THE SHORTEST DISTANCE

Address given by Thos. H. MacDonald, Chief,
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Of the fundamental theorems of mathematics "the shortest distance between two points is a straight line" might seem a strange choice of subject to present before the professional organization of traffic engineers. A public opinion poll of what we refer to in one grand mass as "the traffic", beset with one-way streets, multi-colored lights on busy corners, over-loaded parking places and traffic palliatives rather than traffic solutions would undoubtedly be unanimous in the conclusion that such a simple truth receives no acceptance by the traffic engineers.

But it would be a new thought to most of this same public if confronted with the fact that every traffic device of a restrictive nature had been produced to offset some characteristic of human behavior on the streets and highways.

Traffic engineering has had to develop its practices with all factors running wild. The shortest distance to hoped-for traffic safety has had to be largely a series of expedients to meet acute conditions, but there is the compelling urge to move as rapidly as possible into the field of greater certainty founded upon adequate research. So the real shortest distance between the two points of present traffic engineering practices and of traffic engineering

perfection within attainable limits, is a long, painstaking intelligent effort to measure human behavior, and upon the facts to guide, guard and control those who use our public ways, yet permitting maximum freedom of their movements.

Research studies of the vehicle in motion have not kept in step with research work in other phases of the highway engineering field and as a background it is necessary to touch upon the current trends of vehicle production and highway usage that carry indications of major importance as to the dimensions of the problem on a national basis.

Numbers of Motor Vehicles

In the last 44 years more than 65 million motor vehicles have been produced for United States consumption, and over 34 million of these vehicles have worn out. In doing so, some 238 billion gallons of motor fuel have been consumed, thus indicating more than 3,000 billion vehicle miles of travel.

Our economic studies now in progress indicate that the next 22 years will witness a growth in motor vehicle production somewhat less spectacular but as phenomenal as that in the past. They indicate that by 1960 yearly registrations will be crowding 38 million vehicles, and that the all-time total of vehicles built will be about 137 million passenger cars, trucks and buses.

The relation between the number of new motor vehicles sold in the domestic market and our total population has stabilised during the last 22 years at about 42 persons per vehicle sold, and it is probable that in the next 22 years the entire domestic market will gradually become a replacement proposition in which roughly one vehicle must be consumed or scrapped to afford a market for one new vehicle.

Having given you an indication of broad trends of motor vehicle production and consumption, and a picture of the numbers of such vehicles we may expect to be used in our national highway transport scheme, let us now consider some of the operating unknowns that complicate our highway design and traffic problems.

While much has been said about the necessity for an adequate number of lanes to accommodate traffic on rural highways, there has been a woeful lack of evidence in support of a rational program for defining conditions which justify increased expenditures for additional width of lanes or additional lane facilities. During the past year the Bureau of Public Roads has perfected equipment that registers mechanically the position and speed of all vehicles on a half-mile section of 2-lane road while in the section. This equipment is the outgrowth of a capacity study made last year in cooperation with the Illinois Department of Public Works and Buildings.

Highway Capacity

While the analysis of the 108 thousand records made in Illinois has not been completed, you may be interested in some of the by-products of the observations made on highways during periods when they were at and near congestion limits. From the records the speed of each vehicle and its distance spacing from the preceding vehicle were obtained. By classifying into groups by their speed in miles per hour all vehicles traveling the same speed as the preceding vehicle and obtaining the modal spacing for each group, it was possible to determine the time interval that the majority of drivers maintain between their vehicles and the preceding vehicles when following at the same speed. For speeds between 20 and 50 miles per hour, it appears that the time spacings maintained were close to one and one half seconds with a minimum at about 30 miles per hour. Converting the time spacings to distance spacings, we find that the majority of drivers maintain a spacing of 65 feet at 30 miles per hour, 90 feet at 40 miles per hour, and 120 feet at 50 miles per hour.

With any given volume of traffic the average time spacing between vehicles is easily calculated, regardless of the speed at which they are traveling.

For example, with a volume of 900 vehicles in one direction there will be an average spacing of four seconds

between succeeding vehicles at any point; on the highway sections, however, due to the range of speeds and consequent bunching of vehicles, about 8 percent were traveling at a spacing of less than one second, 41 percent at a spacing of less than two seconds, and 75 percent were spaced at less than four seconds, the average time spacing. At 600 vehicles per hour, 75 percent were spaced at less than six seconds, the average time spacing. In fact, regardless of the average speed or volume on a given highway, the study shows that between 67 and 75 percent of the vehicles are at less than the average spacing.

In considering extra lanes for existing 2-lane highways, it is just as important to know how often a "hole" of a given length will occur in the opposing traffic on a 2-lane highway as it is to know the time or distance required to make the passing.

When passing is not possible on a 2-lane highway, traffic piles up. The desire to pass a vehicle is no doubt just as great when there is an opposing volume of 800 vehicles as when there are 200, yet the study shows that as the opposing volume increases there is a marked decrease in the number of passings; in fact, the chances for passing are greatly reduced when the opposing traffic on 2-lane level tangents exceeds 400 vehicles per hour.

When there is little or no interference between vehicles traveling over a highway, the individual unit will be able to travel at speeds desired and there will be comparatively large differences in speed between succeeding vehicles. As volume increases, the mean difference in speed will be reduced, and this mean difference may be used as an index to measure the relative congestion present on a highway. By correlating the two independent variables, volumes of traffic in the same and opposing directions, with the dependent variable mean difference in speed on a 2-lane tangent, it was found that the maximum volume of 1,980 vehicles per hour may be attained when all vehicles travel in one direction, or 1,120 vehicles in each direction with equal lane ratios. However, at these volumes all vehicles will be traveling at the same speed and the individual drivers will be restricted to travel at the same speed as the preceding car. By applying multiple correlation to data from the observations showing average speeds for varying volumes of traffic, the study makes possible the determination of average speed with varying volumes of traffic in both directions.

Passing Distances

The passing distance observations made during the past two months have been obtained entirely through mechanical means,

thus eliminating the human equation. A record is made of the exact time each vehicle passes over each of 52 air impulse tubes placed at 50-foot intervals. By this means the charts show the position at all times of vehicles on the half mile section of highway by lanes. The preliminary analysis of charts already made indicates that we have developed workable instruments that will make possible detailed study of the passing and general practices of drivers on highways of two or multiple lane width and varied alignment, and that by combining volume or capacity with passing studies a reasonable basis will have been laid for the determination of the logical number of lanes for various volumes of traffic on varied alignments.

The Transverse Placement of Vehicles

The present practice for determining the width of lanes for various alignments and particularly for the classes of vehicles that use the road is by "rule of thumb" largely reinforced by personal opinion based upon a few scattered observations of driving practices. During the past year the Bureau has been interested in perfecting instruments which will automatically give the exact location of the wheels of a vehicle transversely on the highway. From the preliminary field studies we are assured that we can register at all speeds

the location of the center line of the wheels of the vehicle as it passes over a line perpendicular to the center line of the pavement to within six inches. Inasmuch as all axles register it is possible to classify vehicles as between passenger cars and trucks from the charted impressions because of the longer wheel base and the wider tires and treads of trucks. A manual classification will be made, however, of all vehicles.

In order to determine the influence of speed on the transverse placement of vehicles both at the time of passing and when the vehicle has unrestricted use of the entire road, the Bureau has designed and is now assembling an automatic registering speed detector to permit the determination of speeds by single miles per hour in a 40-mile range, say from 30 to 70 miles per hour, or a range of 80 miles per hour for two miles per hour intervals, say from 20 to 100 miles per hour. As in the instrumentation for passing distance, it will be possible to automatically record the speed of passing vehicles in two lanes.

The field work that the Bureau has done in the past year in studies of vehicle behavior, as they refer to capacity, longitudinal and transverse spacing and speed, make possible the automatic chart recording of all the necessary data from

field observations. It is hoped when present field tests have been completed that a concerted effort can be made to procure these data in the States where it is apparent that driving practices are dissimilar. We are looking forward to the time when this painstaking fundamental research will permit us to use the conclusions as basic facts in the design of our future highways better to accommodate the traffic needs and with the same economies that the painstaking research in structural design throughout the past years has accomplished. I believe as you study the instrumentation for these studies, their importance to you as an approach to the solution of regulatory problems will become apparent.

Motor Vehicle Speeds on Grades

During the summer of 1937 a field study was conducted to determine the performance of trucks and tractor-trucks selected at random on a six percent grade on U.S. Route 40 in Maryland. The characteristics of the trucks and their loads were obtained at a Maryland State Roads Commission pit scale.

The selected trucks suitably marked by placard were then, unknown to the drivers, timed as they ascended a long six percent grade about four miles beyond the pit scale. In order to do this accurately and without chance for errors

in human judgment, a series of contact road switches was installed at 170-foot intervals. As the vehicle moved up the grade the road switch immediately ahead was connected with the recording instruments and the time of initial contact charted. Knowing time and distance, accurate determination of speeds between the road switches may be determined.

In the analysis made last winter, some 500 vehicles were segregated in groups of 5,000 pounds gross weight, and the average speeds for the vehicles as they ascended the grade were computed. The study showed that the average vehicle, whose gross weight was between five and ten thousand pounds, did not fall below 19 miles per hour, whereas the trucks most heavily loaded could maintain a speed of only five miles per hour on the grade. In general, the speed of the heavy trucks was greater than similarly loaded tractor-truck semitrailer combinations.

Although these studies of random vehicles showed to good advantage the performance which may be expected from the average commercial vehicle using a six percent grade, it was felt that the information obtained was far from complete. In but few cases was it possible to obtain reliable data on the transmission and axle ratios, and it was practically impossible to determine the condition of the engine. Accordingly, the scope of this study was expanded through the generous cooperation of the motor truck manufacturers, the National Bureau of Standards, and the Ordnance

Department and the Quartermaster Corps of the United States Army, so that thorough field and laboratory tests could be made on new vehicles of known specifications and in the best of condition. Light, medium and heavy trucks and tractor-trucks are being operated on a series of five grades varying from 3.2 to 7.0 percent with loads in increments of 1,000 pounds. The maximum speed which can be maintained on each grade is determined throughout a complete range of loads for each vehicle and with each change of load the rolling radii of the driving wheels are measured. The velocity and direction of the wind and the atmospheric temperature are recorded during each run. In addition, records of humidity and barometric pressure are obtained from the local Weather Bureau station. Tests are conducted currently on all gasoline used.

In this test a deviation of but three or four feet in 1,000 feet is obtained and the maximum error in determining the average sustained speed is well under one percent.

The field records are analyzed and plotted within 24 hours after they are obtained. This investigation will make possible a thorough study and analysis of the design of grades as they affect commercial vehicles that use them. It will furnish data for the regulations regarding commercial motor vehicle performance.

Some States have already considered such legislation and

at least one now has statutory limitations with respect to grade ability. The problem then will be the means of enforcing such regulations. One type of equipment which might be used is the towing dynamometer. Through the cooperation of the Ordnance Department of the U. S. Army, the field dynamometer used at the Aberdeen Proving Ground was employed to determine the tractive effort as well as the rolling resistance of the largest tractor-truck semitrailer combination used in the test. The results of this test will be compared with the actual performance as found in the grade tests for acceleration and deceleration to determine if such an enforcement method of determining grade ability is feasible.