Geometric Design Features of Single-Point Urban Interchanges

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The single-point urban interchange (SPUI) is a relatively new type of diamond interchange. It offers improved traffic-carrying ability, safer operation, and reduced right-of-way needs under certain conditions when compared with other interchange configurations. The distinguishing feature of this interchange is the convergence of all through and left-turning movements into a single, signalized intersection area. The more important visibility issues and geometric design features of the SPUI are summarized. The geometric considerations for left-turn path design and for placement of traffic control devices are discussed, and the effect of certain design features on bridge length is examined. The theme is that the complexity of the SPUI design requires careful selection of all design feature dimensions and an awareness of the impacts of design decisions on traffic operations and structural costs.

In most urban areas, traffic demand on existing arterial roadways has grown to the point where congestion is commonplace. The greatest restriction to traffic flow along these roadways is at signalized intersections. Common solutions to congestion problems at intersections include the addition of traffic lanes or, when right-of-way is unavailable, the grade separation of one or more through movements.

When grade separation is being considered, designers have traditionally considered conventional diamond and partial cloverleaf interchange configurations. One particular type of diamond interchange, sometimes called a compressed or tight urban diamond interchange (TUDI), has proven to be an efficient interchange configuration in terms of both minimal right-of-way requirements and operational performance. The TUDI design includes two closely spaced ramp and crossroad intersections that depend on a well-coordinated signal phasing arrangement for efficient traffic operation.

A new type of interchange has emerged recently (see Figure 1), commonly called the single-point urban interchange (SPUI). SPUI offers improved traffic-carrying ability, safer operation, and reduced right-of-way needs under certain conditions when compared with such other interchange configurations as TUDI and normal diamond-type interchanges (*1–4*). The distinguishing feature of this interchange is the convergence of all through and left-turn movements into one signalized intersection area on the crossroad versus two separate intersection areas. The advantage of this feature is that all intersecting movements can be served by a single signal with, at most, one stop required to pass through the interchange. Approximately 40 SPUIs are in operation in the United States, and a similar number are under construction or consideration.

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There are two basic types of SPUIs: those with the major road elevated over the ramp and crossroad intersection (i.e., an overpass SPUI, shown in Figure 1) and those with the major road depressed under the intersection area (i.e., an underpass SPUI, shown in Figure 2). Most SPUIs are overpasses.

The difference between the two SPUI types is most evident in the design of the bridge structure. The overpass SPUI typically includes a conventional, long single-span bridge; sometimes a three-span bridge is used. In contrast, the underpass SPUI usually requires a deck or platform-type structure to support the various intersecting traffic movements. These differences can be further illustrated by the length, depth, and number of spans in the bridge structure. A typical overpass design would have a single-span bridge of 220 ft in length and a depth of 8 to 9 ft. An underpass design would have two spans of about 70 ft in length and a depth of 3 to 4 ft.

Some important visibility issues and geometric design features of SPUI are summarized here, with particular emphasis on left-turn path design, placement of traffic control devices, and factors affecting bridge length.

VISIBILITY ISSUES

In any type of interchange, unobstructed visibility of the sign-ing, geometric configuration, pavement markings, signaliza-tion, and channelization features are necessary for the drive to safely and efficiently perform the correct maneuvers at th proper time while traveling through the interchange. Thi need for driver visibility at a SPUI is emphasized because left turn movements in a SPUI are quite different from those a the more common TUDI. Drivers who are unfamiliar wit the SPUI design may encounter some initial difficulty in per forming a left-turn maneuver from the crossroad or the off ramp. For this reason, the applicable sight distances and vis ibility lines of sight should be maximized.

Visibility Along the Major Road and Ramps

Visibility and line-of-sight considerations from the major roa to the exit-ramp signing and geometry are important desig considerations. The guide signing should preferably be ove head and conform to the *Manual on Uniform Traffic Contr Devices* (MUTCD) (*5*). Decision sight distance along the ma jor road approach to the exit ramp, as described in *A Polic on Geometric Design of Highways and Streets* (*6*, p. 12

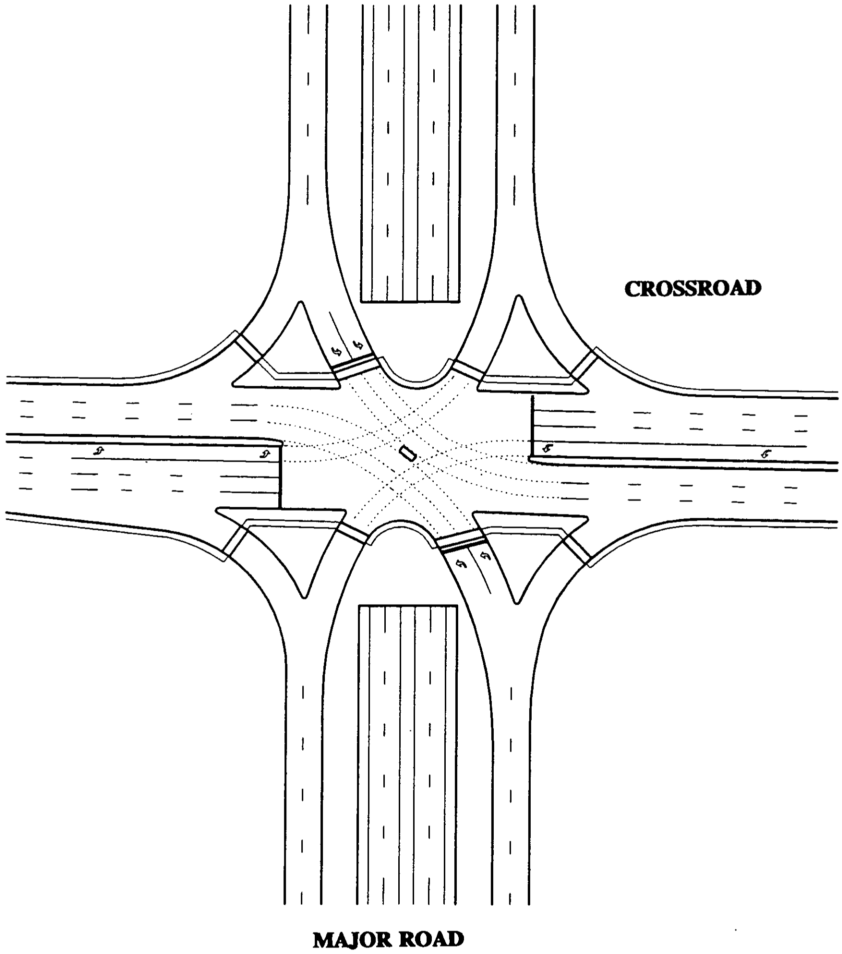

FIGURE 1 Overpass SPUI.

(commonly referred to as the Green Book), should be used as the minimum signing design criteria. Sight distances of 1,000 to 1,450 ft would be appropriate for major road speeds of 60 to 70 mph, depending on the location of the interchange (e.g., urban or rural).

The exit-ramp driver's visibility to the crossroad intersection is especially critical at a SPUI because the decision point to turn left or right will occur somewhat sooner at a SPUI than at other diamond-type interchanges. As a minimum, the horizontal and vertical exit-ramp alignment should provide desirable design values of stopping sight distance (*6*, pp. 284, 293). However, alignments based on decision sight distances (*6*, p. 125) should be used whenever possible. Extremely sharp horizontal or vertical curves should be avoided on the exit-ramps in the vicinity of the left- or right-turn decision point.

The point of initial driver perception of the large triangular intersection island and the point for the left- or right-turn decision should occur at or just beyond the gore point on the off-ramp from the major roadway. The target value of this island can be enhanced by installing appropriate warning and target delineation signs at the decision point and on the nose of the intersection island.

Visibility Along the Crossroad

Although not as critical as the major road, elements of the crossroad approaches to the SPUI should also provide for maximum driver visibility. Decision sight distance for the crossroad approach to the SPUI should be used as the minimum signing design criteria. As a minimum, crossroad horizontal and vertical alignment should provide desirable design values of stopping sight distance (*6*, pp. 284, 293). However, the crossroad alignment should provide intersection sight distances (*6*, p. 760) whenever possible.

Due to the SPUI's relatively unusual design, crossroad drivers rely heavily on guide signing, pavement markings, and lane use signing for the necessary positive guidance to travel safely through the SPUI intersection area. Sight triangle distances and sight lines to the traffic signals and other traffic control devices should be checked for conformance with the MUTCD (*5*, p. 4B-11). The presence of a small, mountable center island with signing and object markers will encourage the correct and proper flow of traffic through the area. High-quality pavement markings along the left-turn path also contribute positively to visibility for the left-turning driver.

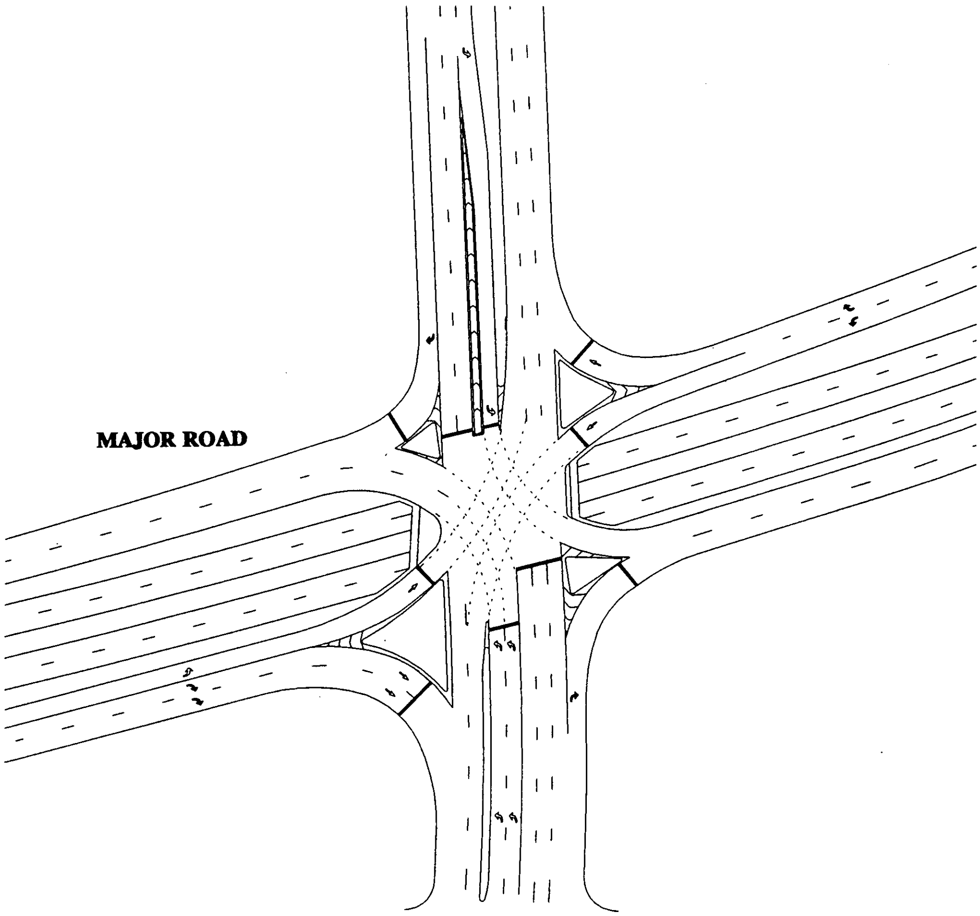

FIGURE 2 Underpass SPUI.

Another enhancement to driver visibility through an overpass SPUI is the use of a multispan structure instead of a single-span bridge. A longer, multispan bridge will provide a more open and less restrictive feeling to the driver as he or she approaches the intersection area. This openness increases the off-ramp left-turn driver's view of the crossroad and probably helps reduce the anxiety of all drivers traveling through the intersection area. A multispan bridge may alleviate driver anxiety by eliminating the "dark hole," or "tunnel," effect that is created by the SPUI's relatively wide overpass structure. Understructure lighting reduces this "dark hole" effect.

GEOMETRIC CRITERIA

Addressed in this section are design considerations for the SPUI left-turn roadway, which is one of the more unusual geometric features. Also examined are the impact of selected geometric features on the length of the bridge and the size of the intersection area.

Left-Turning Roadway Layout

Radius and Superelevation Rate

One of the SPUI's most unique features is its relatively high-speed left-turning roadways. The design of these roadways is complicated by the fact that a portion of the roadway is in the intersection area, and a portion is on the ramp. The portion in the intersection area should not have any superelevation, whereas the portion on the ramp should have a minimum slope for drainage purposes. The AASHTO Green Book (*6*, p. 197) provides some guidance on the relationship between design speed and radius for superelevated turning roadways.

The relationship between design speed and radius described in the AASHTO Green Book is as follows:

$$e + f = V^2/15R \quad (1)$$

where

V = design speed (mph),
R = minimum radius of curvature (ft),
e = superelevation rate, and
f = side friction factor.

The results of several studies of turn speed (conducted in the early 1940s) are reported in the AASHTO Green Book to illustrate the relationship between design speed (i.e., 95th percentile speed) and side friction in Equation 1. Because none of these past studies specified the superelevation rate found at the study sites, representative rates were assumed by the authors of the AASHTO Green Book. The findings from these studies are summarized in the Green Book (*6*, p. 197) and in Table 1 of this paper.

The author is familiar with a number of well-designed SPUIs, and the radii of the left-turning roadways range generally from about 170 to 400 ft. These radii seem to be the most practical and reasonable for design purposes.

Superelevation is difficult to develop on any intersection approach (especially if there is a significant grade or skew in the intersecting alignments) because of the problems of transitioning from normal crown to superelevated to level section within a relatively short length of roadway.

The left-turning ramp roadway approaching the intersection area should be based on a nominal 0.02 ft^2 superelevation or a reverse crown. First, a nominal superelevation of 0.02 ft^2 will facilitate efficient drainage along the curbed, ramp portion of the turning roadway. Second, the added superelevation will allow drivers to travel at slightly higher speeds on the ramp than on the turn path within the intersection area. This will provide a comfortable speed transition along the ramp between the low-speed crossroad and the high-speed major road.

In summary, the radius of the left-turning roadway should be taken from the second column of Table 1 for a predetermined left-turn design speed.

Sight Distance

Left-turn drivers at SPUIs need stopping sight distance along the turning paths as well as intersection sight distance in the intersection area. This latter sight distance represents the minimum distance that a stopped vehicle must have of the conflicting traffic stream such that there is sufficient time to safely enter or cross the intersection from a stopped position. Because these distances are longer than stopping sight distances, designs based on providing stopping sight distance along the roadway do not guarantee adequate intersection sight distance.

In Figure 3, the sight distance for the left-turning roadways for an overpass SPUI is shown where a bridge abutment or slope treatment could restrict the sight distance. In the underpass type, sight restrictions could be created by a concrete bridge parapet wall or other obstruction, such as pedestrian fences and the like.

As a result, intersection sight distance availability should be checked for all turn movements at both the overpass and underpass types of SPUIs. Intersection sight distance values are described in the AASHTO Green Book (*6*, p. 760).

Intersection sight distance adequacy is sensitive to the amount of curvature in the vertical alignment of the crossroad. This concern is particularly applicable to underpass SPUIs because the intersection area at this SPUI type is often located on a crest curve. The rates of curvature (i.e., K values) provided in the AASHTO Green Book (*6*, pp. 284, 293) are based on providing stopping sight distance only. If these AASHTO Green Book values are used in the design of the vertical alignment through the intersection area, adequate intersection sight distance may not be provided. The crossroad vertical alignment should provide desirable values of stopping sight distance, as a minimum, and intersection sight distance whenever possible.

Stopping sight distance along the SPUI left-turn paths is also an important design consideration. This sight distance, shown in Figure 3, is actually across the inside of the curve and is dependent on the lateral location of sight obstructions (e.g., a bridge retaining wall or safety-shape barrier wall). As a result, the sight distance needs of the left-turn drivers on the SPUI can dictate the location of the bridge supports and, consequently, the length of the bridge.

A procedure for calculating the lateral clearance measured from the centerline of the left-most lane of the left-turning roadway to the furthest offset driver sight line is described in the AASHTO Green Book (*6*, p. 219). Using this procedure,

TABLE 1 Minimum Lateral Clearance to Obstruction

DESIGN SPEED (mph)	MINIMUM CURVATURE (ft)	SIGHT DISTANCE (ft)	LATERAL CLEARANCE (ft)
20	92	125	20.3
25	167	150	16.5
30	273	200	18.1
35	409	225	15.4
40	588	275	16.0

1. Maximum radius of curvature in feet for the design speed calculated from AASHTO Green Book for superelevation rate e=0.02 ft/ft
2. Minimum stopping sight distance from AASHTO Green Book Table III-1, pg. 120
3. Calculated lateral clearance distances from AASHTO Green Book Figure III-26A, pg 222

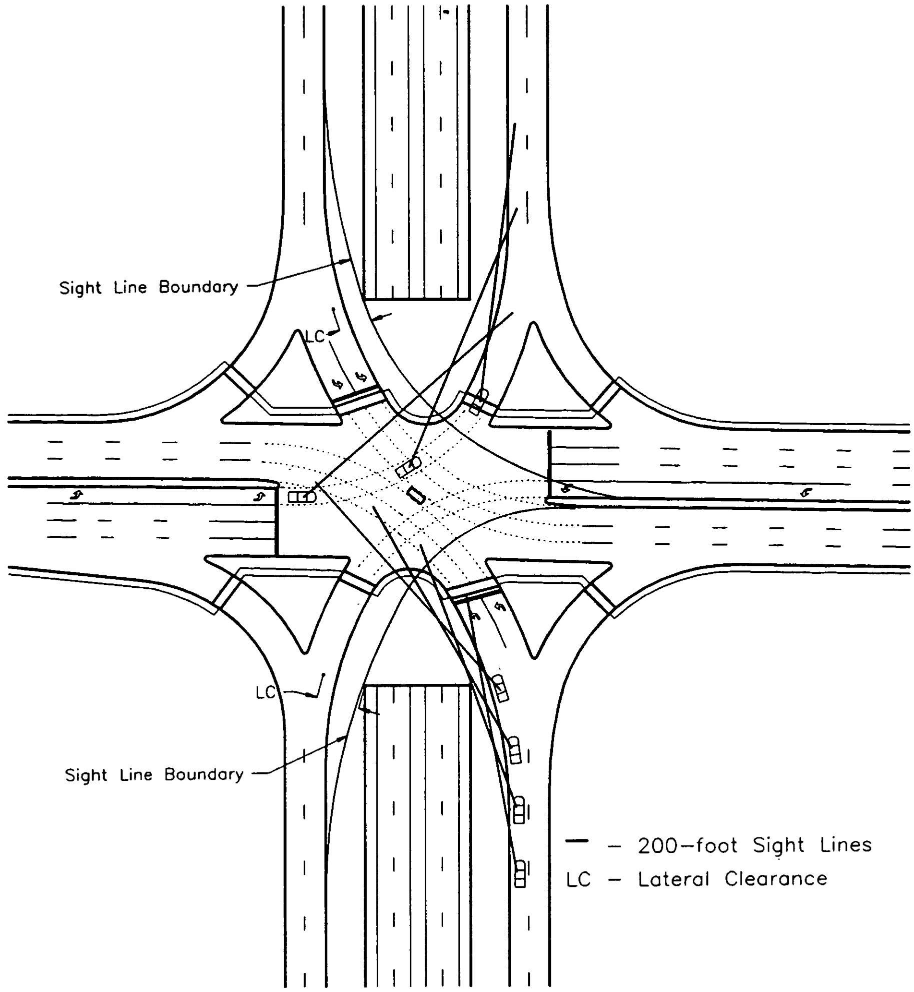

FIGURE 3 Sight distances on left-turning roadways.

the lateral clearance for the range of turn speeds and curvature commonly found at SPUIs will vary from 15 to 20 ft. Lateral clearances based on the left-turn radii are presented in the fourth column of Table 1.

As shown in Figure 3, the lateral clearance boundary formed by the intersection of all possible sight lines changes from zero a short distance before the curve, to a maximum value along most of the curve, and then back to zero following the curve. The lateral clearances in Table 1 represent the minimum values needed along most of the length of the curve. If the lateral clearance listed in Table 1 is provided, adequate stopping sight distance will be available everywhere along the ramp.

Design Speed

Generally, the choice of design speed for the left-turning roadways is critical to the safety and efficiency of the SPUI's operation. It can also have a significant effect on the cost of the structure. Efficient operations can be achieved with a minimum design speed of 25 mph and desirable values ranging from 30 to 35 mph. In cases in which there is a sharp alignment skew angle in alignments, a significant grade on the crossroad, adverse superelevation on the crossroad, or a combination of those factors, a compromise in design speed may be necessar to achieve a reasonable left-turning roadway design.

Curve Geometry

The left-turning roadway layout should be designed to provid a long, constant-radius curve geometry. Broken-back or com pound curves tend to produce undesirable traffic operations including lower discharge rates, increased lane encroachmen by turning vehicles, and higher speed differentials caused b driver hesitancy. Safely traversing a constant-radius curve i significantly easier for the drivers of larger, longer, and wide vehicles.

Another consideration in the SPUI intersection layout i the required separation of the opposing left-turn travel path The relatively high speeds that can be attained on these turn ing roadways cause a certain amount of driver apprehensio in meeting oncoming vehicles. This apprehension can lead t increased erratic maneuvers, unnecessary lane changing, slowe vehicle speeds, higher vehicular speed differentials, and r duced operational efficiency. Therefore, a minimum of 6 between the outside edge lines of opposing left-turning mov ments and a minimum 10-ft vehicle body clearance should be provided.

Number of Lanes and Lane Width for Turning Roadways

Traditional traffic-capacity methods should be used to determine the number of lanes needed in the SPUI design. Designers should always consider dual lanes for both the crossroad and off-ramp left-turn movements whenever possible. Structural problems may arise during attempts to retrofit an existing SPUI to conform to the geometric design standards when the original bridge design provided only for a single-lane turning path.

The pavement width on turning roadways is generally increased slightly to accommodate the off-tracking characteristics of large trucks on curves. The determination of the width of a turning roadway is presented in the AASHTO Green Book (*6*, p. 202). Lane widths under Case I provide for off-tracking in a single lane but not for passing stalled vehicles on the turn path. Thus, Case I is most applicable for the design width of a single-lane left-turn path through the SPUI intersection area. Case II lane widths are based on providing for off-tracking in a single-lane and for passing a stalled vehicle. Case II is applicable for designing the width of single-lane left-turn paths along the SPUI on- and off-ramps. Lane widths for Case III provide for two-lane operation with off-tracking. Case III is applicable to dual-lane left-turn path design both in the intersection area and along the on- and off-ramps.

Grades

Grades on the crossroad through the intersection area should be the minimum necessary for drainage purposes. Grades associated with the ascending off-ramp and descending on-ramp combination of the underpass SPUI can be slightly steeper than AASHTO Green Book recommendations for ramp sections (*6*, p. 964) because gravitational forces can be used to the ramp driver's advantage during deceleration on the off-ramp and acceleration on the on-ramp. Sight distance should always be considered in the design of the ramp grades, as discussed earlier.

Effects of Alignment Skew

The alignments of most intersections and interchanges do not intersect at exactly 90 degrees. There is usually slight skew angle. The same is true of SPUIs. Skew angle is defined as the rotation of the crossroad alignment relative to the major roadway alignment—a clockwise rotation of the crossroad from normal, which results in a positive skew angle.

Skew between the alignments of the major and crossroads can have an adverse effect on SPUI traffic operation because of increased clearance distances, decreased travel speeds on two of the left-turn paths (via shortened radii), and increased difficulty for off-ramp right-turn drivers to see along the crossroad. Alignment skew can also have an effect on the location of the bridge supports, which may require increasing the length of the bridge.

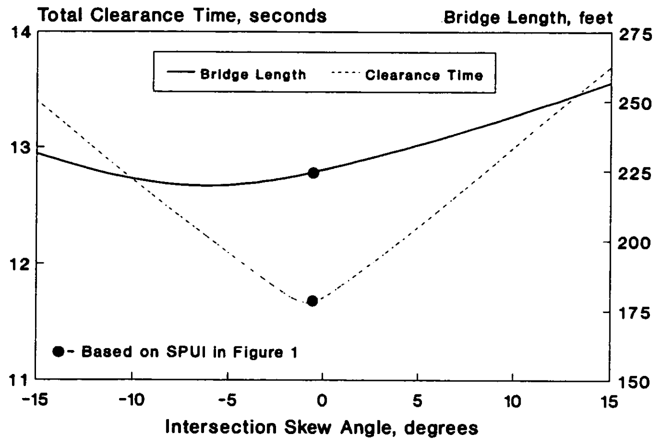

FIGURE 4 Effect of skew angle on clearance time and bridge length.

The effect of skew angle has been examined using a mathematical model of the geometric relationships between the ramp, crossroad, and bridge abutment locations based on ramp driver sight distance requirements (*7*).

Figure 4 illustrates the effect of skew angle on the total all-red clearance time and bridge length for the SPUI shown in Figure 1. Total all-red clearance time represents the sum of the three clearance intervals associated with the crossroad left-turn, crossroad through, and off-ramp left-turn signal phases. Because all-red time represents time not available to serve SPUI traffic, it is a useful measure of the impact of skew on the operational efficiency of the SPUI.

In summary, skew in the alignments can increase the clearance time and bridge length. Large skew angles should be avoided in the design of a SPUI.

Crossroad Median Considerations

Like skew angle, median width also has an effect on bridge length and all-red clearance time. The relationship between median width and bridge length is relatively straightforward. The width of the crossroad cross section must be increased to accommodate an increase in the width of any of its components. For example, if the median is widened, the bridge that spans it must be lengthened. This relationship is shown in Figure 5.

Also shown in Figure 5 is the effect of median width on all-red clearance time. This figure suggests that there is a nonzero median width that yields a minimum all-red clearance time of about 6 ft for this particular SPUI. This analysis assumes that the median nose has compound curvature such that the median curb is designed to conform to the radius of the off-ramp left-turn path until such a point that it reaches a nominal 4-ft width and can be "capped" with a 2-ft nose radius. This design technique is commonly used at most at-grade intersections with wide medians. Its benefit at the SPUI is that it allows the two crossroad median noses to be brought closer together. Since the median nose is typically used to locate the stop lines of the crossroad traffic movements, this technique effectively minimizes the size of the intersection area and the length of the associated clearance paths.

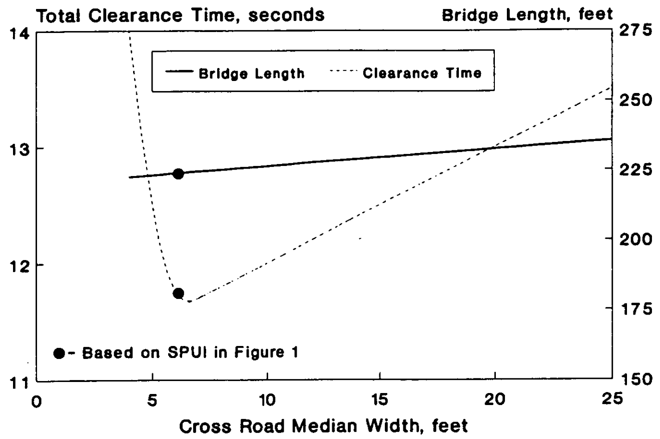

FIGURE 5 Effect of median width on clearance time and bridge length.

In summary, a median of nominal width combined with the median design technique described above can minimize the length of the all-red clearance time.

OTHER DESIGN CONSIDERATIONS

Pedestrian Accommodations

At typical at-grade intersections, pedestrians are accommodated within the signalization by provision of a coincident through-vehicle phase. Unfortunately, at a SPUI, pedestrians crossing the crossroad do not have a coincident through phase because this phase corresponds with the grade-separated major road movement (unless there are frontage road movements). As a result, an exclusive, actuated pedestrian phase is needed or pedestrian movement is not provided for. Pedestrians could be directed to the nearest intersection to safely cross the crossroad.

When a pedestrian phase is not included in the three-phase SPUI signalization, pedestrians crossing the crossroad will not be able to complete the crossing during one signal phase. Pedestrians will have to cross to the median and wait there until a subsequent phase allows them to cross to the other side. If this type of pedestrian crossing is provided, the crossroad median should be sufficiently wide to provide for a pedestrian refuge area.

When an actuated pedestrian phase is included in the three-phase SPUI signalization, the phase is typically assigned to operate concurrently with the adjacent off-ramp left-turn movement. This operation has the advantage of providing some concurrent vehicular traffic service, although it is limited to serving pedestrians on one side of the SPUI at a time. If pedestrian demands are sufficiently high such that they must be served on both sides of the SPUI, then an exclusive pedestrian phase may need to be considered. If pedestrian signalization is provided, the crossroad median would not need to be designed as a place of pedestrian refuge.

Proximity of Nearby Intersections

The distance to the closest intersection measured along the crossroad is a critical issue for all interchange configurations. The ability to provide safe and efficient left- and right-turn movements from the off-ramp to the crossroad at SPUIs is directly dependent on the location, spacing, and signal coordination of the adjacent intersections. If the signal controllers at the SPUI and adjacent intersections are not coordinated, there may be undesirable speed differentials and a high potential for rear-end type collisions. The results of two recent studies of accident patterns at SPUIs (*8,9*) indicate that rear-end accidents on the off-ramps are the predominant type of accident at SPUIs.

Efficient signal coordination at all signalized junctions typically requires a minimum intersection spacing to ensure efficient traffic progression over a range of travel speeds and cycle lengths. Stover et al. (*10*) studied the effect of intersection spacing on arterials and developed relationships among travel speed, spacing, and cycle length that maximize progression efficiency. The results of their study indicate that a ½-mi spacing between signalized intersections will yield the maximum progression efficiency for travel speeds between 35 and 40 mph and cycle lengths between 90 and 100 sec. Because SPUIs also usually require longer signal cycle lengths than conventional intersections, they will fit well into a progressive coordinated system. The ½-mi spacing is desirable between the SPUI and adjacent crossroad intersections. A spacing to adjacent intersections should be about 1,000 ft. This will provide sufficient distance for left-turn bay development and some limited traffic progression opportunities. Lesser spacing is usually the case in urban conditions, but longer distances should be considered during the interchange design process.

Access Control

Another SPUI design consideration is the control of access on the crossroad. Full access control for a reasonable distance from the ramp intersections is needed to provide for the higher speed turns that are common at SPUIs. The AASHTO Green Book (*6*, p. 841) indicates that driveways and entrance approaches should be prohibited along the crossroad within the SPUI's "functional boundary." On the approach side of the crossroad, this functional boundary is generally interpreted to extend a distance equal to or greater than the combined left-turn bay taper and storage length. On the departure side, the functional boundary should extend a reasonable distance beyond the entrance to the off-ramp.

Traffic Signal Placement

Traffic signal placement is an important design decision at a SPUI. Traffic signals at existing SPUIs have been installed over the center island, on the outside beams of the bridge structure, on span wire in advance of the structure, on combination overhead signal and sign structures, and on the triangular islands adjacent to the ramps. Generally, signal heads that are centered over the travel lanes they control offer more positive guidance to the drivers than do the heads mounted adjacent to the traveled way.

Signal heads are mounted either vertically or horizontally at SPUIs. Displays at most existing SPUIs are mounted vertically. When vertical heads are centered over the travel lanes at overpass SPUIs, they should be always external to the bridge structure. Vertical signal heads mounted on the outside girders of the bridge structure and centered over the travel lanes are the preferred design. If terrain and other conditions permit adequate vertical underclearance at little or no additional construction cost, horizontal signal heads suspended over the lanes beneath the structure may be desirable.

The visibility of the signal heads controlling the off-ramp left-turn movement is critical. An advance signal may be needed on the larger triangular island on the off-ramp approach to provide the driver advance notice of the signals ahead. A "pull through" signal on the opposite triangular island can also be placed at SPUIs where travel distances through the intersection are relatively long. In all cases, the placement of the signals, when viewed from the off-ramp approach, should conform to the horizontal and vertical sight-line criteria described in the MUTCD (*5*, p. 4B–11). For the overpass SPUI, the edge of the bridge abutment should be checked for conflict with the visibility of the off-ramp signal heads. The minimum visibility distance to a signal head mounted over the centerline of the off-ramp left-turn lane will normally be provided if the lateral clearances presented in Table 1 are used in the layout geometrics of the interchange.

Signing, Pavement Markings, and Island Channelization

The geometric layout of SPUIs must be coordinated with the signing, pavement markings, and island channelization. Signing at SPUIs is similar to that of other diamond-type interchanges except larger legends and advance signing should be used because of the higher turning speeds in the interchange. Approach directional signing should be mounted overhead with a large legend both on the major roadway and the crossroad. The placement of the support systems for the overhead signing should be considered when developing the preliminary interchange design geometrics.

Pavement markings at SPUIs are also similar to those at other diamond interchanges except for those associated with higher speed left turns. The lane line markings for these movements must be maintained at a higher level of visibility to provide better positive guidance to drivers. In some cases, embedded pavement marking lights, commonly used on airport runways, have been used to enhance the delineation of left-turn movements. The impact of these lights on drivers has not been formally studied, but all indications suggest that the lights have more of a novelty effect than a true operational or safety benefit. When a signal is installed beneath the structure, a small island with signing and delineation is commonly used to protect the under-hanging signal array and to effectively divide and separate the opposing left-turn movements. The shape and size of this small island are important design considerations. The island shape is governed by the travel path geometry in the intersection area and is normally in the shape of a small parallelogram or rectangle. The island size is dependent on the island being large enough to encompass the signing and delineation treatment and satisfying the AASHTO Green Book (*6*, p. 722) recommendation that islands in urban areas are a minimum of 50 ft^2, preferably larger. Based on observations of numerous SPUIs by the author, it is recommended that one side of the island should be around 10 ft long; the minimum recommended length is about 6 ft (*11*).

Right-of-Way Usage

One of the advantages of the SPUI design is the minimal crossroad right-of-way required as compared with other diamond interchange forms. TUDIs with low to moderate left-turn demands on the crossroad typically do not have advance left-turn lanes and may have a slightly narrower right-of-way. TUDIs with extremely high left-turn demands will probably require exclusive left-turn lanes and the right-of-way may be somewhat wider than the SPUI because the TUDI's signal operations will not allow these lanes to be overlapped.

The right-of-way required along the SPUI's major road is considerably narrower than most other interchange forms but is about the same as TUDI. The right-of-way requirements of the SPUI, the distance between the outside back-of-curbs of each on- and off-ramp pair generally ranges from 200 to 600 ft, with an average of about 300 ft. By comparison, TUDIs are generally designed for rights-of-way from 250 to 400 ft.

SUMMARY

All aspects of the SPUI design should be thoroughly examined during the preliminary design stage to ensure that it is both economically and operationally efficient. In no other interchange configuration are the details of the bridge design so interrelated to the geometric and traffic control device design features. Well-designed SPUIs emphasizing the principles of positive guidance can operate safely and efficiently under a wide range of traffic conditions. Every effort should be made to use desirable design values for all features of the SPUI design.

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