NATIONAL CONFERENCE
ON STREET AND HIGHWAY SAFETY

REPORT OF THE

Committee on Protection of Railway Grade Crossings and Highway Intersections

APPOINTED BY
THE SECRETARY OF COMMERCE

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THIS REPORT is one of five issued for consideration in advance of the Third National Conference on Street and Highway Safety. The reports are: I—Protection of Railway Grade Crossings and Highway Intersections; II—Maintenance of the Motor Vehicle; III—Measures for the Relief of Traffic Congestion; IV—Uniform Traffic Regulation (accompanied by Uniform Vehicle Code, Model Municipal Traffic Ordinance and Manual of Standard Street Traffic Signs, Signals and Markings as revised); V—Traffic Accident Statistics. Copies of all of these and of earlier Conference publications (see list at back of this pamphlet) can be obtained from the National Conference on Street and Highway Safety, 1615 H Street, N.W., Washington, D. C.

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NATIONAL CONFERENCE ON STREET AND HIGHWAY SAFETY

Report of Committee on Protection of Railway Grade Crossings and Highway Intersections

Hon. Robert P. Lamont, Chairman,
National Conference on Street and Highway Safety,
Washington, D. C.

Sir: After a careful survey of the subject, your Committee on Protection of Railway Grade Crossings and Highway Intersections is deeply impressed with the importance of proper treatment of the traffic and safety problems that present themselves at such points of hazard.

These problems are receiving active attention by many agencies, from all of which the Committee has received cordial cooperation in its studies. The Committee believes that the work of these agencies, and a better understanding by the general public, will be facilitated through a statement of the main facts concerning the traffic problems at grade crossings and highway intersections and the principles which should apply in their solution.

In the treatment of railway grade crossings and highway intersections and in the regulations and practices applicable thereat, certain points of similarity exist, such as need for removal of obstacles to clear view, uniformity in character and location of warning signs and prudent conduct of motorists in approaching the crossing or intersection. On the other hand, due to the fact that railway trains, necessarily running at high speeds over private rights of way, cannot be expected to stop to avoid collision with highway users, the extra hazards at grade crossings call for additional protective measures.

The Committee submits the following summary of its findings

and conclusions covering both crossings and intersections, and, following the summary, a separate report for each of these subjects, giving explanations of the principal points.

By the Committee,

WILLIAM R. DAWES, *Chairman.*

Washington, D. C.
May 9, 1930.

Summary of Conclusions

The conclusions regarding both railway grade crossings and highway intersections are combined in one group under each of the headings which follow, except in the case of "Protective Measures," which are separately grouped for grade crossings in section 4 and for highway intersections in section 4(a).

Accident Records

1. Accidents at railway grade crossings caused 2,485 fatalities, or 8 per cent, and those at highway intersections (including city streets) considerably more than 50 per cent of the estimated 31,000 motor vehicle fatalities which occurred in the United States in 1929.

Railway grade crossing accidents during the past four years (1926-1929) have averaged 5,783 per year. Of this number 4,399 were motor vehicles struck by trains, 1,272 were cases in which automobiles ran into the side of locomotives or trains, while 110 involved occupants of other vehicles, or pedestrians.

Accurate data as to grade crossing accidents on steam railroads and many electric railways are available, but not as to types of protection sufficient to show which is best. Similar records of accidents at highway intersections, vitally important in the analysis of accident hazards, should be more systematically maintained by the traffic authorities, together with spot maps or card files to show the actual points where accidents most frequently occur.

Grade Separation

2. In spite of active work on railway grade crossing elimination averaging more than $60,000,000 per annum during 1926 to 1928, and in spite of an increasing amount of grade separation at highway intersections, the statistics show that, due principally to new highway construction, the total number of grade crossings and highway intersections is increasing annually.

Financial considerations show that for the immediate future, separation of grades at railway crossings and highway intersections, while facilitating traffic movement and reducing hazards at points of great traffic density, cannot be counted upon as the principal solution of the problem. Chief reliance must therefore be placed upon removal of physical hazards, establishment of uniform warning and other protective measures, enforcement of the applicable traffic regulations and education of highway users.

Reduction of Physical Hazards

3. Reduction of physical hazards at grade crossings and highway intersections requires, in addition to warnings and other protective measures listed below, that there should be:

(a) Practically level and smooth highway surface between the tracks or within the highway intersection and for at least 25 and preferably 50 feet on each side of the tracks or intersection; approach grades not exceeding 4 to 5 per cent; widening of the roadway at the crossing or intersection; avoidance of sharp highway turns and junctions within 250 feet of the crossing or intersection and of important highway intersections within at least 500 feet of the crossing if ultimate grade separation may be contemplated.

(b) Avoidance of standing of railroad cars, parked highway vehicles or other temporary obstacles, and removal of banks, trees, shrubs, standing crops, buildings, billboards or other permanent obstructions to give sufficient view of the tracks or cross road to enable traffic to pass safely under normal conditions of operation, or, if this be impracticable, then, under conditions of more cautious operation, proper indication by warning signs or other protective measures.

(c) Where artificial lighting of highways or grade crossings is economically practicable, special care should be taken to insure that the lights are so located as to illuminate the fixed signs without glare interfering with visibility from the point of view of the highway user. Consideration should also be given to visibility of rolling stock as affected by the color of paint used thereon and as illuminated by automobile head-

lights or street or highway lights at the grade crossing. Visibility from the side should also be provided for in the lighting systems on motor vehicles.

Protective Measures at Railway Grade Crossings

4. Of the 240,000 grade crossings in the United States, the number protected by automatic train approach signals, gates or watchmen increased from 11.9 per cent in 1926 to 12.2 per cent in 1928, the remaining crossings being dependent for protection upon standard fixed signs. The trend of protection is toward visible automatic signals. To facilitate prompt provision of more adequate protection of railway crossings there should be a fair division of costs of such protection as well as of elimination of obstruction to view and other hazards, and of maintenance of roadway between and adjacent to the tracks, following the principles which have been recognized in apportionment of costs of grade eliminations.

Standard Fixed Signs and Markings

To give warning of the proximity and character of a railway grade crossing at sufficient distance from the crossing to enable the driver of a vehicle to regulate its movement so as to be able to stop if necessary, and otherwise to determine before reaching the crossing whether he can cross in safety, the following standard signs and markings are recommended (see foot note):

(a) *Advance Warning Signs and Pavement Markings.*—At each highway approach to a railway grade crossing there should be erected not less than 200 feet (in cities not less than 100 feet) or more than 450 feet from the crossing a standard circular highway advance warning sign, illuminated or with reflecting letters, consisting of a black "RR" and cross on a yellow background.

As a supplementary advance warning of approach to railway grade crossings on hard surfaced, heavily traveled high-

Note: The signs, signals and markings recommended in this report are in complete agreement with those specified in the manuals prepared by the American Association of State Highway Officials for rural highways, the American Engineering Council for city streets and the American Railway Association for signs and signals on railway right of way at grade crossings.

ways where rail traffic is fast or frequent, pavement markings should be employed, using the standard form approved by the American Association of State Highway Officials. On wide highways lane markings are also recommended. On three lane highways the two righthand lanes approaching the crossing should be marked; on highways of four or more lanes, all lanes to the right of the center line.

(b) *Speed Limit or Stop Signs and Supplementary Slow Signs.*—In addition, at a point nearer the crossing, there should be erected a speed limit sign or a stop sign depending on the following conditions:

(i) Outside of business or residence areas, where the view of the track is not obstructed within necessary visibility zones, and no special hazard exists, a standard rectangular 30-mile speed limit sign in black letters and numbers on a white background should be erected 100 feet from the crossing.

(ii) Where the view of the track is obstructed within necessary visibility zones, or where other special hazards exist, a standard 15-mile speed limit sign, illuminated or with numerals of reflecting type, should be erected 50 feet from the crossing.

(iii) Where due to extreme limitation of view or other specially hazardous conditions crossings have been designated by the proper state commission, in accordance with the Uniform Vehicle Code, to require all vehicles to stop, there should be erected not less than 15 or more than 50 feet from the crossing, at such highway approach, a standard octagon stop sign, illuminated or with letters of reflecting type, bearing the word "Stop" with black letters on a yellow background (red letters on yellow background within municipalities and optional elsewhere).

(iv) Where the speed limit or stop sign cannot be seen sufficiently in advance, a standard diamond-shaped slow sign with black letters on a yellow background should be erected not less than 100 feet in advance of the sign specified in paragraph (b) above.

(c) *Crossing Signs.*—At all grade crossings a standard railroad crossbuck sign with two arms mounted across each other should be installed on the railroad right of way. In case of multiple tracks there should be mounted below the crossbuck arms a clearly legible sign indicating the number of tracks.

Train Approach Warning and Protection Measures

At many railway grade crossings the amount or character of railway and highway traffic warrants special warning of the approach of trains in addition to the standard requirements of warning by the locomotive whistle and ringing of the locomotive bell. At such crossings, the following are recommended in addition to the standard fixed signs and markings:

(a) *Automatic Train Approach Signals.*—At crossings on heavy traveled highways where there are sufficient intervals between train movements, either of the following standard visible warning signals should be installed:

(i) A wigwag signal with a swinging target and red light.

(ii) A flashing light signal with two red lights in a horizontal line 30 inches apart flashing alternately.

As adjuncts to other train approach warning measures, but not as substitutes therefor, bells or other audible signals may be used.

Careful study by the railroads should be continued to determine the feasibility of using time control for train approach warning signals at crossings; that is, such control as will give warning always at the same number of seconds before the train actually arrives at the crossing, regardless of the speed of the train.

(b) *Crossing Gates and Watchmen.*—At crossings on heavily traveled highways where frequent switching movements or shortness of intervals between train movements requires more prompt and positive indication of approach of trains and of clearance of the crossings for highway traffic, crossing watchmen or manually controlled crossing gates or signals should be provided. Crossing watchmen should be equipped with standard crossing watchmen's stop signs, red flags and lan-

terns. Gates should be made conspicuous by alternate black and white 12-inch striping at an angle of 45 degrees sloping downward toward the center of the highway.

Obedience to directions given by gates, crossing watchmen or positive crossing signals is required by the Uniform Vehicle Code.

Protective Measures at Highway Intersections

4(a). The enormous number of highway intersections renders both undesirable and financially impracticable protection of all intersections even by standard fixed signs. Furthermore, the volume and character of traffic at only a small percentage of intersections justifies establishment of automatic traffic control systems. Careful study of traffic conditions and discrimination are therefore needed in determining upon traffic control systems, protected stop highways or other systems of fixed protection signs, and particularly in the allocation of available funds as between such protection measures on the one hand and the reduction or elimination of physical hazards on the other.

Standard Fixed Signs and Markings

At approaches to highway intersections, besides the black and white "junction" information signs to be located 350 feet from intersections of important marked highway routes, the following warning signs and pavement markings are recommended:

(a) *Advance Warning Signs and Pavement Markings.*—At each approach to a highway intersection which would not otherwise be readily recognized as such, or where there is hazard not otherwise obvious, a standard square "crossroad" or "sideroad" caution sign with black lettering on a yellow background should be erected not less than 100 or more than 400 feet from the intersection. (In municipalities a standard "cross street" sign at or in advance of the intersection, depending upon conditions.)

At approaches to intersections, center lines—black (or white) on concrete and white (or yellow) on asphalt—should, where practicable, be marked on roadways carrying heavy traffic to

keep vehicles on the right side of the road and to maintain efficient alignment. In case of wide roadways with two or more well defined streams of traffic additional lines to mark each lane are desirable for at least 200 feet from the intersection.

(b) *Speed Limit or Stop Signs and Supplementary Slow Signs and Markings.*—At points nearer the intersection in certain cases, depending on the following conditions, there should be erected either speed limit signs or stop signs:

(i) Where the view of the cross road is obstructed within necessary visibility zones, or other special hazard exists, and the highway is not protected against cross traffic by stop signs, a standard rectangular 15-mile speed limit sign, illuminated or with reflecting letters, with black letters and figures on a white background, should be erected 50 feet from the intersection.

(ii) Where a through highway has been established or serious hazard indicates the desirability of preferential treatment to one highway at an intersection, standard octagonal stop signs, illuminated or with reflecting letters, bearing the word "Stop" in black letters on a yellow background (red letters on a yellow background in municipalities and optional elsewhere), should be erected at each entrance to such preferred thoroughfare.

This sign may be supplemented by a pavement marking "Stop."

(iii) Where the speed limit or stop sign cannot be seen sufficiently in advance, a standard diamond-shaped slow sign should be erected not less than 100 feet from such sign. This sign may be supplemented by a pavement marking "Slow" at the same distance from the intersection.

(c) *Directional Lines or Markers at Intersections.*—To direct the movement of traffic within an intersection, when desirable, special short directional lines marked on the pavement with arrow to indicate direction, or suitable traffic markers (buttons), should be installed.

Traffic Control at Intersections

When traffic is dense on both highways at any intersection, unless grade separation is economically feasible or unless special conditions make a traffic "circle" desirable, there should be stop-and-go control of traffic by automatic signals or by traffic officers. Where traffic is dense on one highway and light on the other, traffic-actuated signals afford a means of avoiding excessive interruption of the main road travel.

Safe Driving Practices

5. The special degree of hazard at railway grade crossings and the special warning and protective measures adopted at such points places upon highway users responsibility for a corresponding degree of prudence and caution in passing the tracks. At highway intersections such a degree of hazard can exist only if one party is driving recklessly or otherwise in violation of law, but the prudent driver will nevertheless exercise caution against this class of extra hazard at highway intersections in much the same manner as he does against the special hazards inherent in railway grade crossings.

Laws and Regulations

6. Even with physical hazards eliminated or reduced to meet reasonable safety requirements and with signs, signals and markings conforming to the standards outlined above, there remains the problem of securing safe conduct of highway users at grade crossings and highway intersections. To afford legal basis for this, the Uniform Vehicle Code and the Model Municipal Traffic Ordinance, besides laying down the fundamental rule against reckless driving, make the following provisions:

(a) At all crossings and intersections motorists must keep to the right, and must obey the indications of stop-and-go signals, traffic officers, railway crossing watchmen or crossing gates.

(b) At all grade crossings common carrier passenger vehicles, school buses and vehicles carrying explosives or inflammables must stop and certain types of slow moving equipment must in

addition provide ample advance warning to the railroad company to enable it to protect approaching trains against the stalling of such equipment on the crossing; at certain especially hazardous crossings designated by the appropriate state commission and properly signposted, all vehicles must stop.

(c) At all highway intersections, including city streets, the standard rules apply governing turning of vehicles and right of way as between vehicles and between vehicles and pedestrians.

Enforcement of Laws and Regulations

7. As grade crossings and highway intersections account for such a large percentage of traffic accidents, special attention of the police to enforcement of the laws and regulations at such points is warranted, and where police authorities do not now exist to do this, the requirements of safety indicate the importance of provision therefor. The same consideration indicates that, in examinations for licensing of operators and chauffeurs, test should be made of the working knowledge of applicants as to the rules and regulations governing traffic at grade crossings and highway intersections. Police having general authority over street and highway traffic should recognize that the function of railroad crossing watchmen is limited to stopping traffic on the approach of trains, and that in other respects the compliance of the highway users with the traffic laws and regulations at grade crossings as well as at highway intersections and elsewhere is under supervision of such general traffic police.

Education of Highway Users

8. Despite all efforts of the authorities to eliminate hazards, to provide ample warning and traffic control measures, and to enforce the rules and regulations applicable at grade crossings and highway intersections, the public must in the main be depended upon for voluntary compliance with the rules of proper conduct at such points. Therefore it is of fundamental importance that knowledge of the laws, regulations, traffic control measures and proper practices in these regards be carried to all of the public concerned. To this end the principles stated in this report, necessarily somewhat complicated and technical in character,

should be utilized by the interested organizations as the basis for suitably prepared selection from the subject matter for appropriate presentation to their members and the general public.

In order to make available in convenient form the facts developed and conclusions reached as to proper treatment of the traffic problems at railway grade crossings on the one hand and at highway intersections on the other hand, the text of this report is divided into two separate sections dealing respectively with these two types of traffic hazard.

I—Protection of Railway Grade Crossings

This section of the report relates to crossings at grade by highways over steam railroads and electric railways other than street railways. The subject is dealt with under the following headings:

Accident records	Safe driving practices
Grade separations	Laws and regulations
Reduction of physical hazards	Enforcement
Protective measures	Education of highway users

Excellent work has been done by several agencies in dealing with some of these problems, particularly the American Railway Association and the American Railway Engineering Association, the American Electric Railway Association, the American Standards Association, the National Association of Railroad and Utility Commissioners, the American Association of State Highway Officials and the U. S. Bureau of Public Roads, many of the state commissions and highway departments, municipal administrations and a number of associations dealing with the technical and safety problems involved.

The National Conference on Street and Highway Safety in 1924, through the reports of its Committees on Construction and Engineering, City Planning and Zoning and Public Relations, presented condensed statements of the principal considerations requiring attention in connection with grade crossing elimination and protection of crossings remaining at grade. The Second Conference in 1926 included in its general report a summary of the principles approved by the Conference up to that time. Since then there has been a further development of practices and a tendency toward standardization in the treatment of the problems as well as a growing appreciation of their importance. While progress has been made, both in the elimination of the more important crossings and measures of protection for those remaining at grade, this progress has been spotty as among the different jurisdictions throughout the country and as to the relative attention given to the several important features of the crossing problem listed above. It is the purpose of this report to present

briefly what are believed to be the best standards and practices in regard to each of these features for the guidance and information of responsible authorities and the public.

It will be observed that there are many points of similarity between the problems at railway grade crossings and those at highway intersections, such as the need for the removal of obstacles to clear view, uniformity in character and location of warning signs and prudent conduct of motorists in approaching the crossing or intersection. On the other hand, due to the fact that railway trains, necessarily running at high speeds over private rights of way, cannot generally be stopped to avoid collision with highway users, the extra hazards at grade crossings call for additional protective measures.

Accident Records

In 1929 there occurred in the United States a total of 2,485 fatalities at highway crossings of steam railroads, and 202 at highway crossings of electric railways other than street railways. These constitute 8.7 per cent of the estimated total of 31,000 traffic fatalities during the year. There were 6,804 nonfatal injuries at steam railroad grade crossings.

Statistics of grade crossing accidents on steam railroads for recent years are shown in Table A.

The following features of the grade crossing accident situation deserve special comment:

(a) The number of grade crossing accidents and fatalities has been nearly constant during the past four years. This is in spite of an increase of 20.4 per cent in motor vehicle registrations in the same period.

(b) Although the recent trend in grade crossing accidents has been more favorable than that for general traffic accidents, the fact that approximately 2,500 persons annually lose their lives at grade crossings emphasizes the continuing importance and magnitude of the question of crossing protection.

(c) To each fatality in grade crossing accidents there were 3.65 nonfatal injuries, whereas statistics from other sources indi-

TABLE A—SUMMARY OF HIGHWAY GRADE CROSSING ACCIDENTS ON ALL STEAM RAILWAYS

(Interstate Commerce Commission Statistics)

	1926	1927	1928	1929
Total accidents	5,862	5,596	5,752	5,912
Total fatalities	2,491	2,371	2,568	2,485
Total nonfatal injuries	6,991	6,613	6,666	6,804
Total fatalities and injuries	9,482	8,984	9,234	9,289
Fatalities caused by trains striking or being struck by				
Passenger automobiles	1,766	1,690	1,820	1,741
Motor buses	15	30	9	7
Motor trucks	281	254	336	337
Pedestrians	293	299	299	307
Others (motorcycles, bicycles, trolley cars, etc.)	136	98	104	93
Vehicles or pedestrians struck by trains				
Accidents	4,585	4,295	4,357	4,358
Fatalities	2,188	2,078	2,240	2,163
Nonfatal injuries	5,240	4,844	4,688	4,631
Vehicles or pedestrians collided with trains				
Accidents	1,129	1,205	1,298	1,454
Fatalities	237	259	285	287
Nonfatal injuries	1,661	1,701	1,923	2,104
Miscellaneous grade crossing accidents				
Accidents	148	96	97	100
Fatalities	66	34	43	35
Nonfatal injuries	90	68	55	69

cate that for all kinds of traffic accidents the ratio is approximately 35 serious personal injuries to each fatality.

(d) The proportion of accidents in which motor vehicles collided with the sides of locomotives or trains has increased materially. The ratio of fatalities to nonfatal injuries in such accidents, however, is about 1 to 7, while the corresponding ratio is about 1 to 2.2 in struck-by-train accidents.

(e) Fatalities to occupants of motor buses as shown in Table A indicate a decrease during the past three years, but these statistics relate to accidents on steam railroads only. If electric railways were included, the year 1929 would show at least 20 additional fatalities which resulted from a single collision between a bus and an interurban electric train, and no doubt there were other accidents of this character during the period covered by the tabulation. It should be noted, moreover, that there were a num-

ber of serious bus accidents in the first four months of 1930, two of which alone caused more than 30 deaths.

The effectiveness of various types of protection at grade crossings cannot be definitely appraised because of lack of data as to the amount of highway traffic passing the crossings at which the various types of protection have been installed, but Table B shows the number of each class of crossing and accidents thereat for a typical year.

TABLE B—GRADE CROSSING ACCIDENTS IN 1928 ACCORDING TO TYPES OF PROTECTION
(Interstate Commerce Commission Statistics)

	Number of Crossings	Accidents	Fatalities	Nonfatal Injuries
Crossing gates	5,707	179	88	106
Crossing watchmen	7,297	643	207	762
Visible and audible signals	8,004	331	192	354
Visible signals	3,635	440	245	431
Audible signals	4,572	318	165	354
Fixed signs	205,933	3,841	1,671	4,659
No signs	4,941			

On 171 electric interurban railways reporting to the Interstate Commerce Commission and operating 256,849,500 car-miles in 1929, the first year for which such records are available, grade crossing accidents totaled 733, with 202 fatalities and 940 nonfatal injuries. Of these, 174 killed and 764 injured were occupants of automobiles. On 43 systems for which comparable figures were reported to the American Electric Railway Association for the years 1924-28, the grade crossing accident record was as shown in Table C.

TABLE C—ACCIDENT RECORDS AT GRADE CROSSINGS ON 43 INTERURBAN ELECTRIC RAILWAYS

	Fatalities per Million Car-Miles	Nonfatal Injuries per Million Car-Miles
1924	0.49	1.66
1925	0.44	1.64
1926	0.30	1.46
1927	0.40	1.65
1928	0.31	2.10

Grade Separation

The number of new crossings added and number of existing crossings (steam railroads with highways) eliminated during three years for all railroads are as shown in Table D.

TABLE D—GRADE CROSSING ELIMINATION
(Interstate Commerce Commission Statistics)

	1926	1927	1928
Number of new crossings added.....	1,876	1,909	2,068
Number of existing crossings eliminated	1,254	1,391	1,204
Number eliminated by separation of grades (included in the last figure above)	195	245	270
Net increase during year.....	622	518	864

While there was a net increase of 2,004 crossings during this three-year period, the crossings that are being eliminated are mainly those where the greatest exposure occurs. The same is true of crossings at which protective devices are installed. Hence the aggregate hazard at unprotected crossings is being reduced more than the figures as to crossings eliminated and protected might indicate.

Expenditures by the railways for grade crossing elimination have averaged more than $30,000,000 per year during the past three years. While figures are not available as to the total expended by the public authorities as their share in such work, it is known that this is generally in about an equal amount with the railway contribution. Thus the average total expenditures by the railways and the public is probably averaging more than $60,000,000 per annum. The average cost of elimination of a grade crossing is not available, but the costs range from as little as $25,000 to as much as $500,000 or more.

The problem of grade crossing elimination was dealt with in the reports of the First and Second National Conferences on Street and Highway Safety and in that of the Committee on Construction and Engineering. The declaration of the Second Conference, in which this Committee concurs, was as follows:

Elimination and Protection of Grade Crossings

Elimination of grade crossings, either by relocation of highways or rail

lines or by grade separation, which constitutes the only perfect solution of the problem, should be carried on under a proper program, first eliminating the most dangerous crossings on thoroughfares carrying heavy traffic, and with due recognition of the enormous costs involved, which, if elimination were attempted on a wholesale scale, would impose an excessive financial burden resting in the last analysis upon the public. The program should have due regard to the relative costs and advantages of grade crossing elimination and other methods of protection, and should be given the most thorough joint consideration by proper authority. In laying out new highways or railroads, or relocating existing highways or railroads, grade crossings should be avoided or eliminated whenever feasible. In eliminating grade crossings, narrow or obstructed underpasses and sharp turns in the approaches thereto should be avoided. Authority to order grade separations or proper protection at grade crossings should be vested in the commission having jurisdiction over the railways, and this commission should also determine the proper division of costs between the railroads and the public. The state highway department or other highway authorities should plan the improvement and initiate the proceedings for all highways under their jurisdiction. Time is an essential element and a prompt decision should be provided for in the law.

A progressive policy should be carried on by the railways and the highway authorities with respect to elimination. However, as there is a total of about 240,000 highway railway grade crossings in the United States it is obvious that the elimination of them all by grade separation is economically impossible, at least for the immediate future. Grade separation cannot be counted upon as a principal solution of the problem, and grade separation projects should be carefully selected to include those which will to the greatest degree reduce hazards and facilitate traffic movement at points of great traffic density. Meanwhile, chief reliance must be placed upon measures for reduction of hazards at the crossings remaining at grade, as will be outlined in the sections of this report that follow.

Reduction of Physical Hazards

The physical hazards at grade crossings to which attention should be directed are those arising from:

(i) Layout and condition of the highway at and on the approaches to the grade crossing:

(ii) Obstructions of whatever character to clear vision from the viewpoint of the highway user;

(iii) Lighting conditions at the grade crossing and visibility of the train equipment as seen by the motor vehicle operator.

The following are the principal physical hazards requiring attention:

Approach Grades.—Highway grades adjacent to railroad tracks should be practically level and smooth for a minimum distance of 25 feet, preferably 50 feet, on each side of the nearest rail. Beyond those points, if feasible, the approach grade should not exceed 4 per cent for main traveled roads carrying a considerable amount of truck traffic, and should not exceed 5 per cent for roads carrying principally passenger traffic. These should be considered as maximum grades and should be reduced wherever practicable.

It should be assumed that the condition "practically level" will be reasonably fulfilled if the tracks are at the center of a long vertical curve on the highway, provided full sight distance of 500 feet along the highway is secured. It is also realized that if the tracks are on a curve and are superelevated it will not be feasible to establish a level grade, but if the grade is uneven enough to cause motor vehicle operators difficulty in driving over it this should be regarded as a strong argument for grade crossing elimination.

Road Surface at Crossings.—If the road is clear and unobstructed, the width of the surface at the crossing should be as wide as the travelable portion of the highway leading thereto, including the travelable portion of the shoulders.

If there is an obstruction in the roadway, the width of the roadway surface allowed for each possible lane of movement of the highway leading thereto (including the travelable portion of the shoulders) should be two feet more per lane at the crossing than the allowed lane widths on the highways. The highways should be widened for a distance of 100 feet on each side of the crossing so that the outside lines of the roadway will be the same distance apart as they are across the railroad crossing. That portion of the road surface located between the rails and between

the tracks should be maintained in as smooth a condition for travel as the adjacent road surface.

Sharp Highway Turns and Junctions Near Crossings.—Sharp turns and junctions of highways should be avoided at crossings. If unavoidable on account of conditions that may exist, they should be kept as far as possible from the crossing, and not less than 250 feet. Curves and junctions detract the attention of the driver from the real danger at the railroad crossing and should, therefore, be far enough removed so that there will be ample opportunity to observe approaching trains after the driver has rounded the curve or passed the junction. Existing sharp turns near crossings should call for a relocation of the highway to eliminate this added danger.

Major Highway Intersections Near Crossings.—Intersections of major highways close to railroad crossings, besides creating the same hazards resulting from sharp turns and junctions near the crossings, offer obstacles to future grade separation of railroad and highway and of highway and highway. Such intersection should therefore not be located within 500 feet of a railroad grade crossing.

Obstructions to View.—The obstructions to view ordinarily encountered are steep banks, trees and shrubs, standing crops, buildings, parked vehicles, cars stored on sidings and billboards.

To promote safety the driver should be able to observe approaching trains while he is still far enough from the crossing to permit him to decide whether he can safely clear the intersection in front of the train. If it is not feasible to provide unobstructed view, obviously greater precautions must be taken to insure full warning to the driver of approaching trains.

The minimum requirements for satisfactory visibility at each crossing should be worked out with care by the highway engineers in conference with representatives of the railroad. Where feasible, such areas should be cleared as to enable the operator of a vehicle approaching a crossing at reasonable speed to see a train approaching from either direction in ample time to stop before reaching the crossing. There is provision hereinafter for speed limit signs to indicate maximum reasonable speeds where

view is unobstructed within these minimum requirements for visibility, and lower proper speeds where view has not been cleared to meet these requirements.

Billboards and signs other than official traffic signs should not be erected closer to the railroad crossing than a point 150 feet from the advance railway warning sign on the approach side.

Lighting Conditions at Grade Crossings.—Where adequate illumination of grade crossings is economically practicable it presents definite advantages in the illumination of the crossing itself, of vehicles on the highway and of railway equipment on the tracks. Special care should be taken in installing lights at grade crossings that glare therefrom is not thrown into the eyes of vehicle operators approaching the crossing and that the lights aid in the visibility of the crossing signs and signals instead of reducing their visibility by the elimination of contrast, or making less visible headlight beams of approaching trains. Consideration should also be given to the visibility of rolling stock as affected by the color of paint used thereon and as illuminated by automobile headlights or by fixed lights at the grade crossing.

Protective Measures

Table E shows the number of crossings and the proportion protected and unprotected for Class I railways:

TABLE E—PROTECTIVE MEASURES AT GRADE CROSSINGS

	1926	1927	1928
Protected by gates, watchmen, or automatic signals	27,927	28,724	29,215
Protected by fixed signs or barriers	202,620	203,817	205,933
Unprotected	4,611	3,742	4,941

A part of the increase in number of crossings from 1926 to 1928 is due to the amalgamation of Class II and III railroads with roads in the Class I railway group.

Table F shows the percentage of the various types of protective measures employed at the present time.

TABLE F—PROTECTION AT GRADE CROSSINGS BY TYPES

Kind of Protection	Percentage of Crossings
Crossing gates	2.4
Crossing watchmen	3.1
Audible and visible signals	3.3
Audible signals	1.9
Visible signals	1.5
Total protected by watchmen or devices to indicate approach of trains	12.2
Protected only by fixed signs	85.8
No protection	2.0
Total	100.0

Such analyses as have been made of the effectiveness of the different types of crossing protection, taking into consideration the volume of traffic on the rails and highways, show that protection is of unquestionable value.

There has been a steady decline year by year in the number of crossings protected by gates, and also in the number protected by crossing watchmen. It should be noted, however, that crossings selected for elimination year by year are largely those where gates, watchmen or both were formerly utilized, and that a part of this decline is also due to the substitution of flashing light or wigwag signals for gates or watchmen. It does not indicate retrogression in methods or extent of protection.

The trend of protection seems to be toward the visible type of automatic signals; that is, devices that indicate the approach of locomotives or trains.

Table G shows what happened between 1926 and 1928 with reference to the number of protected and unprotected grade crossings in the several states.

The installation cost of a flashing light or wigwag train approach signal varies greatly according to number of tracks, type of installation and particular location. Recent studies show a spread in usual costs from $1,500 to $4,000 per crossing, while some installations cost less than the minimum here indicated and others more than the maximum. Annual maintenance, depreciation and operating costs average at least 20 per cent of the cost of installation. A recent study of the cost of manually-controlled

TABLE G—SUMMARY OF CHANGES IN EXTENT OF CROSSING PROTECTION BY STATES BETWEEN 1926 AND 1928

Five states showed decrease in number of both protected and unprotected crossings, indicating definite improvement, as follows:

Connecticut	Massachusetts	Utah
Maryland	New Hampshire	

Thirteen states showed increase in number of protected and decrease in number of unprotected crossings, indicating improvement:

Delaware	Maine	North Dakota
Georgia	Mississippi	Ohio
Idaho	Missouri	Pennsylvania
Indiana	New York	Vermont
Iowa		

Five states showed decrease in number of protected and increase in number of unprotected crossings:

Minnesota	Rhode Island	Wyoming
New Jersey	Tennessee	

Twenty-five states showed increase in number of both protected and unprotected crossings:

Alabama	Louisiana	Oregon
Arizona	Michigan	South Carolina
Arkansas	Montana	South Dakota
California	Nebraska	Texas
Colorado	Nevada	Virginia
Florida	New Mexico	Washington
Illinois	North Carolina	West Virginia
Kansas	Oklahoma	Wisconsin
Kentucky		

gates indicated an average of $1,278 per crossing for installation, with an annual cost (for maintenance, operation, watchman's wages and so forth) in excess of $3,000 per year. With 240,000 grade crossings to be protected, it is obvious that the costs of automatic wigwag or flashing signals or of gates and watchmen would be such a large amount, which, in the last analysis, must be borne by the public, that these special forms of protection can be installed only at the crossings where there is considerable rail and highway traffic.

In order to avoid placing an undue burden upon the railroads, and to assist in expediting the provision of appropriate protection of this character where needed, the public authorities should contribute a fair share of the costs of such protection, following principles similar to those adopted in sharing the expense of grade crossing elimination.

Furthermore, the public authority can expedite the proper pro-

tection of crossings by adoption of uniform standards throughout the country, thus doing away with the hampering effects upon the efforts of the railroads due to the necessity of complying with laws which differ in the various states.

Standard Fixed Signs and Markings

The fixed signs and markings on the highway approaches to railway grade crossings have been standardized for use on rural highways by the Joint Board on Interstate Highways of the American Association of State Highway Officials and the Bureau of Public Roads, and for use within municipalities through the report prepared by the American Engineering Council for the National Conference on Street and Highway Safety. The standards recommended in this report are in complete agreement with those specified by those agencies mentioned above. Similarly the railroad crossbuck sign recommended herein to be installed on railroad right of way at grade crossings is that which has been standardized by the American Railway Association.

To give warning of the proximity and character of a railway grade crossing at sufficient distance from the crossing to enable the driver of a vehicle to regulate its movement so as to be able to stop if necessary, and otherwise determine before reaching the crossing whether he can cross in safety, the standard signs and markings are recommended herein. These may be considered as being located in three groups from the point of view of the motorist approaching the crossing:

(i) Advance warning signs and pavement markings placed far enough from the crossing to give the fastest traffic abundant distance to slow down or, if necessary, stop before reaching the crossing.

(ii) Signs at points closer to the crossing and varying in legend with the character of the crossing, requiring a greater or less reduction in speed or a stop as visibility conditions or other hazards at the crossing may require.

(iii) Signs at the crossing itself erected by the railroads on the railroad right of way. These signs at the crossing itself should be supplemented where conditions require by train approach sig-

nals or crossing gates and watchmen, as will be explained hereinafter.

While the practice of the different states as regards distance of advance signs from the railroad crossing varies at present from 200 to 500 feet, some seventeen states now specify distances of 300 to 450 feet. The American Association of State Highway Officials recommends 350 feet under normal conditions; on long down-grade tangents, 450 feet; for built-up districts, curves and the like, where speed of traffic is limited, 300 feet (or even less, dependent upon conditions). The American Engineering Council (referring to city conditions) recommends that railroad crossing advance signs be placed 100 feet or more from the crossing. If a stop sign is used, the American Association of State Highway Officials specifies that it shall be 25 to 50 feet from the tracks. The American Railway Association and American Engineering Council recommend that the crossbuck sign be placed not more than 15 feet from the railroad crossing (preferably at the side of the highway). The recommendations which follow are consistent with the above.

The heights and lateral spacing from the highway are also specified by the above Associations.

The following are the specific standards recommended:

(a) *Advance Warning Signs and Pavement Markings.*—At each highway approach to a railway grade crossing there should be erected not less than 200 feet (in cities not less than 100 feet) or more than 450 feet from the crossing a standard circular highway advance warning sign, illuminated or with reflecting letters, consisting of a black "RR" and cross on a yellow background.

As a supplementary advance warning of approach to railway grade crossings on hard surfaced, heavily traveled highways where rail traffic is fast or frequent, pavement markings—black (or white) on concrete and white (or yellow) on asphalt—should be employed, using the standard form approved by the American Association of State Highway Officials. This form has been adopted and put into use by six states—Idaho, Indiana, Kentucky, Minnesota, Missouri and Ohio. It consists of two lines 50 feet apart across the roadway at right angles thereto between 300

and 400 feet from the railroad tracks, with an elongated "RR" between the two lines; and two other lines, 10 feet apart, approximately 100 feet from the tracks and parallel thereto. The center line of the roadway is also marked. Five additional states have their own designs and nine other states have experimented with various designs.

On wide highways lane markings are also recommended. On three-lane highways the two righthand lanes approaching the crossing should be marked; on highways of four or more lanes, all lanes to the right of the center line.

(b) *Speed Limit or Stop Signs and Supplementary Slow Signs and Markings.*—In addition, at a point nearer the crossing, there should be erected a speed limit sign or a stop sign, depending on the following conditions:

(i) Outside of business or residence areas, where the view of the track is not obstructed within necessary visibility zones, and no special hazard exists, a standard rectangular 30-mile speed limit sign in black letters and numbers on a white background should be erected 100 feet from the crossing.

(ii) Where the view of the track is obstructed within necessary visibility zones, or where other special hazards exist, a standard 15-mile speed limit sign, illuminated or with numerals of reflecting type, should be erected 50 feet from the crossing.

(iii) Where due to extreme limitation of view or other especially hazardous conditions crossings have been designated by the proper state commission in accordance with the Uniform Vehicle Code to require all vehicles to stop, there should be erected not less than 15 or more than 50 feet from the crossing, at each highway approach, a standard octagon stop sign, illuminated or with letters of reflecting type, with the word "Stop" in black letters on a yellow background (red letters on a yellow background within municipalities and optional outside thereof).

(iv) Where the speed limit or stop sign cannot be seen sufficiently in advance, a standard diamond-shaped slow sign with black letters on a yellow background should be erected not less than 100 feet in advance of the speed limit or stop sign.

(c) *Crossing Signs.*—At all grade crossings a standard railroad crossbuck sign with two arms mounted across each other should be installed on the railroad right of way. In case of multiple tracks, there should be mounted below the crossbuck arms a clearly legible sign indicating the number of tracks.

Train Approach Warning and Protection Measures

At many railway grade crossings the amount or character of railway and highway traffic warrants special warning of the approach of trains in addition to the standard requirements of warnings by the locomotive whistle and ringing of the locomotive bell. At such crossings, the following are recommended in addition to the standard fixed signs and markings:

(a) *Automatic Train Approach Signals.*—At crossing on heavily-traveled highways where there are sufficient intervals between train movements, either of the following standard visible warning signals should be installed:

(i) A wigwag signal with a swinging target and red light.

(ii) A flashing light signal with two red lights in a horizontal line 30 inches apart flashing alternately.

As adjuncts to other train approach warning measures, but not as substitutes therefor, bells or other audible signals may be used.

The American Railway Engineering Association makes this recommendation with regard to location of train approach signals:

"We recommend that wherever wigwag or flashing light signals are used, two shall be used at each crossing, one on each side of the track. Under some conditions, where the street is of sufficient width, the signals may be located in the center of the street."

Signal heights have been standardized at between 6 and 9 feet above the surface of the roadway, depending on the individual location.

The wigwag signal is in more general use west of the Mississippi, while the flashing light signal has been largely adopted by the railroads east of the Mississippi. Bells or audible signals have been used to a considerable extent for the protection of

grade crossings in the past, but are less effective than the above signals and are being replaced by them.

Careful study by the railroads should be continued to determine the feasibility of using time control for train approach warning signals at crossings; that is, such control as will give warning always at the same number of seconds before the train actually arrives at the crossing, regardless of the speed of the train.

On some railroads ordinary highway traffic stop-and-go signals are being used to control traffic at grade crossings. Regarding the use of such signals, the American Engineering Council Committee's report says:

"Regular street traffic control signals are sometimes used at railroad crossings, particularly within city limits. Their use (observance) is enforceable under city ordinances, but they should be used instead of the foregoing standard signal only if operated manually, or by combined automatic and manual control under supervision. If not operated continuously, the standard train approach signal should be used when the traffic control signal is not in operation."

(b) *Crossing Gates and Watchmen.*—At crossings on heavily-traveled highways where frequent switching movements or shortness of intervals between train movements requires more prompt and positive indication of approach of trains and of clearance of the crossings for highway traffic, crossing watchmen or manually-controlled crossing gates or signals should be provided. Crossing watchmen should be equipped with standard crossing watchmen's circular stop signs, with black letters on white background, and with red flags and lanterns. Gates should be made conspicuous by alternate black and white 12-inch striping at an angle of 45 degrees sloping downward toward the center of the highway.

Obedience to directions given by gates, crossing watchmen or positive visible crossing signals is required by the Uniform Vehicle Code.

There appears to be no conclusive data available at present to indicate the relative efficiency of wigwag or flashing signals as compared with crossing gates and watchmen. As the public be-

comes better educated to observance of traffic signals through extension of their use on streets and highways, crossing signals of the wigwag or flashing type should become more effective.

Safe Driving Practices

The United States Supreme Court expressed itself in no uncertain terms when it said in a leading case:

"When a man goes upon a railroad track he knows that he goes to a place where he will be killed if a train comes upon him before he is clear of the track. He knows that he must stop for the train, not the train stop for him. In such circumstances it seems to us that if a driver cannot be sure otherwise whether a train is dangerously near he must stop and get out of his vehicle, although obviously he will not often be required to do more than to stop and look. It seems to us that if he relies upon not hearing the train or any signal and takes no further precaution he does so at his own risk."

The Supreme Court in this opinion has indicated a proper measure of precaution to be taken by a motor vehicle operator in case of existence of an extreme hazard. What constitute safe driving practices at grade crossings under other and more usual conditions?

Absolute regard for positive visible or audible signals warning that a train is approaching is a fundamental requirement of law and prudent practice. Many crossings, however, are not equipped with such signals, and in any case, as the Supreme Court has indicated, the highway user is responsible for exercising the greatest circumspection and caution in traversing any railroad crossing.

In its simplest form a grade crossing consists of a single-track railroad, with both track and highway straight, on level ground with no obstructions to a clear view in all directions. In daylight the vehicle operator familiar with the crossing can assure himself by looking in each direction that no train is approaching and that he can continue safely. However, in order that his observations up and down the track may be sufficiently thorough to see any approaching train, without undue diversion of attention from the road ahead, and in order that he may not jeopardize

himself and other highway users by running at excessive speeds over grade crossings which can seldom be made as smooth as other parts of the highway, he should not in any case traverse grade crossings at a speed in excess of 30 miles an hour. The Uniform Vehicle Code places a special burden upon an operator exceeding this speed at grade crossings, and earlier in this report recommendations have been made for signs to indicate accordingly.

The operator may be approaching a crossing with which he is not familiar. It may look at first view exactly like others with which he is acquainted, but there may be a junction just beyond the crossing, or an industrial siding at an angle, from which a switching engine may emerge after he has convinced himself that nothing is approaching on the main track.

The track may be in a cut, or obscured by trees or buildings. The approaching motorist may be able to see it near the crossing but not at a distance, or there may be blind spaces in an otherwise clear view. In such cases the only safe course is to approach the crossing prepared to stop if necessary.

There are crossings at which, particularly at night, the only way to make sure that no train is approaching is to stop near enough to command a view up and down the tracks. Under the Uniform Vehicle Code, the proper state authority is empowered to designate dangerous crossings at which all vehicles must stop. In any event the prudent driver will make it his rule to stop at such points.

Having assured himself that the way is clear, how will the safe driver proceed? One rule will hardly fit all cases. If he has not been compelled to stop, and the crossing is level and smooth, high gear will take him clear of danger in the shortest time. If he has come down to low speed, or has stopped, he must, above all things, avoid stalling his engine, which sometimes occurs as a result of a sharp grade, an uneven crossing or nervousness caused by the sudden appearance of an approaching train. He should, therefore, go over the crossing in low or second gear. If he has the misfortune to stall on the tracks and cannot restart his engine promptly he should know that, as a last resort, he can generally,

by going into low gear and holding his foot continuously on his self-starter, let it drive the car forward off the track.

All of the foregoing relates to the operator who finds that no train is approaching. If he sees a train is approaching, the safe driver will not proceed ahead of it unless he is absolutely certain that he can get across with an ample margin of safety. Under no circumstances will he race the train to the crossing.

He will stop sufficiently back from the tracks to avoid danger of drifting upon them or being crowded upon them by another vehicle, but near enough for a good view of the tracks in both directions. He will not stop on a nearer track, for fear he might be trapped and struck there by another train. He will not start across at the instant the train for which he has been waiting clears the crossing, but will first make sure there is no other train coming in either direction on another track. A second train obscured by another is a prolific source of danger, and the driver must not overlook the possibility of still another train coming in either direction on a track beyond, or of a train not noticed on a nearer track.

The continued display of the signal indication after one train has cleared the crossing indicates that another train is approaching the crossing.

Highways over railroad yards or the switching approaches thereto have special hazards, and should be considered in establishing priority in grade separation programs. Meanwhile, the safe driver who must use such a crossing, besides exercising all of the precautions called for at main-line crossings, will watch freight cars standing near the roadway, lest they be unexpectedly set in motion by a switch engine; will keep his car under such control as not to stall his engine; will observe the tracks at whatever angles and distances apart, and will not relax his vigilance until certain he is over the entire crossing.

The foregoing can be summed up in these five rules for a driver approaching a railroad crossing:

1. Slow down or stop.
2. Listen and look both ways; when one train passes another may be coming.

3. Shift to a lower gear when necessary to prevent stalling on the tracks.

4. Do not try to beat a train over a crossing.

5. Be doubly careful at night and on strange roads.

Although pedestrians are the victims in grade crossing accidents in a relatively small proportion of such accidents, safe walking practices should be summed up briefly. The pedestrian has but two basic precautions to observe: He must be sure before he crosses each individual track that the way is clear, and in the case of multiple tracks he must not permit himself to be trapped in front of a train, with nowhere else to go.

Laws and Regulations

The Uniform Vehicle Code contains several provisions relating especially to railroad grade crossings. One of these is that operators of motor vehicles must keep to the right in crossing railroads, thereby affording operators coming in the opposite direction opportunity to clear the intersection without delay. Another is the obviously necessary one that railroad warning signals must be observed.

The Uniform Code further requires that certain vehicles, such as street cars, motor buses, school buses and trucks carrying gasoline or other inflammables or explosives, must stop at all railroad grade crossings. This provision is particularly appropriate, inasmuch as the operators of such commercial vehicles have special responsibilities to the public and should be skilful enough as operators to make quite unlikely that the vehicle will stall or run into danger in starting over the crossing after a stop.

In addition, the Uniform Code requires in the case of certain types of slow-moving equipment that provision be made to give ample advance warning to the railroad company to enable it to protect approaching trains against the stalling of such equipment on the crossings.

In some states laws have been passed requiring all motor vehicles to stop at all grade crossings. Such legislation has been vigorously opposed by the motoring public, both because it causes congestion on busy highways, subordinating even the heaviest

highway traffic to the railway traffic no matter how light, and forcing stops many times where there is no need for a stop; and because it can be seriously questioned whether stopping at every crossing and then proceeding across at low speed does not prolong the hazard and introduce danger of stalling. On the other hand, as previously pointed out, it is evident that there are many crossings at which the only safe course for the motorist is to stop and see whether a train is approaching from either direction before proceeding. The Uniform Vehicle Code therefore empowers the proper state authorities to designate and indicate by signs certain dangerous crossings at which every motor vehicle must stop.

Enforcement of Laws and Regulations

The National Conference on Street and Highway Safety has emphasized the importance of vigorous and impartial enforcement of all motor traffic laws. Enforcement is inadequate in many, if not most, states and communities. Motorists and pedestrians make their own rules. Practices are indulged in every day which invite accidents that are avoided only fortuitously. Undoubtedly in many cases the driver who brings himself and his companions to grief at the grade crossing has previously been guilty of many unpunished violations of the traffic laws and regulations. More rigid enforcement all along the line could be expected to reduce materially railway grade crossing accidents.

Analysis reveals that a large number of drivers do not heed the warning given by the flashing light signals, run through crossing gates and even disregard the stop sign of the crossing watchman. Not infrequently they run him down and fatally or seriously injure him.

There could well be check-ups of motorist and pedestrian observance of signals at grade crossings. When a motorist crashes through a crossing gate or dashes under one that is being lowered, he is violating the law in effect in many states. When a pedestrian goes under the gate he is doing the same. There seems to be a tendency on the part of police officers to wash their hands of railway grade crossings and leave it entirely to railroad com-

panies to meet the situation. Enforcement officers should give as much consideration to violations at grade crossings as at other points, cooperating with the railroad officials.

An effective aid in enforcement of traffic laws and regulations is undoubtedly the drivers' license law with examination. Safe driving practice at grade crossings should be given a reasonable amount of attention in such examinations.

Education of Highway Users

Despite all efforts of the authorities to eliminate hazards, to provide ample warning and traffic control measures and to enforce the rules and regulations applicable at grade crossings and highway intersections, the public must in the main be depended upon for voluntary compliance with the rules of proper conduct at such points. Statistics indicate that a large percentage of the accidents occur in broad daylight where there is a clear view of the tracks in both directions, and, as shown earlier in this report, in no small number of cases the vehicle runs into the side of the train. Even after deducting from the latter cases those in which the operator's judgment of speed and distance was bad, and, believing he could clear the crossing first, he nevertheless struck the train near the front, it is obvious that neither laws nor enforcement were effective. There is need for continual effort to educate the public in these matters.

Such educational efforts should be directed not only to impressing motorists and pedestrians with the need for obeying the regulations, but also to making clear to them what are dangerous and what are safe driving practices, and why.

The American Railway Association has, for a number of years, been conducting an effective educational campaign on reduction of grade crossing accidents. The American Electric Railway Association has also been actively at work. The American Museum of Safety, through the Harriman and Brady Awards, has focused attention upon these and other hazards of railway operation.

Many railroad companies follow a consistent policy of supplying speakers to public schools, to clubs of many types, to scout troops and to other organizations, where the importance of safe driving and walking practices at grade crossings and along rail-

road tracks is emphasized. These talks, which are usually made by practical men, have produced excellent results.

The continued large number of grade crossing fatalities and accidents is evidence enough that this work should be actively supported and put on a comprehensive basis.

Therefore, it is of fundamental importance that knowledge of the laws, regulations, traffic control measures and proper practices in these regards be carried to all of the public concerned. To this end the principles stated in this report, necessarily somewhat complicated and technical in character, should be utilized by the interested organizations as the basis for suitably prepared selection from the subject matter for appropriate presentation to their members and the general public.

II—Protection of Highway Intersections

This section of the report deals with the traffic problem at highway intersections under the following headings:

Accident records
Highway grade separations
Reduction of physical hazards
Protective measures
Safe practices at intersections
Laws and regulations
Enforcement
Education of highway users

The highway intersection problem is serious from the viewpoints of both traffic movement and safety, because of the vast amount of highway traffic continually having to pass through an enormous number of intersections at grade of more than 3,000,000 miles of rural highways and countless city streets. As the volume of motor transport mounts, the problems of congestion at points of traffic concentration increase, while with the improvements of additional highway mileage, of highest importance to the national welfare, the enlarged volume of more rapid vehicle movement increases and complicates the safety problem.

Various elements of the problem of congestion and safety have received the attention of public authorities and private organizations concerned with traffic. The American Association of State Highway Officials and the Bureau of Public Roads have adopted standard warning signs for the approaches to intersections on the rural highways, and the American Engineering Council has developed standard signs, signals and pavement markings for city street intersections. The National Safety Council, American Automobile Association, traffic engineers, public officials and others concerned have devoted efforts to improve the situation.

The reports of the National Conference on Street and Highway Safety's Committees on Construction and Engineering and Metropolitan Traffic Facilities in 1924 and 1926, respectively, dealt with certain phases of the traffic problem at intersections, and the present Committee on Measures for the Relief of Traffic Congestion has given careful consideration to intersections as points of maximum congestion. The Uniform Vehicle Code and the Model Municipal Traffic Ordinance include provisions par-

ticularly designed to afford the legal basis for safe and efficient regulation of traffic at such points.

It is the purpose of this report to outline the best standards and practices with regard to these features, and to present for the information of the public authorities in charge of traffic and the great multitude of highway users the principles which should be followed in developing safer conditions at highway intersections.

In the preceding section of this report the detailed recommendations regarding similar problems at grade crossings were presented. There will be found hereinafter corresponding recommendations applicable at highway intersections, together with additional pertinent suggestions.

Accident Records

Consideration of the available data indicates that considerably more than 50 per cent of the estimated 31,000 motor vehicle fatalities which occurred in the United States in 1929 took place at street and highway intersections.

The Committee on Traffic Accident Statistics of the National Conference reports 27,966 motor vehicle fatalities in the United States in 1928, and estimates that there are now occurring at least 35 serious nonfatal injuries for each fatality. This would indicate that in 1928 there were 978,710 serious injuries. The National Safety Council estimates that during that year 74 per cent of all motor vehicle fatalities and 64 per cent of nonfatal injuries occurred at intersections. On the basis of these percentages it would appear that there were 20,655 motor vehicle fatalities and 724,245 motor vehicle injuries at intersections in 1928.

The National Safety Council further estimates that, of the fatalities, 58 per cent occurred to pedestrians, 40 per cent to occupants of motor vehicles and 2 per cent to others; and that, of the nonfatal injuries, 47 per cent befell pedestrians, 51 per cent motor vehicle occupants and 2 per cent others. Thus, while the accident records show that the problem at railroad grade crossings is mainly protection of vehicles and their occupants, pedestrians present a serious additional problem at intersections.

To provide the basis for more comprehensive as well as more detailed analysis of accidents at highway intersections, traffic authorities should carry on more systematic collection and compilation of reports of such accidents, together with spot maps or card files to show the actual points where accidents most frequently occur.

Highway Grade Separations

The physical layout ordinarily established for street intersections provides much opportunity for conflict by the crossing lines of traffic. If two intersecting roadways are equally used by vehicles, the allotment of time at the intersection to each roadway cannot be greater than 50 per cent. Because of interference and time lost in stopping and starting, the actual efficiency in the use of an intersection for either of such roadways is reduced to approximately 35 per cent of the potential capacity of the highway away from the intersection. It is highly important, therefore, to develop means of eliminating the interference, delay and hazard that occur at highway intersections by such physical design as will permit continuous movement with the minimum conflict at the intersection.

Highway grade separations accomplish this most effectively, provided adequate arrangements are made for right turn and left turn movements from one highway to the other. When these turning movements are a large percentage of the through movements from which they turn, or with which they connect, there is opportunity for confusion, unless the by-pass routes utilized for this movement are carefully laid out so that the traffic streams can readily adjust themselves. With adequate design, this separation of traffic streams and assembling of lines of movement can be made with the same degree of freedom as occurs in a well-designed traffic "circle."

Separation of grades to eliminate the crossing of traffic at highway intersections has been receiving increased attention, but as yet has been applied in only a limited number of cases. The cost of such separation at an individual intersection approaches that of a highway railway grade separation. The unit cost for each

intersection is lessened where, as in the case of some major traffic arteries in and near great metropolitan cities, arrangements are made for separation of grades at many or all of the highways crossing the major artery; for example, in the Grand Concourse in New York City, the East Jefferson Boulevard at Detroit and some of the major highways in the Cleveland and Chicago regions. Proposals have also been made for extended systems of special high speed motor roads free of intersections at grade.

It is obvious, however, that the great cost of such projects limits the economically feasible separation of grades, at least for the immediate future, to an insignificant fraction of the highways of general motor use which exist in the United States. Proper treatment of highway intersections at grade and proper conduct of highway users at such points are therefore of obvious importance.

Reduction of Physical Hazards

The physical hazards at highway intersections to which attention should be directed are those arising from:

(i) The layout and condition of the highways at and on the approaches to the intersection;

(ii) Obstructions of whatever character to clear vision and from the viewpoint of the highway users;

(iii) Lighting conditions at the intersection and visibility of vehicle lights from the viewpoint of intersecting traffic.

The following are the principal physical hazards requiring attention:

Approach Grades.—Highway grades at and within highway intersections should be practically level for a distance of 50 feet on each side of the intersection. Beyond those points the approach grade should not exceed 4 per cent for main traveled roads carrying a considerable amount of truck traffic, and should not exceed 5 per cent for roads carrying principally passenger traffic. These should be considered as maximum grades and should be reduced wherever practicable.

Where the topography will not permit the above conditions and separation of grades is not warranted, the highway having the

steeper grade should be given preferential treatment, except in the case of a minor highway on a steep grade intersecting a major highway, and necessary standard advance warning signs and stop signs should be erected.

Roadway Widening at Intersections.—Widening of pavements for several hundred feet on each side of an intersection will permit more vehicles to pass through the intersection with less delay and chance for conflict between the currents of cross travel. Widening of the roadway at highway intersections up to a maximum of three lanes in each direction should be undertaken while the volume of traffic is well below the proper standards for the installation of traffic control signals on highways having single lanes in each direction.

Sharp Turns Near Intersections.—Where sharp curves are unavoidable on account of conditions that may exist, they should be widened or superelevated, and in any case should be kept as far as possible from intersections of major highways, preferably 250 feet or more. A curve detracts the attention of the driver from the real danger at highway intersections and should therefore be far enough removed so that there will be ample opportunity to observe approaching traffic after the driver has rounded the curve. Existing sharp turns near intersections should call for a relocation of the highway to eliminate this added danger.

Roadside Ditches.—At highway grade intersections all roadside ditches should be eliminated for a distance of 100 feet on each side of the intersection by placing tile or pipe near the right of way line so as to do away with the necessity for carrying the water around various curves in open ditches.

Rotary Traffic Distribution.—Where sufficient space is available, rotary traffic distribution by means of traffic circles (which may be true circles, ellipses or other geometrical figures) offers a means, much less costly than grade separation, for reducing the chances for collision, particularly at complicated street or highway intersections.

At traffic circles vehicles move in lanes so that the crossing of their paths in traversing the circle is made just as vehicles moving along a given street maneuver through the stream while

traveling, so as to reach either the righthand lane for a right turn, or the lefthand lane to pass vehicles ahead or make a left turn. Such maneuvering from one side of a street to another can be made with safety if the vehicles are traveling at reasonable speeds and with reasonable space between them. Therefore at circles the speeds of vehicles should be kept reasonably low; that is, less than 25 miles per hour.

Obstructions to View.—Obstructions to view, such as steep banks, trees and shrubs, buildings, billboards and parked vehicles at highway intersections, should be removed to provide visibility for vehicle operators approaching the intersections. In this instance the distances back from the intersection within which the obstructions should be cleared are not so great as for railway grade crossings, because with proper warning signs the speeds of highway traffic will be lower than the speed of the fastest train and deceleration is more rapid. For such intersections advance warning signs indicating the presence of the crossing should be placed in standard locations so that the vehicle should be proceeding under control. When the view is obstructed either standard slow, stop or other control signs should be erected to prevent vehicles from entering the intersections at reckless speed.

The minimum requirements for visibility at each intersection should be worked out by the highway engineers. Where feasible such areas should be cleared as to enable the operator of a vehicle approaching a crossing at reasonable speed to see a vehicle approaching from either direction on the other highway in ample time to stop before reaching the intersection, even though the other operator might be driving at a recklessly high speed. When these visibility requirements cannot be met, there is provision hereinafter for reduced speed limit signs or stop signs to control the movement in all directions from which there is a restricted view of the approaching cross traffic.

Billboards and signs other than official traffic signs should not be erected closer to the highway intersection than a point 150 feet from the advance warning sign for the intersection on the approach side.

In the lighting systems on motor vehicles attention should be given to making the vehicles more readily observed by the drivers of other motor vehicles approaching from the side. It is understood that the Society of Automotive Engineers and the Illuminating Engineering Society are giving consideration to this problem.

Protective Measures

There has in recent years been a rapid development in protective measures at highway intersections through the installation of warning signs and pavement markings, and the establishment of positive traffic control by automatic signals or traffic officers.

The number of highway intersections is enormous, and, at a very large proportion of them, taking into account the traffic and the physical conditions, there is little justification for even the simplest form of protection through establishment of warning signs. The system of standard signs and pavement markings is therefore recommended for immediate installation only at intersections on arteries of high speed travel and at points on other highways where there exist serious hazards or hazards not obvious to approaching traffic.

Good progress is being made in the installation of fixed warning signs and markings at such intersections as are indicated above in most of the states and in a considerable number of the counties and other highway jurisdictions. Good progress is also reported by the American Engineering Council in the application of standard fixed warning signs and pavement markings in a considerable number of cities and towns throughout the country. There is need, however, for complete application of these standard signs and markings within the limits of economic justification outlined above.

The installation of automatic signals has also progressed rapidly in some localities—in some cases, in fact, notably at isolated intersections, beyond the legitimate requirements of traffic, which could largely be met by proper fixed signs and pavement markings to warn and direct traffic movement. Due to the establishment of signals of improper type or without properly worked out relationship with signals at adjacent intersections, the full advan-

tages of automatic signal control have not been attained and at some points traffic has actually been hindered without compensating safety advantages. While properly designed automatic signal systems have been found to contribute to safety in a marked degree, in a few cases recently reported there have been evidences that excessive and unreasonable installations have brought about such a degree of nonobservance as to increase rather than decrease the hazards. On the other hand, the recent development of scientifically designed flexible progressive signal systems to regulate traffic over considerable areas, and the development of traffic-actuated signals, afford means for overcoming some of the disadvantages heretofore encountered through unwarranted interruption of traffic.

The volume of traffic justifying the establishment of automatic signal control is discussed in the report of the American Engineering Council Committee on Street Traffic Signs, Signals and Markings. Careful study of traffic conditions and discriminations are therefore needed in determining upon traffic control systems, designation of through highways or other use of fixed protection signs, and particularly in the allocation of available funds as between such protection measures on the one hand and the reduction or elimination of physical hazards on the other hand.

Standard Fixed Signs and Markings

The fixed signs and markings on approaches to highway intersections prescribed for use on rural highways by the Joint Board of the American Association of State Highway Officials and the Bureau of Public Roads and those recommended for use within municipalities by the American Engineering Council are considered to cover the requirements.

Following generally the same principle as in the case of railway grade crossings, signs and markings should give warning of the proximity and character of every intersection which is not otherwise obvious or where special hazard exists, at a sufficient distance from the intersection to enable the driver of a vehicle to regulate its movement so as to be able to stop if necessary and otherwise to determine before reaching the intersection whether

he may pass in safety. As in the case of approaches to grade crossings, the fixed signs and markings for highway intersections may be considered as being located in three groups from the point of view of the approaching motorist:

(i) Advance warning signs and markings, where necessary, placed far enough from the intersection to give the fastest traffic abundant distance to slow down or stop before reaching the intersection.

(ii) Signs at points closer to the intersection, and varying in legend with the character of the intersection, requiring reduction in speed or a stop as visibility conditions or other hazards at the intersection may require.

(iii) Directional lines or markers on the pavement at the intersection, and automatic traffic signals or traffic officers where the volume of traffic or other conditions justify.

Apart from the above there are provided on important marked federal, state or other highway routes black and white "junction" signs located 350 feet from intersections. These junction signs are only for information as to routes and are installed for this purpose without other reference to the needs from the point of view of safety of traffic than to forestall unnecessary stops at the intersection to determine the route to be taken.

The following are the specific warning signs and pavement markings recommended:

(a) *Advance Warning Signs and Pavement Markings.*—At each approach to a highway intersection which would not otherwise be readily recognized as such or where there is hazard not otherwise obvious, a standard square "crossroad" or "sideroad" caution sign with black lettering on a yellow background should be erected not less than 100 or more than 400 feet from the intersection. (In municipalities a standard "cross street" sign at or in advance of the intersection, depending upon conditions.)

At approaches to intersections center lines—black (or white) on concrete and white (or yellow) on asphalt—should, where practicable, be marked on roadways carrying heavy traffic to maintain efficient alignment. In case of wide roadways with two or more well defined streams of traffic, additional lines to mark

each lane are desirable for at least 200 feet from the intersection.*

(b) *Speed Limit or Stop Signs and Supplementary Slow Signs and Markings.*—At points nearer the intersection in certain cases, depending on the following conditions, there should be erected either speed limit signs or stop signs:

(i) Where the view of the cross road is obstructed within necessary visibility zones as indicated in Appendix A, or other special hazard exists, and the highway is not protected against cross traffic by stop signs, a standard rectangular 15-mile speed limit sign, illuminated or with reflecting letters, with black letters and figures on a white background, should be erected 50 feet from the intersection.

(ii) Where a through highway has been established or serious hazard indicates the desirability of preferential treatment to one highway at an intersection, standard octagonal stop signs, illuminated or with reflecting letters, bearing the word "Stop" in black letters on a yellow background (red letters on a yellow background in municipalities), should be erected at each entrance to such preferred thoroughfare.

This sign may be supplemented by a pavement marking "Stop."

(iii) Where the speed limit or stop sign cannot be seen sufficiently in advance, a standard diamond-shaped slow sign should be erected not less than 100 feet from such sign. This sign may be supplemented by a pavement marking "Slow" at the same distance from the intersection.

(c) *Directional Lines or Markers at Intersections.*—To direct the movement of traffic within an intersection, when desirable, special short directional lines marked on the pavement with arrow to indicate direction, or suitable traffic markers (buttons), should be installed.

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*The provision of center lines is important, not only at the intersections but as a valuable safety adjunct throughout the entire length of rural highways. At intersections and railroad crossings, as well as at curves and hill crests, crossing the center line should be avoided and is frequently prohibited by law. Elsewhere the center line is a valuable guide to the vehicle driver, especially at night or in foggy weather. It is desirable that the center lining be so designed as to give a clear indication as to where it may be crossed without infringing safety rules or legal regulations. For this purpose the use of solid and broken lines is recommended, the solid lines signifying that it must not be crossed and the broken giving a natural indication that it is not intended as a positive barrier. The solid prohibitory lines should extend for 200 feet each way from all signalled intersections.

Traffic Control at Intersections

Where the volume of traffic warrants, automatic traffic lights or traffic officers should be provided. Location and types of signals should be in accordance with the recommendations of the American Engineering Council.

Safe Driving Practices

In approaching a highway intersection, as in approaching a railway grade crossing, the prudent driver will have his vehicle under such control that before he enters an intersection he will be reasonably certain that he can proceed with safety. He will take into account not only the hazard due to other vehicles or pedestrians that may be within the intersection or that may enter it in a lawful manner, but also extra hazard that may result from the incompetent, reckless or illegal conduct of others.

The driver will approach and enter any intersection, whether of rural highways or city streets, at only such speed and in such manner that he can observe all approaching or turning traffic on the intersecting street that can possibly collide with him. He will not insist upon his right of way at the expense of safety, and will not race for the intersection. He will not try to intimidate the other operator, even though he may have the heavier vehicle.

He will scrupulously respect the rights of pedestrians. Realizing that at the busy intersection the pedestrian is largely at the driver's mercy, the safe and considerate driver will be doubly careful to give the pedestrian fair treatment.

The cautious pedestrian will look carefully in the proper direction before entering a roadway. He will cross at right angles or on a proper crosswalk. He will not assume that his legal right of way is a guarantee against all oncoming vehicles, but while the way is open he will proceed across the intersection with reasonable speed.

Laws and Regulations

Because the right of way at highway intersections is qualified for all vehicles and all pedestrians, adequate laws and regulations are necessary to safeguard both motorists and pedestrians.

The Uniform Vehicle Code requires vehicle operators to keep

to the right at highway intersections as at railway grade crossings, with the additional proviso in the case of intersections that a vehicle operator must not overtake and pass another vehicle stopped at an intersection to permit pedestrians to pass in front of it.

A most important provision at intersections where neither highway is given priority over the other is the right of way rule. It is generally accepted that in cases where two vehicles would otherwise reach a common point at the same instant, the vehicle on the left must give the vehicle on the right the right of way. With a common purpose, however, this rule has been stated in various ways in various states, and there has been confusion as to the extent of the prior right of the vehicle on the right over that on the left. After careful consideration a modification of the rule previously contained in the Uniform Vehicle Code is now proposed by the Committee on Uniform Traffic Regulation, under which the right of way of the vehicle entering the intersection on the right does not apply as against a vehicle already within the intersection.

Other sections of the Uniform Vehicle Code bearing upon traffic at intersections are the section prescribing the manner of turning at intersections, that directing motorists to give signals before turning as well as before stopping or starting, that requiring operators to yield the right of way to police and fire department vehicles, that requiring motorists to yield the right of way to pedestrians on crosswalks at uncontrolled intersections, and a prohibition against stopping a motor vehicle within an intersection for any other purpose than to avoid a collision or obey a police or traffic signal.

Enforcement of Laws and Regulations

At highway intersections as well as at railway grade crossings it is believed that much improvement in observance of the laws and regulations will result from a thorough campaign of vigorous and impartial enforcement of the traffic laws in general, including extension to all states of the system of drivers' licenses with examination to require knowledge of the traffic regulations ap-

plicable at such points and driving ability adequate to safe conduct.

As in the case of railway grade crossings, it is believed that there should be check-ups from time to time at typical highway intersections, particularly those which show bad accident records, to see whether all regulations affecting the intersections are being observed. It goes without saying that officers detailed to this duty, whether state police or municipal, should be thoroughly versed in the letter and spirit of the various rules.

Education of Highway Users

Highway intersections, like railway grade crossings, are so numerous that we must depend in large measure upon self enforcement.

There will presumably not be the same occasion for special educational campaigns relating to highway intersections as in the case of railway grade crossings, inasmuch as there is no sharp distinction in physical conditions, hazards or rules of the road as between these intersections and other highway locations. There is, however, continual necessity for comprehensive educational work on all driving practices, and the special dangers of highway intersections should be clearly brought out.

An outstanding difference in the message to be conveyed to the motorist at the highway intersection as compared with the railway grade crossing is that while at the latter his own danger is paramount and the instinct of self-preservation should be a large factor, at the former his own danger may be much less than that of the occupants of other vehicles or pedestrians. It will therefore be correspondingly more difficult to reach the thoughtless operator and to instill in him a determination to obey the rules and regulations.

PUBLICATIONS ON STREET AND HIGHWAY SAFETY

Available on Request to National Conference on Street and Highway Safety, 1615 H Street, N. W. Washington, D. C.

Committee reports submitted to Third National Conference, May 27-29, 1930:

Traffic Accident Statistics
Protection of Railway Grade Crossings and Highway Intersections
Maintenance of the Motor Vehicle
Measures for the Relief of Traffic Congestion
Uniform Traffic Regulation, accompanied by
Uniform Vehicle Code, consisting of
- Uniform Motor Vehicle Registration Act
- Uniform Motor Vehicle Anti-Theft Act
- Uniform Motor Vehicle Operators' and Chauffeurs' License Act
- Uniform Act Regulating Traffic on Highways

Model Municipal Traffic Ordinance
Report on Street Traffic Signs, Signals, and Markings.

Reports of former committees and conferences:

1924	1926
Statistics	Statistics*
Traffic Control	Uniformity of Laws and Regulations*
Construction and Engineering	Enforcement
City Planning and Zoning	Causes of Accidents*
Insurance	Metropolitan Traffic Facilities
Education	Public Relations
The Motor Vehicle	Second National Conference
Public Relations	
First National Conference	

In addition to the foregoing the National Conference has available for distribution publications relative to these subjects issued by participating organizations.

*Out of print