CHANNELIZATION
The Design of Highway Intersections at Grade
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The Highway Research Board was organized November 11, 1920, as an agency of the Division of Engineering and Industrial Research, one of the eight functional divisions of the National Research Council. The Board is a cooperative organization of the highway technologists of America operating under the auspices of the Academy-Council and with the support of the several highway departments, the Bureau of Public Roads, and many other organizations interested in the development of highway transportation. The purposes of the Board are to encourage research and to provide a national clearinghouse and correlation service for research activities and information on highway administration and technology.
CHANNELIZATION
The Design of Highway Intersections at Grade

A Cooperative Project of
Committee on Channelization
Highway Research Board

Texas Transportation Institute
A. & M. College of Texas

Automotive Safety Foundation

National Academy of Sciences—National Research Council
Washington, D.C.
1962
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Foreword

Highway Research Board Special Report 5 "CHANNELIZATION - The Design of Intersections at Grade" was published in 1952. It presented 59 examples of channelized intersections representing current design practices at that time. It was widely used and of benefit to highway and traffic engineers by providing an opportunity to review the works of others. Since channelization has become so much more widely used in recent years, the Committee has compiled this revision which includes more recent design examples of channelization to illustrate present design practice.

This new report represents the cooperative efforts of the Highway Research Board Committee on Channelization and many state and city engineers who furnished examples and supporting data. Much of the work of preparing the examples for publication and the coordination of the committee reviews, etc., have been handled by Prof. B.F.K. Mullins, Research Engineer, Texas Transportation Institute. One hundred and twenty examples were submitted for the Committee's consideration. Much of this material is included in the report in some form.

Progress is usually based on accumulated knowledge of principles and the known experience of their application. The publication of these examples of highway channelization, largely examples of good design, with critical analysis is presented in the hope that highway and traffic engineers may profit by a review of the work of others.

Acknowledgment is made most gratefully to the many individuals and organizations who contributed the basic data which have been used as the basis for this publication. The name of the person submitting the material is shown with each example, and special appreciation is expressed for the splendid cooperation in furnishing the information requested by the Committee.

Appreciation is expressed to the Automotive Safety Foundation for substantial financial support in assembling and organizing the basic material in preparation for its publication by the Highway Research Board.
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The Design of Highway Intersections at Grade

Introduction

The rapid and continued postwar increase in motor vehicle production and use, the attendant record of traffic accidents and congestion, and public clamor for some relief are forcing highway and traffic engineers to consider every possible means of attacking the mounting highway transport problem.

Freeways and expressways are providing essential relief on an increasing mileage of important arteries. However, recognition must be given to the important fact that the major portion of motor vehicle traffic for years to come will move on existing streets and highways. These facilities, many of which are obsolescent, must be used to their maximum efficiency and capacity.

Important and satisfying progress is being made in many localities through the employment of restrictive traffic controls. These include one-way streets, parking prohibition and regulation traffic signal control, pavement marking, through streets, turn prohibition, regulation of transit operation, pedestrian control, truck routing and control of loading and unloading operations, and the use of traffic islands.

Recognizing the intersection as the area of major conflict and congestion, traffic and highway engineers are focusing particular attention upon these critical areas. Channelization has been employed with success at many locations, but it has also failed at other locations where the design has been inadequate or where the basic principles of channelization have been violated.
This report is not intended to establish principles of channelization design, but rather to present current design practice in the form of examples which have received the test of performance under varying conditions of traffic in the hope that highway and traffic engineers may profit by a review of the work of others.

Cities and states were requested to furnish examples of channelized intersections for inclusion in the report. Detailed specifications were provided to indicate the data desired. The requested data included:

Location

Type of Intersection

Physical Data

1. Geometric Design
   a. Plan of conditions after design or redesign, showing graphic scale.
   b. Negatives and/or glossy prints of the following:
      1. Aerial photographs of "after" conditions or photographs taken from an elevated position.
      2. Aerial photographs of "before" conditions.
      3. Several photographs of important design features such as curbs, islands, approach-end treatment, etc.

2. Grades: Grades over 3% on plan sheet; also vertical curve data if critical to channelization design.

3. Surface Type: Roadways, islands, shoulders; also type and height of curbs and islands, and detail if unusual.

4. Cross Section: Typical cross section if of unusual design.

5. Traffic Control Devices
   a. Signs: Type, size, location of warning and regulatory signs.
   b. Signals: Type, location, timing - including a phasing diagram.
   c. Markings: Type, location, color.
   d. Lighting: Location of poles and luminaires, type and size of luminaires.
   e. Other control devices: Guide posts, reflectorized delineators, etc.

6. Abutting property: Roadside culture, property or land use, location of entrances to property.

7. Transit operations: Location of transit, taxi and other passenger loading zones.

8. Right-of-Way: R/W limits on plan sheets where R/W critically influenced the design.

Traffic Data

1. Volumes: Present traffic volumes. One-way approach A.D.T.; design hourly volume if available; and AM and PM peak hour turning movement counts.

4. Accidents: Collision diagrams, for 12-month period before and after, or number of fatal, personal injury and property damage accidents for 12-month period before and after.
5. Pedestrian: Cross-walks and other provisions for pedestrians, and pedestrian volume where significant in design or operation of the facility.

Operational Characteristics

1. Comment on over-all operation of channelized intersection.
2. Comment on elements of the design which contribute to any unsatisfactory operation, such as sight distance, limitations on available right-of-way, etc.
3. Causes of concentrations of accidents or unusual accidents.

Channelization Defined

Like the design of the channelized intersection, the definition of "channelization" is subject to considerable difference of opinion. The following definition was adopted by the Committee on Channelization as being representative of the Committee's area of investigation and research:

"Channelization of intersections at grade is the separation or regulation of conflicting traffic movements into definite paths of travel by the use of pavement markings, raised islands, or other suitable means to facilitate the safe and orderly movements of both vehicles and pedestrians."

Types of Intersection

The commonly accepted definitions for intersection types have been used in categorizing the "examples" of channelized intersections.

The six basic types of intersections are:

1. Three-way Intersections (Figure 1).
   a. Y Intersection.
   b. T Intersection.
2. Four-way Intersections (Figure 2).
   a. Right-Angle.
   b. Offset.
   c. Oblique.

Figure 2.

3. Multiway Intersection (Figure 3).
   (5 or more legs).

Figure 3.

Functional Classes

1. Directional.
2. Divisional.
3. Refuge.

The 1961 edition of the Manual on Uniform Traffic Control Devices for Streets and Highways lists the following three classifications. Islands may be classified functionally and physically as follows:

1. Vehicular and pedestrian.
2. Traffic divisional islands.
3. Traffic channelizing islands.
Channelization Types

Generally islands are delineated by one of the following methods:

1. Raised and outlined by curbs and filled with pavement, turf, or other material.
2. Formed by pavement markings, buttons or raised bars on all paved areas, used in urban districts where speeds are low and space is limited.
3. Unsurfaced flush with the travel way, sometimes supplemented by guideposts, stanchions, or other delineators, used for large islands.

Warrants for Channelization

The Committee suggests that the warrants for channelization as published in the earlier report include the factors generally considered in the design of channelized intersections. Channelization is generally employed for one or more of the following purposes:

1. Separation of conflicts.
2. Control of angle of conflict.
3. Reduction of excessive pavement areas.
4. Regulation of traffic and indication of proper use of the intersection.
5. Arrangements to favor predominant turning movements.
6. Protection of pedestrians.
7. Protection and storage of turning and crossing vehicles.
8. Location of traffic control devices.
11. Control of speed.

Objectives

The central objectives of intersection channelization are to assure orderly movement, increase capacity, improve safety, and provide maximum convenience. When the design provides for orderly movement and adequate capacity, improved safety and convenience will result.

The 1961 Manual on Uniform Traffic Control Devices states: "The island design should be carefully planned so that the shape of the island will conform to the natural vehicular paths and so that the raised island will not constitute a hazard in the roadway. A judiciously placed island at an intersection on a wide street may eliminate the need for traffic signal control by channelizing traffic into orderly movements."

Principles of Channelization

In the analysis of motor-vehicle movements through intersectional areas and in the development of the principles of channelization, consideration must be given to the following:
Factors to be Considered in the Design of Channelization

Human

1. Habit
2. Ability of drivers to make decisions.
3. Element of surprise.
4. Decision and reaction times.
5. Conformance to natural paths of movement.

Traffic

1. Possible and practical capacities.
2. Turning movements.
3. Size and operating characteristics of vehicles.
4. Control of movements at points of intersection, convergence, and divergence.
5. Vehicle speeds and pedestrian movements.
6. Transit operations and accident experience.

Physical

1. Character and use of abutting property.
2. Roadway grades.
3. Surface type and cross section.
4. Sight distance.
5. Total intersectional area.
6. Angles of intersection.
7. Divergence and convergence.
8. Areas of conflict.
9. Speed-change areas.
10. Island design.
11. Traffic control devices.
12. Lighting.

Economic

1. Cost of the improvement.
2. Economic effect on abutting business (where channelization restricts or prohibits certain vehicle movements within the intersectional area).

Budget limitations many times delay the implementation of permanent channelization. Accordingly, much can be accomplished by the use of paint in these instances. Further, in instances where lay authorities have difficulty in understanding the merits of channelization, paint can be used to demonstrate its advantages. This is particularly true in "snow" areas where permanent channelization is sought by the engineer; orderly movement resulting from good delineation when pavements are clear compared to relative disorder on snow covered pavements often provides obvious testimony to the positive effects of channelization. Hence, the engineer "proves" his point, thus accelerating the approval of permanent channelization.

In the design of an intersection, the engineer must consider both the objectives and the principles of channelization. The central objectives of intersection channelization are to assure orderly movement, increase capacity,
improve safety and provide maximum convenience. When the design provides for orderly movement and adequate capacity, improved safety and convenience will result.

The more important principles of channelization which are presented in the following discussion must be observed if an effective design is to be achieved. The degree to which these principles are applied will depend upon traffic and physical features of the over-all design. For example, if traffic signal control is to be incorporated in the design, the angle at which traffic streams may cross without merging and weaving may be less than the right-angled crossing recommended for nonsignalized intersections (Principle No. 3).

Similarly, the separation of conflict points may be undesirable and impractical if the intersection is to be controlled by traffic signals (Principle No. 8).

The designer must clearly understand, however, these principles of channelization. Experience will indicate the degree to which they may be modified to meet conditions at particular intersections. If, on the other hand, the principles of channelization are disregarded, the objectives of channelization will not be achieved and the resulting design will be hazardous and inefficient.

1. The relative speed and impact energy of intersecting vehicles are functions of vehicle speeds and angle of intersection.

   CASE I
   \[ \text{RELATIVE SPEED} = \sqrt{\frac{V_1^2 + V_2^2 - 2V_1V_2 \cos \theta}{2}} \]

   CASE II

2. Channelization reduces the area of conflict.
3. When traffic streams cross without merging and weaving, the crossing should be made at or near right angles.

4. Merge traffic streams at small angles.

5. The speed of a traffic stream entering an intersection may be controlled by bending.
6. The speed of a traffic stream entering an intersection may be controlled by funneling.

7. Channelization provides refuge (shadowing) for turning and crossing vehicles.

8. Channelization separates conflict points within an intersection.
9. Channelization blocks prohibited turns.

10. Channelization may provide locations for the installation of essential traffic control devices.

11. Channelization is required for effective signal control at intersections with complex turning movements.
Comments by Committee Members and Submitters

The Committee recognizes that current channelization design is based, to a large degree, upon the judgment and experience of the designer in the application of the general principles of highway and traffic design to the problem of the intersection. In presenting the examples, the Committee believes that in the absence of qualifying remarks, some designs might be accepted as good practice. To prevent a misinterpretation of the examples by those readers whose experience in channelization may be limited, comments by two Committee members have been included with each example.

Admittedly, this critique, or review, is not intended to supersede the work of the authors. The analyses accompanying the examples should be accepted only as the considered opinion of the reviewer based upon the supporting data furnished and do not necessarily reflect the accuracy or effectiveness of the design. It must also be recognized that the reviewer did not have the designer’s intimate knowledge of the local conditions which so greatly influence the ultimate design.

The critiques prepared by Committee members were furnished to the person who submitted the example and additional comments were solicited. For many of the examples, these additional comments provided important data relating to the design and operation of the intersection and have been included in the textual material.

In addition, Committee members have suggested the following comments as being pertinent to the study, planning, and design of channelization.

Channelization "Pitfalls" - by Donald H. Sides

1. Be sure channelization is necessary, first of all, for traffic volumes, etc.
2. Avoid isolated channelization unless of major proportions.
3. Avoid multiple maneuvers--merging three movements into one--one movement offered three or more simultaneous choices.
4. Be sure islands, etc., are readily visible on approaches.
5. Avoid numerous small islands in favor of a few large ones where possible. Don't forget raised portions of islands should be offset from edge of travel path and raised portion itself should be reasonable in size. Avoid minimum sizes suggested in MUTCD where possible.
6. As plan develops, consult with MUTCD to insure proper placement of signs or signals if possible. Don't forget possibility of future signals.
7. On unsignaled intersections, in particular, provide sufficient width of median to shadow design vehicles.
8. Visualize channelization under all conditions, particularly during periods of high snow storage on islands.
List of "Cautions" for Channelization Designer - by Irving B. Weinberg

1. Never introduce islands on curves or hillcrests.
2. Remember that drivers and pedestrians take most convenient paths.
3. Avoid too many too small islands (50 square feet).
4. Channelization should appear open and natural.
5. Adequate signing and illumination are important features in good channelization design and operation.
6. Approach end of channelization island should be offset left of center-line and should be adequately reflectorized, painted, and/or illuminated for demarcation.

Median Channelization in California

"It is my opinion that the very word 'channelization' is apt to result in young engineers becoming over-eager and introducing many narrow turning lanes and small islands where the proper solution would be an open intersection. About the only channelization that is done now on the California Highway System is the provision of left-turn median lanes.

"The principal points that we would like to bring out, as shown on the enclosed standards, are: (1) The transition taper of the approach nose when widening an undivided highway should be a function of the design speed. (2) As little area as possible should be used for islands, meaning that as large an area as possible remains for the use of automobiles. (3) One thing that seems to be overlooked by many designers is the fact that the control point for the transition taper should be located at the point where the left-turn lane becomes full-width instead of at the point where the island becomes as wide as the left-turn lane. In fact, the island rarely has to be as wide as the left-turn lane.

"(4) Another point that is emphasized in the new standard is that the angle defining the beginning of the left-turn lane is increased and the corresponding length of taper is shortened in order to give a more positive indication or 'clear cue' as to where the left-turn lane begins. It has been observed that long, smooth tapers at this part of the left-turn lane have a tendency to entice through-vehicles as well as to result in doubt on the part of drivers desiring to make a left turn.

"On the exhibit indicating widening on one side, the pavement has been widened on the side approaching the intersection to better illustrate the point of control in the transition. It is also to be noted that the transition length has been made a function of the median width in lieu of the amount of widening. This was necessary because the amount of widening and the median width are not necessarily equal."
MINIMUM MEDIAN LEFT-TURN CHANNELIZATION

Widening on Both Sides in Urban Areas with Short Blocks

DEFINITIONS

L = LENGTH OF TRANSITION - FT
W = WIDTH OF MEDIAN LANE - FT
V = DESIGN SPEED - MPH

Notes

1 L = 500' MAXIMUM
2 WHERE CONDITIONS DO NOT PERMIT, SHOULDERS MAY BE OMITTED AND PARKING RESTRICTED
"The photograph which follows is of a stretch of road, U.S. 50 at Lake Tahoe, California, showing channelization for strip development with many minor cross-roads.

"I believe this is a fine example of simple channelization that accomplishes a great deal of good; namely, it almost eliminates left turn accidents and accidents associated with left turn maneuvers, and vastly improves traffic flow as compared with an undivided highway where turning vehicles stop in the through lanes.

"The pavement is 64 feet wide between asphalt dike curbs. The median is 12 feet, the outer lanes are 14 feet each, and the inner lanes are 12 feet. The highway operates very smoothly with summer traffic and volumes of around 25,000 vehicles per day.

"The median is flush, being marked by double stripes on each side. You may note that it is possible with paint to be much more precise than curbs when dealing with frequent openings.

"There is very little violation of the median in this particular case because legal openings are provided frequently enough so that there is very little call for violation. It is possible to reach every abutting property by means of a legal opening without making a U-turn." — Karl Moskowitz.
Divided section with left turn bays, shadowing, location of traffic control devices, separation of conflicts, and pedestrian refuge by channelization. (Toronto, Canada).
Channelized intersection with addition of island and left turn lane. Note controlled access design to shopping area. (Toronto, Canada).
General illustration of channelization in New Jersey.
"While this report is properly concerned with design, the committee recognizes the operating problems associated with the introduction of channelization at a location where none existed previously. Thus, the implementation of channelization, particularly in cases of raised islands, in most instances requires an indoctrination effort aimed toward acquainting 'repeat' drivers with the new situation." — Warren Travers.

Examples of Channelization

<table>
<thead>
<tr>
<th>Example Number</th>
<th>Three-Way Intersections - T Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1</td>
<td>Michigan, Lansing: Grand River Avenue (US 16) - Marshall Street.</td>
</tr>
<tr>
<td>T-2</td>
<td>Michigan, Pontiac: US 10 - Scott Lake Road.</td>
</tr>
<tr>
<td>T-4</td>
<td>Wisconsin, Eau Claire: US 53 - Presto Gate.</td>
</tr>
<tr>
<td>T-5</td>
<td>New Mexico, Tularosa: US 54 - US 70.</td>
</tr>
<tr>
<td>T-7</td>
<td>California, San Francisco: Laguna Honda Boulevard - Clarendin Avenue.</td>
</tr>
<tr>
<td>T-8</td>
<td>California, San Francisco: Main Drive - Bridge Drive (Golden Gate Park).</td>
</tr>
<tr>
<td>T-9</td>
<td>Delaware, Christiana: Delaware 7 - Delaware 273.</td>
</tr>
<tr>
<td>T-10</td>
<td>California, Berkeley: Derby Street - Warring Street.</td>
</tr>
</tbody>
</table>

Three-Way Intersections - Y Type

<table>
<thead>
<tr>
<th>Example Number</th>
<th>Three-Way Intersections - Y Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y-2</td>
<td>Nebraska, Omaha: 42nd Street - Q Street.</td>
</tr>
<tr>
<td>Y-3</td>
<td>California, San Diego: Nimitz Boulevard - Sunset Cliffs Boulevard.</td>
</tr>
<tr>
<td>Y-4</td>
<td>New Jersey, Hudson County: US 1 and 9 - New Jersey Route 3.</td>
</tr>
<tr>
<td>Y-7</td>
<td>Connecticut, East Litchfield: Route 8 - Route 116.</td>
</tr>
<tr>
<td>Y-8</td>
<td>Delaware, Keidel's Corners: Newport Gap Pike (Delaware 41) - Lancaster Pike.</td>
</tr>
<tr>
<td>Y-9</td>
<td>Delaware, Little Heaven: US 113 - 113A.</td>
</tr>
<tr>
<td>Y-10</td>
<td>Oregon, near Salem: Oregon 22 - Oregon 223.</td>
</tr>
<tr>
<td>Y-11</td>
<td>Texas, Dallas: East Grand Avenue - Gaston Avenue - Garland Road.</td>
</tr>
</tbody>
</table>

Four-Way Intersections - Right-Angled Type

<table>
<thead>
<tr>
<th>Example Number</th>
<th>Four-Way Intersections - Right-Angled Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR-1</td>
<td>Michigan, Dearborn: US 24 (Telegraph Road) - Ford Road.</td>
</tr>
<tr>
<td>FR-3</td>
<td>Texas, Austin: US 183 (Airport Boulevard) - US 290 (Koenig Lane).</td>
</tr>
<tr>
<td>FR-4</td>
<td>Arkansas, Little Rock: Meadowcliff Road - US 67 and 70.</td>
</tr>
<tr>
<td>FR-6</td>
<td>New Mexico, near Clovis: Cannon Air Force Base Entrance - US 60 (Offset) and 84 - New Mexico 277.</td>
</tr>
<tr>
<td>FR-7</td>
<td>Colorado, Denver: Colorado Boulevard - East 46th Avenue.</td>
</tr>
<tr>
<td>FR-8</td>
<td>California, San Diego: 54th Street - University Avenue.</td>
</tr>
<tr>
<td>Example Number</td>
<td>Four-Way Intersections - Oblique Type</td>
</tr>
<tr>
<td>----------------</td>
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</tr>
<tr>
<td>FO-1</td>
<td>Michigan, Lansing: US 16 (Grand River Avenue) - Saginaw Street.</td>
</tr>
<tr>
<td>FO-3</td>
<td>Delaware, Hockessin: Lancaster Pike - Yorklyn Road.</td>
</tr>
<tr>
<td>FO-4</td>
<td>Massachusetts, Seekonk: Fall River Avenue - Highland Avenue - (Offset) Mink Street.</td>
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</tbody>
</table>

**Multiway Intersections**

<table>
<thead>
<tr>
<th>Example Number</th>
<th>Multiway Intersections</th>
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</thead>
<tbody>
<tr>
<td>M-1</td>
<td>California, Modesto: H Street - Scenic Drive - Burney Street - Downey Street - Kimble Street.</td>
</tr>
<tr>
<td>M-2</td>
<td>Arkansas, Magnolia: Courthouse Square.</td>
</tr>
<tr>
<td>M-3</td>
<td>Idaho, Twin Falls: East Five Points.</td>
</tr>
<tr>
<td>M-4</td>
<td>Oregon, Portland: US 26 - SW 58th Avenue - SW Skyline Boulevard - SW Canyon Court - SW Humphrey Boulevard.</td>
</tr>
</tbody>
</table>

**OTHER TREATMENTS**

<table>
<thead>
<tr>
<th>Example Number</th>
<th>Three-Way Intersections - T Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-A</td>
<td>Texas, Bastrop: State Highway 71 - State Highway 95.</td>
</tr>
<tr>
<td>T-C</td>
<td>New Jersey, Metuchen: Holly Street - Central Avenue.</td>
</tr>
<tr>
<td>T-D</td>
<td>California, San Diego: Route 77 - Pomerado Road.</td>
</tr>
</tbody>
</table>

**Three-Way Intersections - Y Type**

<table>
<thead>
<tr>
<th>Example Number</th>
<th>Three-Way Intersections - Y Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y-B</td>
<td>Rhode Island, Pawtucket: Smithfield Avenue - Power Road.</td>
</tr>
<tr>
<td>Y-E</td>
<td>Missouri, Springfield: Chestnut Street Trafficway - College Street.</td>
</tr>
<tr>
<td>Y-F</td>
<td>New York, Wayne County: New York 5290 (Wolcott - Red Creek) - New York 5290 (Westbury).</td>
</tr>
<tr>
<td>Y-H</td>
<td>Canada, Toronto: Unidentified.</td>
</tr>
</tbody>
</table>

**Four-Way Intersections - Right-Angled Type**

<table>
<thead>
<tr>
<th>Example Number</th>
<th>Four-Way Intersections - Right-Angled Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR-A</td>
<td>Arkansas, Little Rock: Markham Street - University Avenue.</td>
</tr>
<tr>
<td>FR-B</td>
<td>Montana, Great Falls: 1st Avenue North - Park Drive.</td>
</tr>
<tr>
<td>FR-C</td>
<td>Delaware, Wilmington: Limestone Road - Kirkwood Highway.</td>
</tr>
<tr>
<td>FR-D</td>
<td>Arkansas, Hot Springs: Central - Grand.</td>
</tr>
<tr>
<td>FR-E</td>
<td>Massachusetts, Natick: Route 9 - Oak Street - Rhode Island Avenue.</td>
</tr>
<tr>
<td>FR-F</td>
<td>Rhode Island, Providence: State Route 2 - Division Street.</td>
</tr>
</tbody>
</table>
FR-G Rhode Island, Providence: State Route 2 - Frenchtown Road.
FR-I Alabama, Huntsville: Jordan Lane - Alabama 20.
FR-J Texas, Bastrop County: Texas 95 - Texas 71 (Loop Road).
FR-L Nevada, Reno: Kietzke Lane - East Second Street.
FR-M Canada, Toronto: Keele Street - Lawrence Avenue.

Example

Number	Four-Way Intersections - Oblique Type

FO-A Michigan, Saginaw: Washington Avenue - Rust Street.
FO-B Arkansas, Little Rock: Markham Street - Kavanaugh - Booker.
FO-C Texas, Lubbock: US 87 - US 82.
FO-D Kentucky, Carlisle County: Kentucky 440 - Kentucky 307.
FO-E Oklahoma, Northwest of Shawnee: Oklahoma 3 - Future US 270.

Multiway Intersection

M-A Minnesota, St. Paul: University Avenue - Robert Street - Aurora Avenue.
M-B Kansas, Kansas City: Central Avenue - Wilson Boulevard - 13th Street - Reynolds.
M-D Texas, San Antonio: Romana Plaza.

Approach-End Treatments

AE-A Arkansas, Jonesboro: Caraway Road - Johnson Street.
AE-D Oklahoma, South of Lindsay: Oklahoma 29 - Oklahoma 76.
**Location**

MICHIGAN, Lansing
Grand River Ave. (US 16, M-78) at Marshall Street

**Submitted by**

Harold G. Beverle
Director of Traffic Division
Michigan State Highway Department
Lansing, Michigan

**Date Opened to Traffic**

November, 1957

**Type of Intersection**

3-Way Tee

**Operational Characteristics**

Grand River Ave. (US 16, M-78) at Marshall Street

**Traffic Control Devices**

- **Curbs:** Bituminous concrete 7" high, where indicated on plan
- **Shoulders:** Class A compacted 4" sloping 1 on 4
- **Islands:** Bituminous curb with bituminous cap

**Volume:** 17% Increase between "Before" and "After" channelization

**Islands:** Bituminous curb with bituminous cap

**Design Vehicle:** C50

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**Within the next year or so, this island construction will be removed and the Marshall Street is the temporary ending of an east-west one-way street system.**

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**Additional Comments by H.H. Cooper, Director of Traffic Division, December, 1957**

Third, again only a refinement of design, but I would be inclined to shorten the crossing distance for the conflicting movements at Grand R and Sheridan. I think a more nearly right-angle crossing would provide better stop locations and a smaller intersection. At the same time, it appears to better delineate the curve of Grand River Avenue by replacing one long gap with two smaller gaps in the center island. (See C on sketch.)

At Saginaw and Marshall, the sketch (See D) segregates the two flows from the major right turn and might be considered for the detour of traffic into Sheridan Street.

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**Comments by Committee Members**

1. **EUGENE MAIER -** This is an excellent example of the use of channelization in the solution of the complex traffic movements resulting in the temporalization of one-way couplets. The channelization at Grand River Ave and Sheridan Street reduced an unnecessarily large intersection and minimized the conflict between southbound Grand River traffic and northbound traffic into Sheridan Street.

2. **R. T. SHOFF -** In principle this is a very fine use of channelization for traffic routing. Regardless of the good accident rate and an improvement in the rate after channelization, the after accident experience raises three questions in my mind which can only be checked by examination of detailed accident reports.

   - First, I question the need for traffic signals at Saginaw and Here. I suspect that part of the increase in accidents is a result of rear-end accidents due to signals.
   - I feel that if signals are to be used with channelization, an important feature is the placement of the heads. Overhead signals placed too close to the stop line as those shown on the drawing appear to me as not conducive to accidents and certainly do not appeal from a standpoint of convenience to the motorists.
   - Second, at least two islands are introduced in the center of one-way streets; and I question if such an advanced Island introduction is warranted for what are probably high-speed roads. The small sketch illustrates at A and B a possible design using raised pavement bars and rubber posts in advance of the physical island.
   - Third, again only a refinement of design, but I would be inclined to shorten the crossing distance for the conflicting movements at Grand R and Sheridan. I think a more nearly right-angle crossing would provide better stop locations and a smaller intersection. At the same time, it appears to better delineate the curve of Grand River Avenue by replacing one long gap with two smaller gaps in the center island. (See C on sketch.)

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**Additional Comments by H.H. Cooper, Director of Traffic Division, December, 1957**

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**Figure 2:** Looking north from the south leg of Marshall Street toward the Grand River Avenue intersection.

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**Examples**

**Example T-1**

**Shaded areas A and B denote simulated islands of pavement bars and rubber posts as advance warning**

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**SUPPLEMENT TO BEFORE AND AFTER ACCIDENT STUDY OF EXAMPLE T - 1**

**US 16 (GRAND RIVER) AT MARSHALL STREET, LANSING, MICHIGAN**

**CHANNELIZATION Construction:** Oct. 17, 1957 through Nov. 30, 1957

**BEFORE PERIOD:** 1 Year, Oct. 17, 1956 through Oct. 16, 1957

- **SUMMARY OF ACCIDENTS**
  - 8 Accidents
  - 1 Injured
  - 6 Accidents in Light Conditions
  - 2 Accidents in Dark Conditions
  - 3 Accidents on Wet Surface

**AFTER PERIOD:** 1 Year, Dec. 1, 1957 through Nov. 30, 1958

- **SUMMARY OF ACCIDENTS**
  - 5 Accidents
  - 1 Injured
  - 3 Accidents in Light Conditions
  - 2 Accidents in Dark Conditions
  - 2 Accidents on Wet Surface

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**SUPPLEMENT TO BEFORE AND AFTER ACCIDENT STUDY OF EXAMPLE T - 2**

**SAGINAW (H-78) AT MARSHALL STREET, LANSING, MICHIGAN**

**CHANNELIZATION Construction:** Oct. 17, 1957 through Nov. 30, 1957

**BEFORE PERIOD:** 1 Year, Oct. 17, 1956 through Oct. 16, 1957

- **SUMMARY OF ACCIDENTS**
  - 6 Accidents
  - 1 Injured
  - 5 Accidents in Light Conditions
  - 1 Accident in Dark Conditions
  - 3 Accidents on Wet Surface

**AFTER PERIOD:** 1 Year, Dec. 1, 1957 through Nov. 30, 1958

- **SUMMARY OF ACCIDENTS**
  - 3 Accidents
  - 1 Injured
  - 5 Accidents in Light Conditions
  - 3 Accidents in Dark Conditions
  - 0 Accidents on Wet Surface

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**SUPPLEMENT TO BEFORE AND AFTER ACCIDENT STUDY OF EXAMPLE T - 1**

**SUGGESTED REVISION**
Location
MICHIGAN, Pontiac
US 10 - Scott Lake Rd.

Type of Intersection
3-Way Tee

Physical Data
Grades: 1.28% East of intersection
Surface Type:
Roadways: 9" concrete with bituminous cap
Islands: Grass seeded and ditched
Curbs: White concrete curb on outer edge of right quadrant left turn. Yellow painted bituminous curb on inner edge of right quadrant left turn.

Traffic Control Devices
Signs: NO LEFT TURN case sign at the intersection for all directions
Signals: Two-phase signalization with dual indications
Lighting: One street light at intersection

Character of land use:
Residential on North side of US 10.
Scattered commercial on South side of US 10.

Traffic Data
Volumes: See Peak Hour Flow Diagram for 1956.
Design Vehicle: C50

Operational Characteristics
Traffic volumes at this location had reached the point requiring signalization. Volumes on US 10 were such that left-turning vehicles could not be permitted to store on the highway.

The channelization shown is very tight due to severe right-of-way limitations.

Accidents about doubled at this location, which is normal for the addition of signal control to the intersection. However, congestion, which previously occurred even without a signal, was eliminated and the intersection operates freely.

Comments by Committee Members
1. KARL MOSKOWITZ - This method of eliminating the left turn at a signalized intersection has been used effectively in California. However, our experience is based on a T-intersection without the additional street nearby. Traffic count does not indicate traffic to second intersecting road, but must be very light if the signalized intersection operates freely. Readers should be wary of using this method at a simple T-intersection because it calls for stopping mainline traffic in both directions for left-turning traffic from the mainline. A left-turn lane in the median calls for stopping opposing main line traffic only, and generally requires less right of way and pavement.

2. DONALD H. SIDES - This general type of intersection is described in some detail in the AASHO Policy on Geometric Design of Rural Highways. See figure VIII-25D and pages 3A2-343. The policy indicates it is an effective treatment particularly for unusually high peak flow of relatively short duration. This "jug handle" design has been employed with 4-way intersections. Sometimes the minor crossroad is split and the pattern becomes a tight rotary with the main road carried directly through. Usually this design is adopted because of the large cost of providing median lanes for left turning vehicles. Sometimes this design is referred to as the "New Jersey left turn" because it is used rather extensively in that State.
ILLINOIS, Menard County, near Greenview
Illinois Route 123 - Illinois Route 29

Type of Intersection
3-Way Tee

Operational Characteristics:

Elements controlling design: Illinois 29 is the preference route. Stop control on Illinois 123. Channelization is for operational safety. Length of left-turn lane is based on speed change requirement.

In the photograph we are looking southeast at the intersection of Illinois Route 123 and Illinois Route 29 south of Greenview in Menard County. From the "oil slicks" we can see that the through movements are predominant. A left-turn lane has been added on the south approach for operational safety even though the turning volume is light.

Comments by Committee Members

1. C. J. KEES - This design represents a good standard treatment for a low volume rural "T" intersection.

Although traffic volume is extremely light, consideration might be given to widening and lengthening the southbound traffic on Illinois 29 to reduce the speed differential between right-turn vehicles (Movement E) and three vehicles (Movement F).

2. R. T. SHOAF - I concur with the comments of C. J. Keese.

Additional Comments by M. K. LINGLE - We concur with Mr. C. J. Keese's comments. In view of the light volumes a separate right-turn lane was not provided at this intersection. Had the volumes been higher at this intersection, a right-turn lane in all probability would have been provided. To make things clear, the state of Illinois does not widen the through pavement a few feet to provide a right-turn lane, as suggested in Mr. Keese's comments. We normally provide an extra full-lane width for this right-turn lane. We are not sure of Mr. Keese's intent with regard to "additional width for south-bound traffic."

With regard to the signs shown on the plan layout, we wish to make it clear that the striped panels above and below the "KEEP TO RIGHT" signs at the nose of the channelization are silver reflective sheeting and orange fluorescent sheeting. All other striped panels are black stripes on silver reflective sheeting.

We wish to call your attention to the fact that the signs as shown are as presently posted and substantially conform to the 1958 edition of the State of Illinois Manual on Uniform Traffic Control Devices. It may be apparent to you that the signs do not conform to the 1961 edition of the Federal Manual on Uniform Traffic Control Devices. The State of Illinois is presently revising its manual to conform with the new federal manual which, when published, will cause the signing at this intersection to be completely revised.
Occasionally a traffic officer is required to direct traffic at the afternoon peak between the two nearby communities.

The plant entrance has adequate capacity for incoming vehicles so there is no back-up into the main roadways. Traffic coming from the southeast and entering the plant is about twice as heavy as traffic from the traffic from the southwest. Vehicles making those movements seem to merge on the approach to the plant entrance without difficulty. The unnamed road leading southwest from the Presto gate in a frontage road. The two ramps to Highway 53, one merging with traffic going northeast and the other crossing traffic going northeast serve as the terminal connectors for this frontage road. The traffic conflicts described were between the two approaches from the two local communities. There are no nearby manufacturing plants. This was a manufacturer plant during World War II.

Occasionally a traffic officer is required to direct traffic at the afternoon peak, but this is generally limited to summer afternoons when volume on US 53 is heavy. This highway carries substantial truck traffic as well as commuter and inter-city traffic between the two nearby communities.

### Operational Characteristics

- **Traffic Volumes**: Specific information is not available at this time for traffic coming from the traffic from the northeast and southwest since workers at the plant live both in Eau Claire and Chippewa Falls. Traffic exits in the evening in both directions. Very little traffic enters the plant making a left turn to southwesterly is also required to stop before crossing the northeast-bound lanes of US 53. Traffic outbound from the plant making a left turn to southwesterly is also required to stop before crossing the northeast-bound lanes of US 53. All other movements merge with the main traffic flows.

- **Roadways**: Portland cement concrete (PCC), except asphaltic concrete (AC) at certain approach areas and on frontage road.

- **Grades**: Nearly flat. Sight distance: adequate.

- **Speeds**: Posted speeds 65 MPH for passenger cars, daytime; 55 MPH for passenger cars, night; 45 MPH for trucks.

- **Design Vehicle**: C50

- **Islands**: Grass, with vertical curb.

### Physical Data

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### Type of Intersection

- **Traffic Data**

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- **Design Vehicle**: C50

- **Islands**: Grass, with vertical curb.
NEW MEXICO, Tularosa
US 54 - US 70

Type of Intersection
3-Way Tee

Date Opened to Traffic
May, 1961

Physical Data
Submitted by
Hurley Von Ehrenkrook
Traffic Engineer
New Mexico State Highway Department
Santa Fe, New Mexico
Grades: Flat; maximum profile grade is 1.1%
Surface Type
Roadways; Plant mix asphalt
Islands: 6" Concrete curb; within islands - chips on one course of asphalt
Shoulders: Curbed parking lane

Traffic Data
Design Vehicle: C-30
Speeds: Speeds generally up 5 m. p. h. in urban area after new construction.
About the same in suburban area.
Pedestrian: No pedestrian cross-walks; no significant pedestrian movement.

Operational Characteristics
Comments on Overall Operation of the Channelized Intersection:
The overall operation is generally satisfactory. The intersection was
designed to stay within the existing right-of-way and serve the major
traffic flow which is turning (east-south) with the flattest curvature
possible, and to more definitely define the motorist's sight-of-way at
the "Y's". This was especially true of the southbound US 70 motorist's
conflict with the northbound US 54 motorist at the south wye.
It would have been desired to superimpose the through lanes to a greater
degree, but this could not be accomplished due to drainage and the necessity
of matching existing property frontage. Circulation to and from a minor
cross street cutting into the south leg of the wye would create a slightly
unsatisfactory condition. It would have been desirable to locate the driveways
to the central development (Gulf Station) farther from the intersections,
as they have induced some wrong-way maneuvers to and from the
intersections.

Accident experience is meager. This is partially due to poor accident
reporting coverage in this community.

1. WESLEY R. BELLS - A very good type of design treatment of "T" Intersection.
   Note that at points of cross-traffic there is positive definition
   of driver intention to aid the other driver. This is very often non-
existant at this type of intersection, thereby causing misunderstanding of
   the other driver's intention which results in unnecessary delays and
   possibly accidents. This design can carry many more vehicles than
   expected in 1980. With simple revisions it can carry double the 1980
   volume.
2. KARL MUSENITE - This is a good solution to the T-intersection of two
   routes where the majority of the traffic is turning traffic. It is
   unfortunate that here, as in so many similar cases, there is so much
   private development in the immediate vicinity and that access must be
   provided for all of these developments. This is a situation that
   often must be lived with and the solution looks good. It is also noted
   that the intersections are adaptable for future progressive signalization
   if traffic volumes become heavy enough to require it. Spreading
   the conflicting movements out into three separate locations rather than
   concentrating them at one location will provide much better capacity than
   would have been possible had the east leg been brought into a perpendicular
   intersection with the north-south road.
EXAMPLE T-6

Location
MONTANA, Whitefish
US 93 - Montana 40

Type of Intersection
3-Way Tee

Date Open to Traffic
August 22, 1960

Physical Data
Surface Type
Roadways and Shoulders: Bituminous surfaced islands and median-4" of gravel over a plant mix surface, outlined by a 6" mountable curb painted yellow. Markings: White for lane lines and yellow for no-passing barrier lines approaching median islands.

Abutting Property: Timber land except for service station. See aerial photographs.

Right-of-way did not influence design.

Traffic Data
Design Vehicle: C50
Speeds: Approach speeds 50 to 60 MPH
Accidents: No accidents of record before or after channelization.

Operational Characteristics
The principal reason for channelizing this intersection is to provide a protected left-turn bay for a relatively heavy left-turn volume. We have had operational difficulties when we have introduced a median at an intersection on a two-lane highway. This is probably due to a lack of illumination and adequate approach treatment for the end of the medians. However, for the short life of this installation there has been no record of reported accidents.

The former intersection was located 800 feet north of the present one. Montana Route 40 intersected US 93 at a skew angle of about 40 degrees and the intersection was located behind a crest vertical curve.

Figure 2: Looking East along Montana Route 40

Comments by Committee Members -
1. GEORGE J. FISHER - Standard treatment well used. Paint markings are needed at ends of median islands on US 93. The drawing shows these but the photographs do not. Traffic channels between two small islands at entrance to Montana 40 are pretty narrow for turning traffic.

2. CHARLES J. KEENE - This appears to be a good realignment to eliminate a bad skew angle and sight distance problem. Judging from the photographs, there appears to be enough area to widen the approach on Montana Route 40 (the unused area around the two small islands) and provide a divisional island. This would ease turns and reduce sight distance problems. The photographs show the conflict point to be at the location of the "stop" on Route 40. A sketch of the suggested revision is shown below.

Additional Comments by MAURICE RICHEY -
1. Pavement markings and perhaps higgle bars would help to delineate ends of median islands. The markings are shown in the photographs; however, poor maintenance has reduced their effect. It is believed that the addition of lane markings and edge-of-pavement markings would help to channelize traffic in a more definite pattern.

2. It is believed the 30' opening between the small islands on Montana 40 is adequate. It is observed from the photos that the left-turn traffic from US 93 is cutting the "stop" traffic lane on Montana 40 south onto US 93. The traffic lane is unoccupied most of the time. It is noted that there are still several feet between the islands that are not being used.

3. The addition of a traffic separator on Montana 40 to channel the left turns from US 93 would decrease any possibility of a conflict between the islands. It would not, however, ease the turning movements since the radius of the turning movement is presently larger than it would be with the separator.

Figure 3: Looking South along US 93

Figure 3: Looking East along Montana Route 40
EXAMPLE T-6

MONTANA, WHITEFISH
US 93 - MONTANA 40

30th Highest Hour, 1960
Type of Intersection

Laguna Honda Boulevard - Clarendon Avenue
CALIFORNIA, San Francisco

Operational Characteristics

Traffic Data

3-way Tee
February 5, 1954

Physical Data

Grades: The approaches are flat.
Surface Types: The roadway surfaces are asphaltic concrete.

Traffic Control Devices

Markings: White
Lighting: The luminaires are 6000 lumen incandescents with Type V surface.

The islands are concrete and raised six inches above the road surface.

Surface Type: The roadway surfaces are asphaltic concrete.

Design Vehicle: The California Division of Highways semi-trailer, 48-foot minimum radius.

The intersection of Laguna Honda Boulevard and Clarendon Avenue shows a minor road with a light to moderately traveled road. The area surrounding it is undeveloped and there is no pedestrian problem, although sidewalks are provided. The intersections of minor roads are controlled by STOP signs and the major road is uncontrolled. The accident experience, as you can see, is very light and the delays encountered by traffic are also very light. The average delay through the intersection in a normal or peak hour is 1.01 seconds of stop delay per vehicle. I feel that this accident and delay record is much better than we could ever hope to achieve if the intersection was signalized, and so far we have resisted efforts on the part of some of the public to have it signalized.

Comments by Committee Members

1. W. R. SHELLS - This is a good design but it is being taxed to the limit in carrying the indicated volumes without traffic signals. A slight increase in traffic and the signals can be deferred no longer. The signals will add a greater capacity, but an increase in accidents and delays is expected. This increase in accidents and delays, compared to past experience, can be expected. This increase in accidents and delays will be less than the accident and delay that would prevail without the signals after the traffic volume has increased.

2. DONALD E. BICK - The treatment provided is effective in carrying large volumes with only slight delay and hazards. Apparently the channelization was introduced within the confines of existing pavement. The presence of retaining walls, a reservoir and steep slope area seems to have made it impractical to widen the west approach for the purpose of lengthening the Laguna Honda Boulevard left-turn slot and raising the somewhat tortuous westbound travel path.

Additional Comments by R. T. SHOAF - True, the channelization near the reservoir was dictated by the existing retaining walls on each side of the roadway. The saving feature probably is the fact that the curving alignment and tortuous westbound travel path.

With the existing 5-second average per lane headway of crossing conflicts in the peak hour, we feel that there is at least a 9% improvement in growth without signals. This judgement is based on another intersection of similar design but without any stop signs or signals operating at an average per lane peak hour headway of 2.9 seconds, without back up and with an extremely low accident experience.

Figure 2: An intermediate stage in channelization

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Figure 3: Latest view, After channelization

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<tr>
<td>2:30 to 2:45</td>
<td>2</td>
<td>160</td>
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<tr>
<td>2:45 to 3:00</td>
<td>2</td>
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<td>0.1</td>
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COLLISION DIAGRAM
1960 Annual Accidents
Total: 2

Legend
O - Non-Fatal
|- Property Damage
D - Daylight
D - Darkness

TRAFFIC VOLUMES

<table>
<thead>
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 SCALE

EXAMPLE T-7
CALIFORNIA, SAN FRANCISCO
LAGUNA HONDA BOULEVARD - CLARENDON AVENUE - SEVENTH AVENUE
channelization because I think too often traffic engineers overlook the fact that good traffic control does not always have to be costly. Many times the stop bar indicates the majority of motorists traveling eastward on Main Drive are following the stop bar. This seems to work very well, better than that at Laguna Honda and Clarendon (Example T-7). The average stop delay per vehicle through the intersection in the normal or peak hours is approximately 0.4 of a second, and it increases only slightly during the heavy pedestrian volume. This wye is at the intersection of Main Drive and Bridge in San Francisco's Golden Gate Park. There is a certain amount of pedestrians, but they do not appear to have any trouble crossing and the channelization is only of the painted type. This is in keeping with the character of the Park which generally avoids the use of both curbs and traffic islands, and it seems to work very well since automobiles, almost without exception, keep in the lined paths. The accident record is very good, especially considering the extremely heavy volume of traffic, and the delay situation is even better than that at Eucalyptus Farms and Claremont (Example T-7). The average stop delay per vehicle through the intersection in the normal or peak hours is approximately 0.4 of a second, and it increases only slightly during the heavy pedestrian volume. In some states whereby it is required that stop bars be supplemented with paint, in lieu of "waiting" for budget approvals, there might not be an additional advantage. At this location, the exclusive use by motorists, in addition to Mr. Travers' concurrence with the idea of "engineering with paint" in lieu of waiting for budgets, there might not be an additional advantage. At this location, the exclusive use by motorists, the argument of others and not necessarily that of Mr. Shoaf. In any event, however, I do not consider Islands to be substantially fulfilling all of the proper requirements, and often are an asset to a landscaped environment, particularly if they are large and not cluttered with a multitude of signs. I heartily agree with Mr. Shoaf on more extensive use of paint generally, even in snow areas, in lieu of "waiting" for budget approvals, etc.

Additional Comments by Ross T. Shoaf - General: I must agree that painted Islands covered with snow would give no delineation. However, I wonder if, in addition to the "nature's" location, and the exclusive use by motorists, it is not possible that the painted pattern followed the major portion of the year would be sufficient to carry over the winter season so that the Islands would be usable from an esthetic point of view in the Park. This question is asked by a traffic engineer with no snow experience at all - or is it? I heartily agree with Mr. Shoaf on more extensive use of paint generally, even in snow areas, in lieu of "waiting" for budget approvals, etc.

Reply to specific comments by Warren Travers: While it is true that the question of esthetics in Golden Gate Park is not a responsibility of the Traffic Engineer, I feel that I would not suggest raised Islands for their esthetic quality even if landscaped. The point about stop bars is well taken. They have no legal status in California and there was some question if they would work without a sign of any sort. However, we were not confident that raised Islands would not be eventually painted over. The restriction in Bridge Drive is approximately 800' south of the intersection and while we do have an offset centerline because of the restriction, traffic flow F has already started to use two lanes even though the wider area is not striped. I do not so readily agree with Mr. Weinberg's criticism regarding pedestrian "islands." Generally, the use of pedestrian "islands" is little, if any, O-D need for pedestrians to cross in this area - and pedestrians seldom do cross even though the age-old path opening almost indicates a possible use. I feel that many times not only is it impossible to physically prohibit pedestrian crossing but at all times it is necessary. However, I do agree that the question of esthetics in the Park is a complex problem. I believe I have demonstrated, during my discussion of typical conditions of pedestrian crossings, that we do not have as much to be concerned with as to when they should be used. I do not so readily agree with Mr. Weinberg's criticism regarding pedestrian "islands." Generally, the use of pedestrian "islands" is little, if any, O-D need for pedestrians to cross in this area - and pedestrians seldom do cross even though the age-old path opening almost indicates a possible use. I feel that many times not only is it impossible to physically prohibit pedestrian crossing but at all times it is necessary. However, I do agree that the question of esthetics in the Park is a complex problem. I believe I have demonstrated, during my discussion of typical conditions of pedestrian crossings, that we do not have as much to be concerned with as to when they should be used.

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Location
DELAWARE, Christiana
Delaware Route 7 - Delaware Route 273

Type of Intersection
3-way Tee

Submitted by
Ernest A. Davidson, Chief Engineer
Delaware State Highway Department
Dover, Delaware

Date Opened to Traffic
November 15, 1960

DELAWARE, Christiana
Delaware Route 7 - Delaware Route 273

Type of Intersection
3-Way Tee

Physical Data
Surface Type
Roadways and Islands: Bituminous concrete
Shoulders: Delaware Route 7 - Select borrow, 8'; Delaware 273 - Bituminous surface treatment, 18'.
Curb: Delaware Routes 7 and 273 from Intersection north - barrier type; in channelization: mountable type.

Abutting Property: Rural, but developing slowly

Traffic Data
Speeds: Delaware Route 7-50 MPH
Delaware Route 273 - 45 MPH
Delaware Routes 7 & 273 - 45 MPH

Accidents: The accident record here is minor.

Pedestrian: Volume is negligible.

Operational Characteristics
This intersection was designed to accommodate traffic of which the majority runs to and from the north and east. The turn from east to south is quite minor. The design was intended to serve turning traffic with the least hindrance to straight traffic. To date, this objective has been reached.

The one drawback to this intersection is that some southbound drivers (especially some truckers) tend to begin their left turn before the end of the barrier lines, and as a result hit the point of the center island. As a result, the entrance is scheduled to be widened to 20 feet.

Figure 1: Looking West on Hare’s Corners Road (Delaware Route 273), showing the entrance, and the approach to the crossing.

Figure 2: Looking from Delaware Route 7 across on Delaware Route 273, showing the southern approach to the intersection. Christiana to the left.

Figure 3: Looking Southeast from North approach, showing right-turn channelization and further painting, allowing a merge condition instead of the yield or stop which would be necessary if both channelizations were used. Christiana to the extreme right.

Comments by Committee Members
1. GUSSEH MAIER - The design appears to be minimum for southbound vehicles turning onto Route 273 and this fact is confirmed in the discussion under “Operational Characteristics”. Good visibility of the islands has been achieved by the use of contrasting color between the island and the roadway surfaces. In rural areas where speeds are in the range of 45 to 50 MPH, some designers choose to use a mountable curb on the islands in preference to the barrier type used at this intersection.

2. IRVING B. WEINBERG - The design as it exists should work well; it performs its function of minimizing the maneuver for south to east. Another feature that is worth emphasizing is the adequate road width at merge locations. Merging flows are not squeezed into a "point of merge".

My only comment about the design itself is that an unnatural reverse curve maneuver is required by westbound to south flows (and it is doubtful that this course would be followed) but instead, a curve-cutting direct course would probably be taken. This would result in the entire pavement between "bull-noses" (median and channelization islands) being commandeered by the east southbound vehicle instead of the pavement being available to a decelerating reverse-curving minor flow vehicle and an east to north major flow vehicle. This condition of improper lane occupation could affect capacity.

It is therefore suggested that the boundaries of the center island be streamlined to encourage the minor flow to keep left and follow a designed path rather than a convenient (and in this case, more direct) path.

Additional Comments by WILLIAM R. CARROW, Traffic Engineer, Delaware State Highway Department - The revised sketch showing a proposed change in channelization at the intersection of Delaware Route 273 and Delaware Route 7 would facilitate easier turns for larger tractor trailers (73' radius). This change would considerably widen this lane (approximately 26'). Should this be done properly, the removal of channelization should extend back to Station 100 on Route 273 (as shown on print).

Figure 1: Looking West on Hare's Corners Road (Delaware Route 273), showing the entrance, and the approach to the crossing.

Figure 2: Looking from Delaware Route 7 across on Delaware Route 273, showing the southern approach to the intersection. Christiana to the left.

Figure 3: Looking Southeast from North approach, showing right-turn channelization and further painting, allowing a merge condition instead of the yield or stop which would be necessary if both channelizations were used. Christiana to the extreme right.
EXAMPLE T-9

DELAWARE, CHRISTIANA
DELAWARE ROUTE 7 - DELAWARE ROUTE 273

Note: All Turning Volumes are expanded from the results of a study of turning volume counts by the planning agency. The study included 4 hours of turning volume counts by the planning agency. The A.M. Peak and P.M. Peak during the P.M. Peak.
1. Wayne Travers - It is assumed that any suggested revisions are to be kept within the confines of the curb lines as shown on the illustration originally submitted. It is further assumed that no turning movement(s) may be prohibited, regardless of magnitude.

General - An attempt is made in the revised sketch to give better definition to vehicular paths and to reduce the size of the area of conflict through more extensive use of painted channelization. Except for the crosswalk, all other operating functions are essentially the same.

Derby Street-East Approach - The crosswalk has been lengthened to provide two (2) lanes on the approach-one for heavy right-turning traffic (767) and one for the very moderate through traffic (1029). The through traffic is required to yield. Hence, since it is in its own lane, it will not interfere with right-turning traffic.

Warring Street-North Approach - Same as above.

Derby Street-West Approach - Traffic on this approach is extremely light (767); hence, a one-lane approach is adequate. Of the total 470 vehicles, 77 turn left and 400 go through, with both of these movements being required to yield. It was felt that the original design did not provide adequate definition of vehicular path from the crosswalk, particularly of interference with the heavy left-turning traffic on the Warring Street approach.

Crosswalk Across Derry Street - The revised plan shows the crosswalk to be relocated to the west side of the intersection. This forces pedestrians crossing between the northeast corner and the south side of Derby Street to cross and recross the traffic flows in the northwest quadrant, which they otherwise would not have to do. In this same regard, however, pedestrians crossing from the northwest corner to the east side of Derby Street presently must cross and recross the heavy left-turning traffic from the Warring Street approach.

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Location
WISCONSIN, Fond Du Lac County
US 151 - Wisconsin 26

Type of Intersection
3-way Y-type

Traffic Data

Submitted by
Wayne N. Volk
Engineer of Traffic Services
Wisconsin State Highway Commission
State Office Building
Madison 5, Wisconsin

Date Opened to Traffic
November 9, 1956

Design Vehicle: C50
Speeds: Posted Speeds 65 MPH daytime; 55 MPH night for passenger vehicles; 45 MPH for trucks

Comments by Committee Members

1. Eugene Maier - This is a good example of the use of channelization at a Y-type intersection to define and control the two major points of conflict. It appears that few accidents occurred at the intersection either before or after the channelization. I would question the use of the "YIELD" sign where eastbound traffic on Route 151 turning left onto Route 26 conflicts with westbound traffic on Route 151. A more positive control would appear desirable, but this observation is not supported by the accident experience.

2. Donald H. Sides - This pattern of channelization is typical of that evolved in many areas where an intersecting road joins a through highway at an angle of about 45 degrees. The designer has made good use of moderately curved alignment to introduce the divided sections.

The accident record does not prove the point but it would appear desirable that somewhat greater speeds be permitted. Additional stops have been placed in westbound US 151. This would have provided more separation between the decision points where US 151 traffic turns to the north on Wisconsin 26 and the crossing of westbound US 151. Also, the very flat angle crossing of the roadways would have been reduced.

The pictures indicate somewhat deficient signing. Possibly speed zone signs should be provided to encourage speeds lower than the legal 65 MPH.

Additional Comments by Wayne N. Volk - The "Yield to Traffic from Right" sign is not a standard "Yield" sign. It is not possible under our statutes to use the standard sign. The sign used merely reminds motorists of the statutory requirement to yield to traffic from the right. We are inclined to agree with Mr. Maier that it would appear desirable that a more positive control sign be used. However, we have found this type of control to be entirely satisfactory in a dozen or more situations located throughout the state. We would have removed stop signs at such crossings.

The number of southbound motorists on Highway 26 turning left to go east on Highway 151 and the reverse movement is very small. This is probably the major reason for the successful operation of these two turning lanes.

The short bituminous wedges were intended to induce through movements to stay in the right-hand lane and to identify the left-hand lane as being for the left turn. Since most motorists stay in the right lane and avoid the bituminous surface, this has not worked out as planned.

We have added some direction signs which were not shown on the original drawing, which may answer Mr. Sides' criticism.
Location
NEBRASKA, Omaha
42nd Street - Q Street

Type of Intersection
1-Way Y

Physical Data

Surface Type
Roadways: Portland cement concrete
Islands: Grass
Shoulders: Grass

Curbs: 6" vertical curb at all paving edges
Right-of-way Limits: Not critical

Traffic Data

Submitted by
Burt Whedon, City Traffic Engineer
30th City Hall
Omaha 2, Nebraska

Date Opened to Traffic
October 2, 1960

Type of Intersection
3-Way Wye

Surface Types
Roadways: Portland cement concrete
Islands: Grass
Shoulders: Grass

Curbs: 6" vertical curb at all paving edges
Right-of-way Limits: Not critical

Traffic Data

Design Vehicle: CS
Speeds: Posted Speed Limit: 35 MPH

Pedestrian: No Cross-Walks. Sidewalks on south side of Q Street only.

Operational Characteristics

Seems to operate satisfactorily, based on limited experience. Elements of design which contribute to any unsatisfactory operation: "Some indecision on the part of drivers on Q Street stopping for signal, - unsure just where to stop; No "Stop" line marked.

Figure 1: North leg looking Southwest

Figure 2: East leg looking West

Comments by Committee Members

1. I R. WEINBERG - I feel that separate left turn space will become a necessity soon. This could be accomplished by flattening the through curve and producing about a 10° of full left turn lane. (Perhaps advance green time on signal may suffice for a period.)

   An extended "ball nose" for traffic flow plus additional acceleration and gap-finding pavement will reduce the possibility of a stopped condition under the present sharp angle of merge with limited gap-finding pavement.

   Consideration of operation at merge points and therefore single lane (plus clearance) pavement with safe merge points: (a) From Q St. to North (merge point of flows B & E). Also at merge of flows C & F.

   (b) Southbound on 42nd St., turning left on Q St. could result in two abreast at the \"STOP\" light before left turn begins. Could cause conflict due to double left on green.

   I favor single lane (plus clearance) pavement width at merge points: (a) From Q St. to North (merge point of flows B & E). Also at merge of flows C & F.

   (b) Southbound on 42nd St. turning left on Q St. could result in two abreast at the \"STOP\" light before left turn begins. Could cause conflict due to double left on green.

   Additional Comments by BURT UHEDON - I believe that I subscribe to all the comments made by the reviewers except the very last one made by Irv Weinberg. The northbound movement on 42nd and turning left onto Q Street was designed for two lane operation at least for passenger cars which predominate at present. There seems to be no conflict caused by this since all the vehicles entering Q Street at this point are making the left turn onto Q. It seemed necessary in designing the intersection to provide two lane operation at this point in order to achieve the desired capacity.

   I may have neglected to mention when I originally sent this example that the traffic volumes shown do not reflect the design figures because 42nd Street north of this location was closed upon the opening of the intersection of 42nd and Q St. Q Street is now open to traffic for all vehicles and I believe this has substantially increased the traffic at this intersection.
UNDEVELOPED AREA

24" x 24" MERGING TRAFFIC

PARK AREA

24" x 24" Double Arrow

DO NOT ENTER

INDUSTRIAL AREA

ON Access to Q Street)

20,000 Lumen Mercury Vapor Luminaires

30' High

COLLISION DIAGRAM

4 Months After
Completion of Project
No Comparable Accident
Experience Before
North Leg Was Not Open

EXAMPLE Y-2

NEBRASKA, OMAHA
43RD STREET - Q STREET
EXAMPLE Y-3

Location
CALIFORNIA, San Diego
Mirantis Blvd. - Sunset Cliffs Blvd.
San Diego, California

Type of Intersection
3-Way Wye

Date Opened to Traffic
May, 1959

Physical Data

Grades: Less than 1% on all legs
Surface Type: Asphalt
Height of Curbs and Islands: 8"
Cross Section: Standard
Traffic Control Devices
Signals: Traffic Signal Standards are Type P-51 with 8" green, amber and red indications.
Markings: Double lines are yellow.
Lighting: Street Light Standards are Type III, 400 watt, 20,000 lumen mercury vapor with Type III distribution. Mast arm for street lights are 6'; for traffic signals 12', with 12" red and 8" green and amber indications. All other indications are 8".
Abutting Property is city park land that is at present new sand and adobe orange fill. No planning schedule or ultimate use plans are available.
Right-of-Way: No limits; city park land.

Traffic Data
Volumes: Mirantis Boulevard was built May 2, 1959. Prior to this Sunset Cliffs Boulevard had an A. D. T. of 7000 cars. The weekday A. D. T. on Mirantis Boulevard is 8,300.
Design Vehicle: C50
Speeds: Speed Limit is 40 MPH on all legs
Pedestrians: None

Operational Characteristics
Mirantis Boulevard was constructed primarily to provide a direct connection between the area at the north end of San Diego Bay and the new Mission Bay Recreational Park three miles to the north. On special occasions and summer weekends, the traffic volumes double. Overall operation is highly satisfactory.

Comments by Committee Members
1. GEORGE J. FISHER - Standard treatment well applied. What happens to northbound traffic on Mirantis that wants to turn east onto Sunset Cliffs? Also, westbound traffic on Sunset Cliffs that wants to go south on Mirantis?
Was accident experience improved?

2. CHARLES J. KEENE - The alignment of the left turn from Sunset to Mirantis makes it difficult to place signals for adequate visibility and clear meaning. The accident experience indicates that signal visibility might have been a contributing factor.

From the pavement width shown, it appears that the 8-inch asphaltic concrete curb or berm is placed at the edge of an 8-foot shoulder. The photographs show no delineation of the shoulder area and indicate use of the full width by traffic. If two-lane use is desired, a wider pavement would be appropriate. The narrowing effect at the end of the curve for northbound traffic on Sunset Cliffs causes the 8-inch asphaltic concrete curb to be placed in such a manner as to be hazardous.

Additional Comments by MARTIN J. BOUMAN - In response to Mr. Fisher's comments, this was new construction for Mirantis Boulevard; therefore there is no "before" accident data available. He also was concerned with turning movements at the intersection; namely, northbound on Mirantis turning east to Sunset Cliffs and westbound traffic on Sunset Cliffs turning to south on Mirantis. Since the first movement is a free right turn and the second movement is the one that passes through the control of the traffic signals, I assume that there is no error in cardinal directions. I would like to point out that there is extremely low demand for the northbound to westbound and for the eastbound to southbound moves. This improvement prohibits the northbound to westbound turn and discourages the eastbound to southbound turn.

In response to Mr. Keene's comments, we certainly agree that the alignment of the intersection makes it difficult to place signals for greatest visibility and clear meaning. Additional analysis of the accidents indicates that an electrical failure might have been involved in one occurrence. Mr. Keene offered additional comments concerning the advisability of delineating the shoulder area from the roadway area. At the present time in San Diego we are not experiencing any difficulty with this type of design. Traffic shows no indications of attempting to form a third lane in an obvious shoulder area such as this, even though there is no delineation or line of demarcation between the through lane and the shoulder area.

At the present time we have no reported accident experience involving the 8-inch asphaltic concrete curb that creates a narrowing effect at the end of the curve for northbound traffic on Sunset Cliffs Boulevard.
### Type of Intersection

<table>
<thead>
<tr>
<th>Type</th>
<th>Date Opened to Traffic</th>
<th>1958</th>
</tr>
</thead>
</table>

### Traffic Data

<table>
<thead>
<tr>
<th>Traffic Type</th>
<th>Southbound on Route 3</th>
<th>Northbound on Route 3</th>
<th>Southbound on US 1</th>
<th>Northbound on US 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>2.88%</td>
<td>2.0%</td>
<td>3.96%</td>
<td>2.57%</td>
</tr>
</tbody>
</table>

### Surface Type

- **Embankment:** 10' normal shoulders with 6' topfill
- **Shoulders:** 6' above pavement; grassed except where narrowing in case of diverger.
- **Island Height and Type:** 8" above pavement; grassed except where narrowing in case of diverger.

### Operational Characteristics

#### Comment on over-all operation of channelized intersection:

- **Speeds:** Posted speeds: 40 MPH

#### Comment on elements of the design which contribute to unsatisfactory operation:

- **Island Height and Type:** 8" above pavement; grassed except where narrowing in case of diverger.

### Additional Comments by Committee Members

1. **R. T. SHOAF** - While fundamentally the channelization looks quite reasonable and certainly must be vastly better than the former traffic circle, in regard to delays, the reported traffic accident experience would indicate that there is additional need for improvement.

   - **Lacking accident diagrams,** I suspect the current problems stem from two factors:
     1. **Fixed-time signals.**
     2. **Lack of understanding the US 9 fans and into Route 3 to a position of secondary importance.**

   - To overcome the first factor, I would consider channeling accident signals instead of fixed-time, making Route 1 & 9 the red entries. This is without knowing conditions as on distance from Secaucus Road and the need for southward coordination.

   - To overcome the second factor, I would consider making a left turn storage slot for northbound Rt. 1 & 9 to Rt. 3 rather than using a Y treatment type of storage, at the same time relocating the storage area for a crossing near the right side to southbound Rt. 1 & 9. This would also permit the merging left turn from Rt. 3 to north on Rt. 1 & 9 to be lengthened by close to 100 feet. This would also permit the extension of signal heads 1 & 2. The right turn from Rt. 3 to Jersey City would be free running, possibly with yield control.

2. **EUGENE MAIER** - This is a typical "suspender" type design which can be used effectively at a T-type intersection. Non-conflicting movements are carried through the intersection without delay and the major conflict in isolated and controlled with traffic signals.

   - Development adjacent to intersections of this type present difficult problems of access, particularly in an area such as this where the street network in the vicinity is limited. Control of access should be acquired, but is not always possible. Although the number of accidents after channelization remain about the same as before, the number of injury accidents is less. In the absence of a collision diagram, it is difficult to relate the accident experience with the design.

### Example 1/4

#### POSSIBLE REDESIGN AS WYE-INTERSECTION

<table>
<thead>
<tr>
<th>Route US 1 &amp; 9</th>
<th>Local reason (1)</th>
<th>Possibility and perhaps require this</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased Moving Distance</td>
<td>Turn</td>
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<tr>
<td>Increased Storage</td>
<td></td>
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<tr>
<td>Left Turn Storage Slot</td>
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</tr>
</tbody>
</table>

#### POSSIBLE REDESIGN AS T-INTERSECTION

<table>
<thead>
<tr>
<th>Route US 1 &amp; 9</th>
<th>Local reason (2)</th>
<th>Possibility and perhaps require this</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Comments on intersection:

- **R. T. SHOAF** - While fundamentally the channelization looks quite reasonable and certainly must be vastly better than the former traffic circle, in regard to delays, the reported traffic accident experience would indicate that there is additional need for improvement.
EXAMPLE Y-6

CONNECTICUT, Columbia
US 6 - US 64
Type of Intersection
3-Way Wye
Date Opened to Traffic
November, 1956

Physical Data

Grades: None in excess of 3°.
Surface Type: Shoulders are constructed of 2" hot asphalt concrete on 6" rolled gravel base. The islands are equipped with reflecting concrete curbing 4" in height while the remaining curbing is bituminous lip type 6" in height. Both types of curbing are mountable.
Cross Section: Standard treatment

Lighting: Highway illumination consisting of mercury vapor units, 400 watt, mounted on wood poles at a height of 25' and providing an average 0.8 foot candles maintained, adequately identify the channelized area during the night-time hours.

Traffic Data

Volume: 1960 Average Daily Traffic; Route 6 west leg 4100; Route 6 east leg 6800; Route 6A 3100. The one-way approach ADT Is one-half of these volumes.
Design Vehicle: C50
Speeds: Posted speed limit on all routes is 40 MPH.

Accident experience at this location was not significant either before or after the installation of a worthwhile collision diagram.

No pedestrians in this area.

Operational Characteristics

As indicated in the average daily traffic, considerable left-turn movement occurs from the west leg of Route 6 into Route 6A. The original installation consisted of a non-channelized "Y" intersection and the left-turn movement from the east on Route 6 into Route 6A had to be stored in the through lane of Route 6. Congestion during peak periods and accidents resulted. With the construction of the deceleration lane for westbound traffic and storage facilities for vehicles stopped for the left-turn movement into Route 6 under the control of the modified signal installation, the difficulty existing at this location was eliminated.

Due to economies in construction, an unsatisfactory condition of minor importance resulted where the right turn from the east leg of Route 6 connected with existing Route 6A. Route 6A at this location is on a banked section with the end result that the connection of the right turn from Route 6 occurs with an adverse cross slope at the point where vehicles enter Route 6A. Accident experience does not indicate this to be of any importance and to date no changes have been deemed necessary in the particulars of design.

Figure 1: Aerial view

Comments by Committee Members

1. H. T. DRURY - It appears from the ADT that this is a satisfactory channelization. I do question the need for traffic signals rather than STOP signs to control the minor cross movements. It would appear that the storage space provided more relief than the signals. Unless signals are actually needed, they should be avoided, because they cause delay and tend to increase accidents. If few occur, they should be used only for a short peak period, they should flash at other times.

2. IRV. WEINBERG - This design should work well if well marked by signs and paint markings. I have two comments:
   (a) Since this type of design is not as common as other "Tees" and "Wyes", it is conceivable that a driver (a stranger) proceeding north on Route 6A wanting to turn west on Route 6 would want to use the most "logical positioned" channel (which appears as if it should be the channel connecting Route 6 to Route 6A for traffic west on Route 6). To prevent this wrong maneuver, I would recommend a curb from the vicinity of the town road to the "bull nose" instead of paint lines.
   (b) It appears that there is an abrupt termination of pavement for vehicles on Route 6 to south on Route 6A at the point where it meets and merges with the channel taking westbound on Route 6 to south on Route 6A. I would recommend additional pavement so that a stop condition will not result. A driver stopped and required to look back for approaching vehicles would result in a more dangerous situation than a right stop.

The way the diagram appears, there is not enough merge - gap selection pavement. More is recommended.
NOTE: White Traffic Line Paint Used for Channelization and Pavement Markings

Channelization Completed February 2, 1960

NOTE: There are no reported accidents for the 12 month period AFTER CHANNELIZATION

EXAMPLE Y-5
PENNSYLVANIA, TROUT RUN, LYCOMING COUNTY
ROUTE US 15 - ROUTE PENNSYLVANIA 14
EXAMPLE Y-5

PENNSYLVANIA, Trout Run
Locality, Route US 15 - Laurel Run, Clarion County, Pennsylvania

Submitted by
Edmund R. Ricker, Director
Traffic Engineering Bureau
Pennsylvania Department of Highways
Harrisburg, Pennsylvania

Date Submitted
February, 1960

Type of Intersection
3-Way Y

Physical Data

Type of Curves and Islands: The islands are grass and there are no curbs.

Traffic Control Devices
Lighting: The intersection is not illuminated; therefore there are no poles or any other types of luminaires.

Traffic Operations: Since this is a rural location there is no mass transit present.

Right-of-Way: Since sufficient right-of-way had been previously purchased by the Department, the design of the intersection was not in any way influenced by right-of-way limitations.

Traffic Data

Design Vehicle: C50; the design was very directly influenced by the presence of many large trucks on both Routes 15 and 14.

Speeds: The 85 percentile speed is not available, nor is there a restricted speed zone. However, there are 35 MPH SAFE SPEED signs used in conjunction with warning signs on Route US 15.

Operational Characteristics

Since the installation of the channelization, the intersection has been operating very safely and efficiently.

The major physical characteristic which tends to contribute to the operational problem is the alignment of the roadway on the southern leg of the intersection, which is a vertical curve in conjunction with a horizontal curve.

Figure 1: Before Channelization. Northbound approach to the intersection approximately 300' away. Note that intersection is hidden by alignment of highway.

Figure 2: Before Channelization. Northbound approach to intersection.

Figure 3: After Channelization. Looking Northeast into traffic island; Route 15 on left, Route 16 on right.

Figure 4: After Channelization. Northbound approach to Intersection; Route 14 right, Route 15 left. Note Southbound traffic from Route 16 using channelization.

Figure 5: After Channelization. Southbound approach to intersection along Route 15. Note channel signs and markings used to channelize Southbound traffic approaching Route 15.

Figure 6: After Channelization. Southbound approach along Route 15.

Commission by Committee Members

1. GEORGE J. FISHER - This standard treatment has obviously proven to be satisfactory since the number of accidents has been greatly reduced. Better operations could be obtained if the Island were curbed and extended east Pennsylvania 14 forming a funnel for southbound traffic.

2. ROBERT E. DUNN - This example is an inexpensive and effective treatment of the "Y" type intersection problem. Its effectiveness is achieved through the use of traffic signs, paint lines and guide posts. However, the aesthetic values of design should not be overlooked. Raised curb, planted or surfaced Islands, illumination and flashing beacons add considerably to the visibility and attractiveness of a channelized area. This in turn makes the device more readily recognized for its function and materially adds to the safety of operation that channelization is intended to provide.

Additional Comments by EDMUND R. RICKER - Both George Fisher's and Robert Dunn's comments are well taken regarding the use of curbing, landscaping, and as forth to increase the effectiveness of this type of treatment. Also, extending the island, as Fisher suggested, would be desirable. These things were not done, however, because the channelization is regarded as a temporary measure until the intersection is reconstructed. Route 15 will probably be relocated and for that reason we do not feel justified in a large expenditure for a temporary physical change.

As can be seen from the photographs, a cross connection between Routes 15 and 16 existed prior to the channelization to handle the turning movements. This connection was widened this crossing, erecting signs and painting necessary markings on southern traffic along Route 15 to use the connection. The cross connection was done Route 16 traffic southbound had less than 250' of sight distance southbound from its normal stopping place and in addition was faced with a long path to cross northbound 15 traffic to get to the right lane before going southbound. By channelizing this movement so that the approach to US 15 is approximately 90 degrees, the sight distance was increased to approximately 450' and the time needed to clear the intersection was reduced approximately 50%.
TRAFFIC CONTROL SIGNAL LAYOUT
SEQUENCE AND TIMING

<table>
<thead>
<tr>
<th>Face</th>
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<th>Side St.</th>
<th>Artery</th>
<th>Artery</th>
<th>Timing</th>
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<tr>
<td>1 &amp; 4</td>
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<td>C</td>
<td>A</td>
<td>A</td>
<td>11&quot;</td>
</tr>
<tr>
<td>2 &amp; 3</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>5&quot;</td>
</tr>
</tbody>
</table>

Artery Artery Energ Min. Clear Flash

Divided Highway Ends

EXAMPLE Y-6

CONNECTICUT, COLUMBIA
US 6 - US 6A
**Location**

CONNECTICUT, East Litchfield
Route 8 - Route 116

**Type of Intersection**

3-way

**Physical Data**

Grades: None in excess of 3%

Surface Type

Roadway: 11" hot asphalt concrete on 1" bituminous concrete binder course on 3" bituminous macadam base on 7" broken stone base.

Shoulders: 21" bituminous macadam on 6" rolled gravel base.

Islands: Lomed and seeded.

Curbline: All mountable type 4" in height; bituminous concrete lip curbing for roadways where shown on plan; concrete park curbing for islands.

Other Details are standard design.

Traffic Control Devices

Signals: The intersection is not signalized.

Lighting: The intersection is not illuminated.

Abutment Space: The abutting land is undeveloped with no commercial value due to the differential between abutting property and existing ground elevation (12-20 feet). It is further protected from shifting land interference insomuch as the abutments are embanked.

Transit Operations: No transit stops are made here.

**Traffic Data**

Volume: 1960 Average Daily Traffic: Route 116, 1350; Route 8 North, 4300; Route 8 South, 6700. The one-way approach AADT is one-half of these volumes.

Design Vehicle: CGO

Speed: The posted speed limit on Route 8 through the intersection area is 40 MPH and that on Route 116 in 45 MPH.

Accidents: This is a completely re-located section of highway and no previous experience is available.

Pedestrian: None

**Operational Characteristics**

Observations of the over-all operation of the intersection appear to be entirely satisfactory.

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**Example Y-3**

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**Comments by Committee Members**

1. **ROBERT E. HANH** - This illustration is a near classic example of "Y" type intersection channelization. It illustrates the worst condition by an almost perfect application of the listed principles.

   The location of the two bridge structures, however, confined the area of design. The application did not provide the larger locations having higher traffic volumes could well utilize a larger land area. This would reduce the cost of the directional lane on the west approach of Route 8 to construct a divided island with a left-turn storage lane for traffic directed to the east on Route 116. The removal of slow moving turning left traffic from the heavier traveled northbound lane on Route 8 would provide safer and faster movement for through traffic, as well as a refuge area for turning vehicles.

   The presence of adequate intersection illumination would also measurably increase the safety of operation during the hours of darkness.

2. **EVEL KNOX** - This is a good solution for the volume of existing traffic. Accident data are not included in the comments, but a condition does exist which could be improved. A left turn median lane for traffic north-west bound on Route 8 needed for west on Route 116 would reduce the hazard to the standing vehicles. A minimum pointed left turn lane to keep the through lane open can be provided at a nominal cost by cutting back the islands and reducing the shoulders to possibly 5 feet.

   The sign striping for southbound traffic on Route 8 has a gap of 60 feet for vehicles turning right onto Route 116. The construction plan indicates the sign to cross the path of the turning vehicles and the gap located alongside the triangular central area between the edges of the main roadway and exit ramp. It would be more appropriate to locate the gap in the edge stripe in the path of the turning vehicles. A gore stripe along both sides of the central area would reduce conflicts with the curb nose and direct the turning vehicles.

   Principles Involved:

   1. Reduction of relative speed and impact energy
   2. Controlling the area of conflict
   3. Crossing of vehicle paths at near right angles
   4. Merging traffic streams at small angles
   5. Providing refuge for turning and crossing vehicles
   6. Locations for traffic control devices

**Figure 1: Aerial view looking Northwest**
### Type of Intersection

3-Way (N-S-S-E-SW/SE)

### Physical Data

- **Location**: Delaware, Delaware's Corners
- **Newport Gap Pike (Delaware 41)**
- **Lancaster Pike

### Traffic Data

- **Date Opened to Traffic**: May 20, 1955
- **P. O. Box 151
- **Delaware State Highway Department
- **Chief Engineer
- **Dover, Delaware

### Description of Traffic

- **Traffic Control Devices**: Guard posts and rumble strip.
- **Markings**: Normal
- **Signs**: Where records of equipment signs or markings were not available, they were not secured, as no time was available for field trips.

### Design Vehicle

- **C50
- **90% of all travel

### Operational Characteristics

- **Although the signal shown is three-phase, it normally operates two-phase as
- **Traffic volumes are not critical here except possibly on summer week-ends.

### Additional Comments

- **The dark stripe between the lanes is a rumble strip several hundred feet long in front of the dividing island.
- **The photographs Indicate a relatively new installation but, even so, the accident experience In such that I doubt that any major change is warranted except to turn the signals off. Since sight distance is good, there is probably more chance that someone will run a red signal light and cause an accident than if the two left turns are controlled by STOP signs (flashing red) only.

### Suggested Revision

- **by Ross T. Shoaf
- **Shaded areas indicate roadway narrowing by painted island treatment
- **Chevrons indicate raised pavement bars

### Comments by Committee Members

1. **VARIED TRAFFIC** - Three-way traffic activated signalized intersection of two state highways. Relatively low volumes—no immediate plans for improvement of approach roadways.

   - It appears from the above, and in consideration of the relative traffic flows, that a few minor revisions would result in a safer and perhaps more efficient operation.

   - The suggested sketch emphasizes driver guidance through the use of pavement markings. In particular, the design between Route 41 southbound and Route 48 northbound may suggest the merging of two lanes to one lane rather than three to two, as indicated in the original plan. Until such time as Route 41 is widened to four lanes, the proposed intersection (volume counts suggest that this roadway will be widened first), it appears that the revised layout is more compatible with the approach roadways.

   - It is suggested that additional pavement be added to Route 48, south of the intersection, as shown. This will form an adequate merging area to accommodate the two-lane storage as it leaves the intersection control point, a more appropriate entrance for the right-turn movement from Route 41 and increased maneuverability with respect to interference to through traffic caused by turn around or local vehicles entering the main opening. It is suggested that the opening between Route 41 southbound and Route 48 southbound be closed and that local traffic be routed via the westbound roadway located between these two routes. This movement can be facilitated by cutting back the acute corner, as shown.

2. **K. T. SHOOP** - The fundamentals of channelization appear to be generally good. The changes suggested by Mr. Travers, however, are significant improvements in design.

   - From the traffic volume involved, I believe the greatest efficiency would be gained by placing the traffic signals on a flashing operation, in which case Mr. Travers' left turn revisions would be of more immediate value.

   - The photographs indicate a relatively new installation but, even so, the accident experience suggests that such a change may have a major impact. I doubt that any major change is warranted except to turn the signals off. Since sight distance is good, there is probably more chance that someone will run a red signal light and cause an accident than if the two left turns are controlled by STOP signs (flashing red) only.

   - In connection with a signal change, I would reduce both left turns to one lane road by means of paint (see small sketch).

   - If I were designing this intersection initially, I believe the only major change I would have included would be to taper the islands introduced in the middle of moving traffic and install advance raised bars (see small sketch).

### Additional Comments by WILLIAM R. CARROLL, Traffic Engineer, Delaware State Highway Department

- We would agree with the reviewers on most Items if the intersection were being newly designed and constructed. Furthermore, if we were experiencing any real difficulty with the width of the left turn roadways, we would reduce the width as suggested. We agree that the widths should be reduced, but it will be done quite simply with edge lines in accordance with the desired travel path, as shown on the accompanying revision. This method has proved successful at other locations.

   - The suggested revision also indicates possible use of future highway lighting for the area.

   - The opening between Route 41 southbound and Route 48 southbound exists by right-of-way agreement, since it is opposite the access to a private estate from which necessary land for construction of the intersection was obtained. Traffic signals in rural areas are placed on flashing operations during light traffic periods. Consideration is being given to the intersection in question at this time.
EXAMPLE Y-8

DELWARE, KEIDEL'S CORNERS
NEWPORT GAP (DELAWARE 41) - LANCASTER PIKE

TRAFFIC VOLUMES
1960 ACT

NOTE: All Turning Volumes are estimated from the results of 4 hours of hourly volume counts by the Traffic Section, 2 hours during the AM Peak and 2 hours during the PM Peak.

TRAFFIC VOLUMES
1960 ACT

NOTE: Roadway Surfaces - Cement Concrete
       Shoulders - Noiseless Surface Treatment
       Area Characterization - Rural Intersection
       at 1/2-Mile Radius from Village

<table>
<thead>
<tr>
<th>Head</th>
<th>Peak Hours</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newport Gap Pike</td>
<td>200 345</td>
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</tr>
<tr>
<td>Lancaster Pike West</td>
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<tr>
<td>Lancaster Pike East</td>
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</tr>
</tbody>
</table>

NOTE: Roadway Surfaces - Cement Concrete
       Shoulders - Noiseless Surface Treatment
       Area Characterization - Rural Intersection
       at 1/2-Mile Radius from Village
Location
DELAWARE, Little Heaven
US Route 113 - US Route 113A

Type of Intersection
3-Way Type

Submitted by
Ernest A. Davidson, Chief Engineer
Delaware State Highway Department
P.O. Box 151
Dover, Delaware

Date Opened to Traffic
1956

Grades: None over 3%
Surface Type: Cement concrete
Islands: Grass, same elevation as roadway (slight slope for drainage). No curb.
Shoulders: Bituminous surface treatment
Cross Section: Normal
Markings: The highway painting has recently been changed to the design as shown on the drawing.

Shutting Property: Rural, with a local accumulation of scattered service stations and houses.

Traffic Data
Design Vehicle: C50
Speeds: US Route 113 - 50 MPH
US Route 113A - 50 MPH
Pedestrian: No pedestrian provisions; small volume.

Operational Characteristics
This intersection was rebuilt five years ago because of the very heavy summer weekend traffic to and from the down-state shore resorts. It was lighted by 250 watt mercury vapor lamps soon after it was built, because of the heavy northbound summer Sunday night traffic. Note that the highway painting has recently been changed to the design shown on the drawing rather than that shown on the photographs which were made in 1956.

There has been no particular history of accidents or malfunctioning of this intersection.

Physical Data

Traffic Data

Figure 1: US Route 113 looking North from the intersection, showing details of crossover and intersecting road. Note that the markings in the picture have been later revised as shown on the drawing.

Figure 2: US Route 113 looking North into the intersection, showing details of approach from the South. The drawing shows a later revision of the markings that those indicated in the picture.

Comments by Committee Members
1. ERL MORSINELI - This is a good basic channelized "Y" design, modified to bring in County Road 372. The moderate traffic volume at the signal and lack of accident history indicate that the plan is adequate.

SUGGESTED REVISION
by William R. Carrow

2. DONALD H. EIES - The indicated channelization is typical for such flat angle layouts. The accident record indicates that motorists readily understand the design. There is indication that U-turns are made under the signalized crossing in lieu of the County Road crossover. Note the worn grass. Signs do not seem to be placed to warn of wrong-way operation. Also, the pavement markings provided for the major movements might cause some erratic operation on the part of traffic to and from the County Road.

Additional Comments by WILLIAM R. CARR, Traffic Engineer, Delaware State Highway Department - The intersection was re-studied by our Traffic Section and Mr. Moskowitz's idea was given consideration. Highway painting was used to merge lanes heading south. The revised sketch indicates the change made here.

Two "No Turns" signs were added on the northbound lane, and on the reverse side of the signs will be two "Do Not Enter" signs.

Additional right-of-way is available on either side of the road for reconstruction at some future date.

The bare spot at the intersection is a concrete pad around a catch basin.
Location
OREGON, near Salem
Oregon 22 - Oregon 223

Type of Intersection
3-way Wye

Physical Data
Submitted by
F. B. Crandall, Traffic Engineer
Oregon State Highway Department
Salem, Oregon

Date Opened to Traffic
July 30, 1957

Surface Type
Inland Curbs: Non-mountable, 1" high
Shoulder: 4' oiled plus 1' gravel - total 8'

Typical cross section of Raised Asphalt Jiggle Bar: 8" wide, 1" high on each side and 2" high in the middle.

Traffic Control Devices
Markings: Jiggle bar areas are outlined with yellow stripe.

Shutting Property: Rural; see photograph.

Traffic Data
Design Vehicle: C50
Pedestrian: Hone

Operational Characteristics
This intersection evolved by reason of a virgin realignment project wherein the channelization layout was part of the original construction. Based on general experience with this type of intersection I do believe that the one reported accident within a year’s period indicates that it has done a good job. The intersection is pretty much rural in nature, being approximately ten miles due west from our capital city, Salem, which is the only near metropolitan area. Again, Oregon 22 is a coast feeder for people in the Salem area and experiences high seasonal peaks with a maximum Sunday running almost three times the ADT.

I might mention that we had to make a minor adjustment in the originally constructed layout. The initial construction did not provide an adequate run of acceleration for the merging movements between movements ‘A’ and ‘B’. We subsequently did some pavement widening and extended this merging area with a projection run of jiggle bars on the trailing nose of the originally constructed curved island. The plan submitted includes this revision of the initial installation.

Comments by Committee Members
1. WESLEY B. BELLIS - This is a good design type for a "Y" intersection. The installation of traffic signals would allow the intersection to accommodate more than twice the volume experienced on peak Sundays.

2. WARREN TRAVERS - The following modifications are suggested:
   a. "Paint out" recovery areas beyond turnouts to better delineate vehicle paths for both through and turning traffic.
   b. Stripe "C" ramp with solid striping to better separate opposing traffic flows.
   c. "Break" centerline of Route 22 at point where "C" movement enters.
   d. Install a stop line to augment stop signs for "C" movement.

Additional Comments by F. B. CRANDALL - One of the reviewers suggests that the recovery areas beyond the turnouts be "painted out" to better delineate vehicle paths. Probably the prime reason we have not incorporated such treatment is the maintenance aspect. There is also the possibility that such paint markings might be misconstrued for raised islands at night, resulting in sudden maneuvers and thereby nullify the basic purpose of providing recovery areas.

It has been suggested that a solid instead of a dashed stripe be painted on the "C" ramp which is the cut-back movement from north to west and reverse. This comment is well taken and there is no reason why there should not be a solid stripe.
COLLISION DIAGRAM
12 Months After Construction
One Property Damage Accident

Overhead Span Wire Mounted Sign

DALLAS
KINGS VALLEY
TO THE COAST
VALLEY JUNCTION

TILLAMOOK
VALLEY JUNCTION

TILLAMOOK

SALEM

DALLAS

W:RGINING TRAFFIC
ON LEFT

V-TRAFFIC SEPARATOR
AHEAD

TRAFFIC VOLUMES

Movement Ave. Daily Traffic
A 780
B 1,290
C 15

Maximum Sunday = 2.8 times A/D

EXAMPLE Y-10
OREGON, near SALEM
OREGON 22 - OREGON 211
The original intersection was restricted due to insufficient right-of-way. The physical arrangement made it necessary to stop Movement E (East Grand Avenue--Garland Road) to allow Movement B to proceed without conflict. With this operation the capacity of the entire intersection was restricted due to the fact that the peak period for Movement E was the same as for Movement B. Movement E, of course, would be for flow A, while Movement B would be for flow C. The comments concerning the location of bus stops are well taken. The curvatures could be flattened out and proper merging areas could be designed.

In designing the improved intersection it was determined that any appreciable increase in the capacity of the intersection must be obtained by allowing Movement E to proceed uncontrollably by signals. Thus, Movements E and B merge rather than conflict. You will note that the two lanes provided for each of these movements become almost parallel at the point of mergence and that four full lanes are provided after they merge for a distance before the transition is made into the normal three-lane section.

In designing the improved intersection it was determined that any appreciable increase in the capacity of the intersection must be obtained by allowing Movement E to proceed uncontrollably by signals. Thus, Movements E and B merge rather than conflict. You will note that the two lanes provided for each of these movements become almost parallel at the point of mergence and that four full lanes are provided after they merge for a distance before the transition is made into the normal three-lane section.

A considerable amount of additional right-of-way was obtained so that all curves could be flattened out and proper merging areas could be designed.
EXAMPLE FR-1

Location

MICHIGAN, Dearborn
69 W 16 (Telegraph Road) - Ford Road

Type of Intersection

4-way Right Angle

Submitted by

Harold G. Bauerle
Director of Traffic Division
Michigan State Highway Dept.
Lansing, Michigan

DATE OPENED TO TRAFFIC

December, 1959

Operational Characteristics

Traffic Data

Surface Type

Roadways: Telegraph Road northbound, bituminous cap; Ford Road north-bound, bituminous cap; other roadways, concrete.

Islands: White concrete curb (backfilled and seeded); 8-foot divider strip.

Traffic Control Devices

Signs: NO LEFT TURN case signs at the principal intersection.

Characteristics of land use: Commercial in the southeast and northeast quadrants; commercial in the northwest and residential in the southwest quadrants.

Grades: Not of any consequence

Surface Type

Roadways: Telegraph Road northbound, bituminous cap; Ford Road eastbound, bituminous cap; other roadways, concrete.

Islands: White concrete curb (backfilled and seeded); 8-foot divider strip.

Traffic Control Devices

Signs: NO LEFT TURN case signs at the principal intersection.

Characteristics of land use: Commercial in the southeast and northeast quadrants; commercial in the northwest and residential in the southwest quadrants.

Operational Characteristics

Design Vehicle: C30

Speeds: Posted speed limits for area 40 MPH

Accidents: Accident experience not available at this time

The original proposal for improving this location was to construct a diamond interchange. However, a detailed analysis indicated that this type of interchange does not provide adequate turning capacity; and in addition, the high turning volumes made this type of interchange unsuitable for use with adjacent highway facilities. The design combines special left-turn treatments of three varieties into one intersection as follows:

1. Left turns from the south to the west have a directional channelization path.
2. Left turns from the north to the east use a right quadrant left turn facility.
3. Left turns from the east to the south and from the west to the north use a right turn and median-lane maneuver.

Signal progression is provided for all left-turning movements. This location is currently the subject of a special study for operational efficiency, which is scheduled to be completed by July 1961. All observations to date indicate that this design operates beautifully.

This intersection has been opened to traffic a little over a year, and no conclusive before-and-after accident comparison is available.

Comments by Committee Members

1. ROBERT E. DUNN - This is an intersection of two high-volume roadways, each carrying approximately 30,000 vehicles per day. In many cases, there would be little question as to warrants for an interchange separation. The designers in this instance, have preserved the fluidity of the intersection-at-grade, by the separation of the major conflicting movements.

The design involves an elongated traffic circle element that provides for some left turn movements that are prohibited at the intersection proper. This causes circuitry of traffic with double entry into the intersection complex and weaving across through traffic lanes. The "turn-right to go left" directional lane in the northeast quadrant, and the oblique angle left-turn directional lane in the southeast quadrant are probably operational through an ingenious signal plan that creates gaps in the through traffic streams for the crossing and storage of turning traffic. This is a delicately balanced arrangement that might not be suitable for general application in many other locations.

The design appears to be correct and the condition warranting the characteristics is basically satisfying the five major principles involved: providing refining areas for turning and crossing traffic; separating conflict points, blocking prohibited turns, providing locations for traffic control devices, and allowing effective signal control for complex turning movements. The reported statement that "...this design operates beautifully", and the indicated high volumes of traffic that it handles, make the reviewer wish he had the opportunity to see it - so that he could believe it.

2. WESLEY K. BELGIS - An ingenious and exciting design worthy of competing with grade separation design. The volumes are very heavy, with heavy left-turning volumes. The percent of trucks should be noted. There are no areas with cross weave. I would think that left turn off of Telegraph Road northbound would work better if signalized. I also feel that the left turn on to Ford Road eastbound would be better if signalized. But, I also know that these types of crossings produce less time delays than if signalized. The signal cycle length and timing should be noted.

Additional Comments by R. C. COOPER, Director of Traffic Division, December, 1959 - Mr. Bellis commented that the left turn off Telegraph Road northbound would work better if signalized. Actually, this turning movement operates in the shadow of the signal from Ford Road. The right-turn off Telegraph northbound would work better if signalized. Actually, Mr. Bellis made the correct statement, "There is no conflict with grade separation design. The volumes are very heavy, with heavy turning volumes. The percent of trucks should be noted. There are no areas with cross weave." Mr. Dunn further commented that the design is one that solves the problem of separating conflict points, blocking prohibited turns, providing locations for traffic control devices, and allowing effective signal control for complex turning movements. The reported statement that "...this design operates beautifully", and the indicated high volumes of traffic that it handles, make the reviewer wish he had the opportunity to see it - so that he could believe it.

The southbound to eastbound left-turn movement onto Ford Road can also be completed in the shadow of the signal, but must turn onto a separate lane on the median side of traffic stopping for the signal on Ford Road at Telegraph Road. As Mr. Bellis stated, "This type of crossing produces less delay than if signalized." Our accident experience, on our existing arrangements of this kind, indicates a very low accident rate.

Mr. Robert E. Dunn commented that there is weaving across through traffic lanes. Actually Mr. Bellis made the comment that there are no areas with cross weave. Mr. Dunn further commented that the design is one that solves the problem of separating conflict points, blocking prohibited turns, providing locations for traffic control devices, and allowing effective signal control for complex turning movements. The reported statement that "...this design operates beautifully", and the indicated high volumes of traffic that it handles, make the reviewer wish he had the opportunity to see it - so that he could believe it.
EXAMPLE PA-2

ILLINOIS, Bureau County, near Normandy
Illinois Route 92 - Illinois Route 88

Type of Intersection
4-way Right Angle

Submitted by
H. K. Lingle, Engineer of Traffic
Illinois Division of Highways
Springfield, Illinois

Date Opened to Traffic
October, 1958

ILLINOIS, Bureau County, near Normandy
Illinois Route 92 - Illinois Route 88

Submitted by
H. K. Lingle, Engineer of Traffic
Illinois Division of Highways
Springfield, Illinois

Type of Intersection
4-way Right Angle

Transit Operations: No bus stops

Traffic Data
Design Vehicle: SU

Operational Characterization
Elements controlling design: Route 92 is the preference route. Present traffic control is a 4-way stop. Existing pavement widths are sufficient for capacity. The layout eliminates additional points of conflict where turning roadways enter the main highway and brings the geometries up to present standards. The 3-centered curve is based on SU Design Vehicle.

The photograph is a view, looking southwest, on the intersection of Route 92 with Illinois Route 88 south of Sterling in Bureau County. Prior to its reconstruction, this intersection had the highest accident rate in the District, with an average rate of 8.7 for the four years preceding channelization. This rate was quite high, since an intersection with an accident rate of 4.0 is considered to be "accident prone". Subsequent to the construction of the channelization, there has been no accidents reported at this intersection. If accidents had continued to occur at the average rate prior to channelization, there would have been approximately 20 accidents during the period since October, 1958. The prevention of these 20 accidents has saved several thousands of dollars of property damage and an unknown number of injuries and deaths. No separate turning lanes have been provided at this location to increase capacity.

The layout minimizes the number of conflicting movements, reducing the possibility of accidents. The interchanges in the intersection reduce the operational safety of the intersection. From the results of our survey, it appears that the islands are doing their job.

Comments by Committee Members

1. C. J. KEESBE - This design appears to be an adequate treatment for the purpose of increasing operational safety of the intersection.
   The need for the 4-way stop sign is questionable for the volumes shown.
   The standard "KEEP RIGHT" signs probably would be more easily understood than the "ONE WAY" and "ONE WAY DO NOT ENTER" signs on the divisional islands.

2. R. J. SHEAF - I concur with the comments of C. J. Keese.

Additional Comments by M. K. LINGLE - We concur with Mr. C. J. Keese's comments concerning this intersection with regard to the four-way stop control. We might mention that volume-wise the four-way stop barely meets the State of Illinois warrants for a four-way stop control. However, in view of the high number of accidents that could be reduced by a four-way stop control, we felt justified in permitting it at this location. Mr. Keese comments on the usage of certain signs at the intersection. These signs have been erected substantially in conformance with the 1958 edition of the State of Illinois Manual of Uniform Traffic Control Devices. As you are well aware, the signs do not conform to the 1961 edition of the Federal Manual on Uniform Traffic Control Devices. The State of Illinois is presently revising its manual to conform with the new federal manual.

The two intersecting routes extend away from the intersection on a straight horizontal alignment for a distance of at least five miles. These highways are believed by the Illinois Division of Highways to be below standard design. The motorists are encouraged to an impending hazard, the intersection. This appears to be true at many of the similar intersections throughout the State where a complete reconstruction and channelization has been accomplished.

We do not believe that the reduction of the accident rate can be attributed entirely to the introduction of channelization which was done as part of the reconstruction of this intersection. There are numerous factors which influence the accident rates here, such as better stop sign placement and concentration of the conflict points at one location. The old intersection had four-way turning roadways in all quadrants concentric with the existing right-of-way lines.

Figure 1: Aerial view of the intersection
Type of Intersection
US 290 (Koenig Lane)
TEXAS, Austin
US 183 (Airport Blvd.)

Cross Section: Not unusual
Grades: Not over 311. Vertical curve data not critical.
4-way, Right Angle

Operational Characteristics
Abutting Property: No entrances
Roadways: Asphaltic concrete
Islands: Consist of 6" vertical barrier curb, topped with grass.

Comments on over-all operation of the channelized intersection:
As can be seen, the Intersection exists on a curved section of the major street (Airport Boulevard). The left turn lane for northbound traffic is partially shaded or obscured, due primarily to a flat grade and to the existence of an 8" rolled-face curb. This condition could be improved by increasing the radius of the curve and reconstructing the curb several feet to the left of where it is now located. It would have been desirable to locate the "through vehicle" detectors on all approaches possibly 10' or 15' farther from the stop lines - at a location which would have prevented the detecting of right-turning vehicles, especially since right turns are in heavy volume. Due to the excessive width of the intersection in an east-west direction, it was felt that extending detectors would be desirable for slow-moving vehicles. The use of those detectors is quite satisfactory for the vehicle interval may be cut to a minimum. This results in no undue extension of two major highway routes, and a scaled down modification at the crossings of principal city arterials.

Additional Comments by WALTER H. KLAPPROTH - The "through" vehicle detectors are located about 70 to 75' from the stop line and this was primarily due to the length of the islands. This appears to be a considerable improvement over the four-turn lanes. The three-phase actuated traffic signal with its skip features allows for the efficient and orderly movement of vehicles through the focus of the intersection. The left-turning movement is controlled by a "stop" and "yield" signal and channelization control of a major intersection having 8,000 to 9,000 vehicles per day on each of four approaches. The curvature in the north-south route (U.S. 183), however, somewhat complicates the left-turn lane design. The principles involved, over-the-lane, are adequately applied in this design. The major turning movements between the north and the east approaches are controlled by a "stop" and "yield" signal and channelization control of a major intersection having 8,000 to 9,000 vehicles per day on each of four approaches. The curvature in the north-south route (U.S. 183), however, somewhat complicates the left-turn lane design. The three-phase actuated traffic signal with its skip features allows for the efficient and orderly movement of vehicles through the focus of the intersection.

As far as the detectors in the left-turn lanes are concerned, they are located about 70' from the stop line and this distance does not require an exceptionally long initial or vehicle extension interval. In fact, these intervals are set at 5 and 4 seconds respectively. From the experience at one or two other intersections, it appears that the detectors for the left turn should be located at about 60' to 70' from the stop line in order to obtain vehicular movement over the detector at an earlier time after the beginning of the initial period.

Our experience at this intersection has been most gratifying. There have been only four collisions this year, none of which involved movement from the left turn lane. This appears to be a considerable improvement over the fourteen collisions which occurred at this intersection in 1958. Only five of the colli­

Comments by Committee Members
1. RAUL MSentz - The author's comments appear to cover practically all conditions.
2. ROBERT H. BOW - This is a fairly well executed example of traffic signal and channelization control of a crossing between two major roadways. The left-turn lane is extended concurrently with the through lanes. This will provide an easy use for left turn vehicles and also lengthen the deceleration lane which appears to be short.

Figure 1: An aerial view looking northeast. A large truck turning left from northbound to southbound.

Figure 2: Aerial view looking west

Figure 3: Aerial view looking southwest
Signal Control: 3-Phase fully actuated controller with 2 minor movement controllers. Although a 2-Phase controller would suffice, the 3-Phase controller will achieve greater flexibility and "skip" features as indicated in the above phase diagram.

NOTE:
1. Prior to revisions the Koenig Lane (West) approach did not exist, as the intersection was "Tee" at that time.
2. No aerial photos of "prior" conditions are available.
3. No pedestrian facilities exist at this location.
4. All detectors located 70' from stop line.
5. Design vehicle CGS.
6. Open fields completely surround the intersection.
7. No transit facilities at this location.
8. All detectors located 70' from stop line.
9. No pedestrian facilities.
10. Prior to revisions the Koenig Lane (West) approach did not exist, as the intersection was "Tee" at that time.

EXAMPLE FR-3
TEXAS, AUSTIN
US 183 (AIRPORT BLVD.) - US 290 (KOENIG LANE)
Submission by
J. R. Henderson
Planning and Research Engineer
Arkansas State Highway Department
Highway Building
Little Rock, Arkansas

Dated Opened to Traffic
October, 1958

Location
ARKANSAS, Little Rock
Meadowcliff Road - US 67 and 70

Type of Intersection
4-way Right Angle

Physical Data
Grades: All less than 3%
Surface Type: asphalt - 6" rolled; access controlled - 6" barrier; islands - 4" rolled.

Signals: None

Shutting Property: The Meadowcliff area consists of a subdivision of approximately 700 homes. The intersection is at the south city limits of Little Rock. Meadowcliff Road (east and west) serves local residential land adjacent to the divided highway. The divided highway is the present location of US 67 and 70 and is four lanes divided for approximately two miles on either side of the intersection.

Traffic Data
Design Vehicle: CSD
Speeds: Speed data is not available. A speed of 50 MPH is enforced on the divided highway.

Operational Characteristics
Comments on over-all operation of the channelized intersection:
This intersection has been in operation for nearly 36 months. At first, acceleration and deceleration lanes were not properly utilized and some accidents resulted from the improper use. An extensive campaign to instruct and force motorists to use the lanes properly was successful. All in all, this intersection functions properly, especially when the prevailing high speeds and high volumes are considered.

Comments on elements of the design which contribute to any unsatisfactory operation:
Since the divided highway is not a fully-controlled access type, some problems are created by entry and exit to commercial property in the intersection, particularly where commercial access is allowed from the acceleration and deceleration lanes. The nearest median cross-overs are about 0.5 mile north and one mile south of the intersection, and some difficulty has been created by motorists entering and/or leaving commercial areas and driving short distances in the wrong direction on the divided highway. The overall rate (property damage and injury) has been low.

Traffic Control Devices
Signals: None

Abutting Property: The Meadowcliff area consists of a subdivision of approximately 700 homes. The intersection is at the south city limits of Little Rock. Meadowcliff Road (east and west) serves local residential land adjacent to the divided highway. The divided highway is the present location of US 67 and 70 and is four lanes divided for approximately two miles on either side of the intersection.

Comments by Committee Members
1. R. T. BERNER - The author's comments seem to cover practically all conditions, with the exception that there seems to be little need for the exit from the corner gas station. It would appear better if the exit on the curb return were altered to force traffic to exit onto the minor road.

2. RALPH A. WEISBECK - This appears to be a good standard treatment for typical intersections on divided highways. However, the median acceleration lanes, and the acceleration and deceleration lanes for right turns in all four quadrants, are not believed necessary for the low turning volumes shown. It is felt that this money could better be spent providing left-turn deceleration-storage lanes at other intersections. The separating islands on the cross road may be too close together, and may be too large for traffic. We would prefer to see fewer openings in the right-of-way line in the near vicinity of intersection.

Figure 1: Aerial view of the intersection, looking north.
EXAMPLE FR-3

Idaho, Eagle Junction, Ada County
US 60 & 26 - Idaho 69

Type of Intersection
4-way Right Angle

Date Opened to Traffic
April, 1957

Grades: 0%

Surface Type
Roadways: 0.2' Plant mix bituminous surface; 0.4' Crushed gravel base, 3/4' mix.; 1.3' Crushed gravel base, 2' max.
Islands have .15' of bituminous surfacing.
Shoulders are paved with bituminous surfacing.

Concrete curb and gutter, curb 6' high; Reflectorized Curb for left-turn bays.

Islands: Left-Turn Bays are 5 3/4" high.

Abutting Property; There is one service station in the northeast corner; the other three quadrants contain farm homes.

Transit Operations: No parking or passenger loading zones in this area.

Traffic Data
Design Vehicle: C50
Speeds: Posted Speed; 60 MPH Day, 55 MPH Night

Operational Characteristics
The overall operation of the intersection is good, and the raised median and left-turn bays help to move traffic through the intersection. For the traffic that wish to turn left there is a place that they can wait until it is safe for them to turn without interference with through traffic.

Since April, 1957, when the intersection was reconstructed with channelization, there have been 12 accidents reported, most of which were due to failure to yield right of way. There was no good accident record available prior to that time.

Comments by Committee Members
1. Warren Travers - This design appears to be adequate. It is noted, however, that the accident record is not particularly good and, further, that most of the accidents are caused by failure to yield right of way. Design consists of a very adequate warning to drivers on the cross street (Idaho 69), so it is possible that sight distance may be somewhat of a problem. Also, the intersection is rather wide, thereby increasing the exposure of crossing vehicles to traffic on the main roadway (U.S. 60). It is suggested that "shoulder lines" be delineated 12 feet beyond the lane lines (8 feet from the curbs), thereby reducing the effective exposure area for cross traffic. This should also increase sight distance substantially since cross traffic, after having started from a complete stop, can be positioned farther away with reasonable safety, thereby giving the driver a "second chance" to avoid a collision, more importantly, a chance to react to a previously misjudged situation.

2. George J. Fisher - Design principle good. As built, it leaves lanes that are too wide.

I recommend, as does Travers, two 12-foot lanes and an 8-foot lane. However, the 8-foot lane can be used as a right turn lane and designated as such.

It seems to me that this intersection is ready for a semi-actuated signal with right-of-way preference given to U.S. 60 and 26. Very large "STOP AHEAD" signs may help on both approaches of Idaho 69.

Additional Comments by E.L. Mathes - Shoulder stripping is not normally used in Idaho. Our experience has been that shoulder stripping does not change the lateral placement of vehicles materially for the relatively short distance as is the case at this particular location. Consequently, no substantial reduction in exposure area would be realized at this junction by a shoulder stripe eight feet from the outside curb.
Location
NEW MEXICO, Cannon Air Force Base
US 80 & 84 - SR 277 - Base Entrance

Type of Intersection
4-Way Right Angle (Offset)

Date Opened to Traffic
July, 1960

Physical Data
Grades: None 3% or more. No critical vertical curvatures

Roadway: Bituminous
Islands: 6' Curbed, with gravel chips on prime coat surfacing

Curbs: 6' high and 6' wide at top; sloping faces; 12' integral gutter.

Traffic Data
Design Vehicle: C50

Operational Characteristics
The overall operation is generally satisfactory. The intersection was channelized primarily to allow free flow from the Air Base in the P.M. and allow storage for a large left-turn inbound A.M. movement. During short periods in the A.M. when the railroad crossing is occupied by a train, inbound traffic occasionally must store, not only between the highway and the railroad crossing, but in the holding lane provided along US 60-84.

Although the State Route 277 intersection is offset instead of re-aligned to make a direct four-way intersection, this has not created any significant problems. Apparently this is because the traffic volumes between the Air Base and State Route 277 are not high enough to preclude the need for storage when traffic is high enough to preclude the need for storage when traffic is high enough to warrant such treatment.

An unsatisfactory feature is the at-grade railroad crossing. Ideally, this could be eliminated by grade separation at both the tracks and the intersection. However, this expense and the uncertainty of continuous of the Air Base does not warrant such treatment. Also, the 26-foot-wide two-way throat of the highway in the vicinity of the Air Base Entrance also provided a better distance between the highway and the railroad.

An undesirable feature is the at-grade railroad crossing. Ideally, this could be eliminated by grade separation at both the tracks and the intersection. However, this expense and the uncertainty of continuous of the Air Base does not warrant such treatment. Also, the 26-foot-wide two-way throat of the highway in the vicinity of the Air Base entrance also provided a better distance between the highway and the railroad.

The principal accident concentration before this entrance was reconstructed was on the east and north caused by northbound vehicles slowing and stopping to make their left turn into the Air Base. All of these accidents happened during the heavy A.M. movement to the Air Base. Since re-construction there have been no such accidents.

Comments by Committee Members
1. Eugene Maier - This design is a good example of the use of channelization to minimize the hazards at the intersection of a high-speed rural highway and the entrance to a facility (Air Force Base) which generates heavy entrance and exit movements. The most important feature of intersection channelization is the left-turn lane which provides a refuge for turning vehicles and sorts the approaching traffic for separate signal control. These principles have been used effectively in this example. The geometry of the design conforms to the major traffic movements and, as noted in the "Operational Characteristics", the only dimension which appears to be less than adequate is the narrow roadway between the throat highway and the railroad. Both texture and color have been used to obtain good contrast between the roadway and the Islands. No visibility to the Islands is achieved with well-placed delineators and good signing.

2. Charles J. Kees - Although the movement from the south turning left (to the west) is relatively light, a divisional Island could be used on the Cannon Air Force Base entrance for better definition of the entrance for left-turning traffic from the east, as indicated in the sketch revision. If a divisional Island is used in a case such as this, care must be exercised to provide a wide open entrance easily identifiable. By location of the ends of the Island, a smooth natural path should be provided.
Before 1955-1959:
- 2-Lane Rural Highway
- Subject to intensive traffic
- No Traffic Control

1955-1959:
- Increased volumes
- Intensive traffic
- Increased speed

NOTE: Before and after channelization, indicated only a slight increase in speed after construction.

Channelization:
- 23' Curve
- Added 1 lane
- Center line
- Solid white line
- Delineator
- 30' STOP

Speed check before and after channelization indicated only a slight increase in speeds.

- New Mexico, Cannon Air Force Base
- Dimensions to face of curb
- US 60-84 & 277 - Air Base Entrance
Colorado Boulevard - E. 46th Avenue

December 10, 1959

Richard C. Thomas
Assistant Traffic Engineer
City of Denver
Denver, Colorado

Traffic Data

Operational Characteristics

Type of Intersection

4-way Right Angle

January 10, 1959

IT mm i

Traffic Data

Grades: Very minor; not pertinent to traffic performance.

Surface Type

Roadway: Asphalt

Islands: The channelizing islands on the northeast and the southwest corners are both paved and outlined by the use of 15" diameter cast iron traffic buttons painted yellow and by delineators on 6" "pans. The ramp islands are paved and have a gravel surface outlined by the use of delineators on 6" "pans.

Shoulders: Gravel, sloping to a surface drainage system,

Curbs: No curbs and gutters in this area.

Traffic Control Devices

Signs: All signs except the truck route sign are reflectorized.

Traffic Control Devices

Figure 2: South Leg Left-Turn Pocket; Right-Turn By-Pass

Figure 3: West Leg Right-Turn By-Pass

Figure 4: North Leg Right-Turn By-Pass

Figure 5: North Leg Fisher Island

Colorado Boulevard

COLORADO, Denver

Richard C. Thomas

E. 46th Avenue

December 10, 1959

Denver, Colorado

Comment on overall operation of the channelized intersection: Over-all efficiency of this intersection has been improved by channelizing left-turn movements out of the through traffic lanes. This is proved by the fact that we have had an average increase in traffic volume (both A.D.T. and Peak Hour) of 28,476 on all approaches since the button channelizing was installed. We now have an average increase in traffic volume (both A.D.T. and Peak Hour) of 28,476 on all approaches since the button channelizing was installed. We

In this office, we have had many discussions concerning the use of left turn arrows to assist heavy left turn movements. The City of Denver has in the past used a leading arrow exclusively in every left turn lane. The greatest difficulty with this signal indication is that it merely "goes out" to end the phase, with no amber indication. We do use a 2-second clearance interval even though some other indications is shown. The left turning motorist is aware that the phase has ended when the arrow goes out, but our biggest problem has been convincing the motorist that he must not "cheat" on the clearance interval while the opposing traffic is approaching the "go" indication. Our answer to this problem was to provide a lagging left turn arrow, but no action has been taken as yet because we have not solved the problem of transition from one type of signal operation to the other. It is very difficult to stop using a leading left turn arrow, because the motorist merely assumes the arrow is burned out and changes off on his left turn movement anyway.

We did not go into great detail about the signal system at this intersection, but as a matter of fact the signals which we reported to you were merely the result of the two types of signal operation to the other. It is very difficult to stop using a leading left turn arrow, because the motorist merely assumes the arrow is burned out and changes off on his left turn movement anyway.

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We did not go into great detail about the signal system at this intersection, but as a matter of fact the signals which we reported to you were merely the result of the two types of signal operation to the other. It is very difficult to stop using a leading left turn arrow, because the motorist merely assumes the arrow is burned out and changes off on his left turn movement anyway.
**Split Phase Times for leading green**
- 15 seconds 7-9 AM and 4-6 PM
- 5 seconds all other times

**STOP timing on 60 seconds background cycle**

**Example FR-7**
COLORADO, DENVER
COLORADO BOULEVARD - E. 46TH AVENUE

**AVERAGE DAILY TRAFFIC**

<table>
<thead>
<tr>
<th>Leg</th>
<th>AM Peak</th>
<th>PM Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>West</td>
<td>19,169</td>
<td>22,620</td>
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<tr>
<td>South</td>
<td>33,364</td>
<td>43,070</td>
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<tr>
<td>North</td>
<td>13,272</td>
<td>15,900</td>
</tr>
<tr>
<td>East</td>
<td>22,620</td>
<td>22,620</td>
</tr>
</tbody>
</table>

**Before Channelization**

**Peak Hours Traffic Flow Diagram**

**After Channelization**

**Additional Notes:**
Traffic signals have been changed to actuated type with detectors on all approaches. Signals are operated semi-automated during off-peak periods and full-automated during the peak periods 7-9 AM and 4-6 PM.

A 60-second background cycle is used during the off-peak hours to ensure an "in-step" signal system. The cycle can be as long as 120 seconds while operating full-automated during the peak periods. Detectors are approximately 150 feet in advance of stop lines.
EXAMPLE FR-8

Comments by Committee Members

1. DONALD H. SIDES - This is a good basic plan with excellent detailing of island and markings.

It is noted that bus stops were provided on the near-side corner islands after a trial period of far-side island use. It would seem to be in the overall interest of traffic movement to utilize the parking lanes on the approaches to the intersection for two stops.

The need for signal phases B-1 and B-2 is not clear. Some inefficiency appears to be introduced by requiring through and left-turning traffic on the east-west road to stop two times in each complete signal cycle.

The fact that a light standard fell victim to a somewhat less than responsible driver (see Figure 1 and ESS-HBD fixed object accident) is not pertinent to the comment that the standards should not be located in the middle of the somewhat narrow sidewalks.

Lateral clearance to the signal posts in the 4-foot median is considered deficient.

2. EUGENE WHALE - An outstanding feature of this example is the effectiveness of the median island between the two traffic lanes. Traffic Signal indications on mast arms have 12" red, with 8" green and amber; all others are 8". Timing: Traffic-activated control by electronic timer with a short left-turn phase unit prevents motorists from utilizing the channelizing islands. The channelization and signal control combine to develop the full capacity of this high volume urban intersection. The introduction of the added left-turn lanes appears abrupt and the design does not conform to normal vehicle path. A minimum taper of 1 in 20 is considered desirable. The narrow 4-foot medians at the intersection do not provide the desirable clearance for the post-mounted signals for the left-turn movements, but the signals are allowed to be installed in the median islands and markings.

Additional Comments by MARTIN J. BOUMAN - We note that both reviewers commented on the substandard four-foot medians or center islands when right-of-way widths permit. Both reviewers also commented on the substandard four-foot medians or center islands when right-of-way widths permit.

Mr. Sides discussed the abrupt taper at some locations. Since the construction of this project the City has adopted a new standard for island tapers, using the design standards of the California Division of Highways. For example, at a design speed of 35 miles per hour our minimum taper is 1 in 12.5.

Both reviewers also commented on the substandard four-foot medians or center islands when right-of-way widths permit. In future designs of this type we would attempt to establish a far-side bus stop in a widened section. We feel that near-side bus stops create an unfavorable merging condition in the middle of a signalized intersection.

The need for signal phases B-1 and B-2 is not clear. Some inefficiency appears to be introduced by requiring through and left-turning traffic on the east-west road to stop two times in each complete signal cycle.

The fact that a light standard fell victim to a somewhat less than responsible driver (see Figure 1 and ESS-HBD fixed object accident) is not pertinent to the comment that the standards should not be located in the middle of the somewhat narrow sidewalks.

Lateral clearance to the signal posts in the 4-foot median is considered deficient.

Mr. Sides expressed concern regarding the need for signal phases B-1 and B-2. As previously discussed, traffic control at this intersection is provided by an automatic signal company. 2-Phase volume density traffic signal controller incorporating a dual left-turn phase unit. Turning volumes from University Avenue and Roosevelt Avenue are heavy enough to warrant a separate turning phase for University Avenue. If a conventional 2-Phase controller were employed, B-Phase would be utilized for all left turns from University Avenue. Once a left turn, or B-Phase, call was received, all straight-through east and west traffic on University would stop for the left turns, even though there were no opposing left turners for one of the straight-through movements. The dual left turn phase in our design does away with this needless stopping of the straight-through traffic. For example, a detector actuation for the straight-through east-west traffic on University Avenue are not stopped more than once during any cycle. Conversely, there are times when straight-through traffic in one direction on University Avenue is allowed to flow during two consecutive phases without interruption, permitting there are no opposing left turners during B-Phase.

From the foregoing it can be seen that straight-through movements on University Avenue are not stopped more than once during any cycle. Conversely, there are times when straight-through traffic in one direction on University Avenue is allowed to flow during two consecutive phases without interruption, permitting there are no opposing left turners during B-Phase.
Location

CONNECTICUT, West Hartford
US 44 - Connecticut Route 185 - North Main Street

Type of Intersection

4-way Right Angle (Offset)

Submitted by

David S. Johnson, Jr.
Director of Planning & Design
Connecticut State Highway Dept.
P. O. Box 2188
Hartford 15, Connecticut

Date

July 31, 1959

Grades: None over 2 1/2%.
The entire intersection is practically level.

Surface Type

Roadways: Mostly bituminous concrete
Curbs: Bituminous concrete lip curbing at pavement edges; concrete park curbing around Islands. Height of curb in the island area is 4" and of mountable design.

Traffic Control Devices

Lighting: Highway illumination providing 1.0 foot candles maintained through the entire area of the intersection and approaches consists of mercury 400 watt lamps, 20,000 lumen, mounted on steel standards at a height of 30'.

Abutting Property: At the present time a large shopping center is located in the southwest corner and another one located in the northeast corner, as may be observed in the aerial photograph. Plans are presently in preparation for the construction of two more shopping centers, one in each of the remaining corners of the intersection.

Traffic Data

Design Vehicle: C50
Speeds: All approach roads are posted at 35 MPH

Accidents: No accident experience has been made available, as the intersection was reconstructed on the basis of traffic operations. Accident experience before and after construction did not indicate any appreciable difference.

Pedestrian: The volume of pedestrian crossing was not significant except for the volume of vehicular traffic on the approach roadways necessary for the pedestrians to cross.

Operational Characteristics

Comment on over-all operation of channelized intersection:

Prior to reconstruction, the intersection and approaches consisted of two-lane roadways on all approaches with a hill located on Route 44 in the vicinity of Flagg Road which created a severe sight restriction for the eastbound vehicles approaching the intersection. Lane capacity to handle the existing volumes plus the numerous turning movements did not exist, and congestion continually occurred, especially during morning and afternoon peak hours.

The design of this entire construction evolved around the traffic signal system. Separate turn lanes were provided at all four approaches to the main intersection, with minor movement controllers provided for each of the left-turn slots on Route 44 as well as provided with minor movement controllers. The signal at Flagg Road is interconnected with the Model 1022 density controller at the main Intersection. Furthermore, three pedestrian interval timers were provided at the main intersection and connected with the 1022 controller.

Since installation of this system it has been necessary to change the timing on several occasions to meet the varying demands of traffic. The movement of traffic through the area, under control of the signal system and with the provisions for all turning movements, has resulted in orderly operation of traffic with an appreciable congestion even during the overloaded peak hours. The signal system is geared for expandable volume but only time will tell whether this system is adequate to handle the increased traffic generated by the two additional shopping centers plus that normal increase of traffic expected on the approach roads to the intersection.

Figure 1: Aerial View

Comments by Committee Members

1. IRV. WEINBERG - It would be of interest to designers and planners alike to know how shopping center traffic affects the operation of this intersection with access to the centers to close to the intersection. It is possible that the two centers to come will also be allowed access close to the intersection. This, I feel, will affect the capacity and efficiency of this intersection.

2. WARREN TRAVERS - The lack of traffic count data makes it difficult to appraise this design completely. It is assumed, however, because of the proximity of the shopping centers, that approach volumes and turning movements are heavy in peak periods. Typical shopping center traffic patterns and fluctuations, coupled with the non-shopping center demands, further suggest that the inclusion of flexible controls, as indicated, are justified.

Considering the relatively small intersection area available, this design, in my opinion, is an excellent example of getting the most out of every inch of pavement. It is appropriately channelized, and the extensive use of paint suggests good path delineation.
EXAMPLE FO-1

MICHIGAN, Lansing
US 16 (Grand River Ave.)
Saginaw Street

H. G. Bauerle
Director of Traffic Division
Michigan State Highway Department
Lansing, Michigan

May, 1958

4-way Oblique

SUBMITTED BY

Grades: Not of any consequence
Surface Type
Roadways: 9" concrete with bituminous cap
Islands: White concrete curb backfilled and seeded
Shoulders: 10', with 4" gravel
Curves: 6"

Traffic Control Devices
Signals: Two-phase interconnected with dual indications
Sign: NO LEFT TURN case sign at intersection facing eastbound Saginaw and westbound Grand River. Neon KEEP RIGHT sign facing westbound Saginaw on island nose.

Character of land use: Large (6000 car) shopping center on the south side of Saginaw Street. Commercial establishments between Saginaw and Grand River Avenue on east and west sides of intersection. Restaurant, motel and golf course on north side of Grand River Avenue.

Transit Operations: No designated bus or taxi unloading zones.

Volumes: Flow diagram attached
Accidents: Accident experience one year before - 14 accidents, 3 injured; one year after - 8 accidents, 4 injured.
Design Vehicle: C50
Speeds: Area Speed Limit 35 MPH

Comment on overall operation of channelized intersection:
This intersection is the easterly terminus of a one-way street system, which was installed at the time of this reconstruction. This became necessary due to a coordination of accident experience and heavy congestion at this intersection, construction of the large shopping center mentioned above, and other planning factors in the City of Lansing. Reconstruction has eliminated the congestion, reduced the accident experience, and has, in general, enhanced traffic operation in the area due to the operation of one-way streets.

Figure 1: Looking east from the west leg of Saginaw Street.

Figure 2: Looking west from the east leg of Grand River Ave.

Figure 3: Looking southwest from the northeast leg of Saginaw Street.

Comments by Committee Members

1. EUGENE MAIER - The channelization of this intersection in connection with the establishment of one-way traffic flow on Grand River Avenue and Saginaw Street to the west has resulted in a substantial increase in intersection capacity and a reduction in accident experience. The pavement area at the point of signal control has been greatly reduced and the volume of traffic through this area of major conflict has been approximately halved.

The delineation of the islands might be improved by the use of raised bars or single bars on the approaches to the ends of the islands. Although the plan indicates no information signs, an over-the-road sign bridge appears in Fig. 2 and Fig. 3. There is an obvious need for adequate lighting at this urban intersection with a relatively high CBD.

2. W. R. BELLIS - An example of simplicity of intersection design in an age where it seems that complexity is the style. This must be considered as part of a 4-way intersection. The other part is absorbed in the one way street system.
Type of Intersection: Washington, Seattle
Date Opened to Traffic: August, 1935

Traffic Data
Transit Operations: No transit or bus zones within the intersection, but transit vehicles do pass through it.

Design Vehicle: 35 MN
Pedestrian: Only an occasional pedestrian crosses in this vicinity.

Optimum Traffic Operations

The existing operation eliminates the minor left turns, and the minor right turns are not encouraged and cause no appreciable problem. The pedestrian crossing occurs between signals, so far as feasible the major right turns have been separated from left-turns. No pedestrian crossing occurs between signals, so far as feasible the major right turns have been separated from left-turns.

The tangent through movement (667. of the total entering from E. Marginal Way South) have a capacity limitation which is a function of the storage between signals, because these movements are controlled at both signal locations. The cross-hatched barrier areas adjacent to the direction islands serve multiple purposes:

1. "Detect bays" for unfamiliar drivers who unexpectedly become trapped in a desired turn lane but wish to go through. The penalty for missing the through lane would be a side trip of approximately two miles for southbound traffic.
2. Storage space in case of disabled vehicles.
3. Emergency space in case of disabled vehicles.
4. Insufficient storage capacity (pavement width) on East Marginal Way South at the southerly Intersection could be relieved if it were possible during the peak hour to route through traffic on East Marginal Way South instead of using the bridge ramp. Although somewhat circuitous, through movement from the north leg of E. Marginal Way South to through traffic on East Marginal Way South is progressed, but this progression depends on a relatively low speed of the left-turning traffic exiting from the bridge.
5. Emergency space in case of disabled vehicles.

Additional Comments by E. E. Lewarch -

(a) Insufficient storage capacity (pavement width) on East Marginal Way South at the southerly Intersection is repeatedly filled, eliminating smooth progressive storage area. This would be "opposed" by left-turning traffic exiting from the southerly Intersection. So far as feasible the major right turns are not encouraged and cause no appreciable problem. The pedestrian crossing occurs between signals, so far as feasible the major right turns have been separated from left-turns.

(b) Larger intersection islands might have favorable effect on accident experience, as well as on versatility and/or flexibility of movement, especially as relates to emergency situations.

2. Warren Travels - The principal capacity problem appears to be in the southbound direction, caused by insufficient storage capacity (pavement width) on East Marginal Way South at the southerly Intersection. The large traffic volumes indicate that the efficiency of the north intersection, it has not been found necessary to double turning movements take place on surface streets there is an accident experience, but unfavorable effect on versatility and/or flexibility of movement, especially as relates to emergency situations.

(a) The three-phase signal at the northerly intersection permits local access via left turns from northbound East Marginal Way South. Since the signal operation is fixed time, a portion of total green which otherwise could be allotted to the two main approaches is devoted to the left turn to and from the access road during peak periods. It appears that this thing could be helpful. The present three-phase signal at the northerly intersection could be made two-phase by prohibiting the left turn from the south into the access road; this movement, if minor, could be routed straight through the intersection and be made to turn right, beyond the intersection, right again onto First Avenue and then re-approach the intersection by First Avenue South. It would be "opposed" by left-turning traffic exiting from the access road; however, this would be a normal left-turn conflict appearance of any two-phase intersection.

The resulting increased green time per se allotted to the major movements at this intersection apparently would not be of too much benefit to through traffic on East Marginal Way South because of the storage problem to through traffic on this street.

(b) The principal capacity problem appears to be in the southbound direction, caused by insufficient storage capacity (pavement width) on East Marginal Way South at the southerly Intersection. The large traffic volumes indicate that the efficiency of the north intersection, it has not been found necessary to double turning movements take place on surface streets there is an accident experience, but unfavorable effect on versatility and/or flexibility of movement, especially as relates to emergency situations.

(c) The three-phase signal at the northerly intersection permits local access via left turns from northbound East Marginal Way South. Since the signal operation is fixed time, a portion of total green which otherwise could be allotted to the two main approaches is devoted to the left turn to and from the access road during peak periods. It appears that this thing could be helpful. The present three-phase signal at the northerly intersection could be made two-phase by prohibiting the left turn from the south into the access road; this movement, if minor, could be routed straight through the intersection and be made to turn right, beyond the intersection, right again onto First Avenue and then re-approach the intersection by First Avenue South. It would be "opposed" by left-turning traffic exiting from the access road; however, this would be a normal left-turn conflict appearance of any two-phase intersection.

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EXAMPLE FD-3

Location

DELANAWARE, Hockessin
Lancaster Pike - Yorklyn Road (Road 237)

Submitted by

Ernest A. Davidson
Chief Engineer
Delaware State Highway Department
P. O. Box 131
Dover, Delaware

Type of Intersection

Data Opened to Traffic

4-Way Oblique
June 16, 1955

Physical Data

Grades: None over 3.7%
Surface Type
Roadways: Cement concrete
Islands: 8" depressed, with topsoil and seed center
Shoulders: 10 feet wide, select borrow
CurbS: 8" parkway reflecting curb
Traffic Control Devices
Markings: Standard Delaware State Highway Department markings of yellow and white
Abutting Property: Slowly developing area on a new through highway by-passing the village of Hockessin

Traffic Data

Speeds: Lancaster Pike 50 MPH
Yorklyn Road 30 MPH
Pedestrian: No pedestrian provisions--small volume

Operational Characteristics

Comment on over-all operation of the channelized intersection:

Lancaster Pike is a secondary main Intercity highway. Hockessin lies near the limits of the Wilmington commuting area. The highway was built about eight years ago, by-passing the village of Hockessin to the east.
The majority of traffic is through. The secondary flow is that between Wilmington and Yorklyn, followed by Wilmington-Hockessin.
Because of the relatively minor traffic volumes, this intersection has operated freely. Local residents have requested a signal but it has not been found warranted.
If this intersection were being designed today, or if a signal is ever warranted, the through highway should be widened in four lanes in order to give through traffic a chance to pass waiting left-turners.
The accident record is quite good.

Comments by Committee Members

1. ROBERT E. DUNN - This intersection with its 135 degree oblique angle crossing of vehicle paths has approximately 1 3/4 times the relative speed and 3 1/2 times the impact energy as would be involved in a collision of vehicles at a 90 degree angle intersection. The basic condition warranting channelization is therefore not corrected in this case, but some of the principles of channelization are applied and some improvement in operation is derived.

The separate right-turn directional lanes in the east and west quadrants merge turning and through traffic stream at small angles. The separate left-turn directional lanes in the same quadrants separate some of the conflict points on Lancaster Pike. In doing this, however, other oblique angle crossing of vehicle paths are created on Yorklyn Road at the entrance to the left-turn directional lanes; and an intersection area approximately 300 feet in length is created on the free-moving, higher-volume Lancaster Pike.

Setting aside all the practical local factors that may have influenced this design, the theoretical application of channelization principles would have called for the re-alignment of the minor volume Yorklyn Road to approach and intersect the Lancaster Pike at a right angle. Separate directional lanes could then be provided for the major right-turning volumes to separate some points of conflict. All left-turning and cross movements would be confined in the small area of conflict of the intersection proper. This type of 90 degree intersection design would have satisfied the warrant condition and the five basic channelization principles involved in this particular case.

2. CHARLES J. KEES - The review and comments by Mr. Dunn are quite pertinent.
The complexity of the directional turning lanes and the number of conflict points created on both roads are very undesirable features.
The photographs (Figures 1 and 2) indicate inadequate signing for this complex treatment.

As suggested by Mr. Dunn, realignment of Yorklyn Road to approach and intersect Lancaster Pike at a right angle would have been the appropriate answer. Although volumes are now quite low, the intersection will have to be redesigned if volumes should increase appreciably.

This design would be difficult, if not impossible, to signalize.

Additional Comments by WILLIAM R. CARRON, Traffic Engineer - We have examined the comments by Mr. Dunn and appreciate his thoughts as to what the ideal design of this intersection should be if high traffic volumes become a problem here.

It must at first be pointed out that this is a very high type design for such a low volume intersection. The standard conflict points have been spread over a larger area in this case and it is felt that any changes in the design at the present are unwarranted.

We realize that should signalization of this intersection become necessary at some future date, some changes in design may be necessary.
DO NOT ENTER Wilmington
LM4CASTER PIKE 6 Miles

COLLISION DIAGRAM
Accident during 1960
(Over-run road, skidded 75° and over-turned)

THAFFIC VOLUMES

<table>
<thead>
<tr>
<th>Road</th>
<th>1960 AM</th>
<th>1960 PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lancaster Pike (Northwest)</td>
<td>1,138</td>
<td>350</td>
</tr>
<tr>
<td>(Southeast)</td>
<td>1,414</td>
<td>315</td>
</tr>
<tr>
<td>Yorklyn Road</td>
<td>1,364</td>
<td>105</td>
</tr>
<tr>
<td>(West)</td>
<td>1,198</td>
<td>88</td>
</tr>
</tbody>
</table>

Daily Commercial Traffic: 2%

EXAMPLE FO-3
DEL MAR, HOCKESSIN
LANCASTER PIKE - YORKLYN ROAD
Location

Massachusetts, Seekonk
Fall River Avenue - Highland Ave. - Mink Street

Type of Intersection

4-Way Oblique (Offset)

Submitted by

Bernard B. Twombly, Traffic Engineer
Department of Public Works
100 Nashua Street
Boston 14, Massachusetts

Date Opened to Traffic

On July 26, 1932 the intersection contained channelizing islands and semi-actuated signals were operating with actuation on Fall River Avenue (west) and Mink Street. The entire intersection was rebuilt in 1957, and no channelizing islands were installed. On April 22, 1957, a semi-actuated traffic signal system was put into operation with actuation on Route 114A. However, this intersection was never closed to traffic.

Physical Data

Surface Type

Rumble: 3" of Class I bituminous concrete. Pavement Type 1-1 in two 1/2" courses.

Islands: Grass or bituminous concrete.

Shoulders: Gravel created with 1 gallon of M.C. per square yard-sand covered.

Curbs: Height 6"; Type-granite edging Type 58.

Traffic Control Devices

Signals: Semi-actuated controller inter-connected

Markings: White

Traffic Data

Design Vehicle: C43

Speeds: Posted 35 MPH

Pedestrian: Very little pedestrian movement

Operational Characteristics

Observations of the overall operation of the new design indicate that the channelization is very successful.

We have not found any unsatisfactory elements of the design nor limitations of movement or control.

The design has reduced the accident record favorably, with the current accident record indicating that the majority of collisions are of the rear-end type and that they are not in excess of the number normally experienced at such a heavily traveled signalized intersection.

Comments by Committee Members

1. ROBERT E. DUNN - This is a good example of blending a minor volume highway (Route 114A) to cross at right angles, merge at small angles, and diverge from the heavier volume highway (Route 6). The basic principles of channelization are appropriately applied. Although numerous islands are involved, they merely fill unusable space and provide well defined channels to guide both the major and minor movements safely through the wide area of the intersection.

   This intersection design with its wide separation of conflict points, good visibility, and approach traffic and moderate volume, might operate more efficiently through the overall period of the day without the use of traffic signal equipment. Whether or not this is true would be a matter of local determination; the point remains, however, that good channelization can forestall the need for traffic signal control.

2. KARL MOSKOWITZ - This appears to be a good solution to a very complicated situation. Normally, we would not favor having as many islands as are shown here; however, in this situation, it appears that the islands shown were necessary.
NO. 2  ROUTE 6 (FALL RIVER AVE.) AT
ROUTE 114A (MINK ST.) SEEKONK, MASS

NO SCALE

INTERSECTION COUNT OF VEHICULAR TRAFFIC FROM
11 A.M. TO 5 P.M. 4/8/55, BEFORE RECONSTRUCTION.

ACCIDENTS PLOTTED FROM JUNE 1957 THRU DECEMBER 1959
TRAFFIC RECORDS.

EXAMPLE FO-4 (OFFSET)

LEGEND
CAR PARKED AT O PEDESTRIAN
SIDE OF ROAD
CAR IN MOTION ® FIXED OBJECT
LIGHT M OVERTURNED VEHICLE
DARK L LIGHT / INJURED

WARNING CLUSTER
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

NO. 2 - ROUTE 6 (FALL RIVER AVE.) AT
ROUTE 114A (MINK ST.) SEEKONK, MASS.

NOTE: STREET LIGHTS ARE MERCURY VAPOR TYPE. LUMENS AS SHOWN

TIMING & SEQUENCE

ACCRETIONS PLOTTED FROM JUNE 1957 THRU DECEMBER 1959
TRAFFIC RECORDS.

EXAMPLE FO-4 (OFFSET)

MASSACHUSETTS, SEEKONK
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

WARNING CLUSTER
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

NO. 2 - ROUTE 6 (FALL RIVER AVE.) AT
ROUTE 114A (MINK ST.) SEEKONK, MASS.

NOTE: STREET LIGHTS ARE MERCURY VAPOR TYPE. LUMENS AS SHOWN

TIMING & SEQUENCE

ACCRETIONS PLOTTED FROM JUNE 1957 THRU DECEMBER 1959
TRAFFIC RECORDS.

EXAMPLE FO-4 (OFFSET)

MASSACHUSETTS, SEEKONK
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

WARNING CLUSTER
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

NO. 2 - ROUTE 6 (FALL RIVER AVE.) AT
ROUTE 114A (MINK ST.) SEEKONK, MASS.

NOTE: STREET LIGHTS ARE MERCURY VAPOR TYPE. LUMENS AS SHOWN

TIMING & SEQUENCE

ACCRETIONS PLOTTED FROM JUNE 1957 THRU DECEMBER 1959
TRAFFIC RECORDS.

EXAMPLE FO-4 (OFFSET)

MASSACHUSETTS, SEEKONK
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

WARNING CLUSTER
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

NO. 2 - ROUTE 6 (FALL RIVER AVE.) AT
ROUTE 114A (MINK ST.) SEEKONK, MASS.

NOTE: STREET LIGHTS ARE MERCURY VAPOR TYPE. LUMENS AS SHOWN

TIMING & SEQUENCE

ACCRETIONS PLOTTED FROM JUNE 1957 THRU DECEMBER 1959
TRAFFIC RECORDS.

EXAMPLE FO-4 (OFFSET)

MASSACHUSETTS, SEEKONK
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

WARNING CLUSTER
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

NO. 2 - ROUTE 6 (FALL RIVER AVE.) AT
ROUTE 114A (MINK ST.) SEEKONK, MASS.

NOTE: STREET LIGHTS ARE MERCURY VAPOR TYPE. LUMENS AS SHOWN

TIMING & SEQUENCE

ACCRETIONS PLOTTED FROM JUNE 1957 THRU DECEMBER 1959
TRAFFIC RECORDS.

EXAMPLE FO-4 (OFFSET)

MASSACHUSETTS, SEEKONK
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

WARNING CLUSTER
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

NO. 2 - ROUTE 6 (FALL RIVER AVE.) AT
ROUTE 114A (MINK ST.) SEEKONK, MASS.

NOTE: STREET LIGHTS ARE MERCURY VAPOR TYPE. LUMENS AS SHOWN

TIMING & SEQUENCE

ACCRETIONS PLOTTED FROM JUNE 1957 THRU DECEMBER 1959
TRAFFIC RECORDS.

EXAMPLE FO-4 (OFFSET)

MASSACHUSETTS, SEEKONK
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

WARNING CLUSTER
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

NO. 2 - ROUTE 6 (FALL RIVER AVE.) AT
ROUTE 114A (MINK ST.) SEEKONK, MASS.

NOTE: STREET LIGHTS ARE MERCURY VAPOR TYPE. LUMENS AS SHOWN

TIMING & SEQUENCE

ACCRETIONS PLOTTED FROM JUNE 1957 THRU DECEMBER 1959
TRAFFIC RECORDS.

EXAMPLE FO-4 (OFFSET)

MASSACHUSETTS, SEEKONK
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

WARNING CLUSTER
FALL RIVER AVE. (RTE II4A) - HIGHLAND AVE. (ROUTE 6) - MINK ST. (ROUTE 114A)

NO. 2 - ROUTE 6 (FALL RIVER AVE.) AT
ROUTE 114A (MINK ST.) SEEKONK, MASS.

NOTE: STREET LIGHTS ARE MERCURY VAPOR TYPE. LUMENS AS SHOWN

TIMING & SEQUENCE

ACCRETIONS PLOTTED FROM JUNE 1957 THRU DECEMBER 1959
TRAFFIC RECORDS.
EXAMPLE M-1

Location
CALIFORNIA, Modesto
H-Scenic-Burney-Downey-Kimble Streets

Type of Intersection
Multilane

Physical Data
Submitted by
Douglas J. Carmody
Director of Parking and Traffic
P. O. Box 642, City Hall
Modesto, California

Date Opened to Traffic
About January, 1958

Grades: The grades for these streets will average .2% to .5%.

Surface Type
Roadways: The street surface is asphaltic concrete from curb to curb.

Transit Operations: This intersection is served by the Modesto Motor Bus Service. One loading zone is shown.

Right-of-Way: The right-of-way at this location does not affect the island design.

Traffic Data
Design Vehicle: 60' Commercial Vehicle

Speeds: The posted speed on all entering legs is 25 MPH. It is well observed and seldom exceeded.

Accidents: Before Channelization - there were none in the twelve months immediately preceding that time. After Channelization - no accidents in three and one-half years.

Pedestrian: Volume Is very low; probably less than 50 per day confined in all crossings.

Operational Characteristics
Comment on over-all operation of the channelized intersection: The intersection of H, Scenic, Burney, Downey and Kimble was channelized as part of Modesto's one-way street system. It has been very successful both in reducing accidents and as a traffic separator.

Comment on elements of design which contribute to any unsatisfactory operation: Because of business in the area more openings had to be made than were desired. However, these additional openings, which are uncontrolled, have not produced one single accident in the three and one-half years the island has been in operation.

General Comment: We, in the past, have used mostly raised bars for channelization, but are now beginning to use concrete raised islands. The change to concrete islands from raised bars is because of the high maintenance cost of raised bars.

Comments by Committee Members
1. ROBERT E. DUNN - The inauguration of the one-way system eliminating the number of conflict points probably had more effect on the operation at the intersection than did the channelization. The U-turn islands correct the warrant condition and satisfy the acceptance criteria. The type of curbing used and the service station opening reduce the potential effectiveness of the channelization.
   a. A single raised island and median divider formed by a continuous curb would be more effective by:
      i. Reducing the potential hazard of wheel and undercarriage damage to vehicles.
      ii. Providing a better island profile for all weather and light conditions.
      iii. Creating a better platform for installation of traffic signs.
      iv. Establishing a more positive and safer traffic control.

2. GEORGE J. FISHER - I concur with Dunn's comments. The channel between the two islands should be eliminated to simplify operation.

Additional Comments by DOUGLAS J. CARMODY - Raised traffic bars offer a greater safety factor to motorists than a single raised island formed by continuous curbs because: raised bars are only 3" high; the average continuous curb is 6" (plus) high. There are few if any automobiles in the world manufactured that have undercarriages lower than 3"—most are 5 or more inches above the pavement.
Location
IDAHO. Twin Falls
East Five Points

Type of Intersection
Multi-way

Physical Data
Grades: 0.5
Surface Type
Roadways: 0.3' plant mix bituminous surface; 0.4' Cr. gravel base course
Shoulders: None; only transverses with concrete curb and gutter.
Curbs: 6" high concrete curb and gutter.
Traffic Control Devices
Lighting: All street lights are 21,000 lumen mercury vapor, 30' from pavement on 8' mast arms.

Traffic Data
Design Vehicle: CSO
Speeds: Speed limit 25 MPH

Operational Characteristics
Comments on overall operation of the channelized intersection: "Before the channelizing was constructed the traffic pattern indicated that due to the large expanse of pavement, drivers were often confused as to the probable action of others. Since the reconstruction with channelization the traffic movements are directed and confined in the proper channels.

Comments by Committee Members
1. IRV. WEINBERG - Channelization installed is uncomplicated and breaks up the former wide expanse of pavement into direct channels for traffic to follow. It should work very effectively.
2. EUGENE HAIER - The success of this channelization project is evidenced by the dramatic improvement in accident experience. Although the channelization may have been an important factor, the before and after photographs indicate that the channelization project provides an occasion for the installation of improved lighting, modernization of traffic signal controls, more effective information signs and improved pavement markings.

Addition Comments by E. L. MATHES - We concur in Mr. I. Weinberg's comment that the traffic separators could be made wider to serve as pedestrian refuge islands. However, due to light pedestrian traffic and the cost involved in getting additional right-of-way this feature was not provided.
Location
OREGON, Portland
US 26 - Canyon Rd. - SW 58th Ave.
SW Skyline Blvd. - SW Canyon Ct.
SW Humphrey Blvd.

Submitted by
F. B. Crandall, Traffic Engineer
Oregon State Highway Department
Salem, Oregon

Type of Intersection
Multi-way

Date Opened to Traffic
November, 1954

Physical Data
Surface Type
Roadways: Asphaltic concrete pavements except that Canyon Road (US 26) has a 1/8" asphaltic concrete skin coat over concrete pavement.
Islands: The small narrow islands on the northerly side of the main intersection are concrete, 7" high. The long narrow median separators along Canyon Road (US 26) in the middle of the intersection are non-mountable concrete, 7" high.
Shoulders: All shoulders not shown on the drawing are gravel, approximately 2' wide.

Traffic Control Devices
Markings: Plain lines are yellow; a solid yellow stripe outlines the joggle bar areas.

Traffic Data
Design Vehicle: For movements receiving traffic signal indication the Design Vehicle is C50; for other movements P or SU.

Operational Characteristics
This intersection is some four miles distant from the Portland central business district and services commuter-type traffic with corresponding relatively high peak hours. Over and above the commuter-type traffic, US 26 is a principal feeder highway between the Portland area and coast points and experiences some high seasonal peaks in the way of recreational traffic. This particular intersection has recently been remodeled with a "tight" diamond-type interchange.

Although probably not particularly pertinent to channelization aspects, I might mention that the grades at this intersection are at the crest of a vertical curve with respect to the main line, US 26, and during icy and snow conditions it is necessary to put the signals on flashing operation, with flashing amber to US 26 and flashing red to the crossroad to preclude a jam-up on the main line.

Figure 1: Aerial view. AFTER channelization.

Comments by Committee Members
1. GEORGE J. FISHER - Appears to be an economical and effective treatment. Left-turn storage lanes well adjusted as to length, for volume handled. Shoulder's intersection be speed zoned to reduce rear-end collisions. Traffic efficiency in low enough and a reduced speed would not hurt much. Looks like a "natural" for the interchange which was built later.

2. DONALD H. SIDES - The "after" treatment was effective in reducing accidents, particularly the usually serious type between through and turning vehicles. The number, however, remained large after provision of the channelization which suggests that high approach speeds and limited sight distance at the crest intersection may be causative factors. The vertical geometry, a 700-foot vertical curve together with five percent approach grades, is suitable for a design speed of about 45 miles per hour. It is possible that the accident record entered into the decision to provide an interchange.

Additional Comments by F. B. CRANDALL - Comments on this example suggest speed zoning as a means of reducing rear-end type accidents. There was signed speed zoning of 35 MPH on the main line through this intersection (this should probably be indicated on the plan).

With regard to the comment ...the accident record entered into the decision to provide an interchange", the warrant and desirability of providing an interchange at this site. Providing an interchange at this location was finance, and channelization was considered an interim treatment, as well as providing some measure of improvement commensurate with cost and monies available at the time.
WASHINGTON STATE HIGHWAY DEPARTMENT

COLLISION DIAGRAM
For the Year After Channelization

Fatal 0
Non-Fatal 0
Property Damage 5
Total Accidents 5

TRAFFIC VOLUMES

<table>
<thead>
<tr>
<th>Movement</th>
<th>Ave. Daily Vol.</th>
<th>P. M. Peak</th>
<th>A. M. Peak</th>
</tr>
</thead>
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<tr>
<td>A (Canyon Rd.)</td>
<td>412</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>B (Canyon Rd.)</td>
<td>404</td>
<td>104</td>
<td>112</td>
</tr>
<tr>
<td>C (Canyon Rd.)</td>
<td>313</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>D (S.W. 58th Ave.)</td>
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<td>10</td>
<td>10</td>
</tr>
<tr>
<td>E (Skyline Blvd.)</td>
<td>333</td>
<td>56</td>
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<tr>
<td>F (Canyon Ct.)</td>
<td>304</td>
<td>75</td>
<td>14</td>
</tr>
<tr>
<td>G (Canyon Rd.)</td>
<td>365</td>
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<tr>
<td>H (Canyon Rd.)</td>
<td>1902</td>
<td>208</td>
<td>13</td>
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<tr>
<td>I (Sthill's P. Rd., Sewist, &amp; Humphrey)</td>
<td>97</td>
<td>104</td>
<td>324</td>
</tr>
<tr>
<td>J (Canyon Rd.)</td>
<td>50 Est.</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

NOTE: Destination Signs Not Shown

EXAMPLE M-4

20,000 Lumen Mercury-Vapor Luminous Unit on 30' Pole

NOTE: Destination Signs Not Shown

20,000 Lumen Mercury-Vapor Luminous Unit on 30' Pole

NOTE: Destination Signs Not Shown
EXAMPLE H-5

DISTRICT OF COLUMBIA, Washington
Constitution Avenue - Maryland Avenue - 2nd Street, N.E.

Type of Intersection
Multiway

Physical Data

Submitted by
Francis E. Twiss, Deputy Director for Traffic Engineering and Operations
District of Columbia Department of Highways and Traffic
Washington, D.C.

Date Opened to Traffic
Late 1936

Grades: None over 3%

Surface Type
Roadways; 2" asphalt concrete over reinforced concrete base,
Islands: Earth (grass)
Shoulders: Parking lanes are same construction as roadway,
Curbs: 9" granite barrier type.

Traffic Control Devices
Markings: Pavement markings all white.
Transit Operations: Bus stops not located in channelization; loading and unloading operations from passenger cars and taxis occur.

Traffic Data

Design Vehicle: C50
Speeds: 25 MPH legal speed
Accidents: During 12 months prior to construction there were 19 accidents of which four were personal injury and 15 were property damage.
In the year following construction there were nine accidents of which four were personal injury and five were property damage.

Operational Characteristics

This multiway intersection is located in the Capitol Hill area where the Capitol, several office buildings for Members of Congress, the Supreme Court Building, the Library of Congress, and other institutions are located. Traffic in the intersection is composed not only of a large volume of through traffic destined beyond the intersection but a significant number of vehicles are destined to the Immediate area. The number of tourists or non-repeat drivers in the intersection is many times those experienced in most areas. Vehicles destined to the area are largely parked on adjacent streets. A large number of spaces are reserved for Members of Congress, their employees, the diplomatic corps, and governmental agencies. This local traffic is observed to be predominantly to and from the west.

Operation in the intersection has been quite satisfactory to date. Backups during the rush hours have been minor. The 3-dial radio master control of the signals is quite effective.

A large stadium was opened in October of 1961 about 20 blocks to the east of this intersection. There is some concern that traffic to major events may cause congestion, particularly if the events are timed to fall at the peak hour, as the east-west route is one of the major routes to the stadium.

Comments by Committee Members

1. IRV. WEINBERG - A very good example of channelization principle, separation of conflicts by using channelizing islands and traffic signals. The islands are used well to direct traffic into uncomplicated paths and to position the vehicles so that they are protected from conflicting traffic movements and yet be in the best position for safe traffic maneuver judgment.

The islands provide a location for traffic control devices and also provide for pedestrian refuge. It is well noting that this intersection design is not cluttered up with many small islands, a common fault sometimes noted in other multiple intersection treatment.

2. CHARLES J. GREESE - This is a good treatment of a complex multiple intersection. The channelization is necessary for efficient operation and appears to be quite satisfactory and well planned.

The signal phasing is necessarily complex but the channelization design appears to accommodate each movement satisfactorily.

Vehicle paths are well defined and this appears to be a good solution to a bad problem.

Although signal phasing is not shown for all of the intersections in this group, it is assumed that all of the signals are coordinated to provide proper phasing through this area.
EXAMPLE Y-A, U.S. 27 - SHEPHERD ROAD, SHEPHERD, MICHIGAN
Submitted by: Philip S. Mentel, Traffic Engineer
Rhode Island State Highway Department
Providence, Rhode Island

EXAMPLE Y-B, SMITHFIELD AVENUE - POWER ROAD, Pawtucket, Rhode Island

EXAMPLE Y-C, 28TH STREET - M STREET - PENNSYLVANIA AVENUE, Washington, D.C.
Submitted by: Francis E. Twins, Deputy Director
Traffic Engineering and Operations
District of Columbia Highway Dept.
Washington, D.C.
OTHER TREATMENTS

EXAMPLE FR-A, MARKHAM - UNIVERSITY, LITTLE ROCK, ARKANSAS
Submitted by: Henry M. DeNoble, City Traffic Engineer
Little Rock, Arkansas

EXAMPLE FR-B, 1ST AVENUE NORTH - PARK DRIVE, GREAT FALLS, MONTANA
Submitted by: Maurice Allday, Traffic Engineer
State Highway Department
Helena, Montana

EXAMPLE FR-C, LIMESTONE ROAD - KIRKWOOD HIGHWAY, WILMINGTON, DELAWARE
Submitted by: J. R. Henderson, Engineer
Planning and Research
State Highway Department,
Little Rock, Arkansas

EXAMPLE FR-D, CENTRAL - GRAND, HOT SPRINGS, ARKANSAS
Submitted by: Ernest A. Davidson, Chief Engineer
State Highway Department
Dover, Delaware
OTHER TREATMENTS

FR INTERSECTIONS

EXAMPLE FR-1, JORDAN LANE - ALABAMA 20, HUNTSVILLE, ALABAMA

EXAMPLE FR-J, TEXAS 95 - TEXAS 71 (LOOP 150), BASTROP COUNTY, TEXAS

EXAMPLE FR-K, U.S. 31 - KENTUCKY 219, MART COUNTY, KENTUCKY

Submitted by: W. D. Crawford, Engineer
Bureau of Survey and Plans
Alabama State Highway Department
Montgomery, Alabama

Submitted by: T. S. Huff, Chief Engineer of Design
Texas Highway Department
Austin, Texas

Submitted by: K. B. Johns, Director
Division of Traffic
Kentucky Department of Highways
Frankfort, Kentucky

Submitted by: W. D. Crawford, Engineer
Bureau of Survey and Plans
Alabama State Highway Department
Montgomery, Alabama

Submitted by: T. S. Huff, Chief Engineer of Design
Texas Highway Department
Austin, Texas

Submitted by: K. B. Johns, Director
Division of Traffic
Kentucky Department of Highways
Frankfort, Kentucky
OTHER TREATMENTS

Submitted by: Oren W. Walker, Chief Road Designer
Nevada State Highway Department
Carson City, Nevada

EXAMPLE FR-L, KIETZKE LANE - EAST SECOND STREET, RENO, NEVADA

SIGNAL INSTALLATION

ILLUMINATION

PLAN
RAISED TRAFFIC BARS

SECTION
TYPE I CURB AND GUTTER

PLAN
RAISED TRAFFIC BARS

ELEVATION

SECTION

SPECIAL DETAILS

EXAMPLE FR-L, KIETZKE LANE - EAST SECOND STREET, RENO, NEVADA

AERIAL VIEW OF TREATMENT
OTHER TREATMENTS OF INTERSECTIONS

EXAMPLE FO-A, WASHINGTON AVE. - RUST STREET, SAGINAW, MICHIGAN

Submitted by: H. G. Bauerle, Dir.
Traffic Division
Michigan State Highway Department
Lansing, Michigan

EXAMPLE FO-B, MARKHAM - KAVANAUGH - BOOKER, LITTLE ROCK, ARKANSAS

Submitted by: Henry M. DeNoble
City Traffic Engineer
Little Rock, Arkansas

EXAMPLE FO-C, U.S. 82, U.S. 51, LUBBOCK COUNTY, TEXAS

Submitted by: T. E. Huff, Chief Engineer
Highway Design
Texas Highway Department
Austin, Texas

EXAMPLE FO-D, KENTUCKY 440, KENTUCKY 207, CARLISLE COUNTY, KENTUCKY

Submitted by: K. B. Johns, Director
Division of Traffic
Kentucky Department of Highways
Frankfort, Kentucky
APPROACH-END TREATMENTS

NOTE: Figure 3 of Example E-7 illustrates the application of large jiggle bars in approach-end treatment.

EXAMPLE AE-A, CARAWAY ROAD - JOHNSON STREET, (ARKANSAS 173) - (ARKANSAS 1), JONESBORO, ARKANSAS

EXAMPLE AE-B, U.S. 44 - U.S. 44A, ASHFORD, CONNECTICUT

EXAMPLE AE-C, ROUTE 16 - ROUTE 9, NEAR ASHMORE, COLES COUNTY, ILLINOIS

EXAMPLE AE-D, OKLAHOMA 29 - OKLAHOMA 76, SOUTH OF LINDSAY, OKLAHOMA
Appendix

Templates for Turning Paths of Design Vehicles

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Introduction

The use of "design vehicles," as established by the American Association of State Highway Officials, has provided a way for proper design of highway intersections and certain ramp terminals at interchanges. Criteria for layout of intersection curves, turning roadways, and interchange ramps—based on the turning characteristics of these vehicles—are now included in the "rural" and "urban" policies of the Association.

To encourage the application of these data and to greatly facilitate the layout of intersections, a set of templates for turning vehicle paths has been developed. The set, illustrated below, consisting of 27 transparencies, pro-
vides for a variety of design conditions, including three types of trucks, three turning radii, and three scales. Trucks represented are the SU—single-unit; C43—intermediate semitrailer combination; and C50—large semitrailer combination. Turning radii, described by the outer-front wheel, are 45 feet (or less), 60 feet, and 75 feet. Scales used to fit the usual range and size of layouts are 1" = 50', 1" = 40', and 1" = 20'. Each transparency includes paths for a variety of turning angles, viz., 30, 60, 90, 120, 150, and 180 degrees.

The templates may be used (1) in review and check of intersection plans, or (2) in design of intersections. In the former, appropriate templates laid over the plan and the superimposed vehicle paths properly positioned indicate whether or not the layout is proper and what adjustment may be necessary. In the latter case, the appropriate templates are laid over a skeleton or base of the intersection plan; and the wheel paths, when located in a desired position, are transferred to the layout. The design is then sketched in, fitting these paths. The transfer of the turning paths is made by placing pencil dots through the perforations provided on the templates. By manipulation of the template, the center hole permits the paths to be adapted to any odd angle of turn.


** The 45-foot turning radius is the minimum for the SU vehicle; for the C43 and C50 vehicles, minimum radii are 40 and 44 feet, respectively. Minimum turning radii, or near-minimum (60 to 75 feet), are normally employed in intersection design.
Illustrative Problem

The technique in the use of these templates is demonstrated in the following design problem, shown in the sequence of Figures 1 to 6.

The basic condition of the intersection is illustrated in Figure 1, in which a divisional island, about eight feet in width, is to be introduced on the intercepted road, and a small directional (triangular) island introduced in the acute-angle quadrant. A complete layout is to be established, including the position and shape of the median opening.

With the approximate position of the divisional island assumed, left-turning paths are next established by placing the template in desired position and making pencil dots through perforations, as in Figure 2, thus transferring the wheel paths to the drawing. Minimum paths (red-band templates) usually apply to acute-angle turns while the larger turning radii, of 65 and 75 feet (green- and blue-band templates) generally apply to obtuse-angle turns. Right turning paths are shown on the front of the template (arrow showing direction of travel). The same templates apply to left-turning movements by using the reverse side.

In Figure 3 the two left turns, by the method described above, have been transferred to the plan and shown by dotted lines.

At this point, the median opening and the crossroad divisional island are sketched in fitting the left-turning paths, as shown in Figure 3.
Figure 4. Normally, the edges of pavements and islands are set at 3 to 4 feet outside the wheel paths. Approach noses of islands, however, are offset several feet more.

The right-turning paths, Figure 4, are added to the plan, by the use of the templates, and the remainder of the plan is sketched in, Figure 5. The plan is completed, as shown in Figure 6, by refining the layout and, where appropriate, fitting calculated lines to it.

Use of Templates for Odd Angles of Turn

In cases where the paths, as shown for each 30-degree increment, do not fit the angles of intersection on the plan closely enough, the template can be manipulated to produce a turning path for any angle of intersection.

Consider the example discussed above, in which the angle of intersection is 68 degrees, and the angle of left turn, therefore, 112 degrees. Thus, the
desired path is between the 90- and 120-degree angles available on the template; these are the stippled or shaded paths indicated in Figures 7 and 8.

Figure 7.

The adjustment for the proper angle of turn is made by placing the template with the beginning portion of the path in a proper position, as illustrated in Figure 7; i.e., the vehicle approach marked (A), is centered on and made parallel to the lane from which the turn is begun, and at the same time the bulge of the outer wheel path (B) is placed so as to permit proper entry into the intersecting road. With the template so located, a sharp pencil is placed through the center hole (C) in the template. The pencil is held firmly and the far end of the path (D) is swung clockwise into position by revolving the template; see Figure 8.

When the template is in its initial position, Figure 7, the beginning portion of the path is transferred to the layout by marking through the perforations, as

Figure 8.
previously illustrated in Figure 2. The remainder of the path is transferred after the template is swung into the latter position, Figure 8. Thus, the effect produced is a described path for the specific or the odd angle of turn required.