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Design of Single Point Urban Interchanges

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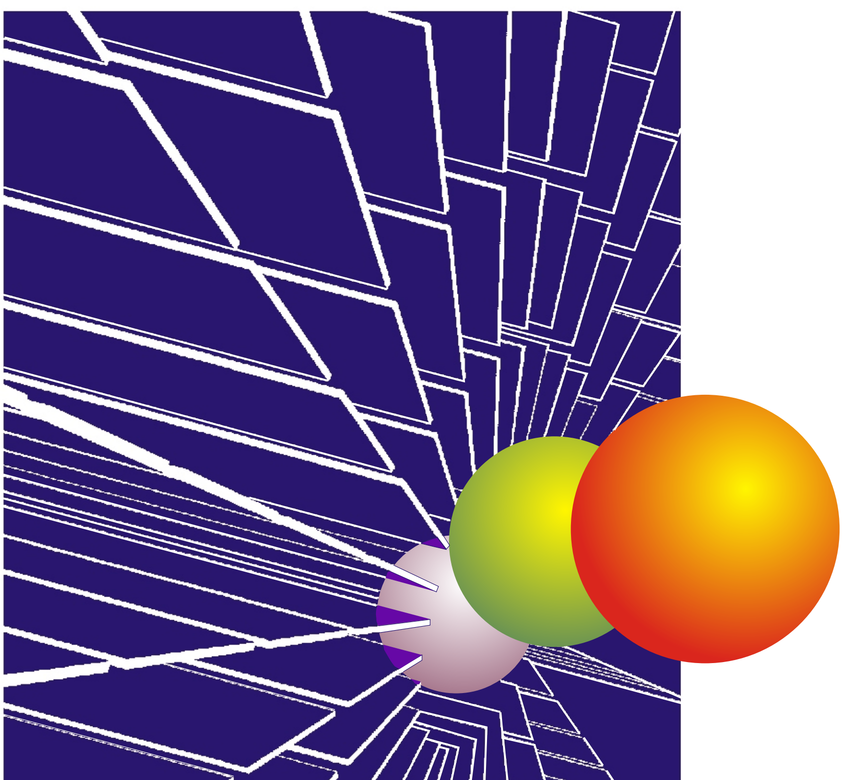

September, 2004

Final Report

Research Investigation 02-015

Design of Single Point Urban Interchanges

MISSOURI DEPARTMENT OF TRANSPORTATION
RESEARCH, DEVELOPMENT AND TECHNOLOGY

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The Missouri Department of Transportation has three functional Single Point Urban Interchange (SPUI) but there are no specific design guidelines for them. This research was undertaken to provide design guidelines for SPUI and provide a set of warrants to decide when to install SPUI as compared to Diamond Interchanges. These guidelines will help MoDOT engineers in making engineering decisions regarding the installation of SPUI

In order to address the objectives of this research, a two step approach was used. First, a comprehensive literature review was conducted. The results of the literature review were used to develop a survey instrument sent out via the AASHTO Research Advisory Committee (RAC) listserve. The questionnaire consisted of 14 questions and was designed to ascertain the current state of practice in the US regarding the planning, design and construction of SPUI and to identify whether other states had any specific guidelines for the design of SPUI. Fourteen states provided responses to the survey.

In this report different key geometric and operational characteristics of SPUI were studied and their influence on SPUI design discussed. Some of the most important geometric characteristics and operational characteristics are grade separation, skew angle, roadway characteristics, signal phasing, left turn radii, right turn radii and traffic volume. Other characteristics such as cost of construction, accident studies etc are also considered important. Most of the states surveyed have different criteria for each of the design characteristics, but certain range of values were recommended as used by most of the states.

Survey results showed that most states ranked right of way as the most important reason for installing SPUI. Some of the states also ranked increase in capacity as the main reason. When there was a need for frontage roads, SPUIs were discouraged as this reduced the efficiency of SPUI. It is commonly agreed that SPUI does not accommodate pedestrian crossing effectively. A separate phasing is required for the pedestrians and this reduces the efficiency of SPUI. One of the main reasons for many states not using a SPUI is that the cost of construction is very high. Also many expressed apprehension that SPUI will cause confusion among drivers.

This study provides recommendations for the considerations in selecting a SPUI and associated key design characteristics. Although there are no specific guidelines for the installation of a SPUI, this study will hopefully make engineering judgment among MoDOT engineers more consistent. This report should be used as a reference whenever a SPUI is being considered.

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EXECUTIVE SUMMARY

In the last two decades vehicle-miles traveled (VMT) in urban areas have grown tremendously and are expected to increase even more during the next 20 years. Between 1990 and 2000, VMT in the United States increased 28.2%, registered vehicles 17.3%, and VMT per driver 12.4% (1). By 2010, the VMT is expected to increase by an additional 35% (2). These increases bring with them dramatic increases in fuel consumption, vehicle emissions and delay. The Federal Highway Administration (FHWA) in its 2002 Conditions and Performance Report to Congress reported that the additional time required in making a trip during the congested peak period, compared to non-peak times, increased from 37% in 1990 to 51% in 2000 (1). Most of this traffic occurs on our freeway system and a majority of all congestion-related problems occurs at interchanges between limited and full access highways – the service interchanges.

One of the common solutions to this traffic problem is to construct Diamond interchange. Diamond interchanges serve well only in low volume conditions and as the volumes increase problems related to congestion increase (3). Since the Diamond interchange has two intersections located close to each other, it requires a large amount of right of way.

In 1970, a new interchange concept was developed by Griener Engineering Sciences Inc., which offered improved traffic-carrying capacity, safer operation and required less right of way than the Diamond interchange. This interchange has been called the Single Signal interchange, Urban interchange, Single-Point Diamond, Compressed Diamond, Urban Grade Separated Diamond, and the Single Point Urban Interchange (SPUI) mainly because of its peculiar geometry. SPUIs are usually used in urban areas with large traffic volumes.

The SPUI is a grade-separated interchange that converges all the movements into one signalized area. There are two types of SPUIs: overpass SPUIs and underpass SPUIs. Overpass

SPUIs are the SPUIs in which the freeway is elevated above the crossroad. An underpass SPUI is one in which the freeway passes under the cross-road. Overpass SPUIs are more common in the US because they require less destruction to the adjacent property and also they are much easier to construct and maintain. Underpass SPUIs are usually constructed in hilly areas where grades are usually high and it is not possible to elevate the freeway.

There are some uncertainties regarding the performance of SPUI. Some researchers believe that SPUIs have more operational efficiency than Diamond interchanges while others favor Diamond interchanges. Not many studies have been conducted to compare these two types of interchanges. Furthermore, there are not many operational SPUIs from which specific conclusions can be drawn.

The Missouri Department of Transportation (MoDOT) has constructed three functional SPUIs but there are no specific design guidelines for them. This research was undertaken to provide design guidelines for SPUIs and provide engineers with a set of warrants to determine when to install SPUIs instead of Diamond interchanges.

In order to address the objectives of this research, a two-step approach was used. First, a comprehensive literature review was conducted. The purpose of the literature review was:

- To understand the unique features of SPUIs;
- To identify critical design characteristics of SPUIs; and,
- To find out advantages and disadvantages of SPUIs compared to Diamond interchanges.

The results of the literature review were used to develop a survey instrument sent out via the AASHTO Research Advisory Committee (RAC) listserve. The questionnaire consisted of 14 questions and was designed to ascertain the current state of practice in the US regarding the planning, design and construction of SPUIs and to determine whether other states had any specific guidelines for the design of SPUIs. Fourteen states responded to the survey.

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Survey results showed that most states ranked right of way as the most important reason for installing SPUIs. Some of the states also ranked increase in capacity as the main reason. When there was a need for frontage roads, SPUIs were discouraged since frontage roads reduced SPUI efficiency. It is commonly agreed that SPUIs do not accommodate pedestrian crossing effectively. A separate phasing is required for the pedestrians and this reduces SPUI efficiency. A primary reason that many states do not use a SPUI is that construction costs are very high. Also many states expressed apprehension that SPUIs will cause confusion among drivers.

This study discusses elements to be considered before selecting a SPUI and its key design characteristics. Although no specific guidelines for the installation of a SPUI exists, this study will hopefully allow for greater engineering judgment uniformity among MoDOT engineers. This report should be used as a reference whenever a SPUI is being considered.

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1 INTRODUCTION

In the last two decades vehicle-miles traveled (VMT) in urban areas have grown tremendously and are expected to increase even more during the next 20 years. Between 1990 and 2000, VMT in the United States increased 28.2%, registered vehicles 17.3%, and VMT per driver 12.4% (1). By 2010, the VMT is expected to increase by an additional 35% (2). These increases bring with them dramatic increases in fuel consumption, vehicle emissions and delay. The Federal Highway Administration (FHWA) in its 2002 Conditions and Performance Report to Congress reported that the additional time required in making a trip during the congested peak period, compared to non-peak times, increased from 37% in 1990 to 51% in 2000 (1). Most of this traffic occurs on our freeway system and a majority of all congestion-related problems occurs at interchanges between limited and full access highways – the service interchanges.

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In 1970, a new interchange concept was developed by Griener Engineering Sciences Inc., which offered improved traffic-carrying capacity, safer operation and required less right of way than the Diamond interchange. This interchange has been called the Single Signal interchange, Urban interchange, Single-Point Diamond, Compressed Diamond, Urban Grade Separated Diamond, and the Single Point Urban Interchange (SPUI) mainly because of its peculiar geometry. SPUIs are usually used in urban areas with large traffic volumes.

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SPUIs are the SPUIs in which the freeway is elevated above the crossroad (Figure 1). An underpass SPUI is one in which the freeway passes under the crossroad. Overpass SPUIs are more common in the US because they require less destruction to the adjacent property and also they are much easier to construct and maintain. Underpass SPUIs are usually constructed in hilly areas where grades are usually high and it is not possible to elevate the freeway.

Figure 1: Overpass SPUI

Source: http://www.thenewi64.org/1d1_designfeat.jsp

There are some uncertainties regarding the performance of SPUI. Some researchers believe that SPUIs have more operational efficiency than Diamond interchange while others favor Diamond interchanges. Not many studies have been conducted to compare these two types of interchanges. Furthermore, there are not many operational SPUIs from which specific conclusions can be drawn.

MoDOT has constructed three functional SPUIs but there are no specific design guidelines for them. This research was undertaken to provide design guidelines for SPUIs and provide engineers with a set of warrants to determine when to install SPUIs instead of Diamond Interchanges.

2 OBJECTIVES

- To examine the state of design, signalization, signing and lighting of SPUI
- Compare and contrast alternative techniques
- To develop a set of guidelines for MoDOT traffic engineers to design SPUIs in Missouri.

3 PRESENT CONDITIONS

At present there are three operational SPUIs in Missouri. Two of them are located in St. Louis: one at the intersection of MO 30 and MO 141 and other at the intersection of MO 141 and MO 100. The third SPUI is located in Springfield at the intersection of US 65 and Sunshine Street. There are several other sites throughout the state where SPUIs are being considered.

Currently MoDOT does not have any standard plans or specifications for SPUIs. MoDOT's Project Development Manual (PDM) does refer to SPUIs, but not in great detail. The PDM states that SPUIs should be considered when a high traffic volume exists and also when right of way is restricted or expensive, but the high volume is not specified. It also mentions that SPUIs generally use less right of way than a Tight Diamond Urban Interchange (TDUI), but requires a longer bridge span when designed as an overpass interchange. It gives general ideas for designing interchanges and refers to the ramp design speed for interchanges, ramp radius, median, island, right turn lane and left turn lane for At-Grade Intersections. Although design details for Diamond interchanges, such as alignment and interchange ramps, are explained, no design details for SPUIs are included. Consequently, MoDOT engineers design SPUIs based on their engineering judgment.

4 APPROACH

In order to address the objectives of this research, a two-step approach was used. First, a comprehensive literature review was conducted. The purpose of the literature review was:

- To understand the unique features of SPUIs;
- To identify critical design characteristics of SPUIs; and,
- To find out advantages and disadvantages of SPUIs compared to Diamond interchanges.

The results of the literature review were used to develop a survey instrument sent out via the AASHTO Research Advisory Committee (RAC) listserve. The questionnaire consisted of 14 questions and was designed to ascertain the current state of practice in the US regarding the planning, design and construction of SPUIs and to determine whether other states had any specific guidelines for the design of SPUIs. The questions in the email survey are detailed in Appendix B.

The fourteen states that responded to the survey are Alabama, Arkansas, Connecticut, Georgia, Idaho, Maine, Michigan, Nebraska, Oklahoma, South Carolina, Tennessee, Texas, Virginia and Wisconsin (Figure 2). In addition to their written replies, representatives from these states were contacted via phone. Their responses are detailed in Appendix C.

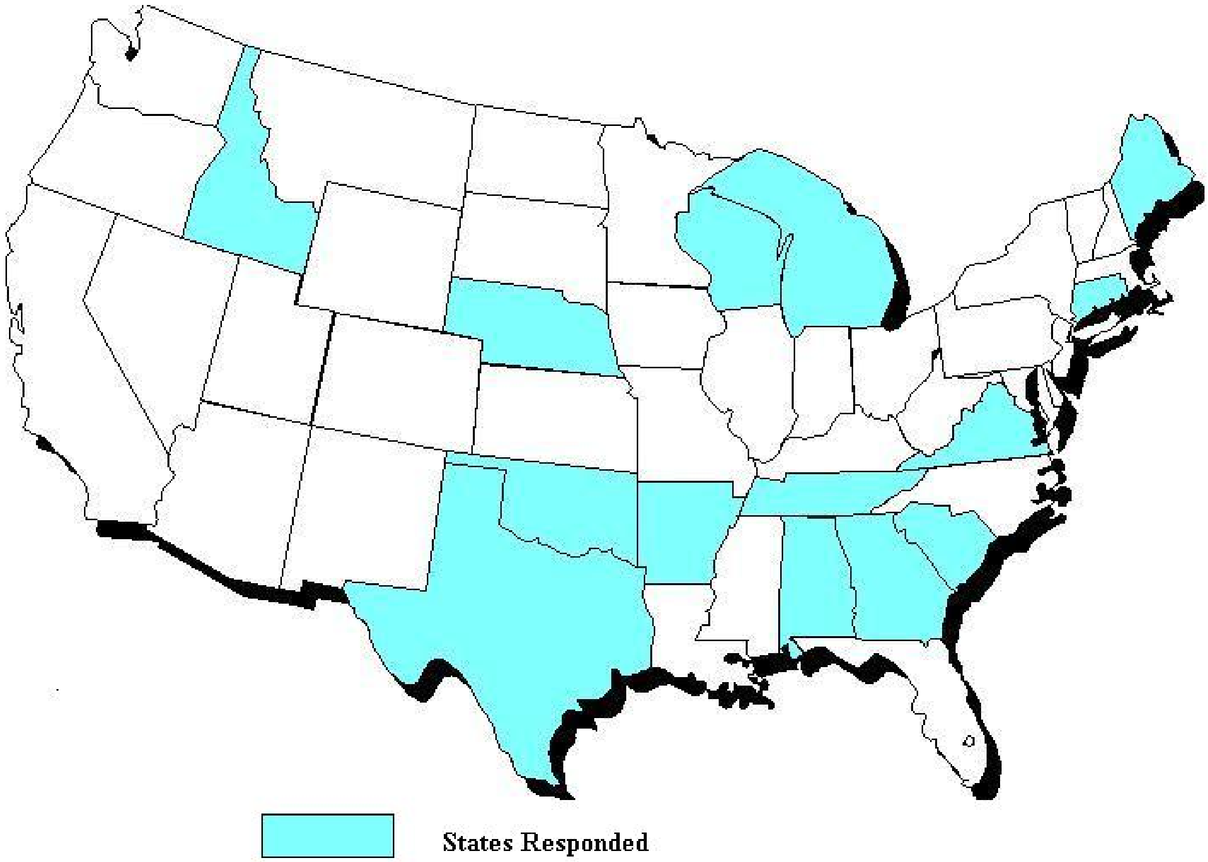

Figure 2: States that responded to the survey

5 RESULTS AND DISCUSSION

The objectives of the research from the work plan were:

- To examine the state of design, signalization, signing and lighting of SPUIs
- Compare and contrast alternative techniques
- To develop a set of guidelines for MoDOT traffic engineers to design SPUIs in Missouri.

A literature review and survey revealed that none of the states have any specific guidelines for the design of SPUIs. Since there were no specific design guidelines, the next step was to identify the key elements in SPUIs and provide design guidelines for them. So the objectives of the research were slightly modified and the new objectives became:

- To examine the state of practice for the placement and design of SPUIs
- To develop a set of warrants for the installation of SPUIs
- To identify the key design elements of SPUIs
- To develop a set of recommendations for MoDOT Traffic Engineers to design SPUIs.

The results are presented in two sections. The first section consists of considerations for the installation of SPUIs and the second of the key elements for the design of SPUIs.

5.1 CONSIDERATIONS FOR INSTALLATION OF SPUI

The unique feature of a SPUI is that it converges all movements (through, off ramp left turn and crossroad left turn) into one signalized area. A simplified design of a SPUI is given in Figure 3.

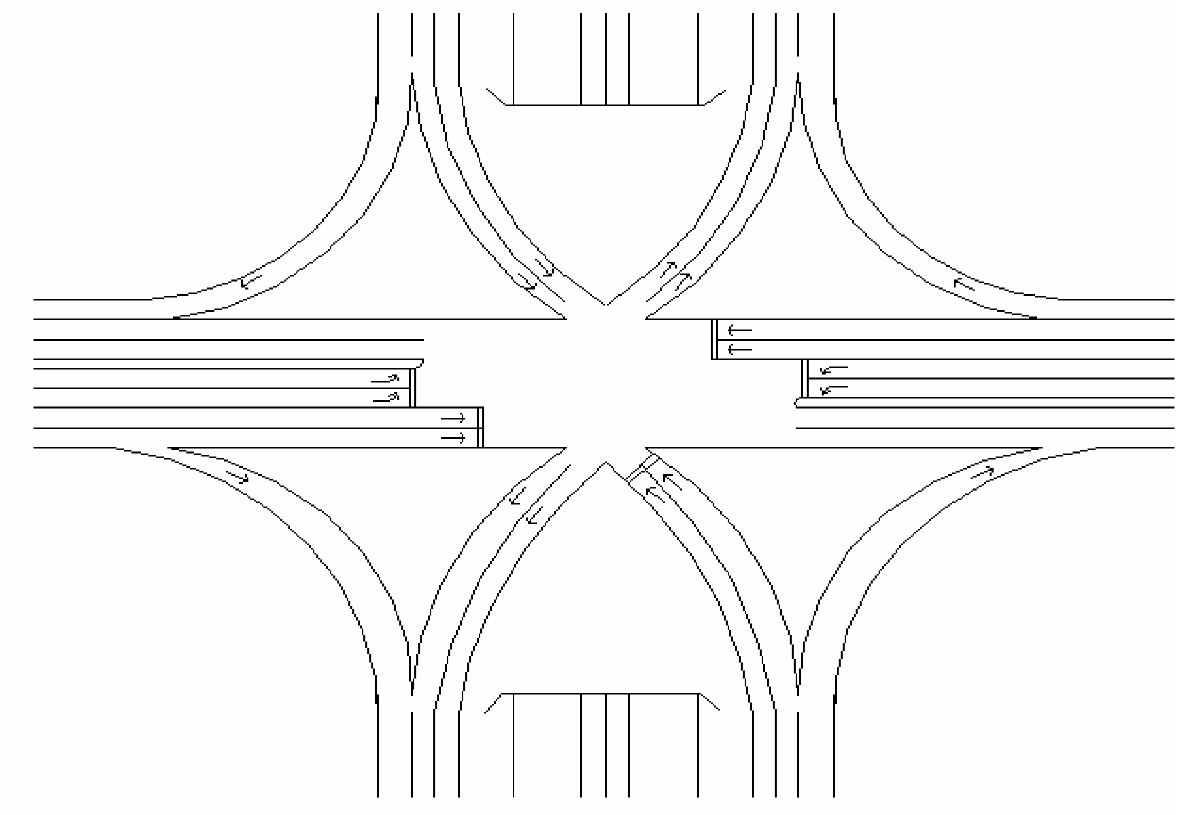

Figure 3: Single Point Urban Interchange

The main advantage of using SPUIs is that the freeway's through movement can be separated from signal phasing without requiring a significant increase in right of way. A SPUI has only one signalized area as compared to two in the case of the Diamond interchange. This allows for a simpler phasing sequence to be used for controlling the movements. Another advantage of using a SPUI is that opposite crossroad left turns and opposite off ramp left turns can be made simultaneously as shown in Figure 3 (3, 4).

From the literature review and the survey, it was found that limited right of way and high traffic volumes are the most important reasons for selecting SPUI over other interchange designs. Other reasons like accommodation of frontage roads and skew angle were also considered. Also

SPUIs can be easily coordinated with other intersections when compared to Diamond interchanges.

In our survey, we asked states to rank various reasons for using a SPUI. The rankings were averaged and are shown in Figure 4. We found that limited right of way is the main reason for selecting SPUIs.

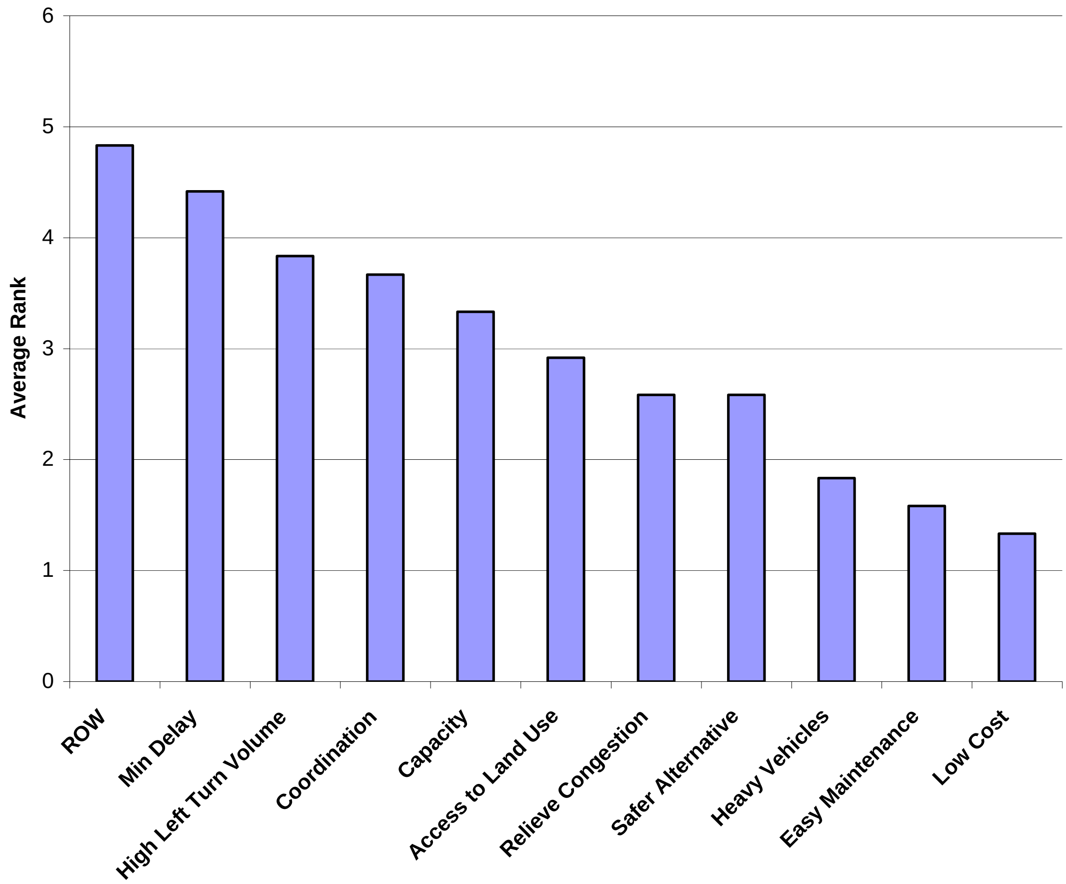

Figure 4: Reasons for choosing SPUI over other interchanges

Thus the major factors favoring the selection of SPUIs are right of way, traffic volume, frontage roads, skew angle and coordination of intersections. Some other factors like construction cost, pedestrian crossings and accident history should also be considered. In the proceeding sections we will discuss each of these considerations.

5.1.1 Right of way

One of the benefits of SPUIs is its smaller right of way needs compared to the Diamond interchange (3, 4, 5). Since right of way at an interchange is influenced by many factors like cross-section and the boundaries of adjacent property, it is difficult to establish a minimum right of way. There is no specific criterion for calculating the minimum right of way value for SPUIs but some values obtained from the literature review can be used.

Typically, right of way for the crossroad is the width of the traveled way plus a border area on each side of the roadway. This border area includes 2.5 feet for curb and gutter, 2.5 feet for utility poles and 5 feet for sidewalk. Thus the nominal right of way should be around 15 feet greater than the back-of-curb to back-of-curb width. The total width, back-of-curb to back-of-curb varies from 80 to 130 feet (6). According to Brown and Walters the minor street would measure about 150 feet from the back of sidewalk on one side to the back of sidewalk on another side of an intersection (7). Usually at SPUIs, crossroads have four to six through lanes, a median, and outside shoulders.

Brown and Walters concluded that SPUIs requires a width of 200 feet for the freeway's right of way (7). The on/off ramps should taper completely into the mainline within 1000 feet from the centerline of the intersection. The Diamond interchange requires approximately 270 feet right of way (8).

The right of way for the major road is measured as the distance between off ramp back-of-curb and the on ramp back-of-curb for each ramp pair, perpendicular to the major road center line (Figure 5). Among the 36 SPUIs studied in NCHRP Report 345, the range of width of underpass SPUIs is quite similar to that of the overpass (4). The two narrowest underpass SPUIs had widths of 160 feet (5). The range of width for the SPUI will usually be between 200 and 400 feet for both overpass and underpass. The minimum distance between ramps was found to be 195 feet (3).

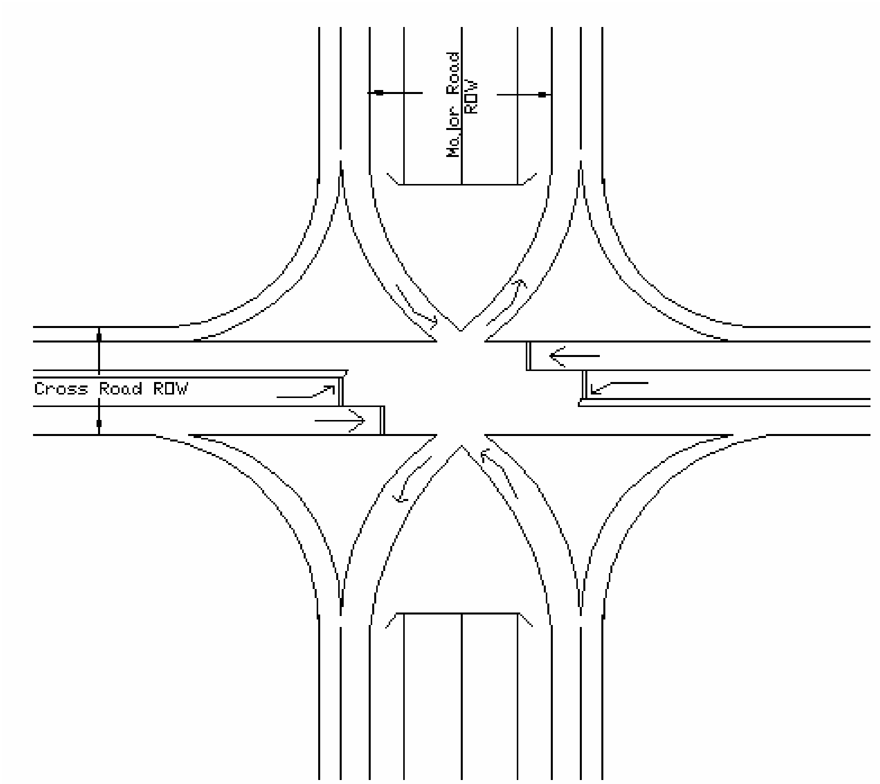

Figure 5: Right of Way Requirements for SPUI

5.1.2 Traffic Volume

Traffic volume is an important factor in determining which interchange to install. We found that SPUIs increase the capacity and, as a result, can accommodate more vehicles than Diamond interchanges. Most of the literature states that SPUIs should be used in high volume conditions although most of them do not provide any specific values. None of the state DOTs provided any specific traffic volume that can be used as a cut off for SPUIs and Diamond interchanges. Only California DOT provided some guidelines on traffic volume warrants.

Diamond interchanges operate well when the entering volumes are low: under 20,000 AADT for the major highway. When volumes are between 20,000 and 35,000 AADT, SPUIs are preferred instead of Diamond interchanges. When the minor road volume is less than 15,000 AADT, Diamond should be used. When the AADT is between 15,000 to 30,000, SPUI should be used (4). A TTI report states that SPUIs are economically viable at daily entering traffic levels as low as 40,000 vehicles (3)

5.1.3 Frontage Roads

When frontage roads are present, Diamond interchanges are preferred over SPUIs. Frontage roads at SPUIs result in increases in signal phasing from three phases to four phases, thus increasing the overall delay at the interchange (3). A SPUI with frontage road is shown in Figure 6. When frontage roads are present at a SPUI, they should be one-way and in the direction of ramp traffic. Ramps should connect to frontage road at least 656 feet and preferably greater than 984 feet from the SPUI. Free U-turns from one frontage road to another should be provided to expedite movement (4, 5, 9)

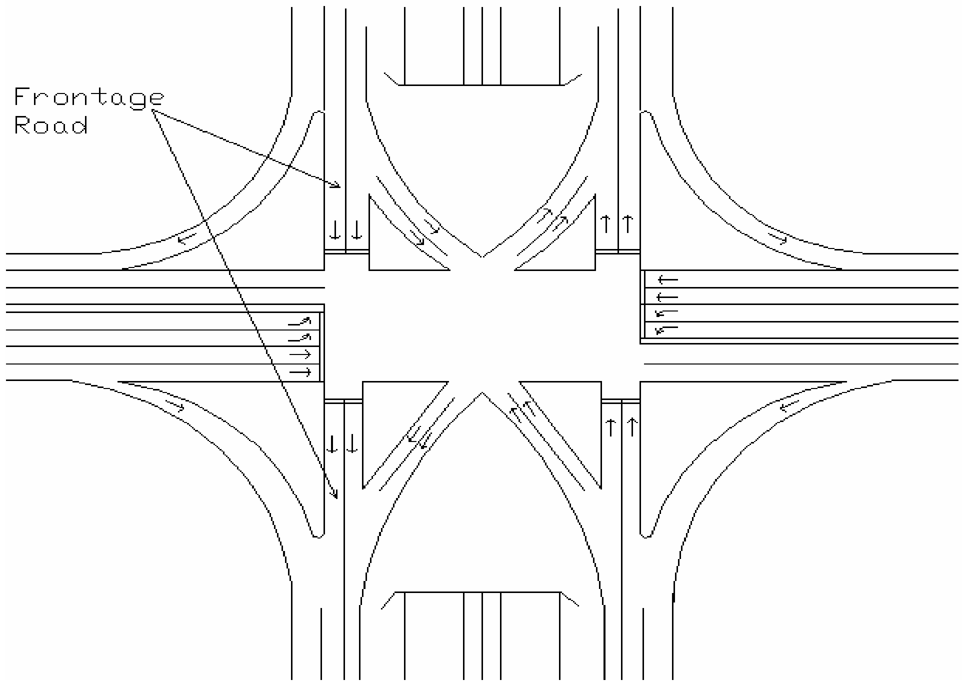

Figure 6: SPUI with Frontage Road

5.1.4 Skew Angle

According to NCHRP Report 345. skew angle is defined as “the rotation of the crossroad relative to the major roadway, with a clockwise rotation of the crossroad from normal indicating a positive skew angle” (4).

Skew generally has an adverse effect on SPUIs because it increases clearance distances, decreases clearance speeds, and adversely affects sight distance by making it more difficult for some off ramp drivers to see along the crossroad (3, 4, 8). Positive skew can make the off ramp, right-turn and the crossroad left-turn movements more difficult, because it often produces a turning path with a smaller radius. A negative skew can make off ramp left-turn and crossroad right-turn movements more difficult. Negative skew, increases stop line separation, although it may improve the visibility of off ramp (3) Skew angles increase the length of the bridge (4, 6).

Skew angles typically range from –30 deg to +28 deg. (3, 4, 6). SPUIs are not recommended when two roads intersect at a large skew angle. The skew angle will produce high construction costs for the SPUI and also result in reduced sight distance at the interchange.

5.1.5 Coordination of Intersection

A SPUI has one signalized intersection as compared to two in Diamond Interchanges. Since SPUIs use a simpler signal phasing it is very easy to coordinate a SPUI with other intersections. Diamond interchanges have two signals in close proximity to each other. So, for the efficient operation of the interchange it is necessary to coordinate these two intersections. Thus, compared to SPUIs, it is much more difficult to coordinate Diamond interchanges with other signalized intersections. States that responded to our survey reported that there is no negative impact on progression because of coordination of SPUI. Synchro is used by majority of states to simulate coordinated signal systems.

5.1.6 Other consideration

Although the five factors previously discussed in Sec 5.1 are the most important, three other factors should also be considered before installing a SPUI. These are cost of construction, pedestrian crossing and accident occurrence.

5.1.6.1 Cost of Construction

The cost of constructing a SPUI is very high. The cost varies from $3 million to $6 million depending on the type of SPUI being constructed. This is about $1 million to $2 million greater than Diamond interchanges.

5.1.6.2 Pedestrian Crossing

It is easier for the pedestrians to move parallel to the cross road, but is difficult for them to cross the cross roads in SPUI. This is because of the size and signal phasing of the SPUI. The signal phasing in a SPUI results in traffic moving through the intersection at all times. Along with signal phasing there are 6 to 8 lanes in a SPUI, which makes it difficult for the pedestrians to cross in one phase. There are four different ways to provide pedestrian movements.

First, provide a two stage movement across the cross road. Pedestrians can cross half of the cross road during the first left turn phase, wait at the median and then complete the other half movement during the other left turn phase (4, 7, 8, 11). Second, provide a separate phase for the crossing of pedestrians. However, the literature recommends against providing a separate phase for pedestrian crossing because it degrades the efficiency of the SPUI (4, 9, 10, 11).

Third, construct a pedestrian overpass near the SPUI. The literature suggests that this is not a very common practice because it is costly to both construct and maintain (4). Fourth, provide a crosswalk at a SPUI or at the adjacent intersection. According to the NCHRP Report 345, no SPUI out of 36 had a crosswalk to cross the cross road (4). In addition when the crosswalks are provided at the adjacent intersection, pedestrians will have to cover large distances to cross SPUI. Therefore based on these issues literature recommends discouraging pedestrian movements at most SPUIs (4, 8, 11, 12, 13).

5.1.6.3 Accident types

Accident studies have shown that rear end accidents occur frequently at off ramps (5). But it was found that there was no significant difference between the frequency of rear end collisions at SPUIs and Diamond interchanges (4, 6). However SPUIs had a larger percentage of sideswipe accidents than Diamond interchanges. A SPUI has a smaller percent of angle collisions than a Diamond interchange (4).

5.2 KEY DESIGN CHARACTERISTICS

The key design characteristics for SPUIs were identified from the literature review and email survey. These key design characteristics are divided into geometric and operational characteristics. Geometric design characteristics address the geometric structure of SPUIs and operational design characteristics address the operational features of SPUIs. The eight geometric and five operational design characteristics are discussed in the following sections.

5.2.1 Geometric Design Characteristics

The key geometric design characteristics are grade separation type, skew angle, number of through lanes, medians, islands, left turn lanes, right turn lanes, lighting and signing.

5.2.1.1 Grade Separation Type

There are two types of SPUI, overpass and underpass . The overpass SPUIs elevate freeways over the crossroad intersection and underpass SPUIs depress freeways under the intersection. On the basis of the 36 SPUIs studied in NCHRP Report 345 it was found that the overpass SPUIs were more numerous (4). Most overpass SPUIs have elevated major road and an at-grade crossroad. The major road is elevated for a simpler structural design and to produce less disruption to existing property and underground utilities (3, 4). Sometimes due to geometric restrictions the crossroad intersection may have to be elevated above the major roadway. The crossroad flyover has the advantage of avoiding drainage problems associated with a depressed design (4).

The type of grade separation influences the SPUI's bridge length, depth, number of spans and abutment types. Selection of an underpass SPUI or an overpass SPUI depends on the site-specific constraints, construction cost and the resulting advantages and disadvantages.

5.2.1.2 Number of Through Lanes

According to NCHRP Report 345, 70 percent of the crossroads have four through lanes and the rest have six lanes (4). The crossroad's number of through lanes does not appear to produce a significant difference in the overpass and underpass designs. Depending on the traffic volume, major roads may have 4, 6 or even 8 lanes (3, 5).

5.2.1.3 Median

All SPUIs have some type of median separation in the major roadway.

Figure 7 shows a SPUI with major and minor road median separation. According to NCHRP Report 345, most of the overpass SPUIs with crossroad median treatments had raised medians (4). The most common widthof crossroad medians for both designs is 4 feet. The average major road median width for overpass was found to be 20 ft compared to an average median width of 18 ft for the underpass design (3, 4, 5).

Medians are typically raised or flushed. Median widths vary from a minimum of 2 feet to 15 feet or more along urban arterials. In developed areas median widths are kept at a minimum due to the right-of-way restrictions. The two-foot minimum is acceptable along the grade-separated lanes and the grade intersection, provided that no pedestrians are expected to cross the intersection. The minimum width for pedestrians is four feet, but six feet is recommended (14).

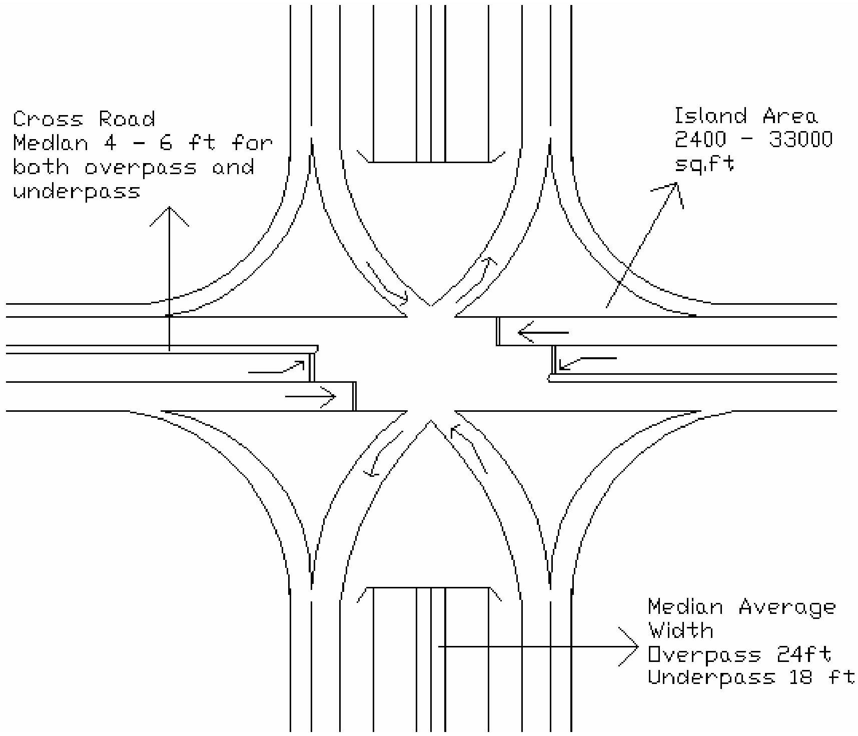

Figure 7: Geometric characteristics of SPUI

5.2.1.4 Islands

SPUIs require islands to separate the left turn and right turn movements. Figure 7 shows a SPUI with an island. Typically, islands are large, varying from 2400 square feet to 33,000 square feet (4, 15). Islands are used whenever the pavement area becomes excessively large for the proper control of the various movements. Islands that are too small are ineffective as a method of guidance and often pose maintenance problems. Islands smaller than 75 square feet should be painted and flushed due to poor visibility (14).

According to the AASHTO Green Book, raised islands provide positive reference and separation (14). On overpass SPUIs, they may protect the traffic signal head that is typically attached to the soffit of the bridge. Studies conducted by the California Department of Transportation suggest that a raised center island is most suitable for a SPUI. The minimum dimension should be 6 feet per side and the surface area should be 81 square feet (4, 14).

5.2.1.5 Left Turn Lanes

One of the most important SPUI feature is the large left turn radius for crossroad and ramp left turn paths. Large radii turns have several advantages for the driver such as greater turning speeds, higher saturation flow rates and reduced off-tracking of lengthy vehicles.

Several studies have shown that saturation flow rate of the SPUI ramp left turn movements is significantly higher than the Diamond interchange ramp and typical left turn movements. The left turn angles in the SPUI are typically 45 to 60 degrees at the ramp stop bars and 90 degrees off the cross street. The radii of left-turning roadways range from 170 to 400 feet for SPUI. It was found to be 50 feet to 75 feet for Diamond interchanges (3, 9).

To turn left from the crossstreet to the ramp averaged 200 feet for both overpass and underpass design. The overpass can have a much wider range of radii because of the fewer physical constraints imposed by bridge structure (4, 14).

Similarly, the average left turn radii for the ramp-to-crossstreet maneuver was found to be 210 feet for the overpass design (4). By contrast, the average left turn radius for the underpass design was found to be 205 feet (16).

The methods for determining the number of left turn lanes depends on the forecasted traffic demands, although dual turn lanes are provided whenever possible. Most SPUIs have one or two left turn lanes (5). It is advisable to provide dual left turn lanes for crossroad and off-ramp movements, since it is difficult to modify design elements after construction (5).

Most states responding to the email survey have no standards for minimum spacing between opposing left turn movements. Alabama responded that it uses half a lane width measured perpendicular from outside the turn radius to inside the turn radius. South Carolina usually has 10 ft between opposing vehicles. Nebraska keeps it less than 15ft.

5.2.1.6 Right Turn Lanes

The operational efficiency of right turn lanes depends on whether the turn begins from the crossroad or from the off-ramp. Right turns from the crossroad have more flexibility and have higher capacity per lane, while the right turns from off ramp are more complex.

SPUIs typically have larger right turn radii than Diamond interchanges. The average right turn radius for both overpass and underpass design on the crossroad is 100 feet while for the off-ramp it is 120 feet. Right turn radii in SPUIs can range from 70 to200 feet (3). This is considerably larger than the Diamond interchange right turn radius, which is usually from 35 to 75 feet A common right turn treatment is to have the right turn share the curb lane with through traffic until 50 to 150 feet upstream of the stop line. At this point, the right turn radius starts and right turning traffic diverges from the shared line. The other treatment is to provide an exclusive lane for right turns. For the single lane right turn movement, the right turn traffic can merge directly with the curb lane on the crossroad or can have an acceleration lane along the crossroad (3, 4). All the states responding to the email survey provided signalized dual right turn lanes. The SPUI dual right turn lanes on the off-ramps were signalized and signed “No Turn on Red”.

5.2.1.7 Lighting

According to our email survey, most of the states prefer to use one conduit run to mount a single signal in the middle of the SPUI. For lighting under bridges, it is recommended to follow specifications given by AASHTO’s *Informational Guide for Roadway Lighting*, FHWA’s *Roadway Lighting Handbook* and the *IES Lighting Handbook*. Some important points when providing lighting are:

- The most important lighting design principles are uniformity of light and minimization of glare.

- SPUI mainlines and crossroads should be well-lighted.
- Good lighting should be provided at the ramp junctions.
- The central intersection area is the most important area of the interchange and it should be well lighted.
- Several designs have embedded directional pavement lights and are installed at one or both of the edges of the pavement *(4)*.
- The use of well-pack lighting units along the vertical walls of SPUI bridge should be discouraged.

5.2.1.8 Signing

Since a SPUI is an uncommon and complex intersection, special attention should be given to signing. Appropriate signing should be provided to avoid confusion. Some important points when providing signing for SPUIs are:

- Overhead guide signing is recommended for the cross road approach.
- Traffic guide sign applications on the exit ramps must be consistent with the mainline signing plan.
- Skip stripes are to be used in the left turn lanes to provide guidance through the intersection area. However, because inclement weather and normal wear reduce their effectiveness, they should be maintained regularly.
- Advance signing such as lane use signs over each lane on the approach are to be used. Sign support structure should be placed at or just beyond the point where the left turn lane is fully developed. Another method is to place lane use signs along the side of the bridge structure.

- At least one set of “WRONG WAY” signs should be placed on the exit ramp to protect against wrong way traffic.

5.2.2 Operational design features

Operational efficiency of SPUIs depends on certain key characteristics. It is necessary to provide appropriate values for these characteristics for SPUIs to work efficiently. This section deals with these operational design characteristics of SPUIs. These characteristics include the signal controller, signal phasing, signal placement, signal cycle, clearance lost time and start up lost time.

5.2.2.1 Signal Controller

Most SPUI use a single, actuated signal controller. Most of the fully-actuated SPUIs used basic gap timing combined with inductive loop detection in advance and at the stop line. Pre-timed control is commonly used in coordinated signal systems that have predictably high traffic demands. With this type of control the phase durations are preset to values that are representative of traffic demands over a relatively long period of time. But most of the SPUIs use actuated signal controllers. Interconnecting signals along the arterial improves coordination of through movements resulting in a more efficient performance. In most of the SPUIs studied where interconnection between signals were used, the delay-reducing benefits of coordination were obvious (3, 4).

5.2.2.2 Signal Phasing

A typical SPUI has three signal phases. The first phase controls both crossroad left turn movements. In the second phase both crossroad and through movements take place. Finally, in the third phase both off ramp left turn movements are made. Figure 8 shows signal phasing for a

SPUI without frontage roads. This signal sequence is provided by a standard NEMA (National Electrical Manufacturers Association) 8 phase dual ring and traffic-actuated controller. The major road's movements are grade-separated and thus are not interrupted by the traffic signal. As a result of the SPUI unusual left turn treatment, the actuated signal controller has the option of overlapping crossroad left turn with the adjacent crossroad left turns (3, 4, 9). This capability improves the operational efficiency of SPUIs when traffic demands are unbalanced. Most of the SPUI had crossroad left turns leads the adjacent crossroad through movements. This type of phasing is called Lead-Lead phasing. The basic three-phase arrangement is used at all SPUI except those with continuous one-way frontage roads, which require a fourth phase. The fourth phase is similar in operation to the major road through phase at a typical at-grade intersection and is shown in Figure 9. In contrast to SPUIs, the signal phasing used at Diamond interchanges is actually a special combination of two three-phase sequences, one for each ramp or crossroad intersection. These two-phase sequences are interrelated by a specific offset relationship that is intended to provide uninterrupted traffic progression between the two intersections (3, 9, 17).

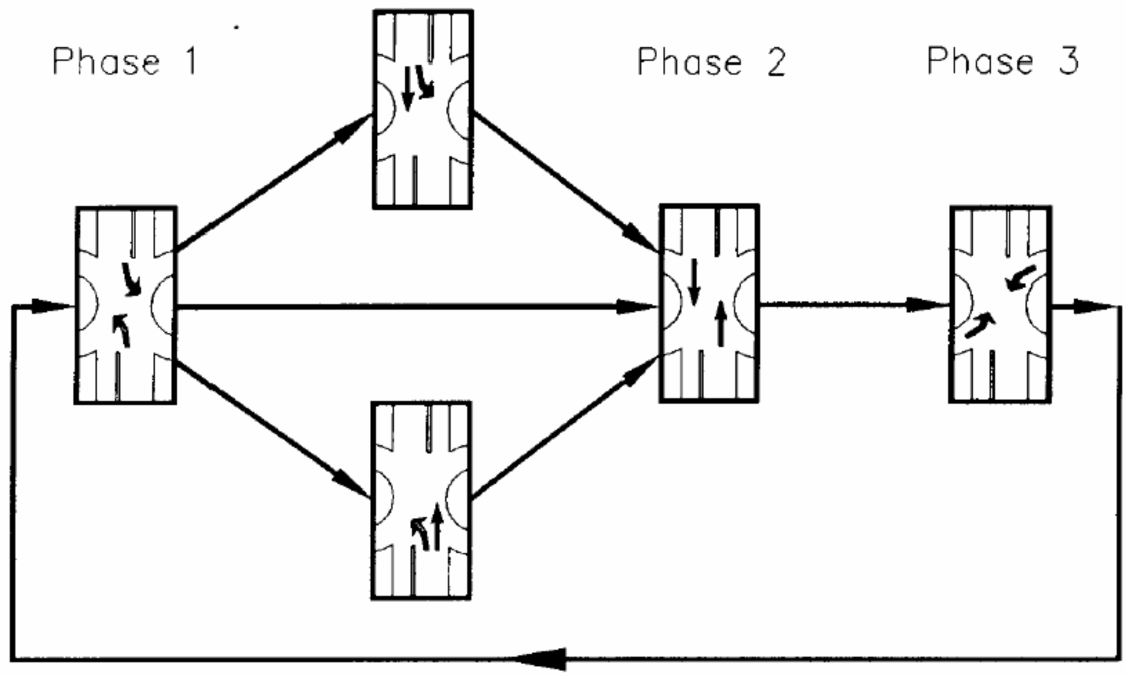

Figure 8: Signal Phasing for SPUI without frontage road

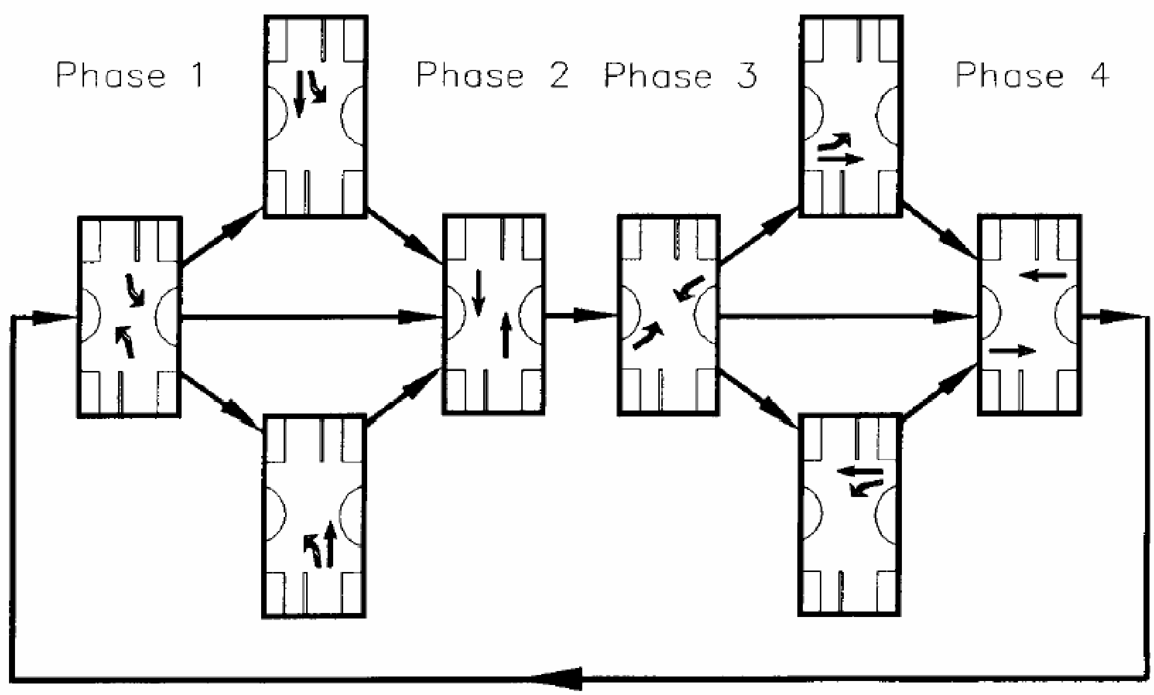

Figure 9: Signal Phasing for SPUI with frontage road

5.2.2.3 Signal Cycle

The durations of the signal cycles and the intervals play a very important role in the safe and efficient operation of the intersection. The green signal should be long enough to serve the traffic demand. The green signal usually used in SPUIs for one phase lasts around 20 sec to 40 sec in high volume conditions (4).

SPUIs usually have longer cycle lengths than most of the other interchanges. Cycle lengths vary from 80 to 180 seconds, with longer cycle lengths usually having fully actuated signal phases for all movements (4, 9). The average cycle length of the SPUI with frontage roads was between 100 and 150 sec. The average phase of the four-phase sequence is about 3 sec longer than the three-phase sequence (4).

5.2.2.4 Signal Placement

The signalized area in a SPUI is very big and complex. To provide safe movement at the signalized area, placement and visibility of the signals plays a very important role. The main factors in signalization of cross roads for the overpass SPUI are restrictions to signal head clearance and sign placement.

For the overpass SPUI, cross street signals are usually placed on the side of the overpass bridge. The signals are usually hung from the bridge deck or attached to the side of the bridge (4, 8, 13, 18). Span-wire mounting is an alternative option for hanging the signals, but is more common among SPUIs with frontage roads (4). The signals should neither be too low nor high. A minimum of 15 ft signal clearance height should be maintained (4). For the ease of maintenance proper access to the signal heads should be provided. According to Caltrans this can be done by providing a catwalk on the overpass to access all the signals on the bridge deck. Their report also states that access to the face of the signal should be provided to the maintenance electrician. If it is not possible to provide access to the face of the signal, provision should be made to rotate the signal head for easy access for the electrician (13).

For the off ramp left turn movement in an overpass design, along with the signals on the bridge deck, a post mounted signal should be provided on the right side of the island (8, 18). For left turn movement onto the freeway a left turn sign R3-5 should be placed adjacent to each of the signal heads for clarification and lane assignment (18). A circular red and yellow indication should be used for left turn signals. The green arrow should be inclined at 45 degrees up from horizontal for left turns (13, 18).

The support of signal heads is the main issue for the underpass SPUI. For underpass SPUI signals are placed over their corresponding turning paths (4, 8, 13, 18). Most of the SPUIs surveyed by Michigan Department of Transportation in their study states that, all the signals for the cross roads were located on a single overhead tubular beam (8). According to NCHRP report 345, in most of the SPUIs span wires were used to hang the signals (4). Steel truss and steel poles with mast arms are an alternative that can be used to hang the signals (4, 18). Thus, all the signals in the underpass SPUI should be placed either using a tubular beam or span wire.

In June 2001, Caltrans issued an internal memorandum to all divisions regarding guidelines for planning, design and operations of SPUI in California. Figures 4B and 4A of this memo gives a typical layout of the signal placement for overpass and underpass SPUI respectively[1]. This document has been placed in Appendix D in its entirety.

5.2.2.5 Clearance Time

All-red clearance intervals are often used at the end of signal phases to allow all vehicles that have entered at the yellow interval to exit the intersection before conflicting traffic enters.

[1] Please note the Caltrans memo reverses the meaning of overpass and underpass SPUI from this report.

In general, long all-red intervals reduce the traffic capacity of a signal phase and thereby reduce the efficiency of the interchange. The timing of the change interval in SPUIs requires special consideration due to the large intersection area and lengthy travel path (4, 9). All-red clearance intervals for SPUIs range from 1.0 to 10.0 seconds. The average red clearance interval is about 3.4 sec. The presence of a frontage road increases the size of the SPUI conflict area and thus the length of all-red clearance intervals (4, 6, 19). A red clearance interval of 4 seconds for entrance ramp left turn and 6 seconds for exit ramp left turn is provided by most states in our email survey.

5.2.2.6 Start-Up Lost time

Since the first three vehicles are expected to experience start-up lost time, the start-up lost time for a phase was calculated as the sum of the headways for the first three vehicles in the queue minus three times the mean headway. When the saturation flow rate is higher, the start-up lost time is greater. That is because when the saturation flow rate is higher, the mean headway is less and as a result the lost time will increase. The start-up lost time was found to be between 1.39 and 1.84 sec. This is much less than the HCM recommended lost time of 2 sec. There was not much difference between the SPUI and Diamond interchange start-up lost times except for the SPUI's ramp left turn movement was 1.84 sec and the Diamond interchange's is 1.49 sec (19).

6 CONCLUSIONS

In this report, different key geometric and operational characteristics of SPUIs were studied and their influence on SPUI design discussed. Some of the most important geometric characteristics and operational characteristics are grade separation, skew angle, roadway characteristics, signal phasing, left turn radii, right turn radii and traffic volume. Other factors such as construction cost and accident studies are also important. Most of the states surveyed have different criteria for each of the design characteristics, but most of the states used values within a certain range.

Survey results showed that most states ranked right of way as the most important reason for installing SPUIs. Some of the states also ranked increase in capacity as the main reason. When there was a need for frontage roads, SPUIs were discouraged since frontage roads reduced SPUI efficiency. It is commonly agreed that SPUI do not accommodate pedestrian crossing effectively. A separate phasing is required for the pedestrians and this reduces SPUI efficiency. A primary reason that many states do not use a SPUI is that construction costs are very high. Also many states expressed apprehension that SPUIs will confuse drivers.

This study discusses elements to be considered before selecting a SPUI and its key design characteristics. Although no specific guidelines for the installation of a SPUI exists, this study will hopefully allow for greater engineering judgment uniformity among MoDOT engineers. This report could be used as a reference whenever a SPUI is being considered.

7 RECOMMENDATIONS

7.1 FOR INSTALLING SPUIS

Although SPUI are considered an alternative to Diamond interchanges, there is no conclusive evidence that SPUI are superior to Diamond interchanges. Many researchers say that SPUI are better than Diamond interchanges, while many others advocate Diamond Interchange. A review of the literature and existing practice did not reveal specific recommendations for installing SPUI. However, it is suitable to construct a SPUI under certain conditions . The following should be considered before installing SPUI:

- Whenever there is a limited right of way, SPUI are a more attractive option. SPUIs require less right of way than Diamond interchanges. There are no specific criteria for calculating the right of way for SPUI. However, it was found that SPUI usually requires right of way in the range of 200-400 feet. The right of way required by Diamond interchanges is about 30% more than that required by SPUI and usually is found to be around 270 feet. When the crossroad volume is between 15,000 and 30,000 AADT, SPUIs are a superior option to Diamond interchanges. SPUI are considered to have more capacity than Diamond interchanges. So SPUI are usually used in high volume conditions. When volumes are between 20,000 and 35,000 AADT for major roads, a SPUI should be used instead of a Diamond Interchange.
- When frontage roads are present, a SPUI should not be used. The presence of frontage roads increase the normal three-phase signal system to four-phase signal system and increases the delay for the overall system. The presence of frontage roads degrades the performance of SPUIs considerably and is not recommended.
- When two roads intersect at a large skew angle, construction of a SPUI is not

recommended. A skew angle increases the construction cost and also reduces sight distance at the SPUIs. The skew angle should be between -30 and +28 degrees for the SPUI to be constructed. If the skew angle is greater, a SPUI should not be selected.

- It is easier to coordinate the SPUI's one signal with other signalized intersections compared to the Diamond interchange's two. Thus the SPUI is preferred when arterial coordination is required.
- SPUI construction cost is much higher than for a Diamond interchange. It costs approximately $1-$2 million more than a Diamond interchange.
- It is not desirable to provide a pedestrian crosswalk for SPUIs. Providing an additional phase for pedestrian crossing degrades the efficiency of SPUI. When pedestrian volumes are high, a pedestrian overpass should be constructed or a pedestrian crossing should be provided at the adjacent intersection or SPUI should not be selected.
- No increase in accidents was observed with SPUIs. SPUIs have an increased number of side-swipe accidents compared to Diamond interchanges, but a smaller number of angle accidents.

7.2 FOR KEY DESIGN ELEMENTS

- Overpass SPUIs are easier to construct and, because of its simpler structural design, less destructive to adjacent property. The typical bridge span length for SPUIs is 120 to 200 feet and about 100 to 150 feet for Diamond interchanges.
- The number of through lanes is usually 4 or 6. Since SPUIs are mainly used for high volume conditions, fewer than 4 lanes are not usually constructed.
- The median width for the crossroad should be 4 feet if no pedestrian crossing is considered, otherwise 6 feet should be provided. Major road medians should be 18 feet

wide for the underpass design and 20 feet wide for the overpass design. Medians are typically raised or flushed.

- Islands should be large, varying from 2,400 square feet to 33,000 square feet. Small islands, less than 75 square feet, should be painted and flushed due to poor visibility. The minimum dimension should be 6 feet per side and the surface area should be 81 square feet.
- Since it is difficult to modify SPUIs after construction, it is advisable to design dual left turn lanes for crossroad and off-ramp movements.
- The left turn radii for the crossroad left turns should be around 200 ft for both overpass and underpass designs while for the ramp left turns the radii should be around 210 ft. The overpass can have a greater range of radii because of the fewer physical constraints imposed by bridge structure. The left turning radii of SPUIs may range from 170 to 400 ft.
- Right turn radii should be around 120 ft for crossroad left turns and 100 ft for off ramp left turns. Right-turn radii in SPUI can range from 70 to 200 ft.
- The most important lighting design principles are uniformity of light and minimization of glare. Use of well-pack lighting units along the vertical walls of SPUI bridges should be discouraged. The central intersection area is the most important area of the interchange and should be well lighted.
- Overhead guide signing is recommended for crossroad approaches. Traffic guide sign applications on the exit ramps must be consistent with the mainline signing plan. At least one set of “WRONG WAY” signs should be placed on the exit ramp to protect against wrong way traffic.

- Most SPUIs use a single, actuated signal controller. A typical SPUI has a three-phase signal using a standard NEMA (National Electrical Manufacturers Association) 8-phase dual ring and traffic-actuated controller. If a frontage road is present, a 4-phase signal is provided.
- The green signal usually used in SPUI for one phase lasts around 20 sec to 40 sec in high volume conditions. Clearance time in SPUIs last much longer than Diamond interchanges because of the large SPUI intersection area. All-red clearance intervals for SPUIs range from 1.0 to 10.0 seconds per phase. SPUIs usually have longer cycle lengths than most of the other interchanges. Cycle lengths vary from 80 to 180 seconds for SPUIs. The average cycle length of a SPUI with frontage roads vary from 100 to 150 sec.
- For the overpass SPUI cross road signals should be placed on the side of the overpass bridge deck or should be hung to the bridge depending on the height of the overpass structure. For underpass SPUI all the signals on the cross road should be placed either using a tubular beam or span wire.

8 IMPLEMENTATION PLAN

Currently, the MoDOT PDM (Project Development Manual) refers to SPUIs (Single Point Urban Interchanges) along with other interchanges. It contains no design criteria of SPUI in particular. Since a number of SPUI are being considered in Missouri, it is necessary to have some guidance about SPUI to which the MoDOT engineers can refer.

SPUI should be included in the PDM as a new section in Chapter 4. They cannot be included in the general discussion for other interchanges as there are many features that are unique to SPUI. This section should include the unique features of SPUI, the warrants for installing a SPUI and the key design elements of SPUI as outlined in this report.

9 REFERENCES

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APPENDIX A
Work Plan

Date: July 1, 2002

Project Number: RI02-015

Title: Design of Single Point Urban Interchange (SPUI)

Research Agency: Curators of the University of Missouri
University of Missouri-Rolla

10 PRINCIPAL INVESTIGATORS

Dr. Gary Spring, Associate Professor, PI
Dr Mohammad Qureshi, Assistant Professor, Co-PI

11 OBJECTIVES

- To examine the state of practice for the design, including signalization, signing and lighting, of SPUI's
- Compare and contrast alternative techniques
- To develop a set of guidelines that may be used by MoDOT traffic engineers in designing SPUI's in Missouri.

12 BACKGROUND

SPUI's have fast become the panacea for all the ills of diamond interchanges. They reduce the number of traffic lights on the local road to one – thus more vehicles can make a turn and clear the interchange in one traffic signal cycle. SPUI's also allow long, gradual turns so larger vehicles like trucks and buses have more room to navigate. They improve efficiency without compromising safety. Their obvious benefits notwithstanding, there exist several questions that must be answered having to do with phasing issues, signal design and standards and signal head placement.

Missouri has several SPUI in operation in Districts 6 and 3. The reaction to these SPUI has been mixed. District 6 has found no problems. District 3 found that an adjustment period was required for drivers to adapt to the SPUI. After this short period, the interchange has been operating efficiently, with fewer signals and reduced overall delay. ·MoDOT Traffic Business Unit's, on the other hand, observed that drivers, especially at rural locations, are easily confused, and some drivers even go the wrong way.

Currently there are no state guidelines on the design of SPUIs. Given that there exist plans to construct more SPUIs in Missouri, guidelines for their design are crucial.

13 WORK PLAN

1. Assess state of practice
   1.1. Review literature on SPUI design.
   1.2. Survey a select set of states about their design and use of SPUIs. The states will be chosen in consultation with MoDOT.
2. Establish a technical advisory committee (TAC) that will provide advice and guidance on such as issues as: other work that has been done in this area (task 1), alternative designs to be considered (task 4), and content and structure of guidelines (task 5). It is anticipated that the TAC membership will be drawn from various MODOT traffic and design divisions - to be chosen with guidance from HQ Traffic Division.
3. Collect video of SPUI operations in Missouri
4. Develop alternative designs based on Tasks 1, 2 and 3.
5. Prepare draft guidelines for design of SPUIs in Missouri for TAC review
6. Dissemination of results
   6.1. Prepare final report summarizing findings and recommendations
   6.2. Present findings and recommendations to MoDOT staff.
   6.3. Prepare journal paper and present at national meeting (such as TRB)

Communications between the Project Team and the TAC will be maintained via Email, FAX, telephone and US Mail. It is anticipated that meetings will be held at project milestones as indicated on the schedule below.

Method of Implementation:

The draft guidelines prepared as part of this research are expected be incorporated into MoDOT policy after proper review.

Anticipated Benefits:

This research will assist MoDOT in standardizing the installation of SPUIs.

Research Period: August 1, 2002 – December 31, 2003

Potential Funding: SP & R

Schedule:

Plan of Work Part 1

Task	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03
1. Assess State of Practice												
1.1 Review Literature												
1.2 Survey States												
2. Establish TAC												
3. Develop alternative designs												
4. Prepare draft guidelines												
TAC REVIEW												
5. Prepare final report												

Plan of Work Part 2

Task	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03
1. Assess State of Practice					
1.1 Review Literature					
1.2 Survey States					
2. Establish TAC					
3. Develop alternative designs					
4. Prepare draft guidelines					
TAC REVIEW					
5. Prepare final report					

Staffing:

Dr. Gary Spring has more than 30 years of experience in the areas of transportation planning, design, construction, and operations and safety. Prior to joining the faculty at the University of Missouri-Rolla, he worked as a professor of civil engineering at North Carolina A&T State University since 1988. Prior to 1988 he worked for 15 years for a state department of transportation, primarily in design, traffic engineering, construction, planning, and research and development. In the last 2 he served at the Project manager level and was involved in environmental impact studies, policy and evaluation questions, and conducted safety related feasibility studies. Dr. Spring has given more than 25 presentations on a variety of safety related topics, expert systems, geographic information systems, systems implementation issues and evaluation methodologies and has published in excess of 30 papers and technical reports on a variety of related topics.

Dr. Mohammad Qureshi has served as an Assistant Professor in the Civil Engineering Department at the University of Missouri –Rolla since August 2000. He has experience in the areas of traffic impact studies, traffic operations, highway safety, highway-rail crossing policy, data collection procedures, and statistical analysis of transportation data. Dr. Qureshi has published papers on signalized intersection operations and rail-highway grade crossing policy. Dr. Qureshi received his B.S. and M.S. in Civil Engineering from the University of California, Berkeley and his doctorate from the University of Tennessee in August of 2000.

Budget:

Budget Item	*Ref.*	*Total Costs*	*Requested*	*CE Match*	*UMR Match*
TOTAL SALARIES	1	$ 41,449	$ 37,835	$ 3,614	
Mohammad Qureshi	1.1	$ 1,717		$ 1,717	
Gary Spring	1.2	$ 9,486	$ 7,589	$ 1,897	
Technician support	1.3	$ 800	$ 800		
Graduate Research Assistant	1.4	$ 29,446	$ 29,446		
TOTAL FRINGES	2	$ 3,001	$ 2,097	$ 903	
Fringes for Faculty (25% of 1.1+1.2+1.3)		$ 3,001	2,097	903	
TRAVEL	3	$ 1,500	$ 1,500		
EQUIPMENT	4	$ -			
SUPPLIES	5	$ 750	$ 750		
DIRECT COSTS (1+2+3+4+5)	6	$ 46,700	$ 42,182	$ 4,517	
INDIRECT COSTS (48% of 6-4)	7	$ 22,416	$ 16,809	$ 2,168	$ 3,438
TOTAL COST (6+7)	8	$ 69,115	$ 58,992	$ 6,685	$ 3,438

Note: Requested indirect reduced by $3438 to bring total UMR & CE cost share equal to 24% of direct costs ($10124)

APPENDIX B

SURVEY QUESTIONS

Objective: To find current state practices regarding the planning, design and construction of Single Point Urban Interchanges

1) How many SPUI do you have installed in your state?

2) Do you have guidelines other than those detailed in NCHRP 345, TTI Research report 1237-F or AASHTO Green Book for the design of SPUI?

3) If yes, could a copy these guidelines be send to Dr. Spring at the address shown below for use in this Study?

4) What, if any, problems do you experience with the guidelines that you use (NCHRP, TTI, AASHTO or your own)?

5) What do you use for warrants in determining the need for SPUI?
6) Using Table One, attached, please rate your reasons for selecting a SPUI over other types of interchanges on a scale of 1 to 5 where 1 represents poor and 5 represents excellent.

Table One

Reason	**Rank**				
Restricted right-of-way	1	2	3	4	5
Efficient signal phasing to obtain minimum delay	1	2	3	4	5
Expected to increase traffic carrying capacity	1	2	3	4	5
Signalization at only one major intersection simplifies coordination on the arterial	1	2	3	4	5
Low construction cost	1	2	3	4	5
Can accommodate high left-turn volumes	1	2	3	4	5
Existence of of excessive large truck operations involving left turns	1	2	3	4	5
Expected to releive congestion	1	2	3	4	5
Safer alternative design	1	2	3	4	5
Easy and/or inexpensive to maintain	1	2	3	4	5
Easier access to surrounding land use	1	2	3	4	5

7) What ramp terminal spacing do you currently use for SPUI (back of curb to back of curb parallel to the cross road)?
   a) Less than 150 feet
   b) 150 feet to 200 feet
   c) 200 feet to 250 feet
   d) Greater than 250 feet

8) How do you mount signals at SPUI? For example, is it better to have signals mounted on either side of the bridge with dual conduit runs or a single mounting in the middle with one conduit run?

9) What are your specifications for under bridge lighting and mounting?

10) Have you incorporated SPUI into coordinated signal systems? If so, was progression negatively affected? Do you have standards governing this issue (for example, spacing from adjacent intersections)?

11) What is your policy on signalization of free dual right turns?

12) Do you provide a red clearance interval for left turn phases? If so, what is it and how do you determine it?

13) Do you have standards for minimum spacing between opposing left turn movements? If so, what are they?
   a) Less than 15 feet
   b) 15 feet to 17.5 feet
   c) 17.5 feet to 20 feet
   d) Greater than 20 feet

14) We've tried to be fairly comprehensive in our questions but in the interests of keeping this survey as brief as possible, we have certainly omitted aspects of interest which may even be critical to successful SPUI design. Please provide comments on design aspects of your SPUI that are not included above. For example, do you use special signing at SPUI's? How do you place signs – using the MUTCD guidelines or do you have your own

APPENDIX C

SURVEY SUMMARY

Arkansas

No SPUI’s

Oklahoma

No SPUI’s

Texas

No SPUI’s, They consider information currently available on this interchange design through TRB and AASHTO as sufficient. They do not repeat any of this information is there design manuals.

Maine

No SPUI’s, There is no special design approach, policy, or handling of SPUIs. It is just another interchange alternative to consider. They have around four SPUIs in Colorado.

Idaho

No SPUI's, design standards or experience in this area are limited.

Virginia, Georgia, Wisconsin, South Carolina, Alabama, Connecticut, Michigan, Tennessee and Nebraska

1) How many SPUI do you have installed in your state?

Virginia:	3
Georgia:	6
Wisconsin:	None
South Carolina:	None as of 3/13/03. Three under construction
Alabama:	None
Connecticut:	One, Route 15 & 111 in Trumbull, which is currently under construction
Michigan:	One
Tennessee:	Either 11 or 13 – Two in Nashville, TN; one in Johnson City, TN; either 8 or 10 in Memphis, TN
Nebraska:	6

2) Do you have guidelines other than those detailed in NCHRP 345, TTI Research report 1237-F or AASHTO Green Book for the design of SPUI?

Virginia:	No but they have some information on Opposing Left Turn Lanes in VDOT’s Road Design Manual.

	Volume 1, Appendix C, Page C – 6
Georgia:	No
Wisconsin:	WisDOT has additional guidance in there Facilities Development Manual (design manual). "SUPI's should be designed such that the mainline passes under the at-grade intersection. There are two primary reasons for this: By constructing the mainline at the lower level columns may be located in the center of the structure thus reducing the clear span of the structure and substantially reducing girder depth, earthwork and the cost. The at – grade intersection should be located on the top level where it is exposed to an even lighted surface, thus not requiring the driver to go from sunlight into shade and back into sunlight. The eye needs time to adjust to changing light conditions. Turning on a curved path through the intersection with changing light condition may be unsafe and problematic particularly to older driver.
South Carolina:	No
Alabama:	No
Connecticut:	No
Michigan:	No
Tennessee:	No
Nebraska:	No

3) If yes, could a copy these guidelines be send to Dr. Spring at the address shown below for use in this Study?

Virginia:	N/A
Georgia:	N/A
Wisconsin:	Procedure 11 – 30 – 1, page 4
South Carolina:	N/A
Alabama:	N/A
Connecticut:	N/A
Michigan:	N/A
Tennessee:	University of Memphis did a study for the SR177/Walnut Grove Road SPUI in Memphis
Nebraska:	N/A

4) What, if any, problems do you experience with the guidelines that you use (NCHRP, TTI, AASHTO or your own)? For example, if right of way costs are less for TDUI and there are no access issues, are SPUI still desirable over diamonds?

Virginia:	N/A
Georgia:	None
Wisconsin:	None in operation

South Carolina:	None
Alabama:	None
Connecticut:	None
Michigan:	None
Tennessee:	None
Nebraska:	Determining optimum left-turn paths

5) What do you use for warrants in determining the need for SPUI?

Virginia:	Limited right of way
Georgia:	Balanced Turning movements Available right of way, Up/Down stream intersection spacing
Wisconsin:	No specific warrants
South Carolina:	Number of signals in the system Adjacent land use and potential impacts Traffic volume Right of way impacts Lay of the land
Alabama:	Traffic Analysis
Connecticut:	Site Constraints
Michigan:	Right of Way
Tennessee:	Restricted Right of Way/ High Traffic Volume
Nebraska:	Engineering Judgement

6) Using Table One, attached, please rate your reasons for selecting a SPUI over other types of interchanges on a scale of 1 to 5 where 1 represents poor and 5 represents excellent.

Virginia:	N/A
Wisconsin:	N/A

Georgia:

Reason			**Rank**		
Restricted right-of-way	1	2	3	4	5
Efficient signal phasing to obtain minimum delay	1	2	3	4	5
Expected to increase traffic carrying capacity	1	2	3	4	5
Signalization at only one major intersectoin simplifies coordination on the arterial	1	2	3	4	5
Low construction cost	1	2	3	4	5
Can accommodate high left-turn volumes	1	2	3	4	5
Existence of excessive large truck operations	1	2	3	4	5

involving left turns					
Expected to releive congestion	1	2	3	4	5
Safer alernative design	1	2	3	4	5
Easy and/or inexpensive to maintian	1	2	3	4	5
Easier access to surrounding land use	1	2	3	4	5

South Carolina:

Reason			**Rank**		
Restricted right-of-way	1	2	3	4	5
Efficient signal phasing to obtain minimum delay	1	2	3	4	5
Expected to increase traffic carrying capacity	1	2	3	4	5
Signalization at only one major intersection simplifies coordination on the arterial	1	2	3	4	5
Low construction cost	1	2	3	4	5
Can accommodate high left-turn volumes	1	2	3	4	5
Existence of excessive large truck operations involving left turns	1	2	3	4	5
Expected to relieve congestion	1	2	3	4	5
Safer alternative design	1	2	3	4	5
Easy and/or inexpensive to maintain	1	2	3	4	5
Easier access to surrounding land use	1	2	3	4	5

Alabama:

Reason			**Rank**		
Restricted right-of-way	1	2	3	4	5
Efficient signal phasing to obtain minimum delay	1	2	3	4	5
Expected to increase traffic carrying capacity	1	2	3	4	5
Signalization at only one major intersection simplifies coordination on the arterial	1	2	3	4	5
Low construction cost	1	2	3	4	5
Can accommodate high left-turn volumes	1	2	3	4	5
Existence of excessive large truck operations involving left turns	1	2	3	4	5
Expected to relieve congestion	1	2	3	4	5
Safer alternative design	1	2	3	4	5
Easy and/or inexpensive to maintain	1	2	3	4	5
Easier access to surrounding land use	1	2	3	4	5

Connecticut

Reason			Rank		
Restricted right-of-way	1	2	3	4	5
Efficient signal phasing to obtain minimum delay	1	2	3	4	5
Expected to increase traffic carrying capacity	1	2	3	4	5
Signalization at only one major intersection simplifies coordination on the arterial	1	2	3	4	5
Low construction cost	1	2	3	4	5
Can accommodate high left-turn volumes	1	2	3	4	5
Existence of excessive large truck operations involving left turns	1	2	3	4	5
Expected to relieve congestion	1	2	3	4	5
Safer alternative design	1	2	3	4	5
Easy and/or inexpensive to maintain	1	2	3	4	5
Easier access to surrounding land use	1	2	3	4	5

Michigan:

Reason			Rank		
Restricted right-of-way	1	2	3	4	5
Efficient signal phasing to obtain minimum delay	1	2	3	4	5
Expected to increase traffic carrying capacity	1	2	3	4	5
Signalization at only one major intersection simplifies coordination on the arterial	1	2	3	4	5
Low construction cost	1	2	3	4	5
Can accommodate high left-turn volumes	1	2	3	4	5
Existence of excessive large truck operations involving left turns	1	2	3	4	5
Expected to relieve congestion	1	2	3	4	5
Safer alternative design	1	2	3	4	5
Easy and/or inexpensive to maintain	1	2	3	4	5
Easier access to surrounding land use	1	2	3	4	5

Tennessee:

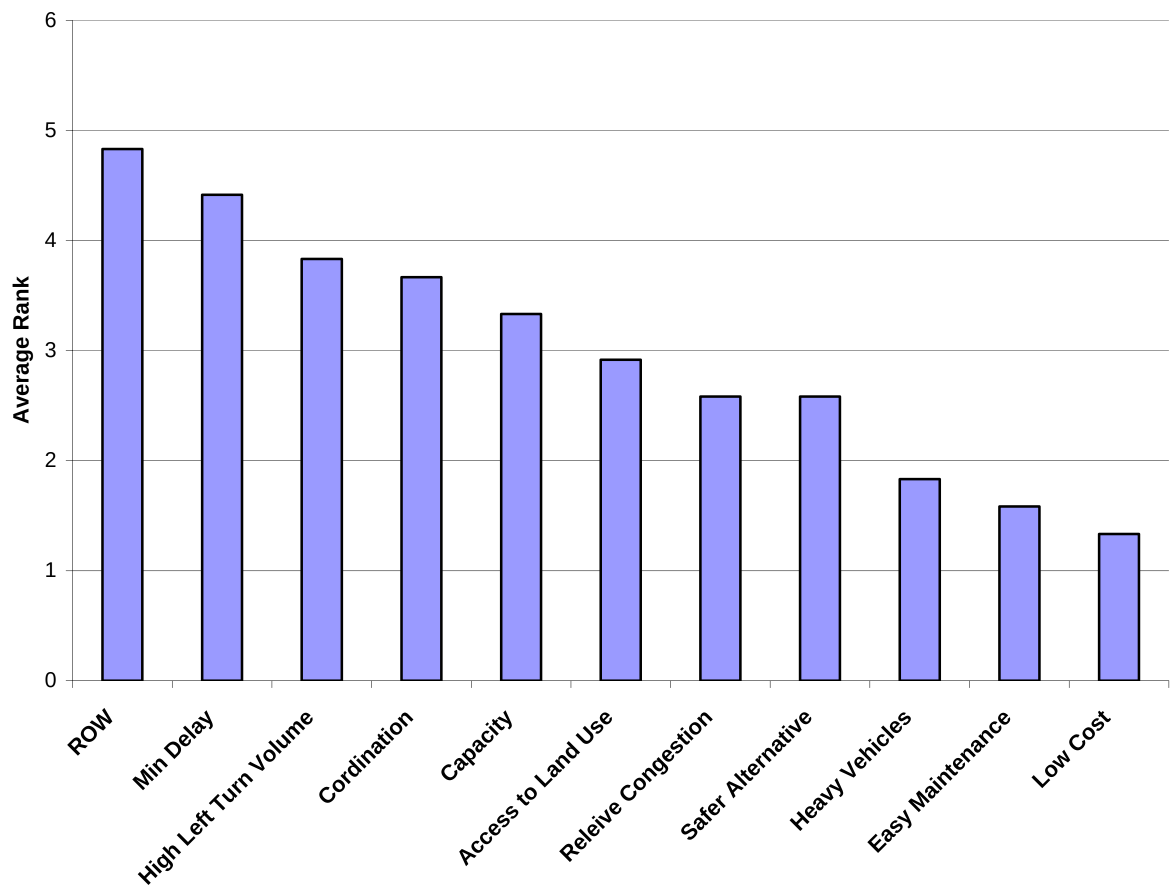
Reason			Rank		
Restricted right-of-way	1	2	3	4	5
Efficient signal phasing to obtain minimum delay	1	2	3	4	5
Expected to increase traffic carrying capacity	1	2	3	4	5
Signalization at only one major intersection simplifies coordination on the arterial	1	2	3	4	5
Low construction cost	1	2	3	4	5
Can accommodate high left-turn volumes	1	2	3	4	5
Existence of excessive large truck operations involving left turns	1	2	3	4	5
Expected to relieve congestion	1	2	3	4	5
Safer alternative design	1	2	3	4	5
Easy and/or inexpensive to maintain	1	2	3	4	5
Easier access to surrounding land use	1	2	3	4	5

Nebraska:

Reason			Rank		
Restricted right-of-way	1	2	3	4	5
Efficient signal phasing to obtain minimum delay	1	2	3	4	5
Expected to increase traffic carrying capacity	1	2	3	4	5
Signalization at only one major intersection simplifies coordination on the arterial	1	2	3	4	5
Low construction cost	1	2	3	4	5
Can accommodate high left-turn volumes	1	2	3	4	5
Existence of excessive large truck operations involving left turns	1	2	3	4	5
Expected to relieve congestion	1	2	3	4	5
Safer alternative design	1	2	3	4	5
Easy and/or inexpensive to maintain	1	2	3	4	5
Easier access to surrounding land use	1	2	3	4	5

All of the states mentioned limited right of way and efficient signal phasing to obtain minimum delay as the most important reasons for selecting SPUI over other interchanges. Some other reasons like accommodation of high left turn volumes, increase in traffic carrying capacity and easier access to land use were also considered strongly. They also mentioned that the cost of construction for SPUI is higher and is difficult to maintain when compared to other interchanges.

Figure 8 shows a histogram for reasons for selecting SPUI over other interchanges in their decreasing order of importance. Rank 5 means excellent and Rank 1 means poor. From the graph we can find that right of way is the main reason for selecting SPUI.



Reasons for selection of SPUI over other Interchanges

7) What ramp terminal spacing do you currently use for SPUI (back of curb to back of curb parallel to the cross road)?
a) Less than 150 feet
b) 150 feet to 200 feet
c) 200 feet to 250 feet
d) Greater than 250 feet

Virginia:	N/A
Georgia:	Varies depending on site and terrain
Wisconsin:	None
South Carolina:	Question not Clear
Alabama:	150 feet to 200 feet
Connecticut:	Nothing Specific
Michigan:	Greater than 250 feet
Tennessee:	150 feet to 200 feet
Nebraska:	Greater than 250 feet

8) How do you mount signals at SPUI? For example, is it better to have signals mounted on either side of the bridge with dual conduit runs or a single mounting in the middle with one conduit run?

Virginia:	On either side of the bridge
Georgia:	Both
Wisconsin:	N/A
South Carolina:	Two of the Three planned SPUI its on the top and planned to be mounted in the middle with one conduit run
Alabama:	On Bridge
Connecticut:	Mounted on a single span in the center of the bridge.
Michigan:	N/A
Tennessee:	For roads going under mount signals either side of the bridge and ramp signals are hung under the bridge for better visibility.
Nebraska:	Either side with dual conduit runs

9) What are your specifications for under bridge lighting and mounting? For example, are lights mounted from the girder below the bridge? How the lights are physically attached and what standards are used to provide the proper lighting under the bridge?

Virginia:	N/A
Georgia:	AASHTO
Wisconsin:	N/A
South Carolina:	One location under construction where SPUI is under bridge, bridge is built on pillars and is about 28 ft high. Due to clearance and pillar construction no special provisions for lighting is provided.
Alabama:	None

Connecticut:	Following guidelines are used AASHTO – Informational Guide for Roadway Lighting FHA – Roadway Lighting Handbook IES – Lighting Handbook Not provide lighting under the bridge for the SPUI because it does not meet lighting requirements.
Michigan:	Mount on the bridge plus low head
Tennessee:	Road Lighting Handbook, FHWA
Nebraska:	N/A

10) Have you incorporated SPUI into coordinated signal systems? If so, was progression negatively affected? Do you have standards governing this issue (for example, spacing from adjacent intersections)?

Virginia:	Coordinated Signal System Progression not negatively impacted Do not have standards on signal spacing
Georgia:	Coordinated Signal System Progression not negatively impacted Do not have standards on signal spacing
Wisconsin:	N/A
South Carolina:	One out of Three has Coordinated Signal SYNCRO to simulate the system
Alabama:	Current design will incorporate SPUI into coordinated signal system.
Connecticut:	Not incorporated
Michigan:	No
Tennessee:	No
Nebraska:	Yes, Progression was not negatively affected

11) What is your policy on signalization of free dual right turns? In general practice, free rights are not allowed where more than one right turn lane is provided – given the potential sight distance problems. If you do allow these turns, what, if any, strategies do you use (for example, geometric alignments, such as staggered stop bars, or acceleration lanes) to address the safety issues?

Virginia:	Signalize dual right turns
Georgia:	Depending on Sight Distance
Wisconsin:	N/A
South Carolina:	Permissive right turns from both lanes
Alabama:	Signalized dual right turns
Connecticut:	Not allow free dual right turns. For SPUI dual right turns on the off – ramp will be signalized, signed for No Turn on Red, and will run during the entrance ramp left – turn phase.

Michigan:	Free Flow
Tennessee:	Site dependent
Nebraska:	Signalize if a dual right is warranted

12) Do you provide a red clearance interval for left turn phases? If so, what is it and how do you determine it?

Virginia:	6 sec all red clearance which is based on the travel distance between the ramps
Georgia:	Provide red clearance, depends on offset, speed, Travel distance
Wisconsin:	N/A
South Carolina:	Provide red clearance, same as main line barring
Alabama:	2 -3 seconds, but would depend on the intersection layout. No SPUI in operation.
Connecticut:	Red clearance interval is provided for both the left turn phases at the SPUI. Entrance ramp left turn 4 seconds and exit ramp left turn 6 seconds. Clearance intervals are determined to provide sufficient time for vehicles entering during the yellow to clear the intersection conflict area and are based on 1) Length of clearance path 2) Length of the Vehicle 3) Speed of the Vehicle through intersection
Michigan:	Any yellow over 5 seconds they provide 2% Red from Cycle Length
Tennessee:	Usually 2 – 3 seconds all red
Nebraska:	No

13) Do you have standards for minimum spacing between opposing left turn movements? If so, what are they?
a) Less than 15 feet
b) 15 feet to 17.5 feet
c) 17.5 feet to 20 feet
d) Greater than 20 feet

Virginia:	N/A
Georgia:	Question not clear
Wisconsin:	N/A
South Carolina:	No standards but usually minimum separation is 10 ft between opposing vehicle paths
Alabama:	Half a lane width measured perpendicular from outside turn radius to inside turn radius to outside turn radius.
Connecticut:	No
Michigan:	No

Tennessee:	No
Nebraska:	Less than 15 feet

14) We've tried to be fairly comprehensive in our questions but in the interests of keeping this survey as brief as possible, we have certainly omitted aspects of interest which may even be critical to successful SPUI design. Please provide comments on design aspects of your SPUI that are not included above. For example, do you use special signing at SPUI's? How do you place signs – using the MUTCD guidelines or do you have your own?

Virginia:	N/A
Georgia:	Elevated SPUI had "landing lights" which define vehicle path on side by side left turn functionality
Wisconsin:	N/A
South Carolina:	MUTCD
Alabama:	Currently No experience
Connecticut:	Currently SPUI under construction. For design, they follow MUTCD and recommendations from several published reports including NCHRP Report 345. Overhead guide signs will be installed on the cross road, in advance of the interchange, to clearly designate which lane the motorist should be in for a particular movement at the SPUI
Michigan:	N/A
Tennessee:	MUTCD Guidelines
Nebraska:	Keep the skew to a minimum

APPENDIX D

State of California | Business Transportation and Housing Agency

Memorandum

To: ALL DISTRICT DIRECTORS
CHIEF, DIVISION OF ENGINEERING SERVICES and
CHIEF, DIVISION OF TRANSPORTATION PLANNING
ALL HOLDERS OF THE HIGHWAY DESIGN MANUAL and
ALL HOLDERS OF THE TRAFFIC MANUAL

Date: June 15, 2001

File:

From **DEPARTMENT OF TRANSPORTATION**
DIVISION OF DESIGN
MS 28

Subject: Single Point Interchange Planning, Design, and Operations Guidelines

The Single Point Interchange Quality Team (SPI Team) has developed guidelines for single point interchange (SPI) alternatives. These guidelines are available on the internet at http://www.dot.ca.gov/hq/oppd/ and are effective immediately. The SPI Interim Design criteria issued March 30, 2000 are superseded.

The Chief, Division of Design and the Chief, Division of Traffic Operations must approve the concept for all SPIs. This authority has been delegated to the Project Development Coordinator and the Traffic Liaison respectively. Concept approval is required prior to approval of the Project Study Report except when the project is initiated with a Project Study Report (Project Development Support). In this case concept approval for an SPI alternative should be obtained as early in the environmental study phase as reasonable, but shall be obtained prior to approval of the Draft Project Report. In addition the HQ Traffic Liaison shall approve all final signing, striping and signalization plans for SPIs.

KARLA SUTLIFF
Acting Chief
Division of Design

for JOSEPH HECKER
Acting Chief
Division of Traffic Operations

Single Point Interchange Planning, Design and Operations Guidelines

INTRODUCTION

These guidelines have been prepared as a comprehensive document covering planning, design and operations of Single Point Interchanges (SPIs). Any SPI within the state right of way must conform to these guidelines. Items not covered shall be in accordance with the Project Development Procedures Manual (PDPM), Highway Design Manual (HDM), Traffic Manual (TM), Ramp Metering Design Manual (RMDM) as well as all other current applicable California Department of Transportation standards and guidelines. The SPI Planning, Design and Operations Guidelines provide a guide for the engineer to exercise sound judgement consistent with the project development philosophy discussed in Chapter 80 of the HDM.

The SPI is an interchange configuration that combines the two separate diamond ramp intersections into a single large at-grade intersection. The SPI, sometimes referred to as an "urban interchange", has been known to most highway agencies for many years, but was seldom used because of its cost, difficulty in constructing and unknown performance characteristics. In recent years, however, the SPI has become increasingly popular in a few states and local agencies. SPIs should be used under specific situations and should not be selected because the interchange is considered “state of the art” or a "gateway" concept.

SECTION 1 – PLANNING, APPLICATION AND APPROVAL OF SINGLE POINT INTERCHANGES

1-100 APPROVAL OF SPIs

The Headquarters Chief, Division of Design and the Headquarters Chief, Division of Traffic Operations must approve the concept for all SPIs. This authority has been delegated to the Project Development Coordinator and the Traffic Liaison respectively. Concept approval is required prior to approval of the Project Study Report except when the project is initiated with a Project Study Report (Project Development Support). In this case concept approval for an SPI alternative should be obtained as early in the environmental study phase as reasonable, but shall be obtained prior to approval of the Draft Project Report. In addition the HQ Traffic Liaison shall approve all final signing, striping and signalization plans for SPIs.

1-200 GEOMETRIC CONSIDERATIONS

Any SPI proposal must be compared to other conventional interchange types. Consistent with the philosophy of the PDPM, several interchange alternatives should be evaluated. The SPI alternative should be compared in particular to spread diamonds, L-9 partial cloverleaves (parclo) and tight diamonds. The type of interchange selected should be based on the discussions in these guidelines in order to select the best overall interchange configuration.

SPI intersections are larger than other intersections. Many existing SPI intersections are 90 meters in length or longer. Most SPI intersections operate with a three-phase signal. A significant distance separates the right turn lanes at exit ramps from the left turn lanes. Because of its unique design, certain geometric features are more critical to the SPIs operation than to other types of interchanges. Among those features are crest vertical curvature, skew angles, intersection length, and large radius sweeping left turn moves. See Section 2, "Geometric Design" for detailed discussion of these design items.

California drivers are relatively unfamiliar with the SPI geometric and operational characteristics. Therefore the selection of an interchange type should consider the number of non-repeat drivers who may not be familiar with the SPI. These locations should include, but are not limited to, airports, hospitals, sports stadiums and resort areas. Additional consideration should be provided to locations where visibility may be reduced by weather conditions.

1-300 RIGHT OF WAY CONSIDERATIONS

The available right of way (R/W) is an important consideration in selecting the appropriate interchange type. Where adequate R/W is available, the first choices of interchange types as described in the HDM are an L-9 (parclo) or an L-2 (spread diamond). These interchange types provide a high degree of safety, capacity, and flexibility while still meeting driver expectations. In situations where R/W is very restrictive, the most common interchange considered is the tight diamond, and in certain rare circumstances an SPI. The right of way requirements for SPIs and tight diamonds are similar.

1-400 CAPACITY

When the SPI configuration is unconstrained by the local road system, it has the capability of handling larger volumes of traffic than the tight diamond. However, in urban situations the local road system is often the controlling factor for overall system capacity. The following constraints influence the selection of an SPI:

<u>Intersection Size</u>

The size of SPI intersections necessitates a long traffic signal clearance interval for all moves. The all-red clearance interval represents dead time to the signal timing cycle, which reduces capacity and efficiency. This needs to be considered during the planning stage of the SPI design.

Adjacent Intersections

The proximity of adjacent intersections and driveways to ramp termini is a critical factor in the operation of any interchange. Under moderate to heavy traffic demands, SPIs require longer signal cycle lengths to maximize operations. When an SPI configuration is used, intersection spacing becomes even more critical because all stopped traffic must be stored between the near stop bar and the adjacent intersection. Often free right turn moves at exit ramps can not be provided due to close proximity of adjacent intersections. See Section 2-300, Right Turns at Exit Ramps" and HDM Index 504.3(2), "Location and Design of Ramp Intersections on the Crossroads", and 504.8 "Access Control" for more information.

Left Turn Movements

SPIs are generally more efficient than tight diamond interchanges in handling large volumes of left turn traffic where it can be accommodated by the receiving roadway. Tight diamond interchanges typically perform better than SPIs when handling large through volumes on the local streets. SPIs are more efficient for high left turning truck volumes due to their large left turn radii. SPIs may not operate efficiently when the moves are unbalanced.

Storage Capacity on Metered Ramp

An SPI can deliver significantly more left turn traffic volume to entrance ramps. Therefore adequate storage capacity shall be provided on metered ramps. See the Ramp Meter Design Manual for additional information. When adequate storage length cannot be provided, the capacity advantages of the SPI diminish.

Bicycles

The presence of bicycles can affect the decision to choose a SPI. Due to their slower speeds, bicycles may adversely affect the capacity and operation of motor vehicles at SPI intersections, thereby negating the benefits of choosing a SPI over another interchange alternative. The required green and all-red clearance intervals necessary for a bicycle to clear most SPI intersections are substantially longer than what is needed for a motor vehicle. The required extended signal timing increases delay for motorists. Accommodation of bicyclists through the SPI intersection is an important consideration. Section 2–800, "Pedestrians and Bicycles" discusses how to accommodate bicyclists through SPI intersections.

Pedestrians

Because signals at SPI intersections are timed to move motorists efficiently through the intersection, pedestrians normally can only cross a portion of the intersection in a single cycle. It may take a pedestrian as many as four cycles to cross the separate ramps connections along the local street as opposed to typically two to four crossings at conventional tight diamonds and partial cloverleaf interchanges. Pedestrians shall be prohibited from crossing the local street within the interchange.

SPIs with incorporated Frontage Roads

SPIs incorporating frontage roads should be avoided.

This configuration requires that the frontage roads be one-way and in the direction of ramp traffic. A slip ramp from the mainline to the frontage road provides access to and from the intersection. An SPI incorporating frontage roads by combining the ramps and frontage road is shown in the 1994 AASHTO "Green Book", Figure X-25.

A fourth signal phase is required with this configuration to allow through moves on the frontage roads. This layout typically requires at least 90 m between stop bars, thus diminishing operational efficiency. The fourth signal phase and additional intersection size required to accommodate frontage roads reduces the available green time. Normally bicycles are allowed to use the traffic lanes or shoulders and can legally turn left at an intersection. In order to accommodate a left turning bicycle in an SPI, longer signal timing is required. This longer signal timing makes the intersection operate inefficiently. At three-phase SPI intersections, bicyclists will normally not be turning left onto the freeways but will be proceeding as through traffic along the local cross streets.

1-500 PARALLEL LOCAL STREETS

In order to take advantage of the three-phase signal of an SPI intersection, the local street system must be able to accept and deliver the traffic. Short spacing from the ramp intersection to adjacent local streets and driveways will limit the ability for the local street system to handle the large volumes of through traffic that the SPI can deliver. The purported advantages of the SPI will often not materialize where the local street system is not compatible.

1-600 OPERATIONAL EXPENSE AND FUTURE PLANNING

SPIs are normally more difficult to operate and maintain than conventional diamond configurations. Their size and shape requires more maintenance effort for structures, electrical, signing, delineation and pavement markings. SPIs constructed with "butterfly" shaped structures lack flexibility for future modifications or expansion (see Section, 1-800 "Construction Costs"). If future expansion or modification is needed, major reconstruction of the structure will typically be necessary due to the complexity of the structure design. Because of the size and geometrics of the SPI, widening of the freeway, local street, or ramp terminals is normally more expensive than for conventional interchanges. This holds true for either overcrossings or undercrossings.

1-700 POWER FAILURE OR FLASHING OPERATION

Intersection operations during conditions of power failure or flashing signals, especially during periods of darkness, requires particular attention. The size of the intersection and position of the entering vehicles complicate the required “stop and proceed in order of arrival” rule. Manually directing traffic will be difficult on an SPI intersection without signal control. Plans for operation of the SPI intersection during power outages should be developed cooperatively between California Department of Transportation and the appropriate local agency.

1-800 CONSTRUCTION COSTS AND STAGING

SPIs require a substantial initial investment. Significant differences in construction costs exist between the SPI and other conventional interchanges. Additional costs are attributed to the larger structure surface area, additional vertical clearance required at undercrossings, retaining walls, and overhead sign structures.

Staging for SPIs can be more difficult than other interchange types and may result in local street closures. It is important that proposed SPIs receive a constructability review in accordance with current procedures.

1-900 ALTERNATIVE SELECTION

Compared to SPIs, diamond and parclo interchanges often result in lower construction costs as well as reduced future maintenance and expansion costs. The choice of interchange type should be based upon the best combination of expense and desired results. The SPI should not be arbitrarily chosen without considering other alternatives. In addition to the "no-build" alternative, an SPI should be compared to a diamond interchange in the project initiation document. Safety, construction costs, maintenance costs, projected traffic demands, right of way impacts, expected bicycle and pedestrian usage, interchange type, and site conditions factor into choosing the best alternative.

SECTION 2 - GEOMETRIC DESIGN

2-100 DESIGN SPEED

The standards for design speed discussed in the HDM Topic 101 apply to SPIs. The design speed should reflect the anticipated 85th percentile speed. However, the selected design speed should not be lower than the posted speed limit. The Project Development Coordinator must concur with the design speed chosen for the local street. Design speed should not be lowered to accommodate economy of design. Design speed of the ramps must be consistent with Index 504.3 of the HDM except as discussed in these guidelines.

2-101 Sight Distance and Visibility

Visibility is a key feature to ensure safe and efficient operation of SPIs. To avoid confusion, drivers must have clear visibility of all pavement, signing, delineation, signals, and curbs within the intersection. It is important that drivers be able to see and understand their destination and path through the intersection. Decision Sight Distance per Table 2-101.1 shall be provided through the SPI intersection along the local street extending 50 m beyond the stop bars. Decision sight distance is measured from a driver's eye height of 1070 mm to an object height of 150 mm.

Table 2-101.1
Sight Distance

Design Speed (km/h)	Stopping Sight Dist (m)	7 1/2 sec Corner Sight Distance (m)	Decision Sight Distance (m)
40	50	90	110
50	65	110	145
55	75	120	160
60	85	130	175
70	105	150	200
75	118	160	215
80	130	170	230
90	160	190	275
100	190	210	315
110	220	230	335
120	255		375

To verify the driver's ability to see the pavement, signing, delineation, signals, and curbs within the intersection, the designer should plot the vertical alignment of each move through the intersection. As would be expected, curbs and raised markers can be seen and understood from further distances because they are raised above the pavement. Based upon field observations, the striping and pavement can be understood by drivers at approximately half of the sight distance on longer crest vertical curves. Table 2-101.2 shows the relationship between sight distance* and the distance that markings on the pavement are visible.

Table 2-101.2

Sight Distance*	Distance to Visible Striping**
110 m	65 m
130 m	75 m
160 m	80 m
190 m	90 m
220 m	105 m
250 m	120 m

* Sight Distance is measured from the driver's eye (1070 mm) to a 150 mm object.
** Distance is from the driver's eye to limits of perceivable pavement delineation. The basis for this measurement is field observation.

This relationship can be helpful in determining visibility of delineation features on SPIs located on crest vertical curves. This information is provided as background material and should not be misconstrued as design criteria. The intent is to provide the reader or designer with information on the relationship between sight distance and the visibility of delineation.

2-102 Vertical Alignment

It is undesirable for the SPI intersection to be located on a crest vertical curve due to the reduction in visibility. The vertical alignment of local streets should have a constant grade or sag vertical curve through the intersection.

Undercrossing vertical alignments should be designed with enough vertical clearance to accommodate signal heads beneath the soffit without reducing visibility to the signal heads. See Section 6-200, "Undercrossings" for related signal guidelines.

2-103 Horizontal Alignment

The horizontal alignment of the local street should be constructed on tangent through the intersection. Where the local street is on tangent, delineation and signing can be better understood by the driver before entering the intersection. When the local street alignment is in a curve, it may be difficult for the driver to determine the proper lane as they approach the SPI intersection.

Where compound curves are utilized for a left turn alignment through the SPI intersection, the smaller curve radius should be at least half that of the larger curve radius. Broken back curves for left turn moves through the intersection should be avoided.

The exit ramps terminus should be designed to avoid aligning headlights into the eyes of drivers on the opposite exit ramp. Exit ramps on ascending grades are particularly prone to directing headlights into opposing exit ramp driver's eyes.

An important consideration for exit ramp left turn movements is adequate visibility to the stop bar and both signals at the ramp terminus (See Item 2-103 in Figure 1). Note that at least two signals are required for exit ramp left turn moves. Place at least one overhead signal near the center of the intersection, and the second signal head mounted on the divisional island or "pork chop" island. See Section 6, " Traffic Signals" and Figure 4A & 4B.

Geometrics for left turn moves provide for higher speeds at SPIs than at typical ramp intersections, therefore stopping sight distance shall be provided along the off-ramp left turn segment. This shall match or exceed the design speed provided by the ramp's horizontal alignment in accordance with Table 203.2 of the Highway Design Manual and be at least 40 km/hr; Index 504.3(1)(a) not withstanding.

2-104 Corner Sight Distance at Exit Ramps

It is important to provide visibility between exit ramp traffic and cross traffic approaching from the left (See Figure 1, Item 2-104). Pedestrian fencing on overcrossings or the bridge abutment on undercrossings may obstruct visibility. There are both safety and operational benefits associated with adequate corner sight distance. If drivers in a queue cannot see approaching vehicles, each driver may tend to slow and creep into the intersection, thus reducing the capacity of the ramp and hindering the operation of the intersection. Intervisibility between vehicles improves safety.

Corner sight distance should be provided from a point 12m before the exit ramp left turn stop bar. Where restrictive situations exist, the minimum corner sight distance shall be equal to the stopping sight distance provided from the same point.

2-200 INTERSECTION SIZE

Minimizing intersection size can be the most significant factor in successful SPI operation. SPI intersections operate best when they are small and compact. See Figure 6 and Section 2-800, "Pedestrians and Bicycles" for information regarding Compact SPIs. Larger intersections require longer paths for vehicles to traverse through the intersection. Drivers may have difficulty identifying key features such as ramp entrances and therefore have difficulty properly traversing the facility. Smaller intersections typically improve the driver's ability to identify and understand the intersection layout, thereby reducing driver confusion and the potential for wrong way moves. Larger intersections also complicate movements for bicyclists. Bicycle issues are covered in more detail in Sections 1-400, “Capacity” and 2-800, “Pedestrians and Bicycles”.

Signal operation has a direct relationship to intersection size. The amount of red clearance time increases with intersection size, thus increasing the overall signal timing cycle length, requiring more storage for waiting traffic and reducing the efficiency of the intersection. In addition, larger intersections expose vehicles to conflicts for longer periods of time.

If an SPI is proposed without a separate bicycle facility, it shall be a Compact SPI. Where a separate bicycle facility is provided in conjunction with an SPI, the following intersection size criteria applies. Where an SPI intersection is located on a crest vertical curve, the distance between opposing stop bars on the local street should not be greater than 50 meters, but shall not be greater than 60 meters. Where an SPI intersection is located on a sag vertical curve or at a constant grade, the distance between opposing stop bars on the local street should not be greater than 60 meters, but shall not be greater than 70 meters.

The following geometric features can reduce the size of a SPI intersection:

1. Increasing the median width of the local street allows the local street stop bars to be placed near the center of the intersection. This aspect can be difficult to visualize but is easily understood if the designer draws and compares the effects of different median widths.

2. Field observations noted that vehicles frequently stop beyond the stop bar and idle within the intersection. A wider median width includes space between the through move stop bars and left turn moves which may compensate for driver error.

3. At undercrossings, signals should be hung beneath the bridge soffit. The vertical clearance should be sufficient to hang signal heads vertically, thus allowing local street stop bars to be located nearer the center of the intersection. See Section 6-200, “Undercrossings” for additional information on signal placement at undercrossings.

2-300 RIGHT TURNS AT EXIT RAMPS

The free right turn moves at the exit ramps are a basic feature of the typical SPI. Lack of a free right can negatively impact operational efficiency. Figure 1 illustrates three common approaches to right turn lane configurations at exit ramps.

The free right turn lane, as shown in Item 2-300(1) in Figure 1, is a typical feature of SPIs and should be used when the right turning vehicles enter the local street in their own lane, and adequate weave and merge lengths can be provided downstream. If volumes are too high for a single lane it is sometimes reasonable to add and signalize the #1 right turn lane as shown in Figure 1, Item 2-300(2). The signalized #1 right turn lane allows vehicles in this lane a protected movement to the local street. In some situations this configuration of a combination free right/signalized right turn layout can mitigate short weaves and merges related to close spacing of the ramp and adjacent local intersections. Where spacing between exit ramps and adjacent intersections is short and/or a large volume of vehicles weave across the local street to turn left at the adjacent intersection, consideration should be given to signalizing the right turn move at the ramp terminus as shown in Figure 1, Item 2-300(3).

Per Index 504.3(2) of the HDM, "Where a separate right turn lane is provided at ramp terminals, the turn lane should not continue as a free right unless pedestrian volumes are low, the right turn lane continues as a separate full width lane for at least 60 m prior to merging and access control is maintained for at least 60 m past the ramp intersection. Provision of the free right should also be precluded if left turn movements of any kind are allowed within 125 m of the ramp intersection." In addition, an analysis should be performed to verify that adequate merge and/or weave distance is provided. If the analysis indicates that additional lane length is required for merge and/or weave, the access control should be correspondingly extended.

2-400 LANE WIDTHS

The lane widths for left turn lanes should be 4.2 m through the intersection. Additional width may be required for truck off tracking (See HDM Table 504.3).

2-500 MERGING AND WEAVING DISTANCE FOR ENTRANCE RAMPS

A typical SPI entrance ramp accepts traffic from double left turn lanes and a free right turn lane. The ramp therefore commonly provides three lanes near the intersection. Since it is California Department of Transportation policy to build one lane entrances except under specific circumstances, three lanes must be merged into one prior to entering the freeway. Merges should occur one lane at a time and provide adequate length consistent with expected vehicle speeds under free flow conditions.

Where a turn lane converts into an HOV lane on the entrance ramps, adequate weaving distance should be provided to ensure vehicles entering the ramp can weave out of the HOV lane to a mixed flow lane. To avoid this weave, it may be feasible to begin an exclusive HOV lane on the local street leading to the ramp's HOV lane. Where this occurs, advance overhead signing should be installed to prepare drivers for the weave. When an exclusive HOV lane does not begin on the local street, an overhead sign should be placed at the ramp entrance stating "HOV ONLY AHEAD".

Where entrance ramps include an HOV bypass lane, adequate distance for merging from the far lane to the HOV lane should be provided.. A fourth lane on the entrance ramp should typically be avoided. Figure 1 illustrates the above concepts.

2-600 SKEW ANGLE

SPIs are best utilized when the freeway and local street alignments intersect at a ninety degree angle. Intersection skew angles should not exceed 15 degrees from normal. However, intersection skew angles shall not be greater than 30 degrees from normal.

2-700 CENTER ISLAND LAYOUT

A raised center island shall be provided. The minimum dimension shall be 1.8 m per side (3 m preferred) with a minimum surface area of 9 square meters. All lanes shall have a 0.6 m offset from the raised center island. See Figure 3, and Section 3-100, “Center Island” for additional information.

2-800 PEDESTRIANS AND BICYCLES

SPIs are efficient in moving high volumes of motor vehicle traffic, particularly left turn movements. Due to their slower speeds, bicyclists are typically difficult to accommodate in the traffic lanes or shoulders without adversely affecting the operational efficiency of the SPI. If moderate to heavy bicycle usage is expected, consideration should be given to selecting a more compatible interchange type. For design purposes, bicyclists are estimated to travel at a speed of 4.5 meters per second and pedestrians at 1.2 meters per second through a level intersection. Therefore, if signal timing were set to accommodate bicyclists and pedestrians, motorists would experience excessive delay waiting for a signal to change.

Figure 6 shows a Compact SPI designed to accommodate bicyclists, and minimize the intersection size thus improve overall operations. An SPI with a 25 m maximum distance from the stop bar to the conflict point is considered a Compact SPI. The conflict point is defined as the middle of the far lane for turning vehicles that bicyclists must cross under a single signal phase. Single free right turn lanes are an integral part of the Compact SPI design, and are considered independent of the signalization. The Compact SPI design utilizes a single lane free right turn lane so bicyclists need to cross only one lane of uncontrolled traffic. However in order to be able to provide free right turn lanes, adequate weave and merge distance from the free right turn to the adjacent intersection must be provided. See Section 300, “Right Turns at Exit Ramps” and the HDM for discussions regarding free right turn movements. In some situations the right turn move can be handled with stop control and thus adequately accommodate bicyclists.

To accommodate bicyclists through SPI intersections, all SPI alternatives shall be Compact SPI except as discussed in the following. If an SPI alternative other than a Compact SPI is chosen, a separate bicycle facility shall be constructed in conjunction with the SPI. The separate bicycle facility would typically be a bicycle overcrossing or undercrossing and should be located in the immediate vicinity of the SPI to minimize out of direction travel by bicyclists. It should be noted that where the right turn movement is signalized, the conflict point is the middle of the far right turn lane. If it is anticipated that in the future the right turn move at a Compact SPI will be signalized, a separate bicycle facility should be incorporated into the current project.

Bicycle push buttons to extend the next through-move green phase for bicyclists have been installed in California. The push button is located at the limit line and near the curb facing the street for easy bicyclist access. This allows the bicyclist to cross the SPI with minimum conflict. The longer green phase however increases the delay to motor vehicles at the intersection and thus reducing its efficiency. This concept may be applicable at other existing SPIs. Where bicycle push buttons are installed at SPIs, a sign advising bicyclists that pushing the button will provide an extended green light on the next cycle shall be installed. The sign should be white on green, have a bicycle symbol and say: "Push button for more time on next green."

Signals at SPIs are timed to move motorists efficiently through the intersection; pedestrians are normally allowed to proceed as far across the intersection as they can in a single phase. Due to the substantial length across the intersection it may take a pedestrian as many as four cycles to cross the interchange as shown in Figure 1.

To safely accommodate pedestrians, a pedestrian push button shall be installed.

SECTION 3 ISLAND FEATURES

3-100 CENTER ISLAND

Consistent with Sections 2-400, “Lane Widths” and 2-700, “Center Islands Layout” of these Guidelines and to facilitate orderly left turn moves, a raised center island as shown in Figure 3 should be provided. The island perimeter should be 80 mm mountable curb. For more information, reference Index 405.4, Traffic Islands, of the HDM.

3-200 MEDIAN ISLANDS

Opposing through traffic on the local street approaching and departing an SPI intersection shall be separated by a raised concrete median. Use a Type A barrier curb within the influence area of the SPI intersection. Raised medians adjacent to a left turn lane should have a minimum width of 1.2 m. A 3.6 m minimum median width is recommended for separation between opposing through lanes (See discussion regarding median width in Section 2-200, “Intersection Size”). Type K markers and R7 signs are required on the median island bull nose.

3-300 LEFT TURN CHANNELIZATION OF LOCAL STREET

On local streets, a striped channelization island to separate left turning vehicles from through vehicles may be provided as shown on Figure 2. If used, the island should consist of 200 mm white thermoplastic striping. The island should be at least 1.5 m wide at the widest point. The island should direct the left turning vehicles towards the freeway on-ramps. A striped divisional island or "pork chop" island (see Figure 6) shall be provided beyond the left turn lane stop bar.

3-400 RAMP ISLANDS

The channelizing island separating the left and right turn lanes where on and off ramps connect to the local street shall be a raised island. The island facilitates pedestrian traffic and must be clear of landscaping or other obstructions that could restrict sight distance. Use a 200 mm vertical (barrier) curb surrounding the island perimeter, with Type K markers at the ramp island nose.

SECTION 4 PAVEMENT DELINEATION AND MARKINGS

The HQ Traffic Liaison shall approve all final signing, striping and signalization plans for SPIs.

4-100 PAVEMENT COLOR

Bridge decks should be a dark color to improve contrast between deck and delineation.

Proper striping and delineation are valuable tools to provide guidance through the intersection. A dark colored deck is beneficial to increase visibility of pavement markings, curbs and other interchange features. Some recommended treatments are dyed PCC, open graded AC, iron oxide-epoxy seal, or a slurry-seal coated PCC. Consult Structures Maintenance and District Maintenance prior to choosing a surface treatment.

4-200 PAVEMENT MARKING MATERIALS

In an effort to reduce lane closures and associated maintenance problems, thermoplastic is recommended for all permanent pavement markings and legends. If thermoplastic is selected as a marking material, consult with the HQ Traffic Liaison regarding the most appropriate type. SPI maintenance operations can require lane closures, which can be problematic and disrupt traffic.

100mm thermoplastic striping material of appropriate color shall be applied around all raised medians and islands, and surround center islands with a 200mm white thermoplastic stripe.

4-300 LANE LINE EXTENSIONS (SWINGLINES)

In an effort to help guide drivers through SPI intersections, swinglines (Detail 40 plus reflective markers at approximately 6.4 m on center) shall be provided for all left turn movements. This will usually be the centerline between double left turn movements. In some instances a second swingline may be appropriate at the left edge of the left lane. Left edge swinglines consisting of Type AY markers or Type H markers spaced no closer than 1.2 m on center for motorists in the number 1 lane may be considered for vehicles turning left from the exit ramp to the local road on larger intersections and/or through crest vertical curves.

4-400 STOP BARS

In an effort to increase visibility and driver conformance, all stop bars should be white thermoplastic, 0.6 m in width.

4-500 PAVEMENT MARKINGS

Conflicting or numerous pavement markings can contribute to driver confusion. Pavement markings between the stop bars at an SPI intersection should be kept to a minimum. Directional arrows or legends between stop bars at SPI intersections should be avoided. However, all lanes approaching the intersection should be clearly marked with the appropriate directional arrows. Additionally, directional arrows shall be placed adjacent to all stop bars. See Figure 2.

SECTION 5 - SIGNS

The HQ Traffic Liaison shall approve all final signing, striping and signalization plans for SPIs.

5-100 STANDARD SIGNAGE

All standard interchange sign packages (R10, R11 etc.) are required and must be located where they are clearly visible to reduce the risk of wrong way moves at exit ramps. In addition to the standard sign packages, the following signs shall be installed at SPIs.

5-200 GUIDE SIGNS

For SPI overcrossings, on-ramp entrances for left turn moves should have G85 signs with arrows mounted on sign bridges as shown in Figure 3. Additionally, G85 & G83 signs are required over local streets on all approaches to the SPI intersection as shown. Guide signage should not be located where they could impair traffic signal visibility. It is desirable to place the G83 in line with the G85 signs on the local street. However, in instances where turn pocket length prevents the placement of these signs in line, the G83 should be placed on the local cross streets as appropriate.

5-300 CENTER/MEDIAN ISLAND SIGNAGE

The center island should be signed with W57 and type N markers placed back-to-back facing each exit ramp, and type K markers at the noses as shown in Figure 3. Signs should be placed for maximum visibility to approaching traffic and to reduce the chance for driver confusion that may be caused by opposing headlights and geometry as discussed in 2-103, “Horizontal alignment”. Signs in the center island shall be mounted on break away posts.

Median island noses must be signed with R7 signs mounted on break away posts and type K markers.

5-400 U-TURNS

U-turns are prohibited on the local roads when exit ramp right turns are signalized due to the overlap of traffic signal phasing. Proper signage must be placed prohibiting this U-turn movement. R34 (No U-turn) signs may be placed on the traffic signal bridge or adjacent to the traffic signal heads. U-turns may be allowed at SPIs as long as the U-turn does not conflict with other movements.

Pedestrian signals must be timed only with the local street through move because of conflicts with U-turns from exit ramps.

5-500 RIGHT TURN ON RED

One of the primary benefits of SPIs is its ability to move large volumes of traffic through the intersection(s). Therefore, SPIs should be designed to allow for free right turns when possible. However, where a free right turn is not feasible as discussed in Section 2 - 300, “Right Turns at Exit Ramps”, consideration should be given to installation of a traffic signal to control this movement. At signal controlled right turn lanes, traffic should be allowed to turn right on red when practical.

In instances where right turn on red is allowed, a sign indicating that right turn on red is allowed should be placed. Where right turn on red is not allowed, a sign indicating that right turn on red is prohibited (R13) shall be placed.

This sign will reduce the risk of driver confusion on the nature of this movement and in enforcement.

5-600 SIGNS ON TRAFFIC SIGNAL BRIDGE

No guide signs are allowed on the traffic signal bridge or adjacent to overhead traffic signal heads. In an effort to increase visibility of the traffic signal, signage should be minimized on the traffic signal bridge.

SECTION 6 - TRAFFIC SIGNALS

The HQ Traffic Liaison shall approve all final signing, striping and signalization plans for SPIs.

6-100 OVERCROSSINGS - TRAFFIC SIGNAL BRIDGE

On SPI overcrossings, a traffic signal bridge spanning the width of the intersection is required. The traffic signal bridge should be placed over the center of the intersection and perpendicular to the through traffic movement. When there are two or more left turn lanes, two signal indications shall be mounted on the signal bridge for that movement. When there are two or more through lanes, two signal indications shall be mounted on the signal bridge for that movement. Signals for right turn movements should be placed as shown in Figure 4A. Far side signals beyond the signal bridge are not allowed. Additional signal indications may be placed on separate poles as shown in Figure 4A. In an effort to increase signal visibility, overhead guide signs, decorative features, artwork, and extraneous messages are not permitted on the signal bridge.

Additionally, as is consistent with good design practices and intersection safety, lighting should not be located where direct or scatter light could possibly reduce the visibility of the signal indications.

6-200 UNDERCROSSINGS

On SPI undercrossings, traffic signals should be mounted under the structure, to minimize intersection width. Oversized back plates are recommended to reduce backlight. If intersection width standards and signal set back requirements can be met, signals may be placed on the face of the SPI structure.

6-300 SIGNAL HEADS

Traffic signal heads, except the near right signal, shall be 300 mm or greater in diameter. Programmable visibility heads shall not be used. -Signals shall be hung vertically as horizontal traffic signals could cause difficulties for colorblind drivers.
In areas where increased visibility is desirable, oversized traffic signal heads may be used. Use appropriate arrow signal lenses for turn movements (45-degree angle is preferred). The indication for through movements must be standard circular lenses.

6-400 SIGNAL PLACEMENT

Signal poles shall not be placed in the center island or on the median island bull nose. Signals may be placed in median islands to control the right turn movements from the freeway exit ramps. See Figure 4A for an example.

There shall be no signal heads located at the far side of the intersection facing through traffic on the local street.

6-500 MAINTENANCE CONSIDERATIONS

SPIs can be more difficult to maintain than other types of interchanges. For ease of maintenance, access to signal heads and signs located over the center of the intersection should be provided. The maintenance electricians must have access to the signal face. To avoid multiple lane closures during maintenance operations, overcrossings shall include a catwalk that provides access to all signals and signs located on the signal bridge. If the catwalk does not provide direct access to the face of the signal, the signals shall be made to rotate or pivot in the direction of the electrician.

SECTION 7 - LIGHTING DESIGN

7-100 INTERSECTION SAFETY LIGHTING

Intersection safety lighting should be maintained at the SPI. The Traffic Manual requires 6.5 horizontal lux as the minimum maintained horizontal illuminance at the intersection of centerlines of the entering streets. Therefore, for SPI, this intersecting point would normally be in the vicinity of the center island that separates all the left turn movements.

Lighting should be provided at each on ramp entrance. All areas bounded by the crosswalks should have minimum maintained 1.6 horizontal lux.

For an overcrossing intersection, Type 15 or Type 21 structure electroliers should be used. High mast lighting may be used, except that it floods the area without emphasis to the ramp entrances.

Sign lighting shall not be allowed on the traffic signal bridge.

For an undercrossing intersection, 70 watts or 100 watts HPS flush mount soffit lighting should be used. The intersecting point of the centerlines should have the minimum maintained 6.5 horizontal lux. All areas bounded by the crosswalks should be lit by either soffit lighting under the structure or by Type 15 electroliers outside the structure area.

The intersection safety lighting should be maintained by the agency responsible for maintaining the signal, as it is an integral part of the traffic signal.

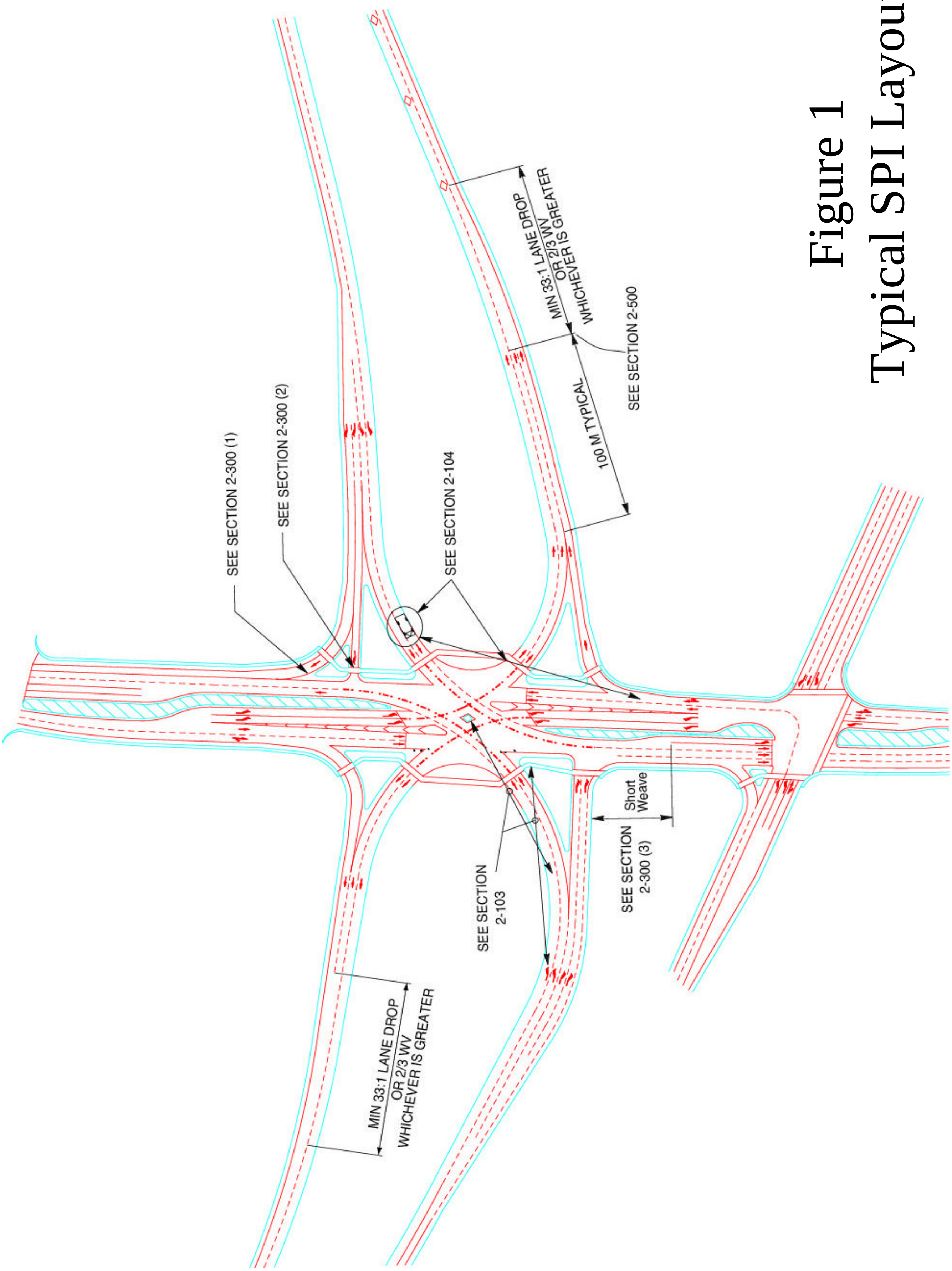
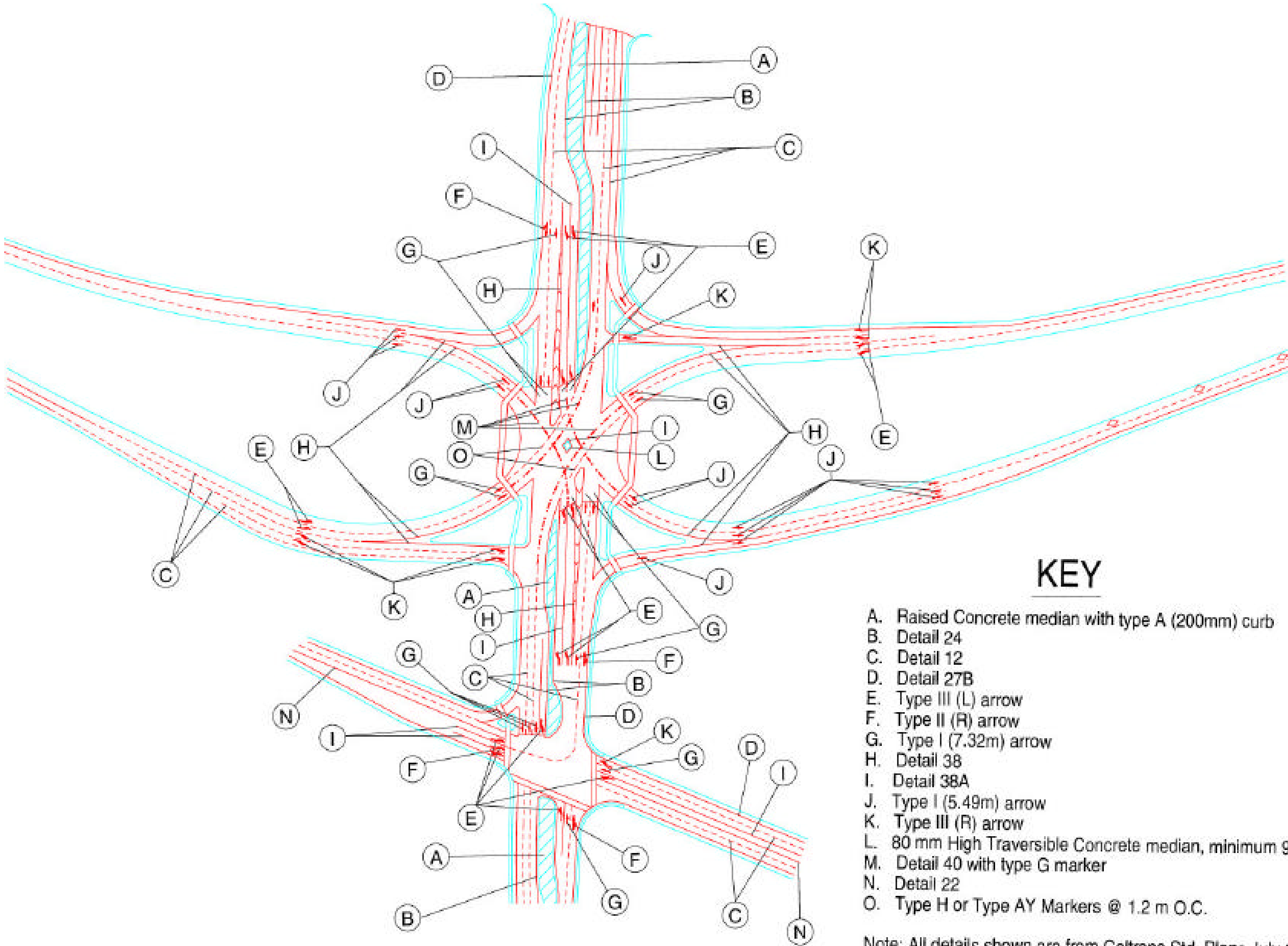


Figure 1
Typical SPI Layout

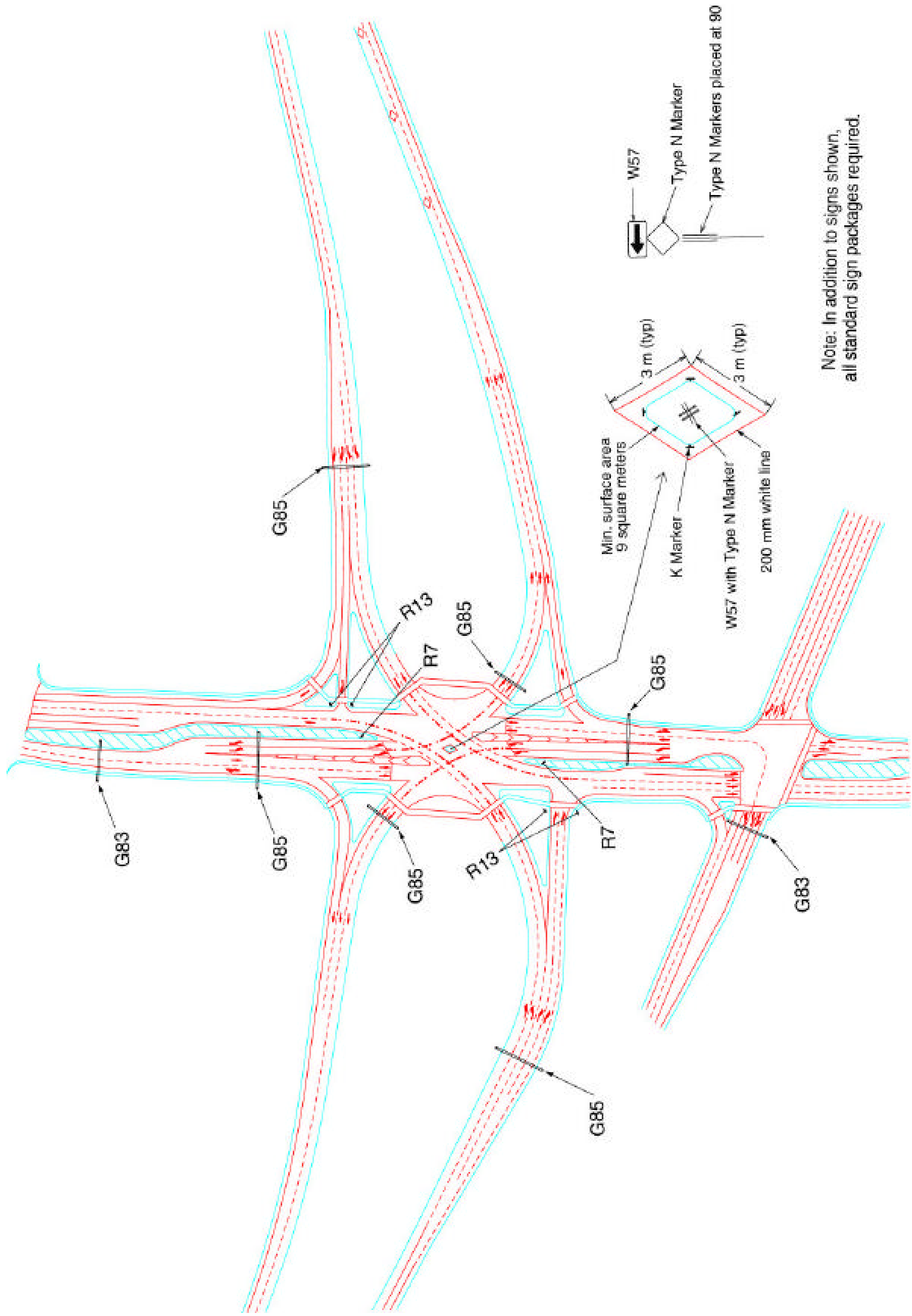


KEY

A. Raised Concrete median with type A (200mm) curb
B. Detail 24
C. Detail 12
D. Detail 27B
E. Type III (L) arrow
F. Type II (R) arrow
G. Type I (7.32m) arrow
H. Detail 38
I. Detail 38A
J. Type I (5.49m) arrow
K. Type III (R) arrow
L. 80 mm High Traversible Concrete median, minimum 9m
M. Detail 40 with type G marker
N. Detail 22
O. Type H or Type AY Markers @ 1.2 m O.C.

Note: All details shown are from Caltrans Std. Plans July 1999.

Figure 2
Typical Pavement Marking Plan



Note: In addition to signs shown,
all standard sign packages required.

Figure 3
Partial Signing Plan

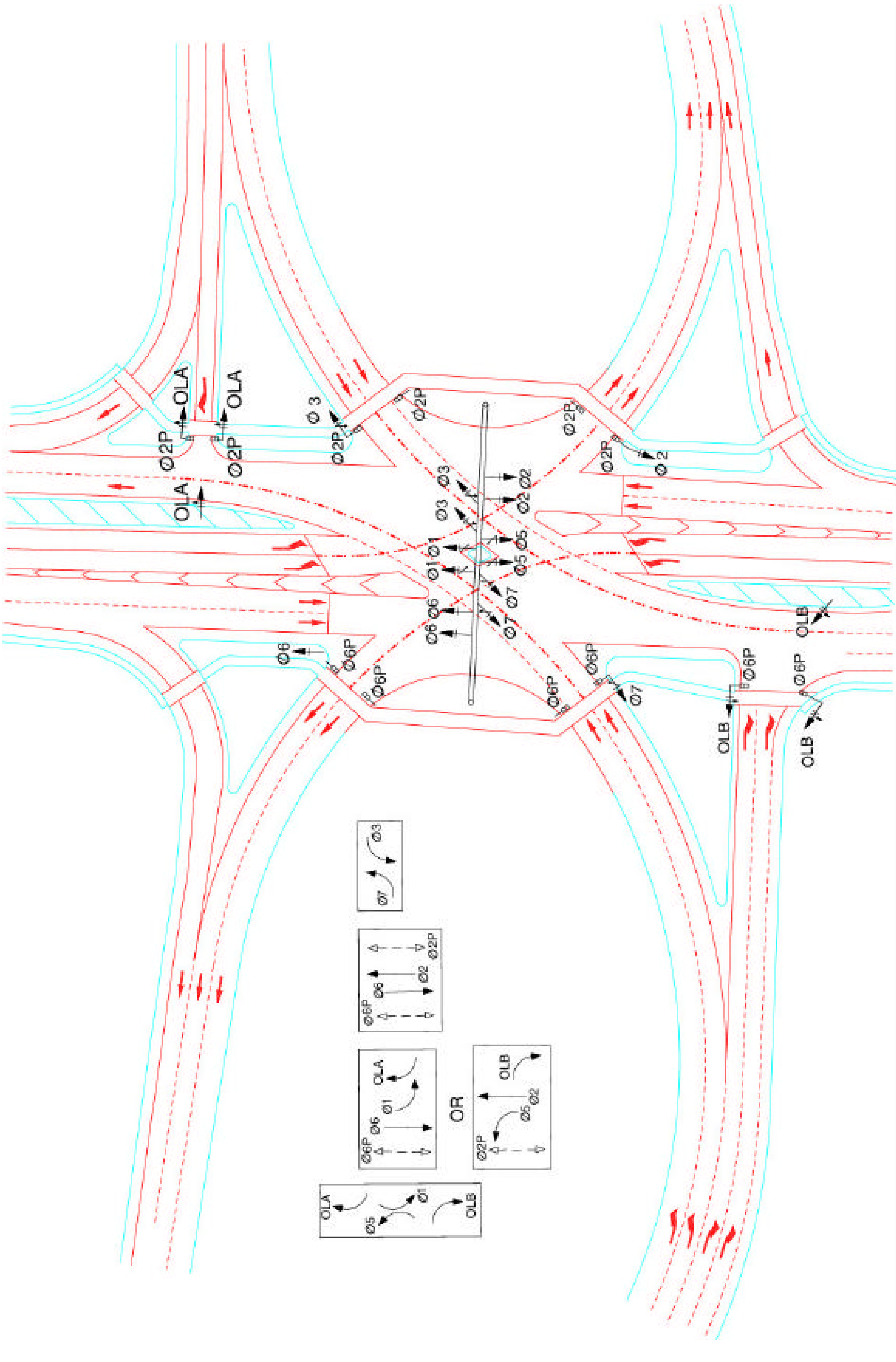


Figure 4A
Typical Signal Layout
(Overcrossing)

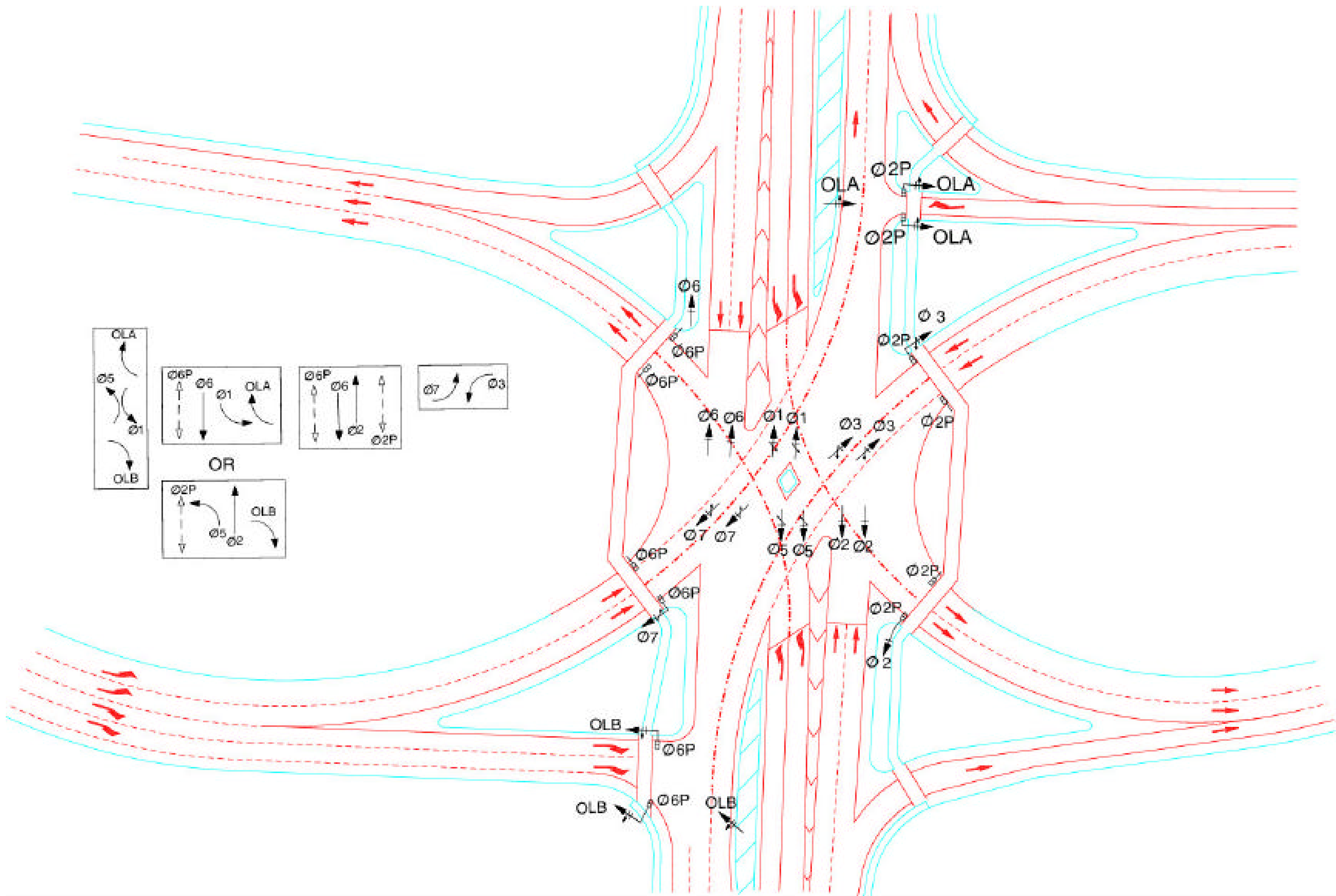


Figure 4B
Typical Signal Layout
(Undercrossing)

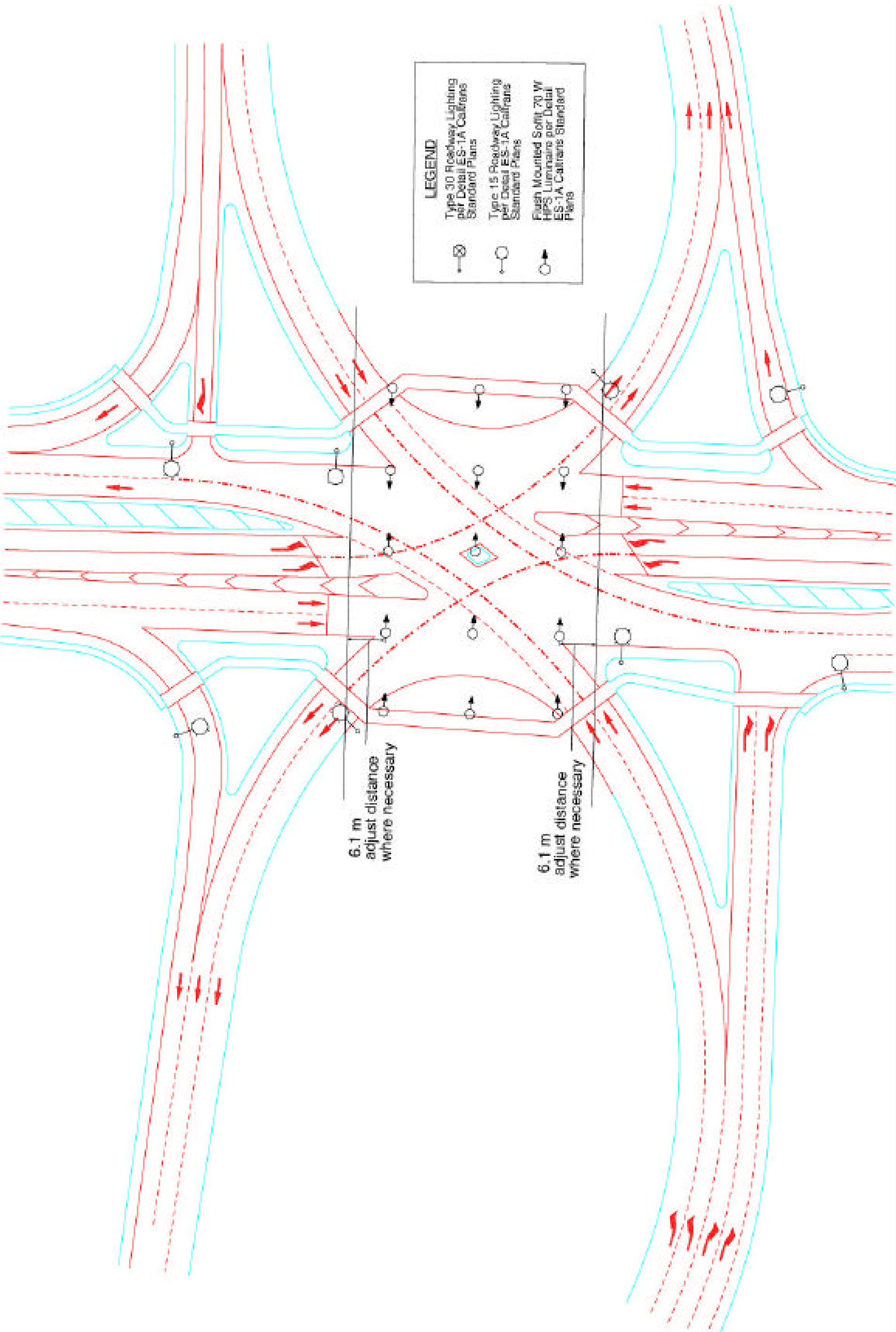


Figure 5A
Typical Lighting Plan (Undercrossing)

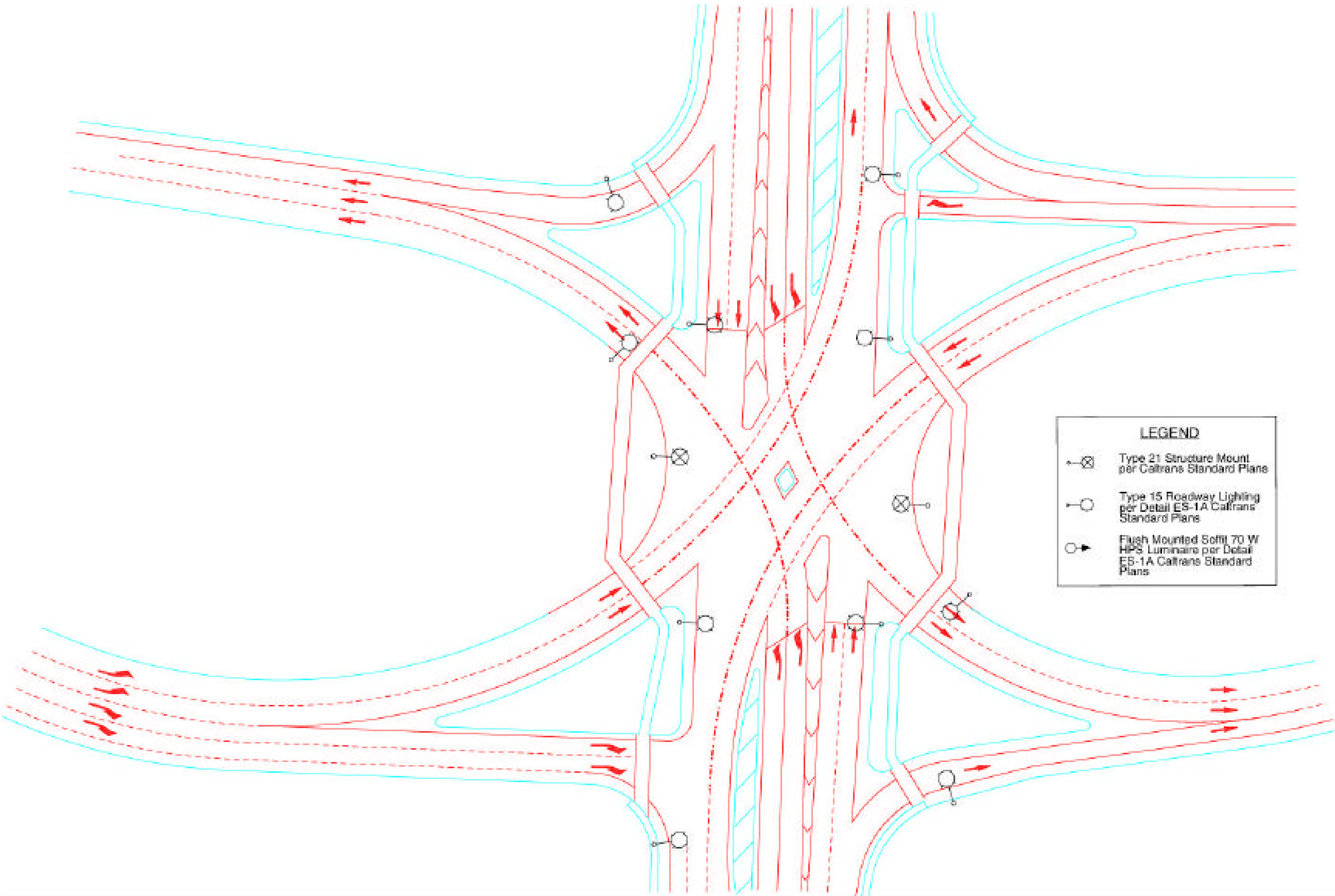


Figure 5B
Typical Lighting Plan
(Overcrossing)

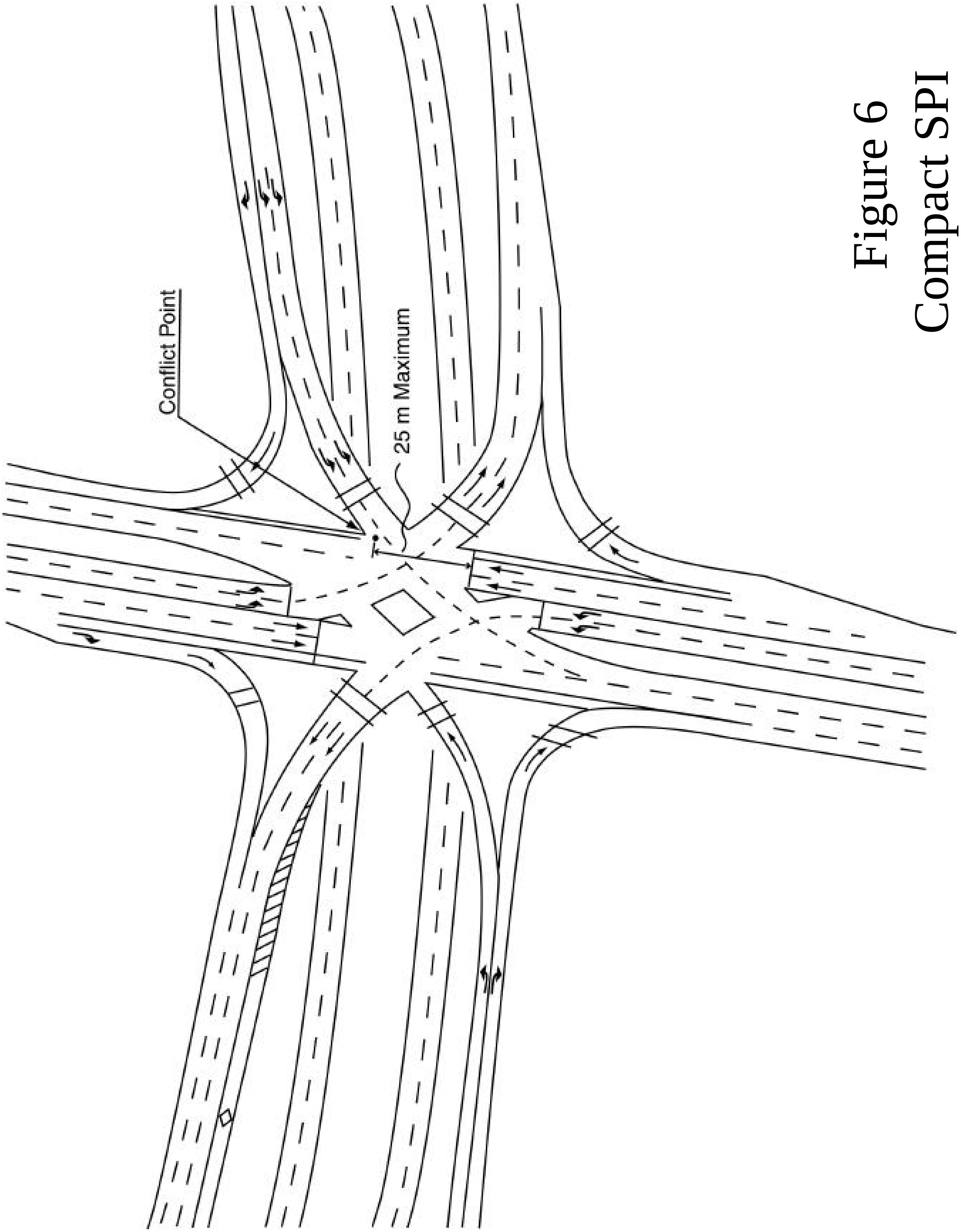


Figure 6
Compact SPI