Traffic Surveys to Solve Highway Problems

Present Tendencies in Anticipating and Providing for Future Conditions

By BRUCE D. GREENSHIELDS
Associate Member American Society of Civil Engineers
Professor of Engineering Science, Denison University, Granville, Ohio

It was about 1850 that the development of the railroad put an end to the early importance of highway transportation. Only within the past 25 years, as a result of the coming of the automobile, have we seen the reemergence of the highway to a position of major importance in the American transportation scheme. Our annual highway bill has reached $1,500,000,000, about 8½ times what it was in 1917, but during the same time motor vehicle registration has reached 26,500,000, an increase of 33 times that of 1917. Due to the rapidly growing traffic demands and large expenditures, new conceptions and new methods in highway construction and planning are necessarily coming to the fore.

We recall the early period as one of local control, characterized by inefficient construction methods, inadequate types of construction, and failure to develop connected systems, all of which meant a waste of public funds. The present period, on the other hand, is marked by a new highway improvement policy involving the development of national, state, and regional highway systems based on a scientific analysis of traffic and engineering facts.

These facts are secured by means of the transportation survey, that is, an investigation designed to portray traffic conditions on a system of highways over at least a 12-month period, so as to show peak and seasonal variations. It includes the gathering and analysis of all data—physical and financial—which enter into the planning of a highway system. In carrying out such a survey, a state is divided into districts or areas, homogeneous in character; and he traffic flow in each area is secured by means of traffic counts taken at a minimum number of stations.

In general, an analysis of the data gathered in this way will show:

1. Population and motor vehicle registration trends in such areas.
2. Amount, weight, and characteristics of passenger and cargo traffic over at least a year's time, so as to bring out peak and seasonal variations.
4. Condition of existing highways, including type of surface and width.
5. Relative use of roads by urban and rural vehicles.
6. Possible future effect of the unusual development of industrial or natural resources.
7. Sources and amounts of highway income.

By intelligent use of these data it is possible to diagnose such highway problems as: (1) where to build roads; (2) when to build roads; (3) how to build roads; and (4) how to justify expenditures or methods of procedure in the face of political pressure or change.

For the sake of simplicity, each of these problems will be considered separately, in the order given, but it should be understood that no part of the study can be made intelligently without an understanding of the problem as a whole.

WHERE TO BUILD ROADS

In order to know where to build roads best to serve traffic, it is necessary not only to learn the present distribution of motor vehicle traffic as to type and volume, but also to estimate future traffic, for that is what the road is constructed to serve. Transport surveys that have been completed show certain general underlying principles that can be applied in estimating future traffic:

1. Traffic volume is largely proportional to population and to motor vehicle registration. This last relationship is shown in Fig. 1, taken from the Report of a Survey of Transportation on the State Highways of Pennsylvania, 1928. The vertical plotting is on a logarithmic scale and the curves for traffic and registration have been moved into contact in each case, for purposes of comparison.
2. Traffic is essentially local.
3. Highway utilization (vehicle and tonnage miles) varies with highway classification and regional features, such as agricultural, industrial, urban, and suburban characteristics.
4. Truck hauling is limited to short distances. The length of a profitable trip is, however, increasing.
5. Foreign traffic is usually a small part of the total traffic but may in certain cases become a large percentage.
6. Highway utilization is increasing absolutely, that is, faster than registration.

A PRACTICAL EXAMPLE FROM CALIFORNIA

The method of applying these principles of highway transportation is well illustrated in a Report on the Orderly Addition of New Roads to the California State Highway System, 1939, by T. H. Dennis, Maintenance Engineer, California State Highway Department. For example, he analyzes Route L, from Riverside to San Diego, shown in Fig. 2.

Local traffic is expected to increase as the tributary farming area is more intensively cultivated. Through traffic will increase in proportion as the distance from Riverside to San Diego, and from Los Angeles via Pomona and Elsinore to San Diego, is shortened by relocation and improvement. For this route a logical alternate to relieve heavy traffic on the Coast route, as well as the most direct line from the San Bernardino and Riverside areas to San Diego and the south.

Traffic will also be greatly increased by construction on a more direct location between Riverside and Escondido and also of a direct connection from Pomona. Assume that such improvements are made during the next four years. The problem is to estimate traffic in 1940. Motor vehicle registrations for the years 1927 and 1929 for Los Angeles, Riverside, Orange, and San Diego counties show an annual increase of 9.5 per cent, but this is probably excessive. Basing the population increase on the traffic census for 1910 and 1920 and projecting ahead to 1940 at the same rate, and assuming that there will be one vehicle registered for every two and a half people in 1940, the increase is found to be 6 per cent each year. This seems reasonable. For a 12-hour period the traffic may then be found as follows:

<table>
<thead>
<tr>
<th>TRAFFIC</th>
<th>SUNDAY</th>
<th>WEEK-DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present traffic (average)</td>
<td>1,400</td>
<td>820</td>
</tr>
<tr>
<td>Normal increase by 1940, at 6 per cent per year</td>
<td>870</td>
<td>480</td>
</tr>
<tr>
<td>Increase of through traffic on account of Pomona to Corona connections, 25 per cent of the through traffic on the Coast route</td>
<td>2,000</td>
<td>1,000</td>
</tr>
<tr>
<td>Total estimate for 1940</td>
<td>4,320</td>
<td>2,500</td>
</tr>
</tbody>
</table>

Such use of traffic data is not confined to California. Letters from state highway engineers in 41 states show that 31 of these states now use to a greater or less extent the results of traffic counts or of transportation surveys in planning highway improvements.

WHEN TO BUILD ROADS

The answer to the question "when to build roads" is based on the economic principle that whether a highway should be improved now or later depends on whether the annual saving in transportation costs will more than equal the annual cost of the improvement. The survey should show the extent to which the improvement of old, or the opening of new, traffic routes is economically justified. This is found by comparing the earning value of a state highway system (based on passenger miles and freight ton miles) with its present worth—replacement value minus depreciation. It should also estimate or show the cost of accidents preventable by highway improvement.

This question of "when" is closely connected with the previous one of "where." Under most conditions there is a greater demand for economically justified improvements than the available funds will cover. Then a highway transport survey will show which jobs should be done immediately and which can be deferred.

ECONOMICS INVOLVED

Suppose that over a certain route the traffic for the next ten years is estimated to average 2,000 vehicles per day. Consider the justifiable expenditure for shortening the route one mile.

It can be safely assumed that one-half the cost of operating a motor vehicle is road expense, say 5 cents per mile. Then the annual saving will amount to:

\[ 365 \times 2,000 \times 0.05 = 36,500 \]

This sum could then be applied to the annual cost of the new construction, which would consist of (1) annual interest on average value, considering depreciation; (2) annual maintenance cost; and (3) annual depreciation.

In addition, the time saved may be evaluated. The U.S. Government estimates the time value of a motor vehicle and its occupants as $3 per hour. Assume an average road speed of 30 miles per hour. The annual saving will then amount to:
STUDIES IN TENNESSEE

An example of a forecast of future traffic and an analysis of expected financial returns is given by N. W. Dougherty, M. Am. Soc. C.E., in the TRANSACTIONS of the Society, Vol. 94, page 497, in connection with the construction of highway bridges that are to be financed by toll charges in Tennessee. In brief, this method consists of a study of license numbers to find the percentage of vehicles originating in (1) the same county—local travel, (2) counties of large registration, (3) other counties of the state, and (4) other states.

A typical analysis is that shown in Table I, for the station at Spring Hill, Tenn., the relative location of which may be seen in Fig. 3. In 1926, the local travel at Spring Hill was 573 vehicles per 12-hour day, from which the ratio of travel to weighted registration is found to be 0.001. That is, approximately one-tenth the tributary motor vehicle registration passed the station every day. All local registration was considered tributary, but only part of the more distant registration was so considered.

Table I, Analysis by License Numbers of Vehicle Traffic per 12-Hour Day at Spring Hill, Tenn., in 1926.

<table>
<thead>
<tr>
<th>County</th>
<th>Total Cars Registered in County</th>
<th>Weighted Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Williamson</td>
<td>80</td>
<td>2,008</td>
</tr>
<tr>
<td>Maury</td>
<td>60</td>
<td>1,614</td>
</tr>
<tr>
<td>Giles</td>
<td>30</td>
<td>2,050</td>
</tr>
<tr>
<td>Lawrence</td>
<td>20</td>
<td>531</td>
</tr>
<tr>
<td>Marshall</td>
<td>20</td>
<td>1,017</td>
</tr>
<tr>
<td>Hickman</td>
<td>10</td>
<td>1,115</td>
</tr>
<tr>
<td>Lewis</td>
<td>10</td>
<td>644</td>
</tr>
<tr>
<td>Total</td>
<td>6,172</td>
<td></td>
</tr>
</tbody>
</table>

In Table I the weighted value was obtained by assuming that the percentage of the cars tributary to the station varied with the distance from the source to the station; and by the engineer's judgment as to the influence of the topography and other characteristics of the localities. The curve of registration was then extrapolated from 1920 through 1927 to 1940, by assuming (1) the probable increase in population, (2) the number of persons per vehicle, and (3) contributory percentages, to remain the same.

HOW TO BUILD ROADS, AN IMPORTANT QUESTION

To throw light on the best type of road for a given location, a survey should provide the following data:

1. Present, and probable future, daily, seasonal, and yearly traffic flow and its distribution on the highway system.

2. Maximum loading and frequency of such loads as an index of the proper pavement width and design for highways contiguous to large centers of population.

3. Cost of vehicle operation over various types of roads. Aside from traffic, many physical problems affect the selection of pavement types but such problems will not be considered here. From the traffic point of view certain general principles are being established that may be used in selecting the proper type and width of paving. For example, a certain highway route is estimated to have an average daily traffic of 1,500 vehicles for the next ten years. Should it be paved with a heavy type of surface, such as concrete or brick, or with a medium type—a bituminous macadam or its equivalent? Assume that the annual costs for these two types of surfacing are as follows:

<table>
<thead>
<tr>
<th>Type</th>
<th>Cost per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Traffic</td>
<td>$4,250</td>
</tr>
<tr>
<td>Medium Traffic</td>
<td>$3,250</td>
</tr>
</tbody>
</table>

Taking the average difference in vehicle operating cost as one-half cent a mile, the justifiable annual expenditure for the costlier pavement can then be computed as follows:

\[ 1,500 \times 365 \times 0.0005 = 2,737.50 \]

This is more than the annual difference in cost of the two types, and the higher type is justified provided that the assumed figures of cost are correct. It is thus seen to be the purpose of the traffic survey to supply accurate data on operating costs and to assist in forecasting future traffic conditions.

TRAFFIC SPEEDS AND ROAD CAPACITY RELATED

As to the question of the traffic capacities of different widths of paving, there is no very definite answer. For conditions in California, Mr. Dennis is using the follow-
ing ultimate safe capacities for computing width of pavement for the estimated traffic in 1940.

\[
\text{Type} \quad \text{Number of Vehicles}\\
\text{Two-lane roadway} \quad 700 \text{ vehicles per hour}\\
\text{Three lane roadway} \quad 2,000 \text{ vehicles per hour}\\
\text{Four-lane roadway} \quad 3,200 \text{ vehicles per hour}
\]

For this volume, fast traffic traveling at 40 miles per hour must be permitted to pass the slower. A safety factor of about 30 per cent is also included, that is, traffic on a two-lane roadway could be increased to 1,000 vehicles per hour without resulting in serious delays.

From the results of an aerial survey of highway traffic between Baltimore and Washington, D.C., A. N. Johnson, M. Am. Soc. C.E., derives a formula for the theoretical discharge of a two-lane highway, which he explained in an article in the Proceedings of the Eighth Annual Meeting of the Highway Research Board, 1928. The number of vehicles per hour, \( N \), passing a given point at a velocity of \( V \) miles per hour, with an average car length of 15 ft., is as follows:

\[
N = \frac{5,280 \times V}{C + 15}
\]

in which \( C \), in feet, is the clearance between the cars. The observed clearance, Fig. 4, is seen to vary approximately as the 4/3 power of the velocity.

If we introduce this value of \( C \) in the formula, we have the discharge per hour for a single line as:

\[
N = \frac{5,280 \times V}{0.5 \times V^{1/3} + 15}
\]

Results are shown by the curve plotted in Fig. 5.

**APPLICATION TO MULTIPLE LANES**

In order to keep the motorist to his proper lane so as to permit unobstructed passing, Massachusetts has introduced the dual-type highway, in which the center lanes are paved with a rougher, less attractive paving. Traffic is automatically kept to the outside so that passing may be made on the inside lanes in safety. From the fact that the annual cost of traffic accidents in the nation as a whole is estimated at one billion dollars, the matter of safety is seen to be of utmost importance.

Under conditions of free passing, the actual capacity of a four-lane road will exceed but little the theoretical capacity of a two-lane route. A highway should not only permit maximum traffic but it should permit it unobstructed. This means that free passing should be available at all times. This can be accomplished by permitting on the inner lane only cars traveling at such a speed that they are potentially passing the cars on the outer lane. This, in effect, is to provide unobstructed travel in one lane each way.

**EFFICIENT EXPENDITURES VERSUS POLITICAL PRESSURE**

Those responsible for the location, building, and maintenance of highways often find it necessary to justify their actions to politicians and the public in general. Specific, detailed information such as that supplied by a traffic survey is the best means available. Highway officials are not slow to emphasize the value of this phase of the traffic survey.

Political changes in highway departments constantly menace efficient administration. An extended program based on the results of a transportation study is the most efficient means of showing the value of a permanent staff. A long-time budget set up to meet a definite plan of operations over a considerable period is the best possible defense against the tendency to divert the gas tax from the control of the state highway department.

For example, the Department of Public Works of California has prepared a report setting forth a 10-year budget for the state legislature. This plan received the endorsement of the engineering staff and also that of the state administration, with the comment that the policy adopted must be based on traffic and not on political pressure.

**WHAT SURVEYS WILL ACCOMPLISH**

Traffic surveys must necessarily form the basis of all computations concerning traffic. A traffic survey, however, is no more than a record of conditions at the time the census is taken. In itself it gives no indication of the future. Of the 41 highway officials who expressed their opinions on the questions which have been discussed in this paper, several in widely separated states declared that a traffic survey was not necessary for predicting future traffic and that, owing to detours and other road conditions, it might give a very wrong picture. Sound engineering principles must still be the guide in road building.

By means of past records, certain underlying principles can be established; and a continued record will make these and other principles and the trend in traffic movements more apparent. State highway engineers are finding periodic traffic surveys of great value for determining the suitability of certain types of surfaces for a given amount of traffic—in brief, for solving the problem of what type of road is best or most economical to serve the expected traffic with the money available.

Specific, detailed data supplied by traffic surveys are the most effective means of justifying highway expenditures to legislative bodies or the general public. Backed by indisputable facts, highway departments may secure, execute, and plan long-time programs, thus securing the maximum return for highway expenditures.