studies indicate the need of protection beyond that provided by signs."

Safety as the Major Criterion

Since grade crossing protection is essentially a safety improvement with its objective being the reduction of accidents and the resulting prevention of fatalities, injuries and property damage—the prime warrant for grade crossing protection should logically be the accident potential of a crossing or group of crossings being considered for improvement.

[1] Manual on Uniform Control Devices

TABLE 1
Existing Warrants for Protection at Public Railroad-Highway Grade Crossings

Warranted Improvement	Warrant	Governing Document	Application
Passive Protection			
Signs			
Crossbuck	Crossing	MUTCD	All Hwys.
Crossbuck with Track Indication	Two or More Tracks	MUTCD	All Hwys.
Railroad Advance Warning Sign	Crossing	MUTCD	All Hwys.
Markings			
Pavement Markings	Highway Speeds of 40 MPH or Over	MUTCD	All Hwys.
	Active Protection	MUTCD	All Hwys.
Active Protection			
Flashing Light Signals With or Without Automatic Gates	Need for More Than Signs	MUTCD	All Hwys.
Flashing Light Signals With Automatic Gates	Multiple Mainline Tracks	Federal Highway Adm. Policy & Procedure	Federal-Aid Projects
	Multiple Track With Simultaneous Train Movements	Memorandum (PPM) 21-10	Federal-Aid Projects
	Crossings with Restricted Sight Distance Used by High Speed Trains	Federal Highway Adm. Policy & Procedure Memorandum (PPM) 21-10	Federal-Aid Projects

There have been several studies to develop "hazard indices" for use in ranking crossings by degree of expected hazard. Further, a few studies have attempted to predict the number of expected accidents at grade crossings.

Probably the most comprehensive and currently most widely used accident predictors are those reported in 1968 in NCHRP 50. That study involved the analysis of data for some 7,720 crossings.

Current Research

In 1971 the Federal Highway Administration retained Alan M. Voorhees and Associates to do further research in the area of accident potential at grade crossings. A data base of over 20,000 crossings was accumulated for that study, over 16,000 of which had 5 years of accident experience. This is the largest data base ever assembled on train-involved grade crossing accidents that includes corresponding crossing descriptive information.

This most recent study analyzed accident potential for individual crossings using regression analysis and for broad groups of crossings using summary accident statistics.

The study found, as had previous efforts, that regression equations developed for individual crossings did not explain a significant amount of the variation in accidents. This was true in spite of the superiority of the data base in comparison with previous studies.

As a result of that finding the FHWA decided to attempt to analyze the accident potential for *groups* of crossings, using least squares regression.

This attempt was further motivated by the fact that FHWA had a recently completed nationwide inventory for groups of crossings as well as data on the total number of train-involved accidents nationwide, the total number at crossings with active protection and with passive protection, the total number at crossings in urban areas and in rural areas, and the total number at crossings protected with automatic gates. The availability of this information permitted a check on the ability of the regression equations to accurately predict the number of accidents nationwide by the categories listed above.

Data used consisted of a sample of 16,340 individual crossings for which inventory data and five years of train-involved accident experience were available. The inventory data for each crossing included average daily highway volume, daily train volume, type of protection, area (urban or rural), and number of tracks. It was provided by four States—Minnesota (6,360 crossings), North Carolina (5,680 crossings), South Dakota (3,250 crossings), and Maryland (1,050 crossings).

Methodology

The data described above were stratified into groups by type of area (urban vs. rural) and by the six types of protection (none, stop signs, crossbucks, automatic gates, flashing light signals, and "other active") included in the nationwide inventory. The numbers of crossings and accidents that fell into each of these stratifications are summarized in Table 2.

The crossings within each group in Table 2 were then separated into several ranges of highway volume and train volume and for each set of data the following values were tabulated and are displayed in Tables A-1 through A-4 in the appendix.

- N_T — Total number of crossings.
- P_O — Proportion of total crossings having no accidents in the 5-year period.
- A — Total number of accidents in the 5-year period.
- $\overline{V}$ — Mean daily highway traffic volume.
- $\overline{T}$ — Mean daily train traffic volume.

The volume ranges of average daily highway traffic and average daily train traffic used for the initial groupings were the same as those in the nationwide grade crossing inventory maintained by FHWA. The volume ranges for both the highway (V) and train (T) traffic volumes were then adjusted to achieve a large number of groups containing a minimum of 30 crossings. As many volume groups as possible up to a maximum of 36, defined by the matrix of 6 highway volumes by 6 train volumes as defined in the nationwide inventory, were obtained for each combination of area and type of protection.

The minimum of 30 crossings for any group mean to be used in the regression was selected to insure that the estimate of the true group mean by the sample group mean was statistically valid.

Multiple linear regression was then used to relate the mean number of accidents per crossing for each group to the mean group train and highway traffic volumes. This approach gave equal weight to each group which met the minimum sample size criterion of 30 crossings; that is, a group mean based on 5,000 crossings was treated the same as a group mean based on 50 crossings.

Limitations in the number of data points for the attempted regressions for the protection devices of "none," stop signs, "other active" and automatic gates led to the aggregation of all passive crossing protection types and all active crossing protection types. This resulted in the development of four equations for expected train-involved accidents as a function of highway and train volume—one each for urban passive, urban active, rural passive and rural active.

Based on analyses of the raw data, several transformations were performed on the variables in the interest of obtaining a linear relationship between the dependent variable and each of the independent variables. The final regression equations take the following form:

$$\text{Log}_{10} \overline{A} = C_0 + C_1 \log_{10} \overline{V} + C_2 \sqrt{\overline{T}}$$

where

$\overline{A}$ = Mean number of accidents per crossing for 5 years in a group of crossings which carry highway and train traffic volumes within preselected ranges.

- C_i = Coefficients of the regression.
- $\overline{V}$ = Mean daily highway traffic volume in the group of crossings.
- $\overline{T}$ = Mean daily train traffic volume in the group of crossings.

TABLE 2

Number of Crossings and Train-Involved Accidents By Area and Type of Crossing Protection

	Urban		Rural		Combined Urban-Rural	
Passive	**Crossings**	**Accidents**	**Crossings**	**Accidents**	**Crossings**	**Accidents**
None	892	109	675	30	1,567	139
Crossbucks	3,234	953	8,439	743	11,673	1,696
Stop Signs	217	112	681	112	898	224
Total Passive	4,343	1,174	9,795	885	14,138	2,059
Active						
Automatic Gates	180	79	77	24	257	103
Flashing Light Signals	1,104	672	637	191	1,741	863
Other Active	122	64	82	14	204	78
Total Active	1,406	815	796	229	2,202	1,044
Total Crossings	5,749	1,989	10,591	1,114	16,340	3,103

TABLE 3

Best-Fit Equations for Group-Mean Observations to Predict Expected 5-yr. Accidents per Crossing

$$\mathrm{Log}_{10}\ \overline{A} = C_0 + C_1\ \mathrm{Log}_{10}\ \overline{V} + C_2\sqrt{\overline{T}}$$

Area-Protection	Regression Coefficients			R[3]	N[3]	E[3]
	C_0	C_1	C_2			
Urban-Passive	-1.813	.321	.164	.90	20	.022
Urban-Active	-1.915	.321	.185	.89	16	.034
Rural-Passive	-3.031	.699	.218	.94	16	.021
Rural-Active	-2.624	.487	.209	.87	13	.040

[3]R = Multiple correlation coefficient
N = Number of groups
E = Standard error of estimate
$\overline{A}$ = Mean number of accidents per crossing for 5 years
$\overline{V}$ = Mean daily highway traffic volume in the group of crossings
$\overline{T}$ = Mean daily train traffic in the group of crossings

TABLE 4

Highway and Railroad Volume Ranges Used for Computation of Group Means for Regression

	Highway Volume Ranges[4]	Train Volume Ranges[4]
Urban Passive and Urban Active	0-300	0-2
	301-600	3-5
	601-1500	6-10
	1501-4000	over 10
	over 4000	
Rural Passive and Rural Active	0-250	0-2
	251-500	3-5
	501-1000	6-10
	1001-5000	11-20
	5001-10000	21-40
	over 10000	over 40

[4]All volumes expressed in terms of average daily traffic.

Table 3 indicates the value of the regression coefficients for the final prediction equations. As shown in Table 3, the C_1 constant in front of the logarithm of $\overline{V}$ indicates that a change in highway volume has the greatest influence in rural-passive crossings where the C_1 value is .699 and has the least influence at urban crossings where the C_1 value is .321. It should also be noted that the changes in highway and train volumes have a greater influence on expected number of accidents in rural areas than in urban areas for both passive and active protection.

Also included are the multiple correlation coefficients which reflect the amount of variation in the dependent variable accounted for by the two independent variables, the standard error of estimate in the prediction equation and the number of groups to which each regression plane was fitted.

The series of experiments performed to finalize the train and highway volume groupings resulted in the stratifications as shown in Table 4. The primary criterion for the final selection of groupings was the magnitude of the multiple correlation coefficient or the best fit of the regression curve through the group means. Since it was felt that the volume ranges should be consistent between active and passive, the volume ranges which produced the highest correlation coefficient for the passive protection categories for urban and rural areas separately were selected and the active protection equations corresponding to their respective passive volume groupings were used.

The regression equations developed were applied to the nationwide inventory of groups of crossings to check their prediction accuracy. Nationwide mean values of highway and train traffic for each group of crossings (as defined in the inventory) were computed. Data from the 1972 Highway Needs study were used to derive mean highway volumes. Mean train traffic was computed using data available from the latest Voorhees study.

The FHWA-FRA Grade Crossing Study Staff estimated for their report to the Congress that about 12,400 train-involved accidents occurred at grade crossings in 1970. This estimate was developed from accidents reported to the Federal Railroad Administration by railroad companies and from selected statewide accident statistics and summaries. Assignment of these nationwide totals of accidents to urban and to rural areas and to those crossings with passive and various forms of active protection, was also made on the basis of available statistics.

The nationwide estimates using the regression equations match the total nationwide accidents within about 2 percent. For other known accident totals such as the crossings with passive and active protection and at crossings in urban and in rural areas, the predictions using the regression equation ranged from within 2 percent to 10 percent of the known totals. This indicates that the equations reasonably well represent the nationwide situation.

Figure 1 illustrates the four equations in graphical form showing expected 5 year accidents per crossing at various highway volumes for a fixed 10 trains per day. You will note that while the expected number of accidents increases with increased highway volume, it does not do so linearly. The steepness of the curve in the low highway volume ranges indicates that changes in highway traffic in these low volume ranges will result in the greatest change in accident potential.

The primary use of the equations is to assess the savings in train involved accidents as a result of upgrading the crossing protection. For example, if a particular rural crossing was carrying 5,000 vehicles and 10 trains per day, Figure 1 indicates that you would expect 1.75 accidents in a 5 year period with passive protection. The expected accidents if the same crossing were afforded active protection would be 0.7 accidents in five years. Thus, an upgrading of this crossing from passive to active would produce a potential savings of 1.05 train involved accidents over a 5 year period.

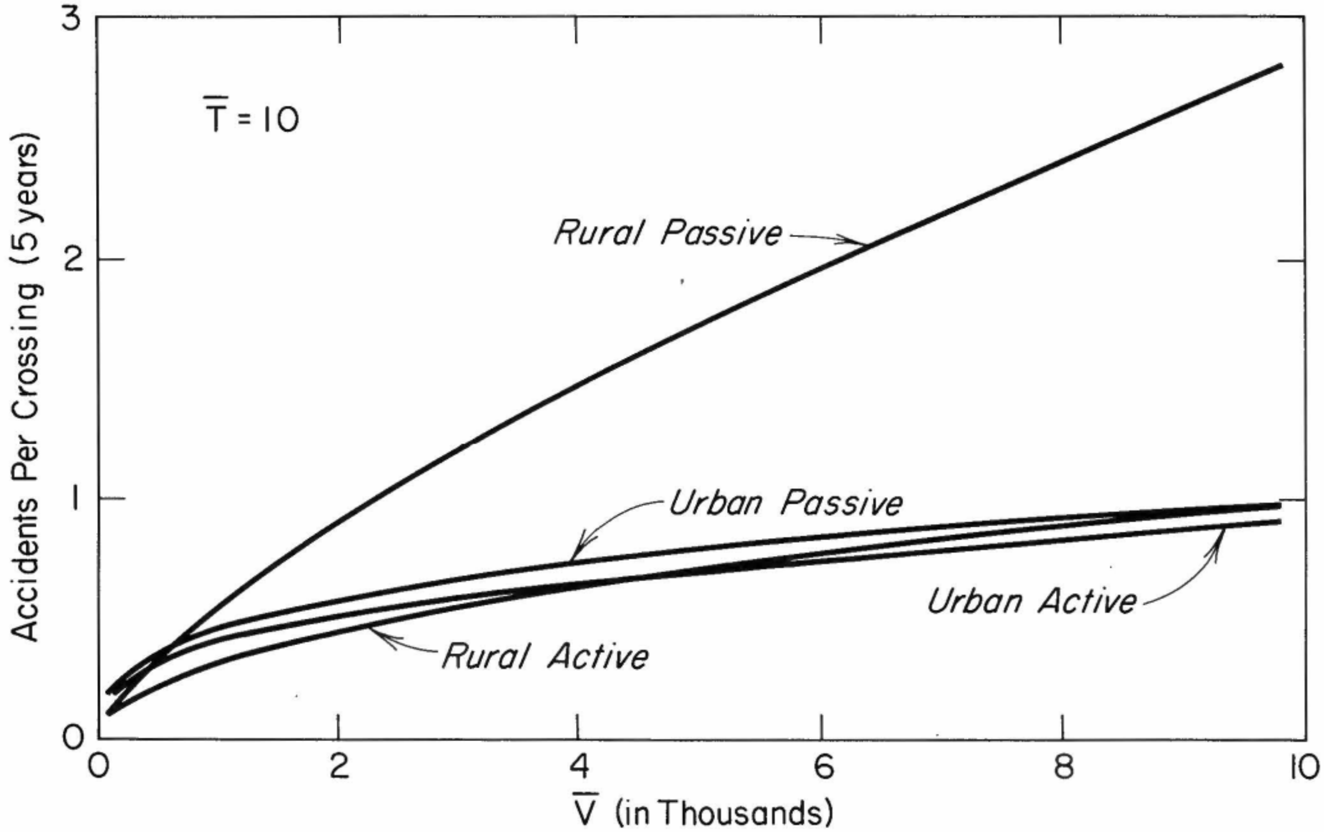

Figure 1: Expected Five Year Accidents Per Crossing for T = 10

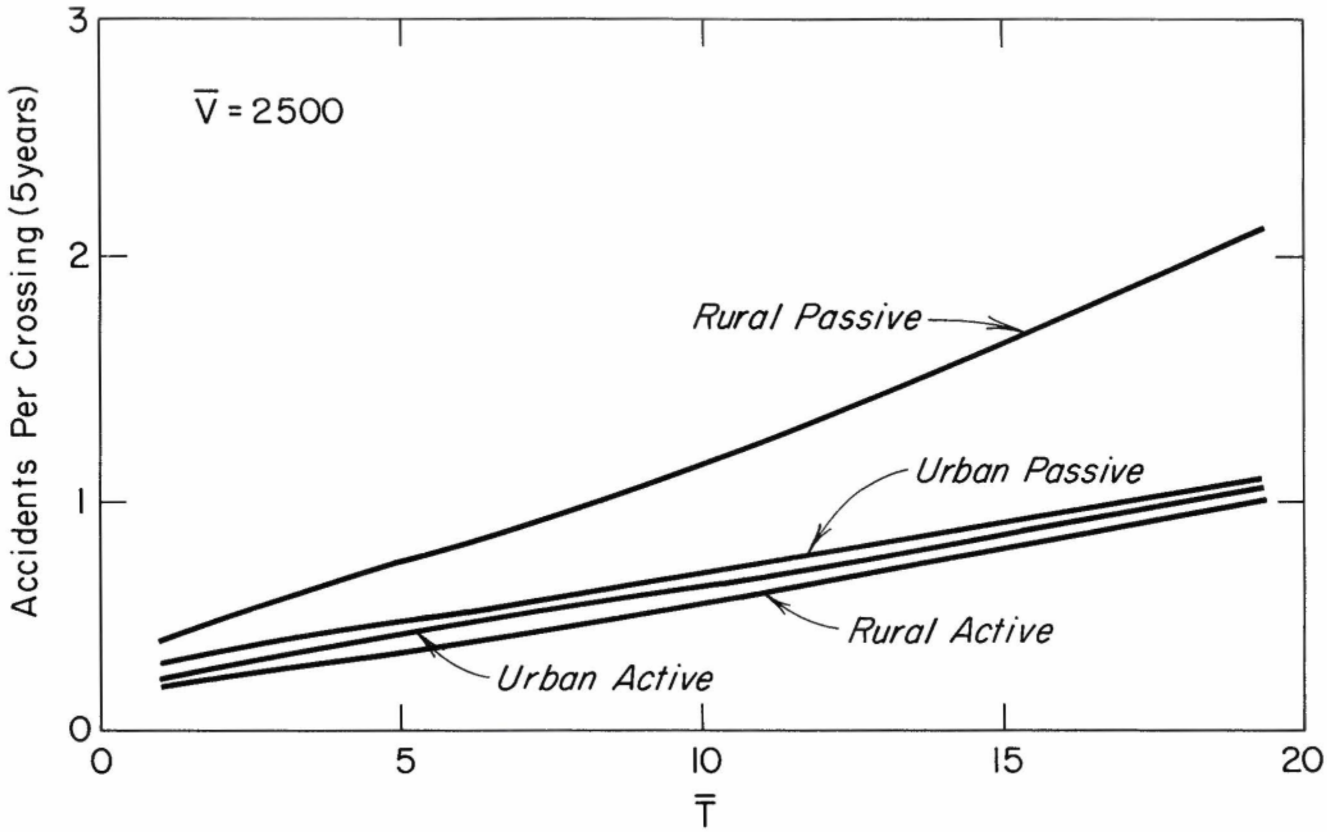

Figure 2: Expected Five Year Accidents Per Crossing for V = 2500

Figure 2 illustrates the expected five year accidents per crossing at various daily train traffic levels for a fixed highway volume of 2,500 vehicles per day. This figure shows that accident frequency increases as train volume increases. You will note that there is generally a straight line relationship between accident frequency and train traffic. It should be noted that the difference in accident potential between active and passive levels of protection is more pronounced in rural areas than in urban areas.

The actual data points represented in the construction of each regression curve are included in the Appendix.

Recommended Application

The train and highway volume ranges for which the equations can be used with confidence are indicated in Table 5. They may be used beyond these volume limits but with much less confidence. It is hoped that FHWA will be able to obtain additional data in the near future to overcome the deficiencies in the data base at the high volume extremes and to permit isolation of specific levels of protection beyond the active/passive stratification.

Nevertheless, these equations can be used to predict accidents at groups of crossings with a high degree of confidence. They can also be used to predict accidents at individual crossings but with somewhat less confidence. The prediction equations reported herein are considered superior to existing regression equations developed for individual crossings since they overcome the problems of skewed data, large numbers of crossings with no accidents, and the fitting of continuous functions to discrete data.

In lieu of using the equation to find the expected accidents at various levels of daily highway traffic and daily train traffic, one may use the actual data points and affix your own curves, perhaps even supplemented with data from your own area.

Severity

Once the accident potential of a crossing or group of crossings has been established, the next essential element in developing warrants is the severity of those accidents.

The level of severity of train-involved accidents in urban and rural areas was estimated by the FHWA-FRA staff from the State summaries of accident reports. These data indicated 0.21 fatalities per train-involved accident at rural crossings contrasted with 0.065 fatalities per accident in urban areas. The available data showed an injury rate of 0.63 injuries per rural accident versus 0.53 injuries per urban accident. Furthermore, the injuries at rural crossings were found to be more severe than the injuries at urban crossings. Available data suggest that severity difference between urban and rural train-involved accidents are largely explainable by differences in motor vehicle and train operating speeds.

The significant difference in severity between urban and rural crossing accidents places the decision maker in a position of choosing between emphasizing a reduction of accidents and a reduction of fatalities.

One approach is the assignment of weights to various levels of severity—fatality, injury, and property damage. A form of weighting is to place a monetary value on the loss to society due to a fatality, an injury or a property damage only accident. This latter approach would permit computation of a composite dollar value for an urban grade crossing accident and for a rural grade crossing accident.

The availability of an accepted composite grade crossing accident cost would afford the opportunity to fully assess the merits of crossing improvements in economic terms. Warrants for the installation of improved levels of crossing protection are then established at that point in the economic analysis where benefits exceed the cost by a preselected amount.

TABLE 5

Valid Range of Application of Regression Equations

Area-Protection	Highway Traffic Volume[6]		Train Traffic Volume[6]	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Urban-Passive	100	8,000	1	20
Urban-Active	100	10,000	1	25
Rural-Passive	0	2,000	1	15
Rural Active	100	2,000	1	15

[6]Traffic volume expressed as average number per day.

TABLE A-1

Summary of Five Year Grade Crossing Accident Data
Area: Urban Protection: Passive
Total Crossings: 4343
(See Note Below)

Train Volume (No./Day)	Highway Volume (Average Daily Traffic)				
	0-300	301-600	601-1500	1501-4000	>4000
0-2	1002	643	429	324	282
	80	88	74	86	113
	.933	.885	.872	.806	.752
	138	460	979	2531	7338
	1.50	1.71	1.69	1.63	1.67
3-5	217	273	161	107	66
	35	73	64	42	34
	.880	.784	.708	.783	.667
	185	474	980	2494	7605
	3.82	3.88	3.88	3.79	3.82
6-10	72	157	74	77	51
	30	46	54	64	44
	.736	.790	.568	.532	.608
	169	485	1041	2676	7816
	6.71	6.99	7.42	7.43	7.57
>10	102	153	63	50	40
	30	84	51	38	44
	.796	.627	.683	.600	.475
	166	481	1016	2516	5667
	18.69	18.16	19.51	20.00	20.75

Note: Values shown in each group are listed in the following order:

N_T = Total number of Crossings
A = Total number of accidents in 5-year period
P_O = Proportion of total crossings having no accidents in the 5-year period
$\overline{V}$ = Mean daily highway traffic volume (Average Daily Traffic)
$\overline{T}$ = Mean daily train traffic volume (No./Day)

Note: The regression equations presented in this report are based *only* on the data for those groups where $N_T \geq 30$ crossings.

TABLE A-2

Summary of Five Year Grade Crossing Accident Data
Area: Urban Protection: Active
Total Crossing: 1406
(See Note Below)

Train Volume (No./Day)	Highway Volume (Volume Daily Traffic) 0-300	301-600	601-1500	1501-4000	>4000
0-2	33	30	85	132	165
	3	8	19	30	72
	.909	.800	.812	.818	.739
	171	503	1039	2676	9055
	1.68	1.87	1.80	1.79	1.67
3-5	12	27	69	89	94
	6	8	12	33	70
	.667	.778	.841	.730	.543
	212	452	1070	2700	8236
	3.92	3.78	3.88	3.97	3.93
6-10	9	21	57	75	95
	5	7	9	34	106
	.556	.762	.842	.667	.432
	167	485	1039	2764	9995
	7.00	7.05	7.00	7.52	7.32
>10	30	72	92	112	107
	33	44	68	86	162
	.300	.653	.652	.619	.402
	184	494	1031	2521	8324
	27.37	19.85	20.28	21.48	23.75

Note: Values shown in each group are listed in the following order:

N_T = Total number of Crossings
A = Total number of accidents in 5-year period
P_O = Proportion of total crossings having no accidents in the 5-year period
$\overline{V}$ = Mean daily highway traffic volume (Average Daily Traffic)
$\overline{T}$ = Mean daily train traffic volume (No./Day)

Note: The regression equations presented in this report are based *only* on the data for those groups where $N_T \geq 30$ crossings.

TABLE A-3

Summary of Five Year Grade Crossing Accident Data
Area: Rural Protection: Passive
Total Crossings: 9795
(See Note Below)

Train Volume (No./Day)	Highway Volume (Average Daily Traffic) 0-250	251-500	501-1000	1001-5000	5001-10000	>10000
0-2	5026	509	281	210	14	12
	125	69	56	39	11	1
	.978	.884	.851	.838	.643	.917
	79	369	743	1961	7075	11512
	1.52	1.56	1.56	1.51	1.54	1.36
3-5	1408	227	92	62	4	3
	75	50	26	41	4	0
	.953	.815	.804	.645	.750	1.00
	98	360	716	1940	6525	11233
	3.95	3.92	4.03	3.84	4.00	4.00
6-10	842	124	59	39	2	
	87	44	23	19	1	NO DATA
	.911	.734	.729	.564	.500	
	107	378	733	1785	5730	
	6.87	6.89	7.07	7.36	6.00	
11-20	641	67	31	26		
	96	26	19	20	No DATA	NO DATA
	.880	.731	.549	.577		
	100	369	732	1948		
	15.04	15.51	15.06	15.31		
21-40	73	15	17	7		
	16	17	10	8	NO DATA	NO DATA
	.836	.467	.706	.571		
	80	362	678	1470		
	24.58	22.80	27.00	24.71		
>40	2	1		1		
	0	1	NO DATA	1	NO DATA	NO DATA
	1.00	0		0		
	70	280		5000		
	44.00	45.00		50.00		

Note: Values shown in each group are listed in the following order:

N_T = Total number of Crossings
A = Total number of accidents in 5-year period
P_O = Proportion of total crossings having no accidents in the 5-year period
$\overline{V}$ = Mean daily highway traffic volume (Average Daily Traffic)
$\overline{T}$ = Mean daily train traffic volume (No./Day)

Note: The regression equations presented in this report are based *only* on the data for those groups where $N_T \geq 30$ crossings.

TABLE A-4

Summary of Five Year Grade Crossing Accident Data
Area: Rural Protection: Active
Total Crossings: 796
(See Note Below)

Train Volume (No./Day)	Highway Volume (Average Daily Traffic) 0-250	251-500	501-1000	1001-5000	5001-10000	>10000
0-2	42	22	47	134	12	11
	1	5	8	30	6	1
	.976	.773	.872	.828	.667	.909
	125	368	736	2333	6506	11300
	1.33	1.69	1.52	1.52	1.83	1.82
3-5	13	42	40	52	3	1
	1	5	10	11	1	0
	.923	.881	.775	.867	.667	1.00
	153	394	743	2183	8576	10100
	4.15	4.14	4.12	3.98	4.00	4.00
6-10	37	43	37	67	11	1
	3	8	5	25	13	0
	.919	.837	.892	.716	.454	1.00
	126	403	750	1984	6330	10750
	6.95	7.00	7.62	17.15	7.45	10.00
11-20	36	30	28	36	9	2
	12	7	11	16	21	3
	.722	.767	.643	.667	.222	0
	155	405	775	1973	6366	12050
	14.81	14.80	15.25	14.58	14.22	17.00
21-40	4	8	2	13	1	
	0	5	1	10	2	NO DATA
	1.00	.500	.500	.461	0	
	127	412	775	2208	6270	
	29.00	24.75	23.00	26.08	24.00	
>40		5	5	2		
	NO DATA	2	5	1	NO DATA	NO DATA
		.600	.714	.500		
		358	610	2180		
		59.40	56.58	65.50		

Note: Values shown in each group are listed in the following order:

N_T = Total number of Crossings
A = Total number of accidents in 5-year period
P_O = Proportion of total crossings having no accidents in the 5-year period
$\overline{V}$ = Mean daily highway traffic volume (Average Daily Traffic)
$\overline{T}$ = Mean daily train traffic volume (No./Day)

Note: The regression equations presented in this report are based *only* on the data for those groups where $N_T \geq 30$ crossings.

TABLE A-5

Regression Equation Results

$$\log_{10}\overline{A} = C_0 + C_1 \log_{10}\overline{V} + C_2 \sqrt{\overline{T}}$$

Plotted Values for Figure 1

$\overline{T} = 10$

		Area—Protection Type		
V	Urban-Active	Rural-Active	Rural-Passive	Urban-Passive
50	.16373	.07345	.07012	.17820
100	.20447	.10297	.11380	.22263
250	.27429	.16095	.21583	.29880
500	.34255	.22565	.35026	.37330
1000	.42779	.31636	.56841	.46637
2500	.57386	.49451	1.07805	.62593
5000	.71667	.69329	1.74951	.78199
10000	.89500	.97199	2.83919	.97695

TABLE A-6

Regression Equation Results

$$\log_{10}\overline{A} = C_0 + C_1 \log_{10}\overline{V} + C_2 \sqrt{\overline{T}}$$

Plotted Values for Figure 2

$\overline{V} = 2500$

		Area—Protection Type		
T	Urban-Active	Rural-Active	Rural-Passive	Urban-Passive
0.5	.20172	.15161	.31397	.24793
1.0	.22851	.17457	.36375	.27689
2.0	.27259	.21311	.44790	.32372
4.0	.34983	.28255	.60119	.40376
7.0	.46055	.38561	.83162	.51512
10.0	.57386	.49451	1.07805	.62593
20.0	1.00244	.92920	2.08193	1.02589

Maintenance of Automatic Highway Crossing Signals and Gates at Grade Intersections of Highways and Railroads

J. R. DePriest
Superintendent Communications and Signals
Seaboard Coast Line Railroad
Jacksonville, Florida

Increased safety at railroad-highway grade crossings is often associated with the installation of new or improved warning devices. It should be recognized that the effectiveness of existing warning devices could be materially improved by adequate maintenance of the devices and their environment.

We have asked a representative of the railroad industry to discuss for us the involved and costly process of rail-highway grade crossing protective devices maintenance.

Mr. J. Roy DePriest, Superintendent Communications and Signals, Seaboard Coast Line Railroad will now address the conference. (D. M. Fergusson)

In the United States as of December 21, 1971, there were about 205,000 miles of railroad lines. Upon these lines 429,814,000 freight train-miles were operated during 1971. From this data, it is evident that an average of 2,096.5 freight trains were operated over each mile of line during the year, or 5.744 freight trains per day over each mile of line. The average consist of each of these trains contained 67.9 cars.

If it is assumed that the average car is 60 feet in length, then the average train length will be the product of number of cars and the length of car or 67.9 times 60, or 4,074 feet. If we divide the speed expressed in feet per second, into the length, the results will indicate the average time a grade crossing is occupied. The result for 60 M.P.H. is 46.29 seconds, 50 M.P.H. is 55.55 seconds, 40 M.P.H. is 69.44 seconds, 30 M.P.H. is 92.59 seconds, 20 M.P.H. is 138.87, 10 M.P.H. is 277.77, and 5 M.P.H. is 555.55 seconds.

Thus each crossing would be blocked by freight trains 265.89 seconds or 4.43 minutes per day or .308% of the day if running at 60 M.P.H., or 3,191.08 seconds or 53.18 minutes per day or 3.69% of the day if running at 5 M.P.H.

In the Department of Transportation's report to Congress, November, 1971, it is estimated there are 231,750 highway-railroad grade crossings in the United States. Of these, 20,730 were protected by highway crossing signals, gates or other active protection for the motorist. To be useful, these protective devices must be maintained in proper working order for use at any time, even though each crossing is occupied by trains an average of less than 5% of each day.

Webster's Seventh New Collegiate Dictionary defines the word "maintain" as a transitive verb which has at least four meanings: (1) To keep in an existing state (as of repair, efficiency or validity), or preserve machinery from failure or decline, (2) to sustain against opposition or danger—uphold and defend, (3) to continue, or persevere in, carry on, keep up, (4) to support or provide for, bear the expense of.

In order to keep the facility in its efficient state as originally installed, the necessary labor and material must be provided. The material can be purchased at a known cost, but to provide the necessary labor with adequate skill is somewhat more complicated. It is usually possible to hire unskilled workmen with a high school education, occasionally one with two years of technical training and rarely one with a college degree. Since few, if any, of our schools teach railway signal maintenance or engineering, it is necessary for the unskilled employees to learn this skill through on-the-job training supplemented by railroad-sponsored off-the-job training.

A new employee generally is hired to work with a construction crew. After acquiring the necessary skills and seniority, the employee may bid on an open job in maintenance. When assigned, his supervisor must spend considerable time with him to locate the equipment and instruct him as to an efficient routine in the maintenance of the facilities on his territory. Of course, the cost to teach this employee the necessary skills in maintenance is properly assignable to the cost of maintenance, but it usually cannot be included in bills presented to an agency participating in the cost. An employee occupying this type of position is usually designated as a Signal Maintainer.

The highway crossing signal consists of at least two lamp units mounted in a horizontal plane, with centers spaced 30 inches apart, equipped with red lenses focused for observation by motorists, or pedestrians approaching the railroad. The red lamps flash at the rate of 35 to 55 times per minute and operate for at least 20 seconds before the fastest train reaches the crossing. The flashing of the lamps continues until the last car of the train has passed the highway intersection. The lamp units are usually mounted on a support located to the right of highway or upon a cantilever bridge support with lamps above the highway.

The maintainer must periodically inspect and clean the lamp units, test, adjust voltage and replace any defective part. The signal lamp units are of high quality using a parobolic reflector with the filament of lamp located at the focal point. It is important that the lamp unit be adjusted for the proper alignment.

In order to control the flashing of the lamps, track circuits and associated logic circuits are utilized.

The elements of the direct current type of track circuit consist of an insulated joint in each rail of the track located at one end of the circuit and two other insulated joints similarly located at the opposite end of the circuit; the rails are used as electrical conductors with each of the individual rails electrically connected with the adjacent rail using a flexible wire or cable called a bond wire; at one end of the circuit, one terminal of a battery is connected through a resistor of suitable value to one of the rails of the insulated section of track and the other terminal is connected to the other rail; at the opposite end of the track circuit one rail is connected to one end of the operating coil of a relay and the other rail connected to the opposite end of that coil. With this arrangement, electrical energy flows from the battery through the rails to the coil of the relay at the other end of the circuit. If any connection is broken or if the battery is discharged, the current will cease to flow through the coil of the relay, which in turn opens the front contacts of the relay and causes the signal lamps to flash. When there are no trains occupying the track circuit or located between insulated joints at each end of the circuit, the first wheels and axle of the engine or first car causes a short circuit across the two rails, reducing the voltage to zero across the rails and thus across the coil of the relay, and thus no current will flow through the coil causing the front contacts of the relay to open. Thus the track relay is used to detect the presence of a train occupying the track circuit: When energized, a train is not present; when deenergized, a train is present.

If the relay of a track circuit is located at a highway crossing and the other end of that track circuit, the battery end, is located 3,000 feet away from the crossing, a train approaching the crossing will cause the front contacts of the track relay located at the highway crossing to open when the first wheel enters and shorts the circuit while the train is 3,000 feet from the crossing. The operation of the track relay will start a flasher relay and alternately energize the lamps of the signal, causing them to flash.

To complete the installation, another track must be provided to cause the signals to operate upon the approach of a train in the opposite direction. And a third track circuit is provided to detect the presence of a train while occupying the crossing.

Relay logic is used to stop the flashing of the signal lamps after the train has passed and is receding from the crossing.

The installation described is the simplest type of installation and is used where the speed of all trains is generally uniform and no switching occurs within the limits of the approach track circuits.

In order to maintain this simple type of highway crossing signal, a Signal Maintainer's headquarters building must be provided and stocked with the necessary spare and replacement parts. The signal supervisory staff must prepare a bulletin inviting bids from qualified employees for the position. The position must be assigned to the bidding qualified employee with the most seniority.

A means of transportation must be provided and this is usually a rail motor car or a truck, preferably equipped with two-way radio. In some instance, it is necessary that the truck be equipped for operation either on rail or highway.

The necessary tools must be provided which include such items as power drills, power grinders, power diggers, welding torches, small tools, climbing tools for line work, electrical voltmeters, ammeters, meggers, ohmmeters, portable telephone, etc.

Ice and and ice water cooler must be provided for the Maintainer. Gasoline, oil, tires and service must be provided for the truck.

Highway crossing signals are usually located where it is necessary for a Maintainer to travel many miles from one location to the other and his routine should be carefully planned in order to reduce the cost of travel and labor while driving, since this time is unproductive. At present, labor rates with fringe benefits costing 33.1% of the basic hourly rate of $5.02 per hour, it is estimated that the cost for labor while driving is about 22.27 cents per mile. If we assume the cost of operating the truck at 10 cents per mile, then the cost of travel is 32.27 cents per mile. With the elimination of the eight holidays, there are 253 working days in a year. On a job where the Maintainer must travel 75 miles per day, 18,975 miles per year will be traveled at a cost of $.3227/mile or a total of $6,123.23. If the Maintainer is able to maintain twenty sets of signals, then it will cost $306.16 a year per location for transportation for him to be in place to perform the actual productive maintenance work. Of course, if more than twenty signals can be maintained by the one employee, then this cost will be reduced.

When the Maintainer has reached the work site, he must test the facility to determine if it operates properly and make necessary repairs, replacements and adjustments.

Each track circuit has a separate battery and, in addition, a main battery is provided to supply power for the signal and associated logic in the event the commercial power is interrupted. The Maintainer should test to determine that commercial power is present and that storage batteries are receiving the proper amount of charging energy.

When primary batteries are used for electrical energy, the elements of the batteries consisting of components such as zinc, copper oxide, potassium, hydroxide and water must be replenished at intervals and this work takes considerable time and effort on the part of the Maintainer.

At regular intervals rail bonds must be inspected and those found to be defective must be replaced. This item of maintenance requires considerable time since more than a mile must be traversed by foot at the average location. At the same time, all track connections and insulated joints must be inspected and tested.

There are many other items of maintenance that must be performed, such as: removal of snow and ice from signals and gates, lubrication of mechanisms, clean and adjust the gate arm torque, record data of operation test, replacement of poles, crossarms, line wire, insulators on pins, inspection and replacement of lightning arrestors, inspect, adjust and repair time element relays.

When a railroad employee maintains railway automatic block signal or centralized traffic control, he receives feedback information concerning the improper operation of the system from the users of the system; however, when he maintains a highway crossing signal, he loses this important feedback information since most motorists do not have any means of communication directly to the Maintainer. When such information is furnished, it is usually secondhand and it sometimes loses its meaning. Therefore, the Maintainer is required to obtain the facts necessary for correction through observation and tests.

The supervisor of maintenance must have a means to communicate with the Maintainer. This can be a commercial phone or railway-owned telephone and radio facility. The cost of providing these communication facilities, when used incident to maintenance of crossing signals, is a proper charge against such maintenance.

In addition to the routine maintenance, the Maintainer must be subject to call at all hours to repair damage caused by motorists, vandals, and storms, etc. Unfortunately this item of expense is substantial.

Periodically all metal of the installation requiring paint must be painted to preserve the metal from corrosion and to improve its appearance.

To maintain a group of highway crossing signals with or without gates, it is necessary to provide a quantity of replacement parts. These parts are usually placed at the Maintainer's tool house. In addition to the cost of the material delivered to the tool house, there is an annual expense for interest on the value of inventory stocked and the cost of transporting the material from the tool house to job site by the Maintainer. If the needed inventory is stocked at two locations on the maintenance territory, the interest charge on the value of inventory will double, or increase directly proportional to the number of locations. However, as the number of inventory locations is increased with uniform spacing, the cost of transportation from job site to inventory location and return is reduced inversely proportional to the number of locations. In order to keep this expense to a minimum, an equation can be written for the cost of material at job site:

$$M_{js} = M \quad + (X\ M\ th\ I)/100 + (L\ N\ C)/(4X) \quad (1)$$

Where:

M_{js} = Cost of material at job site.

M_{th} = Cost of material including transportation charge delivered to the tool house.

X = Number of stock locations on maintenance territory.

L = Length of maintenance territory.

$\frac{L}{4X}$ = Average length of round trip from job site.

N = Number of round trips made annually from job site to tool house.

C = Cost per mile for truck with labor for driver at straight time rate.

I = Annual interest rate in percent.

If this equation (1) is differentiated with respect to X, the following equation is obtained:

$$\frac{dM_{js}}{dX} = (M_{th}\ I)/100 - (L\ N\ C)/(4X^2) \quad (2)$$

If the right side of equation (2) is set equal to zero, the minimum cost of material will be obtained when the equation is solved for X.

$$X = (25\ L\ N\ C)^{1/2}/(M_{th}\ I)^{1/2}$$

$$X^2 = (25\ L\ N\ C)/(M_{th}\ I)$$

$$M_{th} = (25\ L\ N\ C)/(X^2\ I)$$

$$N = (X^2 M_{th}\ I)/(25\ L\ C)$$

Caution is urged in using these formulae, since it was assumed that one tool house would be a necessity and no cost was included in the cost equation for the cost of housing the material. However, it would be relatively simple to expand the equation if it was decided more than one inventory location should be provided in order to reduce the cost of transportation to job site.

If the equation is solved for X by using values of L, N, C, M_{th} and I equal to 150 miles, 50 trips per year, \$.3227 per mile, \$6,050.63 in inventory and 10% per year interest, respectively, then X will be equal to 1.00 tool house when the cost of material at job site is at minimum. If the number of trips to the tool house must be increased to 200 per year, the same amount of materials must be stocked at two locations equally spaced within the territory to be maintained, in order to hold the cost of material at the job site to a minimum.

The actual cost for interest will be \$6,050.63 multiplied by 10 divided by 100 or \$605.06 and the cost for transportation of the material to the job site will be 150 miles divided by 4 and multiplied by 50 trips and multiplied by cost per mile of \$.3227, or \$605.06. It will be noted that the cost of interest is equal to the cost of transportation when the minimum total cost for material at job site is obtained.

Included in the maintenance cost of the headquarters tool house are the costs of heat, light, water, sewage, telephone and interest on investment and real estate taxes.

A proper charge to maintenance is the interest on the investment for tools and the cost of their repair and replacement.

There are many other employees and departments involved in the maintenance of highway crossing signals besides the Signal Maintainer.

When an insulated joint is to be replaced, the employees in the department of Maintenance of Ways and Structures must be used to remove and replace the joint and assist the Signal Maintainer in the replacement of the insulation. These employees must be used to keep switches, derails and other track facilities in proper adjustment, so that circuit controllers will reliably indicate their positions for the proper functioning of the logic circuits. Signal line wires, used for controls and power must be free of contact with trees, limbs or brush, and these employees are used for this purpose.

The services of the train dispatchers of the Operating or Transportation Departments is vital to the Signal Maintainer since he must know when the next train will arrive before performing certain types of work affecting the proper functioning of the signals or gates.

The radio and railroad communication lines used in the maintenance of highway crossing facilities are maintained by employees of the communication department.

The signal engineering office employees are used to replace blueprints when needed and to develop and furnish plans for logic circuit changes that may be necessary due to change of track or operating condition.

Stores Department and Purchasing Department employees are used to procure and furnish the material used for maintenance of the facilities. Since the inventory record is maintained by computer, many employees in the Data Processing Department are involved.

Since the Accounting Department has the responsibility of bookkeeping, employees of this department are used when invoices are paid, payrolls are prepared and paid, charges distributed and bills are prepared against outside parties in connection with the maintenance of highway facilities.

The Labor Relations Department employees are involved in the negotiation of contracts concerning the pay and working conditions of the Signal Maintainers.

When accidents occur, the employees of the Claims Department and the Law Department are used. Also, each time an accident occurs at a highway crossing equipped with highway signals or gates, it is necessary for the Signal Maintainer to check the facility to determine if it was operating properly and to repair any damaged equipment resulting from the accident. Many instances occur when a motorist is unable to stop for a train blocking the highway at a rail crossing and he elects to strike the highway signal or equipment case to avoid hitting the train. Of course, this increases the maintenance cost.

When law suits result, the signal maintainer is usually called as a witness, which results in extra cost for labor and traveling expenses.

Vandalism, theft and hit and run damage to highway facilities require the use of employees of the Property Protection Department.

Liability is an important item of expense in the maintenance of highway signals and this expense is not usually shared by others participating in the cost of maintenance. I recall one case where a train had stopped to either add or remove a car from the train about 4:00 A.M. one morning. The cars near the rear of the train blocked a highway crossing that was protected by a set of highway crossing signals without gates. Witnesses testified that the signals were flashing red and affording the customary indications for automobiles and trucks to stop. A sleepy truck driver passed the flashing signals and collided with the train. His attorney argued successfully that the railroad was negligent since it did not put fuses or flares on each side of the cars blocking the highway and did not send flagmen with red lights down the highway in each direction from the crossing to warn motorists that the train was occupying the crossing. It is my recollection that the driver was awarded $45,000 even though the signals operated properly. In this case, the truck driver did not comply with the signals but was rewarded by the jury's verdict.

Heretofore, maintenance of only simple installations has been discussed but, unfortunately, there are very complex installations which must be maintained. The Bureau of Public Roads (now the Federal Highway Administration) in its Policy and Procedure Memorandum 21-10 issued October 3, 1958, requires, where it participates in the installation costs, that short arm gates and flashing light signals be used for grade crossings of highways with (a) multiple main line railroad tracks, (b) multiple track crossings, with or without main tracks on which more than one train may occupy the crossing at the same time, and (c) single or multiple track crossings where train operating speed is 70 miles per hour or greater and sight distances are restricted. Since the gates will block highway traffic, it is important that the logic circuits include the necessary means to release the route to motorists as soon as safety will permit. Before the advent of the transistor, speed selection circuits and time-out circuits, were provided. These means were effective but expensive.

On most railroads, the main track is equipped with either automatic block signals or centralized traffic control and track circuits are used as the fundamental method of detecting the presence of a train in the operation of such a signal system. Before the transistor was developed, it was necessary to install additional track circuits when a highway signal or gate was installed. The railway signal system had to be modified to accommodate the highway installation.

Since 1950, the transistor has been highly developed and is produced at a reasonable cost. Several firms are now producing an "overlay" voice frequency track circuit that will permit the existing direct current track circuit used for the railroad signal system to continue in use by superimposing the voice frequency energy over the d.c. circuit. This device has eliminated many insulated joints but is more susceptible to lightning damage than equipment it replaced.

A grade crossing predictor, known as a GCP, is a modern device using transistors and other solid state components to calculate the speed of a train and its distance from a highway crossing signal with or without gates. When a train running at approximate uniform speed reaches a point about 30 seconds from the crossing, the signals are activated and the gates are lowered. The distance of the control point varies according to the speed of the train. The equipment is generally adjusted to afford 30 seconds advance operation of the signals based on the train maintaining that speed until it reaches the crossing. If, after reaching the 30 second point for a given speed, the train accelerates, less than 30 seconds advance operation of the signals will be afforded. Conversely, if the train decelerates, more than 30 seconds will elapse. If the train is stopped, the signals will stop flashing and the gates will ascend after a few seconds. It is equipped with the necessary self-checking logic to determine if it is in proper working order.

A motion sensor, detector, or monitor, is similar to the GCP except that the logic for determining speed and predicting the time before a train reaches the crossing is omitted. It will cause the crossing signals to flash after the train reaches a point located a fixed distance from the crossing. If the train stops or reverses its direction and moves from crossing, the signals will stop flashing after a few seconds.

These devices reduce the number of track circuits and insulated joints when used in a location where there is considerable switching and on those lines where the speeds of trains vary widely between large limits. This type of equipment uses more d.c. electric energy than conventional relay equipment and a means is necessary to conserve energy when the commercial a.c. power is interrupted and the signals are operating from storage batteries. These devices are new and it takes considerable time for some Maintainers to reach the same degree of perfection in maintenance as with the relay logic.

Within the last few years, the Federal Highway Administration has required that a parking or emergency lane be provided to the right of the highway. And if a highway signal is provided, it must clear this additional land by 4 feet. This requirement results in the necessity for a cantilever or bridge structure to mount the signal above the highway, and, of course, this requires a greater capital expenditure and substantially increases the maintenance cost.

In some Southern states, 50% of the cost of maintenance of highway protective devices on certain highways is borne by the State and the remainder by the railroad. In order to reduce the cost of accounting and billing, fixed charges are agreed to for certain types of installations. These annual charges range from $650 for the simplest type of highway crossing signal installation to $1,250 for a multiple track gate installation.

If all of the 231,750 crossings in the United States were equipped with highway crossing signals and the maintenance rate for simplest type were used, it would cost $150,637,500 per annum for maintenance. If the highest rate were used it would cost $289,687,500 per annum.

Railroad personnel dealing with reports of accidents at highway-rail intersections equipped with highway crossing signals are shocked by the deaths and injuries occurring at such crossings. This year a Superintendent of a State Highway Patrol was quoted as saying, "Many of the accidents were caused by the continued failure of the motoring public to accept responsibility for personal safety at the crossings. The motorist often ignores the dangers at grade crossings because he feel nothing can happen to him. He makes hundreds of safe crossings without a close call or even seeing a train. Then the day comes when he becomes a statistic."

This gentleman also urged motorists to take these precautions:

1. Watch for and obey round-shaped advance warning signs.
2. If you cross tracks daily, don't let the familiarity with the crossing dampen your caution.
3. Don't start across a crossing immediately after a train has passed.
4. Never drive onto a crossing unless you are sure there is room ahead to clear the tracks.
5. Treat a railroad crossing as any intersection. Heed all warnings and drive defensively.

An analysis of accident report indicates the following rules might well be added to this gentleman's observations:

6. Never stop on a track or where a railroad crossing gate would strike the vehicle if it should decend.
7. Stop as far as practical from the nearest railroad track when allowing a train to pass, and make certain your car does not move toward the track while the train is approaching or passing the crossing.

Unless the motorists are educated and will obey such rules, any protection provided other than grade separations will not eliminate the deaths and injuries even though our maintenance shoud be perfect.

U.S. Department of Transportation Report to Congress on Railroad-Highway Crossing Safety

A Panel

William E. Loftus—*Moderator*
Federal Railroad Administration

This morning we would like to present the culmination of more than a few years' of effort by many people—the Department of Transportation's comprehensive report on grade crossing safety. An intensive, analytical undertaking such as the grade crossing study involves many disciplines, interests, responsibilities and jurisdictions. Many of us set the NCHRP #50 Report on Factors Influencing Grade Crossing Safety as the beginning point of the five-year study and analysis which brings us to the point today where we can chart the direction of change to resolve the grade crossing problem.

In the intervening years we have had the DOT's 11-point program, its Action Group, many key research projects and three national conferences. Many of you have been involved. So, before we start our presentation, the Federal staff would like to recognize and thank some of the key individuals, in and out of government who contributed much to the Report.

Consultants & Researchers; *William J. Hedley, Dave Shoppert, Dan Hoyt, Hoy Richards, Slade Hulbert and Don Newnan.*

AAR-AASHO Committee; *Max Sproles—AAR, Harry Williamson—Southern Pacific, Tom Hutcheson—Seaboard Coastline, Tom Cunningham—Penn Central, Ken Whychoff—Burlington Northern and Alan Sams—Illinois Central.*

Joe Rhodes of AASHO and his committee of highway officials; Bill Price—Arizona, Tom Doyle—Nebraska, Roger Nussbaum—Illinois, S. N. Pearman—South Carolina, J. C. Kohl—New Jersey, Ellis Mathis—Idaho, Len Lindis—Oregon, Ward Goodman—Arkansas and Jacob Kossab—Pennsylvania.

Federal Government; *Charlie Prisk, Jim Wilson, Matt Puncke, Ernie Cox, Walter Osborne, Jim MacAnanny, Mac Rogers, Jean Chrisman, Joe Musslewhite, Molly Schoene, and Dan Collins.*

I have not mentioned the staff you see up here because they'll be their own best spokesman. Several who are not on our program but who were important to our success are John Eicher and Phyllis Huntington of FHWA and Wil Cantey and Tom Bouve of FRA. And finally the girl who typed and retyped thousands of drafts, Miss Sandy Allen of Jim Kirk's office.

I am sure there are a few others I have overlooked, but they may be assured their efforts were very much appreciated.

Part I of this report was submitted to the Congress by the President in November 1971 in response to the requirement of the Railroad Safety Act of 1970. It consisted of a comprehensive statement of the railroad-highway grade crossing problem, including a review of past and current programs and a profile of railroad-highway safety as to location, scope of the problem, accident experience, and economic costs.

Part II refines some of the data in Part I and presents an in-depth analysis of all the above matters. It presents for the consideration of the Congress, alternative program mechanisms for achieving a significant reduction in grade crossing accidents.

There are many issues presented in detail in the report—private crossings, impact of crossings on high speed rail corridors, pedestrian safety, the urban railroad problem, the driver, the train, the warning system. However, time simply does not allow us to discuss all these issues today, and indeed, some of it has already been considered in the past two days. What we will attempt to do this morning is to go right to the heart of the report. We will present the issues in three categories: The Problem, Improvement Needs, and Financing.

Otto Sonefeld will discuss the definition of the problem. Bob Hunter will cover the various program levels indicated in the economic analysis and Jim Kirk will handle the financing alternatives and allocation of costs.

So now, on with the presentation.

The Railroad-Highway Grade Crossing Problem Its Magnitude and Complexities

Otto F. Sonefeld
Transportation Specialist
Federal Railroad Administration

The primary goal of this study was to determine grade crossing needs nation wide and to identify a feasible program level which would adequately address those needs. What this means in Washington, and I think most other places where there is competition for a limited sum of money, is to justify a program based on costs and benefits: that is at least a dollar's return for every dollar spent. The bigger the return, the better are the chances of success.

Underlying almost every such program is a tremendous amount of analysis, which is designed to show as accurately as possible the magnitude and complexities of the problem. This is necessary for both the developers of the program and those who must evaluate and act on it. Today I would like to share with you some of the findings of our analysis and some of the techniques used.

We have approximately 220,000 miles of railroad lines transporting about 500,000 train miles of cargo and people annually. There are 3.7 million miles of public roadways carrying more than 1 trillion vehicle-miles of travel per year. Of necessity these modes are quite often required to intersect, usually at common grade, and therein lies the problem in its most basic sense.

There are in fact almost 400,000 rail-highway intersections. Grade separations account for 35,000; private crossings number 140,000; and the remaining 223,000 are the public crossings which were the major concern of this study since they present the major problems of safety and traffic mobility.

In many critical respects, the situation regarding railroads and highways has changed substantially in the past 50 years. Miles of highway have increased about 20 percent. On the other hand, miles of railroad trackage decreased by about 20 percent.

Even more important, however, is the volume of traffic involved at crossings. In this regard, train miles operated by the railroads in the past 50 years have declined about 50 percent, most of this is passenger train service. However, the estimated motor vehicle miles of travel has increased by some 2400 percent in that same period. The net effect has been an increase in the order of 12-fold in the exposure factor measured by the conflict of vehicle traffic and trains moving over the average grade crossing.

Unfortunately, this increase in the exposure factor can be expected to continue. Motor vehicle miles of travel continue to increase about 4 percent per year and railroad freight traffic has been on a 10-year slight upward trend.

Chart A is a brief summary of the more detailed information found on Table 1 on Page 7 of the Report. The 223,000 public grade crossings are shown divided by administrative system, either Federal-aid or non-Federal-aid, and classified by protection type in two broad classes, either passive or active. Division by location, either urban or rural, is also indicated.

PUBLIC CROSSINGS

ADMINISTRATIVE SYSTEM /PROTECTION TYPE

PROTECTION TYPE	FEDERAL AID			NON-FEDERAL AID			COMBINED TOTAL
	URBAN	RURAL	TOTAL	URBAN	RURAL	TOTAL	
PASSIVE	6,953	20,146	27,099	43,910	103,706	147,616	174,715
ACTIVE	10,122	11,651	21,773	18,140	8,615	26,755	48,528
TOTAL	17,075	31,797	48,872	62,050	112,321	174,371	223,243

Chart A

There is a wealth of information on the detailed table, but I might just point out a few significant items. There are 48,872 crossings on the Federal-aid system, as compared to 174,371 off. Although they are not the same crossings, there is the same ratio between active and passive crossings—174,000 to 48,000. Also note the relative number of crossings protected on and off the Federal-aid system.

Two other very important figures on your chart, but not on this slide, show that only 4 percent of the crossings have automatic gates. The other figure should cause all of us serious concern—over 11,000 crossings with no signs whatever.

Because of the importance of the exposure factor created by vehicle and railroad traffic, it was necessary for analytical purposes to assign crossings to volume classifications on both the highway and the railroad.

As shown on Chart B, six volume classes were established for trains and six for vehicles with the volume ranges for each class shown on this slide. The railroad volume classes can be read from left to right and the highway volume classes from bottom to top. You may refer to Table 2 and Figure 2 to find the exact number and percentage of crossings for each of the 36 volume class cells in the matrix, although this chart will give you a better visual perspective.

DISTRIBUTION—
CROSSINGS BY VOLUME CLASSES

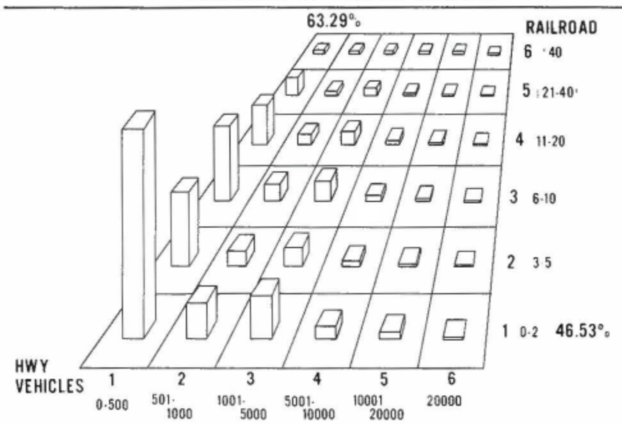

Chart B

If you added all the figures in the left hand column, you would find that more than 63 percent, or 141,000, of all public crossings fall into the lowest highway volume class, which is 500 or less vehicles per day. The total of the bottom line shows that about 47%, or 104,000, of all crossings are in the lowest railroad volume class, which is 2 or less trains per day. Of most significance, however is the lower left cell which shows that almost 32 percent of the total, or 70,000 crossings, fall into both the lowest highway volume class *and* the lowest railroad volume class. As you might expect, the number of crossings in each cell decreases as traffic volumes increase.

Whatever this picture might tell us—and I am sure it can be interpreted in many ways depending on your particular involvement in grade crossing matters—it does show quite clearly that a very large number of crossings carry comparatively light volumes of traffic.

The next step in the analytic process was to determine the factors associated with each volume matrix: that is, where the crossings were located, what kind of protection they have, and the accident experience in each of these subcategories.

As an example, Chart C shows selected portions of Table 3 in the Report, which is a comparison of the levels of protection on and off the Federal-aid system in urban areas.

PERCENTAGE OF URBAN CROSSINGS WITH ACTIVE PROTECTION

SEQUENCE EACH VOLUME CELL: FED.-AID URBAN / NON-FED.-AID URBAN

RAILROAD VOLUME CLASS	1	2	3	4	5	6
6	53.7 45.9					88.6 100.0
5						
4						
3			65.3 47.9			
2						
1	20.2 6.0					56.6 53.4

HIGHWAY VOLUME CLASS

Chart C

In the lowest traffic volume cell, six percent of the non-Federal-aid crossings and 20 percent of the Federal-aid crossings have active protection. In the upper right, 100 percent of the crossings in the highest volume matrix cell have active protection. The percentages tend to become closer as the traffic volumes increase; however, there are generally higher percentages of active protection for crossings with higher volumes of traffic. The chart also shows that Federal-aid crossings are better protected than non-Federal-aid, and that the crossings with a mix of rail and highway traffic generally have a higher percentage of protected crossings than those where only one mode dominates.

Let us turn now to the second factor determining the scope of the problem—The occurance of accidents. Chart D shows an estimated 12,412 collisions at public crossings in 1970. This total was derived from railroad reports to FRA and from summaries of police officer accident reports submitted to the National Highway Traffic Safety Administration. In my personal opinion, this was one of the most important results of the study; that is, establishing that there are in fact three times as many train-involved accidents annually as have been reported in the past. And improved reporting procedures may very well increase these figures. We have also estimated some 28,000 annual accidents related to crossings but not involving a train.

The chart also shows that 60% of the accidents occur in urban areas, and mostly on the non-Federal-aid crossings. However, the majority of fatalities occur on rural crossings. Thus a major decision becomes whether to expend resources in preventing accidents and injuries or to prevent a fewer number of fatalities.

ESTIMATED TRAIN-INVOLVED ACCIDENTS-1970

PROTECTION TYPE	FEDERAL-AID			NON FEDERAL AID			COMBINED TOTAL
	URBAN	RURAL	TOTAL	URBAN	RURAL	TOTAL	
PASSIVE	1,065	1,104	2,169	2,762	2,324	5,086	7,255
ACTIVE	1,751	1,124	2,875	1,873	409	2,282	5,157
TOTAL	2,816	2,228	5,044	4,635	2,733	7,368	12,412

Chart D

Chart E is actually a depiction of selected material from two tables in the Report-Tables 6 and 7. Based on the available accident and inventory data, we have estimated the average number of accidents in each volume class, by both active and passive protection.

ESTIMATED ANNUAL ACCIDENTS BY VOLUME CLASSES

SEQUENCE IN EACH VOLUME CLASS CELL
- NO. GRADE CROSSINGS
- AVG. NO. ACCIDENTS PER CROSSING
- NO. ACCIDENTS

PASSIVE							ACTIVE					
735 0.159 117					4 3.750 15	6	460 0.067 31					39 1.538 60
						5						
		1,404 0.209 293				4			3,383 0.119 402			
21,957 0.021 457						3	3,441 0.018 61					
1	2	3	4	5	6		1	2	3	4	5	6

Chart E

On both charts, of course, the average number of accidents increases as the traffic volumes increase. Note also, however, that the rate of increase is not uniform. The lower volume classes have a similar average accident experience, while the accident experience at high volume crossings is two to three times worse at passively protected crossings.

An important point which I have failed to show on this chart is the relatively small number of accidents in that huge block of crossings in the lowest traffic volume class with passive protection—68,161 crossings with only 796 accidents—or an average of one every 80 years. From an economic standpoint, this means you have to protect a huge number of those crossings to get the same return from protecting a high volume crossing.

Jurisdiction over grade crossing improvements basically resides at the state and local level, so we have attempted to understand the distribution of the problem by states.

The magnitude of the problem varies, of course, from state to state; Illinois, for example, has 16,000 crossings; Nevada has 300. Exposure factors vary widely even with states that have similar numbers of crossings. There is also a wide variation in the laws and procedures followed in dealing with grade crossings.

Recognizing that there are not unlimited railroad and local funds, some states have established special funds for grade crossing safety, as shown on Chart F. California's program is outstanding, and while some of the other funds are comparatively small, they all have the effect of helping grade crossing safety compete with the numerous and severe financial demands on communities and railroads.

SPECIAL STATE FUNDS – 17 STATES

STATE	AMT (THOUSANDS)
CALIFORNIA	11,110
COLORADO	120
CONNECTICUT	500
ILLINOIS	2,400
IOWA	120
KANSAS	300
LOUISIANA	100
MAINE	10
MINNESOTA	360
NEBRASKA	180
NEW JERSEY	2,000
N. DAKOTA	25
OKLAHOMA	INDEF
TEXAS	1,750
WASHINGTON	250
WISCONSIN	400
WYOMING	90

Chart F

Chart G is a two-state sample of what was done to arrive at a comprehensive assessment and ranking of the total problem by state.

COMPREHENSIVE COMPARISON

	CALIFORNIA	MAINE
NUMBER OF CROSSINGS	5	39
%–WITH ACTIVE PROTECTION	7	1
ANNUAL FATALITIES	3	44
ANNUAL FATALITIES PER CROSSING	2	46
EXPOSURE FACTOR	5	31
FATALITIES PER CROSSING IN PROPORTION TO EXPOSURE	38	40

Chart G

As an example, California ranks fifth highest in the number of crossings and ranks a high seventh in the percentage of crossings with active protection, with only six States having done better. On the accident side, California has more annual fatalities than all but two States and has more fatalities per crossing than all but one State. However, this is somewhat explained by the ranking of exposure factor which shows that only four States have more railroad and highway traffic at their crossings. When traffic volumes are considered, California ranks among the better States in fatalities per crossing in proportion to exposure.

Another State which ends up with a similar composite rating, but based on much different conditions, is Maine. It is far down the list with number of crossings, but is first in the nation with percent of crossings protected. Although it finishes with a relatively high ranking, it is probably not as high as might be expected in view of its high ranking in percent of crossings protected. Again, the exposure factor becomes a key determinant.

Briefly on the matter of jurisdiction, there is a table in the report which we think supports the contention that the current division of responsibility and authority at the State and local level results in a rather fragmented approach to grade crossing safety. At the very least, it will be necessary for the States to resolve these jurisdictional problems if they are to take full advantage of any expanded Federal program for crossing safety.

In quick summary then, some of the more important aspects of the overall problem are:

1. Increasing exposure to hazard due to increasing traffic.
2. Changing emphasis in usage of crossing between the railway and highway modes.
3. High severity of crossing accidents.
4. Large numbers of crossings with low traffic volumes and low accident experience.
5. Large numbers of crossings in need of protection off the Federal-aid systems.
6. In many states, a fragmented approach to crossing safety due to divided responsibility and authority.

Public Grade Crossing Improvement Needs

Robert C. Hunter
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This paper presents highlights of the procedures used and results obtained by the FHWA-FRA study staff in evaluating the need for public grade crossing improvements. This subject is covered more extensively in Chapter X of DOTs August 1972 Report to Congress on Railroad-Highway Safety, Part II: Recommendations for Resolving the Problem.

Procedure

Solutions to the public grade crossing probem were evaluated by using an economic analysis.

The procedure involved evaluation of the need for improving crossings grouped—as outlined in the problem section—by administrative category (either on or off the current federal-aid system), by location (either urban or rural), by type of crossing protection and by six volume classes of railroad traffic and six volume classes of highway traffic which use the crossings.

For example, for rural crossings, not on the federal-aid system and with crossbucks as the existing crossing protection, the crossings were distributed by the six railroad and six highway traffic volume classes (Table 1) and the need for improving those crossings in each of the 36 cells was evaluated.

CROSSINGS BY VOLUME CLASSES FOR RURAL NON-FEDERAL-AID CROSSINGS WITH CROSSBUCK SIGNS

	(0-500)	(501-1000)	(1001-5000)	(5001-10000)	(10001-20000)	(20000-)
6 (40+)	413	55	20	3	0	0
5 (21-40)	3152	160	60	6	0	0
4 (11-20)	7,234	453	185	6	1	0
3 (6-10)	14,751	1,005	457	16	7	0
2 (3-5)	15,105	990	461	14	9	1
1 (0-2)	45,350	2,615	1,226	107	59	1

Table 1

Under this procedure, all crossings in a single group or cell were considered to be identical. If the mean values for that group of crossings resulted in a justified improvement, all crossings in that group were considered to warrant improvement. Conversely, if the mean values did not substantiate improvement, no crossings in that group were considered as warranting improvement.

The analysis considered three types of improvements—Flashing Lights, Automatic Gates, and Grade Separation.

It was not possible to include in the analysis, other possible types of improvements such as improvements to signs and markings, crossing illumination, or improvement of the general crossing environment since the benefits from these types of improvements have not been quantified.

Costs and Benefits

Improvement costs considered in this analysis included both initial costs and recurring costs.

Benefits from crossing improvements included both safety benefits and non-safety benefits. Safety benefits were the prevention of both train-involved and non-train-involved motor vehicle collisions. Non-safety benefits were limited to reduced motor vehicle delay and operating costs.

Accident Reduction—Accident prediction equations were used to estimate the expected number of accidents per crossing in each of the several groupings. This permitted an estimate of the expected accident reduction which would result from a crossing improvement. The severity of accidents both in urban areas and in rural areas was determined and appropriate costs were assigned.

Accident Cost—Most of the accident costs were due to train-involved collisions although they also included those costs due to non-train-involved collisions. These costs included the estimated loss to society from fatalities, personal injuries and property damage. In order to place highway safety programs on a common base, the costs used in this analysis were derived from data reported by the National Highway Traffic Safety Administration[1], including the loss to society from a fatality of $200,000.

The composite total cost of train-involved accidents used in this analysis was a little over $60,000 per accident in rural areas and about $25,000 per accident in urban areas.

Delay and Operating Costs—Motor vehicle operating and delay costs caused by grade crossings included both those of slowing down at crossings in the absence of a train and those of stopping for trains.

Discount Rate—All cost and benefit values used in the economic analysis were converted to present worth equivalents using a 10 percent discount rate.

Analysis Period—An estimate of current needs was made using current traffic volumes and using a 20-year analysis period. In order to take into account additional needs expected to develop due to future increases in traffic volumes, 1992 traffic volumes were estimated and the resulting needs established. It was anticipated that train traffic would remain essentially constant during the analysis period.

Needs derived from the economic analysis are only for crossings already in existence. Needs at crossings expected to be created in the forthcoming years are not reflected.

Warranted Improvements

The three specific types of improvements considered—flashing lights, automatic gates, and grade separations—divide into two general categories, Grade Crossing Protection and Grade Crossing Elimination. Crossing protection may be either the installation of new active protection at crossings now equipped only with passive protection or the upgrading of existing active protection.

In this analysis, grade separations were not accepted as a potential improvement at those locations with two or less trains per day. There is no intention to imply that grade separations should not be constructed at such locations as part of an important highway system improvement, or that they should not be constructed at such locations otherwise if a careful analysis of all influencing factors should so dictate.

[1] *Societal Costs of Motor Vehicle Accidents, National Highway Traffic Safety Administration, April 1972.*

Alternative Levels of Improvements

As a result of the economic analysis, three alternatives surfaced as being the most viable. These were:

Alternative 1. Improvements warranted by considering safety and non-safety benefits equally and fully.

Alternative 2. Improvements warranted by considering safety and non-safety benefits equally and fully with restraints on grade separations.

Alternative 3. Improvements warranted by emphasis on safety.

Improvements Warranted by Considering Safety and Non-Safety Benefits Equally (Alternative 1)—The first alternative gave equal weight to the safety benefits of accident reduction and the non-safety benefits of reduced motor vehicle delay and operating costs.

The results of this analysis indicate (Table 2) that some 32,143 crossings warrant immediate improvement, including 3,265 which warrant grade separations. The initial cost of making these improvements is estimated at almost $5 billion with $702 million for protection and $4.3 billion for grade separations. It is anticipated that completion of these improvements would eliminate 4,367 train-involved accidents and 507 fatalities per year at current traffic levels.

ALTERNATIVE 1

CURRENTLY WARRANTED IMPROVEMENTS
INITIAL COSTS & SAFETY BENEFITS

	NO. IMPROVEMENTS	INITIAL COST ($ MIL)	ANNUAL ACCIDENT REDUCTION	ANNUAL LIVES SAVED
PROTECTION	28,878	$702	3,021	403
SEPARATION	3,265	$4,272	1,346	104
TOTAL	32,143	$4974	4,367	507

Table 2

ALTERNATIVE 1

CURRENTLY WARRANTED IMPROVEMENTS
SUMMARY OF COSTS & BENEFITS ($ MIL)

	GROSS BENEFITS	TOTAL IMPROVEMENT COSTS	NET BENEFITS	BENEFIT COST RATIO
PROTECTION	2,624	753	1,871	3.5 TO 1
SEPARATION	3,895	3,038	857	1.3 TO 1
TOTAL	6,519	3,791	2,728	1.7 TO 1

Table 3

Analysis of the present worth equivalent values derived from the economic analysis (Table 3) reveals that the present worth of the gross benefits from completing these improvements is estimated at $6.5 billion contrasted with the present worth of the total improvement costs of $3.8 billion. The ratio of these two numbers is the overall rate of return on investment for this alternative—about $1.70 for each dollar invested.

The present worth of the gross benefits from only the protection improvements is estimated at $2.6 billion, contrasted with the present worth of total improvement costs of $753 million. Thus the overall rate of return on investment for only the protection improvements under this alternative would be about $3.50 for each dollar invested.

Improvements Warranted by Considering Safety and Non-Safety Benefits Equally with Restraints on Grade Separations (Alternative 2)—A second alternative also considered safety benefits and non-safety benefits equally but, in addition, excluded grade separations as a potential improvement at all crossings in urban areas with ten or less trains per day. This was an effort to reflect the decrease in programmed grade separations which might result from careful analysis of the future prospects of relocation and consolidation of some urban railroad lines with only moderate traffic.

The results of this analysis are included in the report. However, since it is a modification of alternative 1 and is contingent on an active railroad relocation program it is considered the least important alternative to present here. Thus in the interest of available time I am going to proceed to alternative 3.

Improvements Warranted by Safety Emphasis (Alternative3)—The third alternative gives greater emphasis to safety benefits by reducing the full impact of operating and delay costs. Under alternative 3 any economically justified improvement must also return at least one-half of the improvement cost in safety benefits in order to be warranted.

The non-safety benefits of reduced motor vehicle delay and operating costs are generally composed of a relatively small individual cost incurred by a large number of motor vehicles. Thus, these delay and operating costs should be a more acceptable burden to the public and to program administrators than the losses associated with the occurrence of a death or a personal injury in a vehicle-train collision.

ALTERNATIVE 3

CURRENTLY WARRANTED IMPROVEMENTS

INITIAL COSTS & SAFETY BENEFITS

	NO. IMPROVEMENTS	INITIAL COST ($ MIL)	ANNUAL ACCIDENT REDUCTION	ANNUAL LIVES SAVED
PROTECTION	26,116	$662	3,588	449
SEPARATION	5	$ 3	7	1
TOTAL	26,121	$665	3,595	450

Table 4

The results of this analysis (Table 4) indicate that an estimated 26,121 existing crossings warrant immediate improvement including only five grade separations. The initial cost of completing these improvements is estimated at about $665 million. Completion of these improvements would eliminate an anticipated 3,595 accidents annually and save 450 lives per year, based on current traffic.

Completion of these improvements would provide gross benefits whose present worth is estimated at $2.4 billion contrasted with the present worth of the total improvement costs of $694 million (Table 5). The rate of return both for all improvements under this alternative and for protection alone, would thus be about $3.50 for each dollar invested.

ALTERNATIVE 3

CURRENTLY WARRANTED IMPROVEMENTS

SUMMARY OF COSTS & BENEFITS ($ MIL)

	GROSS BENEFITS	TOTAL IMPROVEMENT COSTS	NET BENEFITS	BENEFIT COST RATIO
PROTECTION	2,426	691	1,735	3.5 TO 1
SEPARATION	6	3	4	2 TO 1
TOTAL	2,432	694	1,739	3.5 TO 1

Table 5

Comparison of Alternatives 1 and 3

A comparison of alternatives 1 and 3 readily reveals that alternative 3 provides a far greater safety return per investment. Alternative 3 would save some 85 to 90 percent of the lives which would be saved by alternative 1 at about 12 to 13 percent of the cost of alternative 1.

Also, as indicated earlier, the ratio of gross benefits to total improvement cost is about 3.5 to 1 for alternative 3 contrasted with about 1.7 to 1 for alternative 1.

Protection Only

From examination of the results of the three analyses it was also found that—for a given investment—not only would much greater safety benefits be obtained from grade crossing protection, than from separation, but also, that greater overall benefits would be obtained from protection.

Examination of protection only as an improvement (Table 6) indicated that 26,120 crossings would warrant immediate protection under alternative 3 at an initial cost of $662 million. Completion of these improvements would eliminate 3,591 accidents annually and save 449 lives per year at current traffic levels.

The additional cost of $110 million of alternatives 1 and 2 over alternative 3, when considering protection only, would result in a reduction of only 128 more accidents annually and would save only nine more lives annually.

This clearly indicates that, for protection only, much greater safety benefits would be obtained from alternative 3 than from alternative 1.

CURRENTLY WARRANTED IMPROVEMENTS

COMPARISON OF ALTERNATIVES WITH ONLY PROTECTION AS AN IMPROVEMENT		
	1	3
NO. OF IMPROVEMENTS	31,419	26,120
INITIAL COST ($ MIL)	$772	$662
ANNUAL REDUCTION IN ACCIDENTS	3,719	3,591
ANNUAL LIVES SAVED	458	449

Table 6

Off-System Needs—Examination of the distribution of costs and benefits revealed that of the total $662 million initial cost of alternative 3 some 45 percent or $295 million was needed to complete the immediately warranted improvements off the current federal-aid systems. The anticipated reduction of 3,591 in annual accidents which would be achieved by completion of all these improvements would include some 48 percent or 1,734 off the systems.

Annual Needs—A period of 10 years is considered a reasonable time frame in which to accomplish the improvements of the 26,000 crossings warranting immediate improvement under alternative 3. At that rate some 2,600 protection installations should be made annually to existing crossings warranting improvement today.

Additional Needs—In addition to the above noted needs there are those needs created by increased traffic using existing crossings and those needs created by new crossings.

Developing Needs—In analyzing future needs, it was found that if no improvements were made in the meantime 30,033 grade crossing protection installations would be warranted by 1992 under alternative 3. This indicates that increases in traffic volumes on existing crossings will add about 200 crossings annually to the number now warranting improvement.

New Crossings—While the existing crossings are being improved, new road and street construction, particularly in connection with urban development, can be expected to create additional new crossings. The provision of appropriate protection at these new crossings can be expected to add several hundred more crossings (say at least 200) annually which will warrant active protection.

Therefore, to erase the backlog at the end of 10 years, at least 3,000 protection installations, as summarized in Table 7, would need to be made annually. This would be a rate of installation of nearly three times the current rate and is estimated to cost $75 million per year.

Passive Device Improvement—While it is not possible at this time to make a benefit-cost analysis of improved passive devices, such as pavement markings and signing at and in advance of the crossing, there are many crossings with missing or otherwise deficient signing and marking.

As a first step in improving grade crossing safety, each railroad and each responsible public agency which does not already have a program of passive device improvement, should undertake one. Such programs should also include the removal of weeds and brush from the crossing quadrants to improve safety.

PROTECTION NEEDS

	ANNUALLY
EXISTING CROSSINGS:	
CURRENTLY WARRANTED	2600
DEVELOPING NEEDS	200
SUB-TOTAL	2800
NEW CROSSINGS	200
TOTAL	3,000

Table 7

Conclusions

As a result of the analyses presented here, four major conclusions were reached.

I. Grade crossing protection should be given increased emphasis while grade separations and similar elimination-type projects should continue to be included in other highway programs.

II. To be fully effective any federal funding made available for grade crossing protection should be extended to crossings located off the federal-aid systems.

III. An estimated total of $75 million annually for a period of 10 years would adequately fund both those protection devices now warranted and those which will be added by increased traffic and new crossings.

IV. To effectively treat the large number of lower volume crossings which do not warrant active protection and also to provide effective advance warning at all crossings, each railroad and each responsible public agency which does not now have a program for improvement of signs and markings should undertake one immediately.

Financing and Allocating the Cost of Railroad-Highway Intersection Improvements

James E. Kirk
Federal Highway Administration

This presentation discusses the funding and cost allocating alternatives for financing railroad-highway intersection improvements and for sharing such cost between the two modes, railroads and highways, as developed by the FHWA-FRA study staff on railroad-highway grade crossing safety. This subject is covered more extensively in chapers XI and XII of DOT's August 1972 report to Congress on railroad-highway safety, Part II: Recommendations for Resolving the Problem.

The Funding Problem

The problem of funding railroad-highway intersection improvements centers around the following factors.

1. Accidents—Nearly 60 percent of the motor vehicle-train accidents occur at crossings not located on designated federal-aid highway systems. Thus, it is apparent that a significant reduction in grade crossing accidents cannot be achieved without giving more attention to improving crossings located off the systems. The analysis of needed improvements indicated by the report's economic analysis bears this out; for under the more modest program level of needs identified by that analysis, nearly half of the cost of all protection improvements warranted immediately involve off-system crossings.

2. Federal-aid Funds—Under present and longstanding legislative requirements, federal-aid highway funds cannot be used for improving crossings that are not located on designated federal-aid highway systems.

Current annual expenditures nationwide for railroad-highway intersection improvements on all roads and streets, both with and without federal assistance, have in recent years averaged about $240 million a year. Of this sum, the total cost of projects improved under the federal-aid highway program amounted to about $164 million or slightly more than 68 percent of the national total.

3. Other Funds—There are limited amounts and sources of other public funds available for crossing improvements. This is especially the case on projects for improving crossings of local roads and streets without federal assistance. By contrast with the average expenditures in recent years under the federal-aid highway program, the total cost of projects improved nationwide without federal assistance averaged about $75 million a year or slightly less than 32 percent of the national total.

4. Competition—There is a rising need and demand for all types of public improvements and services at the local government level. These needs and demands must be faced under the restraint of limited and hard pressed budgets coupled with a continuing escalation of costs. The net effect is for local officials to seek financial assistance at the federal level.

Funding Alternatives

In light of the foregoing, five possible funding alternatives were developed for consideration in financing railroad-highway intersection improvements. For simplifying this presentation and for ease of identification, each method has been assigned a descriptive label, and is discussed, as follows:

1. Persuasive Approach—Continue existing federal programs without change but encourage all states, in cooperation with local governments, to establish special categories of funds, or to make other public funds available to be used exclusively to share in the cost of railroad-highway intersection improvements located off the designated federal-aid highway system.

2. Permissive Approach—Amend the federal legislation to make federal funds available for financing both elimination and protection type projects located off the designated federal-aid highway systems. For financing similar projects on the systems, continue under the federal-aid highway program without change.

3. Mandatory Approach—Amend the federal legislation to (1) make federal-aid highway funds available for financing both elimination and protection type projects off, as well as on, the federal-aid systems, and (2) for such projects, require each state to spend a minimum of 5 percent of all sums apportioned to it for A-B-C-D highway system improvements under the federal-aid highway program.

4. Protection Approach—Amend the federal legislation so that a fixed amount of federal-aid highway funds would be provided and used exclusively for financing the entire cost of railroad-highway grade crossing protection improvements, both on and off the federal-aid systems. Provide sufficient funds to meet the level of need for protection improvements, as identified in the economic analysis of the overriding report.

5. Highway Safety Approach—Consider the railroad-highway grade crossing safety problem as part of a much larger program of highway safety and address its solution in that context. Included would be such elements as the necessity for achieving clear roadways through removal of roadside obstructions, the correction of skid prone surface conditions, an increased emphasis on proper signing and striping in accordance with the recently issued manual on uniform traffic control devices, and spot reconstruction projects at high hazard locations, as well as the protection of railroad-highway grade crossings. Major construction projects would not generally be included in this program.

Discussion of Alternatives

The first approach essentially entails a continuation of present programs. Thus there is no reasonable assurance that it could be more effective than current and past efforts, which so far have not yet satisfactorily resolved the underlying problem.

While the second and third approaches discussed above should, if adopted, result in some degree of improvement over current and past efforts, the latter two approaches for protection and for highway safety seem to offer the most feasible and effective basis for resolving the grade crossing safety problem.

Conclusions

The selection of a method for financing a program on grade crossing protection hinges upon a broader decision of whether the grade crossing safety problem should be treated separately and exclusively or whether it should be considered as part of a much larger and costlier program of highway safety. Since the scope of a complete highway safety program was not included as part of the study, it was not considered appropriate to make recommendations on which of the funding alternatives discussed above offers the most feasible and effective approach for resolving the problem.

However, any funding alternative chosen should as a minimum, reflect the level of need for grade crossing protection indicated by the economic analysis in the report, and encourage the undertaking of those improvements which will provide the greatest safety return for a given level of investment. It should also provide a sound basis for dealing equally with all grade crossings, regardless of whether they are located on or off the federal-aid highway systems.

The Cost Allocating Problem

The problem of allocating the cost of railroad-highway intersection improvements between the two modes, railroads and highways, centers around three factors, which are discussed as follows:

1. Current Requirements and Practices—There is a wide range and variation in the current requirements and practices for allocating costs between the two modes on federal-aid and non-federal-aid crossing improvement projects.

On federal-aid projects, the railroad's share of the costs for eliminating hazards at railroad-highway intersections is based upon the net benefit a railroad receives from the project, if any, not to exceed 10 percent of the project costs. In practice, the railroads' share is generally either a flat 10 percent of project costs, or none at all, with nominal deviations for special or unusual cases.

By contrast, the railroads' share on projects financed without federal assistance varies quite widely among the various state and political sub-divisions. Railroads are frequently required to pay 50 percent, and in some instances, 100 percent of the cost of improvements; usually less for grade separation than for protection improvements.

2. Railroad Financial Position—The railroads have declined financially. Twenty-one of the nation's largest railroads recorded a deficit in 1970. Five are now operating under bankruptcy laws, including the nation's biggest—Penn Central—and 18 others mainly in the east and midwest, have indicated they are in deep financial trouble. The net effect diminishes the ability of some railroads to assume the proportionate share of construction costs now required of them, particularly on projects financed without federal assistance.

3. Benefits and Costs—On protection-type projects, railroad benefit can be measured primarily in terms of the anticipated reduction of accidents at the crossing being improved. This, in turn, reflects the corresponding reduction in claims for fatalities, personal injuries, and vehicle damage, which otherwise might have occurred had the crossing not been improved.

On elimination-type projects, railroad benefit can be measured in the same manner as for protection-type projects plus the anticipated savings the railroad may receive as a result of greater operational freedom, of eliminating the cost of maintaining and operating the crossing protection or of providing watchmen. Railroads are currently spending about $43.6 million per year for maintaining and operating crossing protection and providing watchmen plus about $28 million per year in paying, processing, and defending grade crossing personal injury and death claims. Thus, in broad perspective, the aggregate annual cost to the railroads for the longer range maintenance and operation of crossing is already substantially more than the annual cost of death and personal injury claims resulting from grade crossing accidents. In turn, this calls for careful evaluation of the merit and propriety of requiring a railroad to contribute to the initial cost of improvements for which they assume all or the major portion of the maintenance and operating costs and from which they derive only a minor share of the benefits.

Cost Allocating Alternatives

In light of the foregoing, three possible courses of action were developed for allocating the cost of railroad-highway intersection improvements between railroads and highways. They were specifically presented for consideration and use on crossing improvements financed with federal assistance, either under current federal-aid programs or under an expanded program, as follows:

1. Continue under existing federal legislation (23, U.S.C., 120 (d) and 130); however by administrative authority under subsection 130 (b), reclassify projects and reset rates for determining net benefits to a railroad and resulting railroad share of cost, as follows:

A. On Highway Improvements and Individual Crossing Improvements—

(1) For all protection-type projects there would be no railroad contribution to the project costs. In effect, the railroads' share would be reduced from the current rate of 10 percent of the project cost to none at all, and;

(2) For elimination-type projects where benefits accrue to the railroad under current classifications, the

railroad contribution would be 5 percent of the railroad benefit related portion of the project cost. In effect, the railroads' share would be reduced from the current rate of 10 percent. For those projects where no benefits accrue to the railroad under current classifications, there would continue to be no railroad contribution to the project costs.

B. On Rail System Improvements—The cost of associated crossing improvements would be the responsibliity of the railroad undertaking the overriding railroad improvement.

C. On Urban Area or Community Improvements—The cost of associated crossing improvements would be distributed among the several parties of interest based upon the amount and type of benefits accuring to each party.

2. Amend the federal legislation so that a cost sharing arrangement between the two modes would be established by incorporating the provisions advocated by administrative action above in the overriding provision of law, 23, U.S.C., 120 (d) and 130. In effect, take action to obtain the same results as in the first alternative but give it the added force and effect of law.

3. Amend the federal legislation so that railroad-highway intersection improvements are treated the same as highway-highway grade separations and highway traffic signal installations, I.E., the entire cost would be at the expense of public funds, at no cost to the railroad.

Discussion of Alternatives

All three alternatives treat crossing improvements alike where they are to be undertaken as part of or generated by an overriding rail system improvement or by urban area or community improvements.

Where crossing improvements are undertaken either as part of a highway improvement or as an individual crossing improvement, alternatives 1 and 2 are essentially the same; one would be accomplished by administrative action and the other by amending the law. The end results stemming from either are identical. Alternative 3 goes a step further than the other two by treating all such improvements as a cost of highway construction to be paid for entirely by public funds.

Recommendations

Adoption of alternative 1 above was recommended. It will provide for the most equitable allocation of costs on a continuing basis by:

A. Continuing the existing special federal financial involvement in grade crossing safety;

B. Establishing a railroad share of the improvement cost which reflects the current benefit to the railroad from the type of improvement involved;

C. Providing administrative flexibility to adjust the railroads' share of the cost, as may be dictated by changing conditions;

D. Providing appropriate relief to the railroad industry in light of their declining financial position;

E. Requiring the party which creates a new crossing to assume the financial responsibility for appropriate protection (or separation), and;

F. Providing for special consideration for allocating costs on complex urban projects which result in special benefits.

An Evaluation of the Report to the Congress on Railroad-Highway Safety

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Previous speakers have detailed the many findings of the two part study prepared by the Department of Transportation as a guide to future efforts to improve railroad grade crossing safety. Among the questions to be asked in a review of the report are:

1. Is the description of the problem adequate to guide the actions of those who have some rule in making improvements.

2. Are the proposed solutions supported by the findings, and are they appropriate to the scale and nature of the problem.

For the purposes of this critique I won't attempt to comment on every aspect of the two reports just described to you, but will deal mainly with train-vehicle public grade crossing accidents, the guts of the problem. Pedestrian accidents, accidents at private crossings, non-train involved accidents, high speed corridors, railroad relocation—are important "Special Issues" as the report calls them.

Part one of the report is presented as "A Comprehensive Statement of the Problem." It tells us that grade crossing accidents have, for a number of years, contributed about three percent of our national traffic fatalities and about half of one percent of our injuries. We learn that the likelihood of an accident is most closely related to the number of train-vehicle conflicts at crossings, and that crossings with active protection devices are safer than those with only possive devices, especially in rural areas.

The report describes the distribution of both protection and accidents among the federal-aid and non-federal-aid highway systems.

Flashing lights and automatic gates are shown to be much more cost effective than grade separations in terms of safety benefits.

The rural-urban distribution of accidents is described, as is the bureaucratic web of government regulation and operation which sometimes hampers effective action to reduce casualties. We are given a profile of the changing distribution of responsibility for the costs of crossing improvement, with the burden shifting gradually from the railroads to the public. The growing federal responsibility for grade *separations* is tabulated, as well as the steady or slightly dropping federal aid for grade crossing *protection* over a twenty-five year period. The report gives a picture of the contribution of the driver to the crossing problem, describing the variety of conditions and chores which face drivers at grade crossings.

In discussing improvements in crossing protection equipment, the report notes the difficulty of stimulating innovation and development under the particular market conditions that prevail in this field. We are, as it is noted, using some pretty dated hardware, still reflecting the influences of the watchman and his red lantern. Recent and current research is catalogued—some of it dealing with details, some of it basic to an understanding of the problems and their resolution.

On balance, however, the first part of the report is less a comprehensive statement of the grade crossing *problem* than it is a description of the status of grade crossing *protection*. The report ends without filling in many of the blanks that need filling before responsible authorities can design corrective measures. The scale of the data is by and large too big to permit state and local authorities to develop corrective programs—either on- or off-site.

Only part of the report material is new. Most of what is presented is already available through such reports as "Rail-Highway Grade Crossing Accidents," published annually by the Federal Railroad Administration for the last 37 years. In addition, much of what *is* available in other routine reports and research material is left *out* of what is billed as "A Comprehensive Statement of the Problem." Those who seek a comprehensive picture of the *problem* here, will be disappointed. Not included is the material—already reported upon elsewhere—that describes the characteristics of grade crossing accidents useful to those who must develop countermeasures: the uncommon day-night distributions; the involvement of different vehicle types; the relative frequency of vehicles hitting trains and vice versa. Also missing is data about driver age, occupation and drinking, vehicle age and condition, seasonal variations and the level of enforcement.

There is no tabulation of even such basic information as the number of accidents and fatalities in each state. If indeed this report is intended to be comprehensive, it falls short of the mark, even as a guide to Congress. And clearly, it is intended more as background for the Congress than anything else. It is unfortunate that the Congress so narrowly defined the information and guidance it sought.

The absent information whets the reader's appetite for two things—more information, and more extensive probing of the information that *is* provided.

The report fails to follow through some of its interesting statistics to define additional questions that should be asked—and hopefully answered. For example, the first report describes rankings among states in the number and rates of grade crossing fatalities. One looks in vain, however, for a discussion of the interesting geographical biases that characterize those states with the highest incidence of fatalities as calculated against exposure rate. If nothing else, it would have been helpful to note this geographic bias, which finds a substantial clustering of the "worst" states in the wheat belt and upper Rockies.

The report also fails to relate railroad fatalities in the *states* to the *national* highway fatality picture—surely an important step to be taken in devising a national program. An analysis of this kind would have shown that the relative importance of railroad accidents varies significantly among the states. Seven states, including the District of Columbia and Puerto Rico, had no railroad fatalities in a representative recent year. In nine others railroad fatalities are less than one percent of all traffic fatalities. At the other end of the scale, nine states have railroad fatality rates over four percent, and ranging as high as eight. Information of this kind would have been useful to show the different priorities that states may properly wish to give this particular safety problem in relation to *other* safety needs. As a matter of fact, there is a brief mention of just this point tucked away in the second report—but not given the prominence it deserves.

Such an analysis would have supported the principle of state flexibility to set safety programs. This would have been helpful to the Congress, which in one current Senate Bill proposes that states spend certain minimum amounts of federal highway aid on railroad crossing improvement. This would require some states to spend a greater proportion of their highway funds on crossing protection than would be justified by the relative importance of their railroad crossing accidents.

A further detailing of the problems covered in the first report would also be helpful in guiding corrective programs. For example, it is recommended—and properly—that driver licensing materials contain information useful to drivers in coping with grade crossing hazards. Unfortunately, there is little in this report that is directly useful to licensing officials—either in designing the information, or in deciding whether it would be important in their state or not. As a matter of fact, progress in designing such material has already been made by the National Safety Council and others.

Considering the detail given to some aspects of *protection*—particularly the protection systems themselves—it is unfortunate that available information on the nature of the *problem* was only partially provided.

Part one was given to the Congress last November, and to some extent serves as a background to part two—which makes a number of recommendations for resolving the problem.

These recommendations include useful proposals for overcoming jurisdictional conflicts and for developing the kinds of information systems needed to fill in the many blanks in our picture of the crossing problem, and of the effectiveness of a wide range of countermeasures—many of which we rely on rather blindly.

The report's research and development recommendations are well thought out. It is good to see that both FRA and FHWA plan a joint research program design.

Recommendations on public education needs are less well defined. If education has a role to play, then FRA and FHWA would do well to put more reliance on public and private agencies that have a longer history of work in the field.

Although other recommendations are made on what have been called side issues, the most pointed conclusions relate to programs of crossing protection improvement.

One such conclusion is that a national effort to attack grade crossing problems should be based on a benefit-cost ratio approach, with monetary values being given to lives saved and injuries reduced. The goal of this recommendation is to reduce railroad crossing fatalities by one-third. This reduction is greater than the general goal set for the nation's safety program in DOT's "1970 Highway and Traffic Safety Report," which called for a one-third reduction in the fatality *rate* over a ten year period. This would hold fatalities at their current level. Cutting deaths is a more attractive goal than maintaining the status quo.

The report proposes that the protection program concentrate almost entirely on installation of flashers and automatic gates on crossings where the expected dollar value of safety benefits substantially exceeds the costs.

The report recommends that financing for this program come largely from an expanded federal effort, with federal highway funds available for improvements *off* the Federal-aid system, as well as on. It also suggests that the railroad share of protection costs be eliminated on federally-funded projects.

The mainstay of the study's recommendations is a ten year program of installation of active crossing protection at 30,000 grade crossings. Also included are a literal handful of grade separations justified on the basis of safety benefits alone.

As earlier speakers pointed out, an analysis was made of the accident potential at classes of grade crossings, defined largely on the basis of train and road traffic volumes. In the light of improvements that might be expected from upgrading protection from passive to active, each class was examined to see whether expected benefits, calculated in dollar value for loss of life and different degrees of injury, exceeded costs.

An approach to safety investments based on a cost-*effectiveness* evaluation is much to be desired. Such an approach, applied to many of the improvements and measures we already use for safety, or which are proposed, would do much toward putting our safety dollars where they will do the most good. This is the gist of the so-called "RECAT" report of the President's Office of Science and Technology. This approach says: "Let's get the most bang for the buck."

The benefit-cost ratio approach taken in the railroad report, however, says: "How many bucks can we spend and still get a bang." And there is a difference. As long as traffic safety is an underfunded public service, and there is every indication that it *will* be underfunded for some time, it is important that we get the most bang for the bucks we have.

There are additional hazards in using the benefit-cost ratio approach in developing life-saving programs. Much depends on the monetary value assigned to life. In the present case, two thirds of the value of a life is based on estimates of future earnings. I have no personal argument with the values chosen, but they *can* be disputed. For example, the railroad report uses a value for a life of $200,000. The Office of Science and Technology uses $140,000. Such differences significantly affect the size of program selected— as does the selected discount rate. Calculating benefit-cost ratios for only part of the safety program, as is the case here, is also a questionable approach to developing a safety effort.

Experience also shows that the public doesn't understand how a dollar value can be assigned to human life.

An alternative step that would have helped railroad and highway authorities would have been to calculate the cost of saving a life in each of the thirty-six railroad-highway crossing classes. With this information it would be possible for public agencies to make consistent decisions about spending limited safety money. For example, the proposed program would cost about $750 million and would save about 500 lives per year over a twenty year period. Over this period this would indicate a payoff of one life saved for every $75,000 invested. By comparison, a recent California study of the payoff from a spot and element safety improvement program showed a cost of $5,000 for each life saved. A more detailed breakdown of the life savings to be achieved in each crossing class might well identify a number of crossings where the cost of saving a life was well below the average $75,000 figure for all "warranted" crossings, and perhaps nearer a figure that would compare favorably with the high payoff from spot improvements. The report *does* discuss the importance of giving attention to individual grade crossings, but recommends no system to insure this is done.

The essential question is not: "What level of investment is *economically* justified by expected accident reductions from grade crossing improvements?" but rather: "Given limited resources, where will we gain the greatest reduction in lives lost and injuries suffered?" This latter is more likely to generate public support for safety investments. This approach, by the way, is suggested in sections of the report on pedestrian accidents.

A second major area covered by the report is financial responsibility. The report takes conflicting stands on this. When reporting on *needs* it states plainly that Federal-aid should go to crossing off the Federal-aid system. In the section on *funding* alternatives, it prefers not to take a position. In the executive summary it implies off-system federal-aid.

The study contends that the nature and extent of railroad grade crossing accidents justify a departure from the general principle of relating financial responsibility to separate classes of highways. More specifically, the contention is made that no significant inroads into the grade crossing problem can be made without considering the non-Federal-aid crossings, where over half of the accidents occur and that this requires federal aid off the Federal-aid system.

Off-system improvements *need* to be made, of course, but there are substantial unmet needs on the Federal-aid system, where over half the crossings—over 27,000 have no active protection. Second, there is evidence that substantial crossing improvements have been made off the Federal-aid systems even under existing funding conditions, and that such improvements can continue to be made by states and local governments—with railroad participation, of course.

Additional funding potential is available in expanded funding of state crossing protection programs, and in Federal revenue sharing. A different message that can be inferred from the report, although not stated, is that a *wiser* expenditure of available funds would probably do as much for safety as a *larger* expenditure of funds.

The aim of any program ought to be to upgrade the protection at the most dangerous crossings, to the extent that funds are or can be made available. To do this the study proposes that Federal-aid funds be spent off-system, on the assumption that only this will make the resources available. The study also shows, however, that over the years, from the point of view of getting the most safety for the buck, there has been a misapplication of funds already available. This points to the need for better programs to identify the high need crossings and insure that resources go there, rather than simply shifting federal funds which might later be spent in low-need locations. Federal-aid is no cure-all. The report gives evidence that in urban areas the highest volume Federal-aid crossings are less well protected—proportionately—than non-Federal-aid crossings. Report also shows some lower volume Federal-aid crossings better protected—proportionately—than higher volume Federal-aid crossings.

Another example of how available funds could have been better spent is seen in the fact that the number of *actively* protected grade crossings in the single lowest railroad-highway class (two or less trains, less than 500 vehicles per day) substantially exceeds *all* of the unprotected crossings in *all* eleven of the top railroad and highway volume classes. One giant step forward in improving crossing protection is to insure that available funds go to the right places.

Some past improvements have been a double misapplication of funds since the report shows, but does not comment upon the fact, that in the lowest train-vehicle volume classes there is almost no significant difference in the relative protection afforded by passive or active devices. Lots of money has been spent to provide decoration, but not much protection, to low volume crossings.

The wisdom of terminating the current practice of reserving federal highway aids for federal-aid system roads can also be questioned on the grounds of scale of problem. It is natural in a report on grade crossing accidents to project the feeling that such accidents represent a special and specially important part of the accident picture. This is partly the basis for suggesting off-system use of federal funds. However, off-system grade crossing fatalities number only about one-half percent of all traffic fatalities. As a matter of fact thirty percent of all fatalities occur off the Federal-aid system, and few would suggest that this justifies opening up all Federal-aid to all roads and streets.

The report is straightforward in dealing with cost allocation, in spite of reference to the difficulty of assigning benefits of crossing protection improvement to either the highway or railroad interests. The recommended change would expand federal responsibility and eliminate the railroad share of protection projects.

While it is difficult to pin-point the railroads' benefits from crossing protection, the report makes clear that such benefits do exist. The only apparent justification for relieving railroads of all protective responsibility is to provide financial relief to the railroads. The blanket relief proposed for railroads presumes, of course, that all railroads are in equal need of relief, and that the logical source of that relief is the highway user. I would dispute both contentions out of hand.

More importantly, however, relieving one partner in a venture from all financial responsibility has predictable bad side effects. Such effects can be seen in many states where regulatory agencies determine the need for railroad crossing protection, but share none of the financial responsibilities. The conflicts created by this state of affairs are familiar to most of you; state highway officials or local authorities find themselves mandated to make improvements which are out of phase with safety program priorities.

The most important argument against relieving railroads of all financial responsibilities on federally aided protection improvement projects is that it will reduce the total funds available for crossing protection. Total Federal funding does not create new resources—it shifts them from other programs.

There is something rather final-sounding about "A Report to the Congress." The fact that the presentation of the report falls at the end of this conference is symbolic. One has the feeling that once Congress acts, a problem has been resolved.

There is every likelihood that Congress *will* act this year upon several of the recommendations contained in the report you've heard described this morning. Chances are good that a highway bill will be passed requiring that a certain minimum sum be spent on railroad grade crossing improvements and other safety work. Ironically, the Congress has indicated its desire that increased federal aid for crossing improvements be dedicated largely to crossing *elimination*, which, as we've heard, is not a cost-effective safety improvement.

The Congress may also call for off-system grade crossing improvements from federal sources—highway user and general.

None of these steps, however, is likely to make a substantial change in the crossing accident experience in the next few years, unless other important steps are also taken.

One of these steps is to insure that railroad crossing accidents are considered accurately in relation to other safety needs in each state and local agency.

A second is to encourage public agencies to know which crossings are most in need of improvement, and most susceptible to various treatments.

The third is to develop a better understanding of *all* the factors that lead to crossing accidents, and a more complete and effective package of countermeasures.

The railroad-highway safety report to the Congress is evidence that the two federal agencies most involved are serious about working together—and this cooperative spirit may be one of the most important products of the Report.

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