Prepared for:

Delaware River Joint Toll Bridge Commission

I-95/Scudder Falls Bridge Improvement Project

TM 27 – NJ-29 Interchange Roundabout Evaluation Study

Contract C-393A,
Capital Project No. CP0301A,
Account No. 7161-06-012

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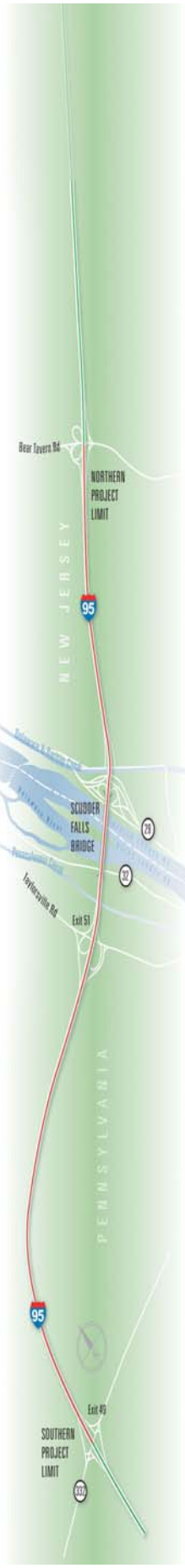

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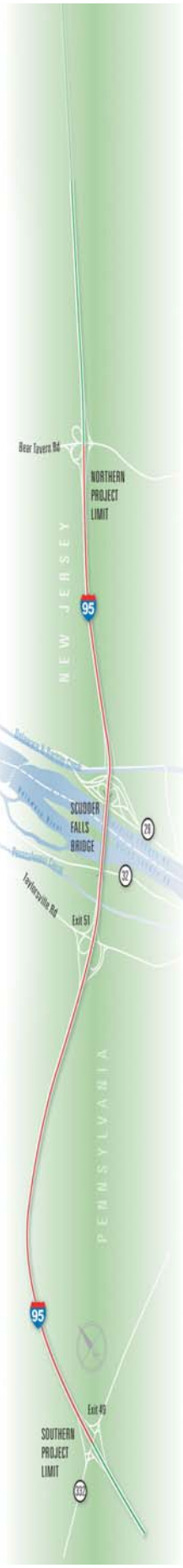


INTRODUCTION

Kittelson and Associates, Inc., as sub-consultant to DMJM Harris, has reviewed the conceptual interchange designs and undertaken operational assessment for the I-95/NJ-29 Interchange. This review primarily focused on the roundabout alternative known as *Option 1C: NJDOT Roundabout*, although comparisons were then made to the signalized alternative previously developed by the DMJM Harris team known as *Option 1A: DMJM "Folded Diamond" Interchange*. The I-95/NJ-29 Interchange will be reconstructed as part of the Scudder Falls Bridge replacement project, which includes the reconstruction of the I-95 Bridge over the Delaware River and the adjacent interchanges in both Pennsylvania and New Jersey.

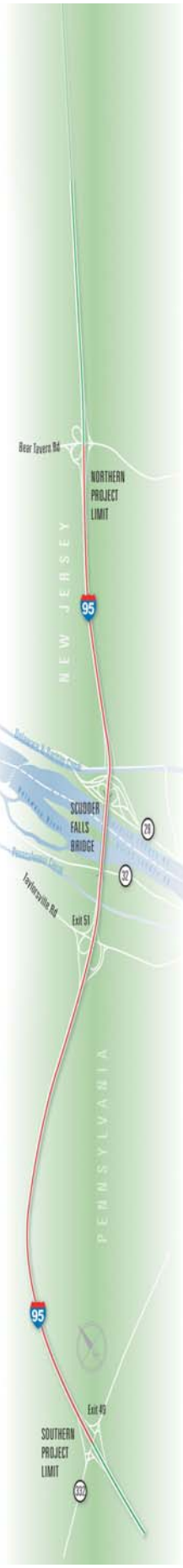
Project Background

The Delaware River Joint Toll Bridge Commission (DRJTBC), in cooperation with the New Jersey Department of Transportation (NJDOT), the Pennsylvania Department of Transportation (PENNDOT), and the Federal Highway Administration (FHWA), is preparing an Environmental Assessment to evaluate potential alternatives and select a preferred alternative that will improve safety and relieve congestion on the Scudder Falls Bridge and along I-95 from PA Route 332 in Bucks County, PA to Bear Tavern Road in Mercer County, NJ.

The existing Scudder Falls Bridge consists of a 4 lane cross section with 2 lanes in each direction. DRJTBC proposes to reconstruct the bridge to a 9 lane cross section with 5 northbound lanes and 4 southbound lanes. Bicycle and pedestrian facilities are also being considered for the new bridge structure. On the eastern side of the Delaware River is the NJ-29 interchange. The interchange provides a connection between I-95 and NJ-29, which provides access to the city of Trenton, New Jersey, to the south, and Lambertville, New Jersey, to the north.

The existing interchange has a relatively complex configuration with loop ramps in the northeast and southeast quadrants and bypass roads for the through movements northbound on NJ-29. A number of priority intersections are also incorporated in the existing interchange.

Currently, northbound traffic on NJ-29 bypasses the interchange along a bypass aligned along the Delaware-Raritan Canal. Southbound traffic on NJ-29 also bypasses the interchange intersections to the west adjacent the Delaware River.



Four interchange alternatives were considered in this assessment:

- *Option 1A: DMJM "Folded Diamond" Interchange* – Interchange loop ramps intersecting with NJ-29 at traffic signals without a bypass road.
- *Option 1A Modified: DMJM Folded Diamond w/Roundabout* – This alternative is generally the same as *Option 1A*; however, it incorporates two-lane roundabouts at the loop ramp/NJ-29 intersections instead of traffic signals. The River Road bypass is not included in this option and all interchange traffic must utilize the two roundabouts
- *Option 1C: NJDOT Roundabout* – Interchange loop ramps intersect with I-95 traffic at single lane roundabouts. Northbound and southbound traffic on NJ-29 bypass the interchange intersections. The single lane roundabouts also include bypass lanes for right turning traffic.
- *Option 1C Modified: NJDOT Roundabout Modified* – This option is based on *Option 1C* and also incorporates single lane roundabouts, however, bypass ramps are not included at the roundabouts. This option includes the River Road bypass.

Option 1A: DMJM "Folded Diamond" Interchange and *Option 1C: NJDOT Roundabout* have been developed by DMJM Harris and are illustrated in Figures 1 and 2 below and at Appendix A. *Option 1A Modified: DMJM Folded Diamond w/Roundabout* and *Option 1C Modified: NJDOT Roundabout Modified* were developed by Kittelson & Associates, Inc. (KAI) and are described in further detail in Chapter 2.

Figure 1. Option 1A: DMJM "Folded Diamond" Interchange

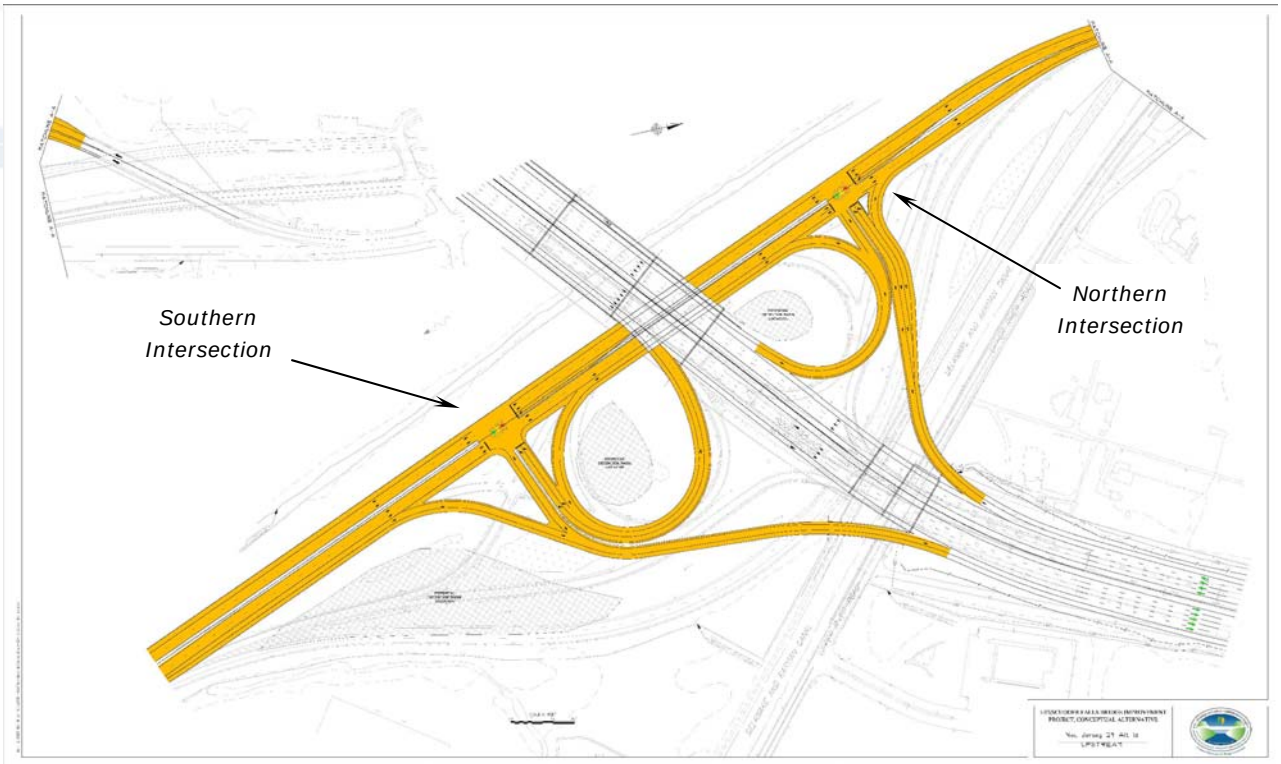
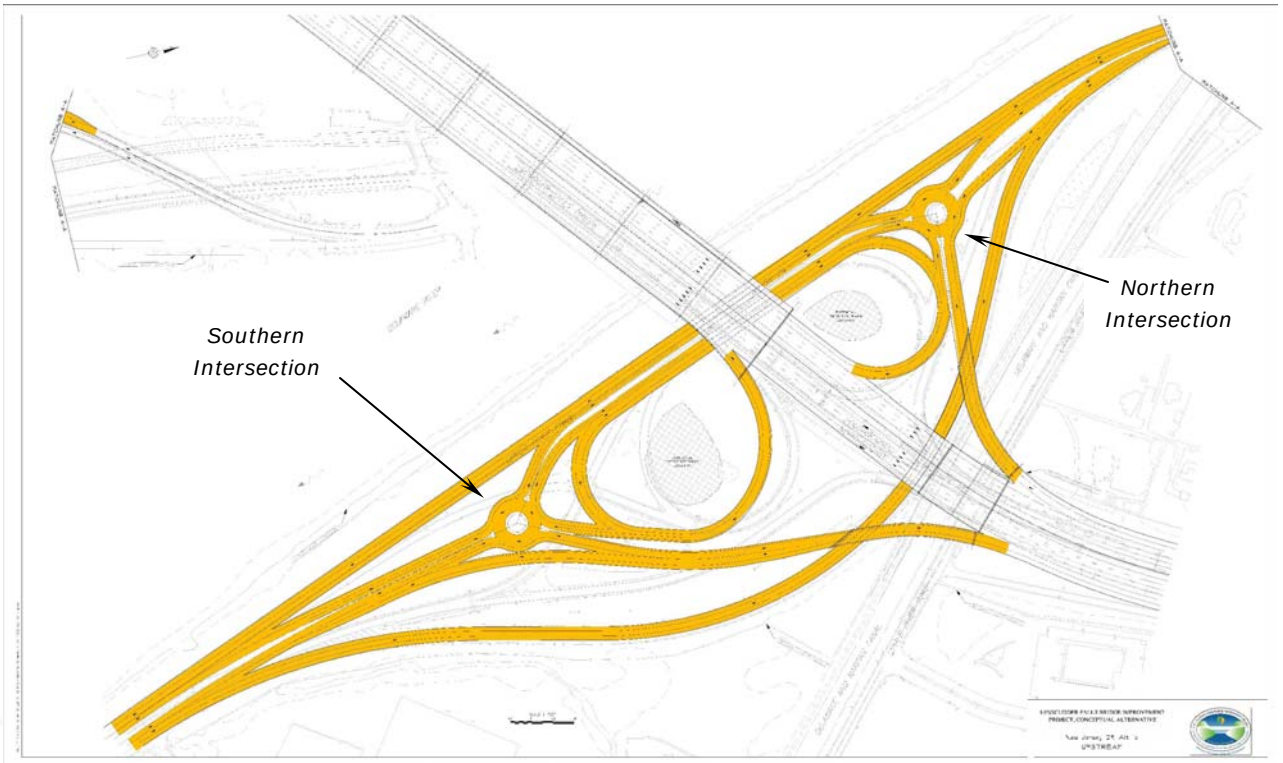


Figure 2. Option 1C: NJDOT Roundabout

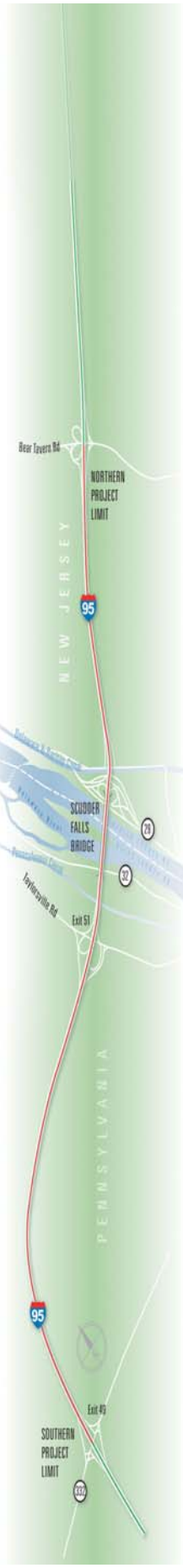


The KAI Assessment Scope

KAI has undertaken these tasks:

- Assess the operation of the proposed ramp terminal interchange roundabouts using an appropriate assessment tool (aaSIDRA or RODEL) for the AM and PM peak hours at the 2030 design horizon;
- Qualitatively assess and compare each interchange configuration considering factors such as number of decision points, conflict points, interchange complexity, signing strategy, accident potential, and cost.

KAI compared the operation of the roundabouts to the results of the SYNCHRO assessment of the operation of the signalized intersections in *Option 1A: DMJM "Folded Diamond" Interchange* performed by DMJM Harris. This allowed the operations of all alternatives to be compared to assist in determining the most appropriate interchange ramp terminal intersection configuration.



DEVELOPMENT OF ADDITIONAL ALTERNATIVE INTERCHANGE OPTIONS

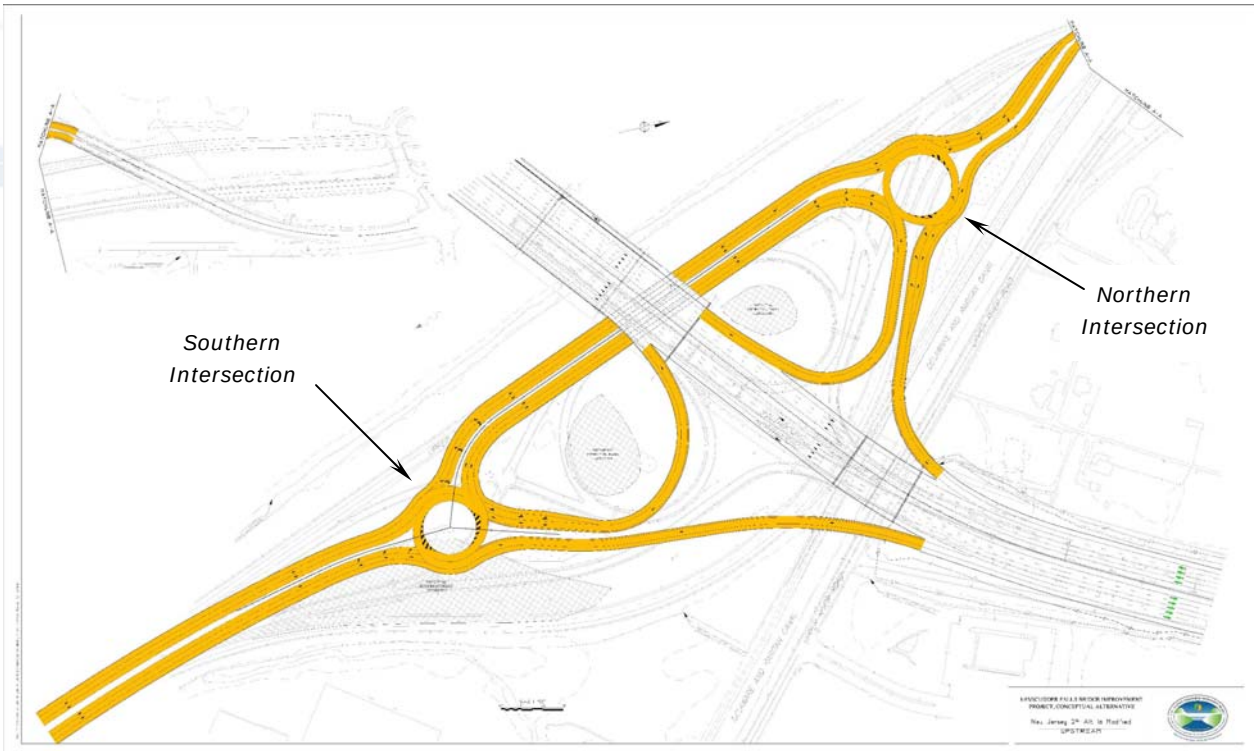
Option 1A Modified: DMJM Folded Diamond w/Roundabout

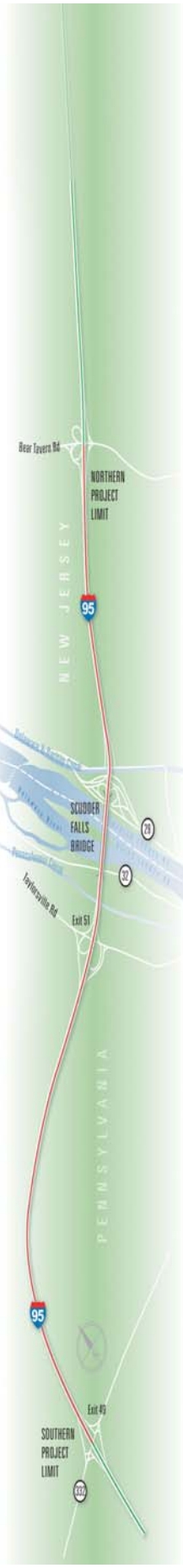
This alternative simplifies the interchange configuration by directing all interchange traffic through the two intersections at the loop ramps as per *Option 1A: DMJM "Folded Diamond" Interchange*. However, in this configuration, roundabouts are proposed as intersection treatments instead of signals. The NJ-29 bypass is not proposed with this configuration, which helps simplify driver decision-making and expectancy issues.

Due to the volume of traffic and approach lane configurations, it is necessary for each roundabout to be designed with two circulating lanes. Furthermore, merging and weaving is reduced on NJ-29 between the two intersections as the approach and departure lane configurations at the roundabouts filter vehicles into appropriate lanes upon departure through signing and pavement marking.

This alternative is illustrated below and in Appendix A.

Figure 3. Option 1A Modified: DMJM Folded Diamond w/Roundabout





Option 1C Modified: NJDOT Roundabout Modified

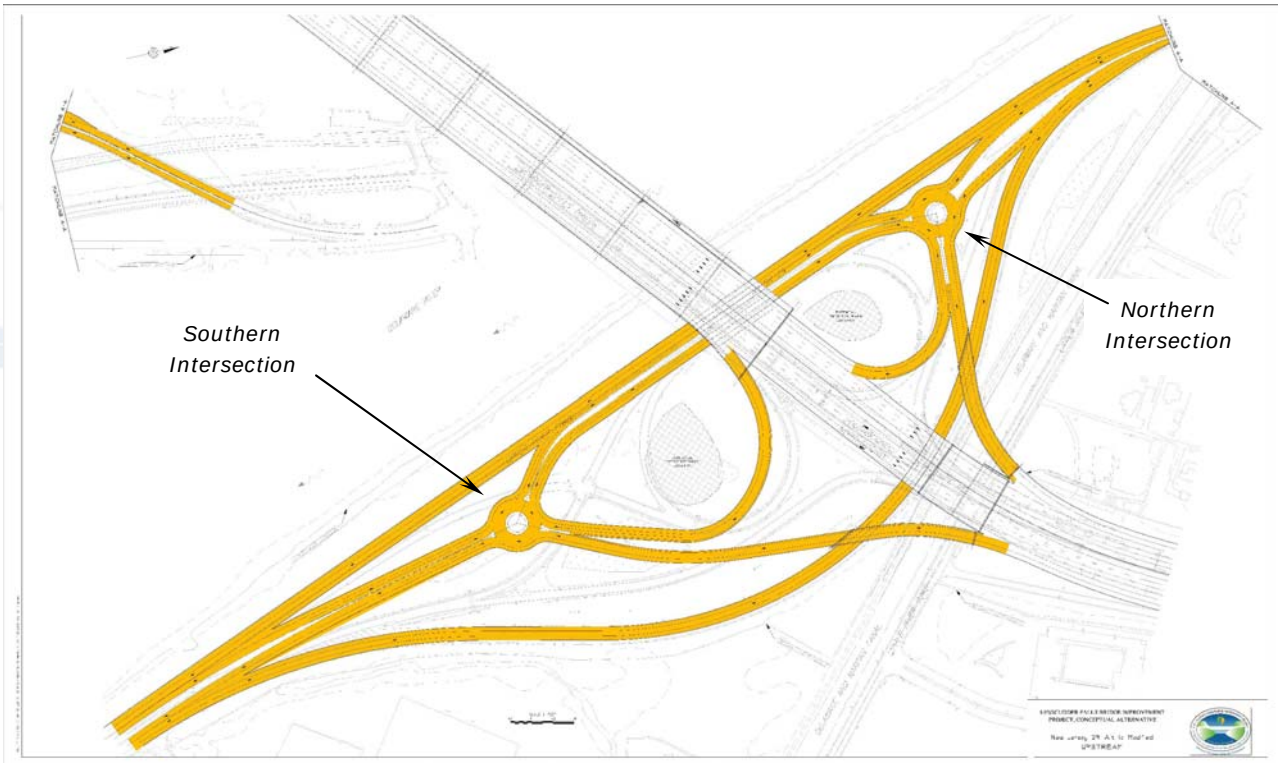
This alternative simplifies the interchange configuration, when compared to the configuration of *Option 1C: NJDOT Roundabout*. By removing the local bypass ramps that are provided at the single lane roundabouts, all loop ramp traffic must utilize the single lane roundabouts.

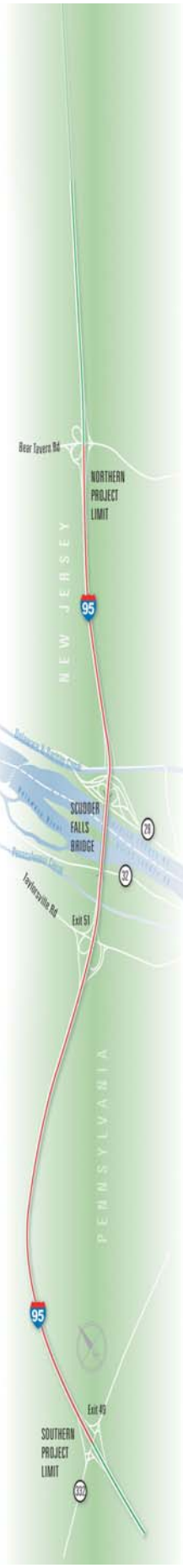
This alternative will increase the traffic flows through the roundabouts; however, it will also decrease the conflict and decision points and allow for a simpler signage strategy, which will decrease the driver workload at the interchange.

This alternative includes the bypass road for north-south traffic on NJ-29.

This alternative is shown below and in Appendix A.

Figure 4. Option 1C Modified: NJDOT Roundabout Modified Interchange Configuration





OPERATIONAL ASSESSMENT

Assessment Tool Selection

Two tools were considered appropriate to analyze the roundabout configurations. These tools were aaSIDRA, which is an Australian software program, and the British Method for assessment of the roundabouts.

The British Method considers relationships between geometric factors such as approach entry lane width, lane tapers, circulating lane width, island diameter and traffic volumes to determine operational performance of a roundabout, with the approach entry width having the largest effect on roundabout performance of these factors. aaSIDRA determines the performance of intersections based on a gap-acceptance model, which is an evaluation of whether acceptable gaps in traffic are available for entering traffic. aaSIDRA also considers similar geometrics factors to the British Method to develop the gap-acceptance model and it also allows consideration of exclusive lane assignments at multi lane approaches and circulation lanes.

This ability of aaSIDRA is particularly beneficial for assessment of *Option 1A Modified: DMJM Folded Diamond w/Roundabout* due to the specific lane assignments and dual circulating lanes proposed for this alternative. Therefore, KAI considered this modeling package as the most appropriate one for reporting the roundabout performance of *Option 1A Modified: DMJM Folded Diamond w/Roundabout* and *Option 1C: NJDOT Roundabout*.

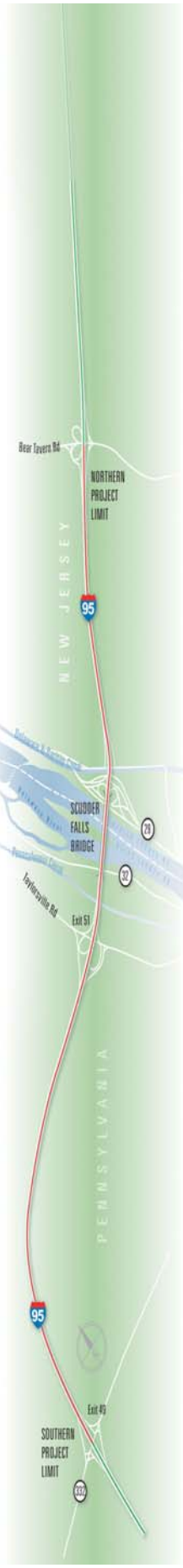
KAI applied both models to determine the most appropriate tool. aaSIDRA results for the cases with multi-lane approaches and multiple circulating lanes were more conservative than the operating conditions predicted utilizing the British Method. The results observed in aaSIDRA were considered more representative of the likely operating conditions. The relative complexity of the intersections is likely the reason that aaSIDRA was better able to replicate in its model.

Vehicle queues and delay times observed in the aaSIDRA analysis were also more conservative than the results obtained with the British Method, which was also considered more representative of the likely operating conditions.

Based on the comparison, KAI selected aaSIDRA as the most appropriate assessment tool for the roundabout alternatives, and therefore, the output results from aaSIDRA are reported herein.

Assessment Results

The results of the operational assessment are summarized in the following sections. The results have been represented graphically comparing a number of performance indicators for the AM and PM peak hour for the 2030 design year across each approach and interchange alternative.



Traffic volumes for the 2030 design year were obtained from the I-95 Scudder Falls Bridge Traffic Study, prepared by the Delaware Valley Regional Planning Commission in September 2004 and provided to KAI by DMJM Harris.

The performance indicators that were considered in the assessment included the following:

- Intersection Level of Service (LOS)
- Volume to Capacity ratio (V/C)
- Average Delay per vehicle (average delay per vehicle, including stop line delay and geometric delay due to travel through the intersection)
- Vehicle queues, queuing was considered in terms of total length in the operational assessment and the "back of queue" position relevant to the ramps in the qualitative assessment

Further to the above comparisons of i*ntersection* operation, average vehicle delay for the *interchange* configurations has also been considered. This is considered to provide a performance measure that will represent the benefits of the 1C-based options that include the NJ 29 bypass.

Numerical assessment outputs, including traffic volumes, are provided in Appendix B.

I-95 Northbound Ramps/NJ-29 (Southern Intersection)

The results of the assessment for the I-95 Northbound Ramps/NJ-29 (southern intersection) are detailed below.

Intersection Levels of Service (LOS)

The LOS as defined by the Highway Capacity Manual (HCM 2000) for delay at signalized intersections has been calculated for each of the alternatives. The HCM does not define LOS classifications for roundabouts; however, we have classified the intersections accordingly to allow for a comparative assessment between alternatives.

LOS can be considered to provide a general overview of an intersection's operation as LOS rankings represent intersection operating conditions from A (best) to F (worst). For this project, LOS A through D were considered acceptable.

The LOS for the southern intersection is outlined in Figures 5 and 6 for the AM and PM peak hour respectively.

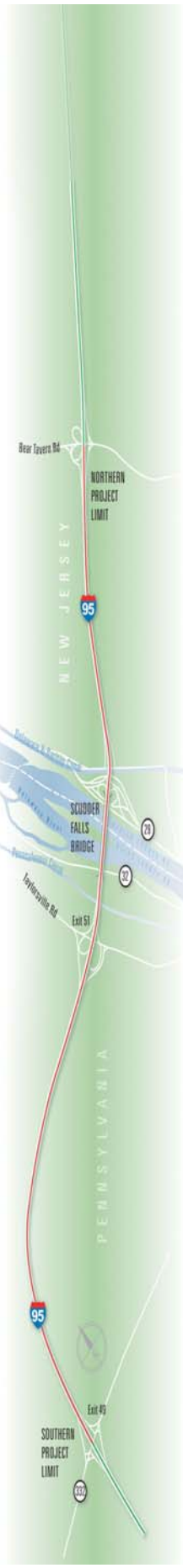


Figure 5

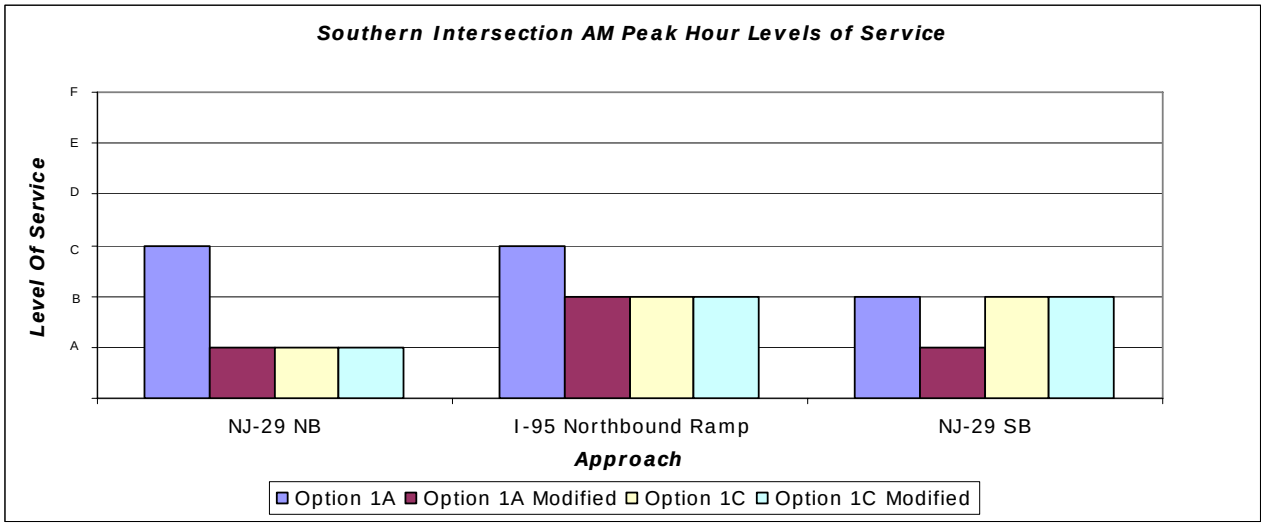
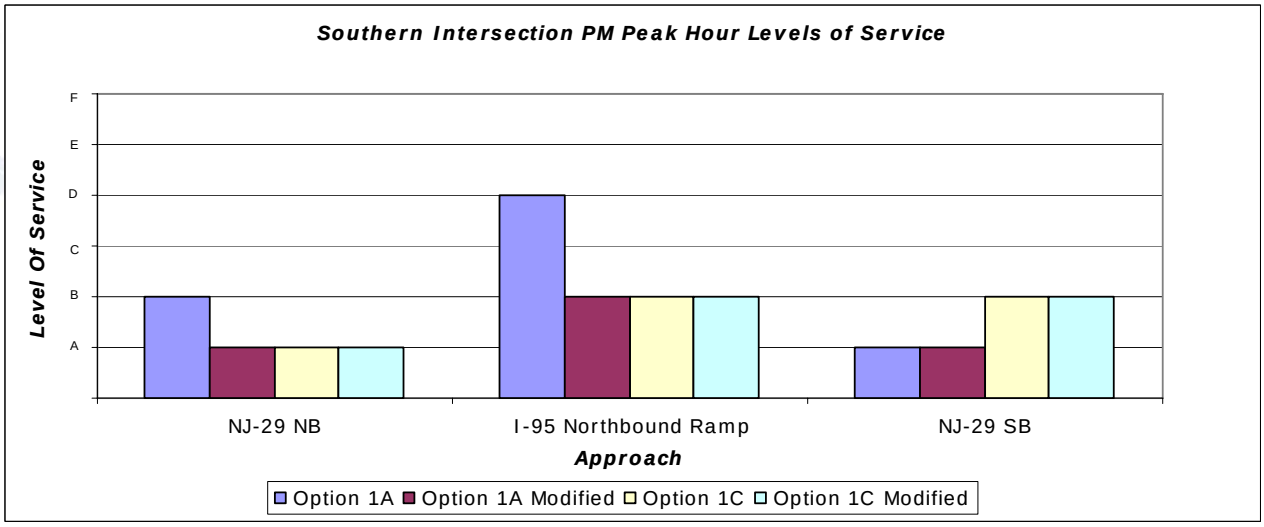
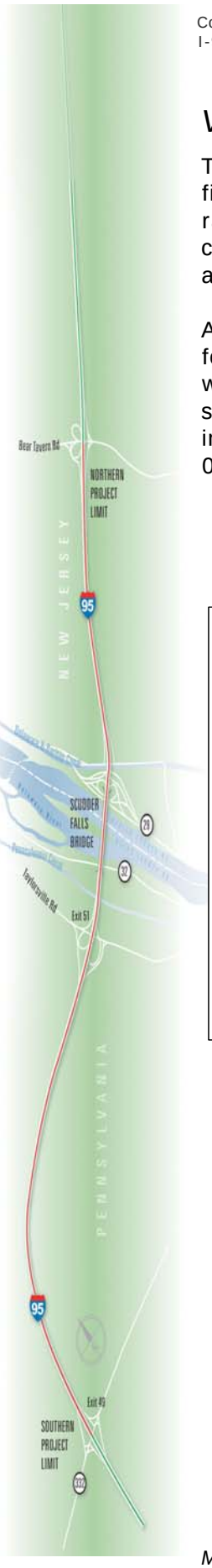


Figure 6



Figures 5 and 6 above illustrate that the alternatives incorporating roundabouts will operate at a better LOS than the signalized intersection alternative. However, all alternatives operate within generally accepted thresholds in all assessment scenarios. *Option 1A Modified: DMJM Folded Diamond w/Roundabout* operates at a marginally better level of service compared to *Option 1C: NJDOT Roundabout* and *Option 1C Modified: NJDOT Roundabout Modified*.

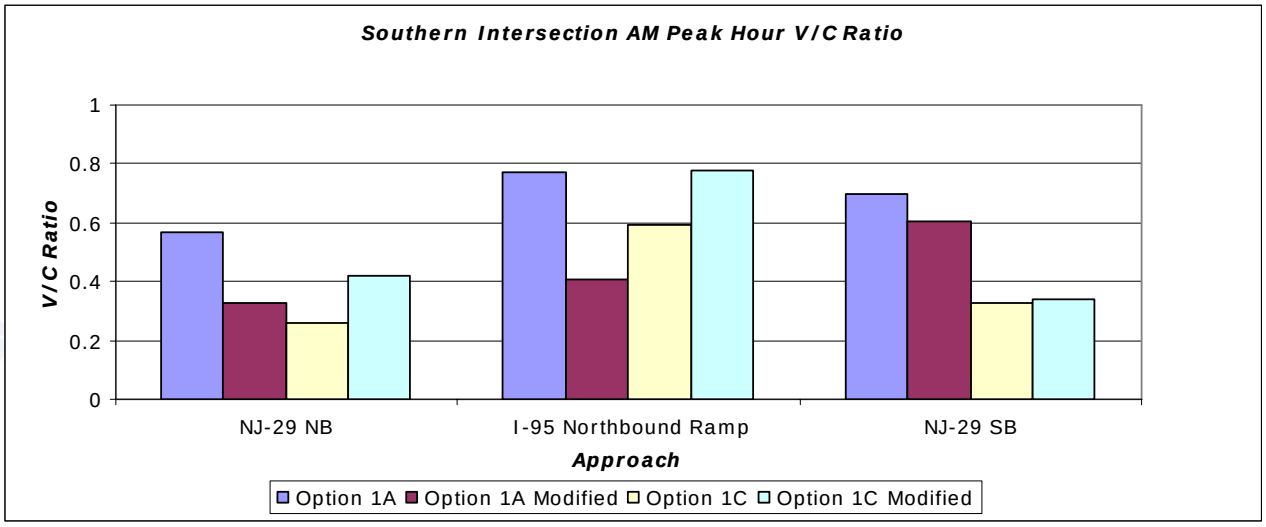


Volume to Capacity Ratio (V/C)

The volume to capacity ratios of the alternative intersection configurations are shown in figures 7 and 8 below for the AM and PM peak hours respectively. The volume to capacity ratio is a ratio of the volumes observed at the intersection compared to the actual traffic capacity of the intersection, which is a factor of the amount of lanes, intersection geometry and signal timing among other factors.

Acceptable thresholds for V/C ratios for the two intersection types in this assessment are 1.0 for signals and 0.85 for roundabouts. For the signals, this threshold represents a scenario where the intersection is at capacity. For the roundabouts, this threshold represents a scenario where the intersection has reached its practical capacity, and delays and queues increase significantly and rapidly as the V/C ratio increases beyond the practical capacity of 0.85.

Figure 7



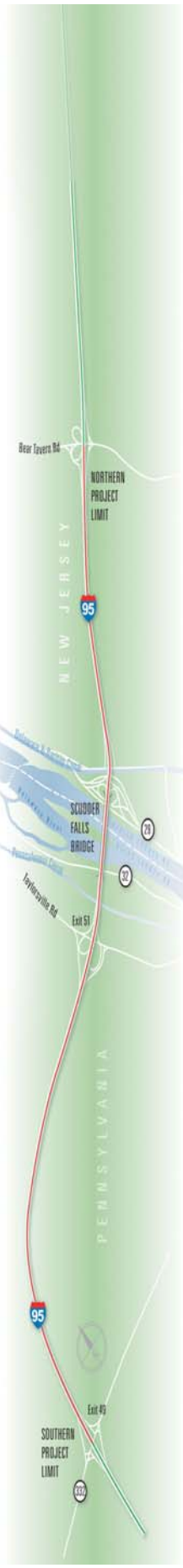
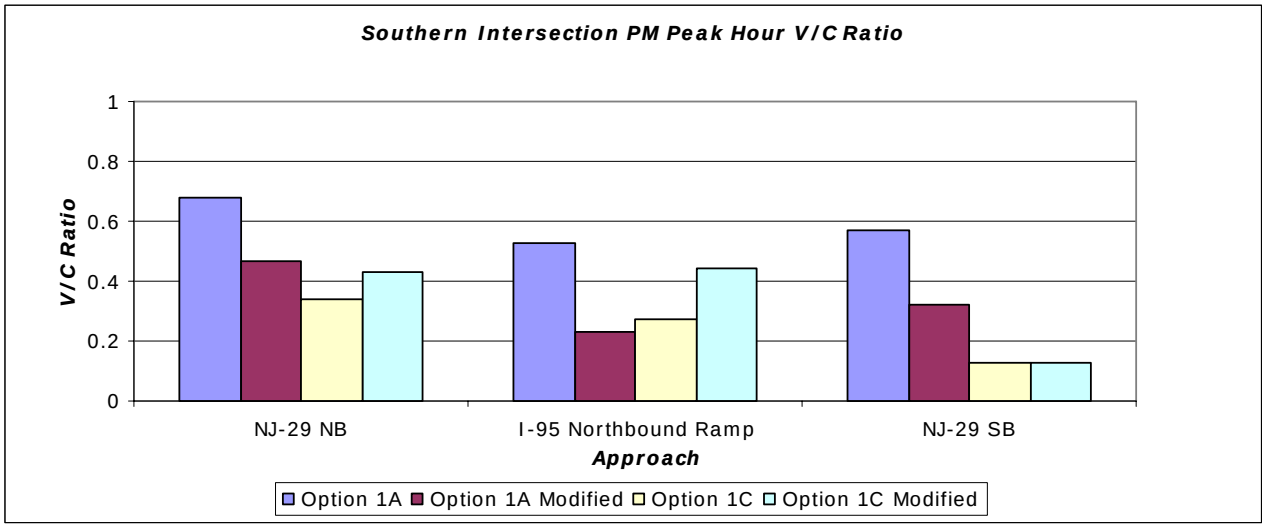


Figure 8

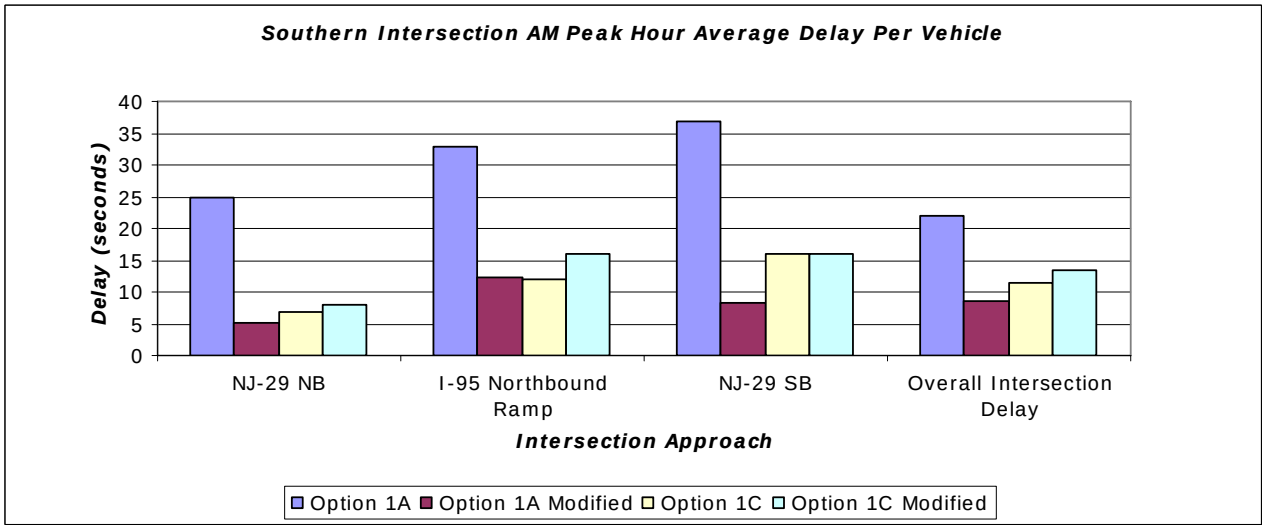


The results displayed in figures 7 and 8 above indicate that *Option 1C: NJDOT Roundabout* will operate with the lowest V/C ratio. This is considered reasonable given that this alternative incorporates a number of local bypass ramps at the roundabouts and north-south traffic on NJ-29 is removed from the intersection via bypass roads. Generally, similar ratios were observed for the remaining alternatives, and all were within acceptable limits.

Intersection Delay

The approach delay for the intersection alternatives has been calculated and the results are outlined in Figures 9 and 10. The overall average delay per vehicle for each intersection has also been computed and is shown on the figures.

Figure 9



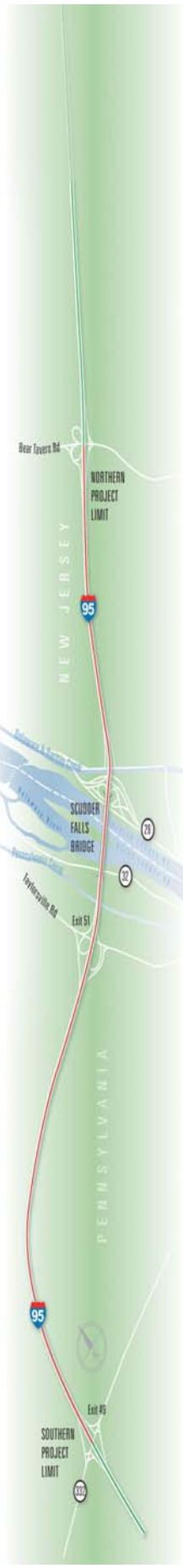
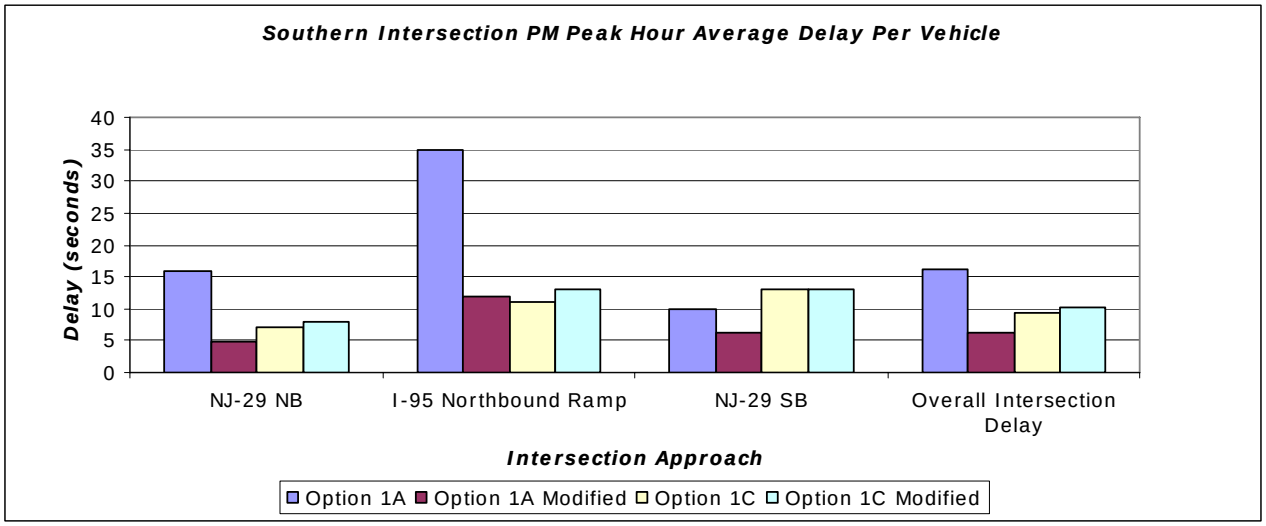


Figure 10



Figures 9 and 10 above illustrate that, with the exception of the I-95 Northbound Ramp approach in the PM peak hour, *Option 1A Modified: DMJM Folded Diamond w/Roundabout* will operate with the least delay. The results also indicate that *Option 1A Modified: DMJM Folded Diamond w/Roundabout* realizes the least average delay per vehicle for the intersection as a whole. The delay that is observed at *Option 1A: DMJM "Folded Diamond" Interchange* is generally significantly higher than that observed for the roundabout options.

The delay that was observed in all cases does not exceed acceptable levels, which is evidenced by the LOS classifications previously identified.

Vehicle Queues

95th Percentile vehicle queues have also been considered. The results are shown in figures 11 and 12 below.

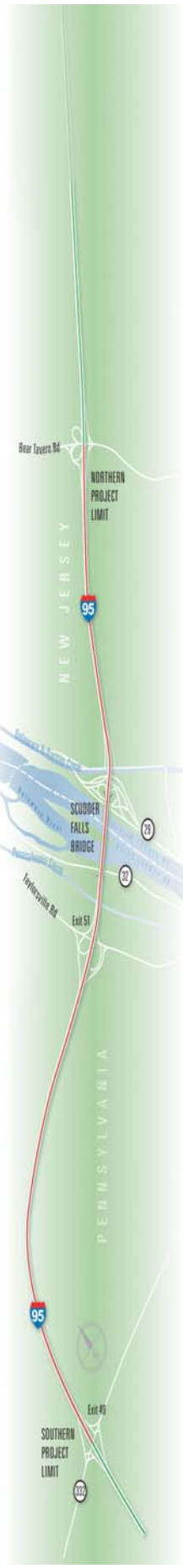


Figure 11

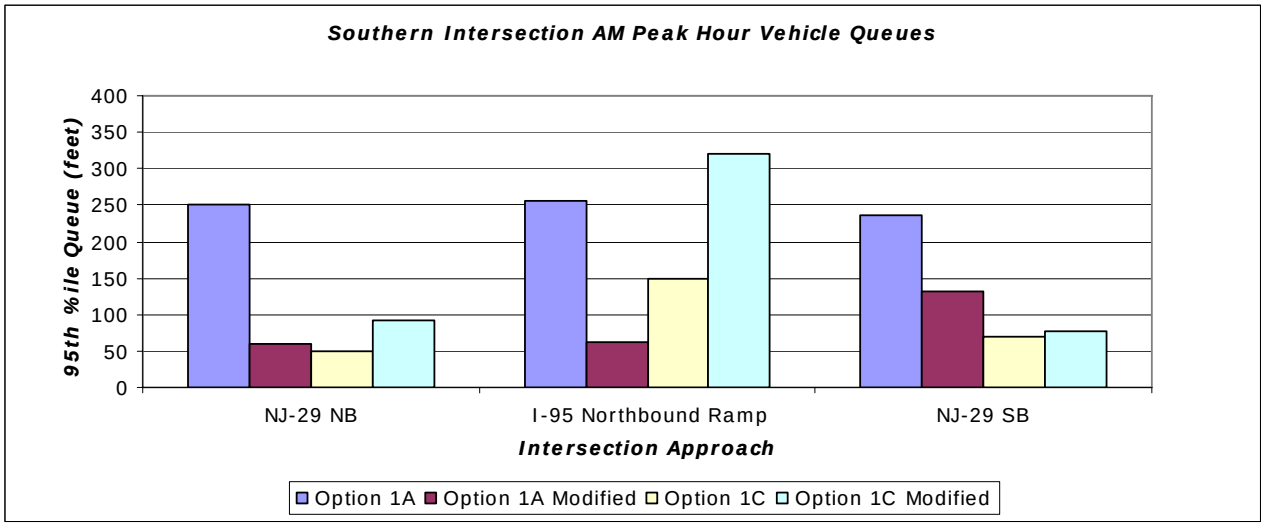
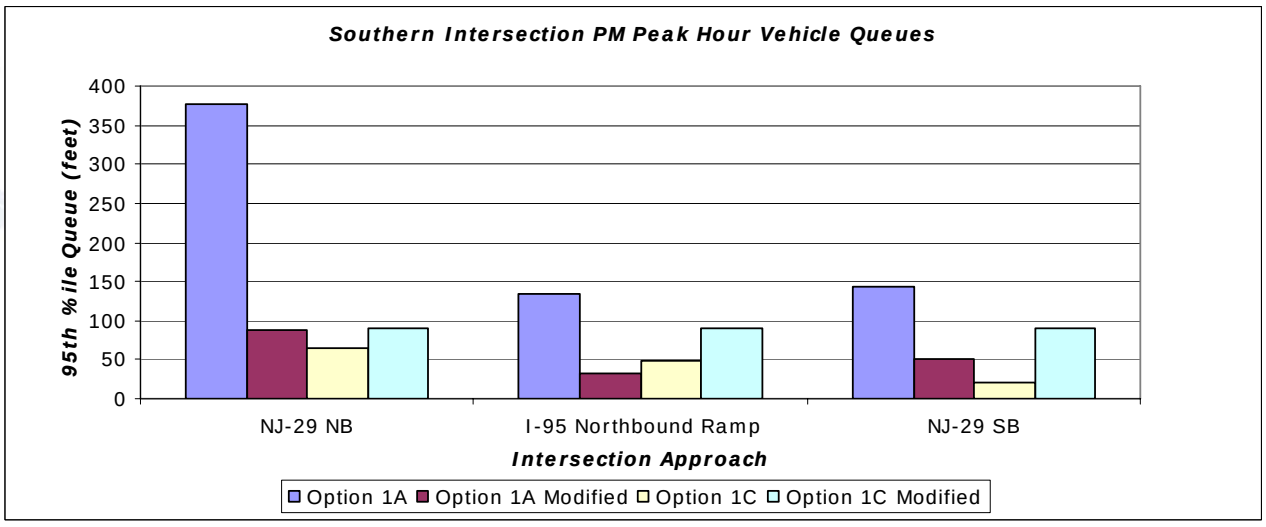
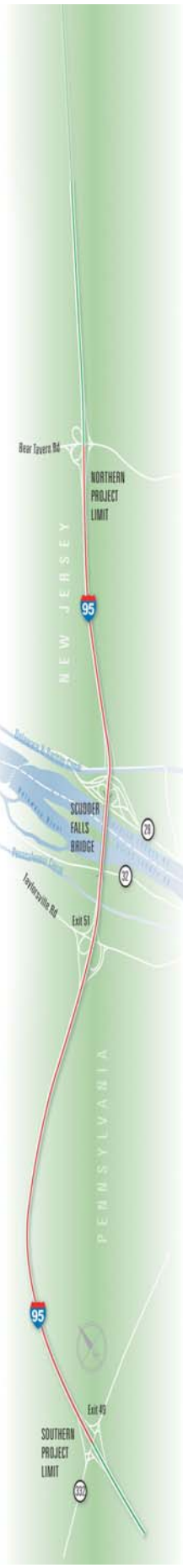


Figure 12





The results indicate that significant queuing occurs on the NJ-29 NB and I-95 Northbound Ramp approaches in *Option 1A: DMJM "Folded Diamond" Interchange* and *Option 1C Modified: NJDOT Roundabout Modified*. Queue lengths on the interchange ramp approach should be minimized to ensure that deceleration distances from the interchange are not compromised. Queues at this approach extend approximately 250 and 315 feet in the AM peak hour in *Option 1A: DMJM "Folded Diamond" Interchange* and *Option 1C Modified: NJDOT Roundabout Modified* respectively. This is considerably more extensive than the alternative options and with the interchange ramp configurations proposed and may conflict with the deceleration distance requirements.

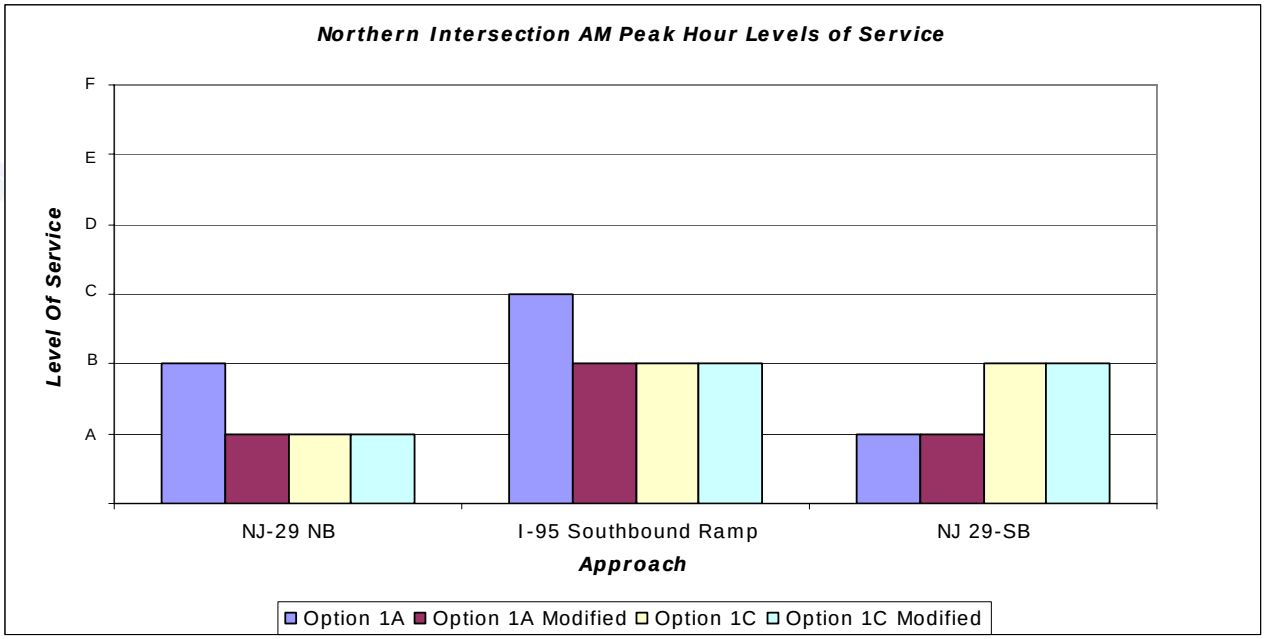
I-95 Southbound Ramps/NJ-29 (Northern Intersection)

The results of the assessment for the I-95 Southbound Ramps/NJ-29 (northern intersection) are detailed below.

Intersection Levels of Service

The LOS for the northern intersection are outlined in Figures 13 and 14 for the AM and PM peak hour respectively.

Figure 13



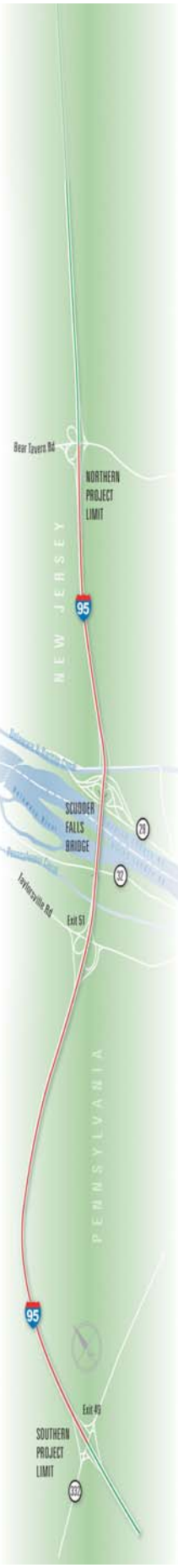
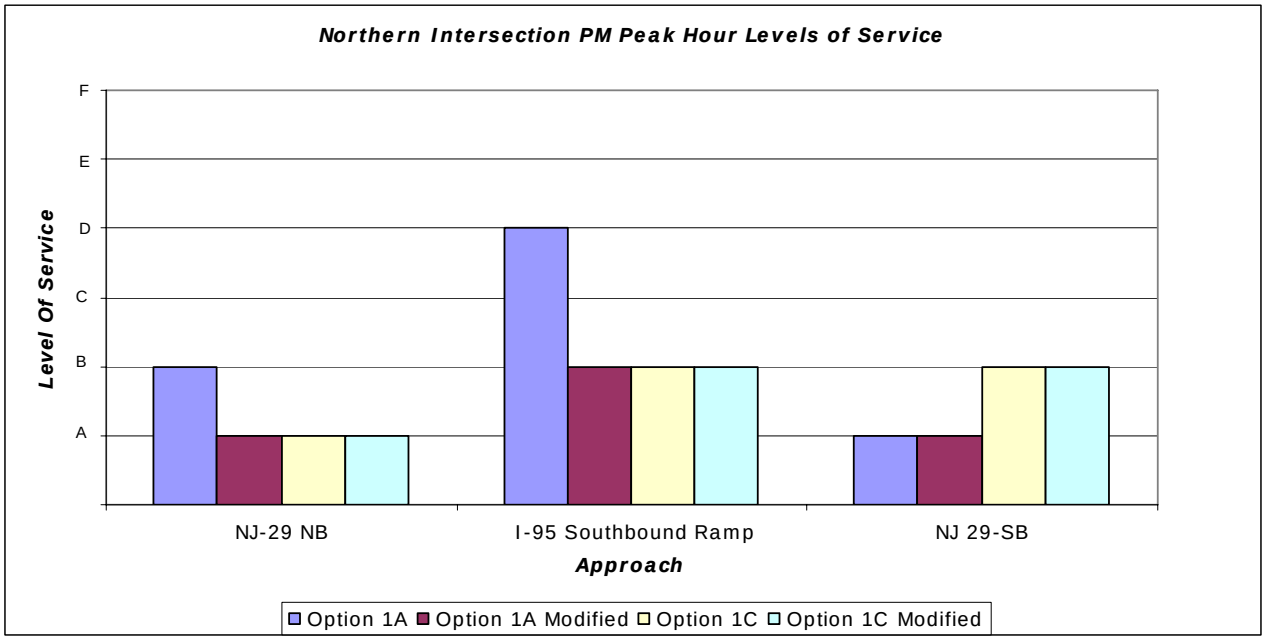


Figure 14



As was the case at the southern intersection, figures 13 and 14 above illustrate that the alternatives incorporating roundabouts will operate at a better LOS than the signalized intersection alternative, with *Option 1A Modified: DMJM Folded Diamond w/Roundabout* operating marginally better than *Option 1C: NJDOT Roundabout* and *Option 1C Modified: NJDOT Roundabout Modified*. All alternatives operate within generally accepted thresholds in all assessment scenarios.

Volume to Capacity Ratio

The volume to capacity ratios of the alternative intersection configurations are shown in figures 15 and 16 below for the AM and PM peak hours respectively.

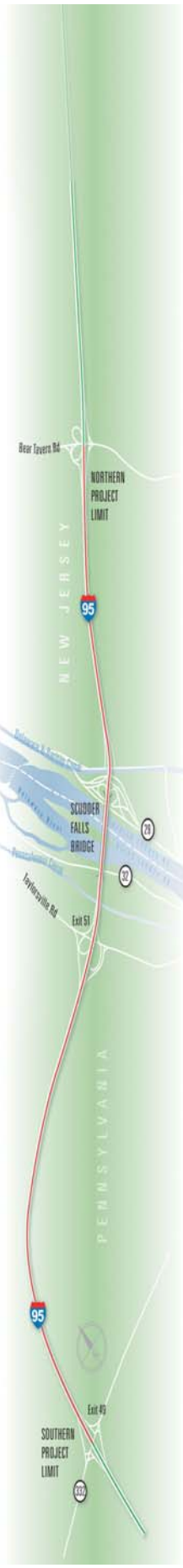


Figure 15

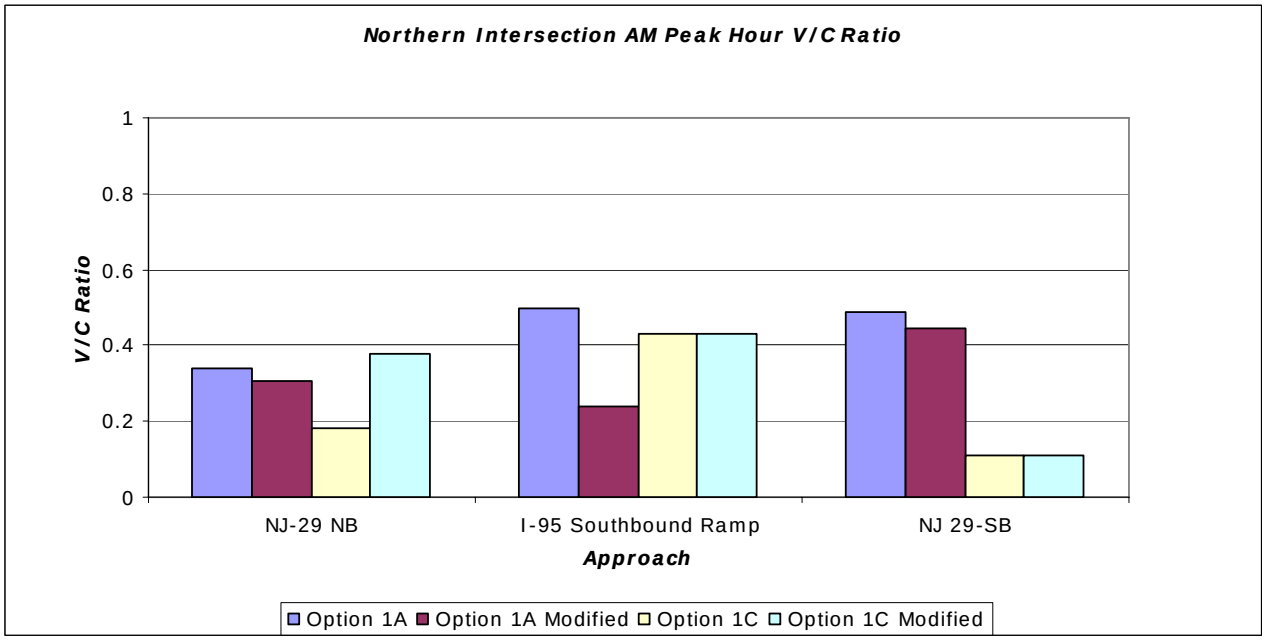
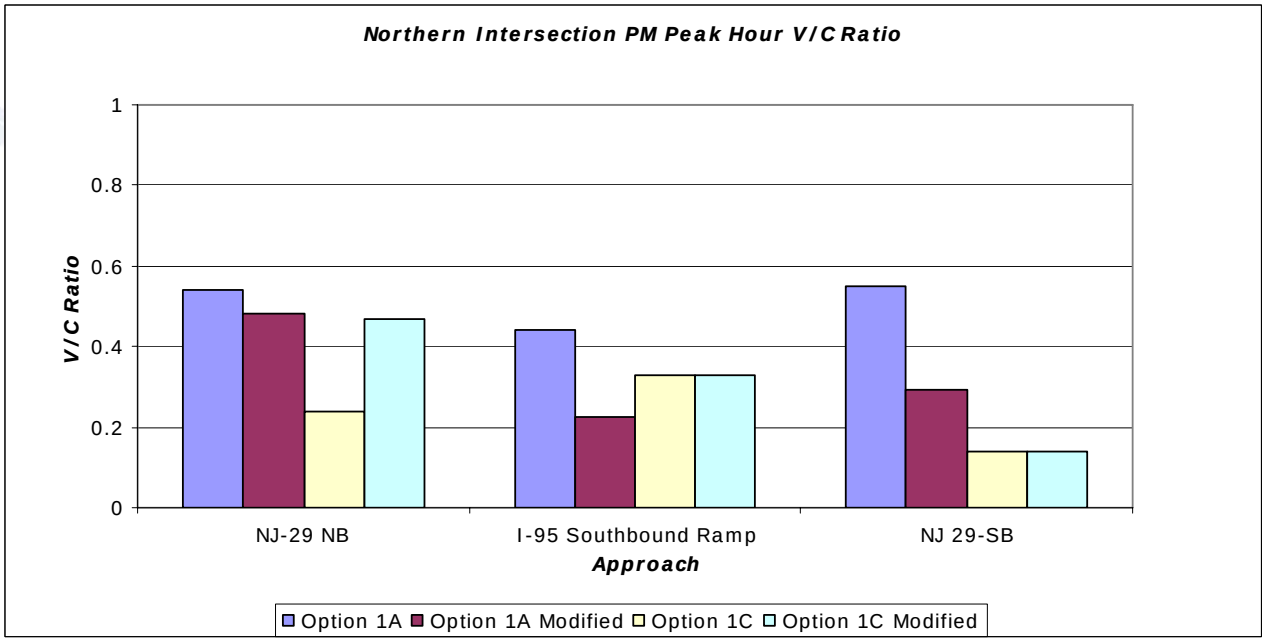
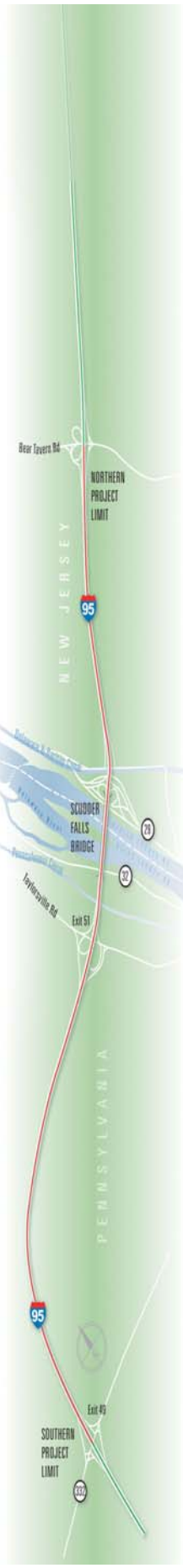


Figure 16



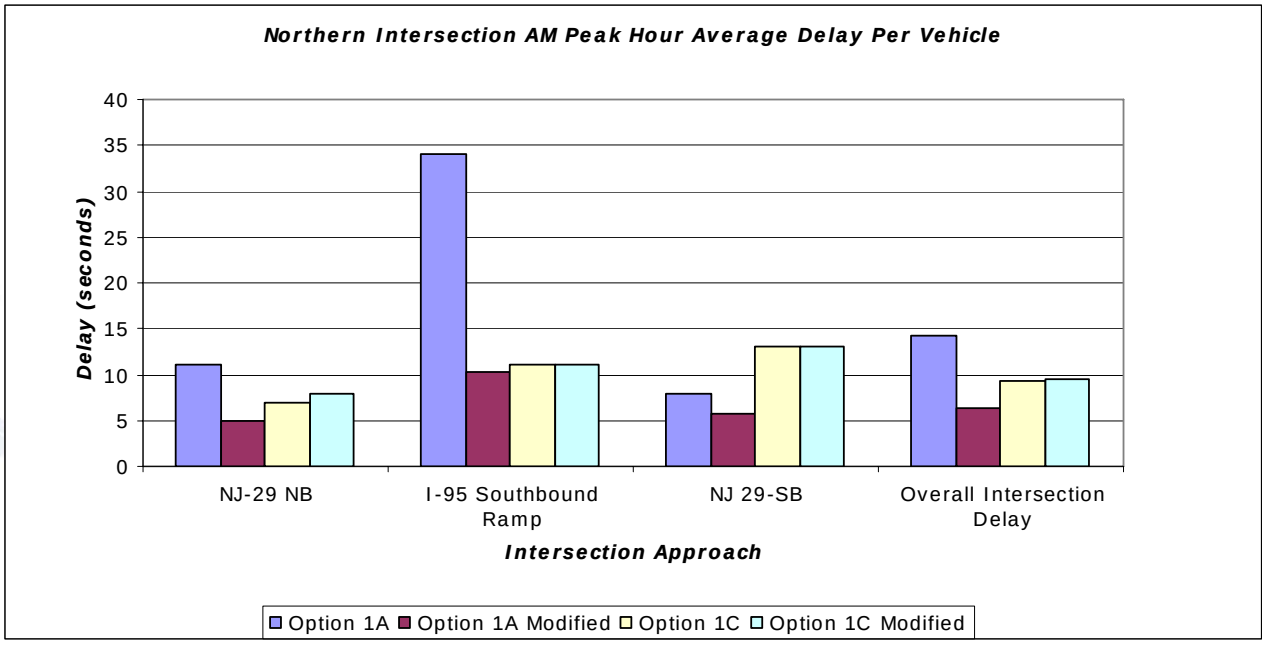


The results in Figures 15 and 16 indicate that *Option 1C: NJDOT Roundabout* will operate with the lowest V/C ratio, similar to the southern intersection. Again, this is considered reasonable given that this alternative incorporates a number of bypass ramps at the interchange and additionally, through traffic on NJ-29 is removed from the intersection via additional bypass roads. Generally, similar ratios were observed for the remaining alternatives. Similar to the southern intersection, all alternatives operate within generally accepted thresholds (V/C <1.0 for signals, V/C <0.85 for roundabouts).

Intersection Delay

The approach delay for the northern intersection alternatives has been calculated and the results are outlined in Figures 17 and 18 below.

Figure 17



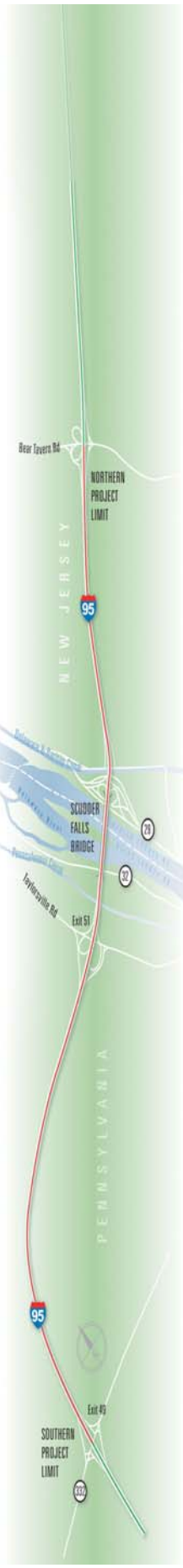
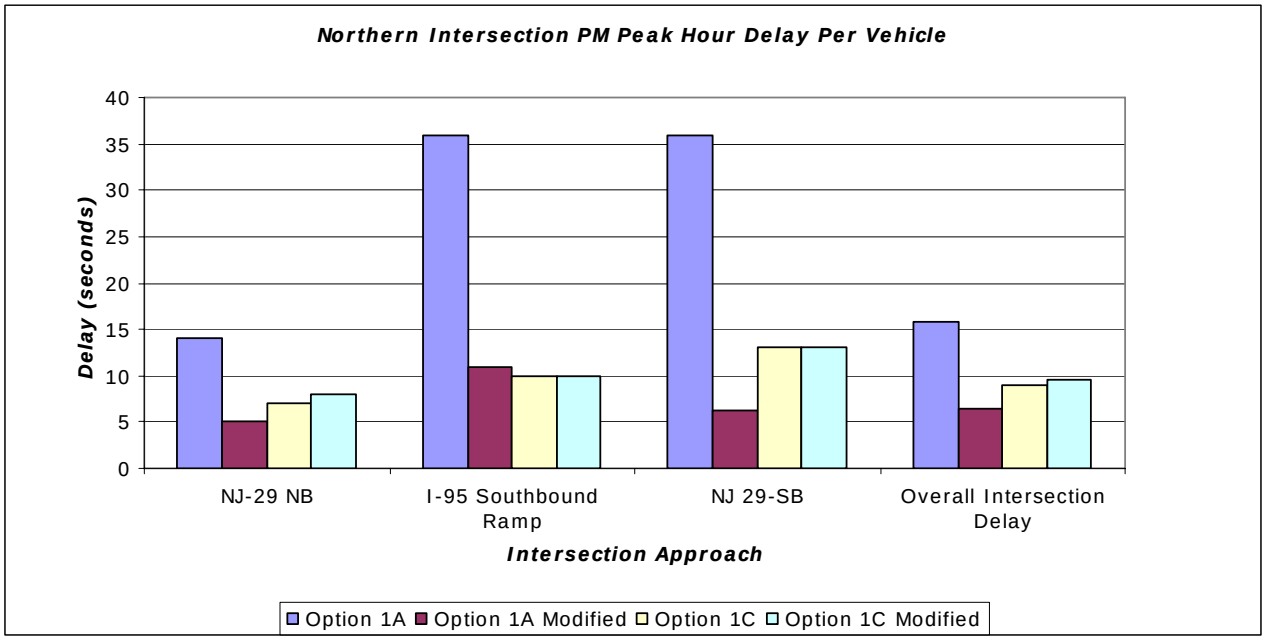


Figure 18



Figures 17 and 18 illustrate that, with the exception of the I-95 Southbound Ramp approach in the PM peak hour, *Option 1A Modified: DMJM Folded Diamond w/Roundabout* will operate with the least delay for traffic utilizing the interchange. The delay that is observed at the signalized intersection (*Option 1A: DMJM "Folded Diamond" Interchange*) is generally significantly higher than that observed for the roundabout options. The results also indicate that *Option 1A Modified: DMJM Folded Diamond w/Roundabout* realizes the least average delay per vehicle for the intersection as a whole.

The delay that was observed in all cases did not exceed acceptable levels, which is also reinforced by the LOS classifications previously identified. This is generally consistent with the results observed for the Southern intersection.

Vehicle Queues

95th Percentile vehicle queues have also been considered. The results are shown in figures 19 and 20 below.

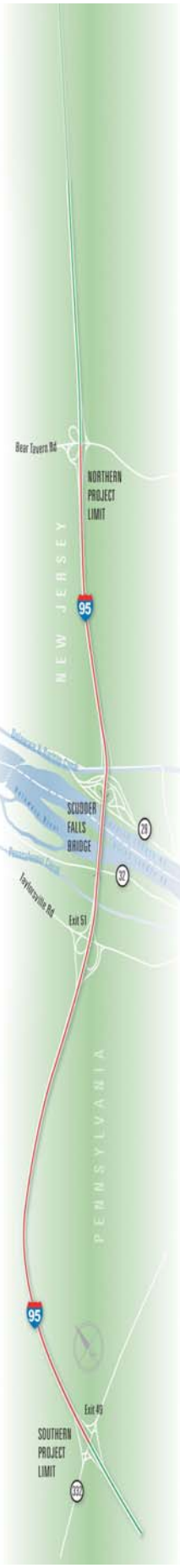


Figure 19

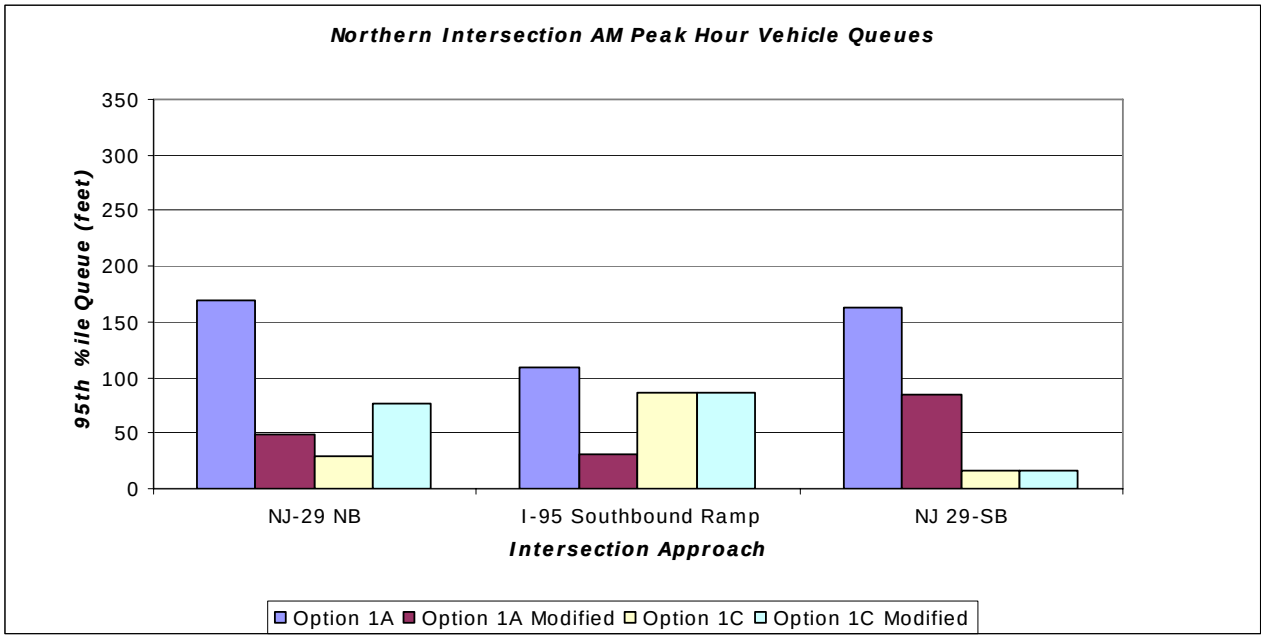
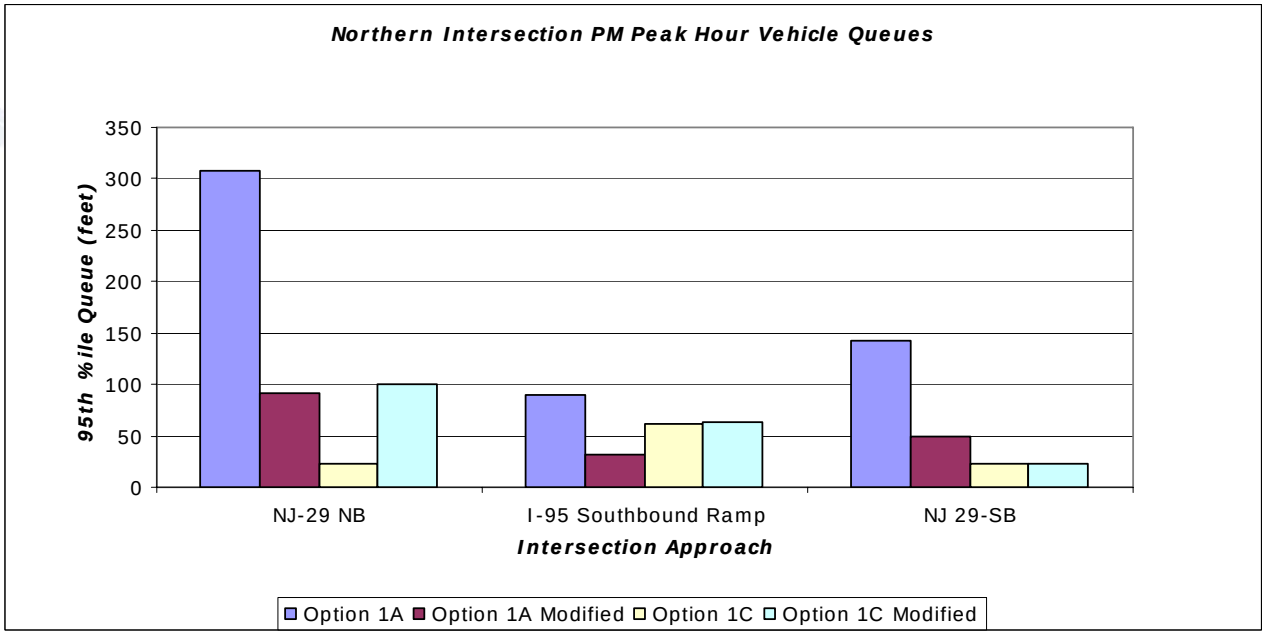
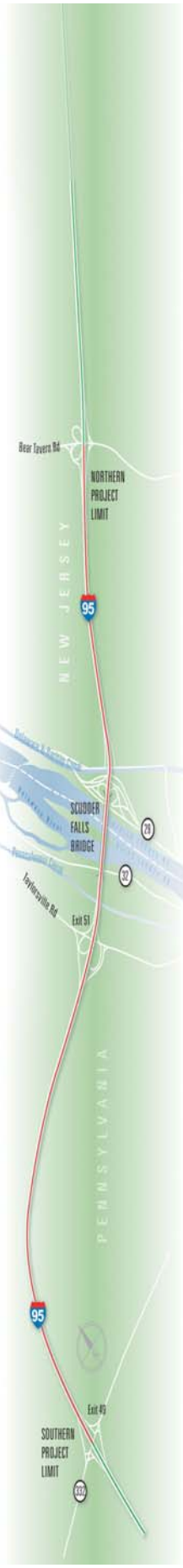


Figure 20





The results displayed in figures 19 and 20 above indicate that the 1C-based options generally record lower vehicle queues on the NJ-29 arterial. This is due to the through traffic bypassing the intersections. The queuing observed on the eastbound arterial approaches in the 1A-based options is not considered significant as sufficient queue storage is available prior to the constraint of the bridge.

Option 1A Modified: DMJM Folded Diamond w/Roundabout also results in the shortest queues on the interchange approaches, which is critical to ensure that sufficient deceleration can be provided for the off ramps.

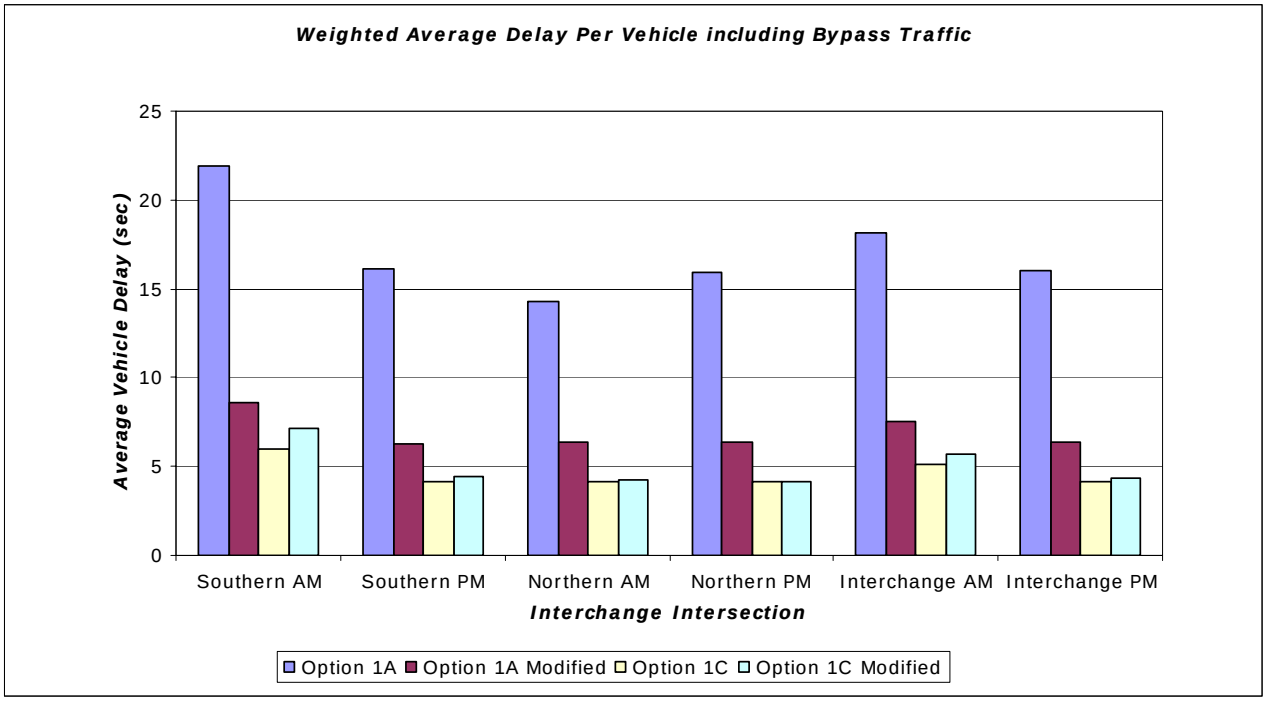
Also, of the 1A-based options, less queuing is observed for *Option 1A Modified: DMJM Folded Diamond w/Roundabout*, which is beneficial as this increases the distance available for any weaving between the roundabouts on the interchange underpass that is necessary.

Interchange Delay Comparison

In addition to the average vehicle delays per intersection reported above, the average *interchange* vehicle delay has also been assessed. This performance measure considers the traffic in the 1C-based options that are not subjected to any delay as they utilize the bypass and do not encounter any intersections.

In the 1C-based options, approximately 50-55% of the interchange traffic (1450vph AM peak hour, 1480vph PM peak hour) bypasses the interchange intersections. To generate this characteristic, average intersection delays for the 1C-based options were weighted to consider the traffic that experiences no delay. The results are illustrated in Figure 21 below.

Figure 21



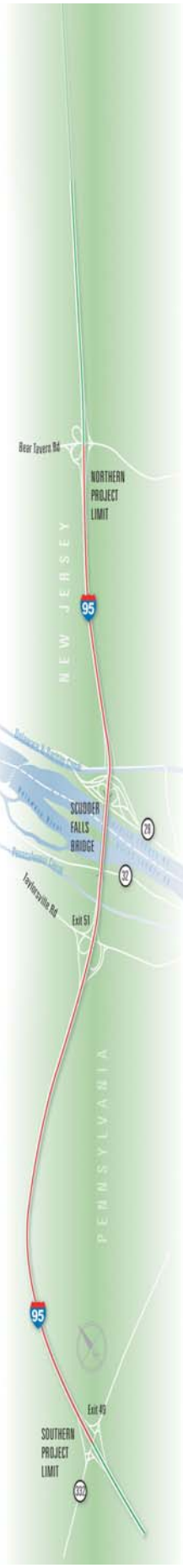
The results indicate that *Option 1C: NJDOT Roundabout* provides the least amount of average interchange delay, closely followed by *Option 1C Modified: NJDOT Roundabout Modified* and then *Option 1A Modified: DMJM Folded Diamond w/Roundabout. Option 1A: DMJM Folded Diamond* operates with the highest delay of the four options.

It is critical to note that all four options operate exceptionally well in terms of average interchange delay. Additionally, the difference in delay between *Option 1C Modified: NJDOT Roundabout Modified* and *Option 1A Modified: DMJM Folded Diamond w/Roundabout* ranges from between 1.5 to 2.2 seconds across all scenarios above.

Operational Assessment Summary

The results outlined in the sections above confirm that *Option 1A Modified: DMJM Folded Diamond w/Roundabout* will operate with the best performance of the four alternatives studied. The results indicate that this alternative will operate within generally accepted thresholds in all cases and generally performs the best out of the four alternatives in all factors.

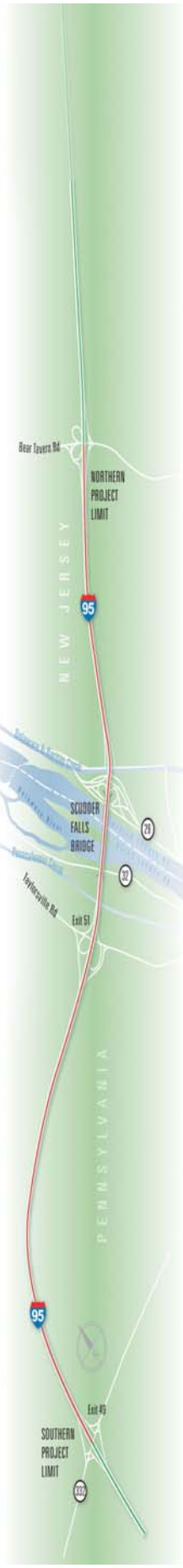
Considering critical parameters such as queue lengths on the interchange ramp approaches and on the underpass merge areas, *Option 1A Modified: DMJM Folded Diamond w/Roundabout* realizes significantly less queues than the other alternatives, providing more length for deceleration and merging.



Additionally, average vehicle delays at the intersections for this interchange configuration are demonstrated to be lower than the other alternatives.

This interchange configuration also performs exceptionally well considering the average interchange delay. Average interchange delay is within 1.5-2.2seconds of *Option 1C Modified: NJDOT Roundabout Modified* and within 2.2-2.6seconds of *Option 1C: NJDOT Roundabout* which is the best performing in terms of interchange delay.

Generally, all alternatives operate within generally accepted thresholds, however *Option 1A Modified: DMJM Folded Diamond w/Roundabout* is considered to be superior from a traffic operation perspective.



QUALITATIVE ASSESSMENT OF INTERCHANGE ALTERNATIVES

Assessment Background

KAI performed a qualitative comparative assessment of the alternatives to consider a wide range of interchange characteristics. Characteristics that were considered included:

- Number of decision points for drivers
- Number of potential weaving and/or merge conflicts
- Potential deceleration/speed differential conflicts
- Potential deceleration/queue conflicts
- Issues regarding interchange ramp grades
- Complexity of potential signage strategy
- Accident potential
- Environmental impacts relevant to Delaware River and Delaware-Raritan Canal
- Overall interchange complexity, which is a general summary of the above characteristics
- Interchange grading and vertical geometry
- Interchange cost
- Overall quality of interchange operations

Additionally, KAI reviewed the accident analysis prepared by DMJM Harris. Accident trends for the corridor suggest that accidents in the corridor occur more frequently at the interchanges than on the highway, which is to be expected, and accident types at this interchange were typically rear-end accidents. These accidents likely occur because insufficient acceleration length is currently provided within the existing interchange configuration. These accidents likely occur when vehicles accelerate to highway speeds with vehicles in front of them. As reported in the analysis, careful design of the interchange geometry is likely to reduce this. No other significant trends were observed relevant to the subject interchange.

The figures outlined in Appendix C provide comments relative to the above characteristics for each interchange configuration. The figures indicate that *Option 1A Modified: DMJM Folded Diamond w/Roundabout* provides the least conflict points (weaving, merging and decelerating conflicts) compared to the three other alternatives and is generally the most "simple" interchange form.

The matrix below outlines the comparative ranking of each alternative for the characteristics outlined above.

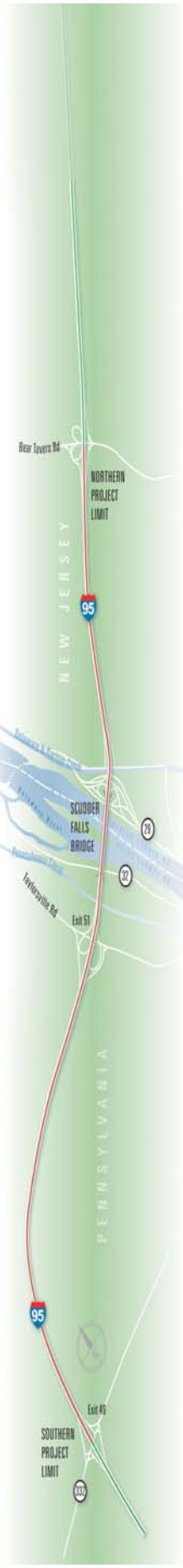
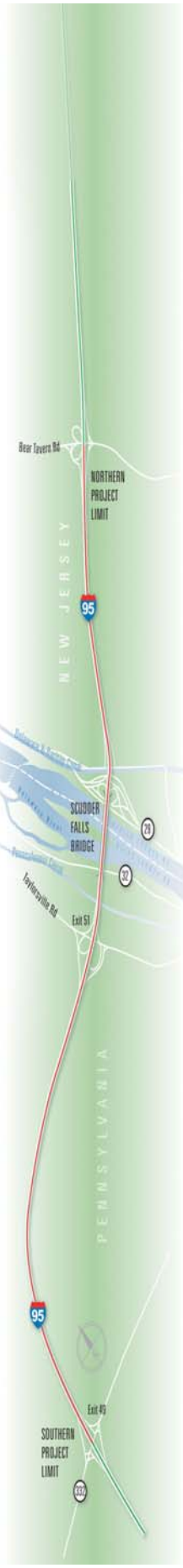


Table 1. Qualitative Comparison Of Interchange Options

Assessment Characteristic (Relative to Alternate Options)	***Option 1A: DMJM "Folded Diamond" Interchange***	***Option 1A Modified: DMJM Folded Diamond w/Roundabout***	***Option 1C: NJDOT Roundabout***	***Option 1C Modified: NJDOT Roundabout Modified***
Number of Decision Points	Good	Excellent	Poor	Good
Number of Merge/Weave Conflicts	Good	Excellent	Poor	Good
Potential Deceleration/Speed Conflicts	Poor	Excellent	Poor	Excellent
Potential Deceleration/Queue Conflicts	Poor	Excellent	Good	Poor
Complexity of Potential Signage Strategy	Standard	Standard	Complex	Standard
Accident Potential*	Poor/Excellent	Good/Excellent	Good/Good	Excellent/Good
Environmental Impact on Adjacent Waterways	Excellent	Good	Poor	Poor
Relative Interchange Complexity	Moderate	Simple	Complex	Moderate
Interchange Geometrics (discussed below)	Poor	Excellent	Good	Good
Interchange Cost (discussed below)	$18.5M	$18.5M	$24.5M	$24.0M
Operational Performance	Good	Excellent	Excellent	Good

*For accident potential, the first value reflects the intersection terminal, and the second value reflects the system/interchange



Consideration of Interchange Vertical Geometry

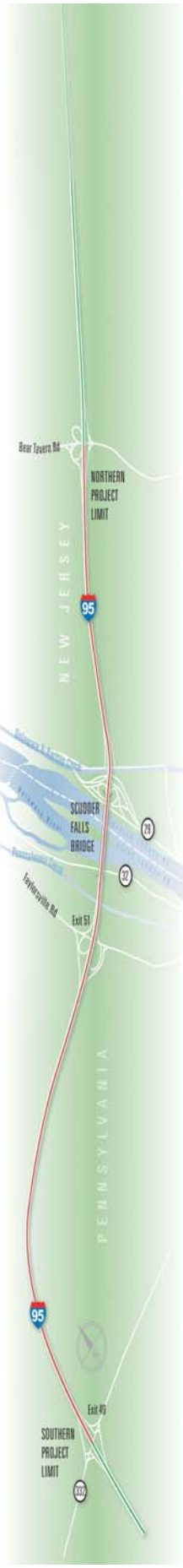
DMJM Harris has also considered the vertical geometry of the four interchange alternatives. Their investigations are summarized below.

The four options were also analyzed from a geometrics standpoint to determine the steepness of the grades between the I-95 mainline and NJ-29. The most critical ramp was found to be the off-ramp between I-95 SB and the NJ-29 northern intersection. Under all options, this off-ramp must provide a minimum vertical clearance of 14'6" over NJ-175 (Upper River Road), while under *Option 1C: NJDOT Roundabout* and *Option 1C Modified: NJDOT Roundabout Modified*, this off-ramp must also provide a minimum vertical clearance of 16'6" over the NJ-29NB bypass, which is maintained under these two options. The geometrics for all profiles were designed to meet NJDOT design criteria, with a maximum desirable downgrade of 6%.

Under *Option 1A: DMJM "Folded Diamond" Interchange*, the maximum grade on this off-ramp is 6%, which is necessary to maintain the required vertical clearance over NJ-175. Just prior to its intersection with NJ-29, a 100 foot "level" area is provided along the ramp for vehicles waiting at the traffic signal.

Under *Option 1C: NJDOT Roundabout* and *Option 1C Modified: NJDOT Roundabout Modified*, the maximum grade on the off-ramp is also 6%, however, because of the 16'6" vertical clearance that must be maintained over the NJ-29 NB Bypass, it is not feasible to provide the desired "level" area prior to the northern roundabout. In order to meet the maximum desirable downgrade, it was also necessary to raise the general elevations of the roundabout, which was possible because of its location with respect to NJ-29. Unlike *Option 1A: DMJM "Folded Diamond" Interchange*, where the off-ramp elevations must coincide with NJ-29 elevations at the intersection of the two, the roundabout does not immediately intersect NJ-29, and it is possible to raise the elevations along the roundabout.

Under *Option 1A Modified: DMJM Folded Diamond w/Roundabout*, the maximum grade on the off-ramp is just under 4%, which is the most desirable from a geometrics standpoint. This vertical profile was developed similarly to the two other options. Because the NJ-29 NB Bypass is not being maintained under this option, it is only necessary to provide the vertical clearance over NJ-175, and because of the location of the roundabout with respect to the location where NJ-29 passes under I-95, it is possible to raise the elevations of the northern roundabout. While this option also does not provide a "level" area prior to the roundabout, it is more desirable that *Option 1C: NJDOT Roundabout* and *Option 1C Modified: NJDOT Roundabout Modified*, because of the 4% approach to the roundabout versus the 6% approach.

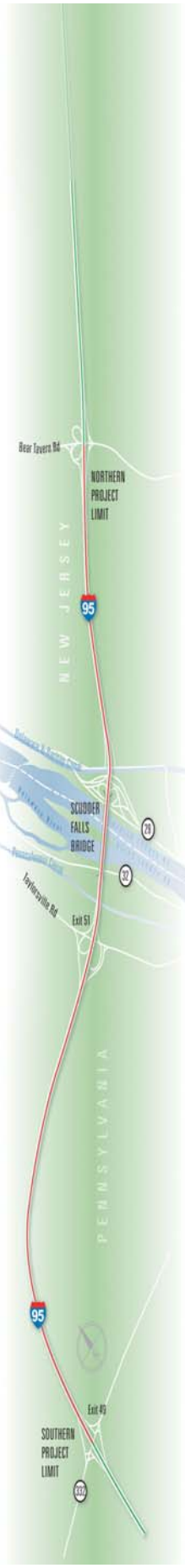


Interchange Cost

DMJM Harris has provided information regarding the expected costs for each interchange alternative that has been considered. The information provided ranks each alternative as follows:

1. *Option 1A: DMJM "Folded Diamond" Interchange* and *Option 1A Modified: DMJM Folded Diamond w/Roundabout* - $18.5M construction and engineering cost
2. *Option 1C Modified: NJDOT Roundabout Modified* - $24.0M construction and engineering cost
3. *Option 1C: NJDOT Roundabout* - $24.5M construction and engineering cost

These costs indicate that *Option 1A: DMJM "Folded Diamond" Interchange* and *Option 1A Modified: DMJM Folded Diamond w/Roundabout* represent a cost saving of approximately $6M compared to the two alternative options. DMJM Harris has indicated that further cost saving could be achieved with *Option 1A Modified: DMJM Folded Diamond w/Roundabout* due to the savings associated without having to construct the two traffic signals.



CONCLUSIONS

Kittelson & Associates, Inc. considered four potential alternatives for the I-95 interchange with NJ-29. This project is part of the wider network upgrading currently under investigation by The Delaware River Joint Toll Bridge Commission (DRJTBC), in cooperation with the New Jersey Department of Transportation (NJDOT), the Pennsylvania Department of Transportation (PENNDOT) and the Federal Highway Administration (FHWA).

Our assessment:

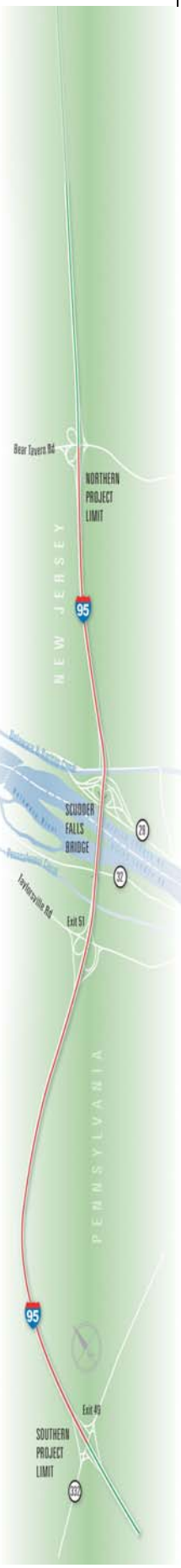
- evaluated the operating characteristics of three roundabout interchange configurations that include roundabouts at the loop ramps of I-95 at the NJ-29 interchange (using the aaSIDRA software package) for the 2030 design year in the AM and PM peak hours. The assessment includes a number of factors relative to the interchange operation, namely levels of service, volume to capacity ratios, average vehicle delay, and queuing. The assessment was also compared to the operational performance of a configuration incorporating traffic signals developed and assessed by DMJM Harris.
- qualitatively analyzed the four interchange configurations. This assessment focused on a number of elements including decision points, weave, merge and speed conflicts, accident potential, and signage strategies. The interchange configurations were ranked in a matrix format for comparison.

The results of the operational evaluation indicate that all four interchange configurations will operate satisfactorily with the exception of potential deceleration/queue length conflicts from the I-95 northbound loop ramps occurring in *Option 1A: DMJM "Folded Diamond" Interchange* and *Option 1C Modified: NJDOT Roundabout Modified*. It is likely that these conflicts may be resolved by extending the queue distance as design of the interchange progresses or with provision of bypass ramps (a trade off which will provide more conflict points). From an operational perspective, we consider that *Option 1A Modified: DMJM Folded Diamond w/Roundabout* out performs the other alternatives.

The qualitative assessment results indicate that the negative aspects of the *Option 1A Modified: DMJM Folded Diamond w/Roundabout* design carry less impact than the other alternatives; however, *Option 1A: DMJM "Folded Diamond" Interchange* is also ranked favorably.

To this end we consider that *Option 1A Modified: DMJM Folded Diamond w/Roundabout* is the most appropriate interchange configuration, followed by *Option 1A: DMJM "Folded Diamond" Interchange*. Both options operate satisfactorily from a performance perspective and were similarly ranked in the qualitative analysis.

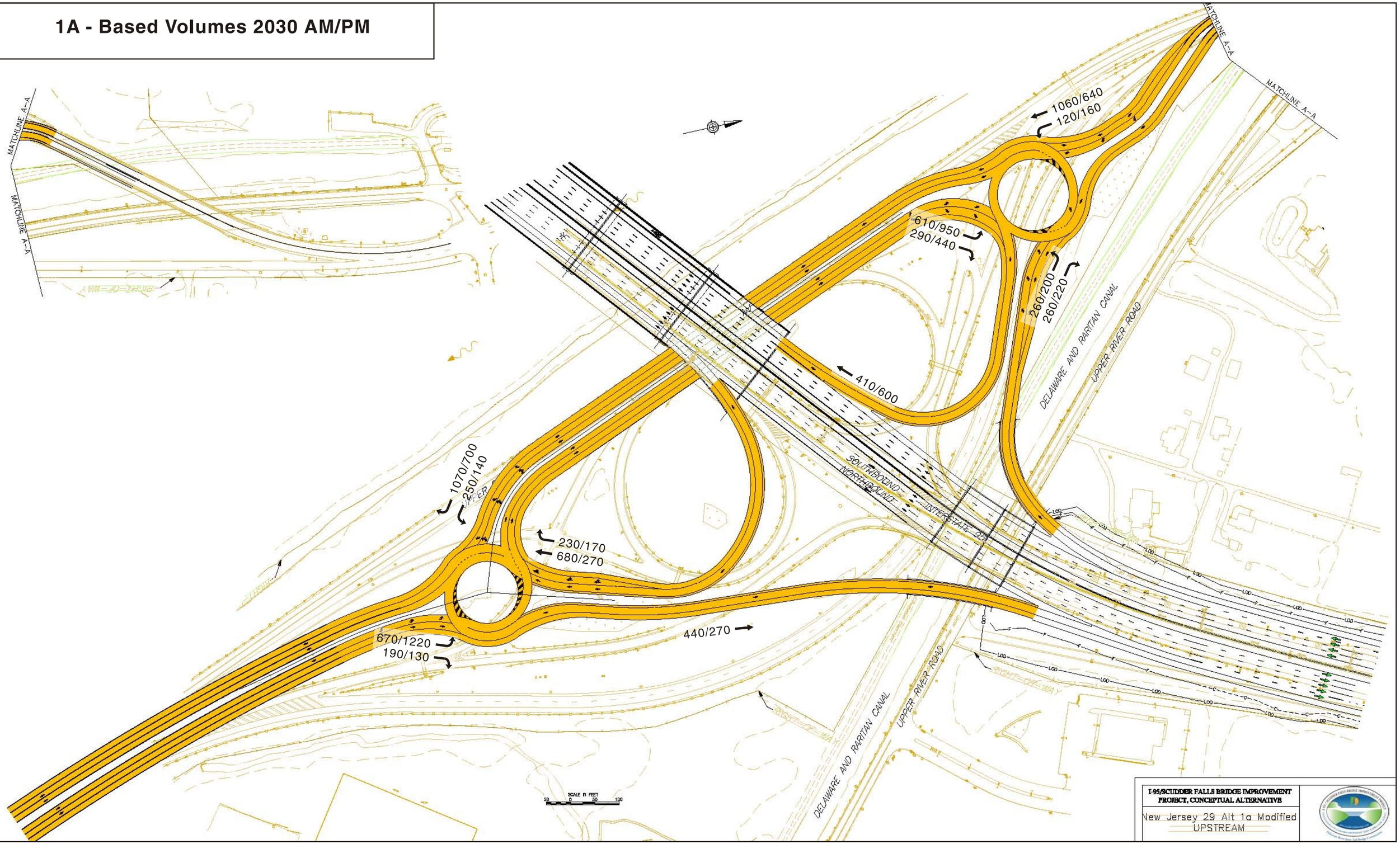
We recommend that *Option 1C: NJDOT Roundabout* and *Option 1C Modified: NJDOT Roundabout Modified* are withdrawn from further consideration due to the numerous conflict points (deceleration, weaving and merge conflicts) within each alternative and the necessity of maintaining the River Road bypass and associated steep grades on the interchange ramp overpasses.



APPENDIX B

Traffic Volumes and Assessment Results

1A - Based Volumes 2030 AM/PM



I-95/SCUDDER FALLS BRIDGE IMPROVEMENT PROJECT, CONCEPTUAL ALTERNATIVE

New Jersey 29 Alt 1a Modified
UPSTREAM

1C - Based Volumes 2030 AM/PM

MATCHLINE A-A

MATCHLINE A-A

RIGHT-OF-WAY

DELAWARE RIVER

SCUDDER FALLS BRIDGE

TO SR 29

POTENTIAL DETENTION BASIN LOCATION

0/0
120/160

230/170
290/440

260/220
260/200

230/130

DELAWARE AND RARITAN CANAL

UPPER RIVER ROAD

MATCHLINE A-A

MATCHLINE A-A

SOUTHBOUND
NORTHBOUND

INTERSTATE 95

RIGHT-OF-WAY

RIGHT-OF-WAY

0/0
250/140

RIVER ROAD

1070/700

230/170
680/270

290/440
190/130

440/270

380/780

POTENTIAL DETENTION BASIN LOCATION

DELAWARE AND RARITAN CANAL

UPPER RIVER ROAD

RIGHT-OF-WAY

SCALE IN FEET
50 0 50 100

I-95/SCUDDER FALLS BRIDGE IMPROVEMENT PROJECT, CONCEPTUAL ALTERNATIVE

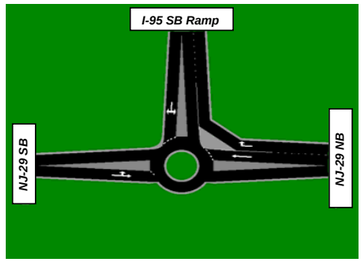
New Jersey 29 Alt 1c Modified
UPSTREAM

#7413 - Scudder Falls Interchange

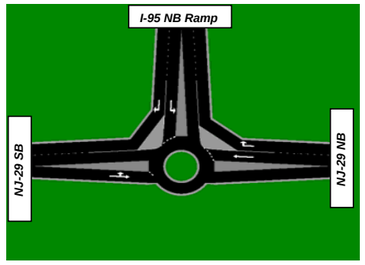
Operational Assessment Results - March 2006

Assessment Option	Scenario	Approach	HCM L.O.S		V/C Ratio		Delay (s)		Queue (ft)	
			SIDRA	British	SIDRA	British	SIDRA	British	SIDRA	British
Option 1C: NJDOT Roundabout	2030 AM Eastern	NJ-29 NB	A	A	0.26	0.23	7	4	49	22
		I-95 Interchange Ramp	B	A	0.59	0.56	12	7	149	91
		NJ-29 SB	B	A	0.33	0.25	16	5	69	45
	2030 PM Eastern	NJ-29 NB	A	A	0.34	0.33	7	4	64	36
		I-95 Interchange Ramp	B	A	0.27	0.24	11	4	48	24
		NJ-29 SB	B	A	0.13	0.11	13	3	21	9
	2030 AM Western	NJ-29 NB	A	A	0.18	0.18	7	3	29	8
		I-95 Interchange Ramp	B	A	0.43	0.41	11	5	86	51
		NJ-29 SB	B	A	0.11	0.10	13	3	17	16
	2030 PM Western	NJ-29 NB	A	A	0.24	0.13	7	3	22	11
		I-95 Interchange Ramp	B	A	0.33	0.32	10	4	61	35
		NJ-29 SB	B	A	0.14	0.12	13	3	22	11

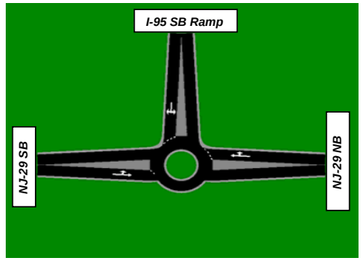
Northern Intersection

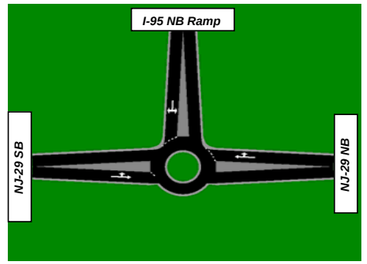


Southern Intersection

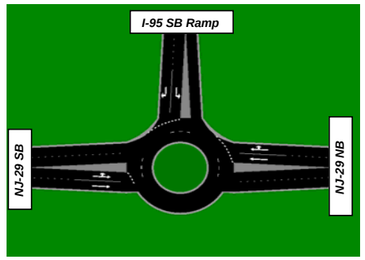


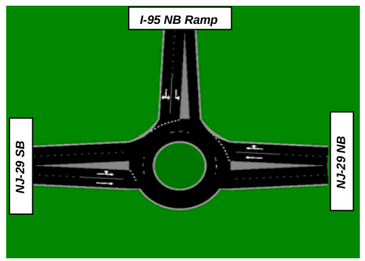
Assessment Option	Scenario	Approach	HCM L.O.S		V/C Ratio		Delay (s)		Queue (ft)	
			SIDRA	British	SIDRA	British	SIDRA	British	SIDRA	British
Option 1C Modified: NJDOT Roundabout Modified	2030 AM Eastern	NJ-29 NB	A	A	0.42	0.38	8	5	92	45
		I-95 Interchange Ramp	B	B	0.78	0.75	16	11	321	188
		NJ-29 SB	B	A	0.34	0.25	16	5	76	25
	2030 PM Eastern	NJ-29 NB	A	A	0.43	0.43	8	5	91	55
		I-95 Interchange Ramp	B	A	0.44	0.39	13	5	90	47
		NJ-29 SB	B	A	0.13	0.11	13	3	91	9
	2030 AM Western	NJ-29 NB	A	A	0.38	0.40	8	5	77	49
		I-95 Interchange Ramp	B	A	0.43	0.41	11	5	87	51
		NJ-29 SB	B	A	0.11	0.10	13	3	17	16
	2030 PM Western	NJ-29 NB	A	A	0.47	0.48	8	5	101	66
		I-95 Interchange Ramp	B	A	0.33	0.32	10	4	63	35
		NJ-29 SB	B	A	0.14	0.12	13	3	22	11





Assessment Option	Scenario	Approach	HCM L.O.S		V/C Ratio		Delay (s)		Queue (ft)	
			SIDRA	British	SIDRA	British	SIDRA	British	SIDRA	British
Option 1A Modified: DMJM Folded Diamond w/Roundabout	2030 AM Eastern	NJ-29 NB	A	A	0.33	0.33	5	2	59	37
		I-95 Interchange Ramp	B	A	0.41	0.40	12	3	62	50
		NJ-29 SB	A	A	0.61	0.58	8	4	132	102
	2030 PM Eastern	NJ-29 NB	A	A	0.46	0.50	5	3	87	76
		I-95 Interchange Ramp	B	A	0.23	0.24	12	3	32	23
		NJ-29 SB	A	A	0.32	0.33	6	2	51	30
	2030 AM Western	NJ-29 NB	A	A	0.31	0.34	5	2	49	38
		I-95 Interchange Ramp	B	A	0.24	0.22	10	2	31	22
		NJ-29 SB	A	A	0.45	0.46	6	3	84	63
	2030 PM Western	NJ-29 NB	A	A	0.48	0.52	5	3	92	81
		I-95 Interchange Ramp	B	A	0.23	0.20	11	2	31	19
		NJ-29 SB	A	A	0.29	0.31	6	2	49	33





Assessment Option	Scenario	Approach	SYNCHRO Results			
			HCM L.O.S	V/C Ratio	Delay (s)	Queue (ft)
Option 1A: DMJM "Folded Diamond" Interchange	2030 AM Eastern	NJ-29 NB	C	0.57	25	250
		I-95 Interchange Ramp	C	0.77	33	257
		NJ-29 SB	B	0.70	37	236
	2030 PM Eastern	NJ-29 NB	B	0.68	16	377
		I-95 Interchange Ramp	D	0.53	35	133
		NJ-29 SB	A	0.57	10	144
	2030 AM Western	NJ-29 NB	B	0.34	11	170
		I-95 Interchange Ramp	C	0.50	34	109
		NJ-29 SB	A	0.49	8	162
	2030 PM Western	NJ-29 NB	B	0.54	14	308
		I-95 Interchange Ramp	D	0.44	36	89
		NJ-29 SB	A	0.55	36	143