Directional Channelization Design

W. R. BELLIS, Chief, Bureau Traffic and Safety Research,
New Jersey State Highway Department

IN January of 1950, the New Jersey State Highway Department reconstructed the intersection of Routes 1 and 25 (Communipaw Avenue) in Jersey City by a unique design which, although it did not use a bridge, proved to serve traffic as well as could have been done with a cloverleaf design. The design includes separate direct roadways short-cutting the center of the intersection. Traffic at the points of crossing is controlled by traffic signals. The locations of the points of cross traffic are designed for normal travel time between points and the best traffic signal synchronization. The number of lanes at each signal is a function of the traffic volume to be served and the signal capacity per lane.

As demonstrated by four intersections constructed by the New Jersey State Highway Department, an entirely new field has been opened to the designer. It is the purpose of this paper to submit proven evidence of the new design technics, to illustrate traffic behavior suggesting more advanced application and to present untested but probable ultimate designs.

The existing intersections do not express freedom of design. They were limited severely by restrictive right-of-way costs and the revisions were adopted as measures to improve existing conditions. Nevertheless, there are design features which are taken advantage of by a few drivers, thereby, increasing the efficiency of the intersection. If these features are refined so that all drivers can use them, the efficiency is increased still more.

A study of these features and accompanying traffic behavior suggests an ultimate design, without the use of bridges, which would permit the free flow of all streams of traffic without the need for stopping and without the need for deviating from reasonable, normal vehicle speed.

● DIRECTIONAL channelization is that at-grade-intersection design which provides for all traffic movements being made without deviating from a normal short-cut path and in which separate roadways (or channels) are provided for turning movements in order to localize the points of conflict between cross movements. At a four-point intersection there are twelve basic traffic movements and sixteen basic cross movements of traffic. Figure 1 shows these movements and conflicts. In this figure all movements are shown directionally.

All of these movements and crossings must be made at any four-point intersection, but the manner of crossing is different for each type of design.

At simple intersections at grade, all of these crossings are made within a small area which has no more capacity than one of the roads with no turning movements. The capacity of the intersection can be increased by pavement widening adjacent to the intersection and easing the turning radius for right turns. However, the capacity for left turns is not improved.

At traffic circles the crossings are made by first merging the movements and then separating the movements. That is, the crossings are made by cross weaving with the crossing vehicles traveling in the same direction. Although the capacity of a traffic circle is no greater than the capacity of a simple intersection having the same approach widths, it can handle larger volumes without the aid of traffic signals. Volumes in excess of the capacity of a traffic circle can be passed through a simple intersection at grade with traffic signals.

At grade separations of the cloverleaf type, the straight-through movements are separated by a bridge, but each left turn must cross weave with two of the other

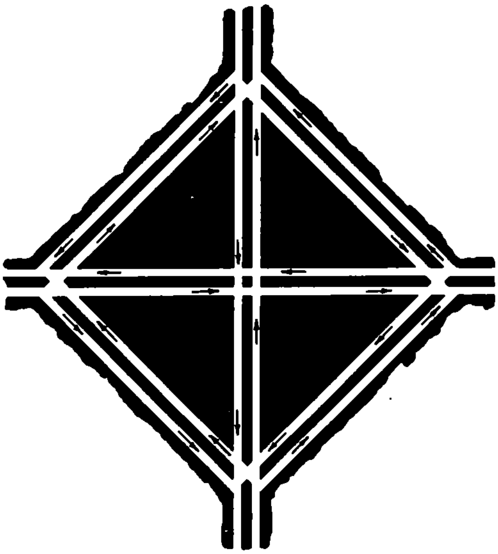


Figure 1.

left turns, in addition to traveling a long, indirect path. The traffic demand at existing well-designed cloverleafs has exceeded the capacity where heavy left turns occur.

At a directional interchange all crossing movements are separated by bridges. Except for three-point intersections, complete directional interchanges have not been used. The four-level interchange in California is sometimes referred to as a complete directional interchange, but this is not completely directional in that the left-turning movements leave the main roadway on the right. The capacity of a true directional interchange is unlimited, it merely being necessary to increase the number of lanes to provide for greater capacity.

The absolute capacity of a four-point traffic circle with equal traffic on all approach roads and even distribution for right turns, left turns, and straight through is reached when the total traffic using the intersection is 6,600 cars per hour. Volumes of this magnitude have been approached at existing circles. The absolute capacity of a cloverleaf for the same conditions is reached at 13,200 cars per hour. This volume has not been approached in actual practice, although the traffic demand on one part of the cloverleaf has exceeded the capacity. Cloverleafs have not been designed up to their full capacity, probably because the cost would then be greater than a directional interchange or a special grade separation with directional interchange principles used in part of the intersection.

The capacity of directional channelization in its ultimate development, like directional interchange, is unlimited, and this design could eliminate the need for stopping any vehicles, even though there are no bridges provided. Despite these possibilities, highway designers have been guilty of shunning the use of channelization and traffic signals. Since it appeared that the grade-separation principle was the pinnacle of intersection design, efforts were concentrated on exploring the possibilities of applying bridges and ramps or interchange connections. Traffic engineers have used traffic-signal control and channelization as measures to increase capacity of existing intersections, mostly as simple alterations within existing right-of-way or curb lines. As a result of this restrictive application, there has been some misuse of both traffic signals and channelization, resulting in an accelerating general dislike for both. Actually, the use of traffic signals and channelization provides a great opportunity for the economical solution of many traffic problems, provided that joint use is made of design and traffic engineering. A good designer must also be a good traffic engineer and vice versa.

Despite the tendency to consider traffic signals and channelization as a low type of intersection design, sufficient applications have been provided to allow observations of traffic behavior and an analysis of such design in a manner suitable for reliable comparison with other forms of intersection design.

The New Jersey State Highway Department has used a combination of channelization and traffic signal control at four major intersections where traffic volumes were far in excess of the capacity

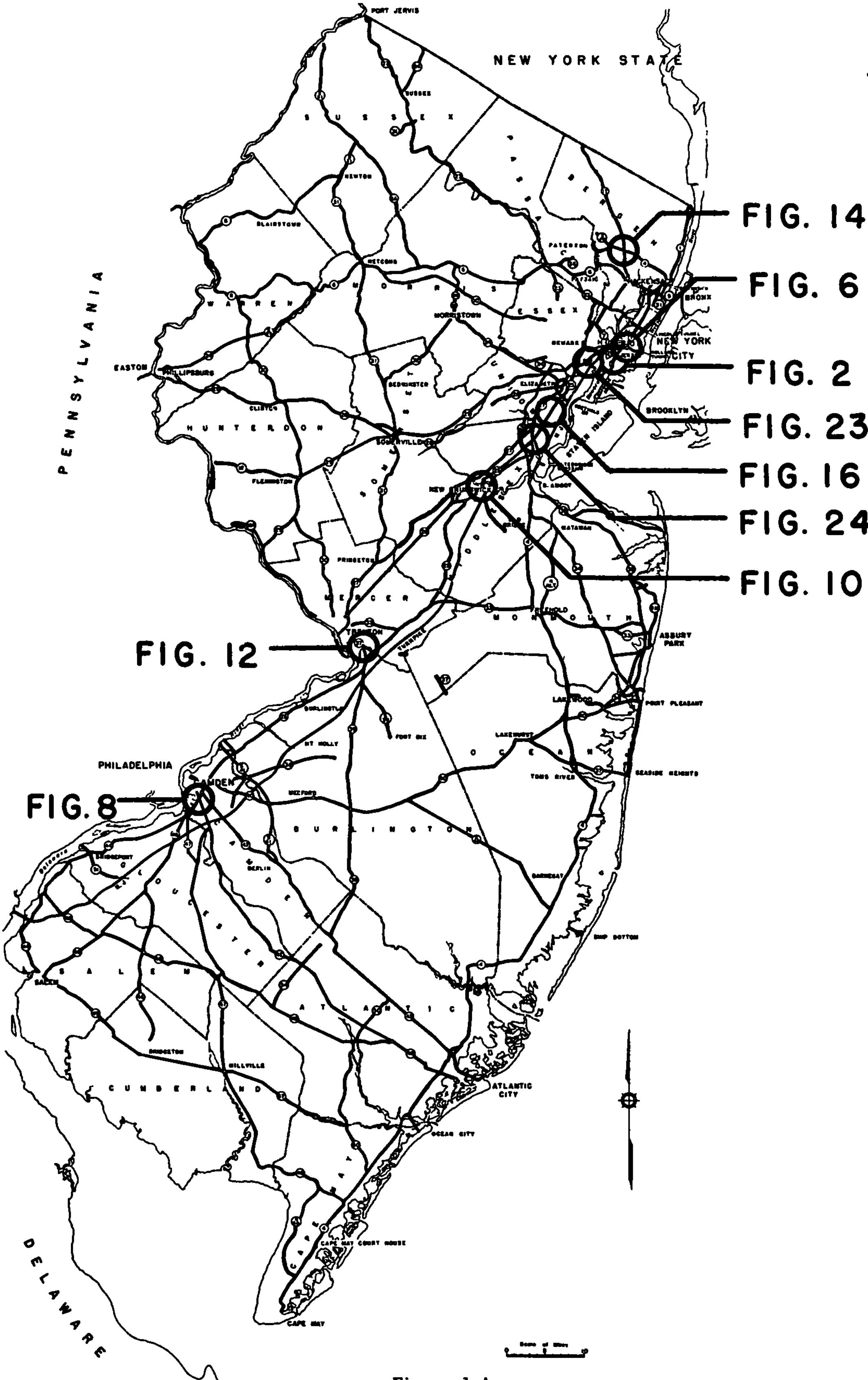

PORT JERVIS
NEW YORK STATE
PENNSYLVANIA
DELAWARE
FIG. 14
FIG. 6
FIG. 2
FIG. 23
FIG. 16
FIG. 24
FIG. 10
FIG. 12
FIG. 8
BRONX
NEW YORK CITY
BROOKLYN
STATEN ISLAND
PATERSON
NEWARK
ELIZABETH
MORRISTOWN
SOMERVILLE
NEW BRUNSWICK
PRINCETON
TRENTON
FLEMINGTON
PHILLIPSBURG
EASTON
NEWTON
BLAIRSTOWN
MATAWAN
ASBURY PARK
POINT PLEASANT
LAKEWOOD
TOMS RIVER
SEAWIDE HEIGHTS
BARNEGAT
SHIP BOTTOM
ATLANTIC CITY
OCEAN CITY
CAPE MAY COURT HOUSE
CAPE MAY
PHILADELPHIA
CAMDEN
BURLINGTON
MT HOLLY
FORT DIX
BERLIN
BRIDGEPORT
SALEM
BRIDGETON
MILLVILLE
SUSSEX
PASSAIC
BERGEN
MORRIS
ESSEX
WARREN
HUNTERDON
SOMERSET
MIDDLESEX
MERCER
MONMOUTH
OCEAN
GLOUCESTER
CAMDEN
ATLANTIC
SALEM
CUMBERLAND
CAPE MAY

Figure 1-A.

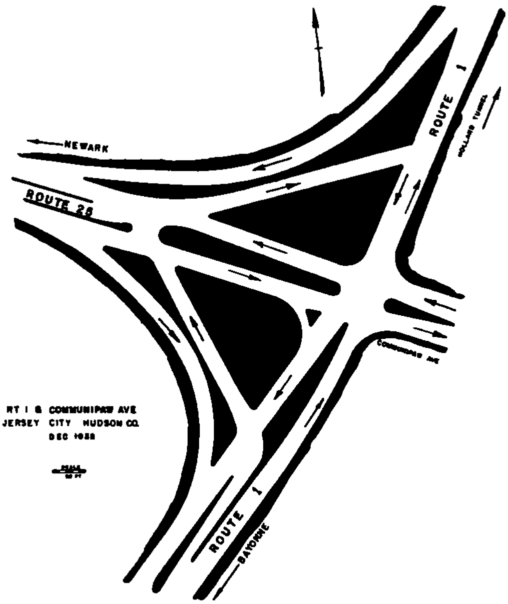


Figure 2.

of the then-existing intersection and where, at each location, it had been planned to construct a grade separation to overcome the congestion. The average saving was more than $1,000,000 per

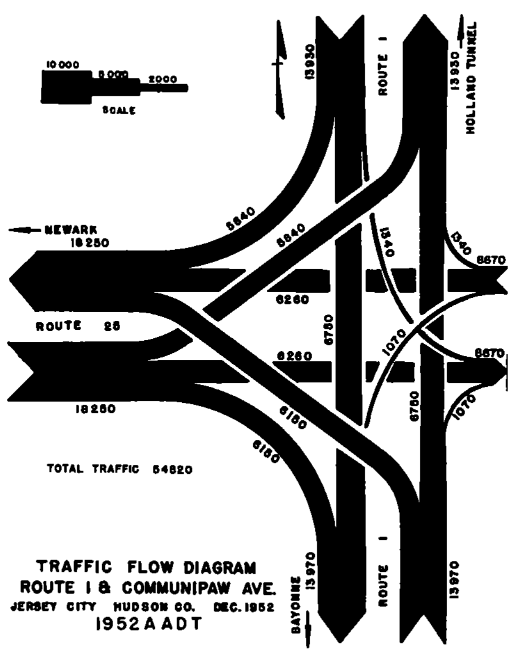
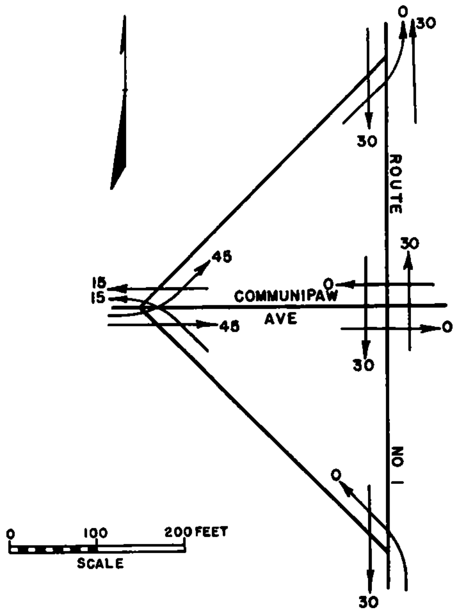


Figure 3.

intersection. These intersections, plus a fifth which does not utilize traffic signals, are shown in the illustrations. None of these intersections provide complete directional channelization, but all do illustrate practical applications of the principle.

Figure 2 shows the intersection of Routes 1 and 25, Communipaw Avenue, in Jersey City. This intersection has been



BASIC TIMING DIAGRAM FOR TRAFFIC SIGNALS
ROUTE 1 & COMMUNIPAW AVENUE
JERSEY CITY DEC 1952

NOTE:- NUMBERS ARE TRAFFIC SIGNAL OFFSETS FOR MOVEMENTS INDICATED BY ARROWS MEASURED FROM BEGINNING OF GREEN

SIGNAL TIMING IN SECONDS

GREEN	AMBER	RED	CYCLE
27	3	30	60

Figure 4.

in use since January 1950, and was described in a previous report. At this location there are two very-heavy left-turning movements, so directional channelization has been provided in two quadrants.

It is readily seen that the intersection shown in Figure 2 could be modified to provide diagonal roadways in the other two quadrants to further increase the efficiency of the intersection. It would then be the type as illustrated in Figure 1. Expensive gas stations occupy the two quadrants in question. Figure 3 shows the A. A. D. T. volumes at this location. Note that the left turns in the two undeveloped quadrants are each about 1,000 cars per A. A. D. T., which are not small left-turn volumes, but the other two left turns are over 5,000 vehicles A. A. D. T. Figure 4 shows the existing signal offsets.

At this location the signals are on a 60-sec. cycle with an even distribution of green time for conflicting movements. Numbers 0, 15, 30, and 45 indicate the relative beginning of the green signal

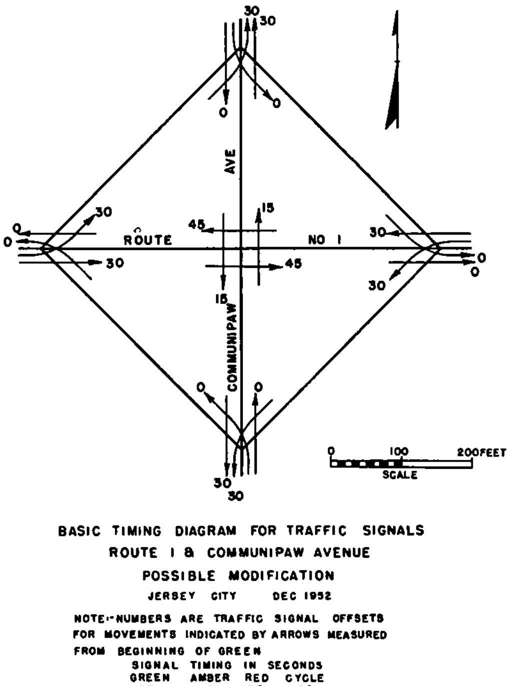


Figure 5.

for the movements illustrated by the arrows at the points of cross traffic indicated. The offsets with the added roadways would be as shown in Figure 5.

Note that progressive offsets are provided for the straight-through movements and simultaneous offsets for the left turns.

At the Communipaw Avenue intersection, nearly all drivers are familiar with the intersection by virtue of repeated use, and there are no high speeds such as experienced in rural areas. High speed here is 40 mph. with 50 mph. rarely experienced on the adjacent roadways.

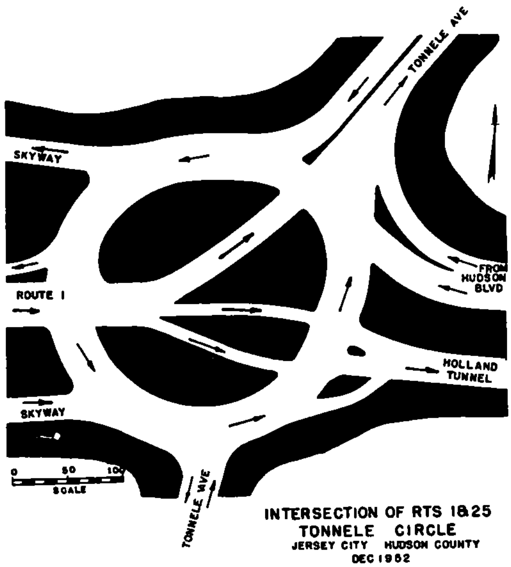


Figure 6.

These two factors, familiarity and reasonably slow speed, tend to make it relatively easy to control traffic with traffic signals. As the speeds become faster, it is more difficult to stop the vehicles, not because of the driver but because of the controlling devices. Drivers will respond to signal control at high speed just as readily as at low speed if the regulatory message is clearly legible.

Lane marking has not been used fully at this intersection, tending to reduce

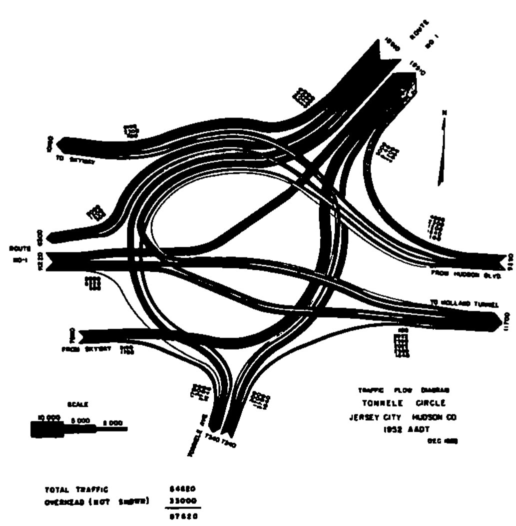


Figure 7.

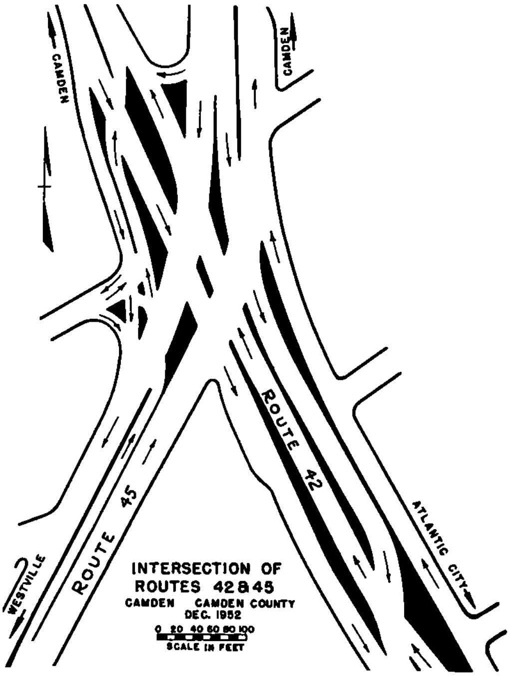


Figure 8.

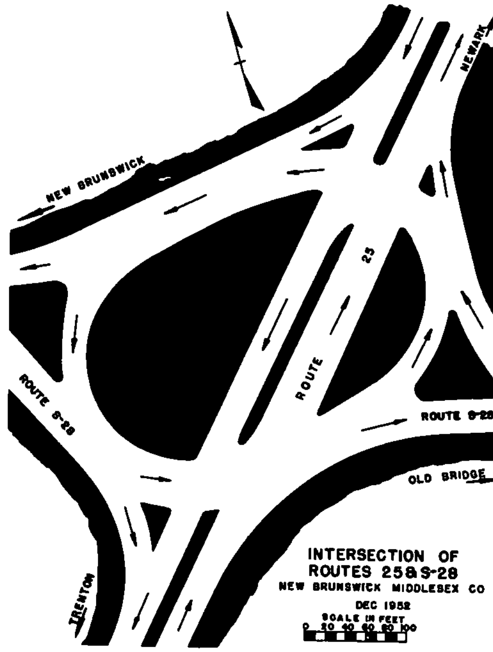


Figure 10.

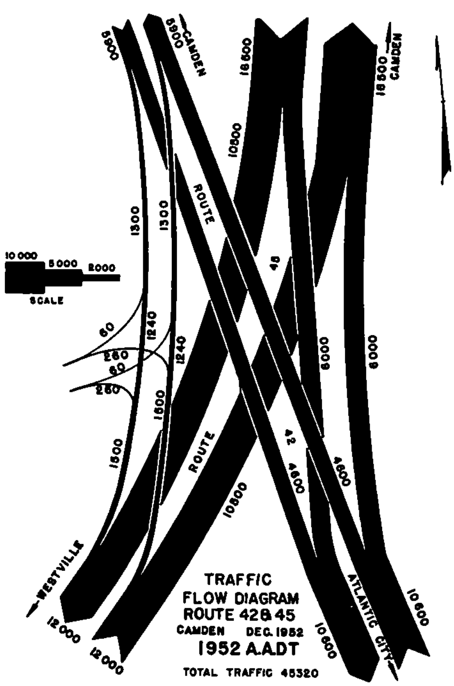


Figure 9.

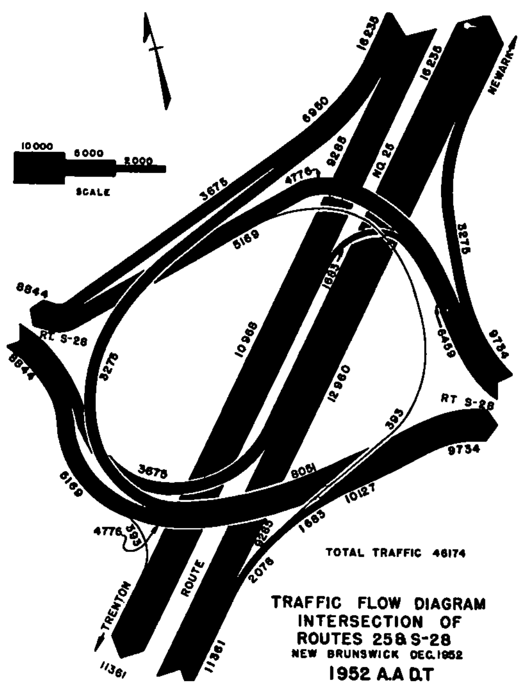


Figure 11.

efficiency. On roadways where two and three lanes in one direction are provided, some drivers overlap lanes and, on curves, cut corners into adjacent lanes. Proper lane marking would reduce this and improve efficiency still more.

Figure 6 shows the Tonnele Circle revision at the intersection of Routes 1 and 25 in Jersey City. This revision proved that channelization with signals, even though there seemed to be many signals, had a much greater capacity than the former traffic circle. It also proved

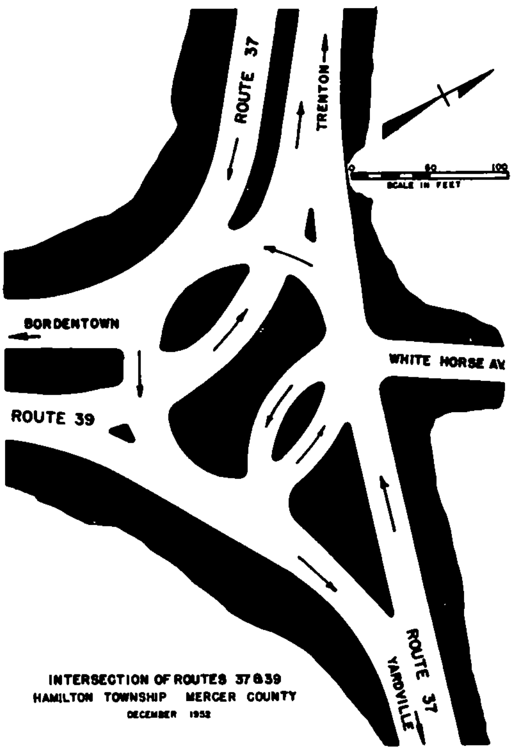


Figure 12.

that traffic-signal timing and coordination and lane requirements could be predetermined and designed to adequately serve the traffic to be expected. Lane marking was used extensively and drivers respect it admirably, even though most of it is on difficult curvature. Illustrated here is the driver's obedience to the stop signal, even at locations where it is desired that he continue. At some locations, because of the compactness of the intersection, drivers see signals that are meant to control other movements. Prop-

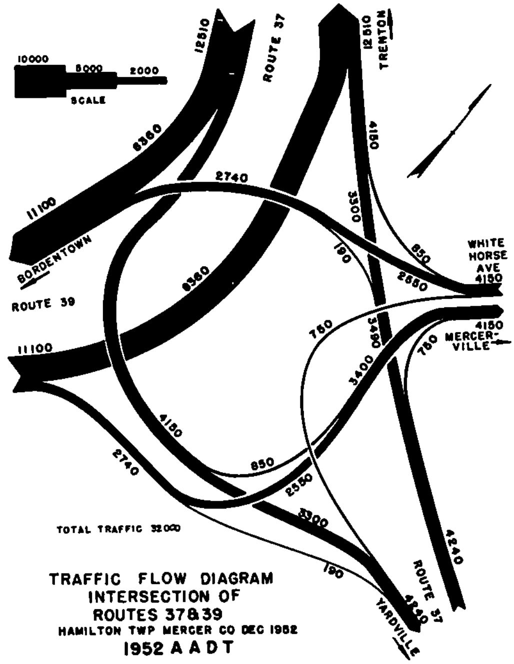


Figure 13.

er shielding has not yet been placed. At this location speeds are also relatively slow. A normal high speed is 30 mph., and 40 mph. is rare on the approach

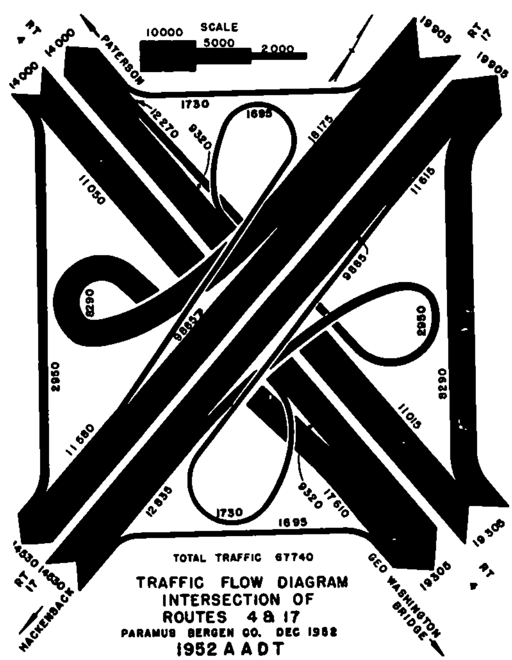


Figure 14.

roads. Most drivers are repeaters, although strangers are not uncommon.

Figure 7 shows the A. A. D. T. volume at this location. Note that the volumes shown do not include the overhead structures.

At the intersection of Routes 42 and 45, in Camden (Fig. 8), further support of the directional-channelization design principle was furnished. Lane marking was used extensively and effectively. Traffic behavior has responded favorably at this intersection, which is admitted to be quite complicated because of the many parallel roadways in a minimum overall width. The speeds are noticeably faster than at the two intersections in Jersey City. Speeds of 40 mph. are common, and 50 mph. can be expected on approach roads and even through the intersection. Higher speeds would be rare, although probably experienced along Route 45.

Figure 9 shows the A. A. D. T. volumes at this location. It should be noted that one left-turn movement is 6,000 cars per day. The plan illustrated provides ample capacity for the left-turn movement, which could not be obtained by conventional designs at grade.

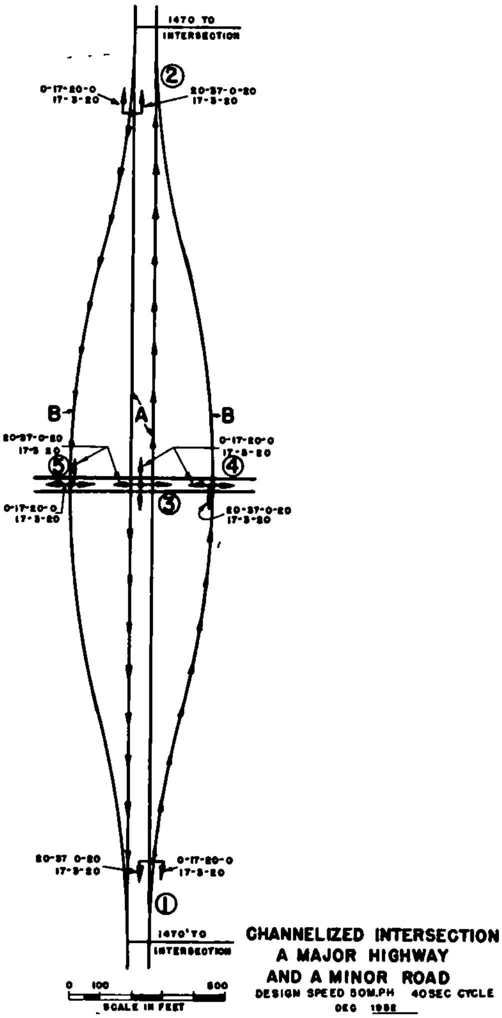


Figure 15.

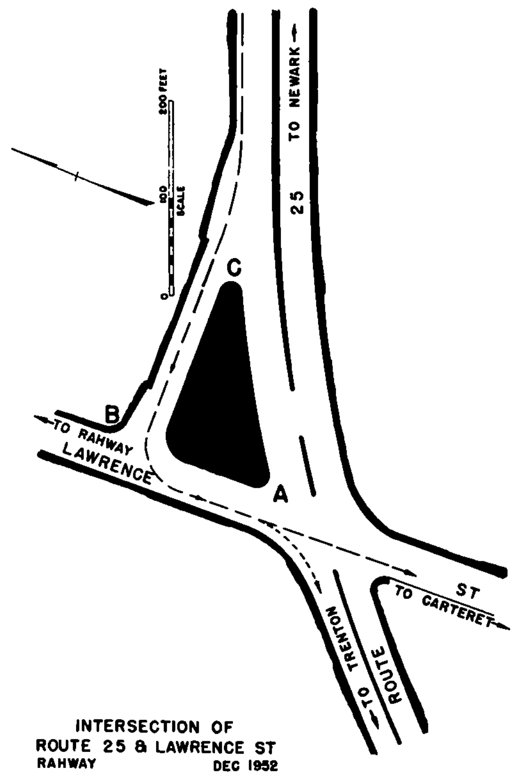
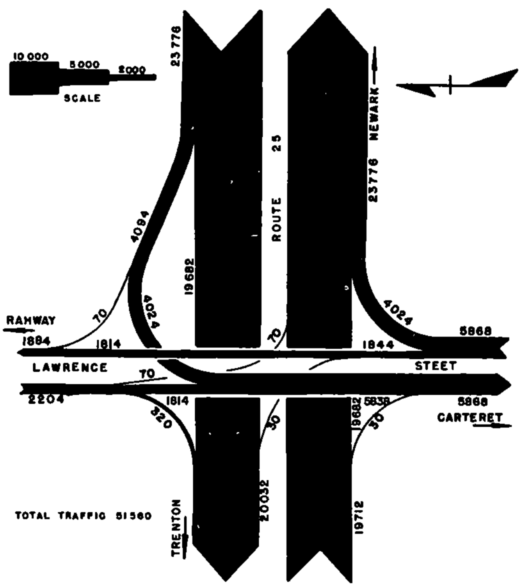


Figure 16.

At the intersection of Routes 25 and S-28 in New Brunswick (Fig. 10) further support has been added for the basic principles of channelization and existing congestion has been removed. The design permits a choice of two routes to go straight through on Route 25. The intended movement is that Route 25 traffic should go straight through, but when the signal is red these drivers can swing to the right on a green arrow, for right turns, and then continue around the circle, bypassing the traffic signals. Many drivers have been observed to take advantage of this opportunity, and if it is practiced during periods of light traffic, there should be no reason to attempt to discourage it; but if it is practiced during peak hours, it may be necessary to alternate the secondary points of crossing by the use of synchronized traffic signals. Observations indicate that about 200 cars per day are using the circle route in place of the straight-through route, compared to 9,000 cars per day using the straight-through route. Figure 11 shows the A. A. D. T. volume at this location.



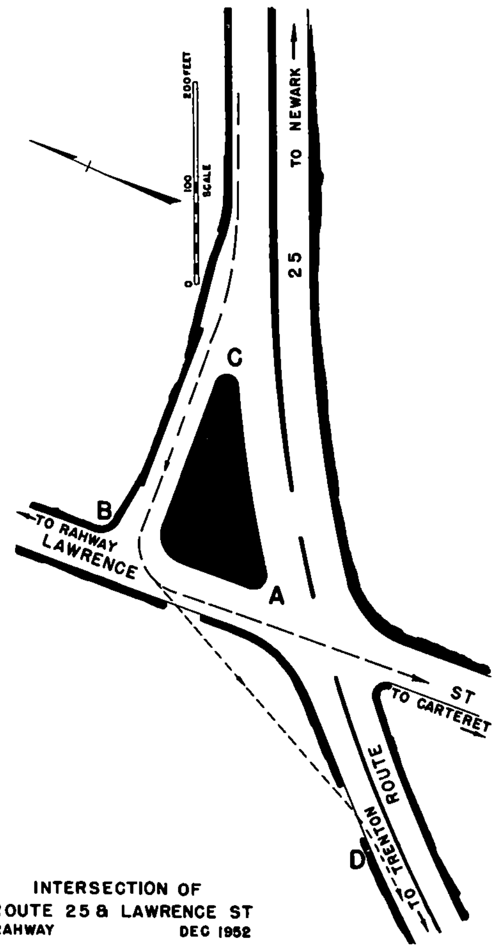
TRAFFIC FLOW DIAGRAM
ROUTE 25 & LAWRENCE ST
RAHWAY UNION COUNTY DEC. 1952
1952 A.A.D.T

Figure 17.

At this intersection it is also possible to use an alternate route around the circle to make either of the left turns from Route S-28 to Route 25. Observations indicate that about 400 cars per day are using the circle route, compared to 1,200 per day using the direct route on one of these left turns.

The speeds for Route 25 straight through are probably higher than for any of the desired channelized intersections mentioned above. Route S-28 speeds are moderate with a normal speed of about 40 mph., while a high speed of 45 is rare in the vicinity of the intersection. On Route 25, speeds of 50 mph. are common, and 60 mph. can be expected occasionally.

Figure 12 shows an application of directional channelization without use of traffic lights. This is at the intersection of Routes 37 and 39 in Hamilton Town-



INTERSECTION OF
ROUTE 25 & LAWRENCE ST
RAHWAY DEC 1952

Figure 18.

ship, near Trenton. At this location, the R. O. W. available limited the size of the basic circle, but an adequate facility was provided by adding separate roadways for two of the left-turn movements. Figure 13 shows the A. A. D. T. volumes.

After completion of the first directional channelization project at the Communipaw Avenue intersection, observations led to

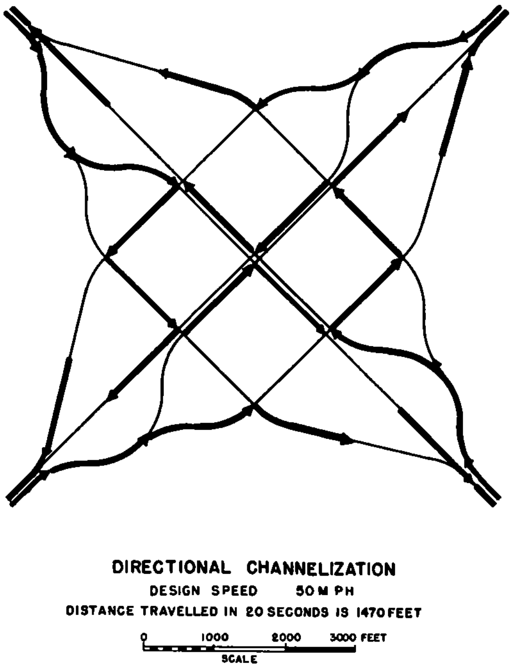


Figure 19.

the conclusion that the directional channelization served traffic better than could have been done by a cloverleaf. To check this conclusion, comparative time studies were made using one quadrant of a heavily traveled cloverleaf at the intersection of Routes 4 and 17 in Paramus (Fig. 14). These studies show that (1) left turns require 13 sec. less time when made directly with signals at the Communipaw Avenue channelization than on the cloverleaf without signals; and (2) for the equal distribution of left turns, right turns, and straight-through volumes, a cloverleaf would be 3 sec. faster per average car than a completed directional-channelized intersection of the Communipaw Avenue type and size. This 3 sec. could be eliminated with further refinements of the directional-channelization principle. Directional channelization, therefore, is a better choice of design than would have been a cloverleaf.

The intersection at Routes 1 and 25, Communipaw Avenue, in Jersey City, and at Routes 42 and 45 in Camden are the two best examples of directional channelization. The one at New Brunswick (Fig. 10) is not directional channelization, because the left turns must first turn right. This type might better be classified as "controlled channelization." It is included here, because it employs the same basic principle used in directional channelization. The basic principle involves the volume of traffic that will use the various parts of the intersection, the traffic distribution per lane and per traffic signal cycle, the capacity per lane per traffic signal timing, the acceleration of vehicles after stopping, the speed of vehicles through the intersection, and the coördination of design to fit these and other traffic behavior factors.

Many of these factors of traffic behavior have been developed into mathematical expressions or applications which are essential to the delicate balance of traffic behavior and design necessary for satisfactory operation. This science of traffic behavior can best be expressed by a coined word "traffodynamics," which would mean that branch of mechanics that treats of forces and laws of traffic. The Tonnele Circle and the New Brunswick Circle revisions are examples of controlled channelization using the technics of traffodynamics. A thorough understanding of traffodynamics is very valuable in a complete treatment of directional channelization, but it will be discussed separately at a later date.

Just as there is a need for coining the word traffodynamics, there is also a need for a better term than directional channelization to include all such especially designed channelizations producing inter-

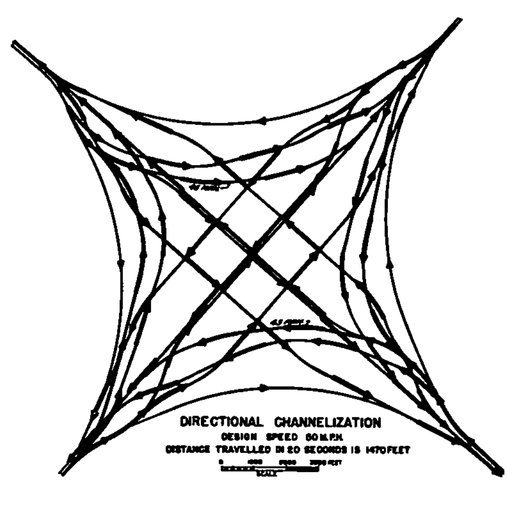


Figure 20.

section types of large traffic-volume capacity without the use of bridges.

Channelization involves the direct crossing at approximately right angles of two streams of traffic, and therefore, the right-of-way at the crossing area must be alternated, generally by the use of traffic signals. The signals must be capable of effectively stopping the moving stream of traffic before the other stream enters the crossing area. This is difficult to do on high-speed roads with the traffic signals that are used as standard today. Nevertheless, with amber signals before the red signals, with the use of all red periods and good coordination at adjacent signals, good results are produced. Probably a strong influence contributing to the reluctance to use traffic-signal control on high-speed roads is the inadequacy of the type signal. There is a need for a more positive signal before directional channelization can be fully applied.

The projects so far completed do not, by any means, indicate the full possibilities in the principle of directional channelization. It is a field where the designer can have wide opportunities for imagination. Figure 15 illustrates a treatment of a major and minor road in which the straight-through traffic on the major highway is never required to stop but, instead, alternates in using Roads A and B. When highway traffic is using Road A, the highway has a green traffic signal along Road A at Points 1, 2, and 3. The minor road has a red signal at Point 3 and a green signal at Points 4 and 5. The highway traffic is kept off Road B by red traffic signals at Points 1 and 2. Red signals also face Road B traffic at Points 4 and 5. If a vehicle approaches on the minor road, it will have a green light at 4 and 5 but a red light at 3. By the use of traffic-actuated detectors at Points 4 and 5, the signals at 1 and 2 are changed to red for Road A and green for Road B. Traffic on the minor road must stop at Point 3, and after sufficient time has elapsed for traffic to clear out of Road A, the minor road will receive a green light at Point 3 and Road A will get a red signal at Point 3. Before the first car from Point 1 or 2 arrives at Points 4 or 5, the signals at 4 and 5 change to red for the minor road and green for Road B. Vehicles on the minor road move from Point 3 to 4 or 5 and wait for the signal system to go back to the original phase. The distance between Points 3 and 4 or 3 and 5 is dependent on the frequency of vehicles on the minor road. A distance of 100 ft. available for storage would satisfy a minor road having an average daily volume of 2,000 if two lanes in each direction were available in the storage area. The distances

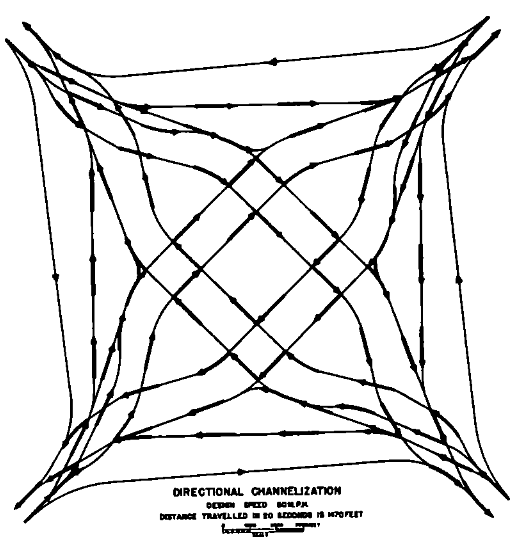


Figure 21.

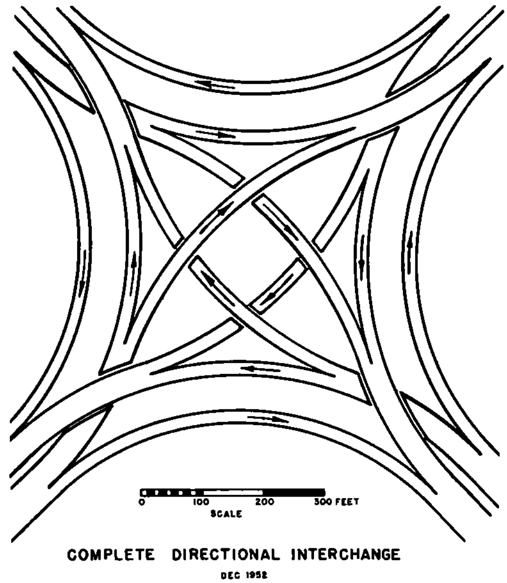


Figure 22.

from 1 to 3 and 3 to 2 are such that the alignment on the B roads will satisfy curvature standards for the design speed.

The success of this type of design depends upon, in addition to the effectiveness of traffic signals, the ability of drivers to make the switch from Road A to B, and vice versa, when so directed by the signals. Observations of traffic behavior indicates that drivers will respond to this type of control. Where the opportunity exists, some drivers can be observed making this movement, even under relatively difficult conditions.

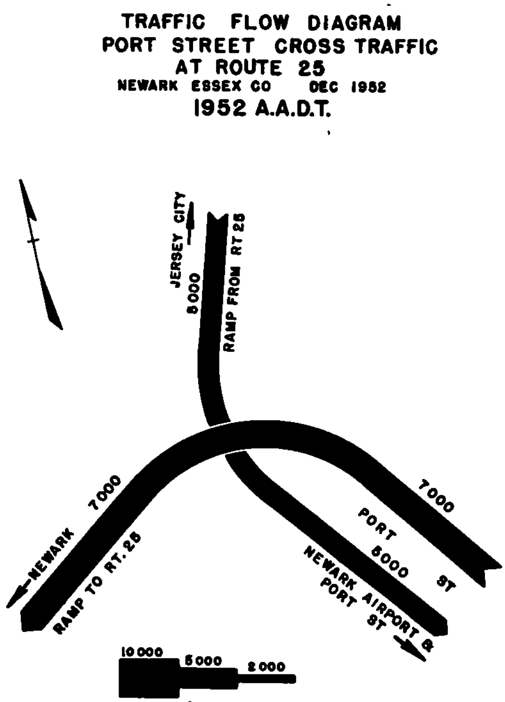


Figure 23.

At the intersection of Route 25 and Lawrence Street in Rahway (Fig. 16), this maneuver has been observed since about 1939. As recounted previously, a similar movement is now found at the New Brunswick Intersection of Routes 25 and S-28. It is quite certain that the movement occurs at many other locations, but the Lawrence Street example can be readily related to design.

Traffic signals control the intersection proper, A, with no signals used at Point B or Point C. The left turn coming from the direction of C is very heavy. Because of this, the one-way roadway from C to B was built in 1930. Left turns at A are prohibited and the heavy left-turn movement is directed to B by signs.

When the amber signal appears, which is 5 sec. long, to be followed by the red signal, vehicles which intend to go straight through on Route 25 can often be observed to swing right, as though to make a left turn, but when arriving at A they turn right. In this way they continue beyond A, whereas other vehicles, which a few seconds before were in front, are now behind, waiting at the traffic signal. This

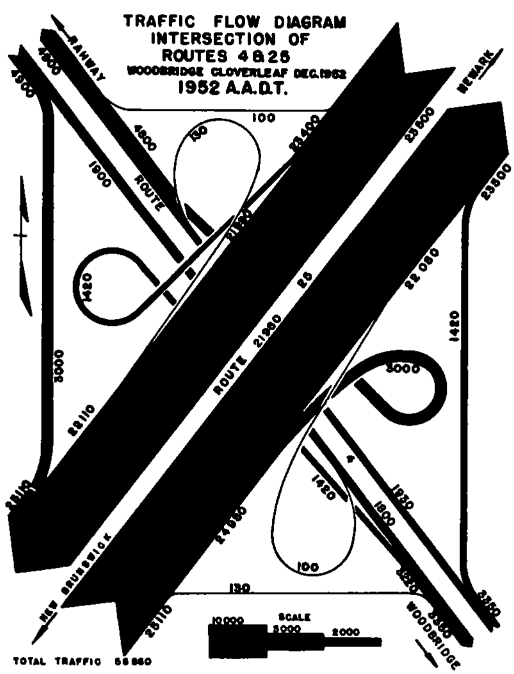


Figure 24.

maneuver depends on quick thinking on the part of the driver. He must be close to Point C but not beyond as the amber first appears. He must be able to do it smoothly, and he must be sure that there are not many vehicles already waiting to complete the left turn, or otherwise he will be caught with a red signal on Lawrence Street, in which case he will lose more time than if he had stayed on Route 25. Through traffic on Lawrence Street is small (Fig. 17) but the Route 25 through traffic is very heavy, so it is essential to separate the left turn.

During the course of these basic observations, the local police erected a sign reading "No Right Turn" in an effort to stop the maneuver, which they claimed was beating the light or evading the intended regulation. The sign was removed after a couple of weeks.

From an engineering viewpoint, one cannot help but imagine what would happen if this maneuver were made physically more inviting, especially since at Lawrence Street there is only an open field where such an improvement would be made.

Figure 18 shows a roadway from B to D, which would make this movement much easier and would not inconvenience any other movement. Traffic signals at B would then be advisable. A further development of this design principle produces the design previously shown in Figure 15, and a still further development produces Figure 19, which will serve an intersection having large straight-through movements and small turning movements. The spacing between points of cross traffic is equal to the distance traveled during the length of a green-signal period.

A still further development of this design principle, which provides for all movements in such a manner that no vehicle needs to stop or slow up below its normal speed, is shown in Figure 20.

Another design providing for all movements without any loss of time is Figure 21.

The capacity of these designs is unlimited. The greater the volume the more the number of lanes needed. Further expansion would involve merely the adding of lanes by widening the roadways. Roadways with 50 lanes in each direction would be no more complicated than roadways with five lanes in each direction.

This type of intersection surpasses all other types, except the complete directional interchange, in capacity and time savings (see Fig. 22). A complete directional interchange has never been built for a four-point intersection, and it is quite probable that a complete directional-channelized intersection may never be built within the lifetime of present-day engineers, but many variations of the basic design principles will be provided. If the ultimate design is clearly understood, better results will be obtained from partial or intermediate designs; and if the intermediate designs are mastered, the problem of the ultimate design becomes simpler.

The capability of designs, such as illustrated in Figures 20 and 21, to serve satisfactorily depends on the designer's ability to pattern the channelized roadways and controls in accordance with natural or normal driver behavior and the ability of drivers to behave or react in accordance with the established design and controls. Existing intersections involving designs and controls applicable to the ultimate design are available for observation and analysis.

Another high-volume example of channelization is at Port Street, Newark, (Fig. 23). For comparative purposes it is also interesting to note the volumes at the famous Woodbridge Cloverleaf (Fig. 24), at the intersection of Routes 4 and 25.

From the projects completed it has been shown that channelized intersections with traffic signals can be designed for some locations which will serve traffic better than other intersection types, with the exception of the directional interchange, in which case the service offered by the directional interchange can be matched. The cost of directional channelization is a small fraction of the cost of the grade-separated intersection in many cases. It might eventually prove that the channelization is less expensive for equal service for all locations.

The greatest deterrent to general application in high-speed rural areas is the traffic-signal control device. It is not effective to the same degree at 60 mph. as it is at 30 mph., although the same signal is used. In this instance, standardization is hampering progress. The existing signal standard is even made a part of the law in some areas. This type of control has been used in Portland, Oregon, (see "Highway Research Abstracts," for October 1952, page 14).

In addition to better signals, it is also possible to utilize advance signals on the high-speed approaches to advise drivers to adjust their speeds so as to arrive at the intersection during the green signal.

With the aid of properly designed channelization, traffic signals can be used to make traffic go instead of stop. In this way, they could be named "Go" signals instead of "Stop" signals.