Accident and Operating Experience At Interchanges

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Geometric highway design can be evaluated only if the relative merits of the design features can be measured in some fashion. A yardstick is needed that will measure the various design features. Studies have been under way for the past two years to evaluate interchanges by three means—accident records, operation, and capacity.

Interchanges can be broken down into three basic elements: (a) the exit terminal, (b) the main portion of the ramp, and (c) the entrance terminal. This paper attempts to show how a variation in the design of these basic elements affects operation and safety.

● DURING the past two years New Jersey has undertaken a comprehensive study of safety, operation and capacity at 50 interchanges.

The first step was to review what had already been done by others. Experience and personal preference largely influences design. No published data could be found in which interchanges or their basic elements had been evaluated. For example, suppose it is decided that a certain ramp terminal design is satisfactory for an inner loop of a radius of 150 ft. What changes, if any, should be made if the radius of the loop was changed to 200 ft? What would be the effect on capacity, traffic behavior and safety?

Geometric highway design can be evaluated only if the relative merits of the design features can be measured in some fashion. In other words, a yardstick is needed that will measure the various design elements.

In this study an effort was made to evaluate interchanges by three means—accident records, operation, and capacity. The first two phases are almost completed, but much work remains to be done on the third item.

In such a study there is always a temptation to select the more complicated interchanges. However the most elaborate interchange is composed only of ramps which have three basic elements: (a) the exit terminal, (b) the main portion of the ramp, and (c) the entrance terminal. This discussion is primarily concerned with the entrance and exits at the main roadway.

In selecting interchanges for study, many of the older ones have been included that today might be considered substandard. This was done to give a range of values so that determination of desirable standards for safe and efficient operation could be made.

The accident records in general are for the 4-yr period from January 1, 1955 to January 1, 1959. A 4-yr period would tend to level out any unusual seasonal or temporary conditions. As, in addition, there is generally a 1- to 2-yr construction and a 1-yr design period, this means that most of the interchanges were designed at least 7 years ago. Many of them are 15 to 20 years old and one of them has been in operation for more than 30 years. At these older interchanges figures show a large number of accidents.

The number of accidents at each interchange varied from 1 to more than 130. In general, the same types of accidents occur at all interchanges; higher type design simply reduces the number of accidents. The older type interchanges with their larger accident experience were thus helpful in determining the real cause of accidents.

As the accident data came in for each interchange, the location of the accident was spotted on a plan and the accident reports and collision diagrams were studied.

The second phase of this study was then started. This consisted of field investigation of the roadway elements, including signs and pavement markings, in an effort to determine what design element was inadequate and what changes would improve the accident record and operating conditions.

All design must be based on assumed traffic behavior. After construction, this assumption can be checked by actual traffic performance. Near misses, variation in speed or lane changing may indicate some shortcoming in design.

The next phase of this study consisted of observation of traffic behavior during peak and off-peak periods.

This field evaluation of design elements calls for a trained observer who has an open mind and a thorough knowledge of both design and traffic behavior. It also requires a special ability to be able to analyze and determine what features are inadequate and what changes are required to provide for most efficient and safe operation.

An inadequate interchange does not have constant traffic friction or near accidents. For example, a highway with an average daily volume of 60,000, carries 22,000,000 vehicles a year. If only one driver out of one or two million gets in trouble, the interchange will have a poor accident record. This is one of the reasons why untrained observers, after a short inspection, do not recognize inadequate design features. It also explains (particularly for low volume roads) why poor design elements can remain in the standards for year after year.

It has been stated that a modern freeway is nothing but a number of interchanges connected with the proper number of lanes.

The AASHO Special Freeway Study and Analysis Committee recognized this importance of interchanges. Its members concluded that most of the traffic difficulties on freeways involve driver hesitancy, erratic driving, and resulting turbulent flows produced by improperly designed ramp terminals, short weaving sections, too close spacing of entrances and exits, abrupt decrease in number of lanes and inefficient marking and signing.

All of these items are connected with interchanges. Further inspection shows that only the ramp terminals are involved.

ENTRANCE RAMP TERMINALS

US 22 at Vaux Hall Road (Fig. 1) carries 66,000 vehicles a day. The ramp has an inside radius of 40 ft.

At first glance, it would appear that most of the accidents at the entrance ramps would be merging accidents and would occur on US 22. This is not true. At the two entrance ramps there were 29 accidents, seven caused by improper merging, whereas 22 occurred at the ramp terminal. These ramp accidents occur at interchanges which do not have adequate acceleration lanes.

At such interchanges vehicles have to slow down or stop before entering the main roadway. This places following drivers on the ramp in the difficult, if not impossible, position of (a) trying to watch the car in front as it merges with traffic on the main roadway, and (b) trying to look to the left at oncoming main roadway traffic.

Most drivers try to solve this problem by watching the car in front until it approaches the main roadway. Then they look to left at traffic on the main route. If at that time the car in front should suddenly stop because the driver at the last second found out that he had misjudged merging conditions, there is almost bound to be an accident.

This interchange also illustrates the importance of curb treatment at the ramp terminal. Unless the left-hand curb is placed so that vehicles are guided into a flat merging path, many of them will cut across one or more streams of traffic. At this location 55 percent of the entering traffic was observed to cut over into the center lanes instead of using the right-hand lane.

The ramp on the 8-lane section of US 1 (Fig. 2) has a 500-ft entrance radius and a

300-ft black top acceleration lane of the parallel type. (Figure 2 shows only the east-bound lanes of US 1.)

One might expect much better accident record and operating experience for this 500-ft radius ramp than for the ramp with the 40-ft entrance radius shown in Figure 1.

However, operating conditions have not been improved. Just before entering US 1, drivers are in the position of trying to watch the car in front and also the ones to the left and rear on the main roadway. There were 12 accidents on the ramp at this location due to rear-end collisions. There were not any merging accidents.

The ramp terminal in Figure 3 is at the junction of N.J. 3 and 17. Two design elements create most of the difficulty at this location: (1) four lanes merge into two in a very short distance, and (2) the left-hand curb line of the ramp does not guide traffic into a proper path of entry. This curb location encourages traffic on the ramp to cross to the center of N.J. 17.

There were 8 rear-end accidents on the ramp due to lack of an acceleration lane and 5 accidents due to improper merging.

Figure 4 shows the terminal of N.J. 62 at US 46. The ramp has a minimum radius of 500 ft with no acceleration lane. All accidents were caused by vehicles slowing or stopping before entering US 46 and being hit in the rear by a following ramp vehicle.

A special study was made of all entrances without acceleration lanes. The radii of the ramps varied from 40 to 1,000 ft.

It was found that increasing the radius from 40 ft all the way to 1,000 ft was of little benefit. The important factor is not the radius of the ramp but whether or not traffic slows down or stops before entering. As long as this occurs, there will be rear-end accidents on the ramps.

Figure 5 is a good example of the foregoing statement. The ramp radius is only 75 ft. The 825-ft acceleration lane eliminated most of the stops before entering and there was only one rear-end accident on the ramp.

The left-hand curb does not guide traffic into a flat merging path. There were two merging accidents.

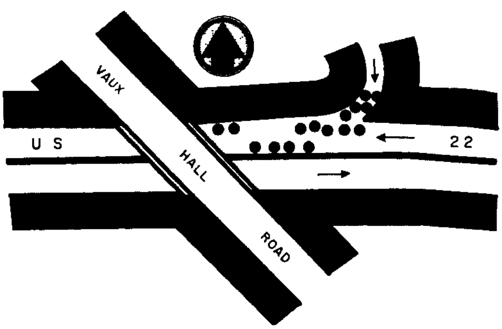

Figure 1. Ramp from Vaux Hall Road to US 22.

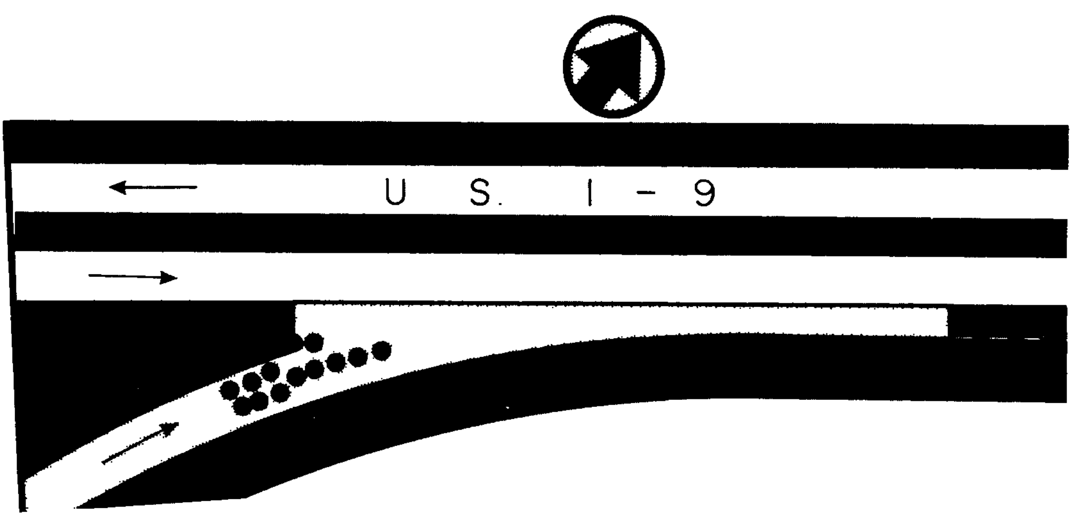

Figure 2. Ramp from Carnegie Avenue to US 1.

The ramp from US 1 to the Garden State Parkway (Fig. 6) shows a good treatment for the left-hand curb line. This connection also has an 800-ft acceleration lane. However, sight distance for entering traffic is restricted and there were three accidents at the entrance terminal.

Figure 7 shows the connection from Route 18 to the New Jersey Turnpike. This terminal design is standard for all interchanges on the turnpike. The left-hand curb line guides traffic into a flat merging path and the tapered acceleration lane is 1,200 ft long. There were no accidents at this location.

This type of design creates two operating conditions that tend to eliminate accidents at entrance ramps. First, drivers do not slow down or stop before entering the highway. This eliminates the rear-end accidents on the ramps that were shown in Figures 1 through 5.

Second, with the long tapered type of acceleration lane, drivers on the main roadway yield the right-of-way to entering ramp traffic. Observations show that this is accomplished either by a slight adjustment in speed or by moving over to the left-hand lanes. This type of driver behavior eliminates merging accidents and provides maximum capacity.

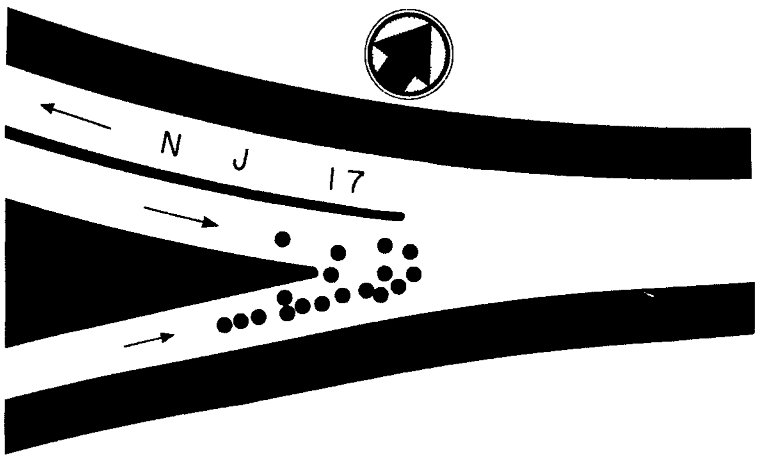

Figure 3. Ramp from N.J. 3 to N.J. 17.

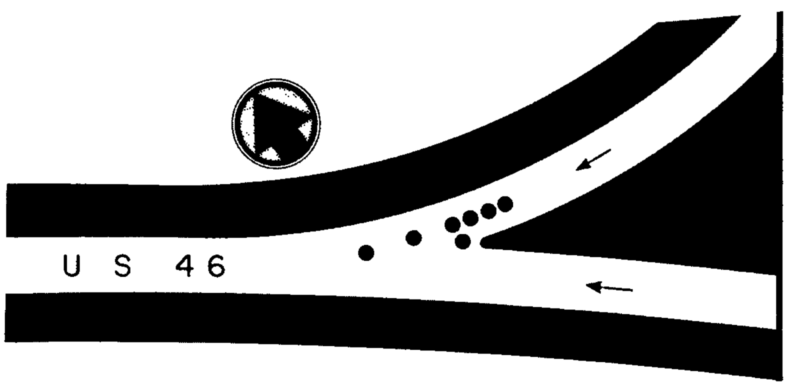

Figure 4. Ramp from Union Avenue to US 46.

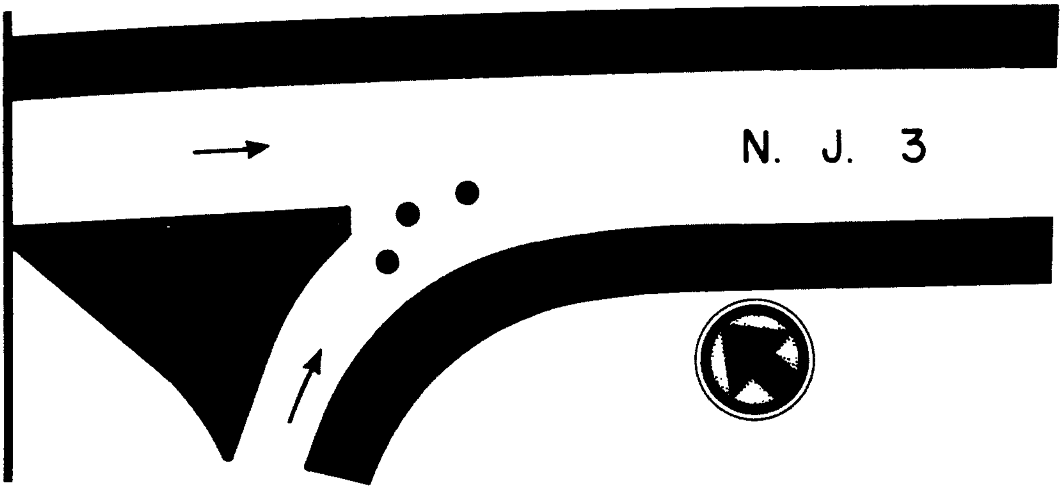

Figure 5. Ramp from Grove Street to N.J. 3.

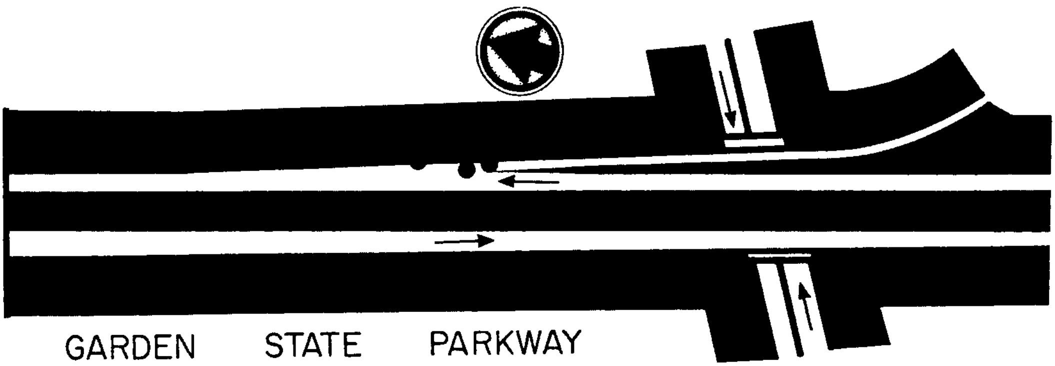

Figure 6. Ramp from US 1 to the Garden State Parkway.

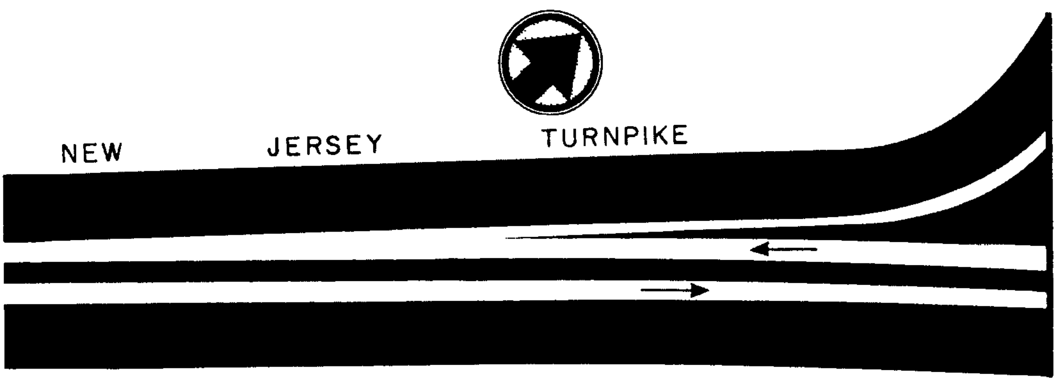

Figure 7. Interchange 9, New Brunswick.

EXIT RAMP TERMINALS

Route 22 at Vaux Hall Road (Fig. 8) is a four-lane land service road operating at capacity, carrying 66,000 vehicles a day.

This exit has a 300-ft radius with no deceleration lane. For these conditions the accidents have been about what would normally be expected.

Nine drivers slowed for the exit and were hit in the rear, 4 tried to turn from the wrong lane, 3 missed the exit and stopped, 3 hit the island nose, and 15 were due to rear ends caused by sudden stops in traffic.

The exit on Route 3 at Main Avenue (Fig. 9) has a 1,000-ft radius compounded to a 75-ft radius.

There were 8 accidents. One involved a vehicle that stopped after passing the exit; 3 were rear ends caused by drivers slowing for the turnout, one vehicle hit the island nose and one was an exit from the left-hand lane.

It is apparent that a higher type of exit would have prevented most of these accidents.

This exit on N.J. 3 at N.J. 17 (Fig. 10) has a 2,000-ft radius with no deceleration lane. This design permits a high speed exit only for the driver who follows the right-hand curb line.

Other vehicles, particularly trucks, tend to hide this type of exit and a driver may not see it in time to make a proper turnout.

The actual length of opening (parallel to the main roadway) through which he may turn with reasonable radius, is very short.

At a speed of 60 mph, a driver who delays 2 sec in making the turnout has the turning radius reduced from 2,000 to 300 ft. The greatly reduced radius decreases the possible speed of the turnout and creates traffic friction on the main roadway. This is reflected in the number of accidents.

The exit from the Garden State Parkway to US 1 (Fig. 11) has an 800-ft radius and an 800-ft deceleration lane. This length is about the absolute minimum. Shorter ones do not receive proper use.

One accident was caused by a driver slowing for the exit, the other one might have been due to inattentive driving.

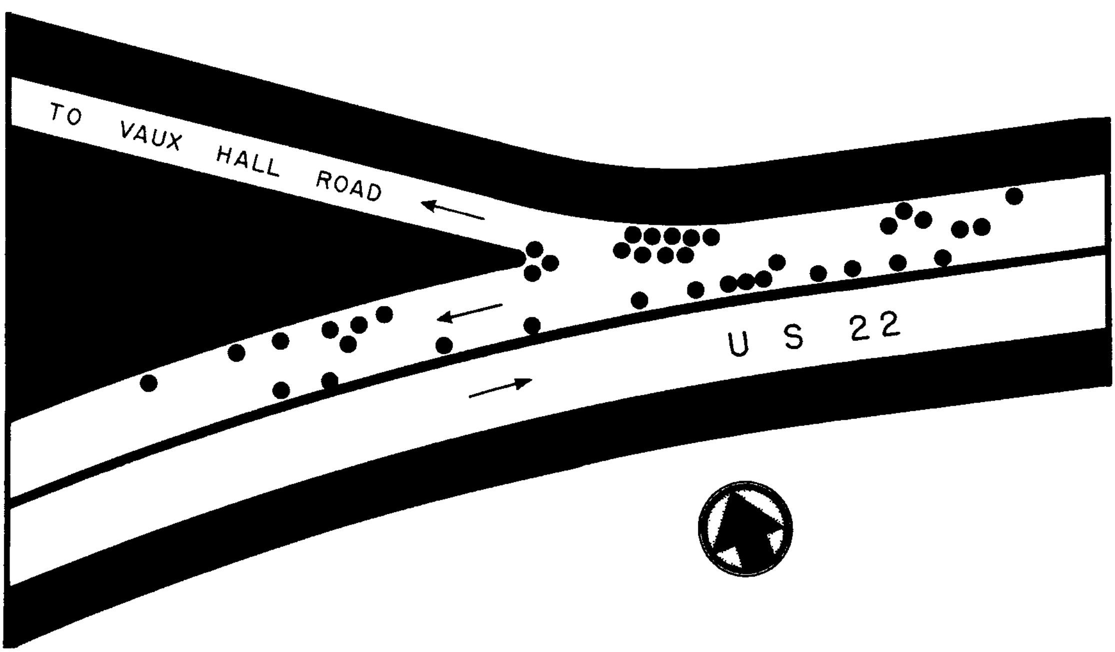

Figure 8. Ramp to Vaux Hall Road from US 22.

The exits on the New Jersey Turnpike (Fig. 12) have deceleration lanes of the parallel type—1,200 ft long.

The added deceleration lane permits traffic to thin out, giving the driver a better chance to see the exit in advance and provides the necessary time and distance to make a safe turnout.

Field observations show that nearly all drivers will use a deceleration lane of the parallel type if it is 1,200 ft long. When the length is decreased to less than 800 ft, some drivers will not use them and the accident rate is increased.

The abrupt beginning of the added lane also prevents drivers (particularly in bad weather) from drifting over into the exit by mistake.

There were no accidents at this location.

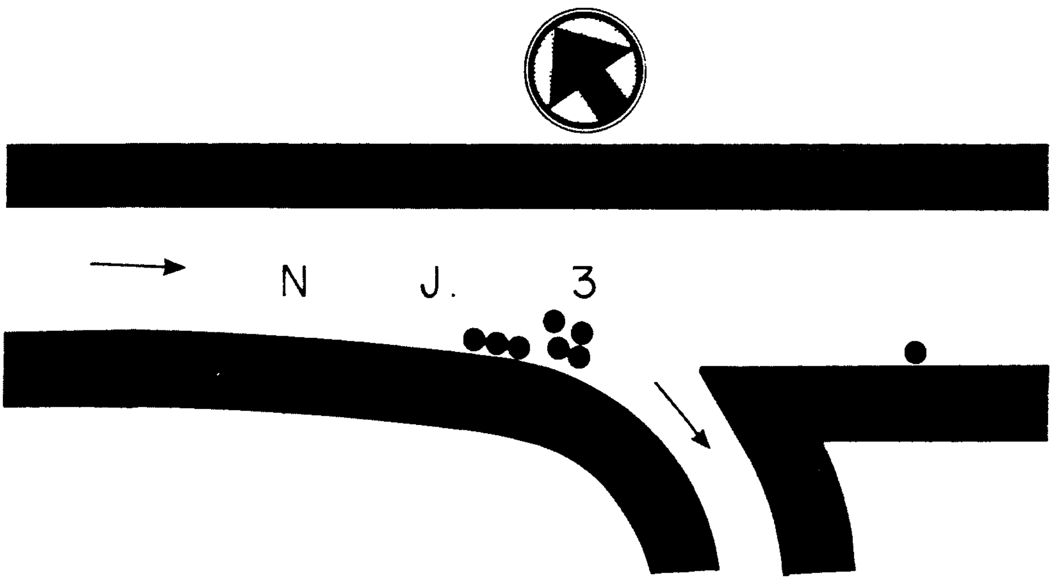

Figure 9. Ramp to Main Avenue from N.J. 3.

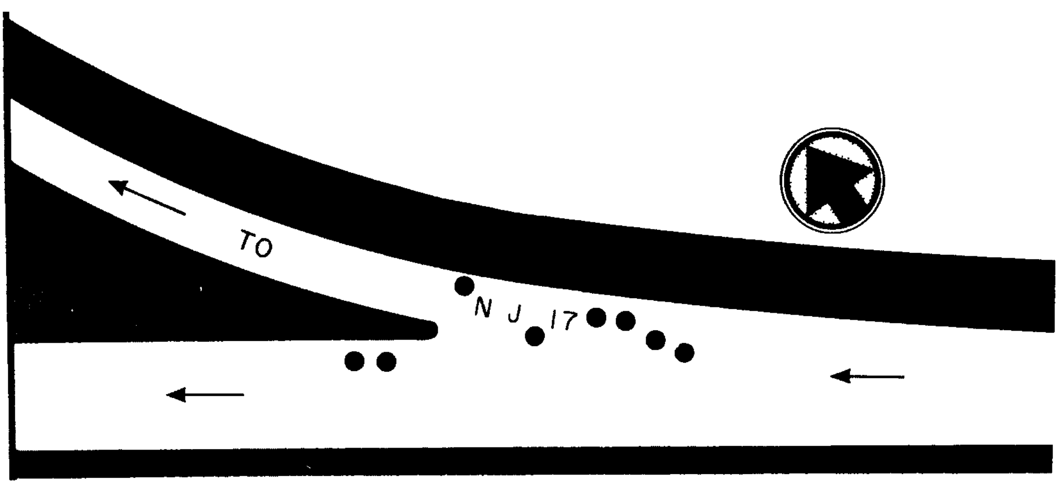

Figure 10. Ramp to N.J. 17 from N.J. 3.

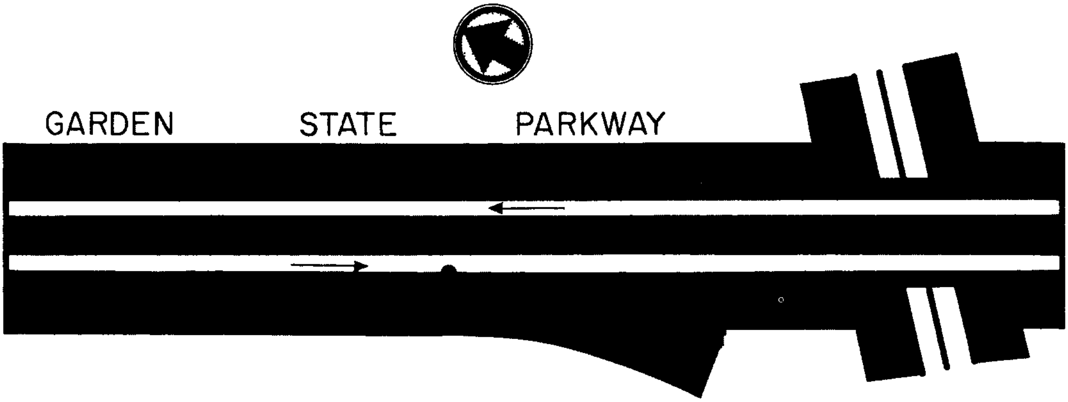

Figure 11. Ramp from the Garden State Parkway to US 1.

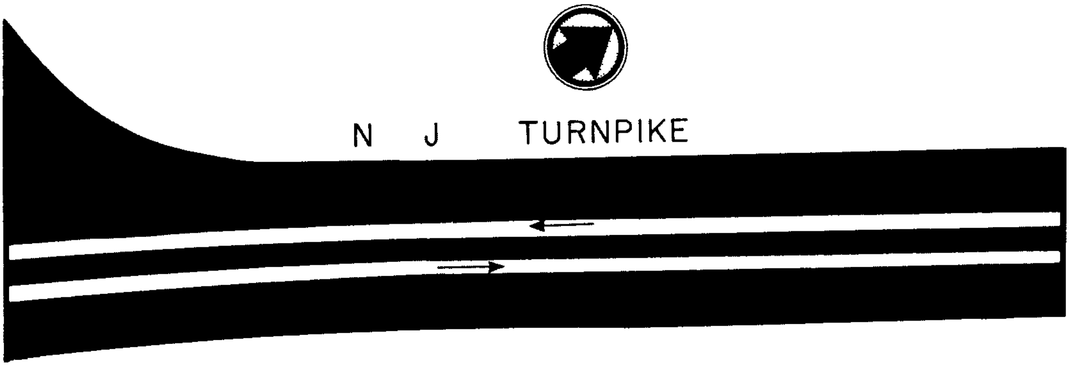

Figure 12. Interchange 9, New Brunswick.

Figure 13 shows the total number of accidents at each terminal compared with length of deceleration lane.

Even a short deceleration lane will help to reduce accidents. The greatest benefit is obtained when they are more than 800 ft in length. The greater length also eliminates much of the slowing down and traffic friction on the through lanes.

In Figure 14 the number of accidents at each terminal are compared with the length of acceleration lane.

Acceleration lanes less than about 900 ft in length have poor accident records. The reason for this is that many drivers will slow down or stop before entering the main roadway. Nearly all drivers will cross over into the main lanes in the first 200 to 400 ft.

When acceleration lanes are of the tapered type and over 900 ft long, an entirely different method of operation takes place. The full length of acceleration lane is used and drivers do not slow down before entering the main roadway. This eliminates the rear-end accidents on the ramp. Main roadway traffic also yields the right-of-way to entering traffic. This is done either by a slight adjustment in speed or by moving to a gap in the left-hand lanes.

The ability of ramp traffic to merge with main roadway traffic at about the operating speed of the highway not only reduces the number of accidents but also creates smooth operating conditions and increases the capacity.

Without adequate acceleration lanes, drivers on the ramp have to find a gap in

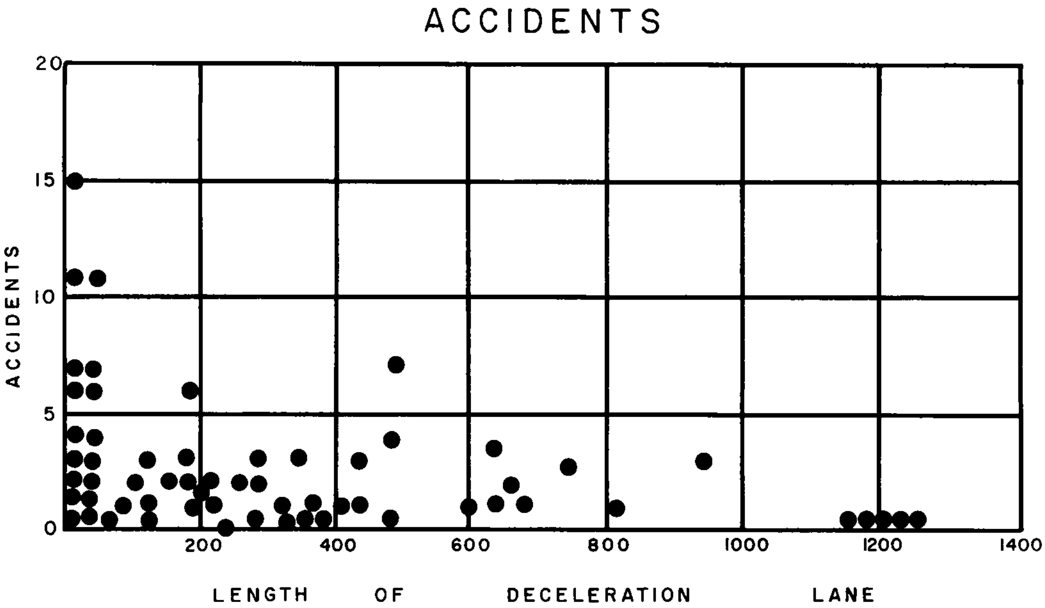

Figure 13.

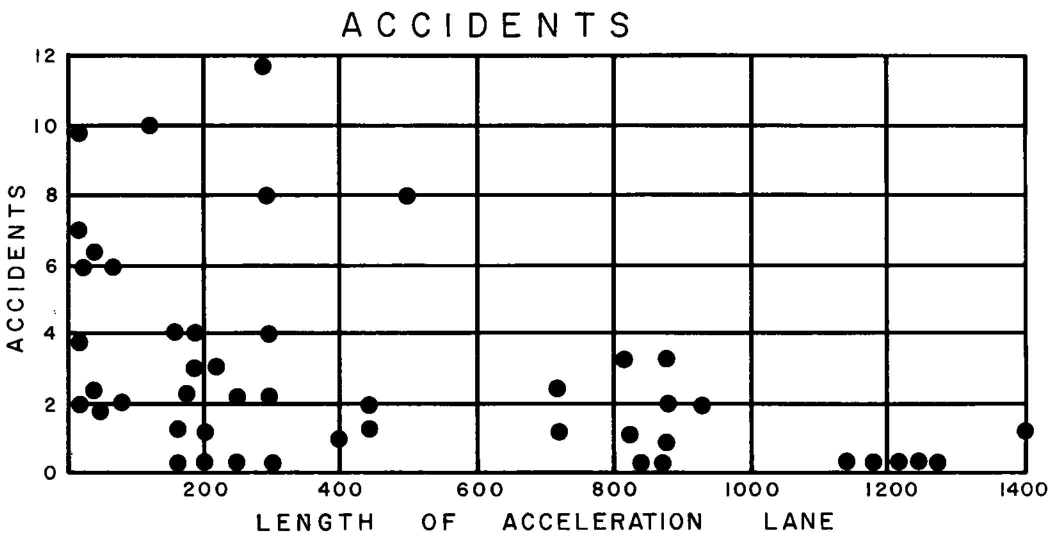

Figure 14.

traffic. Gaps sufficiently long for a vehicle to enter the highway and pick up speed to that of traffic on the main route are generally available only when volumes are low.

This means that when a vehicle enters from the ramp, it frequently forces the first vehicle to the rear on the main roadway to slow down. The second vehicle on the main roadway may have to brake harder and the third or fourth vehicle may have to stop. This reduces the capacity of the route and in many cases discourages use of the right-hand lane.

MAIN PORTION OF RAMP

In general there were very few accidents or any operating difficulties on any of the main portions of the ramps. Problems, if any, occurred at the ramp terminals.

On two-way ramps, there is a tendency for vehicles to swing wide at the beginning of the ramp, thus creating head-on conflicts. For this reason, it is believed that opposite direction traffic on two-way ramps should be separated by a curb.

For inner loops, a series of compound curves has been found to be effective in providing a means for traffic to safely reduce speed. New Jersey for some time has used radii of 750, 500, 250 and 170 ft.

There were not any accidents that could be ascribed to the curvature on inner loops that had radii of over 100 ft. The only ramp that had a poor record was one located past several underpasses, on a long downgrade and with a 70-ft ramp radius with no deceleration lane.

LEFT-HAND FACILITIES

Figure 15 shows part of an older type of interchange with a left-hand entrance ramp.

There were 14 accidents at this ramp. Six were merging accidents; four vehicles were cut off and forced into the guardrail and four were rear ends caused when drivers slowed before merging.

Note that in this design, the slow right-hand lane of the entrance ramp from Bloomfield Avenue has to merge with the left hand fast lane of US 46.

In this example four lanes have to merge into two in a short distance. A better design would be to drop only one lane and have the four lanes merge into three. The problem then becomes which lane to drop. There is considerable difference of opinion on this matter. One method would be to adjust the interchange design so that the three left-hand lanes could be carried straight through. The right-hand lane could be tapered out as a long acceleration lane. This would be a conventional treatment to which the motorist was accustomed and would probably be much less confusing than dropping one of the left-hand lanes. In any case the lane lining should be studied as part of the preliminary design and not something to be added as an afterthought when construction is completed.

Figures 16-21 show left-hand exits. These create different operating conditions than the conventional right-hand exit. Left-hand ramps are few in number compared with the usual right-hand and therefore can create an element of surprise.

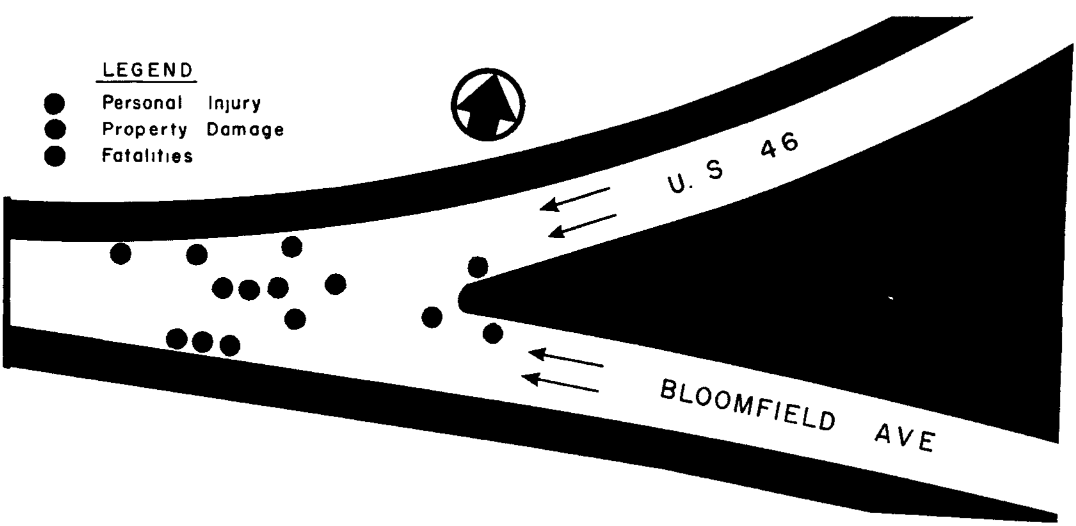

Figure 15. Ramp from Bloomfield Avenue to US 46.

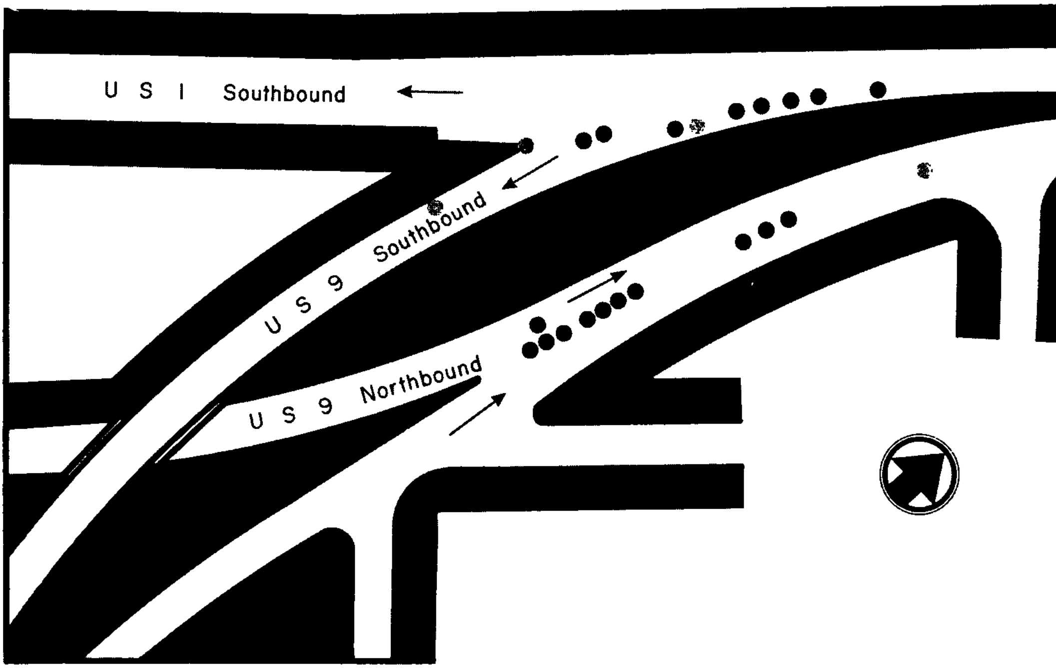

Figure 16. US 1 and 9 Interchange.

In spite of the best of signing and lane lining, some drivers will slow down or even stop before making an exit. This slowing down in the left-hand lane is not normally expected by a following driver in that lane.

A left-hand exit also forces slow-moving traffic in the right-hand lane, to cross over to left, in order to use the exit ramp.

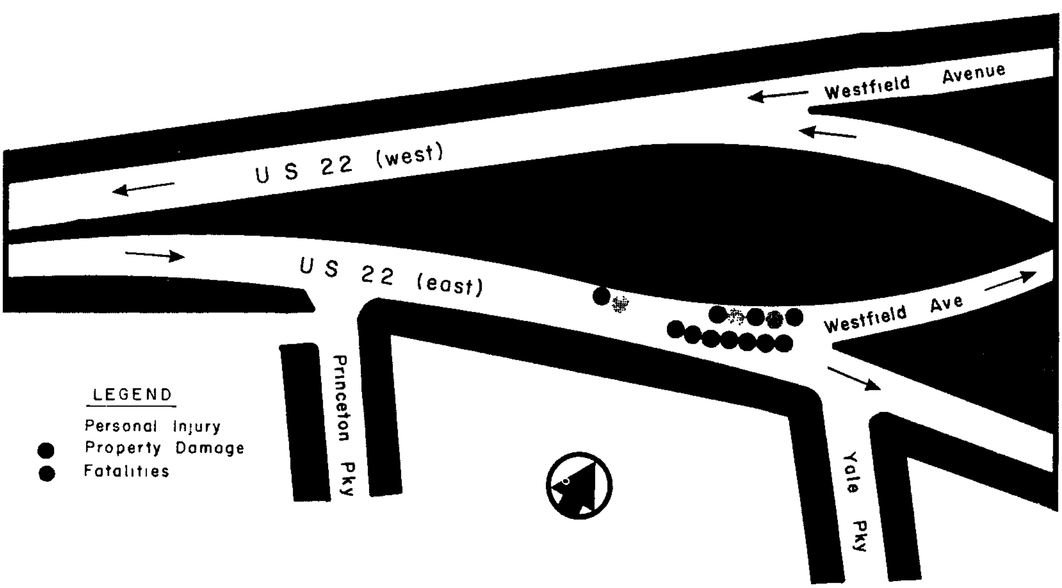

Figure 17.

On most highways the right-hand lane carries the lowest percentage of traffic and the left-hand lane the highest. Placing the exit on the left forces traffic into what may be an already over-crowded lane and makes thru traffic in that lane move to the right.

At the US 1 and 9 Interchange (Fig. 16) traffic makes an even split, 1,200 an hour

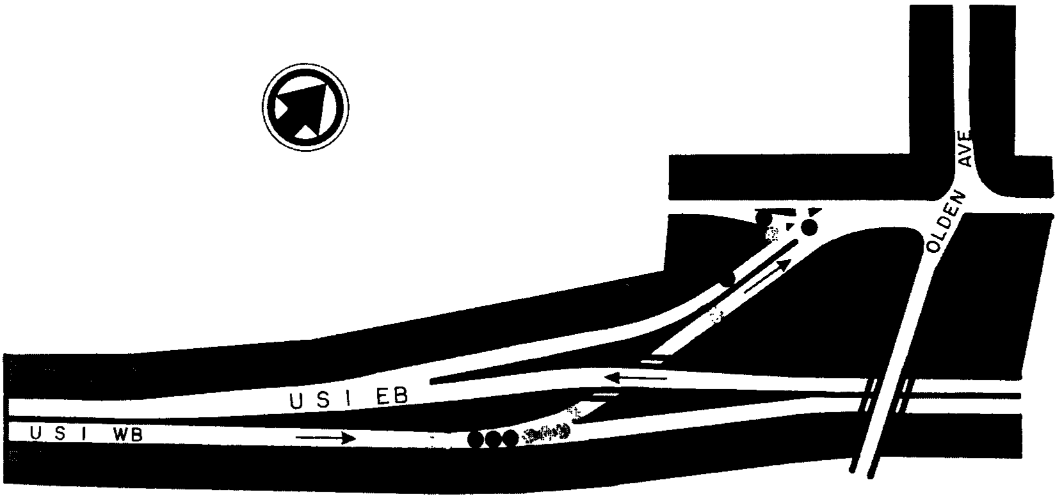

Figure 18.

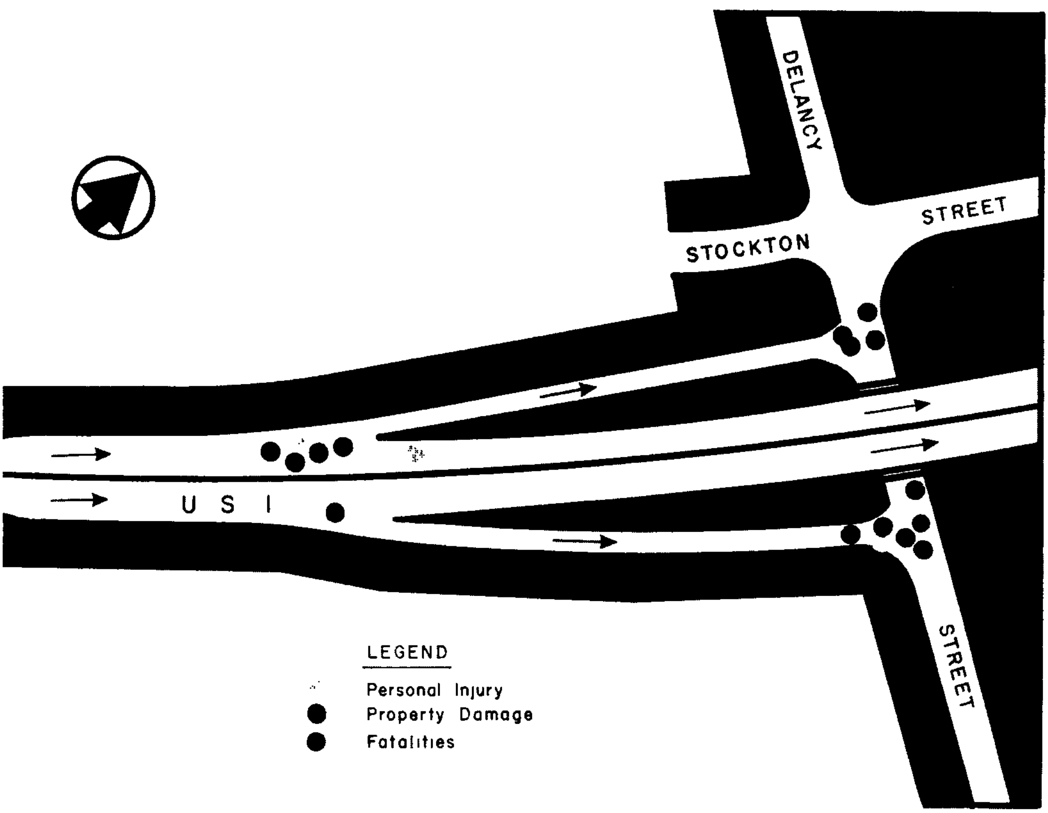

Figure 19.

using each roadway. Both ramps have a 950-ft radius. Particular attention has been directed to the signing at this location. There is a sign bridge with electric signs about 1,500 ft in advance of the exit; large reflectorized signs in the center island and a high mounted electric sign at the gore.

For southbound traffic, there were 12 accidents, two occurring during peak volumes. In seven cases vehicles were in the wrong lane. There were two accidents after midnight in which the drivers lost control of the vehicle and there was one sideswipe. This interchange is quite different from some of the others in that only one accident involved a driver slowing for the turn and being hit in the rear.

Northbound there were 12 accidents. Five were merging accidents, two were rear ends and five were due to lane changing.

US 22 carries 50,000 vehicles a day and Westfield Avenue about 7,000 a day. Eastbound US 22 is lane lined for two lanes and the left-hand exit has a radius of 700 ft (Fig. 17). There are two advance signs with 8-in. letters. These signs are located in the center island. There is also a sign at the gore.

For eastbound traffic, there were 14 accidents. Five were caused when vehicles slowed for the turn and were hit in the rear and seven were due to turns from the wrong lane. Five accidents occurred during peak volumes.

A complete interchange has 16 traffic movements. There are four offbound from the main roadway and four onbound. The same number occur at the local roadway.

This ratio of 16 traffic movements to 1 should be kept in mind in comparing accidents

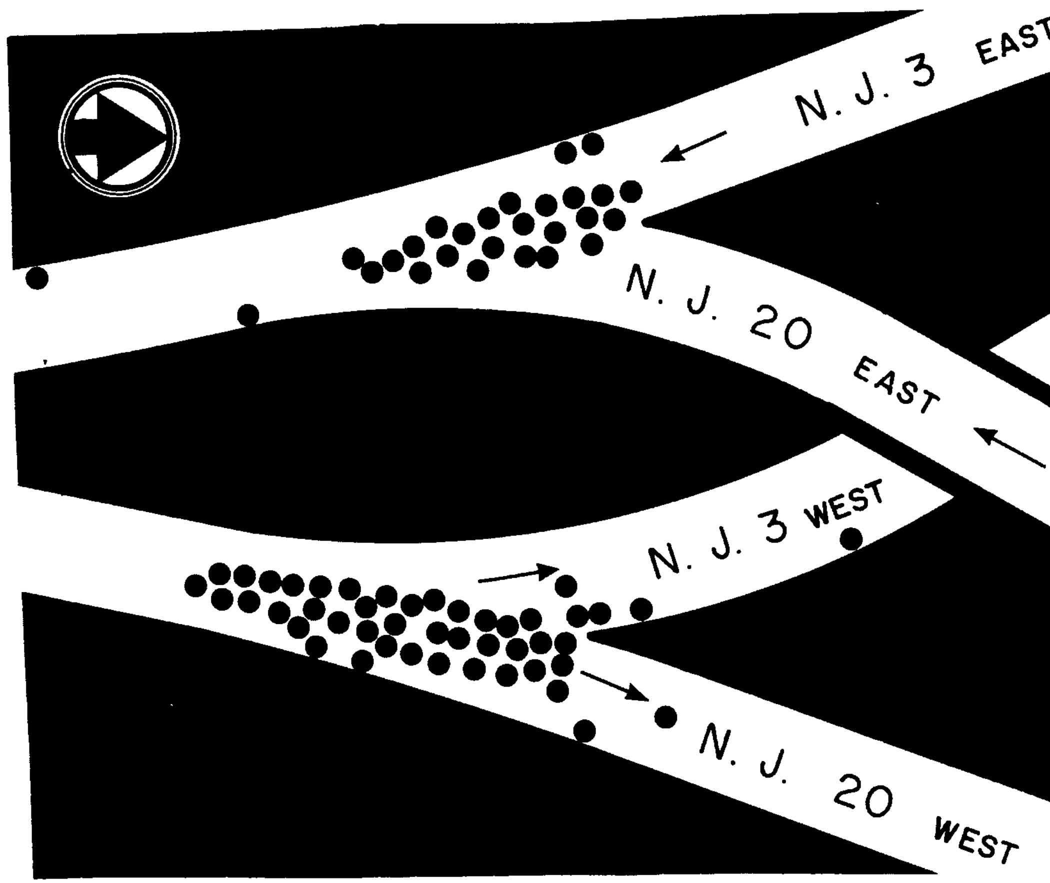

Figure 20.

at a conventional interchange with that of a single left-hand exit or entrance which has only one traffic movement.

At the US 1 Freeway and Olden Avenue (Fig. 18), traffic volumes are rather low. Four-hundred fifty vehicles an hour make the left turn and 950 continue on US 1.

There are overhead electric signs with 15-in. letters. The signs are located near the gore.

There were nine accidents at the left-hand exit. Six accidents were due to left turns from the wrong lane. One driver slowed for the exit and was hit in the rear. This accident resulted in seven injuries. At 1 a.m., when it was clear and dry, one motorcycle ran into another.

This interchange shown in Figure 19 has two exits of nearly identical design—one is a left-hand exit—the other is on the right.

US 1 in this area is of the dual-dual type. Each roadway has two lanes. The northbound outer roadway carries 2,800 vehicles an hour and the ramp 810 an hour. The inner roadway (which is restricted to passenger cars) carries 1,800 an hour and its ramp 560.

The right-hand exit had one accident—a driver made the mistake of slowing for the exit.

The left-hand exit had six accidents. Three were caused by turning from the wrong lane, one was due to lane changing and one driver missed the exit and tried to back up.

Figure 20 shows the intersection of N.J. 3 and 20. N.J. 3 westbound carries 3,900 vehicles an hour in advance of this interchange. Two-thousand six-hundred vehicles an hour use the left-hand exit.

Both the eastbound and westbound ramps have radii of 720 ft.

For westbound traffic, in addition to the route marker signs, there is a sign with 8-in. letters 600 ft in advance of the exit and located on the right; there is one on the left, 250 ft in advance, and one in the gore.

Eastbound there were 31 accidents. Seventeen were merging accidents and 10 were rear ends.

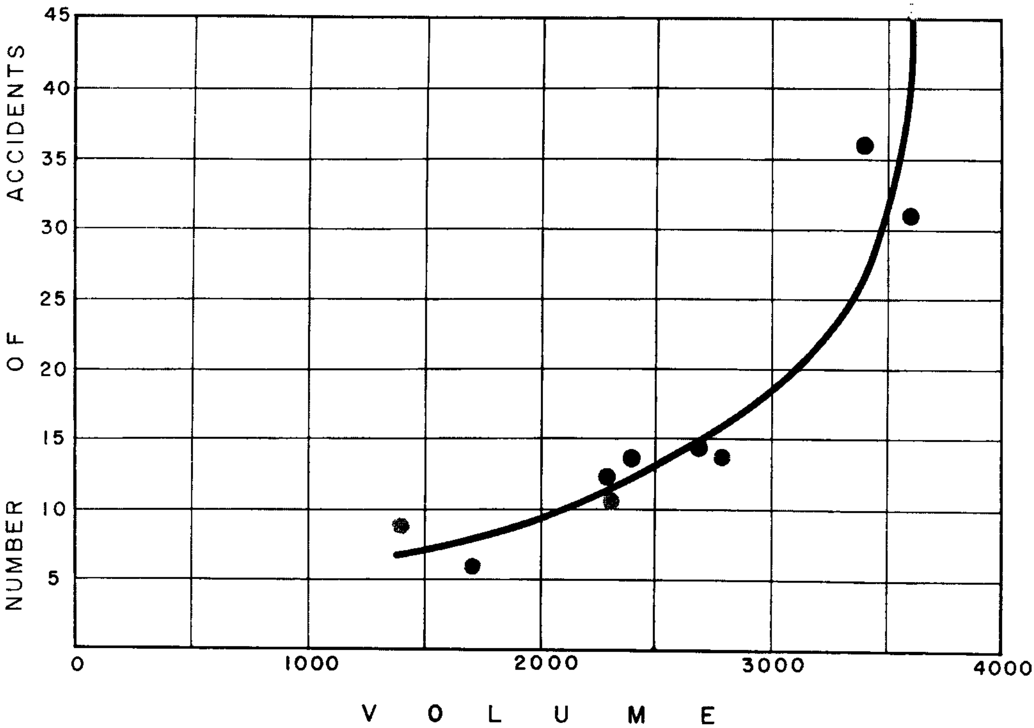

Figure 21.

Westbound there were 45 accidents. Seventeen were left turns from the wrong lane; 16 by traffic slowing for the turn and 5 were rear ends.

Figure 21 shows the number of accidents in comparison to traffic volumes for left-hand facilities. It is believed that the relationship is remarkable, especially when it is considered that some of the interchanges were for land service roads, others for parkway or freeway conditions.

CONCLUSIONS

From this study it is believed that the following conclusions can be reached:

1. There are not any accidents that can be ascribed to the curvature, on inner loops which have radii of over 100 ft. As ramps which have large radii take considerably more property and require more travel time, the use of one-lane inner loops with radii greater than 150 ft would appear to be questionable.
2. When the main roadway has concrete pavement, black top acceleration and deceleration lanes do not receive full use. Most drivers cut over into the main roadway within the first 200 to 400 ft.
3. Unless shoulders are provided, many drivers will not make proper use of acceleration and deceleration lanes.
4. Adequate length acceleration and deceleration lanes together with careful treatment of the terminals, and control of access, can practically eliminate accidents at interchanges.
5. All of the left-hand entrances and exits in this study had poor accident records.