The Diagnostic Team Approach to Rail-Highway Grade Crossing Safety Evaluation

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Rail-highway grade crossing safety has received increasing emphasis since the creation of the Department of Transportation. As a part of an action program announced by the Secretary of Transportation in the fall of 1967, the Bureau of Public Roads has issued an instructional memorandum suggesting guidelines for the implementation of grade crossing safety programs within individual states. Included among the guidelines is a suggestion for the formation of diagnostic teams to conduct studies and recommend improvements for increasing safety at rail-highway grade crossings.

This paper describes the diagnostic study technique as it is applied by the medical profession and relates the applicability of this approach to rail-highway grade crossing safety evaluation. The results of the diagnostic team approach, as a research procedure, in the conduct of a Bureau of Public Roads-Texas Highway Department cooperative project is reported in the paper.

The role of the diagnostic team in safety evaluation is described by defining responsibility in areas such as (a) assignment of team members, (b) scheduling team activities, (c) preparation of diagnostic study support data, (d) development of diagnostic study procedures, (e) questionnaire design, and (f) results of the diagnostic team activities.

In general, the diagnostic team has proven to be a successful procedure in identifying and isolating factors that contribute to unsafe conditions at grade crossings, preparing of priorities for crossing protection, recommending improvements in protective equipment, developing on-the-spot improvement programs, establishing an interdisciplinary approach to the solution of a common problem, and establishing a line of communication between groups and individuals who are responsible for the safe operation of rail-highway grade crossings.

•INCLUDED among the Department of Transportation guidelines for the establishment of rail-highway grade crossing safety programs within individual states is a suggestion for the formation of diagnostic teams to conduct studies and recommend improvements for increasing safety at grade crossings. The Bureau of Public Roads memorandum issued to individual states in early 1968 suggested that the diagnostic teams be comprised of representatives of all groups having specific responsibility and interest in safety at rail-highway intersections.

At the time the guidelines were issued, the Texas Highway Department, in cooperation with the Bureau of Public Roads, was conducting a research project at the Texas

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Transportation Institute that included among its research procedures the application of the diagnostic team approach to rail-highway grade crossing safety evaluation.

The purpose of this paper is to describe the results of the application of the diagnostic team techniques, as developed and implemented in the Texas study, as a research procedure. Hopefully, the results of this phase of the Texas study will be of benefit to sister states in the formation and implementation of diagnostic teams.

DIAGNOSTIC STUDY TECHNIQUES

In the medical profession the epidemiologist has the responsibility for describing patterns of diseases as they occur in groups of people. As a part of his professional training, the epidemiologist must come to know what diseases affect particular groups; their frequency of occurrence; the relative importance of different types of diseases—which are liable to sudden fluctuations in their frequency, which are fairly consistent within the group, which are widespread, and which are localized. In accident analysis the investigator may be faced with very similar, if not identical, questions. For example, the assumption that accidents are caused at rail-highway grade crossings rather than occur at random provides a logical framework in which to study factors which contribute to the cause of these accidents.

As in human illness, the cause of accidents at grade crossings may result from different types of diseases prevalent at a particular grade crossing. Often in the human population, only a small segment of the total group is included in the population at risk for various disease categories. The same may be true in grade crossing safety analysis. Therefore, the basic task of the safety epidemiologist, or in this instance the diagnostic team, is to determine which crossing or group of crossings is diseased and whether the disease is common to the entire group or prevalent in only a selected number of crossings. That is to say, the diagnostic team must know where the disease is to be found.

The medical doctor or team of doctors employs a series of clinical tests to systematically check all of the functions and response systems in the human body. When a malfunction is discovered an attempt is made to identify the cause of the malfunction by comparison with symptoms previously found to be associated with such illnesses. Although precise identity of the illness is not always possible, the probability of existence of various illnesses or malfunctions may be computed. From these computations, decisions are made to administer medicines and/or perform surgery in an attempt to correct the disorder. As a part of this clinical procedure the patients' response to the remedial action is observed. In the event an expected response does not occur, a re-evaluation of the probability of correct diagnosis is made. Since the procedure is based on an analysis of response to remedial treatment, changes in diagnoses are relatively frequent.

Employing the diagnostic procedure, known medical and surgical techniques are applied in a systematic manner to cure illnesses and correct body malfunctions. Many of the techniques developed in the medical application of the diagnostic technique to correct complex body systems may be useful to the proper identification of disease patterns among hazardous rail-highway grade crossings. From the knowledge gained through the application of the diagnostic techniques, the safety epidemiologist may postulate theories relating to the diseases that he has identified. For example, research in the field of rail-highway grade crossing safety has indicated that factors such as probability of conflict (between automobile and train traffic) and obstructions to the driver's view of trains approaching a grade crossing are contributors to accidents. It has also been determined that the contributions that these factors make to hazardous conditions at grade crossings can be expressed in statistical terms. With this information available, the diagnostic team made up of traffic engineers, railroad signal engineers, highway and railroad maintenance engineers, research and administrative personnel and other related professions are better able to put forth logical ideas for the control of the diseases (hazards) that have been identified and isolated.

ASSIGNING THE DIAGNOSTIC TEAM

The primary factors for consideration in the assignment of the diagnostic team members is first, that the team is interdisciplinary in nature, and second, that it is representative of all groups having responsibility for the safe operation of rail-highway grade crossings.

In order that each of the vital factors relating to the operational and physical characteristics of the crossing may be properly identified, it is necessary that individual team members be selected on the basis of their specific expertise and experience. Figure 1 illustrates the basic organization of the diagnostic team described in this paper. It is to be noted that the overall structure of the team is built on three desired areas of team responsibility. These areas include local responsibility, administrative responsibility and advisory capacity. All operational and physical characteristics of individual or groups of crossings may be classified in one of three areas: (a) traffic operations, (b) signal and communication, and (c) administration. In general, the responsibility of team members within each of these categories may be defined as follows.

Traffic Operation. This area includes both vehicular and train traffic operations. Responsibility of highway traffic engineers and railroad operating personnel chosen for team membership includes among other things specific knowledge of the vehicular and train volume, peak period characteristics, operating speeds, and type of vehicle, including information on train class and length, and automobile-truck-bus makeup of vehicular traffic.

Signal and Communication. The highway maintenance and signal control engineer along with the railroad signal and communication engineer, provides the best source for expertise in this area. Responsibility of these team members includes special knowledge of grade crossing warning and protective signal systems, train communication systems, interconnection of adjacent signalized highway intersections, warning and control devices for vehicle operation, highway signs and pavement markings.

Administration. Since many of the problems relating to rail-highway grade crossing safety involve the apportionment of administrative and financial responsibility, it is necessary to recognize this fact in the membership of the diagnostic team. Members of the team representing this area should be carefully selected from the upper echelon of both highway department and railroad company management. The primary responsibility of these representatives is to advise the team of specific policy and administrative rules applicable to any decision to modify or upgrade crossing protections.

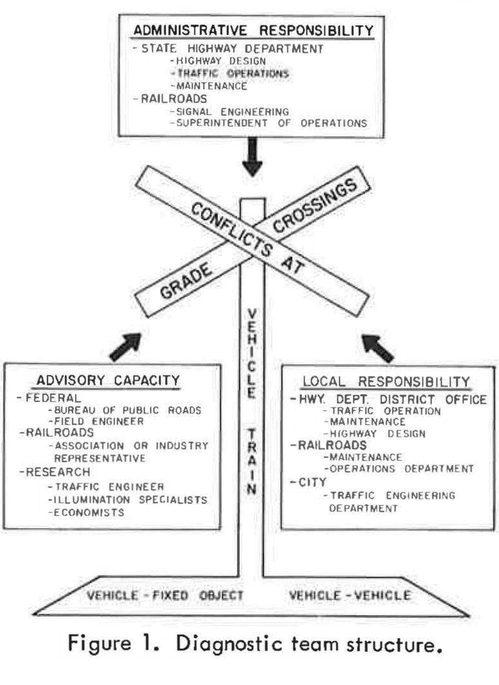

Figure 1. Diagnostic team structure.

In addition to this basic diagnostic team structure, local representatives of highway maintenance, railway signal maintenance, city and county traffic engineers (when applicable), are needed to complete the team membership. The addition of research-oriented advisory personnel to membership on the team provides a highly technical and workable combination of an 8- to 10-member diagnostic team.

Where diagnostic team activities may cover a rather large geographic area, therefore requiring considerable time and travel on the part of team members, it is suggested that the membership be rotated. This practice was employed in the Texas study not only to reduce time and travel requirements of individual members, but also to develop a rather large group of experienced people for future team membership. As a result of this approach, there are currently 65 experienced team members available for assignment to diagnostic teams.

It is suggested that if the rotating membership method is employed, there should be established some degree of continuity among the membership. The permanent membership should have representatives from each of the areas of local responsibility, administrative responsibility and advisory capacity.

SCHEDULING DIAGNOSTIC TEAM ACTIVITIES

The scheduling of team activities will depend primarily on the number of crossings to be studied, the geographic location of the study crossings, and the administrative responsibilities of the highway department, railroad company and cities or counties. Since the State of Texas has an inventory of approximately 2,500 rail-highway grade crossings under the administrative responsibility of the Highway Department, it was obvious that during one fiscal year all crossings could not be evaluated by the diagnostic team. Therefore, it was determined that a sample of 36 crossings would be selected for study. In order that the findings of the diagnostic team would be applicable to the total inventory, classes of crossings representative of all highway department crossing types were established. To be representative, the crossings were classified according to (a) their location in either rural or urban areas, (b) whether or not they had experienced accidents within the last three years, and (c) the type of crossing protective devices, either actuated or non-actuated. Three crossings within each of the twelve classes were selected for study. Another major objective of this phase of the research study was to evaluate the total concept of the diagnostic team approach to grade crossing safety evaluation; therefore, care was taken in the selection of study crossings to insure that as many highway district offices and railroad companies were involved in the study as was feasible.

It was found that once the study crossings had been selected, the scheduling of diagnostic team activities was greatly simplified. The technique used in the research project was to request the responsible and interested agencies to submit qualified personnel, as defined previously, for team membership. Names were submitted by the State Highway Department, Bureau of Public Roads, and the railroad companies. In addition to these, city traffic engineers were invited to participate as members of the team that studied grade crossings located within their respective cities.

The responsibility for scheduling the diagnostic team activities was given to the research project staff. Information relative to the location of each study crossing and the date and hour the team was to assemble to evaluate the crossing was prepared and made available to each diagnostic team participant. Approximately two hours was allocated to each study crossing. No more than six study crossings were to be visited during any one week with all diagnostic work to be accomplished in a period of three months. It is interesting to note that although the schedule was prepared at least a month in advance of the first assembly of the team and the last three crossings visited by the diagnostic team were scheduled some four months in advance, no requests for changes in the schedule were made during the entire study period. Only on three occasions was a team member absent. Since there were more than 65 different people involved in the membership of the various diagnostic teams, this fact speaks well of the interest that can be shown in diagnostic team participation.

DIAGNOSTIC STUDY SUPPORT DATA

The recovery of physical data to supplement and support the diagnostic study of rail-highway grade crossings may be classified by two categories, i. e., operational and environmental characteristics. Operational characteristics include such factors as (a) train and vehicle speed, volume and types; (b) accident records; (c) signalization and signing; and (d) adjacent roadway and railways vehicle and train operations. Environmental characteristics include among other factors (a) roadway geometrics; (b) location of buildings, trees and other structures near the crossing; (c) location of adjacent streets, roadways, and railways; (d) topography of immediate area of the crossing; and (e) population density.

The following data recovery procedures were developed for use in the collection of physical data:

1. Grade Crossing Inventory. From the Texas Highway Department inventory of rail-highway grade crossings compiled jointly by the railroad companies of Texas and the Texas Highway Department, basic information relating to train frequency, speed, etc., was obtained. The highway department and local traffic engineers supplied data relative to vehicle average daily traffic count, distribution by time period, and type of vehicles using the crossing.

2. Inventory of Physical Characteristics. Figure 2 is a reproduction of the data form that was designed to record data relating principally to environmental characteristics of the crossing.

3. Accident Records. The Texas Railroad Commission rail accident report form, Texas Department of Public Safety accident report, and local police accident reports were the primary sources of information necessary to compile these records. A summary of the reports of all accidents occurring at each accident crossing, during the three previous years, was available to the diagnostic team.

4. Aerial Photographs. The highway department provided several aerial views of the study crossings. These photographs were available to the diagnostic team during the crossing evaluations. Since the photographs were produced by photogrammetry methods, they are also suitable for additional analysis through the use of the stereoplotter.

DIAGNOSTIC STUDY PROCEDURE

The first objective of this phase of the study was to determine the manner in which individual member's evaluation of the crossing would be recorded. Previous research at the Texas Transportation Institute employing the diagnostic study technique had revealed that the study questionnaire is a feasible method of collecting these data. The technique of using the critique as a method of recovering each member's observations of the crossing was considered. However, this procedure was rejected because of the relatively large number of participants in the diagnostic study, the lack of adequate methods for noting or recording team member observations and the lack of facilities near the crossing for conducting the critique.

Recognizing that the diagnostic study questionnaire would require field testing and possible revisions, a draft of the questionnaire was prepared for initial diagnostic studies. Subsequent revision to the initial questionnaire design produced an opinion-oriented data recovery form that has satisfactorily met the objective of its intended design.

DIAGNOSTIC STUDY QUESTIONNAIRE[1]

As pointed out previously, the purpose of the diagnostic team study is to determine the conditions that affect safety at rail-highway grade crossings. Therefore, the objective of the questionnaire is to provide a record of the individual team member's evaluation of these conditions at each study crossing.

For organizational purposes the questionnaire is divided into three areas. Two sections are to be completed on each roadway approach and one on the crossing in general. Each of the areas that applies to the crossing approaches is further divided into sections in which driver requirements vary. This may be best explained by referring to Figure 3. Note the placement of traffic cones in the area of the approach illustrated by the drawing. Cone B is placed at the point where the driver must begin making his decision as to whether or not he may safely proceed over the crossing. Cone A is placed where the driver must begin applying his brakes if he is to stop short of the crossing. Both measurements are based on the maximum legal or practical vehicle speed and stopping distance on wet pavements.

[1]Due to the length of the questionnaire developed for the Texas Study it has not been included as a part of this paper. Copies of the questionnaire may be obtained from the authors.

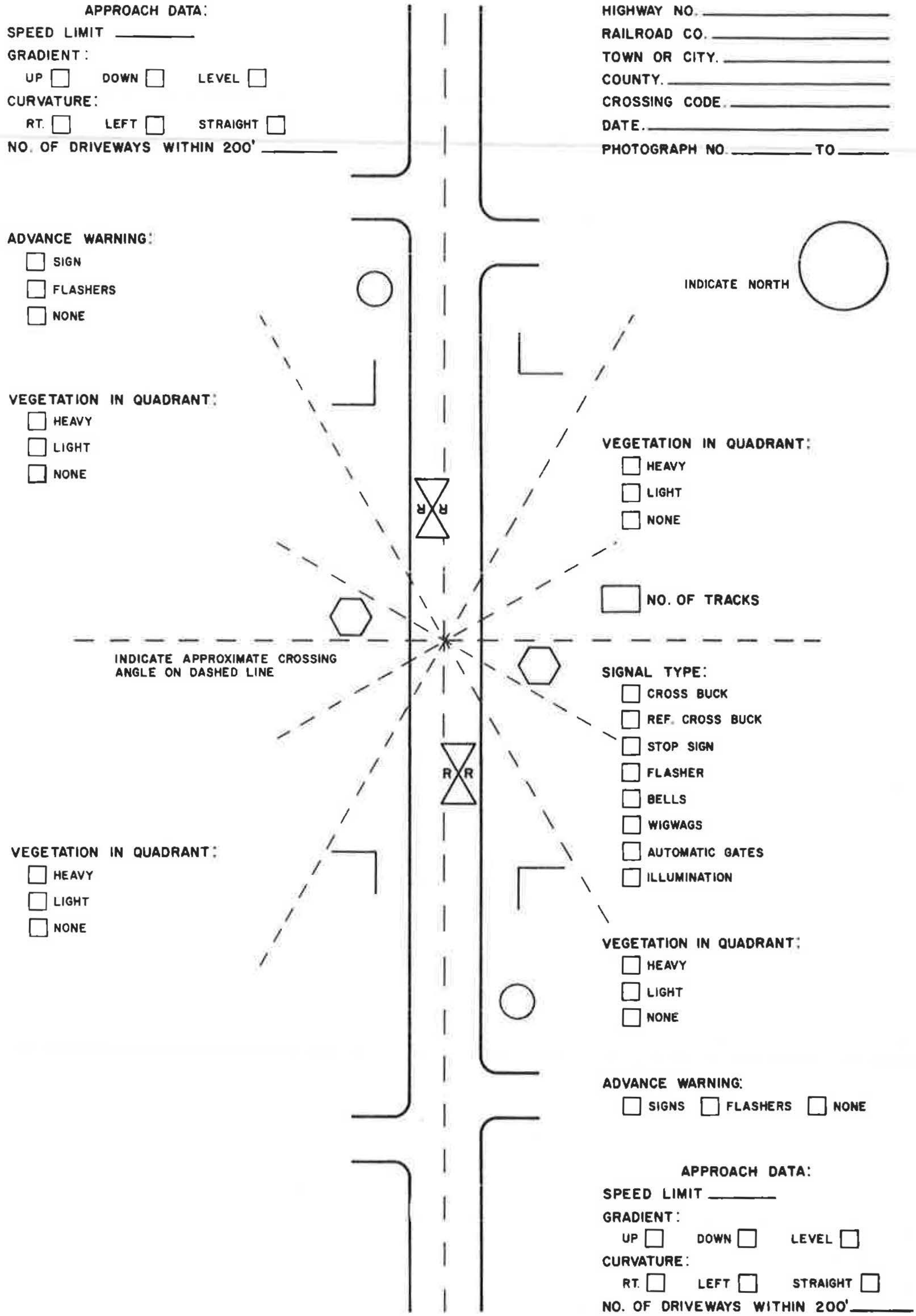

Figure 2. Grade crossing facility inventory.

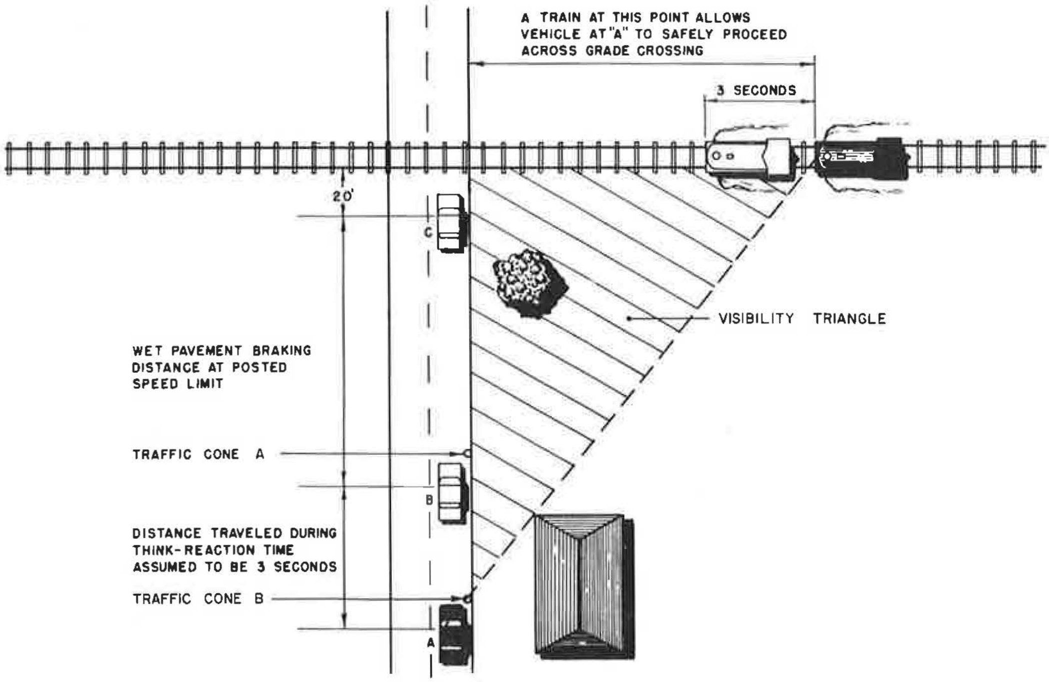

Figure 3. Sight clearance.

Referring again to the organization of the questionnaire, each section may be summarized in the following manner:

Section I. The questions in this section are concerned with whether or not the average driver will be aware of the presence of the crossings. This sense of awareness must be accomplished prior to reaching the first traffic cone so that the driver will be prepared to begin his decision-making process. To properly respond to questions in this section the crossing should be observed in an area of the roadway approaching traffic cone B. Questions in this section of the diagnostic study questionnaire are related to (a) driver awareness, (b) visibility, (c) effectiveness of advance warning signs and signals, (d) geometric feature of the roadway, and (e) repeat driver regard for the crossing.

Section II. The questions in this section are concerned with whether or not the driver has sufficient information to make correct decisions while traversing the crossing. Observations for responding to these questions should be made in the area between the two traffic cones. Where protective devices are installed, questions in this section assume that the devices have been actuated. Factors considered by these questions include (a) awareness of approaching trains, (b) driver dependence on crossing signals, (c) obstruction to view of train approach, (d) roadway geometrics diverting driver attention, (e) location of standing rail cars or trains, (f) removal of sight obstruction, and (g) availability of information for proper stop or go decisions on the part of the driver.

Section III. The questions in this category apply to observations in the section of roadway adjacent to the crossing. Traffic using any adjacent streets or driveways should be observed briefly to determine if traffic not passing over the crossing could affect traffic over the crossing. Questions in this section relate to (a) pavement markings, (b) conditions conducive to vehicle becoming stalled, (c) other traffic control devices contributing to vehicle stopping on the crossing, (d) hazards presented by vehicles required by law to stop at crossings, (e) signs and signals as fixed object hazards, and (f) opportunity for driver evasive action.

General Section. In this section the diagnostic team is given the opportunity to (a) list major features of the crossing that contribute to safety, (b) list features that reduce crossing safety, (c) suggest methods for improving safety at the crossing, (d) give an overall evaluation of the crossing, and (e) provide comments and suggestions relative to the questionnaire.

IMPLEMENTING THE DIAGNOSTIC TEAM STUDY

To describe the manner in which the diagnostic study is implemented, a discussion of the chronological order of events leading to the complete evaluation of a study site may be useful.

Event A—Briefing. As the diagnostic team assembles at the study crossing, informal introductions of team members with special emphasis on individual professional training and job responsibilities are encouraged. With introductions completed, a member of the project staff briefs the team as to purpose and objectives of the study. The questionnaire is then distributed to team members. Instructions are given for the completion of the questionnaire. The first page of the questionnaire has space available for vehicle and train operation data. As this information is made available to the team, appropriate agency respresentatives are asked to verify and update these data. The next step in the briefing is to summarize accident reports and ask for the personal experience of local team members who are familiar with circumstances surrounding the reported accidents. Aerial photographs are then reviewed to give team members a better perspective of the total environment of the crossing.

While the briefing is being conducted, a member of the project staff is locating traffic cones on both crossing approaches according to the criteria discussed previously.

Event B—Driving the Approaches. Team members are assigned to vehicles for the evaluation process. Normally, two vehicles are required for this event. Representatives of railroad, highway, and administrative interests are divided equally between the vehicles. This provides the opportunity for technical questions relating to the crossing operation to be answered in either vehicle. Team members then drive each approach several times in order to become familiar with all conditions that exist on or near the crossing. If the crossing is protected by a signal device, the railroad signal engineer is requested to activate the signals so that flashing light alignment, light intensity, awareness of light and audible signal, and traffic operating over the crossing may be observed. When the team members are satisfied with their familiarity of the driver's view of each approach, the signals are turned off and the evaluation is continued.

Event C—Completion of the Questionnaire. Positioning the vehicles according to the instruction provided by the questionnaire, individual team members answer questions within specific sections of the questionnaire. As each section is completed the vehicle is moved to the next required location until all questions have been answered.

Event D—Inventory of Physical Characteristics. Concurrent with event C, a member of the project staff is completing the physical characteristic inventory form shown in Figure 2. When this is completed, photographs are taken from specified locations. These data and photographs are for the purpose of reconstructing, at a later date, the crossing either with a model or by a drawing.

Event E—Critique. After the questionnaires have been completed, the team is reassembled for a short critique and discussion period. At this point the questionnaires have been collected; therefore, opinions expressed during this session do not bias individual team member questionnaire responses. The critique begins with a permanent member of the team summarizing his observations as to conditions that exist at the crossing. This generally leads to a discussion by team members of possible ways to improve the safety of the crossing. Other areas are open for discussion during this period including better means of communication and cooperation between agencies represented by the diagnostic team members.

RESULTS OF THE DIAGNOSTIC TEAM STUDY

The primary purpose of this paper has been to describe the diagnostic study technique as it applies in the medical profession and relate the applicability of this approach to rail-highway grade crossing safety evaluation. However, the results of the diagnostic team activities in the conduct of a Texas Highway Department-Bureau of Public Roads cooperative project should be of value in determining the effectiveness of the diagnostic team in Federal, state, county, and city grade crossing safety evaluation programs.

Based on conditions observed by the diagnostic team at each of the study crossings, 60 percent of the study crossings were considered to be fairly safe or safe, whereas the remaining 40 percent were rated as either unsafe or hazardous.

Table 1 gives the unsafe conditions observed and reported by the team in order of their frequency of mention. From Table 1 it may be seen that pavement markings were mentioned in the report of unsafe conditions at 72 percent of the study crossings. Also, 60 percent of the study crossings may experience unsafe conditions due to the requirement that certain vehicles must stop at all crossings. Approximately 50 percent of the study crossings were observed as having driver visibility obstructed due to heavy vegetation growth. Illumination, signing, signalization, and fixed-object hazards were mentioned with approximately the same frequency; whereas roadway geometrics, maintenance of railroad devices and traffic conditions on adjacent roadways were the least frequently observed unsafe conditions.

Following the listing of unsafe conditions at each study crossing, the diagnostic team was requested to make recommendations for the improvement of these conditions. Table 2 gives specific recommendations made for grade crossings included in this study. For purposes of this analysis the recommendations have been grouped into three

TABLE 1

UNSAFE CONDITIONS OBSERVED BY DIAGNOSTIC TEAM AT STUDY RAIL-HIGHWAY GRADE CROSSINGS

Conditions Observed	Percent of Crossings at Which Conditions Observed
1. Pavement markings missing, improperly located or in need of maintenance	72
2. Vehicles required by law to stop at all crossings would present a hazard to other vehicles by blocking traffic lanes and obstructing view of protective device	60
3. Driver's visibility of railroad approach obstructed by growth of vegetation	52
4. Under nighttime conditions lack of illumination presents additional hazards at grade crossing	44
5. Conflicts for driver's attention due to traffic conditions and the location of traffic control devices on adjacent roadways	40
6. Advanced warning signs missing, improperly located or in need of maintenance	40
7. Absence of area immediately adjacent to grade crossing for the driver to take evasive action	36
8. Highway signs and fixed objects obstructing driver's view of protective and warning devices	32
9. Fixed mount protective devices or barriers presenting fixed object hazard to vehicles	32
10. Legally parked vehicle would block driver's view of protective and warning devices	28
11. Geometrics of roadway design contribute to unsafe conditions at the crossing	20
12. Railroad protective device not properly located or maintained	12
13. Traffic conditions on adjacent roadway conducive to vehicles becoming stalled or stopped on railroad tracks.	8

TABLE 2

DIAGNOSTIC TEAM RECOMMENDATIONS FOR THE IMPROVEMENT OF SAFETY AT STUDY RAIL-HIGHWAY GRADE CROSSINGS

I. Maintenance and Relocation of Protective Devices, Signs and Pavement Markings.

1. The addition of vehicle stop lines on approach to crossing.[a]
2. Advance warning sign pavement markings be added or relocated to conform with vehicle approach speed.[a]
3. The removal of vegetation to provide adequate sight distance on the approach to the crossing.
4. A safety zone be provided in the area immediately adjacent to the crossing to provide the driver with an opportunity to take evasive action.
5. Protective device be located away from edge of roadway or be replaced with breakaway design.
6. Eliminate parking on all approaches to the crossing to insure driver visibility at the crossing.
7. Protective devices be maintained on a continuing basis.
8. Removal of fixed objects to provide an unobstructed view of the crossing.
9. Relocation of traffic sign obstructing view of protective and warning devices.

II. Installation of Actuated Protective and Warning Devices

1. Addition or relocation of advanced warning signs to conform with vehicle approach speed.
2. Illumination be installed to increase nighttime safety at the crossing.
3. The installation of flashing lights at crossings protected only with crossbucks.
4. Installation of larger diameter advance warning sign.
5. Installation of actuated advanced warning sign.
6. Installation of cantilever-type actuated signals.
7. Interconnect traffic signal with actuated flashing device.
8. Install control signs at cross streets intersecting crossing approach.

III. Widen Existing Roadway or Add Traffic Lanes to Crossing Approach

1. Addition of traffic lanes at the crossing approach for vehicles required by law to stop at all crossings.
2. Widen roadway in area adjacent to the crossing.
3. Realign roadway approach to crossing.

[a]Proper maintenance of pavement markings be accomplished on a continuing basis was included in these recommendations.

categories. Listings of the recommendations within each group are according to their frequency of mention by the diagnostic team.

An analysis of the recommendations indicates that more than 60 percent were directed specifically to the maintenance of signals, signs, and pavement markings. Although approximately 50 percent of the study crossings were protected only with crossbuck signs, less than 30 percent of the diagnostic team recommendations were concerned with or involved the installation of actuated protective and warning devices. Recommendations for widening existing roadway or the addition of traffic lanes at the approach to the crossing made up the remaining 10 percent of the team's suggestion for safety improvement.

SUMMARY AND CONCLUSIONS

The results of the Texas Study suggest that the diagnostic team study technique, applied to the evaluation of rail-highway grade crossing safety, contributed to a safety program in the following manner:

1. The diagnostic team approach provides a highly reliable method for identifying, isolating, and measuring factors that contribute to unsafe conditions that exist at rail-highway grade crossings.
2. The diagnostic team provides a basis for determining not only which crossings should be protected, but more importantly what type of protection should be employed in order to achieve acceptable levels of safety among all crossings.
3. The diagnostic team provides recommendations for improving and upgrading existing protective equipment, roadway, and railway with minimum expense to responsible agencies.

4. The diagnostic team develops recommendations for on-the-spot safety measures such as the relocation of signals and signs, alignment of flashing lights, replacement of broken or worn signs or signal apparatus, upgrading pavement markings, relocation of public or railroad property, and other measures to reduce accident potential at specific crossings.
5. The diagnostic team provides an interdisciplinary approach to the solution of a common problem by utilizing technology acquired by each of the professions represented in its membership.
6. The diagnostic team develops a line of communication between groups and individuals who are responsible for the safe operation of rail-highway grade crossings.

Discussion

B. M. STEPHENS, Southern Pacific Company —In the twelve or so decades that have elapsed since establishment of a system of transporting people and goods by rail, the problem of safety at rail-highway grade crossings has expanded to alarming proportions in spite of the efforts of dedicated and knowledgeable engineers and traffic analysts and the expenditures of monumental sums of money for improvements.

Rail-highway and highway-highway intersections at grade, in the real economic sense, exist for precisely the same reason: to permit two streams of land traffic, in meeting demands for transportation service, to move in intersecting directions to provide this service to land areas under settlement and development. The grade crossing problem is such that it can be credited, with complete justification, to the outstanding economic growth of the nation.

It would be a work of supererogation to catalog and outline the many formulas for evaluating and indexing hazards at rail-highway grade crossings. There are close to two dozen such formulas generally reliable for computing relative hazard and differing basically only in the degree of their analytical sophistication. Unhappily, these formulas deal with the grade crossing safety problem on the basis, essentially, of engineering applications without full recognition of the fact that the problem is a complexity consisting of at least six other equally important elements identified as administrative policies, political ramifications, economic considerations, legal aspects, public relations, and accident analyses. For those interested in details, eleven crossing evaluation formulas have been outlined (1, 2).

In too many instances, decisions to protect rail-highway intersections are the direct result of pressures brought about by emotional outcries of individuals or small groups. In this day of extensive communication systems, the news media, through editorials and television documentaries, provide an opportunity for the thoughts and demands of individuals and small groups to be exposed to a large segment of the citizenry on a daily basis. Without regard to or consideration of the relative hazardous conditions existing with respect to other crossings, action on the part of public officials and railroad companies is demanded immediately. To complicate the problem further, little or no effort is spent in determining what type of protection is best suited for the unique characteristic of the individual crossing to be protected. How often in this decision process are the traffic engineer, railroad signal enginner, design engineer, railroad operating personnel, local law enforcement agencies, and maintenance engineers asked to participate in the selection of which crossing is to be protected, when it is to be protected, and how it should be protected?

It is evident with respect to the gravity of the grade crossing safety problem, despite unnumbered investigations and analyses, the profusion of published and unpublished reports and papers, and existence of some two dozen or so hazard rating or hazard index formulas, that efforts expended and measures adopted are not resolving the problem with notable success nor, in truth, keeping pace with it. Therefore, distinguished analysts and engineers have set out to explore and to endeavor to develop every newly postulated and conceivable avenue of approach, far-fetched or not. Two particular avenues of approach appear to be promising: (a) the utilization of engineering-economic analysis in evaluating grade crossings, and (b) the diagnostic team approach to rail-highway grade crossing safety evaluation.

The diagnostic team technique is not new nor untried in the annals of science. For many years, medical science has applied such technique in the identification and treatment of illnesses and malfunctions in the complex living body systems of both man and beast. On the premise that rail-highway grade crossings induce a complex arrangement of many characteristics and variables (any one of which may contribute to a train-vehicle collision), practicality of employing the diagnostic technique in examining grade crossing safety problems was suggested in papers presented at the 1967 Grade Crossing Safety Symposium at Texas A&M University. That the diagnostic technique theory can be deemed meritorious is revealed by Federal Highway Administration Instructional Memorandum of January 5, 1968, supplemented on January 25, requesting State Highway Departments, among other things, "to form a diagnostic team comprised of representatives of appropriate State agencies, the railroad companies, the Bureau of Public Roads, and others as needed to consider on-the-scene improvements at grade crossings."

In the meanwhile, Texas Transportation Institute undertook to implement the diagnostic team technique in the manner and with results as outlined and described in detail by the authors of the paper under discussion. It was my privilege to take part in several on-site investigations as a member of the diagnostic team and I found that completing the questionnaire (comprised of some 65 questions and personal observations about conditions) that was presented to team members taxed the acumen and ingenuity of the members, all of whom were experienced engineers or analysts in the field of rail-highway grade crossings.

The paper will be of significant interest to those who are aware of the severity of the grade crossing safety problem and who wish to implement a program for the resolution of it. It is likely that some modification of team constituency and procedure and some rephrasing and reorganization of questionnaire content may be necessary to more completely achieve the purpose. To this end, effectual discussions and concise and probing questions should tend to enhance the effectiveness of the diagnostic team technique.

It would seem that the authors of the paper have attempted to describe a procedure by which emotional criteria may be replaced with technical criteria in development of a grade crossing protection program designed to give maximum return for each dollar invested and to weave into the pattern of deliberation not only the element of engineering application but also at the minimum, those elements of accident analyses, administration policies, economic considerations, and legal aspects.

Too often, much of the grade crossing protection work has been done without meaningful knowledge of the "illnesses" of the crossings protected with the consequence that desired results were frequently only partially obtained and sometimes not at all. The apparent success of the initial application of the diagnostic theory to evaluation of grade crossing safety problems, as outlined and described in the paper, would indicate that a remarkably useful tool is available for use in resolving such problems and that the diagnostic team approach should contribute substantially to achievement of better results in grade crossing safety evaluation programs.

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2. American Railroad Engineering Association. Proc., Vol. 50, p. 244-252.

HOY A. RICHARDS, NEILON J. ROWAN, and ERNEST W. KANAK, Closure—Although the paper stresses the evaluation of the crossing site by experts in the field of highway-railway design, maintenance, and operations, attempts were made to determine driver reaction at the crossing by placing team members in the position of the driver during the evaluation process. No attempt was made to study human factors as related to driver performance at rail-highway grade crossing intersections. It is recognized in the paper that financial responsibility is a significant factor to the solution of the rail-highway grade crossing problem. It is the opinion of the authors that the upper echelon of both the highway department and railroad company management should determine policy as to apportionment of the administrative and financial responsibility. This does not necessitate participation in the on-the-site activities of the diagnostic team. However, diagnostic team reports should be prepared in such a manner that administrative decisions may be clearly drawn from these studies.

Most of the study crossings were inspected during both daytime and nighttime conditions. Due to the climactic conditions of the geographic regions in which this study was conducted, the only unfavorable weather conditions under which the studies were made occurred during rain storms and heavy cloud conditions.

At the suggestion of one of the discussants, the final draft of this paper included conditions observed at the study crossings along with specific recommendations for improving safety at these crossings.

Using a priority rating system for ranking all crossings within the responsibility of the state highway department, only those crossings that are indicated to be the most hazardous should be investigated by diagnostic teams. It was not the intention of this paper to suggest that all crossings should be evaluated by diagnostic teams. In the opinion of the authors, the expenditures of the diagnostic team activities are minor compared to the cost of annualized improvement and maintenance cost at grade crossings. It is apparent from the field work reported in this paper that the most significant contribution of the diagnostic team is its ability to recommend the best available protective equipment to meet the unique requirements of individual crossings.

It is the opinion of the authors that the diagnostic study questionnaire is only one method for recording the response of team members. Other techniques may be better suited for conditions that exist in future studies; therefore, only a summary of the questionnaire was included in the paper. In addition, the length of the questionnaire precluded its publication; however, copies are available from the authors.