2013 ITE Western District Annual Meeting

CONCEPT DEVELOPMENT, ANALYSIS, AND DESIGN OF A NEW PARKWAY AT-GRADE INTERSECTION (PAGI)

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The Pima County, AZ DOT has conducted studies over the past several years to identify an intersection design concept to address the traffic operations and safety needs at the intersection of two major arterial roadways designated in the Regional Transportation Plan as "Desert Parkways". Each of these parkways is designated to be ultimately upgraded from a 4-lane divided arterial to a 6-lane divided arterial. Design of one parkway for conversion to a 6-lane parkway is already underway, but the development of an acceptable and affordable design concept for the intersection of the two parkways has been problematic. The extremely high levels of right-turn and left-turn volumes (currently between 900 and 1,400 vph) on three of the four intersection approaches, and the expected growth in traffic through the intersection over the next 25 years has precluded the use of conventional at-grade intersection designs, even with multiple turn lanes.

Several alternatives have previously been evaluated which involved the use of a grade separation and/or the use of a split roadway concept (realignment of the main east/west roadway to the south with a new major intersection created). In general these alternatives provided reasonable levels of traffic performance with some future LOS E or F movements, and costs estimated in the $25M to $44M range. Pima County sought a less expensive alternative.

EPS developed a new and unique unconventional parkway at-grade intersection (PAGI) concept using indirect left-turns onto entrance ramps and 2-phase traffic signals. This concept was shown through simulation to provide much better traffic operations than all of the previous alternatives and is estimated to cost only $16M to build. An interim solution to further reduce cost sought by the Pima Association of Governments Regional Transportation Authority (RTA), the agency funding the project, employs the PAGI concept while maintaining the existing 4-lane cross section. The interim solution is estimated to improve existing intersection traffic operations from LOS E/F to LOS C, accommodate a 50% growth in existing traffic at LOS D, and cost only $7M. The interim solution can accommodate the future widening of the arterial to 6-lanes while maintaining the interim solution elements of the PAGI design.

Origin of the PAGI Concept

The lead author worked with the Maricopa County Department of Transportation (MCDOT) and other consultants for several years on the development and evaluation of their "Arizona Parkway" concept[1] [2] [3] [4] [5], evaluating various intersection design concepts for parkway-parkway intersections, both at-grade and grade-separated. The Arizona Parkway concept strictly employs the use of indirect left-turns and 2-phase traffic signals, restricts major intersection traffic signal spacing to half-mile intervals, and requires right-turn out only egress from roadside

[1] *Enhanced Parkway Study,* prepared for the Maricopa County Department of Transportation, prepared by Morrison-Maierle, Inc., August 2007.
[2] *Enhanced Parkway Study Phase 2 – Continuous Flow Intersections,* prepared for the Maricopa County Department of Transportation, prepared by Morrison-Maierle, Inc., December 2007.
[3] *Enhanced Parkway Study Phase 3 – Refined MLT Intersection Analysis,* prepared for the Maricopa County Department of Transportation, prepared by Morrison-Maierle, Inc., December 2007.
[4] *Arizona Parkway Intersection/Interchange Operational Analysis and Design Concepts Study,* prepared for the Maricopa County Department of Transportation, prepared by Wilson & Company in association with Morrison-Maierle, Inc., August 2009.
[5] *Arizona Parkway Freeway Interchange Analysis,* prepared for the Maricopa County Department of Transportation, prepared by Morrison-Maierle, Inc. in association with Wilson & Company, May 2010.

development[6]. The Arizona Parkway is based on Michigan left-turn parkways that have been in operation in Michigan for over 50 years.

During one of these projects the collaboration of the consultants with MCDOT staff resulted in the development of a completely new grade-separated interchange design for two Arizona Parkways that maintained the indirect left-turn concept for both roadways (see Exhibit 1). Called the Parkway Grade Separated Interchange (PGSI), left-turns and right-turns are made onto entrance ramps in each quadrant of the interchange. The use of the ramps eliminates what is considered a weakness in the indirect left-turn concept in that high volumes of left-turns no longer travel through the main intersection twice. In concept, the ramps are placed sufficient distance from the grade-separation such that they are each at-grade. The 2-phase traffic signals at the ramps stop only traffic opposing the left-turns. In simulation the PGSI provided significantly higher capacity and better traffic operations than all other interchange types tested (see Exhibit 2). Conceptually, ramp design speeds would be 30 to 35 mph and merge area tapers would be consistent with posted speeds on the parkway.

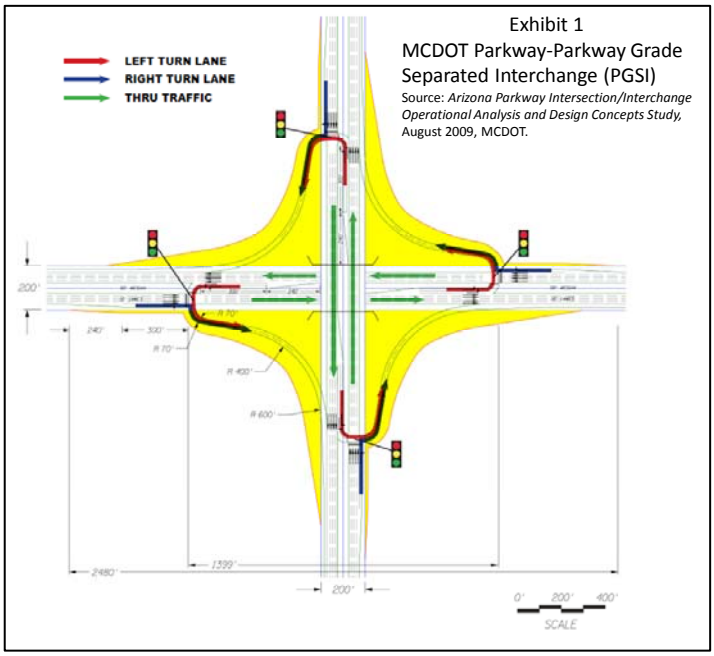


Exhibit 1
MCDOT Parkway-Parkway Grade Separated Interchange (PGSI)
Source: *Arizona Parkway Intersection/Interchange Operational Analysis and Design Concepts Study,* August 2009, MCDOT.

The PGSI became the origin of the new PAGI at-grade intersection concept where the main intersection is also controlled by a simple 2-phase traffic signal. The flexibility of the ramp design and placement, and the overall capacity of the concept exceeded the requirements for the Pima County application.

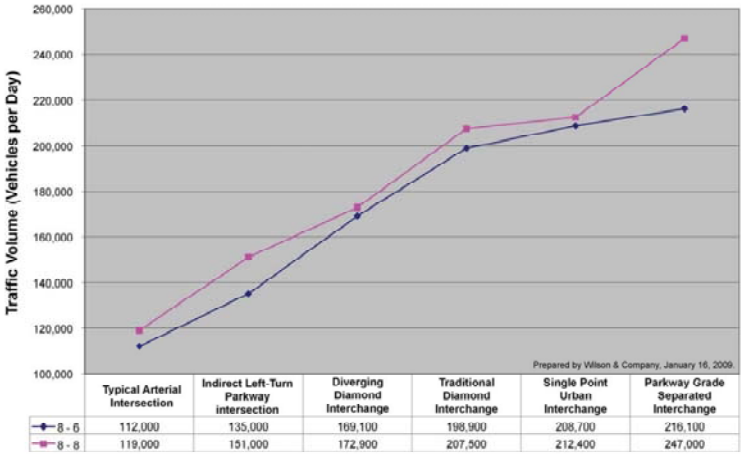


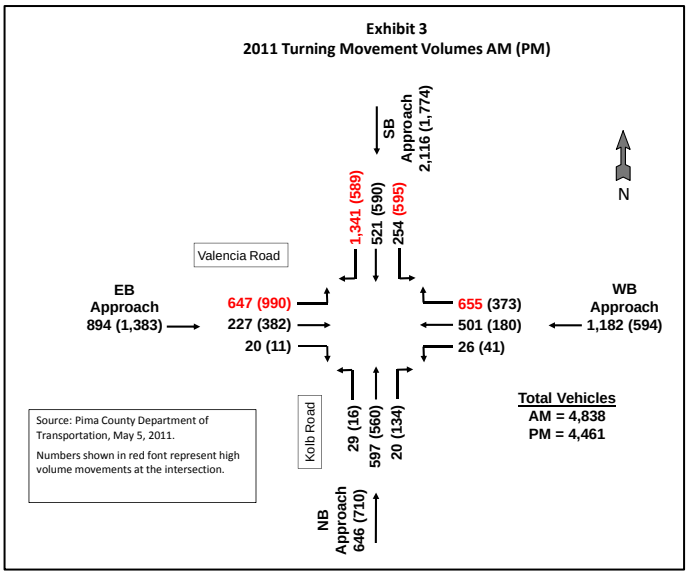
Exhibit 2
Maximum Daily Entering Volume Threshold by Interchange Type Including the PGSI
Source: *Arizona Parkway Intersection/Interchange Operational Analysis and Design Concepts Study,* prepared for the Maricopa County Department of Transportation, prepared by Wilson & Company in association with Morrison-Maierle, Inc., August 2009.

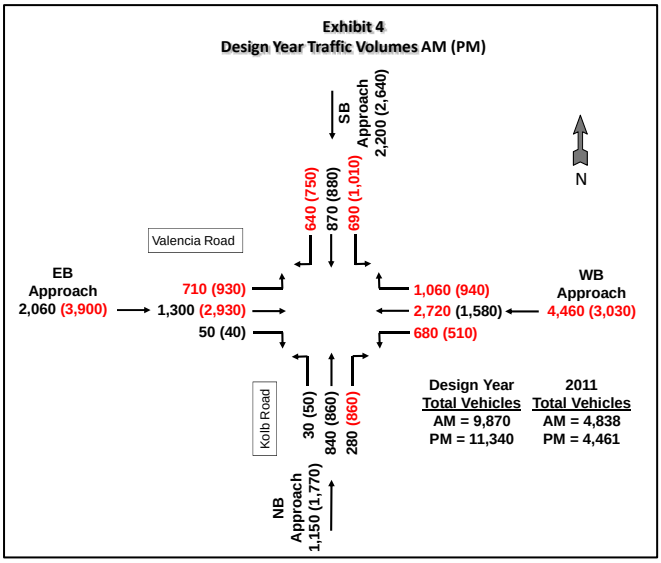
Project Intersection Background

The intersection of Valencia Road and Kolb Road is located in the southeastern portion of the Tucson, AZ metropolitan area 2.5 miles north and 2.75 miles east of connections with Interstate 10. Valencia Road is the major east-west arterial crossing the southern portion of the metro area and Kolb Road the major north-south arterial on the east side. These arterials provide major connections to growing residential areas, commercial and business centers and other major employers, as well as providing connections to I-10. The Pima County DOT has been attempting to identify an affordable long-term solution to significant traffic congestion and safety issues at the intersection for several years. The existing intersection operates at LOS D/F for the AM/PM conditions with several LOS E and F movements

[6] *Design Guideline Recommendations for the Arizona Parkway,* prepared for the Maricopa County Department of Transportation, prepared by DMJM Harris/AECOM, August 2008.

during each time period. The most significant factor complicating the development of a suitable design concept has been the unusually high level of turning movements during the AM and PM peak-hours (see Exhibit 3) and forecast traffic volumes that are 154 percent higher than the existing traffic during the PM peak-hour (see Exhibit 4).





Several studies of the intersection have been conducted since 2004. Alternatives have included a Single Point Urban Intersection (SPUI) at the existing location, which was estimated to become congested again after approximately five years of traffic growth, and the use of a southern bypass route with a diamond interchange at the new southern intersection to provide a long term improvement (see Exhibit 5). Cost estimates for the grade-separated solutions ranged from $25M to $44M.

In 2011, EPS Group, Inc. proposed the use of an innovative PAGI design at the existing intersection with an estimated cost of $17M for a long-term solution. The initial proposal included a ramp for turning movements in each quadrant of the intersection, but early simulation testing indicated that the ramp in the southwest quadrant was not needed due to the low level of westbound left-turn demand, and that this left-turn could be easily accommodated through the use of an indirect left-turn (U-turn/right-turn) movement. The recommended long-term solution included the use of a 3-ramp PAGI along with the already programmed widening of Valencia Road to a 6-lane divided arterial (see Exhibit 6). This alternative was estimated to provide overall delay (cumulative delay per vehicle for all signal controlled locations and on the ramps) in the

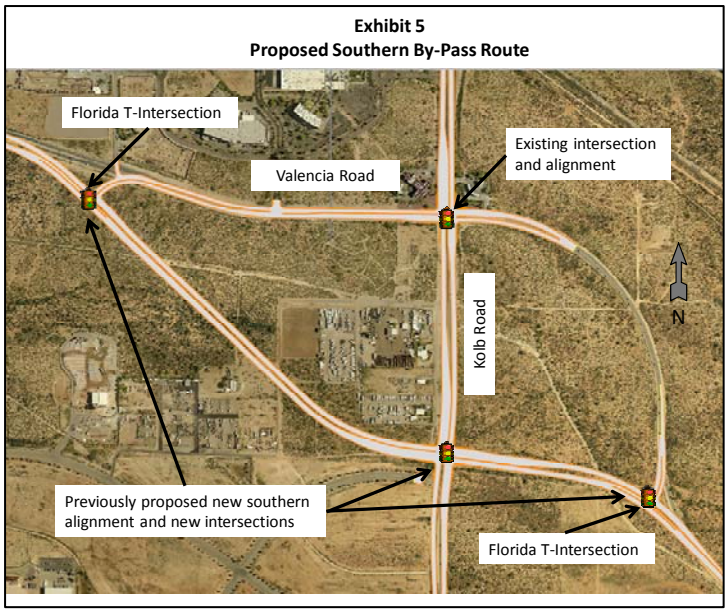


Exhibit 6
3-Ramp PAGI at Existing Intersection

LOS C range for the existing AM and PM peak-hour volumes, and overall delay levels in the LOS D range for the design year traffic[7].

In 2012, the PAG RTA approached EPS to develop a lower cost interim solution to address existing intersection congestion using the PAGI concept assuming that Valencia Road would not be widened to 6-lanes for several more years. A 2-ramp PAGI was recommended with the ramp in the northwest quadrant eliminated in favor of the use of the existing southbound dual right-turn lanes. The low volume northbound left-turn movement would make an indirect left-turn (right-turn/U-turn) using the ramp median opening on the intersection east leg. This alternative was estimated to provide overall delay levels in the LOS C range for the existing traffic and allow for a 50 percent growth in traffic while providing overall delay levels in the LOS D range[8] at a cost of only $7M.

Traffic Operations Analysis of Alternatives

The traffic operations analysis was conducted using the micro-simulation software SimTraffic. Synchro was used to optimize signal timing (cycle length, splits, and offsets) for each alternative. Five simulations were conducted for each alternative and the average result used in the comparison. SimTraffic was calibrated to the existing AM and PM peak-hour conditions and was found to replicate queuing characteristics for existing traffic movements very closely. The simulation results of the existing intersection geometry using the design year traffic volumes were not reported as these volumes overwhelmed the intersection simulation. The results were reported for individual traffic movements at each intersection location (not shown here) and for the entire system of intersections which make up each alternative for the AM and PM peak-hours. The primary metrics used to compare alternatives were delay per vehicle (seconds), total delay (hours), stops per vehicle, and total stops for the one-hour simulation time period. Only the delay per vehicle results are reported here as the results for the other metrics reflected the delay per vehicle results for each alternative.

Several alternatives were evaluated for the long-term design year condition and for the interim condition. Only the results for those alternatives which were considered to provide reasonably effective traffic operations are provided here. Comparison to the existing traffic with the existing geometry is also provided. These alternatives were:

- Long-term solution (6-lane Valencia Road) with design year traffic volumes:
  - 3-Ramp PAGI at existing intersection (dual left-turn lanes eastbound and southbound, single left-turn lane northbound and dual southbound right-turn lanes to ramp, indirect left-turns westbound).
  - Prior Alt-3: New southern Alignment with Diamond Interchange at the new Valencia/Kolb Intersection (Valencia Road traffic is grade separated).
  - Alt S-3 (CFI): New southern Alignment with Continuous Flow Intersection (CFI) at the new Valencia/Kolb Intersection (CFI applied to all four intersection quadrants).
- Interim solution (4-lane Valencia Road) with existing traffic and 50% growth in traffic volume:

[7] *Final Traffic Report for Valencia Road: Wilmot Road to Kolb Road,* prepared for Pima County Department of Transportation, Contract No. 4RTKVI, prepared by EPS Group, Inc., November 20, 2012.
[8] *Evaluation of Interim Improvement for Valencia Road/Kolb Road Intersection,* prepared for Pima Association of Governments Regional Transportation Authority, prepared by EPS Group, Inc., December 12, 2012.

- 3-Ramp PAGI at existing intersection as base condition (dual left-turn lanes eastbound and southbound, single left-turn lane northbound, and dual southbound right-turn lanes to ramp, indirect left-turns westbound).
- 2-Ramp PAGI at existing intersection (dual left-turn lanes eastbound and southbound to ramp, with indirect left-turns northbound and westbound, and dual southbound right-turn at Valencia/Kolb intersection).

The results for the Long-Term solution are provided in Exhibit 7. The 3-Ramp PAGI provides the best overall traffic operations for the long-term solution at the lowest cost of all the alternatives considered. The southern alignment alternatives all suffer from the same basic problem, which is that the alignment concept introduces additional 3-phase signalized intersections into the system and maintains the existing 4-phase signal at the existing intersection. These additional multi-phase signals add significant additional delay into the system even with the use of grade separation at the southern Valencia/Kolb intersection. The 3-Ramp PAGI was recommended.

The results for the Interim solution are provided in Exhibit 8. The 2-Ramp PAGI is virtually as effective as the 3-Ramp PAGI for the interim condition. The use of the third ramp in the northwest quadrant does reduce delay to the heavy southbound right-turn movement in the AM, but the use of the existing dual southbound right-turn lanes at the main intersection is nearly as effective and saves considerable cost for the interim condition. Note that both alternatives are capable of accommodating a 50% increase in traffic volume for all movements and still provide overall traffic operations in the LOS D range. The 2-Ramp PAGI was recommended.

The key element in the ability of the PAGI design concept to provide a high capacity at-grade intersection is the use of simple 2-phase traffic signals at all locations. This makes signal coordination between the ramp signals and the signals at the main intersection possible in both directions at the same time, and provides a condition where extremely high

Exhibit 7

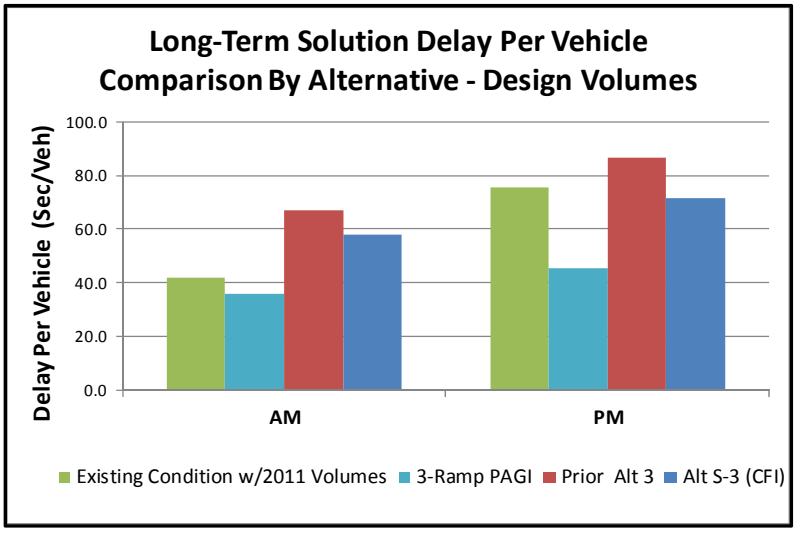
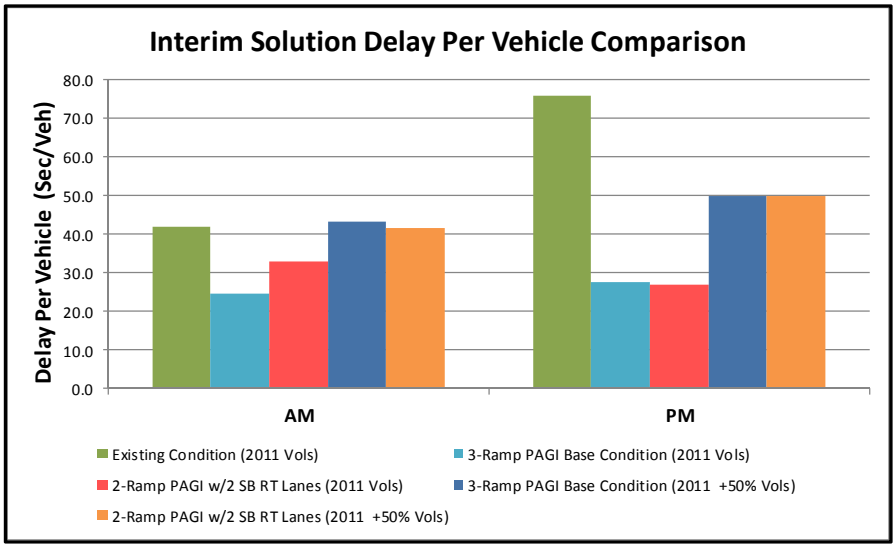


Exhibit 8



volumes of left-turns can be accommodated by coordinating the downstream left-turn green with the upstream main intersection.

Flexibility of Design Concept

The PAGI design concept is extremely flexible in its application. Unlike the CFI design concept where the left-turn application must be used on opposing approaches even if it is only required on one approach, the PAGI ramps can be applied on individual approaches depending on demand. Right-turns lanes can be placed at the ramps, right-turns can be made only at the main intersection, or provision for right-turns can be provided at both locations depending on the right-turn demand. In this application, dual westbound right-turn lanes were recommended at the main intersection with right-turns restricted at the ramp to avoid combining the heavy right-turn demand with the heavy eastbound left-turn demand on the ramp. The ramps can be designed and placed relatively close to the main intersection, or as in the case of this application they can be placed to avoid existing development. Also in this specific application the ramp for the southbound left-turn was moved south to the southern alignment to take advantage of available right-of-way, which was possible due to the curvature of Valencia Road.

Access Options and Flexibility

In order to maintain the high capacity potential of the PAGI, access to roadside development should not include the use of full access median openings. Egress should be right-out only with U-turn locations placed conveniently downstream of major driveways. Left-turn/U-turn ingress can be provided at appropriate intervals along the main arterials and when necessary these can be 2-phase signal controlled. This basic concept has been very successfully used in Michigan for over 50 years and is well documented[9].

The PAGI concept provides additional access options through the use of the ramps and ramp median openings. Right-turn and left-turn lanes can be provided from the ramp to adjacent local development depending on the ramp location and design. U-turns will also be permitted at the ramp median openings to provide access to properties on the opposite side of the roadway. Ramps can potentially be developed for two-way traffic provided that the access limitations for the main arterial roadway are maintained as right-out only and that conditions on the ramp that increase delay to ramp traffic are avoided. At the Valencia/Kolb intersection the ramps in the northeast and southeast quadrants are candidates for two way traffic operations with the provision of turn lanes to access adjacent development. This will provide signalized access to adjacent land at the ramp median openings. Access through ramp merge areas should be restricted, but the length of the restricted area is comparable to or less than similar restricted areas when using a grade separated interchange or a CFI design.

Summary and Conclusions

The PAGI design concept has been shown through simulation of a specific application to be a very high capacity and very flexible concept. The PAGI was shown to provide traffic operations and levels of service that exceed that of a grade separation and other at-grade intersection designs that employ the use of 2-phase traffic signals, and was the least expensive alternative identified to provide a long term solution. In other words, “it works better and costs less” than the other alternatives tested. The PAGI concept enhances the application of indirect left-turns by providing ramps for the high volume left-turn movements eliminating the need for these vehicles to travel through the main intersection twice. The design and placement of the ramps can be adapted to specific existing development conditions and the ramps can be used to provide access to adjacent properties. Right-turns can be made at the ramps and/or at the main intersection providing another level of flexibility in the design to adapt to traffic demand. PAGI ramps were only necessary in the northeast and southeast quadrants of the intersection for the application at the Valencia/Kolb intersection for the interim solution.

[9] *Synthesis of the Median U-Turn Intersection Treatment, Safety, and Operational Benefits, TECHBRIEF,* FHWA Publication No.: FHWA-HRT-07-033, 2007.