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 ¾-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

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

The organization of personnel was as follows:

Three weighing parties—four or five men each.
Eleven recording parties—two men each.
Two density parties—one man each.
One night party—two men.

The stations operated numbered 354 and were operated once each month. Weights were taken at 156 of the 354 stations once every two months. A proportionate number of operations were carried out during the year from Monday to Friday, also Saturdays and Sundays.

The hours of operation were from 6 a. m. to 4 p. m. and 10 a. m. to 8 p. m. alternately for day operations and 8 p. m. to 6 a. m. for night operations, thus giving a complete 24-hour cycle at each station. No weights were taken on Sundays.

Information secured consisted of the total number, origin and destination, trip mileage, type of car or truck, and number of passengers per car of all vehicles during the scheduled hours. In the case of trucks the commodity transported with the estimated value were determined and at weighing stations the weight on both front and rear axle and type of tire used were noted.

Traffic Density

On the 84,884 miles of rural highway in Ohio it is estimated that there was in 1925 a motor vehicle movement of approximately 3,746,360 vehicle miles. On the state highway system of 11,000 miles, 13 per cent of the total rural mileage, there was in the same year an average daily motor vehicle

Table 1—Vehicle Mileage on State and County Highways

Section	State Highways			County Highways		
	Highway Miles	Daily Vehicle Miles	Vehicle Miles per Mile	Highway Miles	Daily Vehicle Miles	Vehicle Miles per Mile
Northeastern Total	2,821	2,258,000	801	5,916	1,128,000	191
Division A	1,261	1,251,000	993	2,761	608,000	220
Division B	451	248,000	549	824	104,000	126
Division C	1,109	759,000	684	2,331	416,000	178
East Central Total	1,285	650,000	508	2,654	319,000	120
Division A	866	532,000	614	1,730	257,000	149
Division B	419	118,000	281	924	62,000	67
Southern Total	2,756	952,000	345	5,086	424,000	83
Division A	122	98,000	801	288	54,000	187
Division B	571	255,000	446	1,193	124,000	104
Division C	2,063	599,000	291	3,605	246,000	68
Southwestern Total	736	571,000	776	1,788	353,000	197
Division A	376	355,000	944	1,003	237,000	237
Division B	360	216,000	601	785	116,000	147
Northwestern Total	3,402	1,478,000	434	7,547	813,000	108
Division A	117	134,000	1,144	567	152,000	267
Division B	419	303,000	723	907	152,000	168
Division C	2,866	1,041,000	363	6,073	509,000	84
State Total	11,000	5,909,000	537	22,991	3,037,000	132

movement per 24-hour day of approximately 5,900,000 vehicle miles or an annual traffic of approximately 2,160,435,000 vehicle miles or 57.7 per cent of the total motor vehicle traffic. This corresponds to an average of 538 vehicle miles per mile of highway or over nine times the average daily traffic on the county and township roads. This traffic was by no means evenly distributed over the entire state highway mileage but varied from a maximum of 5,583 vehicles on State Route 5 (Lincoln Highway) between Canton and Massillon to a minimum of 10 vehicles on State Route 197 in Mercer County.

The heaviest traffic was confined to the areas adjacent to the larger centers of population and to certain "through routes" on which local traffic is augmented by traffic between the large cities. This concentration of traffic is particularly apparent in the Cleveland-Akron-Canton-Youngstown area. (See table 1.)

In general, truck density varies with passenger car density, though the ratio is not constant. For the state as a whole, trucks form 9.5 per cent of the total vehicle mileage on the state highway system. The variation in ratio is indicated by the fact that on State Route No. 1 (National Road) a few miles west of the West Virginia line, trucks were 11.3 per cent of the total vehicles, while on the same road just west of Zanesville trucks form but 7.0 per cent of the total vehicles.

Of the 11,000 miles of state highways, 131 miles (1.2 per cent) carried over 2,500 motor vehicles per average 24-hour day; 858 miles, (7.8 per cent) carried over 1,500 motor vehicles; while 7,761 miles (70.6 per cent) carried less than 600 motor vehicles. There were 3,250 miles carrying over 600 motor vehicles per day.

Highway Utilization

The 11,000 miles of state highway, 13 per cent of the total rural mileage, carry 57.7 per cent of the total traffic. The 22,991 miles of county highways, 27.1 per cent of the total mileage carry 29.6 per cent of the total traffic. The 50,893 miles of township roads, 59.9 per cent of the total mileage carry only 12.7 per cent of the total traffic in Ohio. The average daily density of the state highway system is 538 motor vehicles per mile, 132 per mile on the county roads and 26 per mile on township roads. *A mile of state highway serves more than four times as much traffic per mile as a mile of county highway, and more than twenty times as much traffic as a mile of township road.*

Maximum Traffic

Seasonal traffic reaches its peak in August, daily traffic on Sunday. Routes carrying an average daily traffic of over 1,500 motor vehicles may be expected to carry in excess of

3,450 vehicles on the day of maximum traffic and routes carrying over 2,500 vehicles, in excess of 5,750 vehicles.

Composition of Highway Traffic

Of the total passenger car traffic, 10.2 per cent is foreign and 55.4 per cent is business use. Passenger car traffic originating in the cities is 87.6 per cent and traffic originating on farms 12.4 per cent.

The average trip mileage of Ohio passenger cars is 31 miles and foreign cars 134 miles. The average trip mileage of city passenger cars is 51 miles and farm passenger cars 10 miles.

Of the total daily truck miles only 4.7 per cent is foreign. City trucks represent 84.5 per cent of the total daily truck miles and farm trucks 15.5 per cent.

Commercial trucks operated for hire on a contract or traffic basis produce 21.1 per cent of the truck mileage on the state highways.

Highway Traffic and Population

There is of course, a general relation between density of population and density of vehicle traffic in any given area. The highways carrying the largest daily volume of traffic are those radiating out of the important cities, but on most of these routes the traffic falls off rapidly as the distance from the city increases. Certain exceptions however are found in the case of "through routes" such as the Buffalo-Chicago Road, the Lincoln Highway, the National Road, etc. Such highways carry a very considerable volume of long-distance traffic, which may have little relation to the density of population along the route.

The predominance of local traffic in the state as a whole is indicated by the fact that 69.7 per cent of the passenger car trips recorded were less than 50 miles and 50.7 per cent less than 20 miles. For motor trucks the percentages were even lower—only 28.4 per cent of the trips exceeded 30 miles. Less than 30 per cent of truck traffic and less than 40 per cent of passenger car traffic in our area is produced outside a 30-mile zone about the area.

In general, traffic density measured in terms of vehicle miles per mile of highway may be said to vary directly with population density, although the degree of correlation is too low to permit of any mathematical relationship.

The ratio between population density and traffic was found to differ widely in different sections of the state. This variation appears to be related to several factors. For example, in sections having dense population, or including large cities, the ratio of traffic density to population is much lower than in rural sections. In sections of light population the presence

of important "through routes" results in an abnormally high ratio. In sections having high motor vehicle registration in proportion to population, i. e., having a low number of persons per car, other things being equal, there is found a relatively high traffic density.

The significance of an analysis such as has just been outlined lies in its relation to highway planning and finance. Subject to the variations mentioned, population density is a reliable measure of the total highway traffic in areas of considerable size. In preparing future highway plans, the rate of increase or decrease of population in a given area provides a basis for estimating probable needs five or ten years ahead. Finally, the distribution of highway traffic in relation to population throws considerable light on the problem of highway finance. Since a considerable part of the traffic in the areas adjacent to large cities has its origin in those cities, and since a considerable volume of the traffic in certain regions is through traffic, it is apparent that an equitable scheme of highway taxation must be based on larger geographical units than when traffic was a distinctly local movement.

Motor Truck Capacities and Loading

Although motor truck traffic on the state highway system, on an average day, is slightly less than 10 per cent of the total motor vehicle traffic, the importance of the motor truck in highway traffic is much greater than this percentage would indicate.

The average gross weight of motor trucks on the state system is between 2 and 2½ times that of passenger cars while maximum motor truck weights run as high as 4 times the maximum weights of passenger cars. The importance of the truck in highway planning is further emphasized by the fact that many trucks are equipped with cushion and solid tires as compared with complete pneumatic tire equipment on passenger cars. A study of the rear-wheel tire equipment of motor trucks using the state highway system has shown that 15 per cent of the trucks are equipped with solid tires on their rear wheels and a like percentage with cushion tires. It must also be considered that the use of solid and cushion tires is greater on the larger trucks. Only 5 per cent of the trucks of 3-ton capacity or larger have pneumatic rear tires.

Because motor trucks carry heavier gross loads than passenger cars, because many of them (particularly large capacity trucks) are equipped with solid and cushion rather than pneumatic tires, and because motor trucks do not have such refined shock-absorbing devices and spring equipment as passenger cars, the motor truck forms an appreciable part of motor vehicle traffic and presents a special problem for the highway builder.

On some of the less important routes of the state system the number of trucks is negligible insofar as the planning of highway routes is concerned, there being several routes with an average of less than one truck per day. There is little likelihood that the motor truck will assume sufficient importance on these routes to warrant special consideration for some time to come.

There are, however, many routes on which the daily density of trucks is as great as 200 and even 300 trucks. On several short sections of the state system are found on an average day over 400 trucks with a considerable number having ratings of 3 or more tons.

It is obvious that different types of highways must be constructed to provide for various types of truck traffic. It is not economical to build a high-type highway to carry a few small trucks nor a low-type highway to carry a great volume of large trucks. The provision of highway facilities for large-capacity trucks in the state, at the present time, is somewhat relieved by the legal maximum gross load limitation of 20,000 pounds. This limit restricts, to some extent, the use of trucks of 5 ton capacity or larger.

Considering the state system as a whole, the following distribution of trucks according to capacity classes is found:

Capacity Tons	Trucks Per Cent
½-1½	75.3
2-2½	15.1
3-4	7.5
5-5½	2.0
6-7½	0.1
Total	100.00

Only 2.1 per cent of the trucks are of 5 ton capacity or larger. The average light weight of 5 ton trucks is approximately 11,250 pounds. A full capacity load added to this light weight would result in a gross load of 21,250 pounds or 1,250 pounds above the maximum permitted by law. The 5-ton truck, in many cases, cannot be legally used to its fullest capacity and is therefore an uneconomical unit. This lack of economy in use of large trucks is, of course, more pronounced in the case of trucks of over 5-ton capacity.

The location and size of cities and towns determines very largely the volume of motor trucking on the various routes of the state. Centers of population are the main sources and also the destinations of goods transported by motor truck. To find the most important trucking routes in the state one need only pick out the largest cities. The most important routes out of these cities will be those connecting with other sizable cities and towns. The effect of the population of cities and towns upon motor truck traffic can be seen in the following tabulation which shows the average daily truck traffic per route out of cities of various populations:

Population class of cities (1920)	Average daily trucks per route	Average daily 3-7½ ton trucks per route
5,000—10,000	59	5
10,000—15,000	67	5
15,000—20,000	99	8
20,000—30,000	117	10
30,000—50,000	134	13
50,000—100,000	158	13
Over 100,000	187	28

Ohio Forecast Summary

Traffic in Ohio cannot be forecasted on the basis of a historical traffic series, since no such series exists. In five states (Massachusetts, Maine, Maryland, Wisconsin and Michigan) a study of traffic records extending from 1909 to 1926 indicates close agreement in the rates of increase of highway traffic and motor vehicle registration. The Ohio traffic forecast is, therefore, based upon estimates of registration to 1925.

The trend of Ohio motor vehicle registration from 1913 to 1924 indicates an increase of 51 per cent between 1925 and 1930, and an increase of 28 per cent from 1930 to 1935. The number of persons per car for 1930, obtained from estimated registration and from population estimated by means of the method of the Census Bureau, will be one registered motor vehicle in 1930 for each 3.36 persons within the state.

The present number of persons per car varies widely in different parts of the state, as does the rate of population growth. The rates of decrease in persons per car within these areas are, however, in close agreement.

To allow for differences in the increase in registration and in traffic in the different counties of the state, the number of persons per car, based on estimated population in 1925 for each county of the state, were obtained. To this 1925 value for each county was applied the rate of decrease in persons per car for the state between 1925 and 1930. The 1930 estimated registration for each county was then obtained by applying the estimated number of persons per car in 1930 for each county to the estimated 1930 population of that county. From the actual county registration in 1925 and the estimated registration in 1930 the percentage increase in registration and in traffic for the county was obtained. This results in the same total for the state as a whole and reflects the differences between counties in intensity of registration in 1925 as well as differences in county rates of population growth. The expected county registration and traffic growth, 1925 to 1930, varies from 41.3 to 74.9 per cent, the latter rate for a county showing a rapid rate of population increase.

The expected average daily 1930 traffic at each of the sur-

vey stations is determined by applying the county rates of traffic increase to each of these stations.

Because of possible industrial and suburban development as well as changes in the highway system both as to location of routes, routing of traffic, and types of improvement, it is not expected that these estimates will in all cases reflect exactly the actual traffic in 1930, but it is believed that these estimates will reflect with reasonable accuracy the traffic in the larger areas and on routes of considerable length.

Commodities Transported

Products of manufacture form the principal class of commodities transported over the state highway system in Ohio—55.9% of all loaded trucks were engaged in the transportation of this class of commodities. The most important items included in this class of commodities are bakery goods, groceries, beverages and bottles, used furniture and household goods, wooden containers and empty cans.

Products of manufacture comprised 46.6 per cent of the net tonnage hauled. The average length of haul was 36 miles.

Used furniture and household goods are significant commodity because of the distance they are hauled. Their average length of haul is 117 miles, with individual hauls frequently running up to 200 and 300 miles. Used furntiure and household goods constitute 4.0 per cent of all motor truck net tonnage.

The second most important class of commodities, from the standpoint of trucks engaged and the length of haul, is products of animals. This class constitute 14.3 per cent of the trucks and 12.7 per cent of the total net tonnage. Milk and other dairy products and meat and other packing house products are the principal commodities in this class. The average haul for this class of products is 28 miles.

From the standpoint of net tonnage transported, the second most important commodity class is products of mines. In this class are such commodities as coal, sand, clay, gravel and stone. The average length of haul is only 8 miles and while such commodities compose 16.9 per cent of all commodity net tonnage, they involve only 8.5 per cent of all trucks operating.

Products of agriculture involve 10.5 per cent of all loaded trucks and 9.2 per cent of the total net tonnage. The chief commodities in this class are fresh fruits and vegetables, feed and grain which together account for 76.2 per cent of the trucks hauling products of agriculture.

Products of forests comprise the least important commodity hauled by truck in Ohio. Only 3.3 per cent of all loaded trucks are engaged in the hauling of these products which are 4.4 per cent of the total net tonnage.

Manufacturing companies are the main type of origin and retail establishments the main type of destination of loaded trucks. Over 50 per cent of all motor truck loads originate at or are destined to manufacturing companies and wholesale and retail establishments.

Comparison of Railroad and Motor Truck Net Tonnage

Distance is an important factor in the amount of tonnage hauled by truck. For example, it was found that between Columbus and Akron, Toledo and Cincinnati, distances of over 100 miles, a very small part of the total tonnage is hauled by motor truck. On the other hand, between Columbus and Grove City and between Columbus and Alton, distances of 8 and 9 miles respectively, almost all the tonnage is transported by truck.

For hauls less than 20 miles, 84.5% of the total tonnage is transported by motor truck; between 20 and 39 miles motor truck tonnage is 54.7% of the total tonnage, between 40 and 59 miles truck tonnage is 32.0%; between 60 and 99 miles—24.2%; 100 miles and over truck tonnage is 2.3% of the total tonnage.

As the proportion of motor truck tonnage decreases with increase in distance both rail C. L. and L. C. L. increase. No appreciable amount of rail L. C. L. is noted under 40 miles. Between 40 and 59 miles L. C. L. is 5.6% of total tonnage; this proportion increases to 20.3% for distance of 100 miles or more.

In general the results of the survey indicate that length of haul is the primary factor in determining what amount of total net tonnage will move by either motor truck or railroad.

Commercial vs. Non-Commercial Trucks

Commercial trucks, those trucks operated by hire on a contract or tariff basis, constitute 21.1% of all motor trucks operating on the state highway system. The transportation of milk and empty cans is the most important movement of commercial trucks. Of the total trucks operated for hire 20.7% are engaged in hauling milk and empty cans accounting for 14.5% of commercial net tonnage. The average length of haul for milk is 27 miles.

Household goods constitute another important commodity hauled by commercial trucks. Household goods are hauled by 11.0% of the commercial trucks. Commercial trucks haul household goods for an average length of haul of 127 miles.

Of the commercial trucks 23.8% are of 3-ton capacity or larger while only 7.0% of the non-commercial trucks are of the same capacity.

Commercial trucks are loaded nearer to full capacity than non-commercial trucks.

A larger percentage of non-commercial trucks operate in the short mileage zones and a larger percentage of commercial trucks in the long mileage zones.

A continuation of the survey work in the future will add greatly to the value of the information obtained originally. This can be carried on with a small skeleton organization, using selected key stations, which is the procedure contemplated in Ohio. Future traffic can be estimated with considerable accuracy from the evidence of the past. However, it is not possible to predict what change in the character of highway traffic may be imminent. The advent of the motor truck—and more recently the bus—was certainly not fully anticipated by those in authority. I recently attended the exhibit of equipment in connection with the annual convention of the American Electric Railway Association. The largest and by far the most interesting part of this electric railway show was a display of motor buses.

A transport survey also has a material value to private business, especially the types that derive their patronage from motorists. The information can be used by such enterprises in a variety of ways.

The formulation of a method for approximating the traffic on a given highway without the necessity of a field survey is within the range of possibility, using the data available as a result of transport surveys. It is believed that the problem is capable of solution if proper consideration is given to such factors as:

(1) The tributary area.
(2) Population density.
(3) Motor vehicle registration.
(4) Character of population—urban or rural.
(5) Classification of predominating industry—industrial or agricultural.

I am informed that this problem is being given consideration by the Committee on Highway Traffic Analysis of the Highway Research Board.

The idea of a traffic survey is one that has always appealed to students of highway affairs. It can represent either a waste of money or a very profitable investment. The author is not skeptical of its value to highway administration but does, however, wish to emphasize the fact that the survey has value only as a means to an end. The economic production of transportation service is the business of the highway departments of the country. A thorough knowledge of the requirements of this service is one of the basic principles upon which rests the success of modern highway administration.