Arizona Parkway Intersection/Interchange Design Concepts Study in Maricopa County, AZ

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ABSTRACT
The Arizona Parkway is a roadway classification adopted by the City of Goodyear, Town of Buckeye, City of Surprise, and Maricopa County Department of Transportation (MCDOT). The design concept includes an intersection treatment referred to as the indirect left turn (Michigan Left Turn). This intersection eliminates left turns at cross streets by incorporating a wide median for U-turns downstream of cross street intersections. The Arizona Parkway design provides additional capacity and safer at grade intersections and provides an at grade intersection alternative to grade-separated interchanges. However, grade separation is still necessary at high volume parkway-to-parkway intersections.

The study focused on parkway segments integral to two regional networks (I-10/ Hassayampa Valley Transportation Framework Study; I-8/I-10 Hidden Valley Roadway Framework Study) and included the establishment of at grade parkway to parkway intersection thresholds and identification of locations where parkway to parkway interchanges will be needed. The project categorized all parkway to parkway intersections and developed design templates for grade separated solutions, including a new interchange concept. The results of the study provide a framework for categorizing future parkway to parkway intersection and interchange treatments for the purpose of protecting future right-of-way (ROW) needs.

Although interchange treatments were suggested, the intent of the study was not to explicitly identify a specific interchange type for each location. HOWEVER, because the unique interchange design developed by the study team exceeded operational expectations and out-performed a diamond, a single-point, and diverging diamond interchanges, MCDOT adopted the Parkway Grade-Separated Interchange (PGSI) as its standard for high-volume parkway to parkway grade-separated intersections.

THE ARIZONA PARKWAY NETWORK

Background and Purpose

The Maricopa County Department of Transportation (MCDOT), the Maricopa Association of Governments (MAG), and its funding partners recently completed two regional framework studies in Hassayampa Valley (I-10) and in Hidden Valley (I-8 and I-10). The Arizona Parkway was identified by these two studies as the facility of choice to serve high traffic volume corridors in the West Valley. MCDOT commissioned a study to evaluate the level of service in these corridors and establish right-of-way needs for parkway to parkway intersections.

The Arizona Parkway design requires a right-of-way footprint of 200 feet and includes use of an intersection type referred to as an indirect left turn (Michigan U-turn or median U-turn). This intersection eliminates left turns at all cross streets and uses a wide median to facilitate U-turns downstream of cross street intersections. The indirect left-turn operations provide additional travel capacity eliminating the need for full grade separation at most parkway to parkway intersections. However, grade separated intersections may be required at certain high-volume locations.

The intent of the Arizona Parkway Intersection/Interchange Operational Analysis and Design Concepts Study was to evaluate forecast average daily traffic volumes on the Arizona Parkway network and identify:

1. The number of lanes required for each segment of the Arizona Parkway system, where a segment is a connection between two major facilities in the Maricopa County roadway network (including all other jurisdictions in the study area);

2. The number of intersections created by the crossing of two parkway facilities, i.e., parkway to parkway intersections, and whether or not these intersections would require flaring – or added lanes – on the intersection approach to accommodate forecast entering volumes;

3. The number of required parkway to parkway grade-separated intersections, due to the inability of an at grade intersection with a given number of lanes to accommodate entering volumes;

4. The interchange types for each grade separated intersection location and the most suitable interchange design for the parkway system; and

5. The amount of right-of-way necessary to preserve for grade separated interchanges in addition to the 200-foot right-of-way identified in the Design Guideline Recommendations for the Arizona Parkway.

Study Area

The study area encompasses approximately 3,300 square miles in Maricopa and Pinal Counties and lies within the Hassayampa Valley planning area and the western portion of the Hidden Valley planning area. The project study area extends from I-8 in the south to SR 74 in the north and from SR 303L (Loop 303) on the east to 459th Avenue on the west. It includes all of the communities of Buckeye, Gila Bend, Goodyear (including the Sonoran Valley), and Surprise. A small portion of western Glendale also lies within the project study area. The roadway networks defined for the planning areas of each study were reviewed and inventoried to identify the parkway to parkway intersections to be analyzed and categorized. There were 62 parkway to parkway intersections identified in the study area. The long-range travel demand forecasts for these studies focused on buildout conditions.

Parkway Volumes (2030) and Lane Recommendations

Forecast daily volumes from the September 2008 MAG model runs (using buildout travel demand data) were used to conservatively identify the highest traffic volume between parkway segments. This data was used to evaluate the forecast roadway volume and compare it to the threshold capacity of the Arizona Parkway.

Table 1. Arizona Parkway Level of Service E Threshold

Total Number of Lanes	Threshold Daily Traffic Volume (vehicles per day)
4	49,400
6	74,100
8	98,800

Source: Wilson & Company and Morrison-Maierle, October 2008.

Because the forecast traffic volumes are based on a fully urbanized buildout condition, LOS E was selected as the acceptable threshold capacity for parkways in the study area. The LOS E roadway capacity thresholds for 4, 6, and 8-lane parkways were based on earlier Arizona Parkway studies[1] assuming a balanced green time allocation per lane at high volume intersections, a capacity of 950 vehicles per hour (vph) per lane, a K factor of 0.075, and a peak hour factor (PHF) of 1.0. The K factor utilized for this analysis is consistent with current peak hour conditions in the Phoenix metropolitan area, and based on traffic data compiled by MAG. The PHF value of 1.0 recognizes the uniformity of saturated peak hour traffic loads associated with buildout conditions.
The forecast traffic volumes were compared to the LOS thresholds of Table 1 to establish the minimum number of lanes required for each parkway segment. The minimum lane requirements were then reviewed with jurisdictional input in regard to lane continuity and feasibility to arrive at a recommended number of lanes for each parkway in the study area.

PARKWAY TO PARKWAY INTERSECTION ANALYSIS

Intersection Daily Entering Volumes (2030)

For the intersection-level evaluation, MAG buildout model volumes (two-way) were used to identify daily inbound volumes to each parkway to parkway intersection. Inbound volumes on each leg were assumed to be half of the two-way volume from the model. The inbound intersection leg volumes for each intersection were then summed to give the total daily entering volume. The entering volumes were then compared to a calculated parkway to parkway intersection threshold representing daily traffic volumes.

Intersection Capacity Threshold Methodology

Table 2. Parkway to Parkway Intersection Lane Combinations

Number of Lanes		Parkway A 4	Parkway A 6	Parkway A 8
Parkway B	4	4x4	6x4	8x4
Parkway B	6	-	6x6	8x6
Parkway B	8	-	-	8x8

Six parkway to parkway intersection possibilities were identified as shown in Table 2. Each possibility was tested to determine the daily entering volume capacity at which the indirect left turn concept would fail. As noted above, a LOS E was adopted as the threshold value for the evaluation of parkway segments. However, for the more specific analysis of parkway to parkway intersections, a LOS D condition, as established by MCDOT guidelines for the County roadway system, was used for purposes of identifying the intersection failure point.

The methodology for evaluating the threshold of at grade, parkway to parkway intersections followed a three step process:

1. Estimate maximum average daily intersection entering volumes for each intersection. Maximum volumes are based on the capacity thresholds in Table 1.

2. *Estimate maximum peak hour approach and turning movement volumes*. Peak hour entering volumes for each intersection approach were derived assuming a K factor equal to 0.075 and a 60/40 directional split. Turning movement volumes were then derived using model data from the MAG framework studies and the standard methodology for estimating future turning movements presented in National Cooperative Highway Research Program (NCHRP) Report 255.

3. *Evaluate the intersection LOS and iteratively adjust volume until the threshold is attained*. AM and PM peak hour turning movements were evaluated using Synchro analysis software with an 80-second cycle length and optimized splits for lane volume distribution. Initially, all intersections were assumed to have one left turn lane and two right turn lanes. However, testing of each intersection determined that only one right turn lane was necessary, if the forecast right turn volume was less than 900 vehicles per hour (vph). Final intersection evaluations used one left turn lane and one right turn lane.

   Entering volumes were iteratively adjusted down in five percent increments until the intersection was just over the LOS D/LOS E boundary. The peak hour entering volume at this point was then converted back to a daily volume and deemed the daily entering volume capacity for the intersection lane combination.

Figure 1 shows the results of the analysis for the six intersection combinations. The lowest and highest entering volume thresholds are 81,000 vehicles per day (vpd) and 151,000 vpd for the 4x4 and 8x8 intersection types, respectively. The graph indicates that a 15,000 to 20,000 vpd increase in the daily entering volume corresponds roughly to two additional through lanes into the intersection.

The analysis of the at-grade intersections also revealed that traffic volumes at the main parkway to parkway intersection were the first to exceed the LOS D/LOS E boundary, rather than the indirect left turn (U-turn) locations.

At-Grade Intersection Entering Volume Thresholds

Each intersection in the study area was tested against the appropriate maximum daily entering volume threshold to identify the intersections that could operate at grade or if grade-separation was needed. The threshold test for at-grade intersections with less than eight lanes assumed that the intersection could be flared to accommodate additional lanes if necessary to provide additional capacity. Because a typical parkway design is widened to the inside (i.e., into the median), additional lanes at the intersection approach would be flared to the left approaching the intersection and traffic would diverge to the left. Beyond the intersection lanes would drop from the left and traffic would merge to the right.

The results of the at-grade intersection threshold analysis are presented in Table 3. The table presents the daily entering volume threshold for each lane combination and the number of intersections of each lane combination that fall under the threshold value, that require additional intersection lanes, and that require grade separation.

Table 3. Parkway to Parkway Intersections Daily Entering Volume Threshold Analysis

Lane Combination	Threshold Capacity	Under Threshold	Over Threshold	
			Additional Lanes	Grade Separation
4x4 (7 total)	81,000	7		
6x4 (13 total)	96,000	8	5	
6x6 (6 total)	115,000	4	2	
8x4 (7 total)	115,000	4	3	
8x6 (17 total)	135,000	9	4	4
8x8 (12 total)	151,000	3		9
TOTALS (62)		**35**	**14**	**13**

Source: Wilson & Company, October 2008.

The analysis shows that 56 percent of the intersections in the parkway network will be able to accommodate full buildout volumes with no additional lanes or grade separation. Additional intersection lanes will be required at 23 percent of the intersections. Finally, the analysis shows that grade separations will be required at 21 percent of the intersections, but that the majority of these are for the 8x8 lane combination.

In preparing the analysis, it was found that in some of the 8x6 lane combinations, the entering volume was too great to meet the threshold criteria even if additional lanes were added. These 8x6 intersections were identified as requiring grade separation. In all cases with the 8x8, if the entering volume was greater than the maximum threshold, the intersections were identified as requiring grade separation because a 10-lane parkway is undesirable.

It is important to note that threshold values calculated for the intersection lane combinations are based on capacity volumes under *typical* conditions. Given that each intersection can be better or worse than typical as site-specific conditions change, each intersection identified as requiring grade-separation was further evaluated with site-specific conditions using the MAG model data and Synchro/SimTraffic. Based on the site-specific operations analysis, each of these intersections was shown to have a failing level of service confirming the need for grade separation and the need for additional right-of-way.

Grade Separation Capacity Threshold Analysis

As part of the grade separation analysis, a standard diamond interchange, a single point interchange, and a diverging diamond interchange were evaluated in concept to identify the best solution for high volume parkway to parkway crossings. The concept design for each interchange assumed that the parkway median section was narrowed to reduce footprint on the bridge, as necessary. In each case, the higher volume parkway was given the priority for grade separation, and traffic signal operations on the minor parkway were maximized to provide the best progression for all approaches to the intersection.

Based on a similar analysis methodology described for maximum intersection thresholds, the maximum threshold volumes for the three grade separated interchange types were determined. The results of this analysis are shown in below in Figure 2. For comparison, Figure 2 also shows the maximum entering volume capacity of a typical arterial intersection and an indirect left-turn parkway intersection.

The figure is not meant to represent the ultimate capacity of the interchange type in all situations, but rather given the theoretical conditions of this planning study. It is understood that site-specific conditions will change the operational characteristics of each interchange type, characteristics which are not detailed by this analysis.

The entering volumes of 13 intersections requiring grade separation were compared against the results of interchange capacity analysis. The results of that comparison revealed that any of the three interchange types would be an acceptable solution treatment for 10 of the 13 intersections. The three exceptions are forecast to have exceptionally high daily volumes (in excess of 220,000 vpd) and would require additional grade-separation of turning movements.

Right-of-way requirements were calculated based on the conceptual layout of each parkway to parkway interchange type. Table 4 summarizes the right-of-way impact of each interchange type representing the amount of right-of-way required for the interchange *in addition to* the 200-foot right-of-way guideline established by MCDOT for the general parkway section. This concept level analysis did not account for site-specific conditions, which may reduce or increase the amount of right-of-way impact (i.e. drainage, utilities, railroad). In addition, the concept analysis incorporated conservative estimates for side slope conditions.

Table 4. Right-of-Way Requirement for Each Interchange Type

Interchange Type	Total Additional Right-of-Way (Acres)
Standard Diamond	29.0
Single Point	19.1
Diverging Diamond	30.6

Source: Wilson & Company, May, 2009.

A NEW IDEA – THE PARKWAY GRADE SEPARATED INTERCHANGE (PGSI)

Subsequent to analyses of the three initial interchange concepts for the parkway, MCDOT pursued a new interchange concept specifically developed for application at the intersection of high volume parkway to parkway intersections; where forecast traffic volumes exceed the capacity of an at-grade intersection. The concept behind the new interchange was a design that would maintain driver expectations of the indirect left turn treatment associated with the parkway design (unlike traditional interchanges), and also accommodate the high volume parkway intersections. The new design concept, shown in Figure 3, is referred to as the Parkway Grade Separated Interchange (PGSI).

Figure 2. Maximum Daily Entering Volume Thresholds by At-Grade Intersection

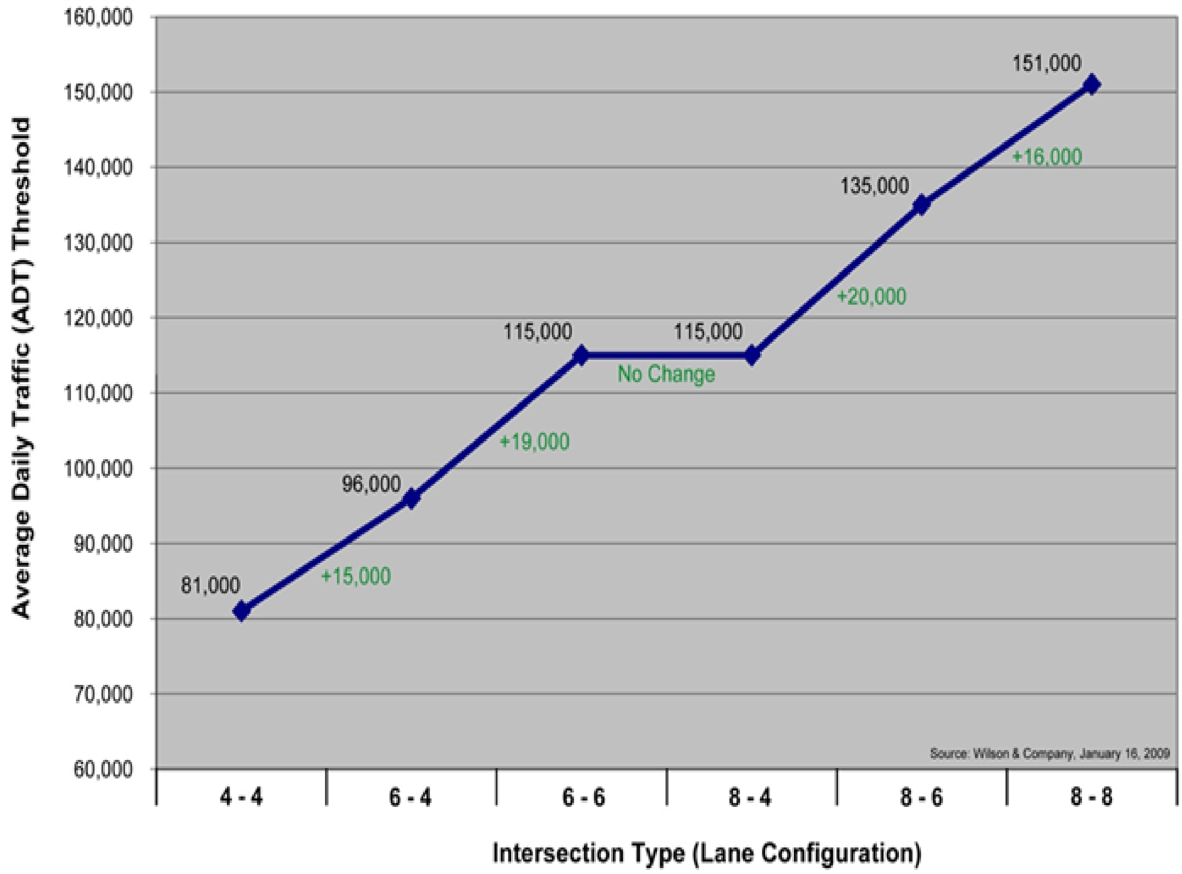
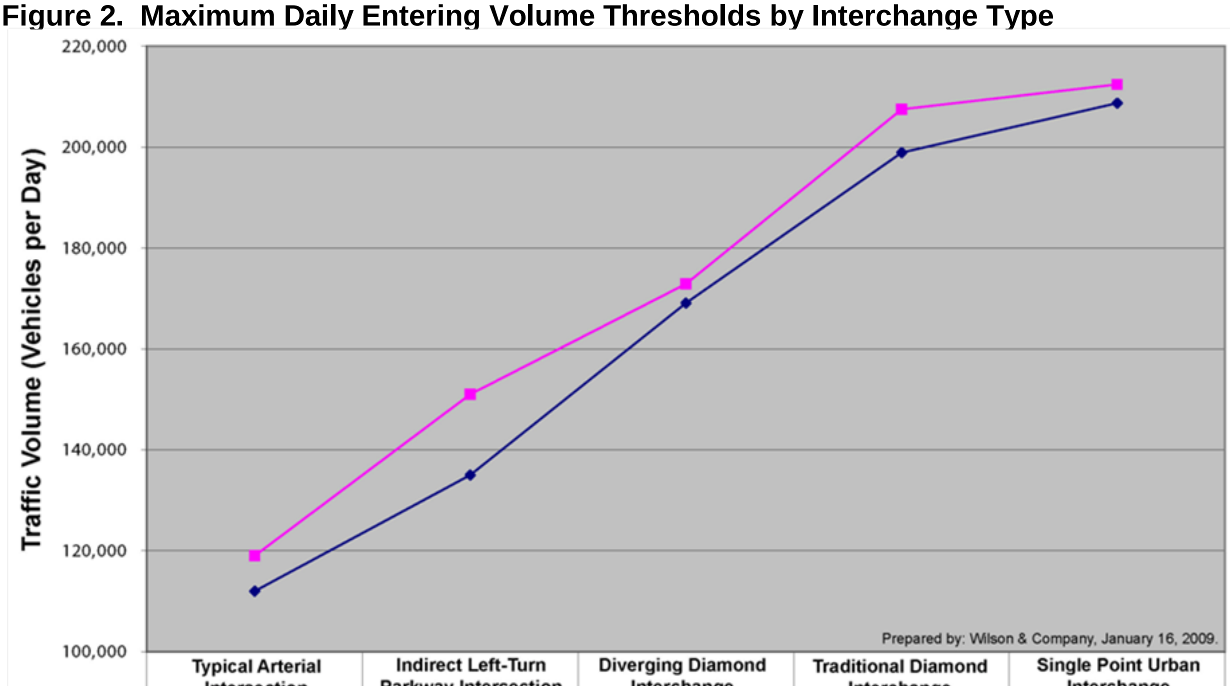
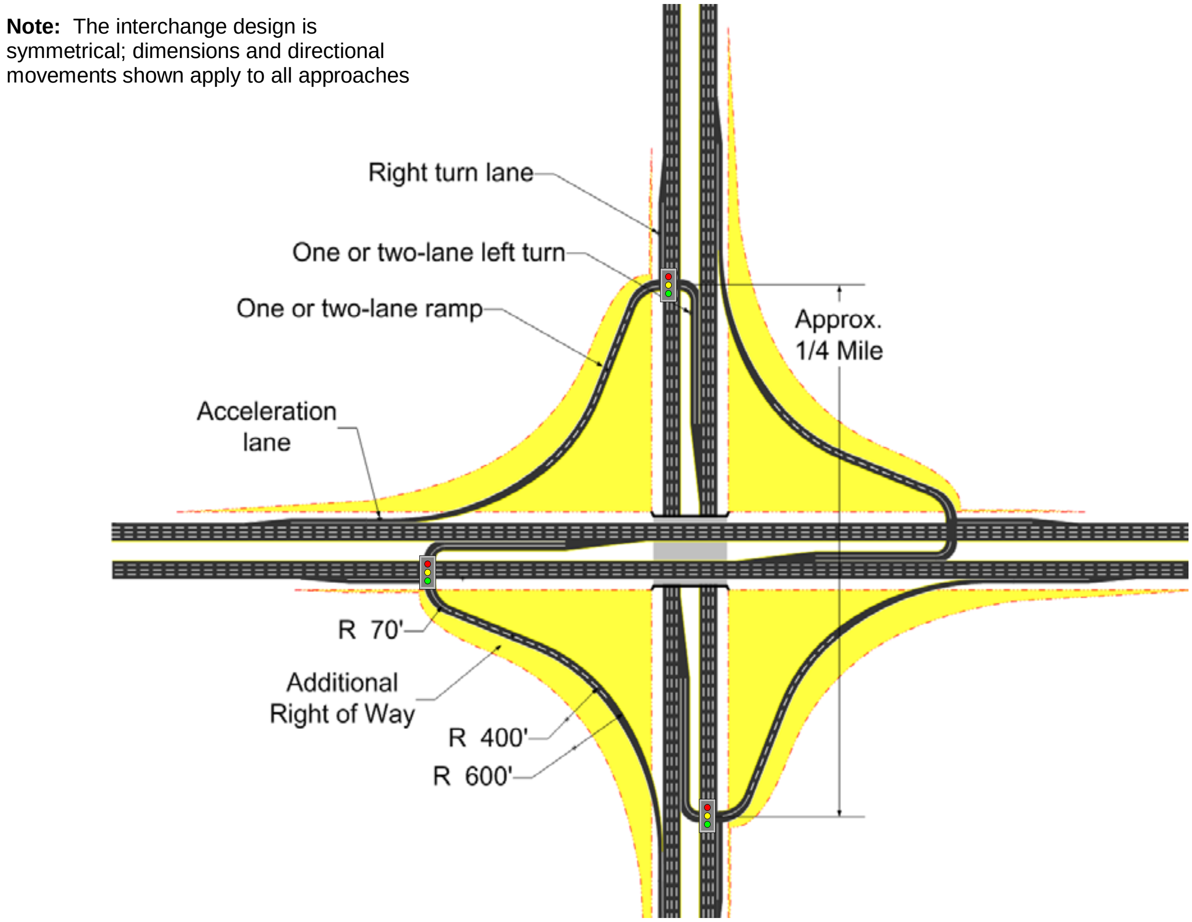


Figure 2. Maximum Daily Entering Volume Thresholds by Interchange Type



	Typical Arterial Intersection	Indirect Left-Turn Parkway Intersection	Diverging Diamond Interchange	Traditional Diamond Interchange	Single Point Urban Interchange
8 - 8	119,000	151,000	172,900	207,500	212,400
8 - 6	112,000	135,000	169,100	198,900	208,700

Figure 3. Parkway Grade Separated Interchange Concept Design



Concept Characteristics

The underlying principle of the PGSI is that it incorporates the indirect left-turn movements of an at grade intersection while maintaining a two phase signal operation. The PGSI concept maintains a traffic flow treatment consistent with that experienced at the at grade intersections along the entire parkway – unlike the commonly used diamond and single point interchange concepts. The principal characteristics of the PGSI include:

- 80-second cycle lengths and coordination with 2-phase parkway signals
- One signalized intersection per approach
- Allows for a double left turn at crossover and two-lane ramp
- U-turns at crossover permitted for the inside left
- Less pedestrian friendly with crossings at two locations per ramp
- Low right-of-way requirement
- Minimizes left turn conflicts (4)
- Reduces traffic queues
- 16 points of conflict

Operational analysis

Like the other interchanges, the PGSI was evaluated in Synchro to identify the maximum average daily threshold volume. The results of the analysis show that the

PGSI has an entering volume threshold of 216,100 to 247,000 vehicles per day (vpd) for the 8x6 and 8x8 intersections, respectively. The daily thresholds for the 8x6 and 8x8 SPUI lane combinations, which has the highest threshold of the interchange types evaluated, are four percent and 14 percent below those of the PGSI for the 8x6 and 8x8 lane combinations, respectively.

The right-of-way analysis of the PGSI revealed the additional right-of-way needed is less than the other interchange types. This is due mainly to the PGSI ramps generally being at-grade, whereas the typical interchange requires additional right-of-way for substantial embankment to raise the ramps to meet the crossing parkway. Table 5 shows the right-of-way comparison between the PGSI and the other interchange types.

Table 5. Right-of-Way Requirement for Each Interchange Type

Interchange Type	Total Additional Right-of-Way (Acres)
Standard Diamond	29.0
Single Point	19.1
Diverging Diamond	30.6
Parkway Grade Separated	14.8

Source: Wilson & Company, May, 2009.

Although the PGSI works for the majority of the intersections requiring grade separation, two excessively high volume locations on the parkway network will require more than a typical grade-separated interchange, regardless of type. These two intersections will require direct connector and flyover ramps to accommodate high volume turning movements and will require additional right-of-way.

Pedestrians

The high capacity of the PGSI design is not conducive to easy pedestrian movements. First, the Arizona Parkway itself will be six to eight lanes wide with a center median of 50 to 60 feet. Thus, pedestrian movements across the Arizona Parkway must be carefully planned and controlled. Pedestrian movements at a PGSI will be complicated due to the high volume of turning movements. Linear pedestrian movements will not be an issue, as the Arizona Parkway urban cross section includes a six foot sidewalk and seven foot landscape buffer to accommodate pedestrian and bicycle movements.

The unique character of the parkway to parkway intersection and the impedance to pedestrian movements created by the intersection of two parkway facilities is complicated when an interchange requirement is established. A concept for pedestrian movements has been developed using the signalized intersections and pedestrian underpasses; however, more detailed evaluation and refinement will need to be conducted on a case by case basis to reach an optimal solution for addressing specific pedestrian movements.

Access Management

The MCDOT Design Guideline Recommendations for the Arizona Parkway provides guidance regarding vehicular access to the parkway facility. The details of this guidance are not repeated here, however, the typical access plan for the Arizona

Parkway was found to be applicable within the PGSI interchange concept. Within a one half mile segment upstream of the interchange, there could be at least four points of access along the parkway. However, fewer access points could be accommodated downstream of the PGSI, as it would not be advisable to have access points interfering with traffic merging into parkway traffic from the cross street ramp that accommodates the right turn movement from one parkway to the other.

RECOMMENDATIONS

A determination was made during this study that an interchange design that maintains consistency with the Arizona Parkway's efficient and unique operating concept would be preferred. Therefore, a new interchange called the PGSI was developed and evaluated. This concept was tested for its effectiveness with respect to the indirect left turn movement and the two-phase signal operation of the Arizona Parkway. Traffic simulations supported the conclusion that the PGSI provides efficient and high-capacity functionality. It also is adaptable to the different intersection configurations and, therefore, will fully support the capacity requirements of the parkway system.

The PGSI provides the capacity necessary for all except two of the 13 intersections requiring grade separation. Directional travel volumes at these two locations are expected to exceed the capacity of the left turn phasing embedded in the PGSI. These locations will require direct connector and flyover ramps to accommodate the exceptionally high turning movement volumes.

It was concluded that the PGSI can support the higher capacity of the Arizona Parkway network more effectively than the other interchange types. And, as noted above, the operation of this interchange maintains a consistent driving experience by incorporating the left turn subsequent to passing through the intersection. Although each intersection needs to be evaluated in detail during the design concept stage of roadway development, it is recommended that the PGSI design solution be implemented at all grade separated parkway to parkway intersections to satisfy buildout traffic conditions. The PGSI can be implemented as an interim solution for the exceptionally high volume intersections, wherein direct connector and flyover ramps will ultimately be required to accommodate high directional travel demand.

The 200-foot right-of-way preservation requirement associated with the standard Arizona Parkway cross section is adequate to meet the needs of at grade parkway to parkway intersections up to eight lanes. However, additional right-of-way will need to be preserved at parkway to parkway intersections requiring grade separation. The PGSI will require approximately 15 acres of additional R/W to accommodate the intersection of two 8 lane parkways. The right-of-way estimate of 15 acres assumes a generally flat intersection location and typical layout conditions, i.e., there are few major natural or manmade physical features requiring modifications to the typical design. As a result, right-of-way needs may increase given the presence of special conditions, such as canals, utilities, railroads, adjacent roads, and adjacent land uses.

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[1] MCDOT Enhanced Parkway Study, Phase 3, Final Report, prepared for the Maricopa County Department of Transportation, prepared by Morrison-Maierle, Inc., March 2008.