REPORT OF COMMITTEE ON HIGHWAY TRAFFIC ANALYSIS

GEORGE E HAMLIN, *Chairman*

Superintendent of Maintenance, Connecticut State Highway Department

TOLL BRIDGES AND TOLL HIGHWAYS

Publicly and privately owned toll bridges and privately owned toll highways have been constructed in the United States to provide traffic facilities not furnished by free bridges and highways built by cities, counties and states Both toll bridges and toll highways have been built because public funds have not been considered available for their construction at the time of their conception While these are the usual reasons for permitting the construction of toll bridges, toll highways may be discussed from other viewpoints.

The construction of a toll highway also may be considered from the standpoint of providing traffic facilities of an exceptional character, in addition to and supplementing facilities furnished by a public highway or highways. A toll highway of this type might be constructed on a private right-of-way with light grades, long curves, without railroad or highway grade crossings, and having a roadway width for four or more moving traffic lanes Under proper regulation, it is conceivable that on such a highway it would be permissible to travel safely at higher speeds than is ordinarily allowed on state or county systems This feature of operation is characteristic of the famous toll highways of Italy which are built as described above.

From the viewpoints of providing additional traffic facilities and the possible reduction of traffic congestion on specific bridges and sections of highways upon which no toll charges are levied, your committee is of the opinion that the dual subject of toll bridges and highways comes within the scope of its activities and therefore it has placed this subject upon its research program for the coming year.

TRAFFIC PLANNING IS AN ENGINEERING PROBLEM

Present-day municipal traffic planning is primarily an engineering problem For the solution or maximum amelioration of the complicated and ever-growing traffic problems of cities, scientific methods must be used. Comprehensive fact-finding, and thorough fact-analysis of the entire problem must be bases for improvement plans, instead of unproved opinions and recommendations based upon an incomplete or incorrect conception of the problem as a whole.

The engineer is trained in scientific approach to problems; hence, traffic planning work should be under the direct charge of a traffic engineer.

It should be recognized that the qualifications, training and experience of the police do not fit them to direct traffic engineering work On the other hand, especially trained traffic officers must retain the important traffic functions of manual traffic dispatching, street training and education of drivers and pedestrians, and the exceedingly important functions of supervising and enforcing traffic law observance.

As between traffic engineering work and police traffic work, there should be no conflict, provided that each organization limits itself to its own work. There should be a close cooperation between the two divisions. Enforcement of the law is vitally necessary to the success of the efforts of the traffic engineering bureau. Without such cooperation in the enforcement of the law, the best plans of the traffic engineer and the most judicious enactments of the legislative body will be of no avail.

MOTOR VEHICLE PARKING AND STOPPING

In connection with investigations relative to motor vehicle parking and stopping, the committee has adopted the definition of parking included in the " Modern Municipal Traffic Ordinance " drafted in 1928 by a Committee of the National Conference on Street and Highway Safety. The definition is as follows: " The standing of a vehicle, whether occupied or not, upon a roadway, otherwise than temporarily for the purpose of and while actually engaged in loading or unloading, or in obedience of traffic regulations or traffic signs or signals."

Parking is a desirable privilege. However, there are certain conditions which warrant the withdrawal of the privilege. Thorough study should be the basis of recommendations on this important subject

Parking at curbs reduces the traffic capacity of a roadway. In recognition of this fact, many municipalities have prohibited parking at one or both curbs on certain streets for periods when traffic is especially congested In some cases no parking at any time is allowed at one or both curbs, as, for example, on heavily used business streets and on some through or arterial streets whose roadways are only of sufficient width to provide the number of traffic lanes required for moving vehicles.

In many instances, especially in business districts, the prohibition of parking does not render available the full traffic capacity of a roadway because of the stopping of vehicles at the curb " temporarily for the purpose of and while actually engaged in loading or unloading." It is a fallacy, however, to presuppose that the traffic capacity of a roadway is not increased by the prohibition of parking when stopping temporarily is permitted. It has been observed that in many cases, especially during peak traffic hours, a traffic lane at the curb has been free of standing vehicles for the full length of a block. Furthermore, double parking, and loading and unloading from the second lane, are practically eliminated, a factor of prime importance in many cities from the standpoint of reducing traffic congestion.

The Pittsburgh 1927 Traffic Survey showed that based on returns from patrons and employees of 48 stores, the distribution as to modes of transportation used in entering the central business district was as follows:

	Per cent
Street cars	63.6
Automobiles	13 3
Trains	12 4
Walked	7 0
Motor coach	3 7
	100 0

This Survey also showed that only 2.8 per cent of the patrons of 48 typical stores in the central business district parked their automobiles at the curb.

It has been developed by a recent Philadelphia survey to determine the relationship between parking and shopping that out of every 100 customers in the downtown stores 8 came by automobile parked at the curb, 69 by public conveyance, 8 by automobiles parked in garages and 15 on foot.

A report of the Committee on Street Traffic Economics of the American Electric Railway Association gives the following statistics: " In Chicago in 1926 before complete ' no parking ' rules were established those parking at the curbs during a business day were only 3 per cent of all persons who entered the district. They were but 17 per cent of all who drove into the district by automobile, and of

96,082 customers at business establishments who were interviewed only 1 57 per cent were those who used parking space at the curb In Boston only 7 7 per cent of 35,169 customers of retail stores who were interviewed used curb parking space Interviews with 56,000 customers of large and representative stores in central Philadelphia showed 9 02 per cent to have used curb parking space The parked vehicles in the central business district carried 2 per cent of the people entering that district "

The importance of parking therefore as an adjunct to the shopping business may be exaggerated. If parking were abolished absolutely not more than three Pittsburgh or eight Philadelphia shoppers in a hundred would be affected in being obliged to reach the stores in one of the other fashions of the remaining ninety-seven or ninety-two shoppers For these communities, therefore, parking need not be protected in order to sustain the mercantile business of the central business district.

The elimination of parking accomplishes the following valuable results:

1. It enables vehicles at frequent space intervals to pass street cars, even on narrow streets, on the right; this being the correct side upon which to pass street cars, for safety reasons
2 On three or four-lane streets, it permits horse-drawn vehicles or other slow-moving vehicles to pull to the right to permit street cars or other faster vehicles to pass
3 It largely eliminates delays and decreases the hazard to moving traffic lanes, often including street cars, caused by vehicles "working their way" in or out of short parking spaces at the curb
4. It is of great value to merchandise loading and unloading *where this must be done on the street* (it should be done off-street or in alleys as far as possible)
5. It largely eliminates double-line parking, or loading and unloading from the second lane from the curb
6. "No Parking" enables passenger vehicles, motor coaches, and taxicabs to discharge passengers at the curb, thereby not holding up lanes which should be exclusively for moving traffic It thereby eliminates for passengers the hazard and discomfort of alighting in the middle of the street
7. Because of the above-mentioned factors, it reduces congestion and enables a speeding-up of traffic movement, especially on

the more narrow streets Increase in speed of mass transportation units means improved service to the great majority of the public.

8. Because of the speeding-up of traffic and the easy accessibility of loading entrances, trucking and deliveries are considerably reduced in cost.
9 The elimination of parking is of tremendous value to the Fire Department, both in moving along the street and in fighting a fire at such a location
10. It reduces the hazard created by pedestrians walking out from between stopped vehicles
11 It facilitates street cleaning considerably, and snow removal tremendously.
12 It greatly improves the effectiveness of display windows to people riding past in street cars, busses, or as passengers in automobiles.
13. Parking elimination makes congested business districts more accessible to the considerable majority of people who use public vehicles (including street cars, busses, and taxicabs) as compared to private automobiles Business in general is benefited by the increased number of patrons who may conveniently enter and leave the district.
14. In important business districts, it encourages the development of off-street parking facilities so that even customers coming in private automobiles will find shopping more convenient and less time-consuming than with street parking permitted. The elimination of "hurried shopping" by customers fearing the end of short-time parking limits, is one of the benefits to merchants.

    These off-street parking facilities also make unnecessary the troublesome and time-consuming search for parking space by persons engaged in certain types of business which demand the use of automobiles intermittently during the business day

    Off-street parking facilities also provide all-day, protected storage for those who still desire to use a private automobile in coming to the district.
15. "No Parking" reduces the number of stolen cars, a factor no longer unimportant Even though in large proportion, stolen cars are recovered, they have usually suffered damage.

If it is desired to secure free and continuous traffic movement on the curb lane of any street where loading and unloading of pedestrians or merchandise must be expected, the solution is a NO STOPPING rule. This is a very drastic measure, which should generally be used only during peak hours, and then only where absolutely essential

A somewhat less drastic rule, which is a partial further step toward continuous movement on the curb lane, is a regulation prohibiting parking and the loading and unloading of merchandise, but permitting loading and unloading of passengers Such a rule of "NO STOPPING EXCEPT FOR PASSENGER LOADING" will not permit free and continuous movement on the curb lane It will result in only short-time interruptions, however, and under certain conditions may prove desirable

The committee believes that parking spaces, taxicab stands, and bus terminals should be considered as functions of business rather than a public responsibility, to be furnished off the public highway by those benefited.

SIGNALIZING OF MAIN ARTERIES

On heavy traffic urban streets where the traffic volume on most side streets is light, it is usually unnecessary to install traffic control signal at every intersection A generally satisfactory method of control is to make the main street a Thru Traffic Street with traffic control signals at the more important intersections, and with effectively sign-posted compulsory STOP regulations for all other cross streets. The traffic control signals should be arranged in a flexible progressive signal system. As the distance between traffic control signals exceeds about 1200 to 1500 feet, satisfactory coordination is less and less to be expected. Therefore, some such distance probably represents the reasonable limit for expensive inter-connection. For greater distances coordination may be justified with synchronous motors which by design must operate at exactly the same speed if the same source of energy is used.

The above-described method of signalizing and stop-sign-protecting main arteries has, in general, the following advantages:

1. Through traffic will be attracted to these arteries because of protection against entering vehicles at all intersections, and because of the opportunity of progressive movement.
2. Pedestrains and vehicles in a given district are offered locations not too widely spaced apart where they may cross the major streets under protection of traffic control signals.

3 Even at non-signalized intersections, side street vehicles and pedestrains desiring to cross the major street, gain some advantage because of the general group movement on the major street.

It must be realized that the above statements are generalizations and that each case should be thoroughly analyzed to see if conditions exist which should alter the interpretation of these statements. Some such factors are: considerable proportion of slow-moving vehicles, wide roadways, bad paving conditions

The committee strongly opposes the use of the traffic control signals spaced several intersections apart and intended to control traffic at intervening cross streets. This is a highly hazardous procedure; it also brings about the blocking of crosswalks by vehicles whose drivers must wait near the curb line in order to see the signal several intersections away.

INSTALLATION AND OPERATION OF TRAFFIC CONTROL SIGNALS

An attached chart (Table I) gives three methods of determination of minimum requirements for the installation and operation of a traffic control signal. These are under consideration of the Committee on Signs, Signals and Markings at Railroad Crossings and Major Highway Intersections of the National Conference on Street and Highway Safety.

Proposal No 1 is stated to have been drafted by one of the larger western cities where extremely heavy traffic loads are encountered

Proposal No 2 is of Massachusetts origin

Proposal No. 3 is a tentative standard and approaches the opinion expressed by the members of this committee

The present Pittsburgh minimum standard which is believed by those in charge to be too liberal, provides for consideration of the installation of a traffic control signal when traffic volume is 600 vehicles per hour in the peak hour with at least 25 per cent on the lighter traffic street; also at least 250 pedestrians for the hour including the closing of school. If an intersection meets these minimum requirements such additional factors as the following are considered: need of speed control; school child protection; possibility and effect of inclusion in a progressive signal system; effect upon traffic routing, especially as to channelization of flow on main arteries and Thru Streets; intersection visibility; complications of grades, intersection layout, and traffic movements, traffic accidents; effect upon street car operation.

TABLE I

Standards for Rush Hour Operation

Proposal (No 1)		Massachusetts (No 2)	Tentative Proposal (No 3)
A Two roadways with two free lanes for movement in each direction	1200 vehicles passing through it in maximum hour with 25% of this on the lighter travelled street	A & B (1) Vehicular Volume Regardless of streets or lanes any signal may be operated during any hour when the total traffic is 500 vehicles per hour and the cross traffic is 125 vehicles per hour (2) Pedestrian Volume 500 vehicles 250 pedestrians (3) Speed Control Special cases where excessive speed under uncontrolled conditions (4) Coordination Where majority of installations of system fulfill vehicular volume requirements and where it adds to the efficiency of the system (5) Traffic Actuated Anywhere, at any time, when properly timed	(1) Vehicular Volume Regardless of streets or lanes any signal may be operated during any hour when the total traffic is 750 vehicles per hour and the cross traffic is 200 vehicles per hour (2) Pedestrian Volume (a) 750 vehicles per hour (b) 300 pedestrians per hour (3) Speed Control (a) 750 vehicles per hour, total flow (b) Excessive speed under uncontrolled conditions (4) Coordination (a) Where majority of installations of system fulfill vehicular volume requirements, (b) Installation must add to the efficiency of the system. (5) Traffic Actuated Anywhere, at any time, when properly timed
B Two roadways with three free lanes for movement in each direction	25% more than the above set for two free lanes		
Standards for All Day Operation			
C Two roadways with two free lanes for movement in each direction	16,000 vehicles pass in a 16-hour period and in addition has the rush hour standard	Practically the same as above If reduced to a total at 500 per hour, would be 6000 or ½ of the 16,000 required by the National Code Requirements	Same as above
D Two roadways with three free lanes for movement in each direction	25% more than above set for two free lanes		
Standards for Non-Operation			
If traffic falls below 800 vehicles per hour, signals cannot be operated during such hours and an illuminated "Stop" or "Caution" sign should be displayed		If traffic falls below 500 vehicles per hour signals must be turned off from control operation and turned onto flashing yellow operation as a warning indication If a through way, then red toward side street and yellow on through way	Same, except 750 vehicles

VEHICLE ACTUATED TRAFFIC CONTROL SIGNALS

Until quite recently automatic traffic control mechanisms have been designed to provide continuously a pre-arranged, regular program or cycle. Some variations have been developed, but in general, the controllers give fixed percentages of the cycle to the different streets, these percentages being based on the average, or in some cases upon the peak hour, time requirements of traffic on the streets at the intersection.

Obviously, such a fixed program will not always prove efficient in time utilization. Sometimes traffic on one street will be held when there is no traffic using the "Go" period on another street.

Theoretically at least, it is evident that it is desirable for a signal to change its proportioning in accordance with changing traffic time demands. Where signals are not operating in a system, it is also desirable, within certain limits, that the cycle length change with changing time demands.

Such reasoning has brought about the development of several types of signal mechanisms actuated by vehicles approaching or waiting at the intersection. Although most, if not all, of these types of mechanisms are still in the development stage, the principle must be recognized as sound, although the field of practical application is, in general, considered to be limited. In general, these vehicle-actuated mechanisms include pedestrian push-buttons so that persons will not be required to wait for unreasonable periods before receiving a signal to cross. At certain intersections made up of more than two entering streets, properly designed full vehicle-actuated control covering all entering streets may have especial merit.

Some of the reasons why the field of application of most so-called vehicle-actuated signals is considered limited are:

1. In general, a traffic control signal is only considered warranted where and when traffic is quite heavy, and consequently the number of times when the regular program is inefficient is not unduly great. At least the inefficiency is usually not great enough to warrant the generally much greater cost of vehicle-actuated control.
2. Where flexible progressive traffic control signal systems are in use, all signals must operate on the same cycle length and a definite relationship must be retained between the starts of the "Go" periods at succeeding intersections. It is conceivable that some-

thing like a progressive system might be developed by interconnection of vehicle-actuated signals, and indeed some development has been made along this line. However, any such system would be complicated and costly.

3. The anticipation of rapid growth and stabilization of traffic at an intersection, or plans shortly to include the intersection in a flexible progressive signal system, will warrant careful consideration as to whether traffic actuated control should be installed.

TRAIN ACTUATED SIGNALS AT RAILROAD GRADE CROSSINGS

The necessity for uniform signs and signals for railroad grade crossings has been the subject of recommendations by this committee for several years Since separation of railroad grade crossings can be accomplished only gradually, the committee believes that in order to facilitate and safeguard traffic movement, train signals actuated by approaching trains shall present to the highway traffic the appearance of the horizontally moving red light, the direction of which shall reverse alternately; the signals to be erected and function in accordance with the recommendations of the Signal Division of the American Railway Association, approved July, 1925.

Where a full view of these signals is less than 500 feet on account of curvature or grade in the highway, an additional signal consisting of a continuously flashing yellow light, embodied in the standard disc railroad approach sign (and so designed that the letters "RR" will be illuminated), shall be installed approaching the curve or grade so as to give advance warning of the curve and the railroad

This committee further recommends that no road authority shall permit the erection of any horizontal alternately flashing red lights on the highways under their jurisdiction, except for the purpose of indicating the approach of trains (or interurban street cars) at grade crossings. The committee also recommends that the use of the standard disc approach sign shall be continued and additional ones erected as necessary, these approach signs to be used on unimportant roads where railroad and highway traffic is very light. The committee favors illumination of these wherever practicable. In cases where illumination is not practicable, the committee favors use of signs in which at least the letters "RR" are rendered luminous by automobile headlights.

LEFT TURNS

The committee believes that, since the capacities of two intersecting streets are limited by the capacity of the area within the intersection, the best turning method is the one that will permit the greatest movement within the intersection with the least interference with other movement

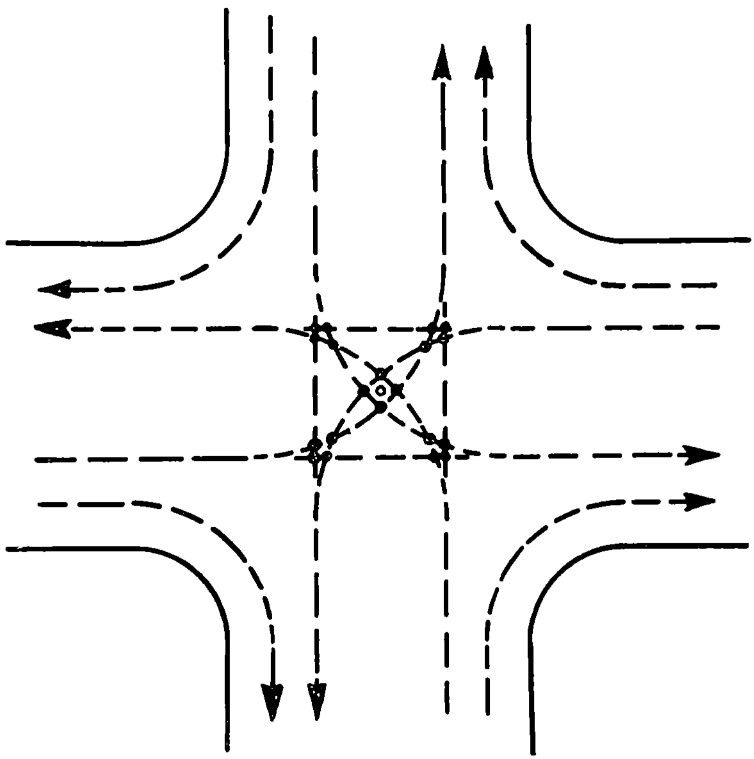


Figure 1 Uncontrolled Intersection—Left Turns Around Corner—12 Movements—20 Crossings

Vehicles approaching a normal intersection uncontrolled by lights or officers, from each of the four directions have the choice of three possible movements within the intersection; straight through, turn right or turn left A total of twelve movements is possible

The right turn away from the intersection causes little trouble or interference with other vehicles

Through movement may be interfered with by cross traffic and left turns

Left turns may intersect the paths of other turning vehicles as well as the through vehicles, and they therefore cause the most concern and greatest delay.

It is possible to make left turns in a variety of ways, a few of the most common are illustrated in Figures 1 to 8

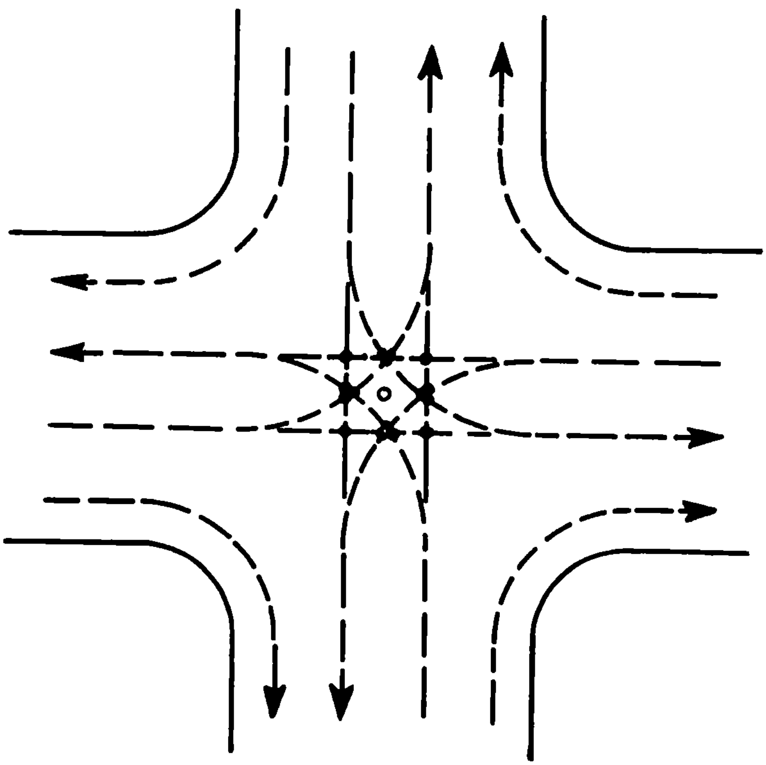


Figure 2 Uncontrolled Intersection—Left Turns Short of Center—12 Movements—16 Crossings

Figure 1 illustrates the movement in an uncontrolled intersection, vehicles turning left around the intersection of the center lines of the two streets There are twelve movements with twenty points at which the paths cross.

Figure 2 illustrates an uncontrolled intersection, vehicles turning left short of, or " inside " of the center of the intersection There are twelve movements with sixteen points at which the paths cross

Figures 3 and 4 illustrate the movement in an intersection controlled by lights, giving a separate period for all left turns, usually the amber light, as well as the " stop " and " go " periods In these cases the reservoir or storage space for left turning vehicles is at the

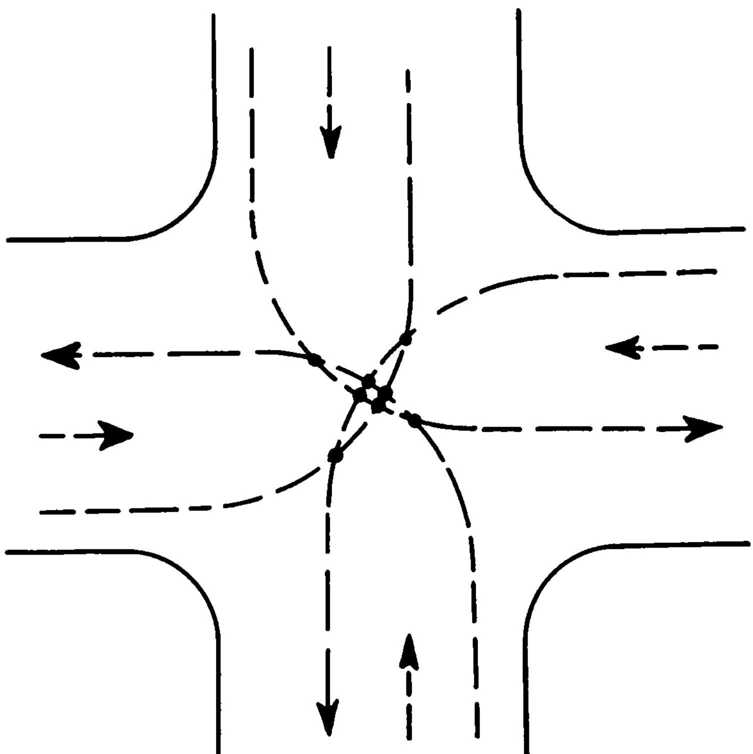


Figure 3 Left on Special Light—Around Center—4 Movements—8 Crossings

right curb, occupying and obstructing the paths of through vehicles and those turning right The throat of the intersection is obstructed and part of the street area lost The light cycle is split into three parts and the left turns, when made, permit only four movements within the intersection The paths cross at eight points when the turns are made around the center, and at four points when the turns are made short of the center, as in Figure 4

The facts remain the same when the turns are made from the lane of traffic to the right of and nearest the center lines of the streets instead of from the position at the curb. In both cases vehicles with long wheel bases will be unable to execute the movement if forced to

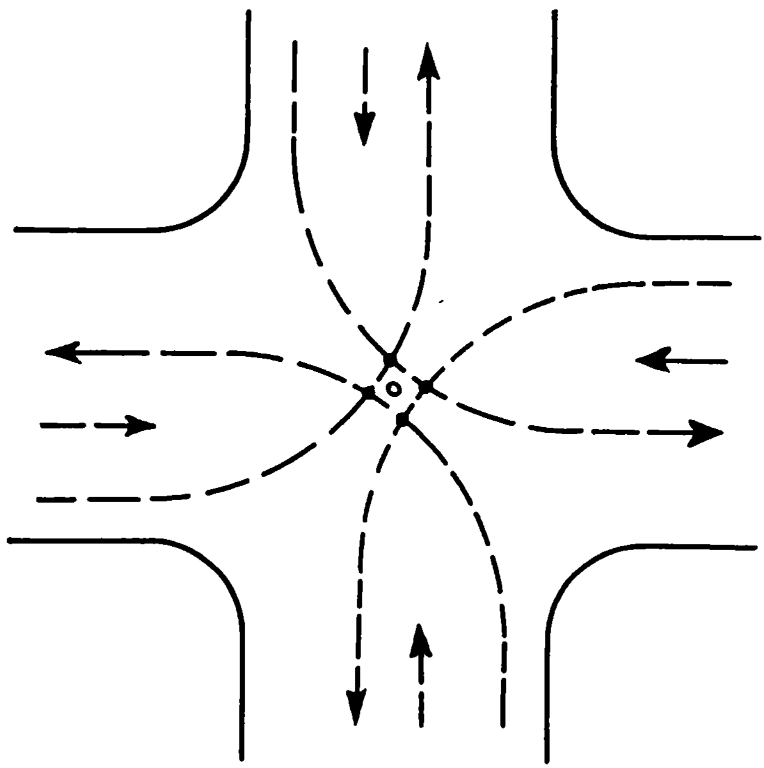


Figure 4 Left on Special Light—Short of Center—4 Movements—4 Crossings

pass around the center of the average intersection instead of being permitted to turn inside such center.

The most simple method of controlling traffic at an intersection is undoubtedly the best, provided that the maximums of movement and safety are assured Certainly nothing is more simple than to permit traffic to proceed on one street for a time while the other is stopped and then reverse the procedure.

Figure 5 illustrates the free movement on one street, including right and left turns, while all movement on the intersecting street is

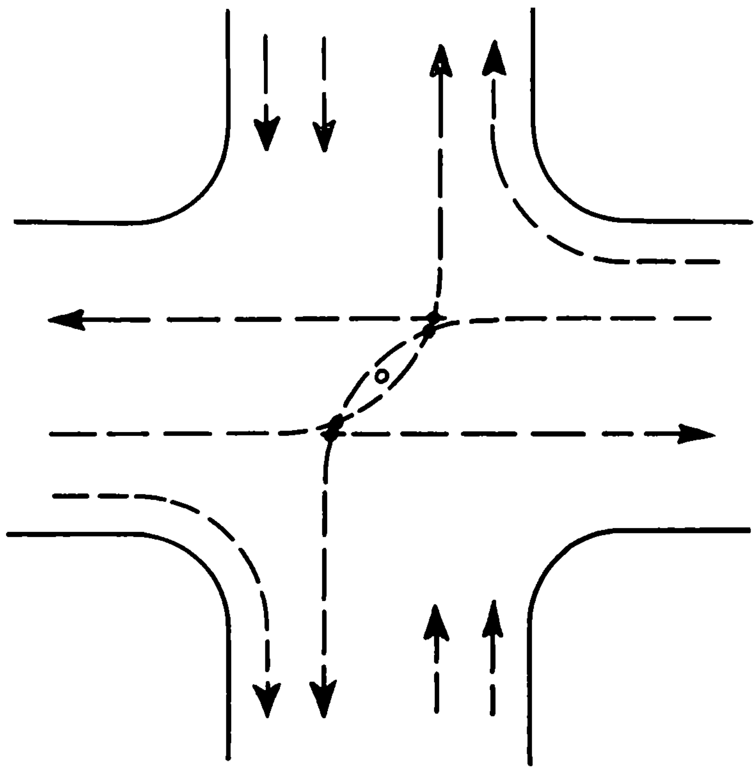


Figure 5 All Turns on Green Light—Left Turns Around Center—6 Movements—4 Crossings

stopped In this case, left turns are made from the lane of traffic next to and to the right of the center line of the street, and pass around the center of the intersection There are six movements taking place within the intersection, and the paths cross at four points

Figure 6 illustrates the same features except that left turns are made inside of the center of the intersection. There are eight move-

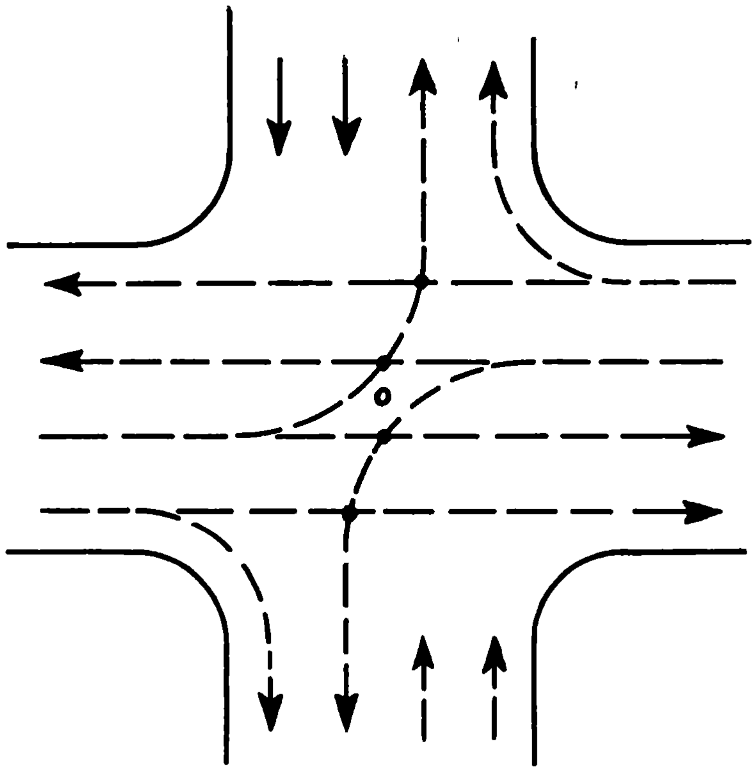


Figure 6. All Turns on Green Light—Left Turns Short of Center—8 Movements—4 Crossings

ments taking place, the paths crossing at four points. With six movements the paths would cross at only two points.

Figure 7 illustrates what is popularly known as the " left turn on the red," recommended by the committee as undesirable and counter to general practice. In this case the same narrowing of street width is encountered due to vehicles stopped before the green light awaiting the red light to make the turn as are to be found in illustrations three

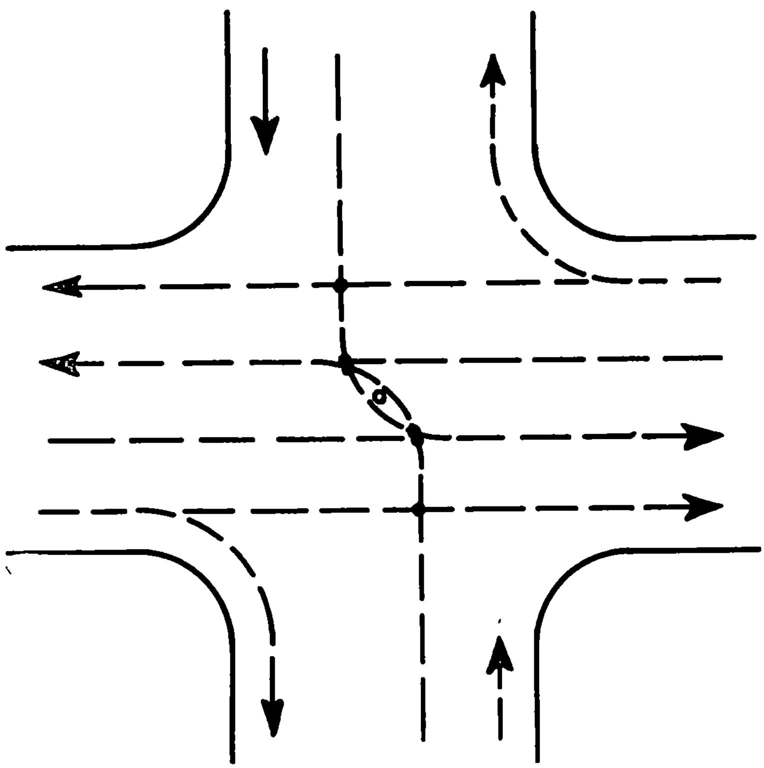


Figure 7 Left Turns on Red Light—Around Center—8 Movements—6 Crossings

and four, where the special turning period is inserted in the cycle It is possible for eight movements to take place within the intersection with six points where the paths cross.

At intersections of streets wide enough for only one lane of traffic in each direction, no space is available for the storage of vehicles awaiting a special turning period. All turns must be made on the green or " go " signal

Figure 8 illustrates what is known as the "rotary left turn" It is adapted only to unusually wide streets and under certain other favorable conditions It has the apparent advantage that free movement through the intersection is possible without any interference from left turns There are, however, several important objections to the method:

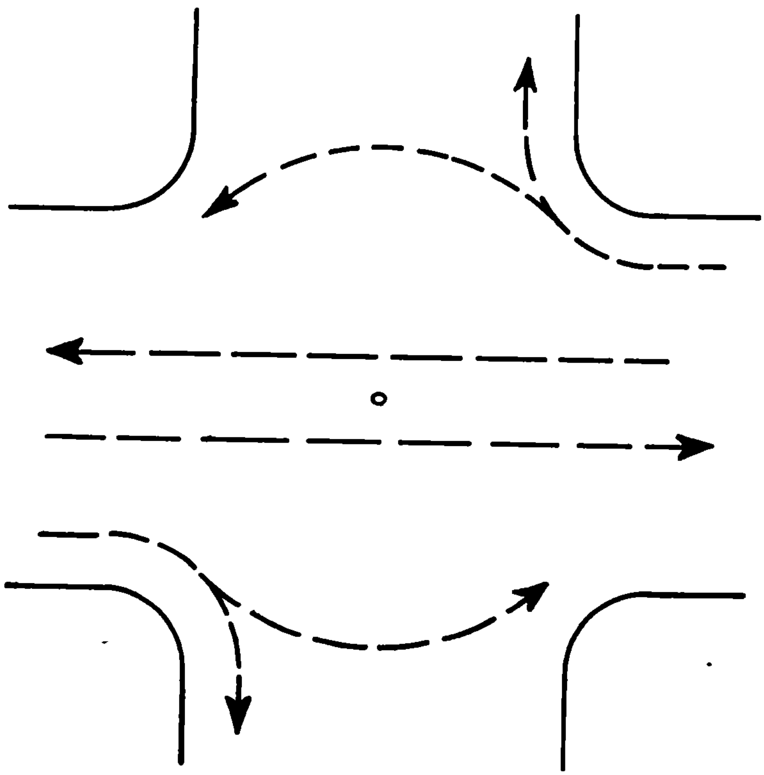


Figure 8. Rotary Left Turns

1 It is unusual, not in accordance with general practice, and therefore not easily understood by strangers, hence it causes confusion and delay within the intersection

2. Vehicles waiting to turn left may block the crosswalk It also leaves the pedestrian in uncertainty He does not know whether to jump forward to avoid a right turn or backward to avoid the rotary turn

3 The width of the intersecting street may prove insufficient to provide storage space for all left turning vehicles, resulting in delay.

4. If the number of left-turning vehicles is large, the vehicles to turn left block either or both the right turning vehicles and the straight moving vehicles
5. On streets with car tracks, a lag in starting the rotary movement when the signal changes will result in a street car moving across to be blocked by the rotary movement; the result being that vehicular traffic is stalled in both directions and the intersection congested for a time.

The method illustrated in Figure 6 is clearly demonstrated to most completely meet the requirements, i e, maximum freedom of movement with least interference and possibility of universal adoption. This method is also in accord with the normal turning procedure at an uncontrolled intersection

Therefore, the committee recommends that left turns be made on the green or " go " signal, from the lane of traffic immediately to the right of and nearest to the center of the street, the turning vehicle passing inside or to the left of the center of the intersection and as closely as possible thereto

THEORETICAL LIMITS TO TRAFFIC CAPACITY

The theoretical capacity of a highway may be determined for an assumed uniform condition of traffic flow To get the maximum flow of vehicles uniform speed and a constant distance apart must be assumed. Observations on the highway indicate that drivers space themselves in proportion to the square of the speed of travel. This is as it should be because the distance necessary to stop a moving vehicle is proportional to the square of the speed of travel. Assuming a distance from the front of one vehicle to the front of the next vehicle when standing still as 15 feet, assuming four wheel brakes with a coefficient of fraction of 0 6 and assuming one-half second reaction time, we have the following equation for the theoretical capacity of one lane:

$$N = \frac{5280Y}{0.73Y + 0\ 056\ Y^2 + 15},$$

where N is the number of vehicles per hour and Y is speed in miles per hour It will be noted that the capacity varies with the speed—the maximum capacity coming with a speed of 16 5 miles per hour

When the travel is heaviest the speed drops down to that of the slowly moving vehicle. If there are no horse drawn vehicles or very heavy trucks on the road, the capacity of one lane will actually approximate the theoretical capacity. The speed of movement for the faster vehicles will be decreased but the actual discharge will be more than can be expected if the average speed is 30 miles per hour.

When vehicles are moving at different speeds making it necessary for some of them to pass others going in the same direction, the problem becomes more complicated If the highway has two lanes, the opposing lane must be free at the time of passage This cuts the

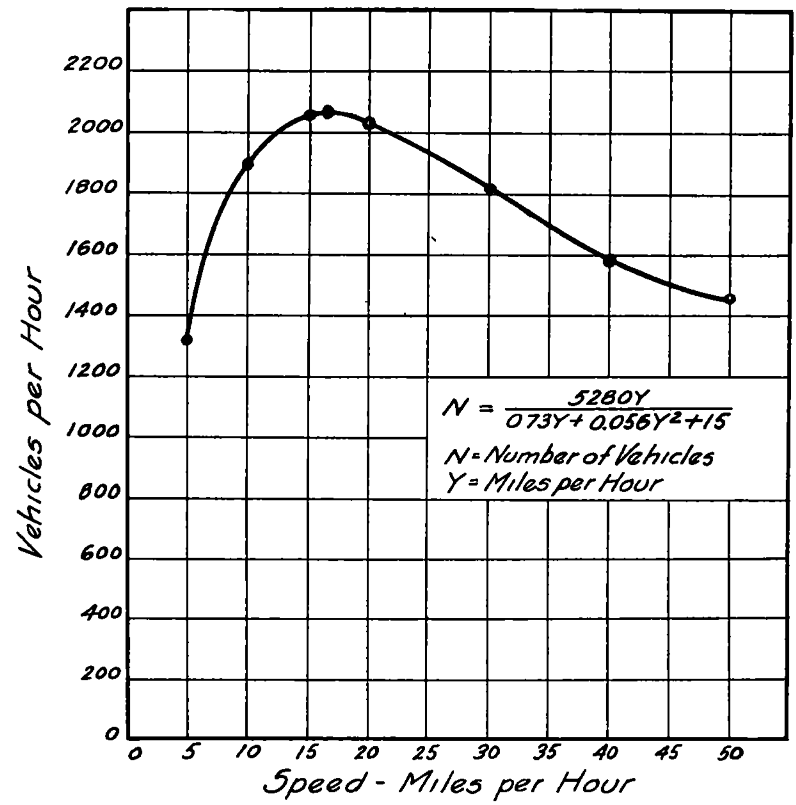


Figure 9. Capacity of One Lane at Different Speeds, Assuming Four-Wheel Brakes

capacity of the oncoming lane and if the number of slower vehicles is large it may reduce the carrying capacity of the second lane to a minimum.

A third, or passing lane, may be used to advantage if the mixed travel is predominantly in one direction during the peak flow Here is introduced a danger element which makes the three lane road questionable for a balanced flow of mixed travel. If the balanced flow is more than the capacity of two lanes, four lanes are needed

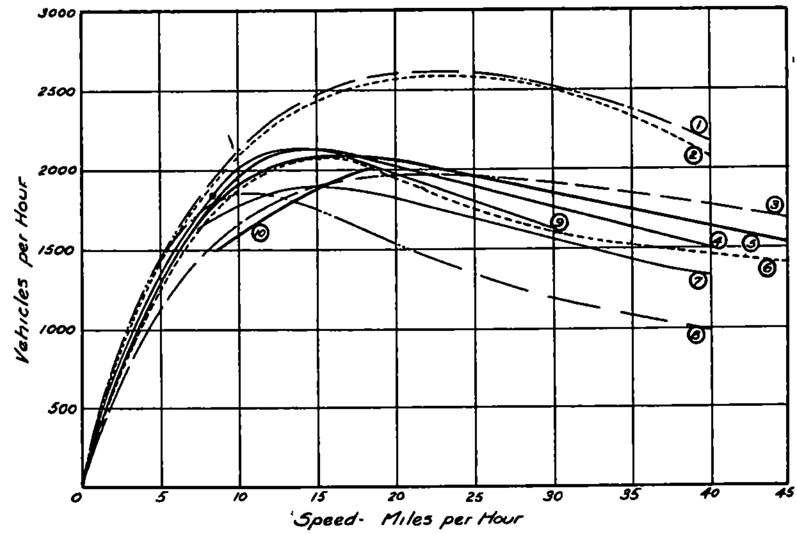


Figure 10 Comparison of Curves Showing Maximum Hourly Capacity of a Single Traffic Lane at Different Speeds. Data from a Number of Sources

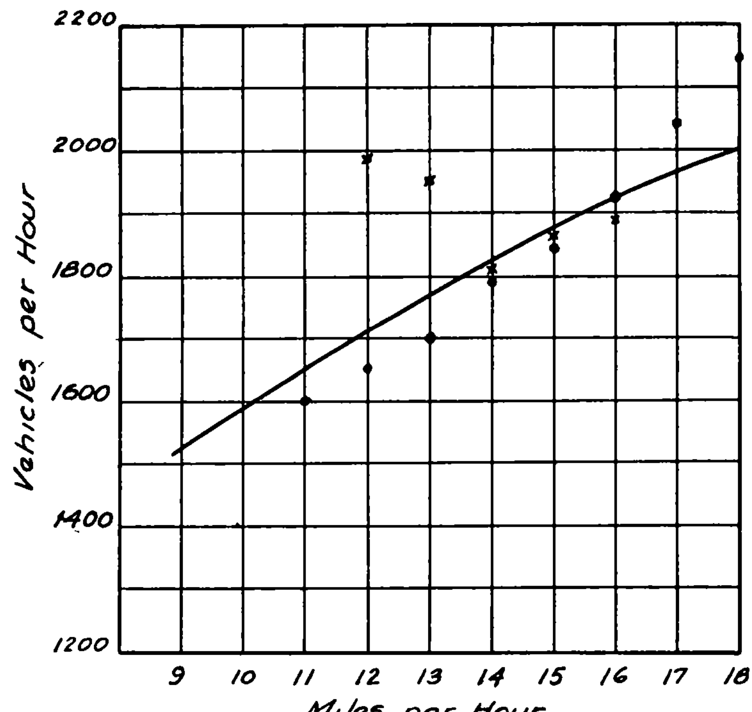


Figure 11. Hourly Capacity, One Free Wheel Traffic Lane. Bureau of Traffic Planning, Pittsburgh, Pa. Based upon Studies in Downtown Pittsburgh. Figures Given Are Theoretical, Representing the Number of Vehicles There Would Be in a Full Hour's Flow of Traffic Moving in a Flexible Progressive Signal System. For Actual Capacity Lane Flow at an Intersection, the Percentage of " GO " Time on the Street in Question Must Be Applied to the Graph Figure at the Proper Speed. Example; 45 Per Cent " GO " Time on "A" Street, Average Speed of Traffic Through Intersection 16 Miles Per Hour, Actual Lane Capacity Through Intersection Equals 0.45 × 1925 Equals 866 Vehicles

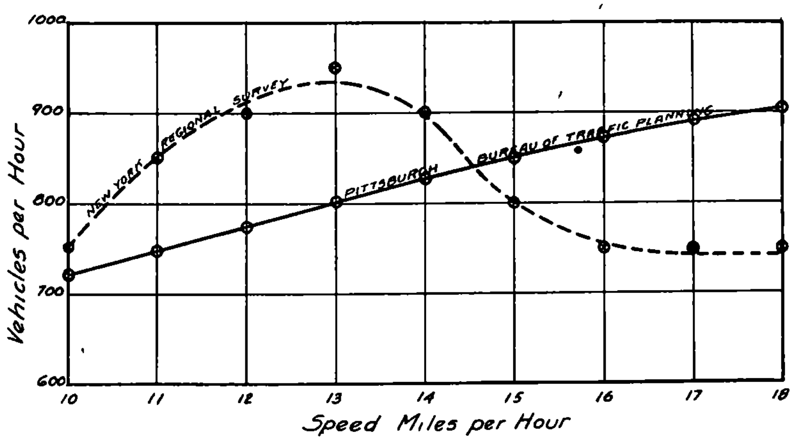


Figure 12 Comparison of Lane Capacity Data, Showing Curves for New York Regional Survey and Bureau of Traffic Planning, Pittsburgh, Pa. Both Curves Are on the Basis of a Cycle of 53 Seconds "GO" Time of 45.3 Per Cent of the Cycle or 24 Seconds

MEASURE OF TRAFFIC CONGESTION

Congestion—Hindrance to Movement of Vehicles over Highway or Street due to other Vehicles

1 Congestion is a relative term depending upon the kind of road and the area which it serves A vehicle is not expected to move at the same speed in the "Loop District" of Chicago as on the "Speedway" at Indianapolis

The committee believes that vehicular congestion exists

(a) On rural highways. Where, because of other vehicles, speed is frequently less than 30 miles per hour

(b) On urban highways: In residential areas where, because of other vehicles, speed is frequently less than 20 miles per hour

(c) In business districts where speed, because of other vehicles, is frequently less than 12 miles per hour

2 Methods of studying traffic movement Forms of equipment will vary with the information sought. Most elementary studies may be made using a stop watch and ordinary speedometer. More careful studies may be made by using self-recording time distance instruments

TRAFFIC LANE MARKINGS

(a) *Urban* Any street having more than two lanes in one direction will have its effective capacity reduced by irregular lateral spacing of vehicles. The effective designation of lanes aids drivers materially in keeping in place. It also aids in reducing accidents

Lane lines may be constructed with the pavement by the use of longitudinal construction joints or by the insertion of markers Where lane lines are not constructed with the pavement, the most common method of marking is by use of paint In order to reduce cost and to differentiate them from continuous center lines, lane lines are generally broken or dashed lines with considerable spaces between the dashes.

Although general lane marking is desirable, the expense of marking can be reduced if the lines are carried only adjacent to intersections, opposite safety zones, on curves, and at other points where it is especially important for the expedition and safety of traffic that vehicles keep within their own lanes Special directional arrows can sometimes be used effectively to supplant lane lines, as for left turns inside of the center of the intersection or for other routings not easily indicated otherwise. Where continuous center lines are used, some effectively different marking should be used at locations where traffic is not to cross the center line, as on sharp horizontal and vertical curves and at railroad grade crossings

Where paint is used, extensive tests by the Pennsylvania and Connecticut Highway Departments indicate that white is the most effective color. A four-inch width is being successfully used and is believed to be practically as effective as the six-inch line formerly used.

In order to eliminate the considerable cost of repainting, much experimentation has been carried on to find satisfactory "permanent" insert markers. Numerous obstacles have been encountered Where snow plows are used, all markers must be practically flush with the pavement surface, for the impact of the blade against any rigid obstruction will nick or shatter the blade and interfere with the snow removal operation. In any case, markers should not be raised above the surface more than ½ inch and they should have rounded edges, so as to present a better surface to hard tires Markers must also be firmly imbedded in the pavement, or they will be worked loose and finally removed by vehicles There is a rather difficult problem of securing effective night visibility. This problem is reduced where there is overhead illumination or practically continuous traffic in both directions. The marker must always present an easily visible contrast to the pavement surface—they must not become dull in service For any extensive use, the markers must be reasonable both in purchase price and installation cost Several types of markers have been developed which are reasonably effective for at least certain pavement surfaces.

(b) *Rural* On rural roads it is probable that lane marking will be valuable at intersections or in semi-congested conditions. In general, however, the committee believes it is unnecessary to lane mark four lane highways, and that a slight amount of traffic control and supervision will keep drivers in their proper positions

Most of the discussion for urban streets applies for rural highways. The statement about snow plows and the problems of night visibility are especially applicable. A flat paint has been found to reflect more light from headlamps than a glossy finish

RESPONSIBILITY FOR PROVIDING FOR PEDESTRIAN TRAFFIC

The existing condition is that on some sections of rural road, especially where the roadside development is intermediate between rural and urban, at the outskirts of large communities, for instance, or running through a small village, there is an amount of pedestrian traffic which, with high-speed motor vehicle traffic, introduces a large element of hazard, especially at night.

The difficulty is that in such cases the local community does not have adequate means for providing sidewalk facilities. The historical phase is that the road was utilized with comparative safety for pedestrian traffic some years ago, but that the road surface has been improved and traffic has increased and has been speeded up, so that now the road is, with consideration to safety, impracticable for pedestrian use.

.The roads are being built and maintained with motor vehicle funds, license fees and proceeds of the gas tax, and the general impression is that the motorist should not be expected to provide facilities for the pedestrian, but justice would seem to indicate that the motorist having pre-empted facilities formerly enjoyed by the pedestrian, should provide substitute facilities. This is the logic of the principle by which a railroad company, laying track within an established highway right-of-way is required to provide at its own expense a road equal to the one that it has taken over. Similarly, State Highway Departments must soon recognize the responsibility for taking care of pedestrian traffic and provide adequate and safe footpaths at locations where such traffic is sufficient to warrant the expenditure

VALUE OF ESTABLISHING INDEPENDENT HIGHWAY ROUTES FOR HIGH SPEED AND LOW SPEED TRAFFIC RESPECTIVELY

1 Congested areas
2 Industrial areas

This topic is of particular interest in city and zone planning but may also be of interest to some of the State Highway Departments in the near future.

The anticipated condition is that on certain roads, particularly in and in the vicinity of large cities, there may be such a volume of low speed truck traffic that the usefulness of the road to passenger motor vehicles will be seriously impaired

Under this circumstance, the most apparent relief is the widening of the road surface to provide an outside lane in each direction of traffic for the low-speed trucks However, in case the combined volume of passenger vehicles and trucks exceeds the practicable carrying capacity of the 4-lane road, local conditions may prevent the further widening of the road, right of way for instance in or entering a community where the properties are built up in such way that extra widening would require excessive expenditure In such cases relief might be provided by construction of parallel road If along considerable lengths of either the original or the parallel road, there are no sources or destinations of truck traffic, or if access to the other road may be provided to such truck traffic as may originate or be destined within such sections, the condition would appear to be favorable to segregation of the trucks on one of the roads, leaving the other for the sole use of passenger or high-speed motor vehicle traffic There should be no objection to the use of the truck road by such passenger vehicles as might be willing to accept the unfavorable operating conditions of that road Segregation of the low-speed traffic as well as facilitating the movement of traffic on the other road offers the possibility of reducing the maintenance costs and increasing the durability of the surface utilized by only light-weight vehicles.

Pennsylvania Department of Highways records, at the present time, do not show any road sections where truck traffic is of sufficient volume to warrant construction of separate roads

FORMS FOR TRAFFIC INVESTIGATIONS

The forms submitted herewith are illustrative of current practice and are presented as basis for a uniform system.

It is the intention of the committee to conduct a further study of traffic forms during the coming year, and to include definite recommendations in the next report

Form Number 1. This is the form used where it is unnecessary to list the traffic separately by the direction in which it is moving, or by right and left turns The directions at the top of the columns indicate the directions of the road from the intersection For instance, at the intersection of two roads (commonly known as a four-way intersection) there are roads to the north, south, east and west. The total passenger car traffic then on the north road would be the amount entering the intersection from the north road plus the amount leaving the intersection by the north road Counting traffic on this basis involves counting the vehicle once on the road by which it approaches the intersection and checking it again on the road by which it leaves the intersection It will be noted that at the top of the sheet there is a space for station number. In a large survey it is essential that for ease of reference and for general efficiency each station be given a number, the roads involved at this station being listed on each density sheet as well as on a control sheet held in the office

Form Number 2. This form is suggested for use at intersections where the volume of traffic is small but where a record of the distribution of traffic by directions and turns is desired The form provides space for 12 directions, the number of sheets required depending upon the period of the count and the time interval used. It is assumed that one man can record all traffic and that the hand tally method of counting is employed.

Form Number 3. This form is suggested for use at heavy-traffic intersections in cities. It provides space for four directions, the maximum number which one man can handle where the volume of traffic

(NAME OF ORGANIZATION)

TRAFFIC DENSITY

Station No ______ Day ______ Date ______ Hours Scheduled ______

North Road ______ East Road ______

South Road ______ West Road ______

Hours	Passenger Cars				Trucks				Busses				Total			
	North	South	East	West	North	South	East	West	North	South	East	West	North	South	East	West
6- 7 A.M.																
7 -8																
8- 9																
9-10																
10-11																
11-12																
12- 1 P M.																
1- 2																
2- 3																
3- 4																
4- 5																
5- 6																
6- 7																
7- 8																
8- 9																
9-10																
Total																
Foreign																

Remarks ______

Weather ______ Recorders ______ Party No. ______

Form Number 1

is great. In many cases, particularly at an important four-way intersection, only three directions of traffic can be counted by one man, in which case the last bloc on each sheet is not used

(NAME OF ORGANIZATION)

Traffic Density

Location Day Date Sheet No

	Direction	Passenger Cars	Trucks	Busses	Total
TIME: From To	N to W				
	N to S				
	N to E				
	E to N				
	E to W				
	E to S				
	S to E				
	S to N				
	S to W				
	W to S				
	W to E				
	W to N				
TIME From To	N to W				
	N to S				
	N to E				
	E to N				
	E to W				
	E to S				
	S to E				
	S to N				
	S to W				
	W to S				
	W to E				
	W to N				

Remarks

Weather Recorder

Form Number 2

As the form indicates, passenger cars and motor trucks are counted by means of a tally counter or clicker The readings recorded from the clicker should be cumulative The recorder, during the course of the count, should not set the clicker back to zero Space is provided to permit the hand tallying of motor busses and street cars.

(NAME OF ORGANIZATION)

Traffic Density

Location Day Date Sheet No.

Time	Passenger Cars		Trucks		Busses	Total	Street cars
	Clicker	No.	Clicker	No.			
Direction:							
:00- :15							
:15- :30							
:30- :45							
:45- :00							
:00- :15							
:15- :30							
:30- :45							
:45- :00							
Direction:							
:00- :15							
:15- :30							
:30 - :45							
:45- :00							
:00- :15							
:15- :30							
:30- :45							
:45- :00							
Direction:							
:00- :15							
:15- :30							
:30- :45							
:45- :00							
:00- :15							
:15- :30							
:30- :45							
:45- :00							

Weather Recorder

Remarks

Form Number 3

Sheet No.________________

______(NAME OF ORGANIZATION)______

ORIGIN AND DESTINATION OF TRAFFIC

Road______________________ Location of Station______________________

Direction of traffic______________ Date______________ Day______________

Hour	Car	Truck	Origin		Destination	
			Description	Zone	Description	Zone

Weather______________________ Recorder______________________

Form Number 4

This change, without doubt, has been brought about mainly through the general adoption of closed cars, which make it possible to ride comfortably in stormy weather No doubt, too, the better attention given to our roads, particularly the removal of snow, has helped to increase the use of road during bad weather

Another set of data illustrating the relative use made of roads during fair and stormy days was collected at a given point on the Baltimore-Washington road near the University of Maryland Traffic was counted on a stormy day for a period of one hour Suppose this happened to be on a Wednesday Then the next fair Wednesday, at the same hour, traffic would be counted again at the same point. Seven such comparisons were made on different days during March and April, 1929. The ratio of rainy weather to good weather traffic varied from a minimum of 67 per cent to a maximum of 111 per cent; in the latter case it happened that the hour counted for the rainy weather was in excess of that of a similar count of the fair weather traffic The average, however, was 87 per cent.

With the continued improvement of vehicles and road surfaces, it may be expected that the difference between the use of our roads in good and in bad weather will continue to decrease, and that highway departments are amply justified in employing every practical means for the improvement of road surfaces during bad weather.

DISCUSSION

ON

THE REPORT OF THE COMMITTEE ON HIGHWAY TRAFFIC ANALYSIS

WILLIAM H. CONNELL, *Executive Director, Regional Planning Federation of the Philadelphia Tri-State District* Before entering into a discussion of highway traffic analysis, I want to compliment the committee on what I consider an exceptionally good and comprehensive report on a very important subject. Instead of discussing the recommendations in the report, and the subject matter in detail, I will confine my remarks to pertinent observations relative to the subject. I will also submit for your information a discussion of a very interesting Origin and Destination Traffic Survey made by the Regional Planning Federation of the Philadelphia Tri-State District in June, 1929.

There has been considerable discussion relative to the advisability of having traffic engineers in charge of traffic divisions in all communities and cities where the problem is of sufficient importance, and in all state highway departments. To my mind this suggestion does not go quite far enough A traffic division is important but there should also be a planning division working in conjunction with the traffic engineer, because highway traffic is naturally the most important consideration in connection with street and highway planning Regulations designed to best serve the traffic on city and rural highways are very often simply a temporary expedient best suited for existing conditions, knowing that the proper solution can only be brought about through changes in the existing street or highway system This is pretty generally the case, particularly in the older sections of built-up communities as the street systems were not laid out for present day traffic So the present traffic regulations and the proposed changes in the street systems to improve conditions are so closely inter-related that their functions should be closely allied if not included in the same division

There can be no solution of the traffic problem without it being the result in a very large measure, of comprehensive planning for the future, which includes provisions for belt line highways, grade separations, widening and extension of street systems, underground sidewalks, bridge approaches, arcading, consideration of zoning provisions, etc The problem, therefore, is primarily one of planning in general, of which highways and street systems constitute the backbone

The enforcement, however, of traffic regulations is naturally a proper function of the police There should, of course, be the closest cooperation between the traffic and planning divisions, and the enforcement division

HIGHWAY GRADE CROSSING SEPARATIONS

Highway grade separations are most important, and have not been considered seriously enough in the past Very often separating the grades where two main highways intersect will more than double the traffic capacity of the highways

Cook County, Illinois About a year ago, the Cook County, Illinois, Commissioners appointed a Cook County Grade Crossing Advisory Committee, and a program of highway grade crossing separations has been recommended involving 30 highway grade separations and 8 combined highway and railway grade separations The commission made the statement that the intersections of important highways are the determining factors governing the rapidity of the movement of the traffic on those highways

Bronx and Westchester County. An outstanding illustration of a highway system without grade crossings is that of the Bronx and Westchester County Park Commissions of New York This highway system, when finished, will consist of 163½ miles of parkway. Thirty-six miles of these are now completed and 20 miles additional are under construction, the greater part of which will be completed by the end of 1931 This highway system is without grade crossings As a matter of fact, with so many heavy traffic highways crossing, it would be practically impossible to carry the traffic that these highways are called upon to accommodate if the grades of intersecting highways were not separated

New Jersey Studies were made in New Jersey to determine upon the economics of proposed highway grade separations, and the published reports show that the separations greatly increase the traffic capacity Grade separations will often make it unnecessary to widen existing highways or build parallel routes to accommodate the traffic and for a far less cost New Jersey has already provided for several grade separations and has planned for several more where heavy trffic routes intersect.

Philadelphia Tri-State District There are many instances in the Philadelphia Tri-State District where grade separations at intersections of very heavily traveled highways are the only solution of the problem The importance of grade separations cannot be too forcibly emphasized as they are not only essential from the standpoint of increasing the traffic capacity of the highways, but will also result in greatly decreasing the highway accidents.

PARKING

Consideration should be given to the elimination of parking on through state highways in peak hours and on Sundays and holidays This will increase the traffic capacity over 25 per cent at least.

TRAFFIC LANE MARKING

The Report states: "On rural roads it is probable that lane marking will be valuable at intersections or in semi-congested conditions. In general, however, the committee believes it is unnecessary to lane mark four lane highways, and that a slight amount of traffic control and supervision will keep drivers in their proper positions"

It seems to me that traffic lane marking is very important for two reasons Experience has shown that it will increase the traffic capacity of highways, and it will reduce the number of accidents Generally, traffic lanes should be marked at intersections, vertical and horizontal curves, and at sufficient intervals on long tangents, both on two and four lane traffic highways A vigorous campaign should be carried on to eliminate the middle of the road driver, as he is one of the principal causes of accidents A severe penalty calculated to prevent this nuisance should be imposed

UNIFORM SIGNALS AND SIGNS

The need of uniform signals and signs for night as well as day driving should be stressed Night driving particularly has never been given the consideration it should Inadequate signals not only delay traffic but cause accidents.

CITY TRAFFIC PROBLEM

The report has gone extensively into this phase of the traffic problem, has made a number of recommendations and cited a number of examples of traffic conditions There is no cure-all for this problem. The general regulations should be uniform throughout the country, so that strangers will know what to expect, but the details concerning the operation and regulation of the traffic in each city are a problem unto themselves. They depend on the social and economic conditions, the street lay-outs, the location of business and residental sections, and so forth

SIDEWALKS

One consideration to which the report does not call attention is the predominance of pedestrian traffic at a number of the important intersections in the business districts In a survey recently made in Philadelphia by the Mitten Management, it was shown that at certain downtown important intersections, 34 per cent of the people crossed in vehicles and 66 per cent on foot. Of the 34 per cent crossing in vehicles, 2 per cent were in taxis, 24 per cent in private automobiles and 74 per cent in trolley cars The problem in the central business district in Philadelphia is largely pedestrian. Underground sidewalks are suggested as a possible solution.

ORIGIN AND DESTINATION TRAFFIC SURVEY

MADE BY THE REGIONAL PLANNING FEDERATION OF THE PHILADELPHIA TRI-STATE DISTRICT

THE PHILADELPHIA TRI-STATE REGION

The region covers an area of 4,000 square miles, and comprises a group of political sub-divisions, having a population of 3,500,000, so related geographically, physically, economically and socially that they have a common interest in the solution of the inter-related facilities upon which their common welfare depends. The Region embraces parts of three states, sixteen counties and more than 360 political subdivisions It is bounded roughly by New Hope, Pa, and Princeton, N. J., on the north, Wilmington, Del, on the south, Coatesville, Pa, and Pottstown, Pa, on the west, and the New Jersey Pinelands on the east.

The Regional Planning Federation of the Philadelphia Tri-State District, in cooperation with the chief engineering officials of the Region and the Technical Advisory Committee, which consists of the outstanding engineers, architects and landscape architects of the Region, is engaged in preparing a comprehensive plan to provide for the orderly development of all the major physical facilities necessary to the best interests of the social and economic life of the people living in the interdependent communities that compose the region.

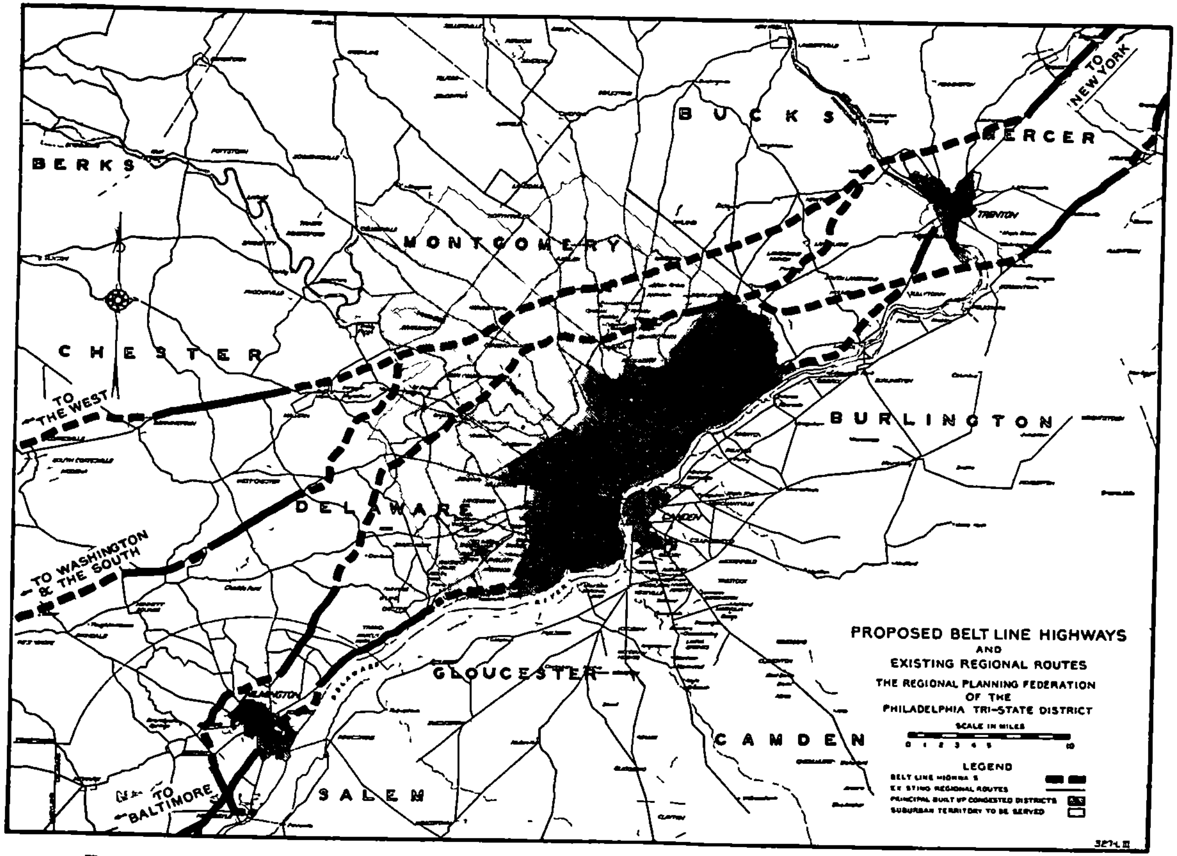
The major physical facilities include highways, railways, airways, ports and waterways, parks, parkways and recreational centers; use of land, and sanitation, drainage and water supply.

An ideal Regional Plan in a more or less built-up and thickly populated area can be accomplished only through the cooperative effort of all its political subdivisions Regional planning is an effort not only to arrest, but to correct so far as possible, haphazard developments resulting from failure to visualize the future needs.

The highways are, of course, the backbone of a Regional Plan.

THE SURVEY AND SOME OF THE RESULTS

The task of preparing a comprehensive plan for the development of the Philadelphia Tri-State District requires a very intimate knowledge of the movement of people in and through this vast region. Basic to any such planning, of course, is the study of existing transportation facilities, population and its distribution and rate of growth, and knowledge concerning the origin and destination of the daily moving



Proposed Routes for Belt Line Highways Around Philadelphia, Trenton and Wilmington to Carry Through Traffic as Well as to Serve Local Suburban Territory Without Going Through Congested Districts population It is necessary to know the facts regarding the causes, the means and the diversity of this movement if the plans that are being formulated are to be founded on something more than the general knowledge and familiarity on the part of individuals with this movement.

Accordingly on Thursday, June 6, 1929, the Regional Planning Federation undertook a comprehensive regional Origin and Destination Traffic Survey of all modes of transportation of regional importance in the Tri-State District in cooperation with the railroads, bus companies, inter-urban electric lines and the highway departments of the three states concerned. Close to a million questionnaire cards were distributed to the traveling public and about half of this number were given to persons using the highways That phase of the survey concerned with highway traffic is presented herewith.

The purpose of the survey was to obtain not only a relative idea of the "from where to where" movement of the people in motor vehicles, but also to show the "how" and "why" of this movement.

The highway questionnaire cards contained nine pertinent questions, briefly as follows:

1. From where
2. To where
3. Kind of vehicle
4. Driver or passenger
5. Number in vehicle
6. Time received
7. Other transportation used
8. Time for trip
9. Purpose

The cards were designed so that a simple checking of items listed would suffice for answers in the majority of cases, and simplify the work of tabulating the results.

The survey was preceded by a very extensive publicity campaign to acquaint the public with its purpose This was carried on through the newspapers, by the distribution of hand-bills, and samples of the cards with instructions as to their use were also widely distributed.

The Highway Survey was made possible by the cooperation of the State Highway patrol in Pennsylvania, the New Jersey and Delaware Highway Departments, the Fairmount Park Commission, the Delaware River Bridge Joint Commission and the several ferry companies These organizations detailed their men to count the traffic and distribute the cards at the 63 locations chosen for the work. These stations were located principally at gateways to large population centers so as to obtain the movement of traffic from suburban areas into business and industrial centers. In addition a few stations were located at important regional cross roads, thus obtaining the data for through traffic as well as that entering the cities of Philadelphia, Camden, Trenton and Wilmington The stations were distributed as follows:

36 in Pennsylvania
6 in Delaware
6 in North New Jersey
9 in South New Jersey
6 at Delaware River Crossings in South Jersey

Cards were distributed between the hours of 6:30 A. M. and 8:30 P. M. to each occupant of every motor vehicle passing a station except where the occupant had previously received a card from another station Only the vehicles traveling inbound towards centers of population were counted and given cards, the feeling being that a one direction story for such a large area would be practically the same as if the survey was made for traffic traveling in both directions. The hours were extended into the evening to obtain an idea of late afternoon and early evening traffic which was generally for purpose of recreation

The survey included the origin and destination of *all* occupants of motor vehicles in order to compare properly the results from the highway survey with those obtained on rail and bus transportation units. Furthermore, it was expected that where several persons were riding in a vehicle both the origin and destination as well as the purpose for the trip might be different To separate the story for the driver of the vehicle as distinguished from the other occupants or passengers, a place was provided on the questionnaire card for the occupant to check as to whether he was driver or passenger in the vehicle The business reply card privilege of the Post Office Department was utilized to obtain the return of the cards distributed at the stations The reverse side of the questionnaire card was printed with the address of the Federation and two cents was paid to the Post Office Department for each card returned.

Somewhat over 200,000 vehicles excluding busses were counted, and the returns on the highway questionnaire cards amounted to about 20 per cent.

The following are some illustrations of the data obtained from this survey; which show the need for the proposed highways shown on page 127.

The analysis indicates that, of the traffic coming from Trenton and north and west of Trenton and the New York region, crossing the Delaware into Pennsylvania on the Lincoln highway at Morrisville

64 per cent was destined for the built-up section of Philadelphia and points between Trenton and Philadelphia.

15 per cent was destined for the immediate suburbs, north and west, of the built-up portion of Philadelphia

7 per cent destined for Wilmington, Del, and points within the region beyond the Philadelphia suburbs.

14 per cent through traffic to more distant points to the south and west.

This analysis shows that 14 per cent may be classed as strictly through traffic to distant points, but 36 per cent would naturally use a by-pass or belt line highway beginning near Trenton and passing Philadelphia on the north and west The Pennsylvania State Highway Department is now making surveys and studies with a view to eventually provide such a highway.

An analysis of the traffic from the west and south also indicates that about the same percentage would naturally use a belt line highway around Philadelphia toward Trenton

The survey, and also a count made by the State Highway Department of New Jersey, indicate that about 50 per cent of the traffic from Philadelphia and points south and west, going north toward Trenton is destined to points beyond Trenton All of this traffic would flow into the belt line highway north and west of Philadelphia, if it also by-passed Trenton to the north and connected with the direct route to the New York region A highway to meet this situation is shown on the map and is under consideration by the Pennsylvania and New Jersey State Highway Departments. Surveys are now being made for the section of this highway which will start at the Lincoln Highway at Philadelphia City Line, cross the Delaware River north of Yardley, and connect with the proposed New Jersey State Highway which will pass Trenton to the north and connect with the New Jersey direct route to New York

An outer belt line highway from New Jersey to Maryland, connecting with routes north and south, is also under consideration and the traffic analysis indicates that it will not be many years before this outer belt line highway will be required to relieve the inner belt line from the strictly through traffic.

The analysis also indicates, as previous traffic studies have, the necessity for the proposed industrial highway from Trenton to Chester and Wilmington, and the early construction of the section between Philadelphia and Wilmington.

An analysis of the traffic over the Philadelphia-Camden Delaware River Bridge and the ferries shows that about 76 per cent constitutes regular daily traffic between the built-up section of Philadelphia and Camden and South Jersey. This analysis is from a count made on Thursday, June 6, 1929, so it does not give the story of the shore traffic which is not well under way until later in the season, and is at its peak on Saturdays, Sundays and holidays. The summer shore holiday traffic, of course, consitutes the greatest portion of the traffic on the Delaware River Bridge. The analysis emphasizes the necessity for belt line highways around all large centers of population, connecting with radial highways to the different business and residental centers to diffuse the traffic.

Through traffic is always considerably greater on Saturdays, Sundays and holidays, and also during the tourist season which starts in July and ends in the early fall. A count, taking this traffic into consideration, would increase the average percentage of the traffic destined to go around Philadelphia to Trenton, and likewise, around Trenton to destinations beyond.

These are just a few illustrations of the results of the survey The Federation now has complete information relative to the origin and destination of the traffic in the region, and of the traffic passing through the region. From this information a comprehensive highway system is being planned, which will enable traffic to go to and from the points of origin and destination by the most direct routes

PROCEDURE IN ANALYZING RETURNS FROM REGIONAL HIGHWAY ORIGIN AND DESTINATION SURVEY

JOHN NOLEN, JR, *Regional Planning Federation of the Philadelphia Tri-State District.* The analysis of the vast amount of information obtained in the survey involved primarily a consideration of the reliability of the data and secondly provision, in tabulating, for applying it in a great variety of ways. There were 41,000 cards returned, for each of which there were, to the nine questions, a possible 150 different answers, not including a multiplicity of combinations of these answers The task was to group, and finally tabulate this information in a simple, concise and usable manner, so as to obtain a complete inventory of returns, and so arranged that any desirable grouping of results could be extracted readily. Throughout every operation and listing, the data had to be related to the per cent return which the original cards represented at each of the 63 points from which they were distributed, for only in this way could a measure of accuracy of the known results be obtained.

An idea of the extent of the analysis may be visualized from a study of a facsimile of the card (Figure 1).

Each Person Will Please Fill Out Only One of These Cards for Each Trip Today

The Regional Planning Federation of the Philadelphia Tri-State District, The New Jersey, Delaware and Pennsylvania Highway Departments Will Appreciate Your Co-operation

1 My trip started from: TRENTON
Name of Suburb Borough or City — If in Philadelphia, check section of city below
1 ☐ Central Spring Garden to South St. 2 ☐ South South of South St 3 ☐ Southwest South of Baltimore Ave 4 ☐ West North of Baltimore Ave
5 ☐ North North of Spring Garden St. 6 ☐ Northwest Chestnut Hill Germantown, Roxborough, etc 7 ☐ Northeast Torresdale, Frankford etc

2. My final destination is:
Name of Suburb, Borough or City — If in Philadelphia, check section of city below
1 ☐ Central Spring Garden to South St. 2 ☐ South South of South St 3 ☐ Southwest South of Baltimore Ave 4 ☒ West North of Baltimore Ave
5 ☐ North North of Spring Garden St. 6 ☐ Northwest Chestnut Hill Germantown Roxborough etc 7 ☐ Northeast Torresdale, Frankford, etc

3. I am riding in a: 1 ☒ Passenger Vehicle 2 ☐ Commercial Vehicle
4. I am 1 ☒ Driver 2 ☐ Passenger

5. Number of persons in this vehicle 2 **6 I received this card at** A M 5 P. M.

7. After leaving this vehicle, my transportation to destination will be
1 ☐ Private Auto 2 ☐ Taxi 3 ☒ Walking 4 ☐ Bus 5 ☐ Trolley 6 ☐ Subway-Elevated 7 ☐ Railroad 8 ☐ Ferry

8. The total time required for my trip from start to destination will be
1 ☐ 1 to 15 min. 2 ☐ 16 to 30 min 3 ☐ 31 to 45 min. 4 ☐ 46 to 60 min 5 ☒ 1 to 1½ hr 6 ☐ Over 1½ hr

9. The main purpose of my trip is
1 ☐ To Daily Work 2 ☐ From Daily Work 3 ☐ Shopping 4 ☐ Education 5 ☐ Recreation 6 ☒ Other Reasons

DEPOSIT IN ANY MAIL BOX—NO STAMP IS NECESSARY

A B C D E F G H K L M

Figure 1.

It will be noted that the card was designed so that a simple checking of items listed would suffice for answers in the majority of cases, and would simplify the work of tabulating the results.

Identification of each card with the station at which it was distributed was made by coding the cards before distribution to the various stations. The letters along the bottom of the card were checked with crayon by warping a handful of cards and marking the letters indicating each station.

This provision made it possible to determine the route of travel between origin and destination and to compute a per cent return for each sation, by comparison of the cards returned with the volume count. If the results of the tabulation of data from each of the 63 stations were to be comparable, one with another, adjustment must be made for the variation in per cent return at different stations. It would not be permissible to combine or compare the origins and destinations indicated at a station for which there was a 10 per cent return with those at a station for which there was say a 20 or 25 per cent return, unless allowances for these variations were first made Furthermore, by multiplying the cards returned by a factor based on the per cent return, it would be possible to obtain a quantitative estimate of traffic between origin and destination

Although over 200,000 vehicles, excluding buses, were counted on the day of survey, calculation has shown there were approximately 170,000 *different* vehicles contacted carrying somewhat over 300,000 persons Due to the fact that some stations were so situated as to cause many vehicles to be counted more than once, the actual per cent return could only be obtained after allowances for this duplication were made. This net return after corrections averaged over 17 per cent, varying generally between 10 and 30 per cent at the different stations. From the occupants of the vehicles there were a total of 41,000 usable cards, 29,000 being from the drivers There was an average of 1.77 persons per vehicle

In order to analyze the origin and destination data of the survey, the region was divided into zones for grouping the origins and destinations indicated on the cards Thirty-three zones were chosen within the region and in order to provide for the listing of traffic coming into or going out of the region, 14 additional outside zones were chosen, which were generally directional in character, but which enclosed important areas like the New York Region, Seashore Resorts and the Baltimore-Washington area This made a total of 47 in all The boundaries of these zones coincided with county lines or subdivisions of them, and enclosed areas of similar function, having a common community of interest By adopting boundaries along political subdivision lines, comparisons can be made between the traffic generated, the population and motor vehicle registration This should make possible the establishment of a law of traffic relationship between zones which can be expressed in terms of population, registration, area and distance.

These zones were next assigned code numbers and all the cards coded for the proper zone of origin and destination Individually each card was then checked for consistency of the information shown upon it, and adjustments made where obviously items had been incorrectly checked, or were not according to standard

For the tabulation of the results, the data on the original survey cards were then transferred, by adoption of code numbers, to Hollerith tabulating machine cards The process of sorting and tabulating this varied mass of information was thus mechanized and shortened, for the Hollerith machines sort cards at the rate of 400 a minute

The tabulated data were entered upon forms, 11 by 17 inches in size, designed specially for the purpose Three major tabulations were made and information taken off in the following sequence:

- I Station
  - A Time Handed Out
    - 1 Occupant (i e Driver or Passenger)
      - a Kind of Vehicle
        - i Number in Vehicle (Drivers' Cards Only)
- II Origin Zone
  - A Destination Zone
    - 1 Station
      - a Occupant
        - i Kind of Vehicle
        - ii Purpose
- III Station
  - A Destination Zone
    - 1 Occupant
      - a Facility to Destination

After tabulation, it was necessary to prorate a small percentage of the minor data that were unchecked on the original cards. This was done in accordance with ratios shown for the checked items Additional adjustments were also made, principally for trips indicated in the "reverse direction by error," than that in which the survey was taken.

Out of a possible 47 by 47, or 2209 origin and destination combinations, there were 1302 for which the survey showed movement of people Out of these there were only 277 or 21 per cent for which the returns indicated only one person moving between zones. The complexity and magnitude of the regional movement can thus be imagined.

The practical application of the results of the survey depends on what is to be proved. General tendencies can be worked out from the tabulated results of the actual cards returned, but for a true comparison of traffic between zones, the final adjustment for the variation in per cent return at different stations is necessary. This then provides a basis for establishing quantitative estimates of the origin-destination composition of traffic at any point. It is to be noted that, while the number of returns indicating trips between certain zones may be small, the outstanding fact is that a combination of many small and different trips together establishes a large and definite relationship at any one point between the groups of zones on either side These relationships can then be expressed most forcibly in terms of percentage.

With the data analyzed and tabulated as described above, they can be expended to almost any degree, or adapted to a variety of uses When the analysis is finally completed the survey will have supplied in addition to origin and destination relationships, basic data on the purposes for which motor vehicles are used, and the time spent in making trips, the relation between home and work, and finally the importance of coordinating all other transportation facilities with the highway system.

While the work of analyzing the results from such a survey has a diversity of difficulties, perhaps the most important consideration is to organize most carefully and completely the task of actually making the survey Properly executed, the results will be exceedingly worth while, and lend themselves readily to systematic analysis

MR V. R BURTON, *Deputy Highway Commissioner, Michigan.* I was very much impressed in the uniformity of the traffic which Dean Johnson has shown on the charts They show a condition comparable to that which we have in Michigan in our heavy industrialized areas, but not at all typical of what we have in our agricultural and resort regions. In the resort regions variation is very great They have a very sparse population and a very high number of vehicles during July and August. During the winter time, because of the small population—only the main roads being open—the traffic may amount to only 20 to 25 per cent of the average yearly traffic During July and August that traffic commonly runs from 300 to 400 per cent of the average yearly traffic. The average traffic as determined in Michigan is made up of traffic counts taken in four traffic quarters and these traffic quarters were determined by the flow of funds from the gas taxes. We know exactly what the medium month in each of the traffic quarters is and the counts are taken in that medium month A good many of the traffic counts taken have been very misleading because they did not represent the average throughout the entire year, and where the traffic is so variable, if you want an accurate average it is necessary to carry on the traffic count throughout the year That is one of the reasons why our general traffic averages show very much less traffic than some taken in a number of other states whose counts extend only through the summer season In the industrial areas our counts show very much the same variation that Dean Johnson's do In the agricultural areas there is not as wide a difference as there is in the resort areas. This is something with which we must concern ourselves very much in the design of our highways We feel that the order of improvement should be determined by the average traffic and that the design must be determined by the peak traffic, and if we are to determine the proper order of improvement and adequate design, it is very necessary that our traffic counts be taken in a great deal of detail and studied with much care

MR CARL F MEYER, *Worcester Polytechnic Institute.* I would like to say something about signals, especially signalizing of intersections, and with particular reference to Massachusetts. Traffic control is a very pressing matter in this state We are forty-fifth among the 48 states in mileage of state highways, twelfth in volume of registration, and first in the number of cars per mile of highway Massachusetts has just made a pioneer attempt at a uniform system of signalizing intersections.

By legislative action electric traffic control signals in Massachusetts either in cities or towns or on state and county highways in rural districts can only be erected on state highways by written approval of the Department of Public Works, and only at intersections and only used during the time of day, when traffic volume warrants There have been many signals erected by counties and towns without regard to uniformity and often without regard to traffic volume Signals have not served to expedite traffic They have often retarded it. The department specifies the minimum traffic requirements for signalizing an intersection, these figures being a total of at least 500 vehicles per hour with at least 125 per hour on the cross streets Even though the total traffic is considerably in excess of 500 vehicles per hour, the signal is not considered warranted unless the cross street has a traffic of at least 125 These are minimum requirements and are not to be interpreted as necessitating signal control However, if the pedestrian traffic on the cross street is of sufficient volume the signal may be allowed even though vehicular traffic volume is much less than 125 per hour.

The department has made a survey of the types of signals in use in the state, and has attempted to specify the type and the location of the signal which according to the present state of our knowledge, will conform with good engineering principles, at the least expense for changing the existing signals The principal features in addition to the traffic requirements have to do with location and type All signals installed in the state from now on, as the result of definite traffic counts, must be of the three lens vertical type with four signals, one at each of the far right hand corners. The locations of the lenses are also definitely fixed The red lens must be at the top with the yellow and green in that order, vertically The lenses must be separately illuminated and with a bulb of at least 60 watts to furnish the necessary illumination The clear height from the road to the signal is a function of the distance between the stop line on the near side of the intersection and the signal on the far side, and that varies from eight to sixteen feet in the specifications No turns of any kind are allowed when the red light is shown unless a green arrow lens pointing left or right is illuminated at the same time. This lens is allowed only when the streets are wide enough to allow separate lanes for such turning traffic It is recommended that no attempt be made to synchronize signals at intersections spaced more than 200 feet apart.

I have just jotted down these points, and I am sure that any of the contact men or others who wish to acquaint themselves with the details of this system can secure Traffic Bulletin No 2 by writing the Department of Public Works in Boston Massachusetts

PROFESSOR R. L MORRISON, *University of Michigan* As was brought out this morning, all of us know that, in general, the same people pay for building the roads and operating them If the value of vehicle time is assumed to be $3 00 per hour, and if every one of our motor vehicles, 25,000,000 of them, is delayed three minutes a day due to congestion from lack of grade separations, or other causes, the total cost per year is nearly $1,400,000,000.

PROFESSOR W. E LAY, *University of Michigan.* I would like to see some kind of regulation of the green and red advertising signs They are often about the same height as the traffic control signals, and contribute greatly the difficulties for the average driver.

CHAIRMAN MATTIMORE. We gave that suggestion on the law, in Pennsylvania especially on the gas station that have the red blinkers.