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REDUCES ACCIDENTS

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PRESENTED AT THE
STATE SAFETY CONFERENCE
IN DETROIT, MAY 21, 1947

MICHIGAN
STATE HIGHWAY DEPARTMENT
Charles M. Ziegler
State Highway Commissioner

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Presented by Harry C. Coons
Deputy Commissioner-Chief Engineer
At The State Safety Conference
Detroit, May 21, 1947.

PAPER BY HARRY C. COONS,
DEPUTY COMMISSIONER-CHIEF ENGINEER
STATE HIGHWAY DEPARTMENT,
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"MODERN DESIGN REDUCES ACCIDENTS"

The adequacy of highway capacity and design is one of "the most important" elements in promoting traffic safety, from an engineering viewpoint. This is true in spite of the fact that several other factors affect accident occurrence in some degree.

It is known, for example, that certain conditions only remotely related to either traffic or roadways influence the accident rate. It appears that when times are good, drivers tend to become careless and accidents increase. The present unexpected decline in the traffic fatality rate can be attributed, in part at least, to the current difficulty in getting new cars, which makes owners unwilling to take chances with the old ones.

But factors such as these merely cause fluctuations in accident occurrence. The major trends are established by the basic developments of traffic and by the relative adequacy of the facilities which are provided for traffic accommodation and control.

And I might digress at this point to say, that while we in the Michigan State Highway Department are constantly studying traffic problems and will do everything possible to build safety into highways through modern design and construction of grade separations, divided highways and other safety features, we know these things will not stop highway accidents and deaths. There still will be careless drivers who will kill themselves and innocent victims who get in their way. If everyone would be careful

and courteous we would have few accidents and we could avoid building expensive divided highways and, therefore, spread our construction money a lot farther.

We know that more accidents are to be expected when the volume of traffic goes up. During the past two years, while Michigan traffic increased by 34 per cent, reported accidents mounted from 83,000 in 1945 to over 110,000 in 1946, an increase of $32\frac{1}{2}$ per cent. Accidents are a direct, though unwelcome, product of traffic movement.

Sound and progressive design practice can alter and improve the fundamental conditions under which traffic operates. For that reason it is the primary means of curbing this basic process of accident production.

Cooperative Basis of Design

Responsibility for structural design rests mainly with the design engineer, but his work must be based on information provided by those who are closely concerned with the operation of the facilities after they are built. Ranking high among the sources for such information are the maintenance engineer, the traffic engineer, and the automotive design engineer.

The maintenance engineer supervises the upkeep of such highway elements as the surface, ditches, culverts, bridges, signs and signals, and all the other physical items within the right of way lines. His experience and his analyses of the expenditures in this work must be considered in the over-all picture of service value as relate to the first cost, the annual cost, and the life of the improvement.

The traffic engineer contributes invaluable data pertaining to the speed and volume of traffic, the placement of signs and signals and pavement markings, the accident experience of the system, the operation of traffic through intersections, and the behavior and characteristics of

drivers and vehicles. His work in the control of entrances and exits to the pavement and of strip parking between intersections is just as important in preserving the safety elements that have been built into the highway as is the maintenance of the physical plant.

The highway designer must also keep abreast of current knowledge regarding the future trends of motor vehicle design. He does this through contact with the automotive industry and its engineers.

Contributing to knowledge from all these sources and serving to test and correlate highway practices and standards, are the research and experimental projects conducted or sponsored by the several state highway departments, the U.S. Public Roads Administration, the Highway Research Board, the American Association of State Highway Officials, the professional and business organizations of the highway industry, and the leading engineering and traffic schools.

Basic Factors in Design

In designing highways for efficient and safe operation, the basic factors to be considered are the characteristics of the traffic to be served and of the terrain to be traversed. The significant characteristics of traffic are its volumes, speed, and composition. The important topographical features are those which affect highway alignment and sight distance; included are roadside developments which generate or influence traffic movement.

Decisions regarding design speed, sight distances, the number of traffic lanes and type of highway, as well as the width of lanes are all made with reference to these factors. To a very large degree, highway safety depends on how wisely these decisions are made--on how accurately the final design provides for facilities that meet the needs and conditions as they will actually exist during the expected period of service.

Design Speed

Almost the first thing the highway designer needs to know is the proportion of traffic traveling in the higher speed ranges. On the basis of this information he decides upon the design speed, which, in turn, is basic in establishing all the other design factors that provide for the safe movement of traffic. Sight distance, lane widths, lateral clearance to roadside obstructions, maximum curvature, superelevation on curves, and the general cross-section must be consistent with design speed.

Speed observations made on Michigan rural trunklines in 1941, revealed that 85 per cent of all vehicles traveled at speeds of 60 miles per hour or less. Other studies made following the lifting of speed and other restrictions in 1945, showed that this 60-or-below group had increased to include nearly 95 per cent of all traffic. It is probable that speeds are now tending to return to the 1941 distribution as the supply of new cars becomes more normal.

These Michigan data as well as a wide record of experience elsewhere, indicate that there is not much justification for a design speed on rural primary trunklines of above 70 miles per hour. This standard is applicable for approximately level terrain. In rolling sections of the state, a design speed of 60 miles per hour is desirable. For expressways in urban areas, 60 miles per hour can be considered adequate.

Contrary to some schools of thought, it appears to be unlikely that the adequacy of highways built to these speed designs will be directly affected by higher speed characteristics of future vehicles. Top speeds are usually governed by the preference of the drivers rather than by the speed capacity of the vehicles; raising the latter will not raise general speed rates except as accompanying improvements in vehicular stability, acceleration, and braking, increase the confidence of large numbers of

drivers in their driving competence and control.

A vital safety requirement in relation to design speed is consistency in its application. A recent nationwide study disclosed that the accident rate on road sections with isolated sharp curves was more than double that on sections where such curves occurred five or more to the mile. Good safety design demands that the same design speed be used on the same kind of highways throughout large areas. In locations where topographical or other conditions make a variation absolutely necessary, transition to lower speed sections should be smoothly graduated and clearly marked with signs.

In considering this whole subject of speed in design, it is well to keep in mind what design speed really means in terms of travel speed. Increases in the number of vehicles on a highway, even those within its practical traffic capacity, cause reductions in top speeds that can be attained.

Take, for example, a 2-lane highway with a design speed of 70 miles per hour and an average 24-hour traffic of 3000 vehicles. With the normal distribution of traffic in hourly volumes, only an insignificant proportion of the day's traffic will be able to average within two or three miles of 70 miles per hour; these cars will be traveling at the lowest volume hours.

Of all the traffic which wishes to travel at 70 miles per hour, about half will be able to maintain an operating speed of from 60 to 67 miles per hour. Of the remainder which must travel slower than 60 miles per hour, 20 per cent will encounter hourly volumes of more than 350 vehicles and will be limited to average operating speeds of 53 miles per hour or less.

Thus, it will be seen that only a small percentage of average traffic desires to travel at the highest rates of speed, and that a large percentage of this faster traffic is limited to considerably less than the desired rate. It also is apparent that design speed is closely related to the determination of practical highway capacity.

Highway Capacity and Highway Types

Highway capacity in relation to traffic volumes is a primary factor in safety. When a highway is loaded to the point where movement is reduced to an unreasonably low speed, some drivers become impatient and either trail too closely to the vehicle ahead or take chances at passing in the face of opposing traffic. The result is a sharp increase in the number of accidents.

Reduction of such conditions depends not only on the provision of an adequate number of lanes, but on the selection of lane arrangement best suited for safe traffic use. Highway and traffic engineers have given the problems of highway capacity and type much study. In the course of these studies, the importance of the overtaking and passing maneuver has been recognized as basic.

The passing maneuver makes it possible for vehicles traveling in the same direction at different speeds to use the same roadway. As traffic increases from minimum volume, the number of passings required to permit all drivers to drive at their desired speed will increase somewhat proportionately. In actual practice, the number of passings will increase proportionately only until a certain volume has been reached; as this volume is exceeded, the number of passings first will increase at a decreasing rate, and then will begin to decrease.

These characteristics of the passing maneuver are closely related to the design and safety of highways of different widths.

The 2-lane highway is the minimum facility accommodating traffic traveling in different directions at various speeds. When it becomes so filled with traffic that openings for passing do not occur with convenient frequency in the opposing lane, congestion begins.

The 3-lane highway was designed to provide an additional lane for the specific use of passing vehicles in both directions; but when competition for the use of the center lane becomes too keen, hazard and then congestion develop.

The 4-lane highway is the narrowest highway on which passing can be accomplished without entering lanes subject to use by opposing traffic; but when traffic in one direction so fills its own lanes that drivers desiring to pass are tempted to cross the centerline to perform the maneuver, it becomes congested and dangerous.

The divided highway, with two or more lanes for traffic in each direction, was designed to prevent conflict between opposing streams of traffic; here congestion occurs when volume reaches a point where more passing maneuvers are required than the passing lane will accommodate.

Safe passing on 2- and 3-lane highways requires that the driver shall have a long clear view of the road ahead. He must see far enough to be assured, not only that the portion of the passing lane he must use is clear when he starts passing, but that no vehicle approaching from the opposite direction will enter it before he completes his maneuver and turns back into line. For design speeds of 50, 60, and 70 miles per hour the distance for both types should be, respectively, 1,600, 2,300 and 3,200 feet.

Such sight distances are difficult to provide, especially in rolling country. Modern highway practice prohibits passing on highway sections where curves, hills, or other conditions limit the view of the road ahead to less than these safe distances. These "no passing zones" reduce the working capacity of a highway. In the case of the 3-lane highway, they frequently result in considerable sections of the center lane being prohibited for use by traffic from either direction.

"No passing zones" are not established on 4-lane roads because there should be no need for passing vehicles to enter an opposing traffic lane. On these highways it is sufficient if the driver can see the passing lane for the distance required to bring his car to a halt. These distances for speeds of 50, and 60 miles per hour are, respectively, 350 and 475 feet.

To distinguish them from the much longer safe passing sight distances required on 2- and 3-lane roads, they are called "safe stopping distances".

The degree of freedom and safety with which the passing maneuver can be performed is the vital factor in determining highway capacity. The accurate determination of practical working capacities for different types of roads and the selection of the proper highway types to accommodate the various volume ranges are the most important steps in designing highways for safety.

The 2-lane highway is, for obvious reasons, the basic highway type in this state and in the country at large. It is the minimum highway facility which will accommodate all the requirements of traffic up to its capacity limit. It comprises 90 per cent of our paved rural trunkline mileage. Other types are built only when the capacity of the 2-lane highway is exceeded. Much study has been devoted to learning what the limits of its efficient carrying ability are.

It has been found that on a 2-lane road with 150 vehicles per hour in the opposing lane, a driver can make two out of three passings without slowing down. But when there are 400 vehicles in the opposing lane, he can make such undelayed passings only once in three times.

On the reasonable presumption that 400 vehicles in the opposing lane represented the maximum hindrance to free driving that drivers will tolerate, this quantity has been made the basis for estimates of 2-lane capacity. By placing 400 vehicles in each lane, the value of 800 vehicles per hour has been derived as the maximum possible capacity of these pavements.

However, this value is too high as a measure of capacity because average experience shows that highway traffic does not normally flow with equal volumes in both directions. Particularly during peak hours, about two-thirds of total volume flows in one direction. Thus, when 400 cars are in one lane there

will be 200 in the other lane, or a total of 600 vehicles per hour, this constitutes the practical operating capacity of a 2-lane highway. Above that volume, large numbers of drivers are encountering intolerable restriction of the passing maneuver.

Highway designers cannot and should not attempt to provide completely adequate capacity for every vehicle traveling a highway. They should provide for all but the highest volumes, however, and the 30th highest hour of the year has been selected by highway authorities as setting the limit to their responsibility.

In Michigan experience, a highway with a traffic of 600 vehicles in the 30th highest hour of the year will have an annual average 24-hour daily traffic of just over 3,000 vehicles.

Studies of accident occurrence on 2-lane roads under varying conditions of volume substantiate this critical value. They reveal that the accident rate increases as volume increases up to 3,000 vehicles per day. Above that volume the rate declines quite abruptly, probably because lessened vehicular speeds cut down the number of the more violent collisions.

Three roadway types--the 3-lane, the 4-lane undivided, and the 4-lane divided--are available for construction to succeed the 2-lane roadway where traffic has exceeded capacity.

It has been found that the practical working capacities of 3-lane and 4-lane undivided roads is 5,250 and 10,500 vehicles for the average 24-hour day. There is reason to believe that a carefully designed 4-lane divided highway can carry volumes of rural trunkline traffic as high as 14,000 vehicles per average day at reasonable speeds and with freedom of movement under controlled access basis.

Accidents in Relation to Highway Types

A recently completed study of more than 22,000 accidents on the rural

trunklines in this state gives considerable information concerning the relative desirability of these various highway types. The accidents occurred in the years 1936 to 1941 inclusive, a period of normal traffic. They cover more than 5,000 miles of rural highways, or practically all of the paved rural trunkline mileage. In many important particulars, the results parallel those obtained in prior studies based on less comprehensive data.

This study found that the rates of accident occurrence per million vehicle miles on the four types of roadways were:

1.7 on the 2-lane,
2.0 on the 3-lane,
nearly 2.5 on the 4-lane undivided, and
1.3 on the 4-lane divided.

The 2-lane roads' record for the more serious fatal and injury accidents is well below that of all other types except the divided 4-lane highway. The occurrence of only two kinds of accident--the non-collision and the fixed object accidents--is above the average on these roads. These are mostly "off the road" accidents, and the high rates are probably due to the fact that on 2-lane highways all vehicles travel next to the pavement edge.

The 4-lane undivided highway is indicated as the most hazardous type of roadway, with the 3-lane highway close behind. The 4-lane divided has by far the lowest rate of accident occurrence of any type investigated in this study. The rate for 4-lane undivided is nearly 90 per cent higher than the rate for the 4-lane divided. The rate for the 3-lane is 54 per cent higher.

The divided type has a particularly marked advantage over these other two road types in the occurrence of head-on collisions, which are the most deadly kind of accident. The rate for the 4-lane undivided is 460 per cent higher than for the 4-lane divided and that for the 3-lane is 390 per cent higher.

These findings regarding the relative accident producing characteristics of divided and undivided multi-lane highways are borne out by the

reported experience in other states. Typical are the before and after records of accident occurrence on a New Jersey trunkline which was converted from a 4-lane undivided to a 4-lane divided highway. These show that the change in roadway type resulted in a 40 per cent reduction in total accidents and an 83 per cent reduction in fatal accidents.

From the point of view of traffic safety as well as of efficient traffic operation, the divided 4-lane is the most desirable type of highway to serve traffic volumes beyond the capacity of a 2-lane road.

Other Safety Features

The details of highway designing are constantly being developed and refined to better serve and protect traffic. Many of these details cannot be described in a short paper, but some of them require at least brief mention. Among these are lane width and pavement marking.

Experience with and study of traffic and vehicle behavior has led to a progressive widening of the traffic lanes. The early 8 and 9-foot lanes are now practically things of the past and 10 feet has been the minimum dimension for a number of years. But with increasing volumes, greater speeds, and a tendency toward greater width of vehicles, the need for expanding the lane continues to be felt.

Justification for 11-foot and even for 12-foot lanes is found in observations of actual vehicle placement and accident records. On 2-lane pavements with 10-foot lanes, more than 20 per cent of commercial vehicles and 10 per cent of passenger cars normally travel with their bodies extending to the left of the centerline. Even when passing vehicles, nearly 4 per cent of trucks and 3 per cent of cars continue to trespass into the opposing lane. The number of intruding vehicles is found to be reduced by about 30 per cent on roads with 11-foot lanes and by about 50 per cent on 12-foot lanes.

The better separation of opposing traffic permitted by more ample traffic

lanes is reflected in accident experience. The rate of accidents per million vehicle miles has been found to be reduced progressively from 5.2 accidents for highways less than 18 feet wide, to 3.4 accidents for highways with a width of 23 feet and over.

Encroachment into the opposing lane can be controlled to a great extent by marking the center line of the 2-lane pavement. A system of pavement markings to accomplish this purpose and to prohibit passing and overtaking maneuvers in sections where sight distance is restricted has been worked out and has attained a promising degree of standardization among the states. Such marking in combination with signs is an effective safety practice.

Preservation of Safety Characteristics

With these principles and methods, highway engineers can design and operate highways that should be safe, convenient and economical for highway transportation. However, the continued enjoyment of these values cannot be assured unless they are protected by obtaining right of way on a controlled access basis.

This is a problem of very real significance. The safety characteristics of our trunkline highways are being depleted by the rapidly expanding developments along the roads. This is particularly apparent in the vicinity of the cities and in intensive resort areas in Northern Michigan.

These roadside developments create an increasing number of intersections, wide entrance driveways, parking strips, mail-boxes, and other features that interfere with the free flow of traffic. Signs and lighting devices distract drivers' Attention and multiply the hazards.

There are those who believe that this roadside exploitation is depleting the ability of our trunkline highways to serve traffic safely and conveniently, faster than we are able to build new roads. The highway engineer has designed and is building arteries with very high safety and efficiency standards. In the interest of the motorist who pays for these roads, we must find and use practical remedies that will preserve their safety and operational characteristics for his protection and enjoyment.