need of Lafayette for such a parking place to relieve the congested business streets and they did not question that such a project constituted a public use within the meaning of the law. But in the absence of a court decision definitely establishing that fact, they would not recommend the purchase to the bond company because the small commission received would not justify placing in the hands of any customer a bond issue that was to be involved in litigation.

*This matter is still pending but it is of such a character that it should be of interest to the officials of every city in Indiana.

In the enactment of no-parking and limited-time parking regulations in our cities, there are a number of factors to be taken into consideration which will apply to most of our cities with but slight modifications to meet local conditions. No-parking zones must be established where needed to meet the needs of traffic. The operation of street cars, taxi cabs and large motor buses with the location of their terminals are factors to be taken up and definitely provided for in any regulatory measure. The establishment of through streets and the by-passing of through tourist traffic are also items to be considered in the solution of the general problems of relieving the narrow congested streets in the business portion of the city from its heavy burden of traffic.

THE TRAFFIC PROBLEM

By W. A. Van Duzer,
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(Note: Mr. Van Duzer was unable to attend the Road School and Mr. C. C. Albright, Location Engineer of the Penna. Highway Department, presented the paper in his place.)

Traffic as a factor enters every principal division of highway activity, administration, finance, location, design of construction and maintenance. The traffic problem more often is the future development of transportation than the care for present conditions.

Development of the automotive industry, improvements of motor vehicles, steady reduction in their costs, road improvement, increasing population and abundant prosperity have released a flood of highway traffic beyond any previous comprehension and we must expect future years to bring still...
further increased highway traffic. In certain locations traffic is already overtaxing our improved road facilities, while in others places our roads have not yet been given any surface improvement. Expediency demands in most cases that completion of the system be given priority over reinforcing overloaded parts. The expectation of future large increase of traffic makes the problem serious.

The development of motor traffic is largely measured by motor vehicle registration. In 1895 there were four motor vehicles in the United States; in 1900, there were eight thousand; in 1905, seventy-eight thousand; in 1910, a little under half a million; in 1915, a little under two and one-half million; in 1920, more than nine million; in 1925, nearly twenty million; and 1926, twenty two million, three hundred and thirty thousand.

**Relation of Motor Vehicle Registrations to Population**

In 1925 there was one motor vehicle to each 6.5 persons of population. In California the ratio of population to registration was lowest (8.20). Iowa was second with a ratio of 4.08; Indiana eleventh with 4.95; Ohio seventeenth with 5.36; Illinois twenty-fourth with 6.32; New York thirty-eighth with 8.25; and Alabama forty-ninth (last) with 14.39.

Pennsylvania is the twenty-ninth state in order with 6.87 persons per motor vehicle as compared with the United States
average 6.5. In Pennsylvania the percentage of rural population is 35.7, while the corresponding figure for the entire United States is 48.6. What may be the minimum figures of ratio that will be reached in the various states we do not know, but we are certain that the so-called "saturation point" has not been generally reached as yet. Road systems are not yet complete and their continued development and ultimate completion will undoubtedly encourage increased registration.

Fig. 1 shows population and registration curves for Pennsylvania. These curves are extended for prophecy. The "saturation point" is shown by the ratio curve becoming horizontal at about 1935.

Relation of Traffic to Registrations

It is generally assumed that traffic increases with registration. In other words the theory is that the annual mileage of travel per vehicle remains about the same from year to year so that as the number of motor vehicles in use increases the total of motor vehicle traffic also increases.

As a matter of fact, the combined influence of increased efficiency of automotive equipment, decreased operation costs and increased road facilities (notably uninterrupted use of the roads throughout the winter) must be expected to continuously increase the ratio of traffic to registration from year to year.

Observations in Maine ("Public Roads," May, 1925, page 55) show that the average daily traffic in per cent of total registration increased from 23.6 to 26.0 between 1916 and 1924, and the records of Maryland, Massachusetts and Wisconsin indicate some expansion of annual travel mileage per vehicle between 1919 and 1924 (United States Bureau of Public Roads, and Pennsylvania Department of Highways Co-operative Survey of Transportation).

Within the economic life of the flexible types of road surfaces that we are now building in Pennsylvania, we expect traffic to double in volume. It is to be expected that United States Census curves produced will provide closely approximate estimates of population for the future years in which we are interested and that the population curve can be applied in attempting the solution of the traffic problem.

Laying out the System

The first influence of traffic is in the selection of the road system. It is a general condition that in any given locality a certain percentage of the roads may be designated as of principal importance and these principal roads will carry a much larger percentage of the total volume of the area's traffic than the percentage of their mileage is of the total mileage of public road in the area. Disregarding the traffic on city
streets, it is generally true that one-tenth of the rural roads of a locality will carry three-fourths of the traffic. Therefore, a comparatively small mileage of road in any locality can be depended upon to carry the bulk of the transportation if the system is laid out with due regard to the traffic needs. The routes radiate from the centers of population and connect the more important places and of course conform to the topography of the state.

The volume of traffic furnishes a measure by which to test the economics of relocation and grading. A shortening of line or a reduction of grade will lessen the cost of operation for each vehicle using the road. The total volume of traffic, therefore, indicates the annual saving in operation that is to be considered in connection with costs of relocation and grading.

**Determining the Width of Pavement**

Traffic largely determines the extent of road surface to be provided. This is the heart of the traffic problem. The essential characteristic of the public road is that it is open to the public and the traffic demand is for roads of adequate carrying capacity. Preliminary to the consideration of the question of carrying capacity, there are five important conditions:

First. Within reasonable limits the public is free to enter and use the road at discretion as to points of entry and departure, and as to direction and speed of travel. As a general rule there can be no supervision over routing, (no train dispatchers) and a single track cannot be made to serve the purpose of a double track by the addition of occasional turnouts.

Second. A conglomeration of freight and passenger business which tends to cause confusion and congestion must be permitted.

Third. At the present time, there is not the effective apprenticeship or control over highway drivers such as the railroads provide for their locomotive drivers and the fallibility of automobile drivers must be accepted as a road condition that increases the required factor of safety and lessens the real capacity of the road.

Fourth. It must be assumed that the time of the traveler is valuable and he must not be needlessly delayed.

Fifth. Road hazards must be eliminated as far as possible and minimized when they cannot be eliminated.

If we were free to assume that motor traffic could be handled in continuous lines spaced only with respect to avoiding danger of ramming when one vehicle in line might slow down or stop, and if we could bottle up traffic and disregard road delays, the carrying capacity of our two-lane highway
would be so great that there would be very few cases that would involve extra width roads.

According to a Pennsylvania computation which checks sufficiently close with Los Angeles observations, a single line of traffic, with the vehicles moving at from ten miles per hour to thirty miles per hour, and spaced at intervals increasing with the speed, sufficient to avoid risk of ramming, might run 2,000 to 2,400 vehicles per hour, say 50,000 vehicles in twenty-four hours. Then the two lanes of a double-lane road running full would have a carrying capacity of 100,000 vehicles per twenty-four hour day. These figures bear only remote connection to actual figures of annual daily average.

The characteristic advantage of highway transportation is the freedom of a driver to overtake and pass a slow moving vehicle, and the preservation of this favorable feature of highway traffic without sacrificing safety of operation sets the practical limit on carrying capacity. In order to permit constant passing, the total number of cars on a two-track road should not exceed the theoretical capacity of a single lane, that is to say, a two-lane road should not carry traffic exceeding about 2,000 vehicles an hour. A general condition as demonstrated in Pennsylvania is that the roads carry the greatest volume of traffic Sunday afternoons in late July and early August. Three curves representing state average variations by hour, by day, and by season are shown in Figs. 2, 3
Fig. 3. Traffic Analysis—7 day Comparison.

Fig. 4. Traffic Analysis—12 Month Comparison.
and 4. The average hour is only one-half of the maximum hour, and the traffic for the maximum day will be about twelve times, rather than twenty-four times the maximum hour’s traffic—that is, about 24,000. The average day of the week is about four-sevenths of the maximum day or about 14,000 vehicles. Taking into account the seasonal variation, travel in the latter part of July and the early part of August is about 160 per cent of the average of annual traffic so that the annual daily average capacity of the two-lane road actually reduces to five-eighths of 14,000, or about 9,000 vehicles.

These figures apply on roads that are not impeded with curves, grades and crossings, and the maximum capacity of two lanes in terms of annual daily average is about 6,000 for road conditions such as generally prevail in localities where there is heavy traffic.

We cannot expect a full hour of uniform flow of maximum traffic without some congestion but it would not be practical to build for unusual conditions or for occasional peak loads, and it is to be understood that our roads must be expected to carry occasional brief overloads such as on Sunday afternoons in summer and on special occasions such as county fairs, automobile races and football games.

In addition to the variation of traffic that has been mentioned as occurring from hour to hour, from day to day, and from season to season, there is a natural change, an increase in volume, of traffic approaching the cities. The name “trunk” applied to our principal roads is very apt. Approaching cities, branch roads intersect and traffic converges and grows in volume. Hence it may be necessary to increase the width of the road to carry the increasing traffic. For example, the Lincoln Highway approaching Philadelphia is 18 to 20 feet wide to Downington (about 30 miles from Philadelphia), 30 feet wide between Downington and Paoli (about 15 miles from Philadelphia), and 40 feet wide between Paoli and Philadelphia.

Four lanes permit segregation of slow travel to the outer lanes and unimpeded use of the inner lanes by rapid travel so that a four-lane road may be said to have a capacity of 4,000 vehicles per hour or 12,000 vehicles annual daily average, plus whatever slow travel may occur, usually 10 per cent to 20 per cent additional.

Adding one lane width to relieve congestion of a two-track road is not looked upon with universal favor. There is some ground for the criticism that the use of a middle path for passing from either direction involves risk. Practically, however, some roads are liable to occasional crowding of one-way travel and the three lane road may be a very serviceable transition between the two-lane and four-lane width.
Car Mile Costs

The effect of traffic on maintenance costs is important. In general, maintenance and repair of road surfaces are necessitated by traffic and weather. With most types of surface, a certain amount of traffic is a preservative rather than a destructive agent. On an earth, gravel, or stone road, light traffic will keep the road from heaving. Bituminous binders will retain their life, that is their elasticity, longer if they are under compression at moderate intervals than if they are permitted to lie dormant. Even in the case of hard surfaced roads a certain amount of weight of traffic is helpful in reducing subgrade upheaval and temperature expansion.

The amount of traffic that is beneficial to various types of road surface under different conditions is not known definitely but it is generally a small percentage of the volume of traffic that the particular type of road will carry economically, so that in practice we are accustomed to consider that maintenance costs increase with the volume of traffic. Records in Pennsylvania show maintenance costs increasing with volume of traffic for all types except hard surfaces. Our hard surfaced roads are comparatively new and so far do not show sufficient wear to determine relative effects of varying volume of traffic.

The final measure of costs is the vehicle-mile or ton-mile. Including allowance for depreciation and interest on the costs of construction as well as maintenance and repair costs, a number of sections of road in Pennsylvania on which we have investigated show with very fair consistency vehicle-mile costs ranging between a fourth and a half of a cent.

Highway economics have not reached a stage where we can say definitely what constitutes the best practice in this respect, but there is a certain apparent advantage to be gained by combining the two units of traffic, passenger and freight, and using gross tons of freight vehicles with approximate weight equivalents of passenger vehicles. There is a considerable difference in the tire equipment of these two classes of vehicles but a balancing difference in speed, so that gross weights of passenger and freight vehicles can reasonably be combined for general study. This method offers the advantage of brevity and convenience over the use of combinations of passenger and truck figures. Whatever form of expression is used, the vehicle-mile cost, or ton-mile cost, is a figure that is of great interest in connection with problems of selection of type for improvements.

The development of an improved road system in any place attracts and develops traffic. People will travel longer distances if necessary to ride on improved roads and established businesses will be increased and new businesses encouraged by comprehensive improvements. The improvement
of a road always brings an increase of travel, occasionally an increase far beyond anticipation, and may bring a kind of traffic not previously known to the locality.

A class of traffic that has already reached significant proportions on some of our roads and promises to become an increasing factor in the future is the commercial vehicle operating under the jurisdiction of the state public utilities and interstate commerce commissions. This class includes interurban passenger buses and common carrier freight trucks. These increase the number of vehicles that are of much greater weight and body dimensions than the average passenger car, and they are more seriously affected by sharp curves and steep grades, so that they are a factor in the design of surface and also furnish an additional reason for reducing curvature and gradient. They very often travel at a lower rate of speed than the individual passenger car prefers so that their greater body dimensions complicate the passing problem.

The public roads are provided for the public use and it is not proper to restrict the use of the road except insofar as the public good definitely requires. Accordingly, the weight and dimension limitations on vehicles are very liberal and the large size vehicle and the heavy load are constantly becoming of greater importance especially in the vicinity of our larger cities.

In some cases it is necessary to curtail the privileges of the individual for the good of the public. Reckless driving and obstructing traffic are both such grave infringements on the rights of others that they cannot be permitted on the public highways. Accordingly, it has become general practice to formulate regulations and enforce them by means of a motor patrol.

Each state establishes its own laws. Through the association of automobile registrars uniform practice will eventually be worked out. The principal features of the laws are now practically universal, a maximum speed limit governing except in certain zones which are posted for reduced speed, no parking with all four wheels on road surface, no parking on curves or hills, no passing on curves, hills, or at road crossings, no glaring headlights. To increase the carrying capacity of roads and in an attempt to reduce accidents due to passing, minimum speed limits are being established in some states.

Present day traffic conditions have made “Service and Safety” the watchwords of the highway departments. In 1917 there were 9,097 automobile fatalities; in 1920, 11,074; in 1923, 16,452; in 1925, 19,828. It is true that the fatalities in ratio to registrations have decreased from 178 per 100,000 in 1917 to 100 per 100,000 in 1925, but the actual number
of accidents is more important than registration ratios. In addition to fatalities there are many accidents in which persons are uninjured. In Pennsylvania in 1925 the number of accidents reported on state highways was 1,666 with a toll of 135 killed and 1,501 others injured.

The so-called "tourist traffic" has become a perceptible percentage of the total travel. For this reason, and also because if we build, mark and maintain our roads in such a way that we furnish complete and safe service to the visiting driver, the local driver will unquestionably be served. The Pennsylvania practice is to plan for the visiting driver.

Telephone poles along state highway routes are whitewashed, all routes numbered and marked conspicuously on the road and on maps that are available for distribution.
Substantial direction signs are placed at intervals along the road and where temporary detours are necessary they are marked each week while maps showing what detours will be in use for the following week are circulated. Substantial roadside signs are placed to provide warning for curves, steep hills, railroad crossings and road intersections. Supplementary warning signs are painted on the pavements for railroad crossings (see Fig. 5) road intersections and steep hills. Traffic line is painted along the center of the pavement at railroad crossings, road intersections, at curves and on hills and no passing or parking is permitted in the zone of the traffic.
line. Reflector signs are provided to furnish warnings for drivers at night. Railroad grade crossings, narrow bridges and all road obstructions are being eliminated or safe-guarded as rapidly as possible. (See Fig. 6.)

The road surface is widened and banked at curves. Wire rope guard fence with an upper line of one-inch and a lower line of 3/4-inch steel cable is placed along the side of the road at all places where there is likelihood that a vehicle might leave the road and suffer injury. A new method of attaching the cable to the post so as to furnish a railing that will hold a vehicle on the road without damaging it is being tried out. (Figs. 7 and 8.)

Snow Removal

The most striking example of traffic service is in snow removal. Pennsylvania's handling of this problem illustrates present practice. The principal routes (about one-half of the mileage) of the state system are designated in the “Snow Removal Program” and the orders are that these roads be kept continuously open. Additional main roads may be opened but this work may not interfere with keeping the “Program” roads open. Truck and tractor equipment, moldboard plows, V-plows and rotaries are distributed and together with operators are held in readiness in heated garages for duty in each of 52 maintenance districts. Snow is removed from the entire road surface and from an eighteen-inch strip of shoulder along each side of the road. Hills that become slippery are covered with a scattering of stone chips or cinders.

Our purpose is to take care of the traffic, as it comes, in such way that the driver, whether or not he is familiar with the locality and road, need only exercise reasonable care to be assured of reaching his destination with a safe, comfortable and expeditious trip. This is the every-day solution of the traffic problem.

INTERPRETING RESULTS OF A STATE-WIDE HIGHWAY TRANSPORT SURVEY

By G. F. Schlesinger, Director, Ohio Department of Highways and Public Works, Columbus, Ohio.

The Ohio Transport Survey covered one year from December 15, 1924, to December 15, 1925.

The organization of personnel was as follows: