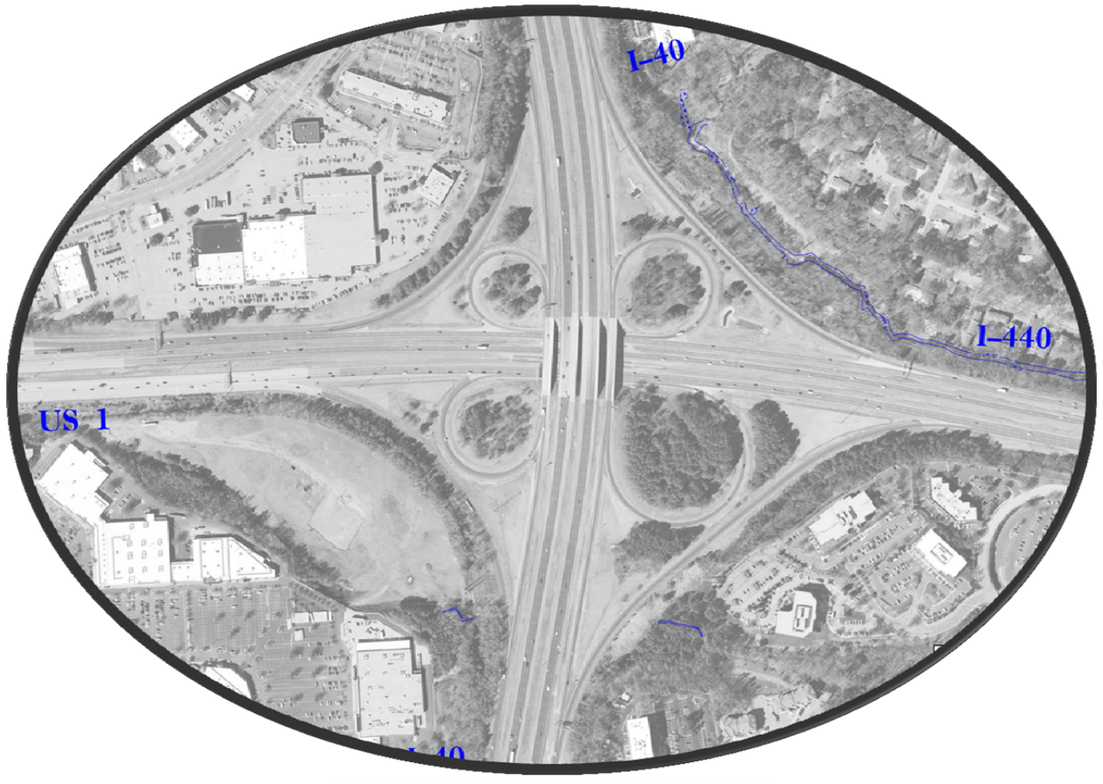
I-40 AT I-440/ US 1/ US 64
INTERCHANGE
FEASIBILITY STUDY



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August 2015

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Executive Summary

The I-40 at I-440/US 1/ US 64 Interchange (hereafter referred to as the Interchange) is the highest volume interchange in the NC Capital Area MPO's (CAMPO) planning area serving over 200,000 vpd with forecasts to carry more than 300,000 vpd by 2035. As evidenced by multiple studies, the current cloverleaf interchange already has severe capacity constraints, primarily due to weaving operations between the four existing loops. The purpose of this study is to identify feasible and appropriate transportation solutions for the Interchange that can accommodate future capacity needs, minimize impact to adjacent development, and be implemented as a stand-alone project.

In the first phase of this study, a review of the overall interchange and long term plans for the interchange area were examined. In addition, review of existing and future land use, traffic, and roadway characteristics was conducted. These steps are summarized in Section A and Section B of this report.

The data and findings from previously completed studies were taken and refined to develop interchange alternatives. These alternatives included a combination of previously developed alternatives (primarily from NCDOT's FS-1005A feasibility study of the interchange and the U-2719 EIS for improvements to I-440), new concepts, and refinements of interchange concepts proposed by others.

Brainstorming Session

The first phase culminated in a Brainstorming meeting held with key stakeholders including CAMPO, NCDOT, the City of Raleigh, and the Town of Cary. The meeting included a presentation of 12 interchange concepts roughly fitting into 5 interchange types. A summary of these interchange concepts and key elements discussed in the Brainstorming session are included in Section C.

As part of the Brainstorming session, considerable time was also spent discussing two key elements that were considered as part of the interchange analysis.

- **Managed Lanes** – Managed lanes have been identified along I-40 as part of CAMPO's 2040 Metropolitan Transportation Plan and subsequently investigated by NCDOT as part of FS-1005 (a managed lane feasibility study along I-40. A key assumption in the current evaluation is that although managed lanes may have a long term role for the I-40 corridor, the initial interchange improvements would not include managed lanes. Instead, the interchange concepts to be examined would be for a general purpose lanes improvement that would not preclude future managed lanes.
- **Direct Access to Crossroads** - In examining overall traffic operations, it was identified that maintaining direct access into the Crossroads retail development was critical for maintaining acceptable operations on the local roadway network. Specifically, it was determined that simply closing the existing flyover into and slip ramp out of Crossroads and rerouting that traffic to Walnut Street would cause unacceptable congestion and queuing on Walnut Street, the existing ramps, and back onto the US 1 CD system. Due to the existing issues and close proximity of the Walnut Street/ Buck Jones Road/ Crossroad interchange, this area is included in the study. However, the issues and any solutions at this adjacent interchange are secondary to the project area and should be viewed as a separate stand-alone project.

Key issues and concepts for examining Managed Lanes and Crossroads Access are summarized in Section D.

Alternatives for More Detailed Review

Based on the elements and concepts summarized in Section C and D, the Brainstorming committee identified three concepts for further refinement, evaluation, and comparison in Phase 2 of the project. The alternative concepts selected for final comparison include:

Concept	Figure	Refinements to be Considered
Alternate S-2 Stack Concept	ES-1	None. Based on FS-1005A preferred layout without managed lanes. Used for comparison only.
Alternate B-4 Box Concept	ES-2	Modify Box to utilize CD system for exits from I-40 (similar to B-3) while identifying methods to access Crossroads. Replace US 1 SB to I-40 WB with loop.
Alternate T-4 Turbine Concept	ES-3	Utilize higher speed flyover type ramps (instead of 2-level turbine) and utilize existing loops for local traffic to Crossroads.

Figure ES-1 Alternative S-2 from FS-1005A Modified Stack 2nd iteration (3 Flyovers)

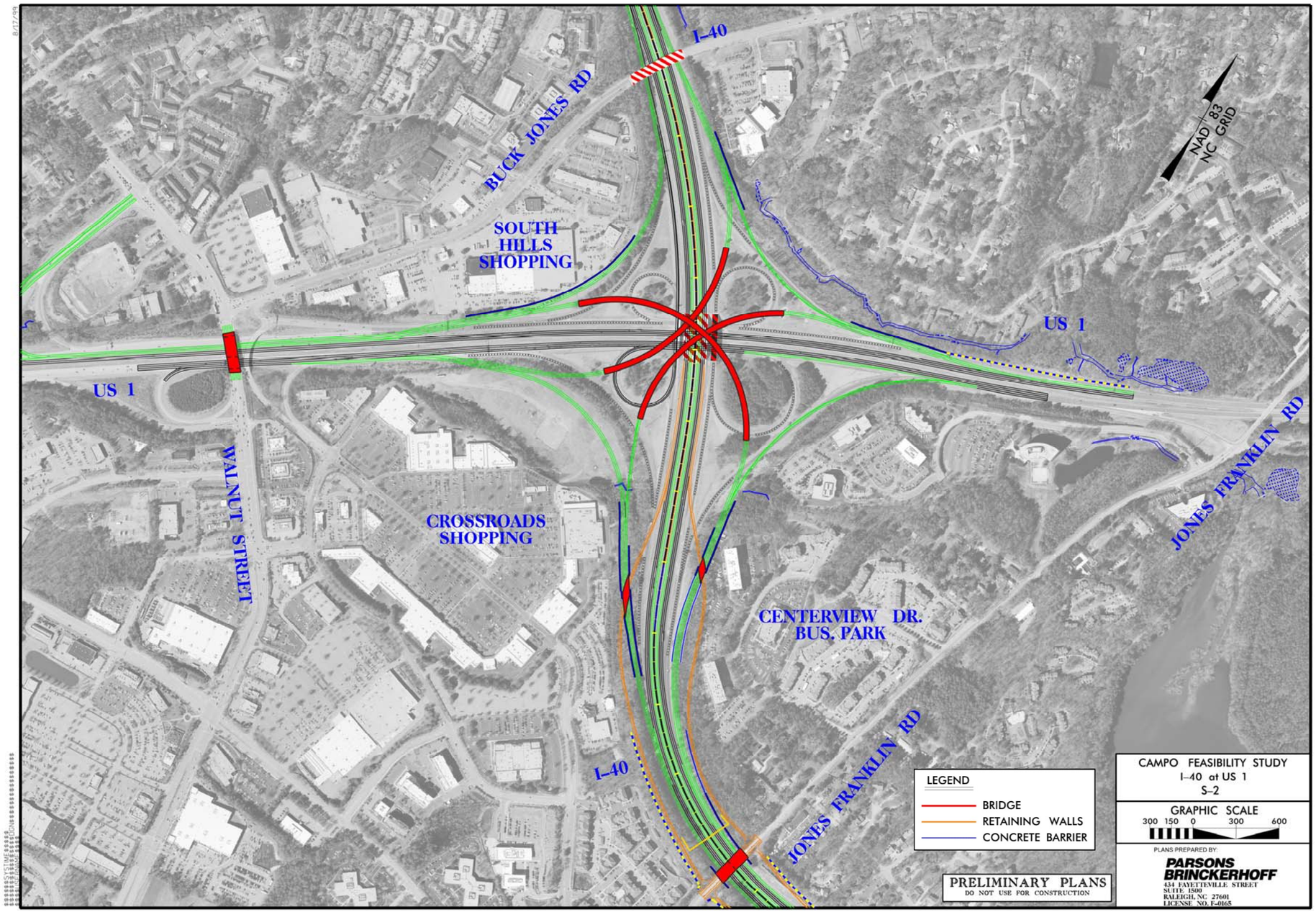


Figure ES-2 Alternative B-4 Modified Box with CD & 4 Loops for Crossroads Access

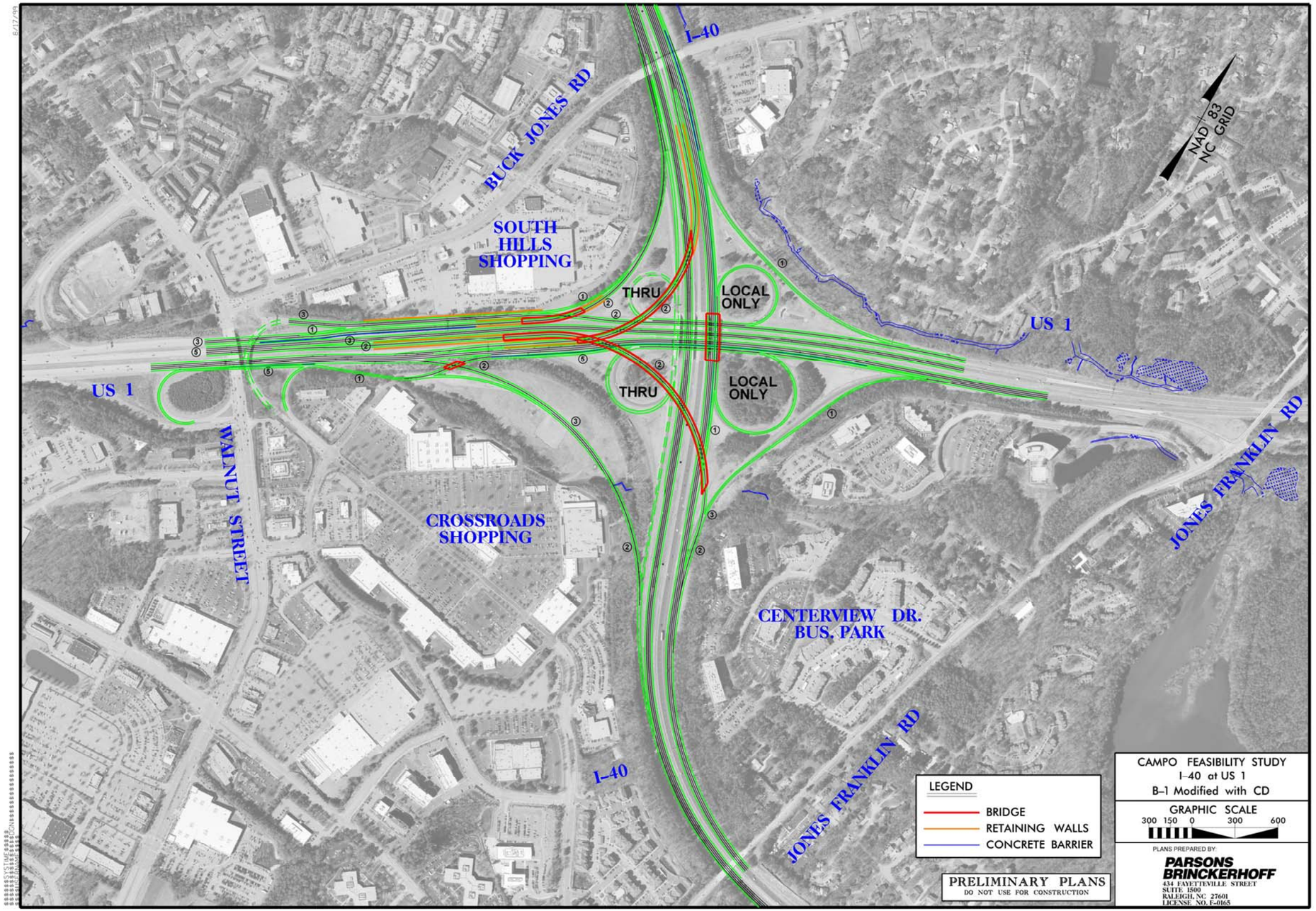
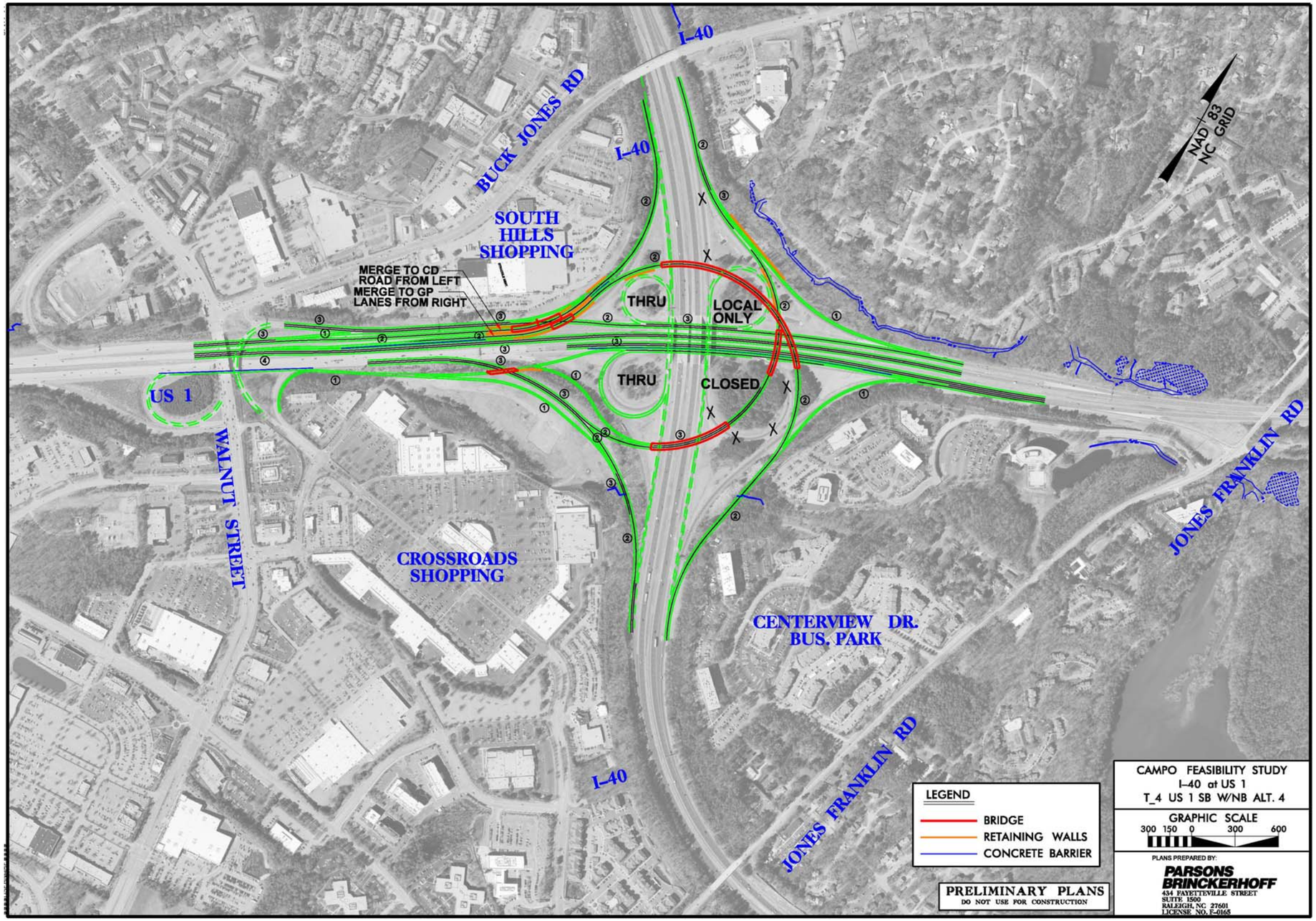


Figure ES-3 Alternative T-4 Flyover Version of Turbine with CD & 3 Loops for Crossroads Access



Evaluation of Key Factors

These alternative concepts are refined and examined in Section E considering the following factors: For each of these factors, a comparison matrix compares each of the three interchange concepts. Based on this comparison of specific elements, an overall ranking is identified for each factor.

- ***Traffic Patterns***: Focused on I-40 and US 1 through traffic and high volume ramps. (See Table ES-1) In the review of existing and future traffic volumes, the key movements were identified as:
  - US 1 northbound to I-40 westbound (AM peak) & the reverse I-40 eastbound to US 1 southbound (PM peak)
  - US 1 northbound to I-40 eastbound (AM) & the reverse I-40 westbound to US 1 southbound (PM peak)
- ***Crossroads Access***: Evaluated how well and in what manner access to Crossroads is maintained. (See Table ES-2)
- ***ROW and Related Impacts***: Identified likely impacts to South Hills Mall and Plaza in the northwest quadrant, office buildings in the southwest quadrant, and environmental impacts to Walnut Creek in the northeast quadrant. (See Table ES-3)
- ***Natural System Impacts***: Potential impacts to Walnut Creek introduce two separate challenges for the project . In addition to the construction issues related to providing walls to minimize impacts, a key hurdle in the NEPA planning process will be minimizing or preventing impacts to Walnut Creek. (See Table ES-4)
- ***Structure Requirements***: Structural challenges considered in the evaluation include the overall lengths and complexity of structural elements as well as the need for three or four-level structures. (See Table ES-5)
- ***Maintenance of Traffic Issues***: A planning level assessment of the viability and ease of MOT during construction. (See Table ES-6)
- ***Provisionn of Future Managed Lanes***: Key challenges and opportunities as well as the overall scale of providing a future managed lanes connection to US 1 from I-40 managed lanes. (See Table ES-7)

Summary Comparison of Alternatives

A summary matrix, Table ES-8, summarizes the seven factors for each of the alternatives under review (the Stack, the Box, and the Turbine). For each of the seven key factors, the matrices (Table ES-1 through ES-8) and the Section E summaries were reviewed.

As noted in the brainstorming comparison, a numeric scoring system was utilized for the comparison of specific types of alternatives, but are more difficult to apply when comparing different types of alternatives. In order to prepare a more valid comparison between alternative types, the analysis for each of the seven factors was subdivided to focus on specific elements within each factor. By focusing on smaller issues, it is possible to more effectively compare the three different alternatives. Discrepencies between alternative types are reduced since the same sub-elements are compared within each of the seven major factors.

Regardless, a formal scoring system or color coding was not implemented for the final comparison of the three concepts.

Table ES-1. Traffic Operations Comparison

OVERALL	STACK	BOX	TURBINE
Network Efficiency (VHT)*	4120 Primarily due to local traffic congestion related to Crossroads	3,243	3,321
Number of Loops at Main Interchange	1 - SW loop to serve through traffic	4 - NW & SW loops serve throughs, and NE and SE loops serve local only.	3 - NW & SW loops serve throughs, NE loop serves local only, & SE loop eliminated.
Weaves at Main Interchange	0 - No weaves & existing CDs eliminated at existing loops.	4 weaves. 3 operate at LOS C using existing CDs. US 1 NB will operate at LOS D if barrier separated CD provided.	2 weaves would remain (US 1 SB and I-40 EB). Both have existing CDs.
Design Exceptions	None	Shoulder & barrier offsets reductions required on US 1 NB under I-40 bridge. Other minor items.	Slight speed reduction on I-40 WB to US 1 SB flyover to minimize ROW take. Other minor items.
US 1 NB Approach to I-40 Ramps	Both I-40 exits on the right. Results in queuing prior to Walnut Street exit in rightmost lanes. Left lane operates without queuing for US 1 NB traffic.	I-40 west exit on the left and I-40 east on the right. Less queuing on US 1 NB approach from Cary Parkway. Reduced speed flow noted in both left and right lanes, however.	Both I-40 exits on the right. Results in queuing prior to Walnut Street exit in rightmost lanes. Left lane operates without queuing for US 1 NB traffic.
Merge of US 1 Ramps onto I-40 WB	Both US 1 movements merge onto single ramp before dual lane merge onto from right side onto I-40.	Two separate merges onto I-40 WB - two lanes from the left (from the US 1 NB flyover) and one lane on the right (from the CD). Transmodeller shows turbulaence & reduced speed at the combined merge area affecting all lanes.	Both US 1 movements merge on CD system before dual lane merge from right side onto I-40.
Other Traffic Operations Issues	Weaves between Walnut & main interchange require multiple lane changes.	Left exits and entrances for major movements. S-curve required for mainline US 1 SB alignment due to structures in median of US 1.	Slight speed reduction on I-40 WB to US 1 SB flyover
Signing Issues	Layout reflects preferred practice for signing with single right exits from mainline freeway on all approaches. Requires additional signs for new Jones Franklin interchange.	Layout introduces separate left exit from US 1 NB and additional decision points on US 1 NB mainline. Requires additional signs for local traffic to/from Crossroads.	Layout reflects preferred practice for signing with single right exits from mainline freeway on all approaches. Requires additional signs for local traffic to/from Crossroads.

* Network efficiency measured in vehicle hours travelled as summarized in Section E.2.1 and Table 4.

Table ES-2. Local Traffic Access to Crossroads Comparison

OVERALL	STACK	BOX	TURBINE
Network Efficiency (VHT)*	4120 Primarily due to local traffic congestion related to Crossroads	3,243	3,321
Into Crossroads from Interchange (i.e. on US 1 Southbound)	Crossroads ramps removed. Traffic must utilize Walnut Street. New interchange proposed for Jones Franklin Road at I-40 to mitigate.	Southbound CD to Crossroads flyover provided with major braid under I-40 WB to US 1 SB ramp. NE loop retained to serve local traffic only. Requires S-curve for US 1 southbound mainline.	Southbound CD to Crossroads flyover provided with major braid under I-40 WB to US 1 SB ramp. NE loop retained to serve local traffic only.
From Crossroads to Interchange (i.e. on US 1 Northbound)	Crossroads ramps removed. Traffic must utilize Walnut Street.	Northbound CD serving Walnut & Crossroads exit to be constructed. SE loop retained to serve local traffic only. Weave under existing I-40 bridge requires CD with barrier & design exceptions to operate at LOS D.	Northbound CD serving Walnut & Crossroads exit to be constructed. Instead of using SE loop, local traffic diverted onto main flyover from CD. This eliminate US 1 NB weave issue.
Walnut Street Congestion	Signal delays with V/C over 150%.	LOS F delays will occur with V/C less than 120%	LOS F delays will occur with V/C less than 120%
New Jones Franklin Road Interchange	New interchange proposed to mitigate removal of Croosroads ramps & resulting Walnut Street congestion.	Not required.	Not required.

* Network efficiency measured in vehicle hours travelled as summarized in Section E.2.1 and Table 4.

Table ES-3. Right of Way & Impacts Comparison

OVERALL	STACK	BOX	TURBINE
Estimated ROW Cost	$48M	$7M	$14M
Building Impacts	Up to 6	0 (highly confident)	0 (confident)
NW Quadrant - South Hills	Realignment of outside ramp and widening of US 1 results in possible take of main building plus up to 3 additional buildings. Major parking impacts anticipated even if buildings saved.	Realignment limited to CD system parallel to US 1 & not outside ramp. ROW impacts avoided with wall.	Realignment limited to CD system parallel to US 1. Ramp from I-40 WB to US 1 SB likely requires design speed reduction to avoid impacts to South Hills parking. Short wall proposed to avoid ROW impacts.
SW Quadrant - Crossroads	ROW required from adjacent land near Crossroads. Ramp braids for Jones Franklin interchange increase ROW take, but no building impacts anticipated.	Outside ramp from US 1 NB to I-40 EB realigned to allow for CD. ROW taking from vacant land adjacent to Crossroads is anticipated.	Outside ramp from US 1 NB to I-40 EB realigned to allow for CD. ROW taking from vacant land adjacent to Crossroads is anticipated.
SE Quadrant - Office Park	Combination of realigning outside ramp & braiding for Jones Franklin interchange result in impacts up to 2 office buildings.	Outside ramp from I-40 WB to US 1 NB remains on existing alignment. Minimal/ no ROW anticipated.	Realignment of outside ramp for flyover requires ROW. No building impacts anticipated.
NE Quadrant - Walnut Creek	Realigning of outer ramp requires 2 large walls (2400 lf) to mitigate impacts of Walnut Creek & church/school	No ramp realignments. No ROW takes.	Flyover tie-in at outside ramp results of realignment toward Walnut Creek. 1 large wall (800 lf) to mitigate impact to Walnut Creek.

Table ES-4. Natural System Impacts Comparison

OVERALL	STACK	BOX	TURBINE
Likely Impacts	Moderate impacts to Walnut Creek mitigated by 2 walls (2400 lf)	No impacts to Walnut Creek	Minor impacts to Walnut Creek mitigated by 1 wall (800 lf). Wall may be able to be built outside of Walnut Creek limits.
NEPA Requirements	Mitigation for impacts will likely be required. Walls will be longer and higher. More difficult to avoid construction impacts.May be possible to minimize/ eliminate impacts with the use of walls.	Documentation would still be required to examine potential construction impacts.	Mitigation for impacts may be required. May be possible to minimize/ eliminate impacts with the use of walls.

Table ES-5. Structural Requirements Comparison

OVERALL	STACK	BOX	TURBINE
Estimate Structure Cost	$51M	$34M	$26M
Number of multi-level flyover bridge structures	3 1 4th level curved flyover (2 lane) 2 3rd level curved flyovers (1 & 2 lane)	2 1 4th level curved flyover (2 lane) 1 3rd level curved flyovers (2 lane)	2 1 3rd level curved flyover (2 lane) 1 2nd level curved flyovers (2 lane)
Number of bridges (for braid over US 1 NB CD)	0 bridges	1 I-40 EB to US 1 SB ramp	2 I-40 EB to US 1 SB ramp & I-40 WB flyover over NB CD
Number of simple two-level bridge structures	0 bridges	1 (braid of I-40 EB to US 1 SB ramp over NB CD)	2 (braid of I-40 EB to US 1 SB ramp over NB CD and I-40 WB flyover over NB CD
Reconstruction/ replacement of existing bridges	5 4 bridges carrying I-40 & CDs over US 1 Walnut Street Bridge	2 I-40 WB and I-40 WB CD over US 1	0 bridges
Bridges required for new Jones Franklin Interchange	3 2 for ramps plus replace Jones Franklin bridge	0 bridges	0 bridges
Bridges Removed & Not Replaced	2 Crossroads Flyover & US 1 NB CD	0 bridges	0 bridges
Walls between traffic lanes (MSE)	4 walls (900 lf)	7 walls (5200 lf)	6 walls (1500 lf)
Walls to minimize ROW & cut/fill impacts	3 walls (3700 lf)	1 wall (1200 lf)	4 walls (1600 lf)
Walls due to new Jones Franklin interchange	9 walls (6200 lf)	0 walls	0 walls

Table ES-6. MOT & Constructability Comparison

OVERALL	STACK	BOX	TURBINE
MOT on I-40	Requires replacement of 4 bridges on I-40 over US 1 (the I-40 mainline & CDs) 4 bridges (including 3 flyovers) to be constructed over I-40 possibly requiring temporary closures	Requires replacement of I-40 WB bridge and I-40 WB CD bridge over US 1 Requires median construction with walls & elevation differences at connection of proposed flyover from US 1 NB to I-40 WB 2 flyover bridges to be constructed over I-40 possibly requiring temporary closures	In general, improvements will occur to outside with minimal impact to I-40. 2 flyover bridges to be constructed over I-40 possibly requiring temporary closures
MOT on US 1	Phasing will focus construction to the outside and then shift traffic to the new pavement. Median construction would not include elevation differences & walls.	US 1 SB will need to be diverted to US 1 SB CD to allow for realignment with S-curve to avoid US 1 NB ramp to I-40 WB to be constructed in median Requires construction with walls & elevation differences at median connection of proposed flyover from US 1 NB to I-40 WB & at braid of 1 ramp over US 1 SB	Likely phasing would widen to the south first, divert US 1 SB to new pavement, and then construct median area. Median construction would not include elevation differences & walls. Requires construction with walls & elevation differences at braid of 2 ramps over US 1 SB.
Loop Operations during MOT	3 flyovers extended over 3 loops (NW, NE, & SE) that will be removed in final phase for MOT purposes. All loops will remain open during majority of MOT until no longer needed. LOS F operations likely due to replacement of I-40 bridges, however. Short term structural closures of all 4 loops required.	0 flyovers extended only for MOT reasons. All loops will remain open during majority of MOT. Short term structural closures of lower volume NW & SW loops required.	1 flyover extended over SE loop solely for MOT reasons All loops will remain open during majority of MOT. SE loop will remain open until US 1 NB to I-40 WB flyover completed in early stage. Short term structural closures of higher volume NE & SE loops required.
Access To Crossroads during MOT	Crossroads flyover & slip ramp to be permanently closed. Walnut Street exit will be only access during construction to/from I-40.	Possible closure of US 1 SB CD required for 1 bridge being braided over CD. US 1 NB CD will likely be late phase during construction. During CD closures, Walnut Street will be primary access to/from I-40.	Possible closure of US 1 SB CD required for 2 bridges being braided over CD. US 1 NB CD will likely be late phase during construction. During CD closures, Walnut Street will be primary access to/from I-40.

Table ES-7. Provision of Future Managed Lanes Comparison

OVERALL	STACK	BOX	TURBINE
Required Median Area on US 1 for Future Connection of Managed Lanes	Managed lanes connect directly with 4 ramps into US 1 median. Required width for future Managed Lanes is 174 feet.	Managed lanes connect directly into US 1 median with 2 ramps and converting 1 GP ramp. Required additional width for the future managed lanes is approx. 44 feet. Could increase substantially depending upon I-40 WB to US 1 SB movement.	Managed lanes concept utilizes vacant land adjacent to Crossroads in SW quadrant. No median connections required.
Required Median Area on I-40 for Future Connection of Managed Lanes	Similar requirements in all scenarios.	Similar requirements in all scenarios.	Similar requirements in all scenarios.
Utilization of Vacant Land Near Crossroads	Not included as part of proposed interchange, but modifications may allow.	Not included as part of proposed interchange, but modifications may allow.	Assumed as part of proposed interchange.
Likely ROW Impacts	Major impact to NW Quadrant including South Hills Shopping Center.	Impact to NW Quadrant includes a wall to preserve South Hills Shopping Center parking. Could increase substantially if I-40 WB to US 1 SB movement is new flyover.	Impact to NW Quadrant includes a wall to preserve South Hills Shopping Center parking
New structures required	3 managed lane flyovers (3rd or 4th level) required in Phase 2 implementation. - US 1 south to/from I-40 east (both US 1 NB to I-40 EB & I-40 WB to US 1 SB) - 2 ML - US 1 NB to I-40 WB - 1 ML - I-40 EB to US 1 SB - 1 ML	2 flyovers required (3rd & 4th level) in Phase 2 implementation. - US 1 NB to I-40 EB - 1 ML - US 1 NB to I-40 WB - 2 GP to replace converted flyover Also note that if ramp added for I-40 WB to US 1 SB managed lane movement (to eliminate weave across I-40), an additional managed lane flyover would need to be constructed.	3 managed lane flyovers (2nd or 3rd level) required in Phase 2 implementation - US 1 NB tol-40 WB & I-40 WB to US 1 SB - 2 ML - I-40 WB to US 1 SB & US 1 NB to I-40 EB - 2 ML - US 1 NB and SB to ML take off point at vacant land
Shared Ramps	No shared ramps required.	Managed lanes would require conversion of Phase 1 GP ramp from US 1 NB to I-40EB to be converted to two-way managed lane ramp. New flyover would be reconstructed to carry GP traffic. I-40 WB to US 1 SB shown with shared ramp. Shared ramp could be eliminated, but would require new median to median ramp from I-40 WB to US 1 SB.	No shared ramps required.
Weaving Issues	Managed lanes and general purpose lane traffic fully separated.	Modified Box concept with Managed Lanes (Figure E-12) requires I-40 WB managed lane traffic to weave across 4 lanes of I-40 to utilize right exit to US 1 SB. Weave could be eliminated, but would require new median to median ramp from I-40 WB to US 1 SB.	Managed lanes and general purpose lane traffic fully separated.

Table ES-8. Comparison of 3 Final Alternatives using Overall Rating for Key Factors

Alt #	Interchange Concept	Traffic Operations (See Table ES-1 & Section E.2.3)	Crossroads Access (See Table ES-2 & Section E.3.4)	ROW & Impacts (See Table ES-3 & Section E.4)	Natural Systems Impacts (See Table ES-4 & Section E.5)	Structural Requirements (See Table ES-5 & Section E.6)	MOT Issues (See Table ES-6 & Section E.7)	Provision of Future Managed Lanes (See Table ES-7 & Section E.8.4)	Planning Level Cost Estimate (See Section E.9)
S-2	**Stacked 4 level with 3 flyovers & 1 loop - No Managed Lanes (See Figure ES-1)**	Fully directional ramps except 1 loop. Major merge for I-40 EB & I-40 WB to US 1 SB results in slow flow and queuing.	Crossroads flyover & slip closed. Jones Franklin interchange proposed to redirect traffic. Lower network efficiency than other alternative concepts..	Ramp realignments needed for tying in directional ramps & MOT. ROW needed in all 4 quadrants. South Hills Mall & Plaza impacted. Walnut Creek impacted.	Moderate impacts to Walnut Creek mitigated by 2 walls (2400 lf)	$51M structure cost 3 major curved flyovers. High cost, but less restricted than flyovers to/from median.	Replacement of 4 bridges carrying I-40 over US 1 is major issue with I-40 traffic shifted to/from CD bridges & weave areas. Closure of Crossroads ramps will impact alternate routes.	Managed lanes likely must use median area with 174 ft cross section for managed lanes at tie-in to US 1. Major phasing & reconstruction issues.	$200 M $130M Construction $48M ROW $22M Jones Franklin Interchange
B-4 with CD	**Refined Box with 2 GP flyovers tying to US 1 median - with Crossroads ramp & CD (See Figure ES-2)**	Left exit & entrance unconventional, but does split 2 heaviest turns. 4 loops and 4 weaves including LOS D US 1 NB weave. Flyovers provided for major movesUS 1 SB mainline requires S-curve.	Crossroads flyover & slip maintained. 4 loops required with 4 weaves. US 1 NB CD operates at LOS D with weave.	Reduced impacts with no alignment changes to outermost ramps. South Hills Mall & Plaza not impacted.	No impacts to Walnut Creek	$34M structure cost 2 major curved flyovers. Most complicated structure option with MSE walls & long flyovers. Requires CD ramp braiding structures.	Flyover from US 1 north simplified. Construction of ramps in median area will require lower speed shifts or shared CD use on US 1.	Future managed lanes to median would need to share flyovers & shift GP to new outside flyovers. I-40 WB to US 1 SB movement will either require additional flyover from median or weave across I-40.	$132 M $127M Construction $5M ROW
T-4 with CD	**1/2 Turbine using Flyovers with Crossroads ramp & CD (See Figure ES-3)**	Higher speed flyovers, 3 loops with two LOS C weaves, removing local traffic improves major merge in NW quadrant.	Crossroads flyover access provided with CD & local loops. Movement to I-40 west merges onto flyover eliminating 2 weaves.	Improved ramp angle & reduced traffic allow NW merge to be shifted away from South Hills Mall & Plaza. Impacts to Walnut Creek may require wall.	Minor impacts to Walnut Creek mitigated by 1 wall (800 lf). Wall may be able to be built outside of Walnut Creek limits.	$26M structure cost 2 major curved flyovers. Requires CD ramp braiding structures.	MOT simplified & constructible. Some tight spaces, but no high level structures. All structures will be designed to accommodate 4 loops during MOT.	Managed lanes simpler with removal of 3rd turbine and keeping NW loop. Opportunity to shift managed lanes to vacant land.	$109 M $94M Construction $15M ROW

A. Introduction

The North Carolina Capital Area Metropolitan Planning Organization (CAMPO) identified the I-40 and I-440/US 1/ US 64 Interchange (the Interchange) as needing a detailed study to determine appropriate transportation solutions. This feasibility study will evaluate interchange concepts for meeting future capacity needs and minimizing impacts to adjacent development and resources. The results of this study will help CAMPO and collaborating agencies/stakeholders with decision making related to the Interchange project and its inclusion in the Metropolitan Transportation Plan (MTP).

CAMPO's I-40 and I-440/US 1/ US 64 Interchange Feasibility Study include the following goals:

- Evaluate the existing travel conditions
- Identify existing natural and cultural impacts related to transportation improvements
- Identify and analyze operational and safety improvements
- Provide recommendations and transportation solutions to meet current and future travel needs

This study has been conducted with the specific intent of using available data, information, and ideas from other studies to the maximum extent possible. This study was divided into two distinct phases. The initial phase involved the review of existing studies and the identification, development, and analysis of multiple concepts in a cursory level review. On June 4, 2015, a brainstorming meeting was held with CAMPO, NCDOT, Raleigh, Cary, and the Parsons Brinckerhoff team. Based on this meeting, two interchange concepts were identified for more detailed review. All outputs from this review are conceptual in nature and will require refined design and review as part of follow-up studies.

The documentation of the analysis performed for I-40 and I-440/US 1/ US 64 Interchange Feasibility Study are divided into the following sections:

- Section A introduces the study area and related studies.
- Section B reviews the key features in each interchange quadrant, traffic operations, and other roadway characteristics.
- Section C identifies and analyzes multiple interchange concepts prepared and analyzed as part of the Brainstorming preparation and presentation.
- Section D examines two key components of a viable alternative – the future provision of managed lanes and access to/from Crossroads for local traffic
- Section E examines and compares three concepts identified for further review after the Brainstorming session

A.1. Study Area and Understanding

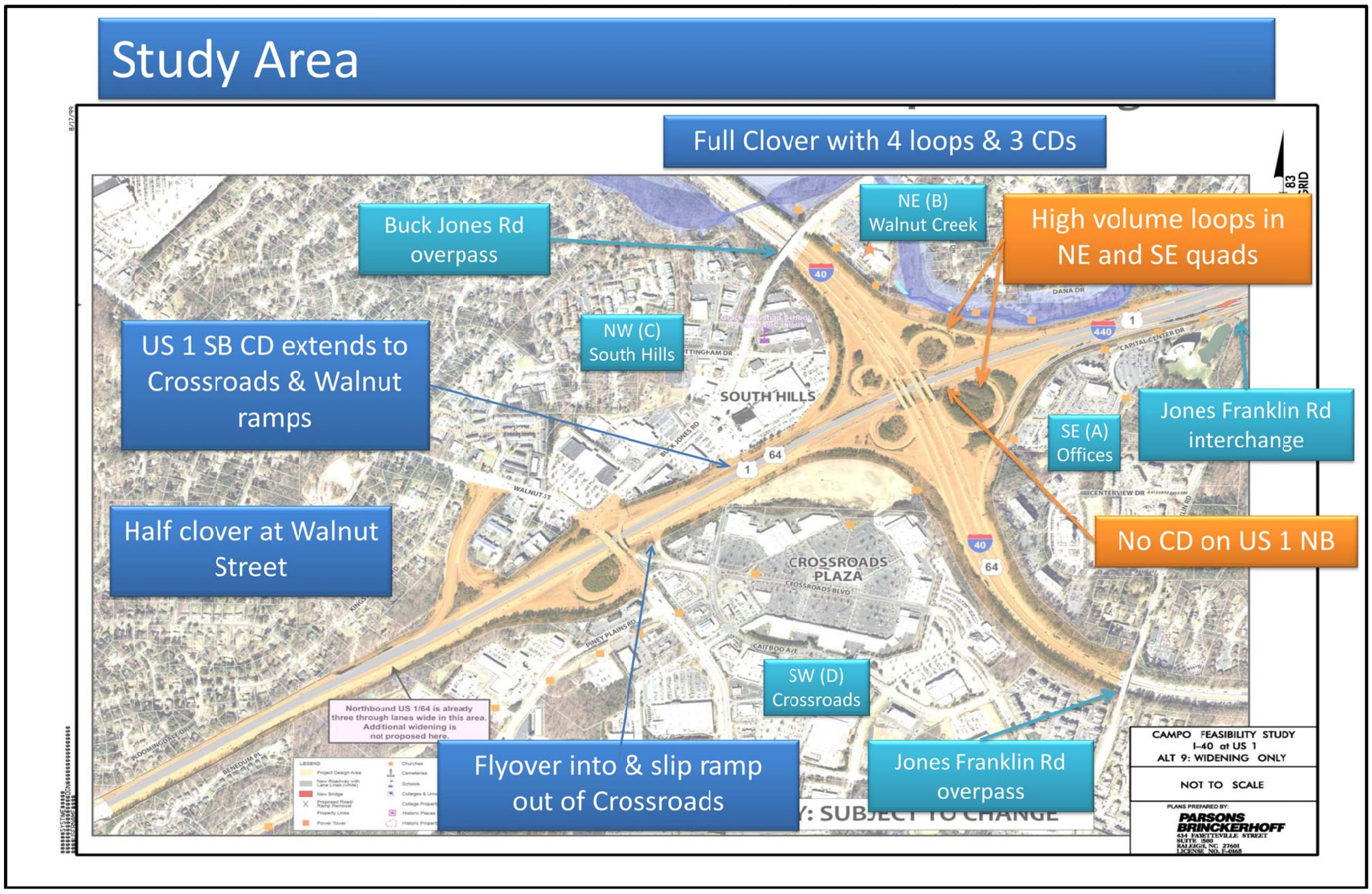
The Interchange is a full cloverleaf interchange with four loops and three collector-distributors (CD). It is identified at Exit #293 on I-40 and is located between and adjacent to the Town of Cary, unincorporated Wake County, and the City of Raleigh. An adjacent interchange at Walnut Street, west of the Interchange, is connected with the southbound US 1/westbound US 64 CD. Between the Walnut Street and I-40 interchanges there is a flyover and slip ramp to allow traffic from I-40 and US 1 to the north to access the Crossroads area directly.

Approximately 200,000 vehicles per day travel through the Interchange. The highest volume connector is I-40. The high volume results in traffic congestion, particularly for the US 1 northbound to I-40 westbound directions during the morning, and on the I-40 westbound in the evenings.

General commerce and retail destinations are in Crossroads Shopping Center (southwest quadrant of the Interchange) and shops at South Hills Mall and Plaza (northwest quadrant of the Interchange). Accesses to these sites are generally through the US 1/westbound US 64 CD to the Walnut Street interchange and direct ramps. The Center Drive Business Park and other businesses are the primary feature in the southeast quadrant. The key environmental feature in the area is Walnut Creek which is located adjacent to the existing interchange in the northeast quadrant. The study area is shown in Figure A-1

To provide consistency in the discussion of key issues and impacts based on the plan layouts, the quadrants were named based upon the plan layout that showed US 1 going from left to right and I-40 going from bottom to top. Using this layout, the assumption was made and is utilized throughout this report using the northwest (NW), northeast (NE), southwest (SW), and southeast (SE) as defined in the bullets above. This nomenclature is used throughout this report.

Figure A-1. Project Study Area



A.2. Review of Previous and Ongoing Studies and Projects

The Interchange is an important link and would overlap multiple NCDOT projects, their funding prioritization processes, and current environmental studies. Therefore, existing and ongoing transportation studies within the study area were reviewed. Key items identified during the review include:

- Considered and recommended interchange alternatives
- Impacts due to the proposed improvements
- Availability of traffic forecast information or existing traffic counts
- Environmental and cultural features

Recently completed, ongoing and planned projects adjacent to the study area are listed in Table 1 and shown in Figure A-2. Funding status is based on NCDOT STIP from May 2015 and CAMPO's 2040 Metropolitan Transportation Plan (MTP). The majority of I-40 projects are identified in the STIP as programmed for planning and design only with the purpose of expediting a new statewide STI project on the corridor.

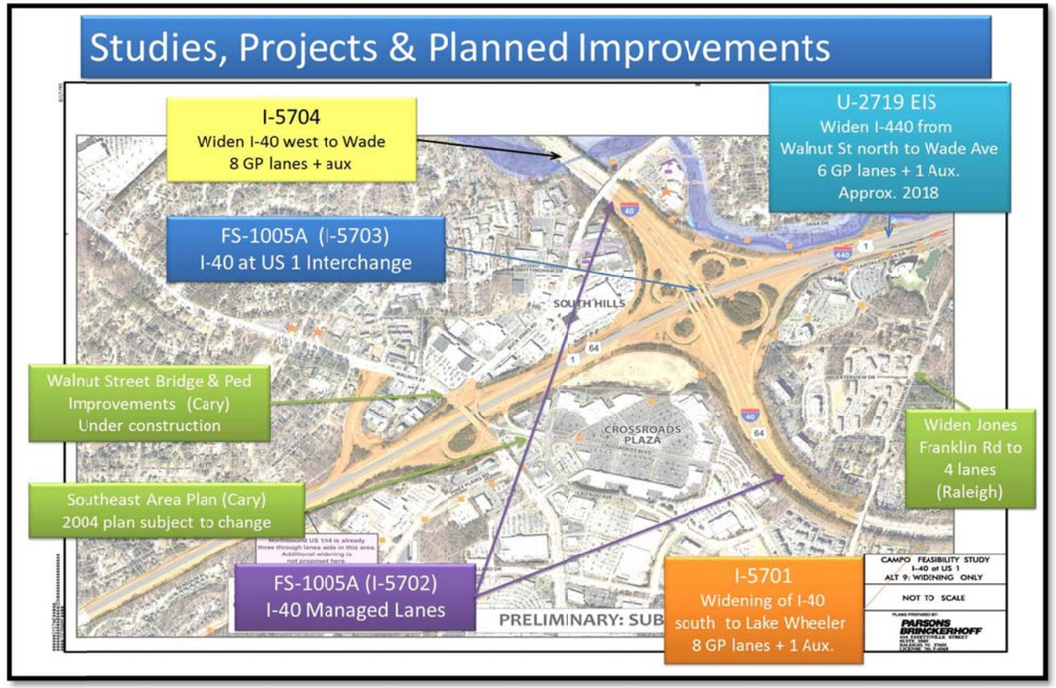
Local municipalities have also identified the following projects:

- Raleigh: Widening Jones Franklin Road to 4 lanes (MTP - A560b in 2040)
- Cary: Walnut Street Bridge realignment and pedestrian improvements (under construction)

Table 1. Status of Adjacent and Overlapping Projects

Roadway	Location	Improvement	Related Studies	MTP Year & Project	NCDOT Project Number & STIP Funding
I-40	West of Interchange to Wade Avenue	Widen from 6 to 8 lanes		2020 F16	I-5704 programmed for planning/design only
I-40	East of Interchange to Lake Wheeler Rd	Widen from 6 to 8 lanes		2020 F43	I-5701 programmed for planning/design only
I-440	North of interchange to Wade Avenue	Widen from 4 to 6 lanes	U-2719 EA being developed	2030 F10	U-2719 2018 – begin construction
I-40 Managed Lanes (Toll)	I-40 from Wade Avenue to Johnston County	Add 2 managed lanes (1 per direction per MTP)	FS-1005A feasibility study	2030 F41	I-5702 programmed for planning/design only.
I-40 Interchange at US 1/ I-440/ US 64	Study interchange	Long term solution for general purpose & managed lanes	FS-1005A feasibility study	2030 F43 (partial)	I-5703 programmed for planning/design only.

Figure A-2. Studies, Projects & Planned Improvements



B. Existing & No-Build Conditions

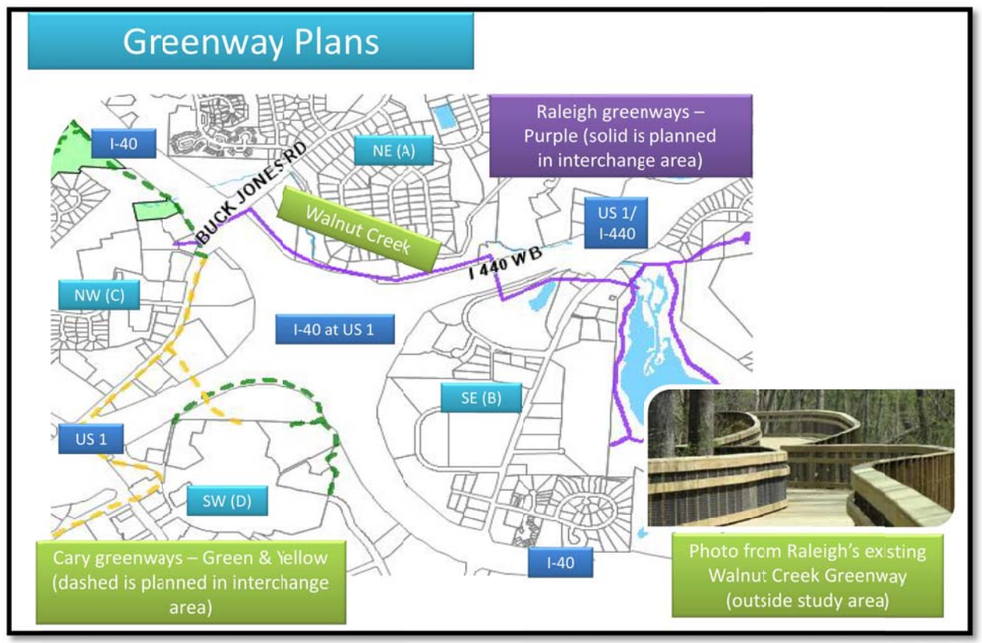
The initial steps in determining potential improvements at the Interchange involve understanding existing conditions as well as assessing future conditions if no improvements are made to the existing interchange layout. This step requires a review of the existing area for key land use as well as natural and cultural resources. In addition, analysis of traffic volumes and traffic operations and an identification of roadway issues is required.

B.1 Environmental / Cultural Features

A review of existing potentially sensitive natural and cultural resources was conducted for the study area. The review was based on existing information that is part of the U-2719 I-440 Improvements Environmental Impact Statement (EIS). The key natural feature was Walnut Creek and related flood plain in the northeast quadrant. No historical or other cultural resources were noted adjacent to the interchange area.

As part of the review of Walnut Creek, additional information was identified regarding long range plans for greenways in the area. As shown in Figure B-1, greenways are planned in 3 of the 4 quadrants. This includes a greenway planned to roughly parallel Walnut Creek in the northeast quadrant. On the west side of I-40, Cary has planned greenways along Buck Jones Road and Walnut Street. Linkages would be extended to provide access through and around the Crossroads area. After review, it was identified that the provision of greenways and sidewalks would be outside the required ROW for I-40 and US 1.

Figure B-1. Greenway Plans



B.2 Land Use

In addition, a review of land use in each of the interchange quadrants was conducted as part of the study. The land use and natural resources in the study area are listed in Table 2 and shown in Figure B-2. Graphical presentations of key land use and environmental/cultural features for each quadrant are included in Figures B-3 through B-6. The potential impact areas are illustrated separately for each quadrant.

Table 3. Potential Impact Areas & Resources

Quadrant	Figure	Key Developments	Natural Resources	Other
Northwest South Hills Mall	B-3A	South Hills Mall & Grace Christian School	None	none
Southwest Crossroads	B-3B	Crossroads Shopping Center & Access Ramps	Undeveloped property	Overhead Power Lines
Southeast Office	B-3C	Office Park	None	Overhead Power Lines
Northeast Walnut Creek	B-3D	Grace Christian School	Walnut Creek	Walnut Creek Greenway planned by City of Raleigh

Figure B-2. Key Features of Study Area

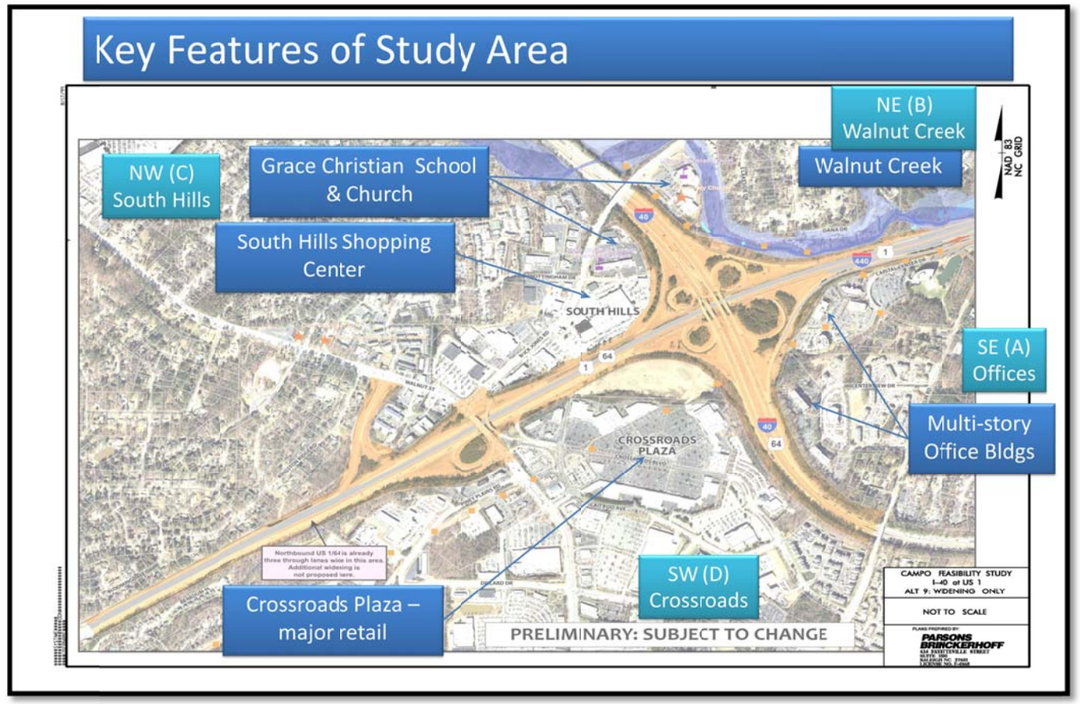


Figure B-3. SE Quadrant (A) – Center Drive Business Park

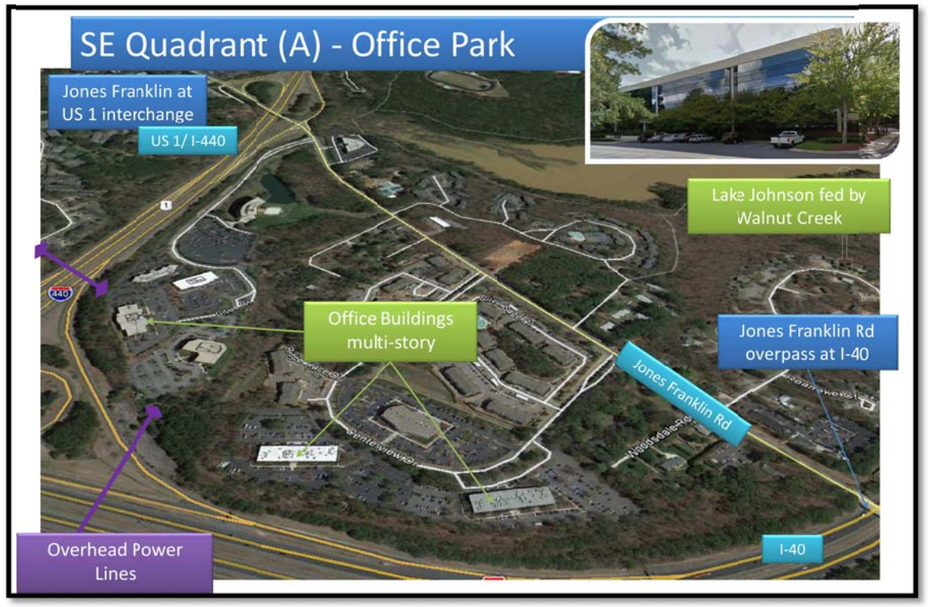


Figure B-4. NE Quadrant (B) – Walnut Creek

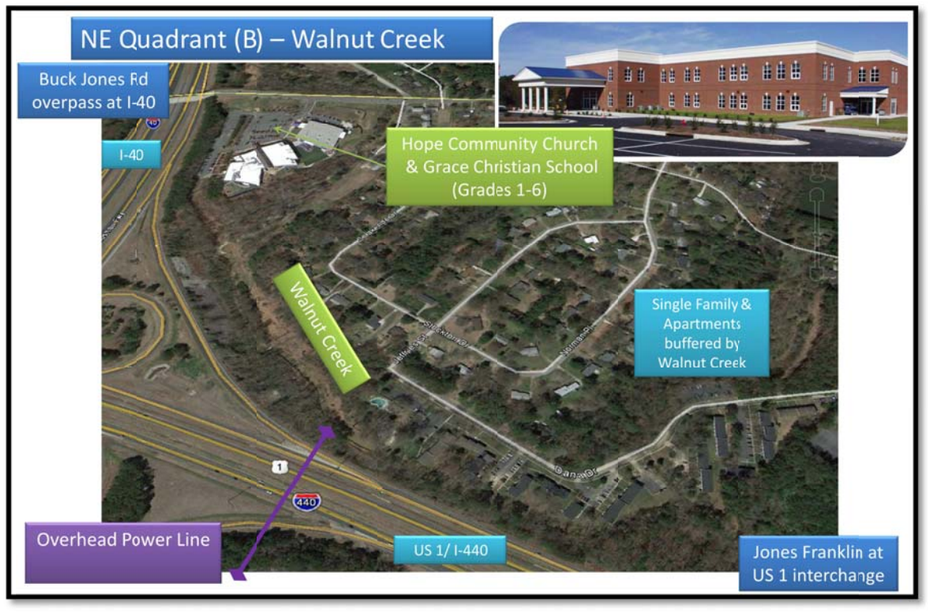
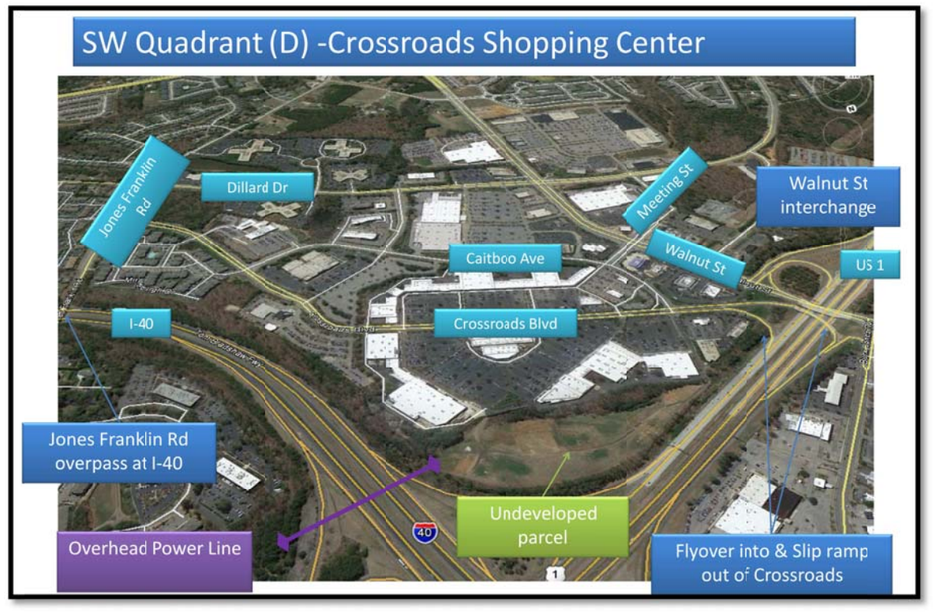


Figure B-5. NW Quadrant (C) – South Hills Mall & Plaza

Figure B-6. SW Quadrant (D) – Crossroads Shopping Center



B.3 Traffic Volumes & Operations

The primary driver for improvements to the existing interchange is high traffic volumes on both I-40 and US 1. These volumes are anticipated to increase further in the future.

B.3.1 Data Collection & Field Observations

A field visit was conducted to identify critical impact areas. Current traffic operation conditions, key junctions, weaves, merges, and diverges that impact traffic flow were identified. In addition, a review of previous and ongoing transportation studies was conducted. No field traffic counts were conducted as part of this study. Instead, available data from NCDOT and other studies were utilized.

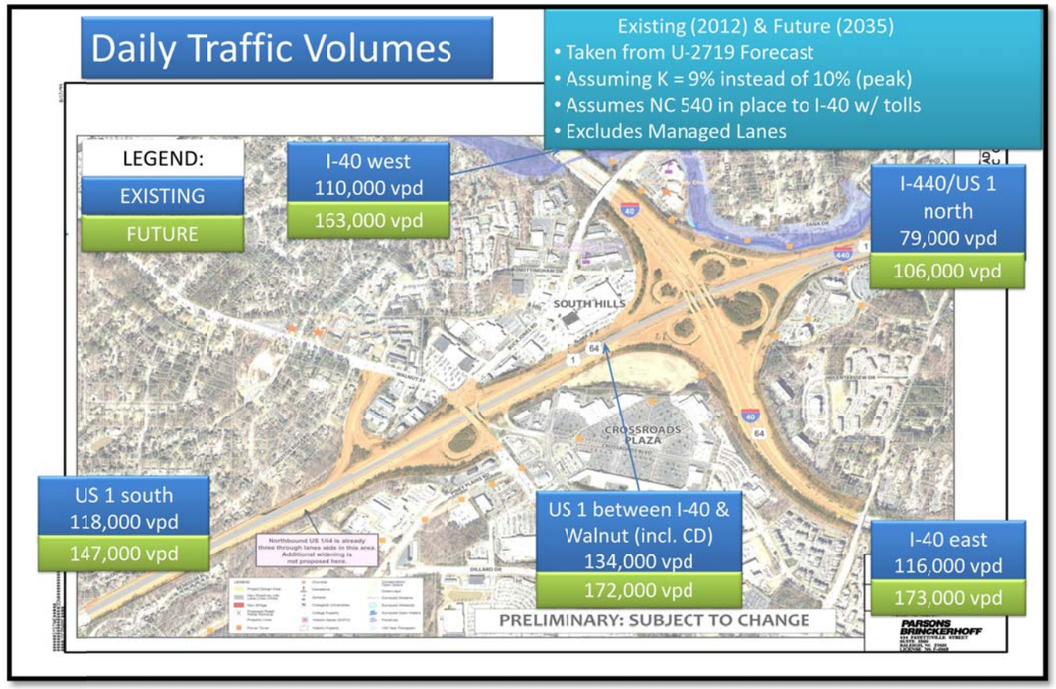
Key observations include:

- The I-40 westbound weave serves two high volume loops with resulting queues extending past the CD and into mainline I-40 westbound traffic. Recurring queues of up to 1 mile are observed on I-40.
- US 1 northbound has recurring queues that extend up to one mile. The current queues are the result of two capacity issues:
  - For US 1 northbound, the number of through lanes narrows down to two lanes north of the I-40 interchange. As a result, traffic avoids the leftmost lane in anticipation of the drop.
  - The US 1 northbound section includes a weave between two loops. Due to the high volume on the SE quadrant loop and the lack of a CD system in this direction, significant delays and queuing are noted as part of weave operations.
- US 1 southbound is split into a separated CD and through lanes. The CD section encounters delays due to slow moving and weaving traffic. Primary issues are:
  - The weave between the two loop ramps carries high volume traffic from I-40 westbound. In addition to weaving, this traffic must accelerate uphill to reach the speed limit.
  - A second weave occurs between the main ramp from I-40 eastbound to US 1 southbound and the existing Crossroads flyover. The primary reason this weave is functioning is that traffic from the CD does not need to switch lanes to exit at the three lane exit to the Crossroads flyover.

B.3.2 Traffic Volumes

Daily traffic volumes and peak volumes were determined from the U-2719 (I-440 Environmental Assessment) traffic forecast for the existing (2012) and future (2035) conditions for the study area. The existing and future daily traffic are summarized in Figure B-7.

Figure B-7. Daily Traffic Volumes

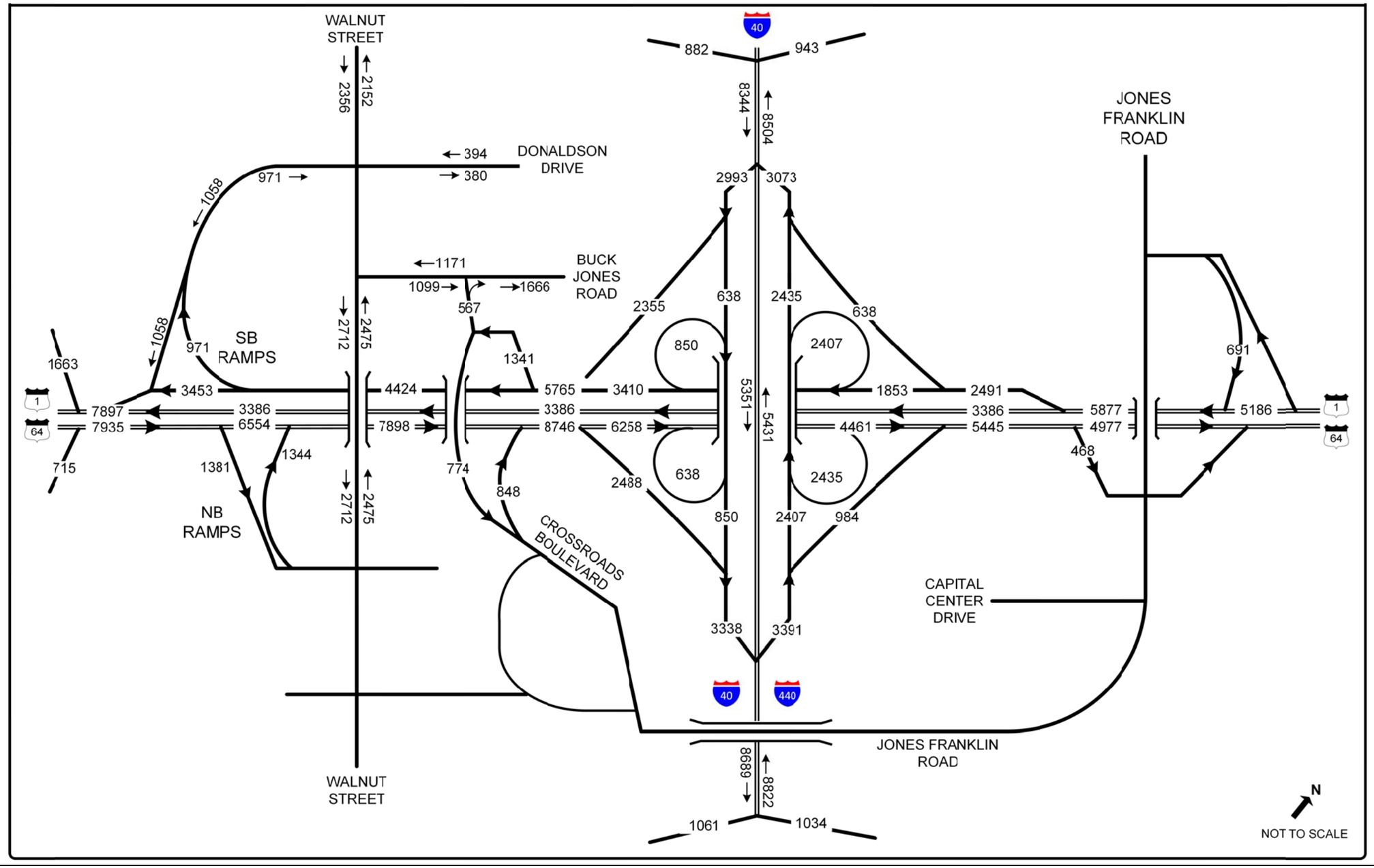


For this study, some adjustments to U-2712 forecast were assumed after discussions at the project kick-off meeting. These adjustments included:

- K factor of 9 percent instead of 10 percent (for peak operations)
- NC 540 will be in place with tolls by 2035
- Managed lanes were not included in the forecast
- The peak hour was combined (AM peak for US 1 northbound and I-40 westbound, PM peak for US 1 southbound and I-40 eastbound) for a worst case analysis.
- For the four existing loops, the AM and PM peak volumes were compared and the higher volume was modeled for a worst case analysis.

Using the adjusted traffic forecast, an origin destination matrix was developed and assigned to a TransModeler network. For each alternative, the trip assignment varied to reflect differences in ramp connections and access to local roads. A summary of the peak period No-Build traffic volumes is provided in Figure B-8.

Figure B-8. 2035 No Build – Peak Hour Demand



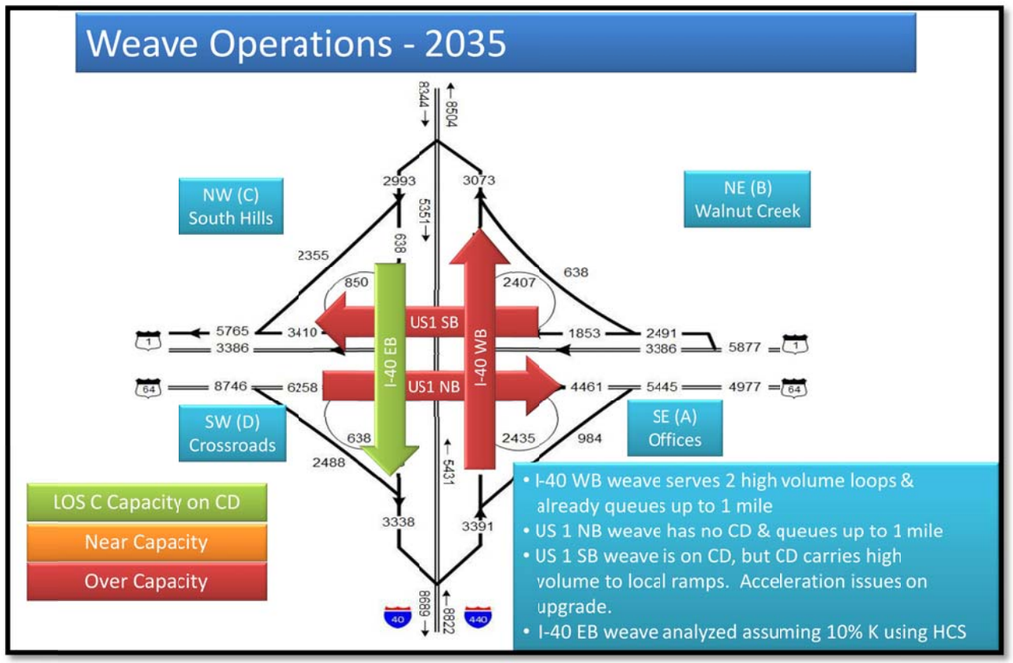
B.3.3 Capacity Analysis – No Build

In reviewing the volumes, multiple traffic analysis tools were applied. Ramp volumes were examined using volume to capacity ratios to identify which ramps would need 1 or 2 lanes. Weave analysis was conducted using primarily Highway Capacity Software (HCS 2010). In addition, analysis done as part of previous studies was utilized if available.

Analysis of 2035 weave capacity indicated that three of the four existing weaves will exceed capacity in 2035. (Figure B-9)

- The I-40 westbound weave already operates at LOS F during peak periods due to heavy volumes on both ramps. The off peak level of service will continue to deteriorate in the future as volumes are anticipated to exceed 2,200 vph on both loop ramps (which would require dual lane loops separate from any weaving considerations).
- The US 1 northbound weave also operates at LOS F during existing conditions. A primary reason is the lack of a separated CD system in this direction.
- The US 1 southbound weave is also anticipated to reach LOS F in the future.
- Nevertheless, the I-40 eastbound weave is anticipated to operate at LOS C based on HCS analysis. This section has a separated CD system and serves two lower volume loops. This observation provides some opportunity for utilizing the NW and SW loops as part of interchange concepts.

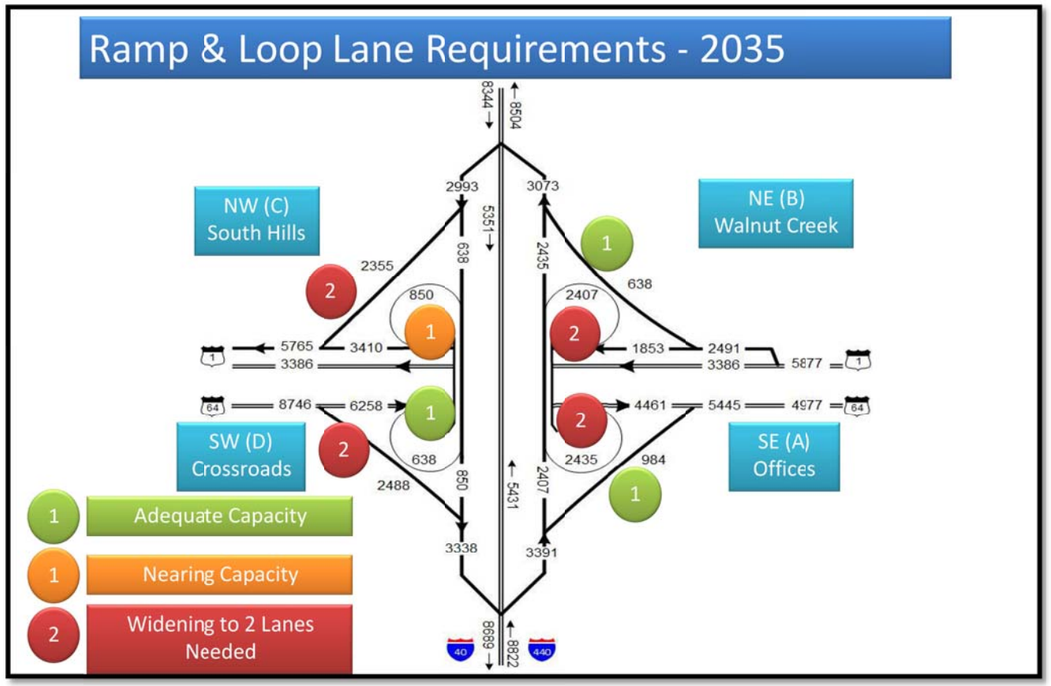
Figure B-9. Weave Operations - 2035



Analysis of ramp capacity with future (2035) conditions identified the following issues:

- Of the 8 ramps in the current full clover interchange, 4 are anticipated to require two lanes by 2035 and 4 could remain single lane ramps. (Figure B-10) The two lane ramps serve traffic to/from US 1 to the south and the one lane ramps support movements to/from US 1/I-440 to the north. The ramps and loops requiring two lanes are:
  - Ramp from US 1 NB to I-40 EB.
  - SE quadrant Loop from US 1 NB to I-40 WB.
  - Ramp from I-40 EB to US 1 SB.
  - NE quadrant Loop from I-40 WB to US 1 SB.
- Two-lane exit and entrances are needed for all CDs from I-40 and US 1. Note that for purposes of this study, detailed analysis of the tie-ins of CD lanes with I-40 were not conducted since these tie-ins would not vary significantly between alternatives.

Figure B-10. Ramp & Loop Lane Requirements - 2035

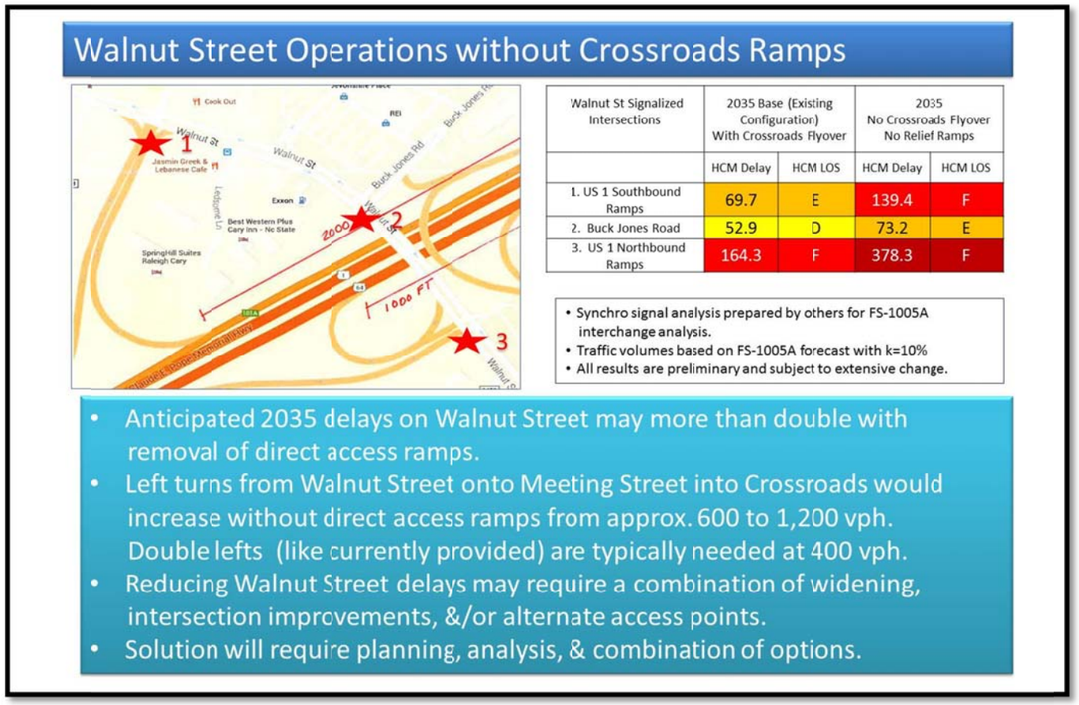


B.3.4 Access to/from Crossroads

A signal analysis on Walnut Street was examined by others as part of the FS-1005A study. The purpose of this analysis was to compare the signal operations at the Walnut Street/ US 1 interchange if the existing direct ramps to/from Crossroads were closed requiring that traffic to utilize the Walnut Street interchange.

As shown in Figure B-11, LOS E and F congestion is anticipated even with the Crossroads ramps maintained. If the Crossroads ramps are removed, traffic congestion expected to reach extreme LOS F congestion. Based on this review, it was determined that mitigation would likely be required if the Crossroads ramps were to be removed. A more detailed review of this issue is included in Section D.

Figure B-11. Walnut Street Operations without Crossroads Ramps



B.4. Key Roadway Issues

An assessment of the existing interchange design was conducted based on reviews of ongoing studies, aerial photography, and field conditions. This assessment reveals:

- Structural constraints: Each bridge was examined to identify the maximum potential cross section. The results are shown in Figure B-12. Note that, in some cases, the maximum allowable laneage is subject to design exceptions on shoulder widths and offsets.
- Utility constraints: The alignment of a major overhead utility power line was identified in the interchange area crossing I-40 and US 1. See Figure B-13.

Figure B-12. Horizontal Clearance at Existing Bridge Spans

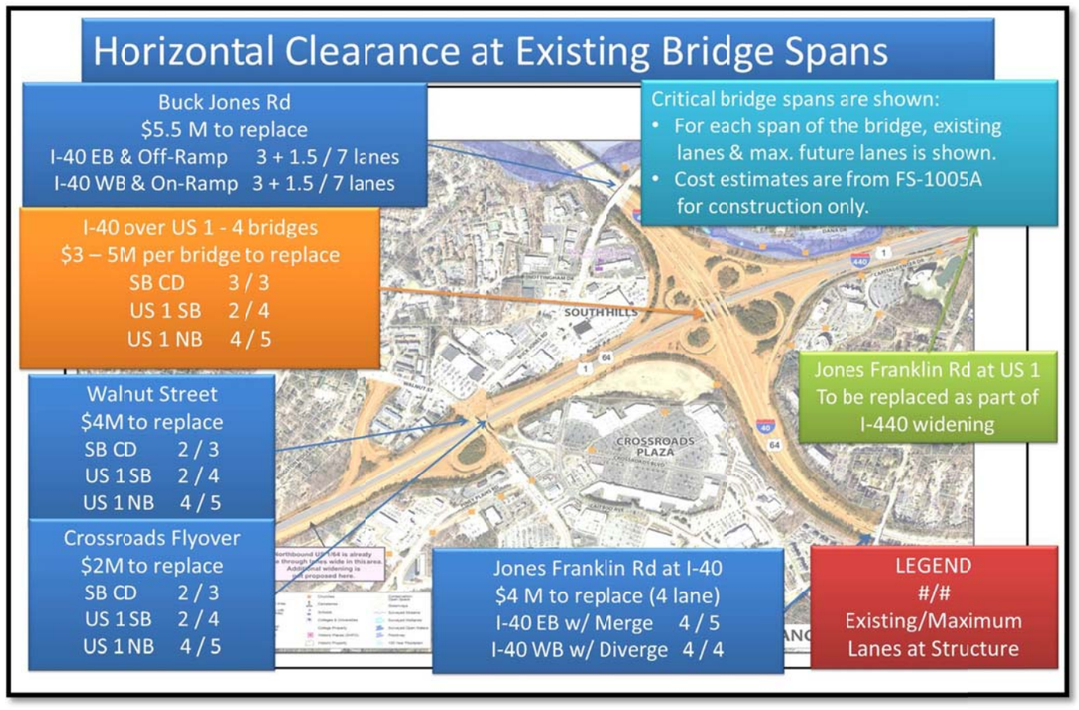
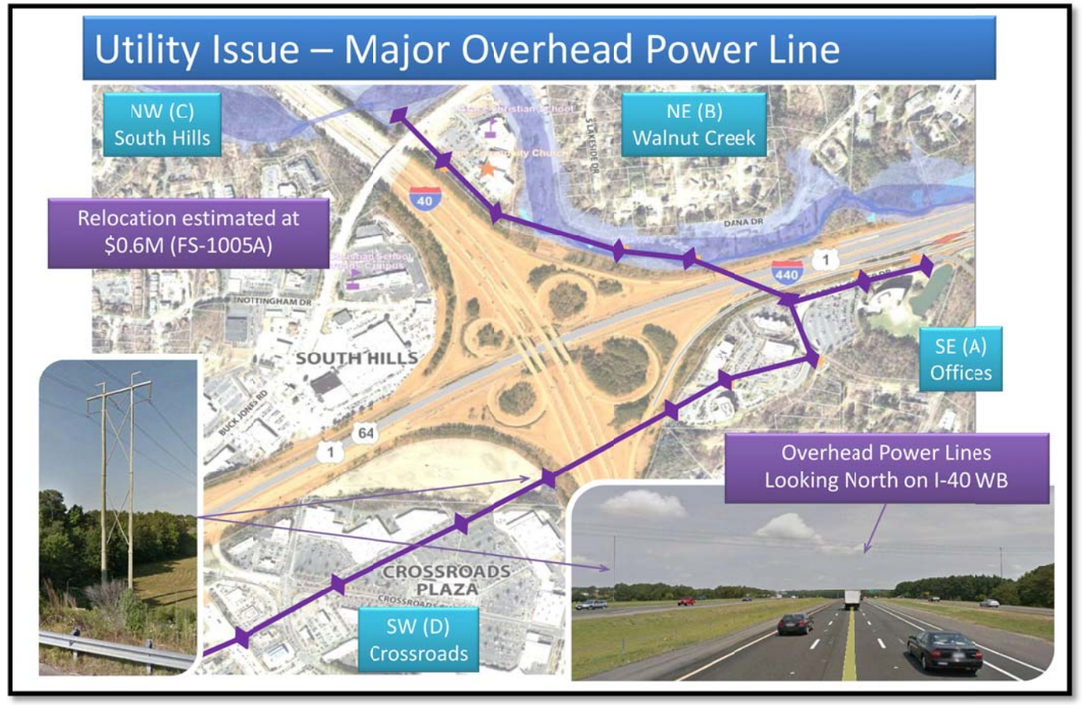


Figure B-13. Utility Issue – Major Overhead Power Line



C. Evaluation of Transportation Improvements – Brainstorming Session

C.1 Initial Screening Process

A brainstorming meeting was held on June 4, 2015 to identify viable interchange alternatives and concepts for the project. The meeting was attended by key stakeholders in the area including the NC Capital Area MPO, NCDOT, City of Raleigh, and the Town of Cary. Parsons Brinckerhoff facilitated the discussion. Overall, there were 21 attendees.

The Brainstorming meeting was divided into the following key agenda items:

- Meeting Goals
- Overview of Project & Key Issues
- Review of Initial Concepts
- Breakout Groups for Additional Brainstorming
- Group Presentation of Concepts
- Evaluation & Discussion
- Recommendation of 2 Concepts for Additional Analysis

C.1.1. Comparison of Interchange Concepts – Brainstorming Meeting

After a review of key features and design issues, the meeting focused on an overview of potential interchange concepts. The concepts were divided into five types including:

- Dual Loop Concepts
- Stack Interchanges
- Box Interchanges
- Turbine Interchanges
- Windmill Interchanges

Variations were presented for each concept type. A conceptual design and layout of each variation were presented along with identification of key positives, negatives, and other factors to consider. If the variation was based on a previous design from another study, the source was identified.

C.1.2 Ranking Methodology

A summary matrix was presented focusing on six key factors in comparing each design option. These six factors included:

- ***Traffic Patterns***: Focused on I-40 and US 1 through traffic and high volume ramps.
- ***Crossroads Access***: Evaluated how well and in what manner access to Crossroads is maintained.
- ***ROW and Related Impacts***: Identified likely impacts to South Hills Mall and Plaza in the northwest quadrant, office buildings in the southeast quadrant, and environmental impacts to Walnut Creek in the northeast quadrant.
- ***Structure Requirements***: Structural challenges considered in the evaluation include the overall lengths and complexity of structural elements as well as the need for three or four-level structures.
- ***Maintenance of Traffic Issues***: A planning level assessment of the viability and ease of MOT during construction.
- ***Implementation of Future Managed Lanes***: Key challenges and opportunities as well as the overall scale of providing a future managed lanes connection to US 1 from I-40 managed lanes.

For each of these factors, a grading system ranging from 1 to 5 (with 1 being Exceptional to 5 being Very Poor or Difficult) was applied. For this grading process, each of the six key factors noted above were equally weighted and an overall average score was assigned for each interchange considered. In addition to the numerical scoring, a series of colors was applied ranging from dark green to pink to provide a visual comparison of the interchanges.

Note that this method was utilized for comparison of specific interchange concepts within each of the five major concept types and was used for initial comparisons only – not as a determinant of a final preferred alternative. The reason for this distinction is that it simpler and more effective in comparing similar features to determine whether a minor variation provides improvements or works more effectively. When comparing differing alternative types, however, the differences between specific features and their impact on a specific criterion are more subjective and more difficult to compare directly using absolute scores.

Exceptional =1	Desirable =2	Acceptable = 3	Poor/ Difficult = 4	Very Poor/Very Difficult = 5	Fatal = 10

C.1.3 Planning Level of Design

The direction for this project was to examine multiple interchange operations from a planning level perspective in a compressed two-month schedule. As a result, the level of design does not meet and is not intended to meet normal NCDOT design requirements for preliminary design. Instead it is intended to focus on selecting a viable interchange type and identify key design features applicable for the interchange. As such it is anticipated that all proposed concepts and design ideas will need more refined review at a later planning and/or design stage.

Based on this approach to the design concepts, multiple assumptions were made in order to maximize the number of alternatives under review. Key assumptions include:

- The alignment geometry is shown with consideration of the roadway design speed, but reverse curves were used in lieu of tangents and spirals, so the alignments will need to be refined and designed for superelevation once a final design is selected.
- Vertical profiles were not developed for this study but there were cursory reviews in some instances to verify viability of the horizontal geometry. In those cases, 25 feet of clearance was assumed (17 feet of vertical clearance plus a conservative 8 foot structure depth).
- 12 foot lane widths are shown in some instances for simplicity in lieu of required ramp widths.
- Design exceptions for shoulder widths are assumed under some bridges where needed to provide additional lane(s).
- Retaining walls are approximated graphically but precise locations and limits not based on vertical profiles.
- The use of straddle bents is assumed for proposed bridges with large skews.
- The designs and widening shown with this study do not consider the location of longitudinal concrete pavement joints or other pavement details.

C.2 Alternative Concepts Evaluated in Brainstorming

Each of the five types of concepts developed in the Initial Screening process were presented and discussed as part of the Brainstorming meeting. The key findings for each interchange type are presented below:

C.2.1. Dual Loop Concepts

Three concepts were examined and compared in a matrix format. The key component of these concepts was the use of existing loops in opposing quadrants to eliminate weaves along both I-40 and US 1. To accomplish this, dual flyovers are required to replace the loops to be removed. The three concepts included:

Dual Loop Concepts (See Figure C-1 for a comparison matrix)

- Alternative O-1 from U-2719 – Opposing Loops in the Northwest and Southeast Quadrants with 2 Flyovers (see Figure C-2)
- Alternative O-2 – Refinement of U-2719 Alternative with Opposing Loops in the Northwest and Southeast Quadrants with 2 reduced length Flyovers (see Figure C-3) (Intent was to reduce ROW impacts.)
- Alternative O-3 – Opposing Loops in the Southwest and Northeast Quadrants with 2 Flyovers (see Figure C-4)

A comparison of the three concepts revealed alternatives that will improve overall traffic operations slightly, but have unresolved issues with maintaining access to Crossroads as well as maintenance of traffic during construction. In addition, without more detailed design, it was deemed likely that vertical alignment requirements will result in the need for additional right of way due to alignment challenges being located beyond the existing loop alignments.

General consensus at the Brainstorming meeting was that the Dual Loop concepts will not meet the long range requirements of the interchange. Therefore, these concepts were not discussed in greater detail or considered for additional review.

Figure C-1. Dual Loop Concepts Comparison Matrix

Alt #	Interchange Concept	Source	Traffic Patterns	Crossroads Access	ROW/ Impacts	Structure Requirements	MOT Issues	Implementation of Future Managed Lanes	Score
O-1	**NE & SW Quadrant Flyover with 2 loops (NW & SE)**	I-440 EA Eliminated	No weaves. Maintair 1 low speed loop & 1 dual lane loop. Need to widen some existing ramps.	CD road and merge difficult to provide with higher volume merge areas in NW quadrant. local traffic from I-40 west can be diverted to flyover.	South Hills Mall & Plaza building removed.	2 curved flyover ramps on 3rd & 4th level (1 each). Each crosses loops.	Flyovers overlapping all 4 loops.	Median open for future managed lane ramps. Simpler due to reduced height flyovers	4.2
O-2	**Refinement of NW & SE Loops with Flyovers**	PB variation	No weaves. Maintair 1 low speed loop & 1 dual lane loop.	CD road and merge difficult to provide with higher volume merge areas in NW quadrant. local traffic from I-40 west can be diverted to flyover.	Concept shows minimal impacts to South Hills Mall & Plaza. However, if need to modify alignment in NW & SE quadrant, impacts will increase.	Grading & slope issues at the east and west points 2 flyovers cross in NW & SE quadrants. Increasing distances between the merge points will increase impacts and ROW requirements.	Flyovers realigned to avoid loops. MOT issues where overlapping ramps in NW & SE quads intersect ramps	Median open for future managed lane ramps. Simpler due to reduced height flyovers	3.8
O-3	**SW & NE Loops with Flyovers**	PB variation	No weaves. Maintair 1 low speed loop & 1 dual lane loop.	CD road and merge difficult to provide with higher volume merge areas in NW quadrant. May be able to divert all traffic to CD system, but challenging.	Concept shows minimal impacts to South Hills Mall & Plaza. However, if need to modify alignment in NW & SE quadrant, impacts will increase.	Grading & slope issues at the east and west point 2 flyovers cross. Increasing distances between the merge points will increase impacts and ROW requirements.	Flyovers realigned to avoid loops. MOT issues where overlapping ramps in NE & SW quads intersect ramps	Median open for future managed lane ramps. Similar to Stack with only 2 of 3 bridges to avoid.	3.7

Figure C-2. Alternative O-1

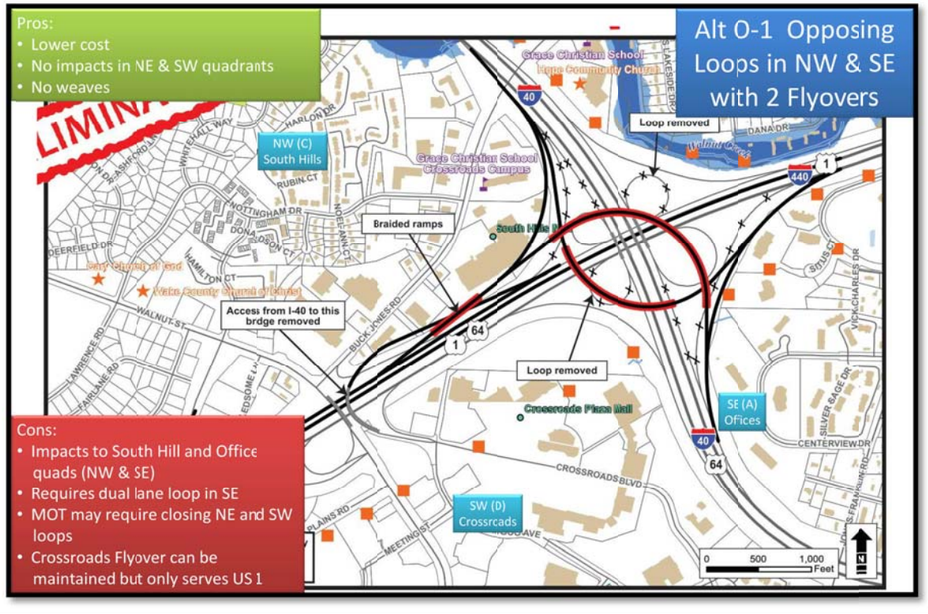


Figure C-3. Alternative O-2

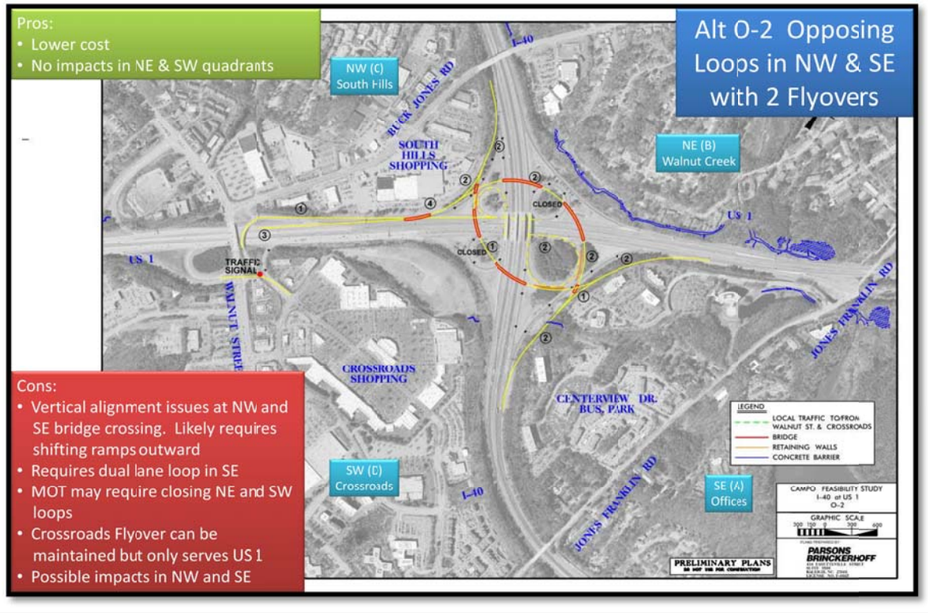
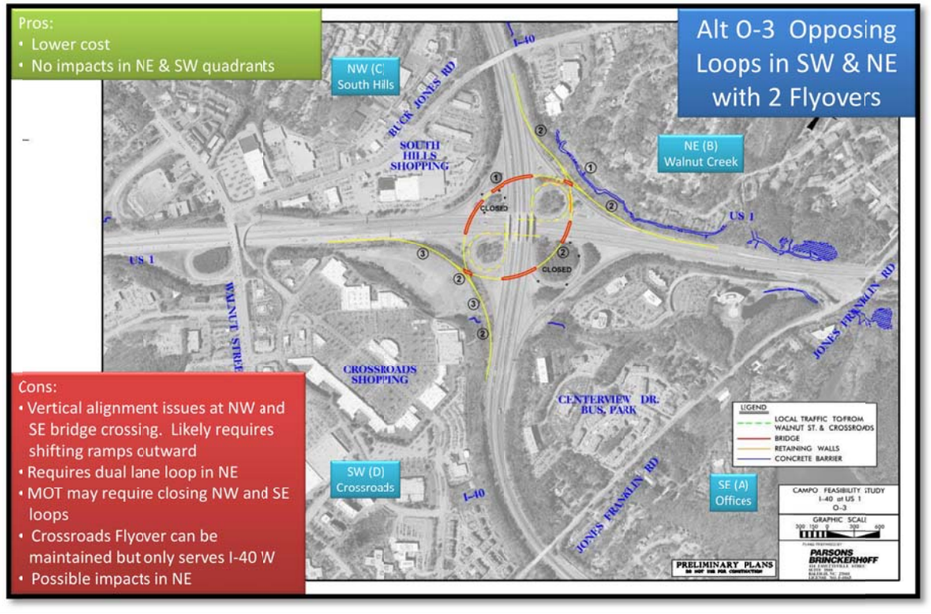


Figure C-4. Alternative O-3



C.2.2. Stack interchanges

For the Stack interchange concepts, the evaluation and comparison focused on the designs presented in the FS-1005A Feasibility Study. As part of the NCDOT feasibility study, a Stack interchange concept was selected as the preferred solution and refined for future consideration. This refined version was also used in estimating costs for the latest round of the STIP project prioritization process. Although the FS-1005A study included the provision of managed lanes as part of the ultimate concept, the evaluation in this CAMPO study focuses on an initial phase without managed lanes (with consideration of managed lanes in the future).

Stack Concepts (See Figure C-5 for a comparison matrix)

- Alternative S-1 from FS-1005A – Stack 1st Iteration (4 Flyovers) (see Figure C-6)
- Alternative S-2 from FS-1005A – Stack 2nd Iteration (3 Flyovers) (see Figure C-7)
- Alternative S-3 from FS-1005A – Modified Stack with 3 Flyovers with Median Used for Managed Lanes (see Figure C-8)

A review of the evaluation matrix for the Stack concepts highlights the observation that this concept provides a very high level of traffic operations for I-40 and US 1 with the provision of direct connections for all high volume movements. The key negatives were the elimination of direct access to Crossroads as well as a high level of ROW impacts including South Hills Shopping Center and possibly office buildings in the southeast quadrant. In addition, impacts to Walnut Creek are likely. It was also noted that although implementation of future managed lanes could be provided with direct ramp connections to the median of US 1, the ultimate provision of managed lanes in the US 1 median will require a 174 foot cross section which is a key reason for ROW impacts to South Hill Shopping Center.

A key discussion point was recognition that the Stack alternative is the solution recommended by NCDOT as part of the FS-1005A Feasibility Study and, as such, it is acknowledged that it should be carried forward as a viable alternative in any future NEPA or other studies. Since the purpose of this study, however, is to examine potential alternatives it was determined that additional refinements were not needed at this time.

It was recommended that Concept S-2 be utilized as a baseline comparison of possible alternatives without additional adjustments.

Figure C-5. Stack Concepts Comparison Matrix

Alt #	Interchange Concept	Source	Traffic Patterns	Crossroads Access	ROW/ Impacts	Structure Requirements	MOT Issues	Implementation of Future Managed Lanes	Score
S-1	Stacked 4 level with 4 flyovers	NCDOT FS-1005A	Fully directional ramps all movements.	Crossroads flyover & slip closed. Jones Franklin interchange likely required.	ROW needed in all 4 quadrants. South Hills Mall & Plaza impacted. Walnut Creek impacted.	4 major curved bridge flyovers. High cost, but less restricted than Box flyovers.	Need to lengthen some flyovers to allow for loops to operate for MOT. New ramp alignments to outside should allow for construction to outside.	Managed lanes likely must use median area with 174 ft cross section for managed lane at tie-in to US 1. Major phasing & reconstruction issues.	3.7
S-2	Stacked 4 level with 3 flyovers & 1 loop	NCDOT FS-1005A	Fully directional ramps except 1 loop.	Crossroads flyover & slip closed. Jones Franklin interchange likely required.	ROW needed in all 4 quadrants. South Hills Mall & Plaza likely impacted. Walnut Creek impacted.	3 major curved bridge flyovers. High cost, but less restricted than flyovers to/from median.	Longer bridges allow for loops to operate for MOT. New ramp alignments to outside should allow for construction to outside.	Managed lanes likely must use median area with 174 ft cross section for managed lane at tie-in to US 1. Major phasing & reconstruction issues.	3.5

Figure C-6. Alternative S-1

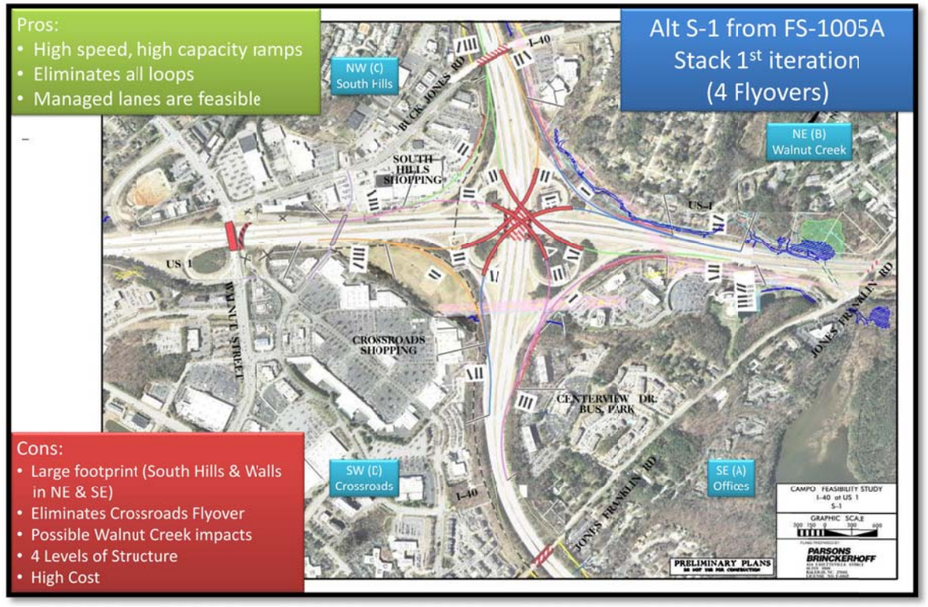


Figure C-7. Alternative S-2

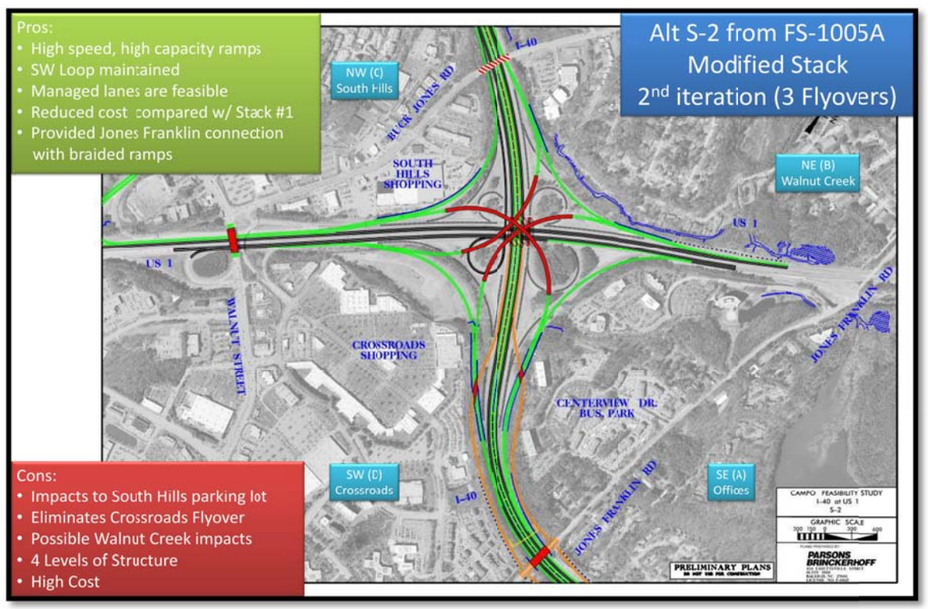
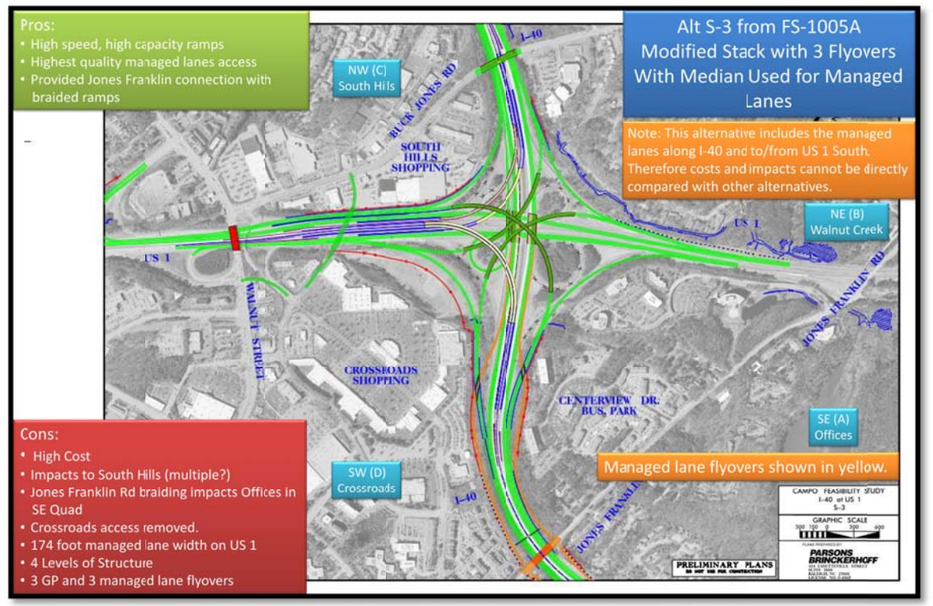


Figure C-8. Alternative S-3



C.2.3 Box Interchanges

A Box interchange concept was considered by NCDOT as part of FS-1005A but not selected for further evaluation. Although the specific reason for this decision was not identified, a key consideration was the difficulty in accommodating future managed lanes with the Box concept. The challenge identified is that the use of the median area on US 1 south of the interchange and on I-40 both west and east of the interchange potentially preclude managed lanes from utilizing the median area without reconstruction of ramps and widening of the median area.

Key features of the Box concept included the use of medians on I-40 and US 1 to provide left entrances and left exits for three of the four left turns at the interchange. The key advantage was limited ROW impacts since the major ramps tied into the median instead of the outside lanes of the freeways. For this study, three variations were considered. B-1 represented the original NCDOT proposal with 3 flyovers. The two proposed variations (B-2 and B-3) provided tie-ins for the critical ramps, but in general functioned similarly.

Box Concepts (Matrix Comparison on C-9)

- Alternative B-1 from FS-1005A – Box with Median Used for General Purpose Flyovers (C-10)
- Alternative B-2– Box with Median Access for General Purpose Flyovers to US 1 South Only (C-11)
- Alternative B-3– Modified Box with 1 General Purpose Flyover Using Median Per Direction (C-12)

In all variations, ROW impacts are low, but traffic operations required left exits and entrances. At the same time, it was noted that there are heavy flows on US 1 northbound to both I-40 west and I-40 east and that there may be traffic operations benefits to separating these key exit points to I-40. The variations did provide more straightforward maintenance of traffic by maintaining the US 1 southbound CD. In terms of scoring, however, each variation scored similarly.

During the brainstorming breakout sessions, there was discussion on potential variations that could further improve the viability of the Box concepts. In addition, it was identified as desirable to preserve the loop in the northwest quadrant to eliminate the flyover from US 1 southbound to I-40 eastbound. Highway Capacity Software analysis confirmed that the weave on the I-40 eastbound CD could be maintained at LOS C in 2035 if the NW loop is preserved.

After discussion, a combination of Concepts B-2 and B-3 was identified that eliminated left exits from I-40 while continuing to use the median access to/from US 1 (to be referenced as B-4).

Figure C-9. Box Concepts Comparison Matrix

Alt #	Interchange Concept	Source	Traffic Patterns	Crossroads Access	ROW/ Impacts	Structure Requirements	MOT Issues	Implementation of Future Managed Lanes	Score
B-1	Box with 3 GP flyovers tying to median	NCDOT FS-1005A	Left exit & entrance unconventional, but does split 2 heaviest turns. Flyovers provided for major moves.	Crossroads flyover & slip closed. Jones Franklin interchange likely required. May be possible to connect local CD access.	Reduced impacts with no alignment changes to outermost ramps. South Hills Mall & Plaza not impacted.	Most difficult structure option with walls & long flyovers.	Can flyovers be constructed over loops under traffic? Construction required on both median and outside of roadway.	Future managed lanes to median would either need to share flyovers, shift GP to new outside flyovers, or not allow direct access from US 1.	3.5
B-2	Box with 2 GP flyovers tying to US 1 median only	PB Variation	Left exit & entrance unconventional, but does split 2 heaviest turns. Flyovers provided for major moves.	Crossroads flyover & slip closed. Jones Franklin interchange likely required. May be possible to connect local CD access.	Reduced impacts with no alignment changes to outermost ramps. South Hills Mall & Plaza not impacted.	Most difficult structure option with walls & long flyovers.	Flyover from US 1 north simplified. Allows for more flexibility.	Future managed lanes to median would need to share flyovers & shift GP to new outside flyovers. Eliminating median ramp to north simplifies future managed lanes compared with Box #1.	3.3
B-3	Box with 2 GP flyovers tying to different medians	PB Variation	Left exit & entrance unconventional, but does split 2 heaviest turns. Flyovers provided for major moves.	Crossroads flyover & slip closed. Jones Franklin interchange likely required. May be possible to connect local CD access.	Reduced impacts with no alignment changes to outermost ramps. South Hills Mall & Plaza not impacted.	Most difficult structure option with walls & long flyovers.	Flyover from US 1 north simplified. Allows for more flexibility.	Future managed lanes to median would need to share flyovers & shift GP to new outside flyovers. Connection to I-40 East is more complicated with I-40 EB to US 1 SB removed from median.	3.5

Figure C-10. Alternative B-1

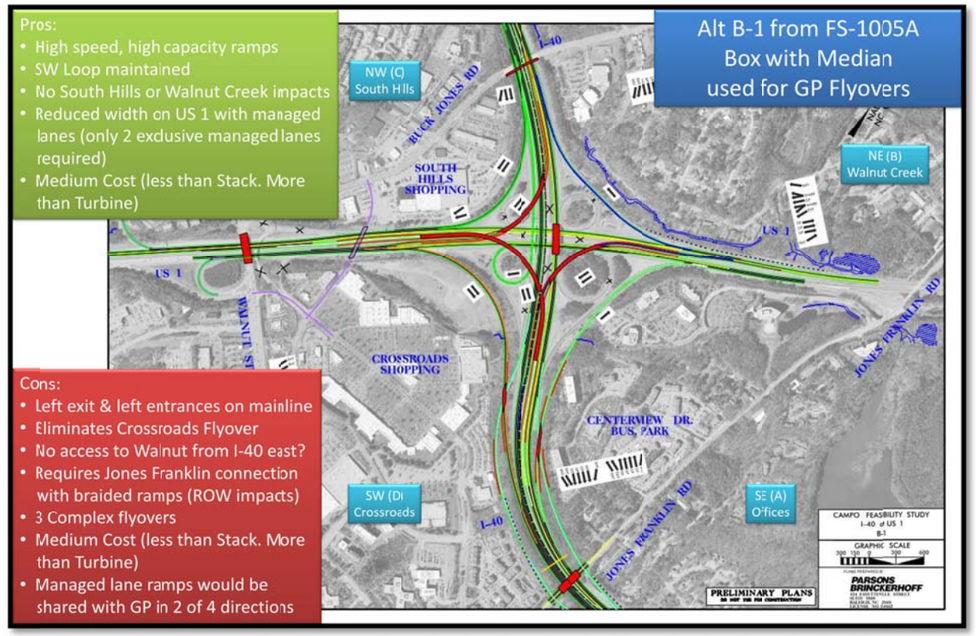


Figure C-11. Alternative B-2

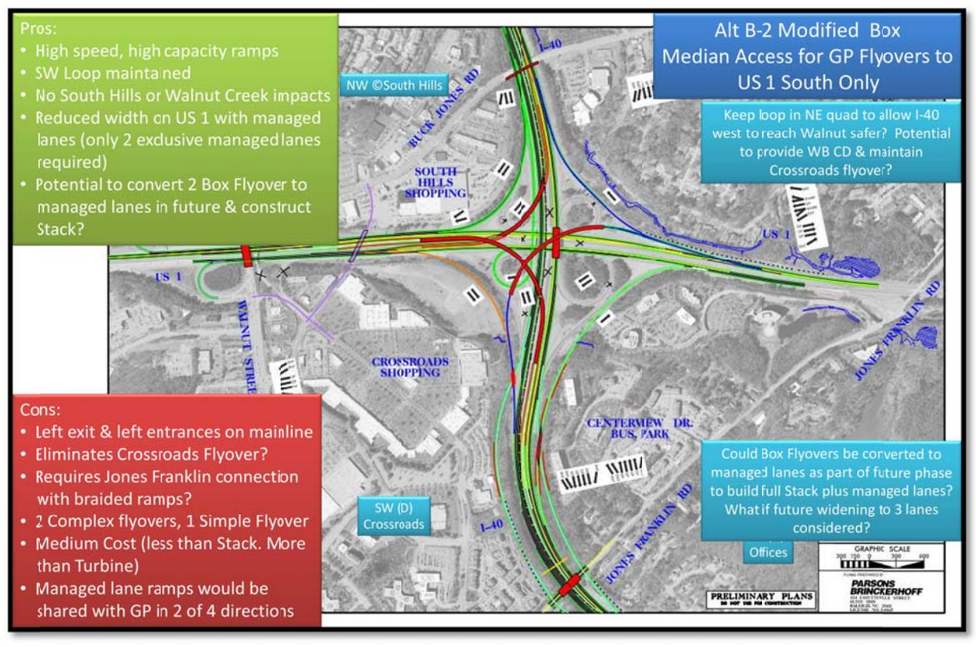
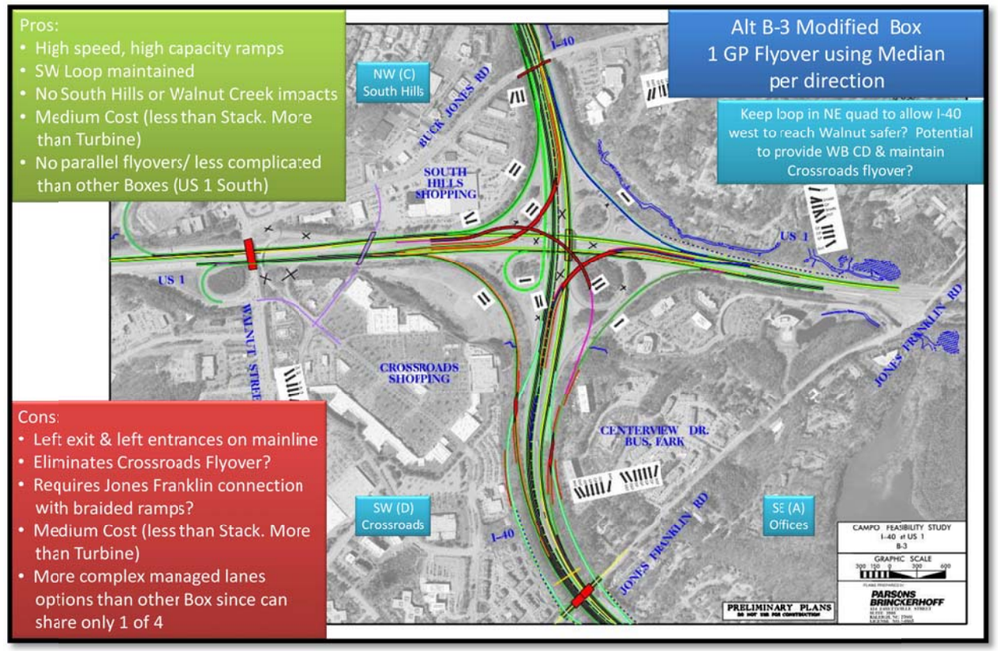


Figure C-12. Alternative B-3



C.2.4 Turbine Interchanges

A Turbine interchange concept was also considered by NCDOT as part of FS-1005A but not selected for further evaluation. Key reasons for elimination of the Turbine included right of way impacts, maintenance of traffic issues with key turbine flyovers overlapping loops, and difficulties with implementing long term managed lane access. Nevertheless, it was evident that the Turbine provided opportunities for reduced construction costs due to utilization of two-level grade separations reducing structural costs.

For this brainstorming analysis, four Turbine options were presented. A matrix comparison of the Turbine concepts is presented in Figure C-13. The concepts evaluated include:

- Alternative T-1 from FS-1005A – Turbine (3/4) (C-14)
- Alternative T-2A – Modified Turbine with 2 Loops and No CD (C-15)
- Alternative T-2B – Modified Turbine with 4 Loops and CD (C-16)
- Alternative T-3 – Flyover Version of Turbine T-2 with CD (C-17)

The alternative concepts included NCDOT's design considered in the FS-1005A feasibility study (T-1) and a similar variation that utilized two loops allowing for one less turbine flyover (T-2). The T-2 option allows for maintenance traffic by setting the flyovers outside of the existing loops and with tighter spacing between flyovers. In preparing concept T-2, two variations were considered for local access: Option T-2A which restricted access to the Crossroads flyover and eliminates two loops and option T-2B which maintains all four existing loops to tie into a CD system that maintains full access to the Crossroads flyover. In addition, a higher speed T-3 variation on the turbine was provided that relied on more conventional flyover connections with a third structural level. Although requiring more expensive structures, the traffic operation is very similar to option T-2B with an assumed CD and four loops in place to maintain local access to Crossroads.

The discussions of the Turbine options focused on multiple features including the potential for lower costs and the ability to maintain traffic during construction. A key benefit was the ability to maintain local access to Crossroads. As part of the discussion, it was noted that HCS analysis indicated that the four loops could be maintained with LOS C weaves using existing collector distributers for three of the resulting weaves. On US 1 northbound, it was identified that a LOS D weave could be maintained, but that some design exceptions would likely be required.

The recommendation from the brainstorming session was to examine the flyover version of the turbine concept (option T-3) in greater detail including more detailed review of local access options. The provision of more conventional flyovers was preferred due to improvements in traffic operations despite the potential cost savings of a true turbine ramp. In addition, the flyovers reduced right of way impacts.

Figure C-13. Turbine Concepts Comparison Matrix

Alt #	Interchange Concept	Source	Traffic Patterns	Crossroads Access	ROW/ Impacts	Structure Requirements	MOT Issues	Implementation of Future Managed Lanes	Score
T-1	3/4 Turbine	NCDOT FS-1005A	Lower speed flyovers - check capacity, 1 lower volume loop.	Crossroads flyover & slip closed. Jones Franklin interchange likely required.	South Hills Mall building removed Potential Walnut Creek impacts, near building in SE quadrant.	Multiple flyover ramps but lower level with turbine.	MOT needs to allow for loops during construction. More difficult with lower level turbine ramps (3)	NCDOT concluded not compatible with managed lanes. Appears that turbine bridges would require managed lanes to reach higher elevation sooner.	4.0
T-2A w/o CD	1/2 Turbine without Local loops	PB variation	Lower speed flyovers - check capacity, 2 loops with LOS C weave.	Crossroad flyover eliminated. All access to Walnut. 1800 ft weave across 4 lanes. Can braid to future Jones Franklin intg.	Minimal South Hills Mall & Plaza impact. Potential Walnut Creek impacts, near building in SE quadrant.	Multiple flyover ramps but lower level with turbine.	MOT simplified & constructible. Some tight spaces, but no high level structures.	Future managed lanes simpler with removal of 3rd turbine and keeping NW loop. Opportunity to shift managed lanes to vacant land.	3.0
T-2B with CD	1/2 Turbine with Local loops & CD	PB variation	Lower speed flyovers, 4 loops with LOS C weave, removing local traffic improves major merge in NW quadrant.	Crossroad flyover access provided with CD & local loops.	Minimal South Hills Mall & Plaza impact. Potential Walnut Creek impacts, near building in SE quadrant.	Multiple flyover ramps but lower level with turbine.	MOT simplified & constructible. Some tight spaces, but no high level structures.	Future managed lanes simpler with removal of 3rd turbine and keeping NW loop. Opportunity to shift managed lanes to vacant land.	2.7
T-3	Higher Speed 1/2 Turbine with Local loops & CD	PB variation	Higher speed flyovers, 4 loops with LOS C weave, removing local traffic improves major merge in NW quadrant.	Crossroad flyover access provided with CD & local loops.	Improved ramp angle & reduced traffic allow NW merge to be shifted away from South Hills. CD can fit into ROW.	2 flyovers span loops and need 3rd level.	MOT simplified & constructible. Some tight spaces, but no high level structures.	Future managed lanes simpler with removal of 3rd turbine and keeping NW loop. Opportunity to shift managed lanes to vacant land.	2.7

Figure C-14. Alternative T-1

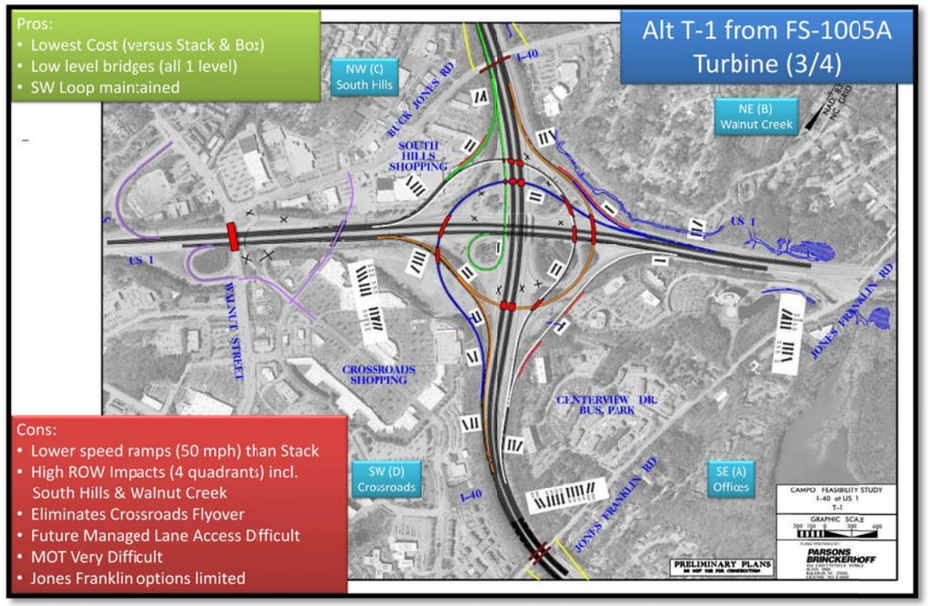


Figure C-15. Alternative T-2A

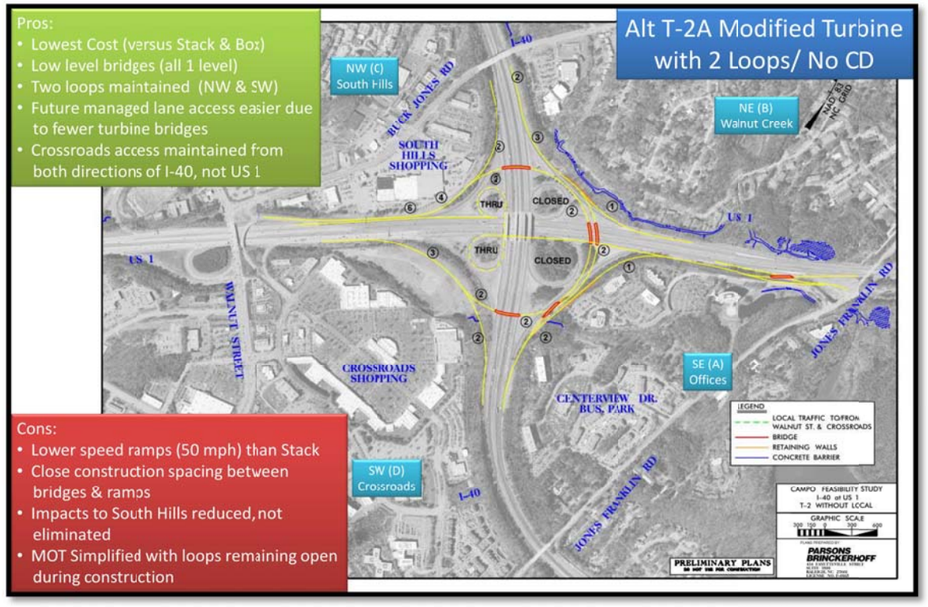


Figure C-16. Alternative T-2B

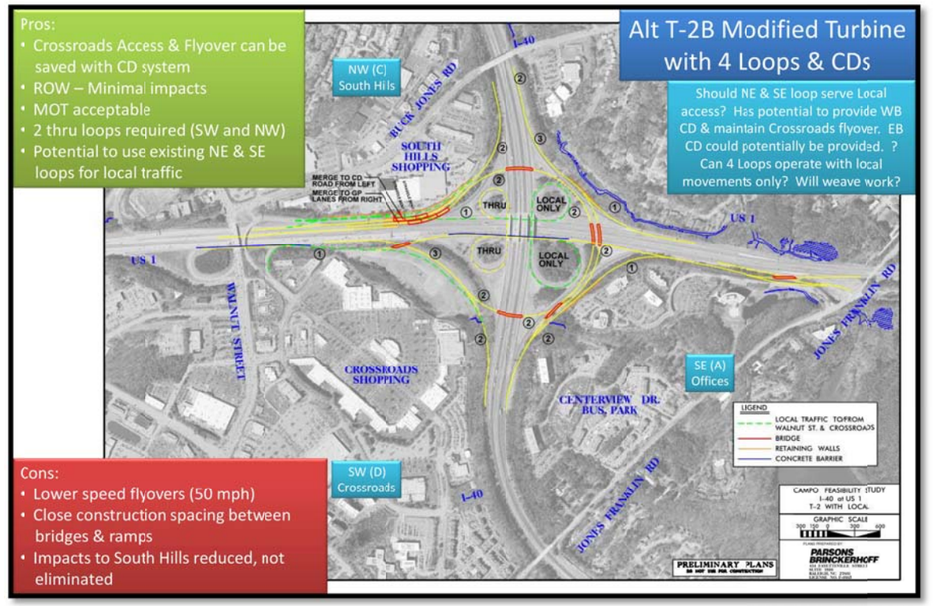
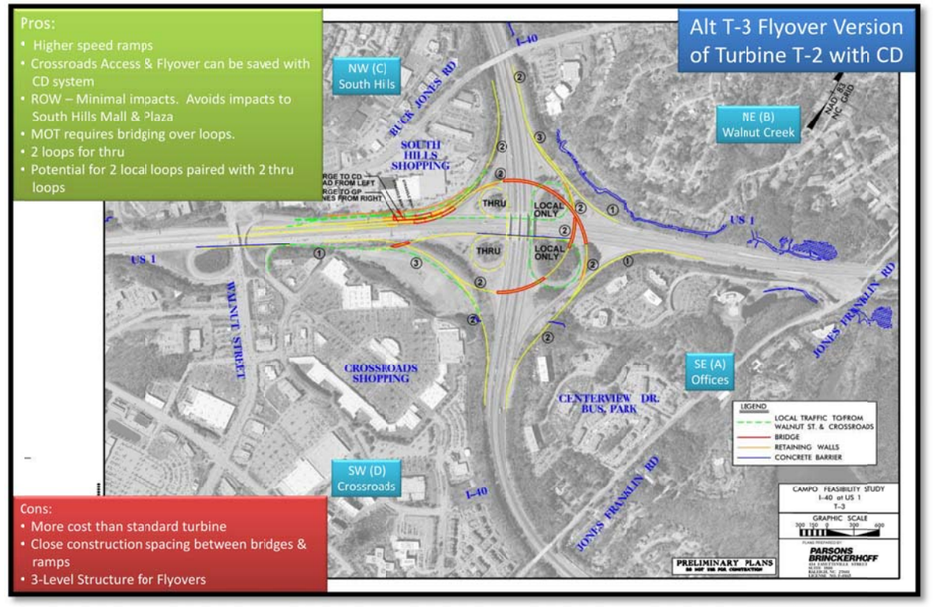


Figure C-17. Alternative T-3



C.2.5. Windmill Interchange Concept

As part of the brainstorming session, an alternative interchange concept was discussed. Based upon a preliminary traffic engineering planning-level sketch, the original concept comprised of taking the existing CD on the right side of the freeway, allowing right turns to exit, increase grade and introduce a left curve to climb over the mainline freeway, and then curve back down onto the CD in the opposite direction to allow for a left turn. This would be done on all 4 approaches.

This concept allowed for the use of left turns to replace loop movements while minimizing ROW impacts. Multiple issues were identified included low design speeds, geometric requirements for crossing over the mainline traffic, and issues with US 1 northbound flow having no CD system. Nevertheless, based on the initial discussions, some stakeholders requested that this option be considered in more detail.

In order to facilitate the determination of a preferred solution, the Windmill concept was examined for application at this location after the Brainstorming meeting. This evaluation focused on geometric issues. The key factor was identifying the amount of distance required to start the CD, raise the grade to provide adequate clearance over the mainline, shift the CD horizontal grade over the mainlines, and then descend back to grade to be able to utilize the existing bridge. Although multiple factors affect this calculation, it was determined for one approach that achieving grade could require 1200 feet to 1600 feet while maintaining a maximum 5 percent grade. Shifting the horizontal alignment for a 35 mph alignment would take 800 feet and require an "S" curve. Overall, this shift required over one-half mile.

Shifting the alignment this far on all four approaches resulted in multiple issues. Most critical, the grade changes would overlap with adjacent bridges crossing the freeway (i.e. Walnut Street and Jones Franklin on US 1 and Buck Jones and Jones Franklin on I-40) on all four approaches. As a result, the shift could not be completed geometrically without reconstructing these bridges on effectively a third level. In addition, the initial observations that ROW impacts would be minimal were inaccurate since with the extended approach of the CD results in impacts and widening of the existing mainline and realignment of the outer ramps into adjacent sections including the SW quadrant office buildings, Walnut Creek, and South Hills. A quick review of the original concept concluded grades would need to exceed 10 percent and design speeds would be reduced below 25 mph on the CD to theoretically work without pushing back the CD exit point.

A comparison on the Windmill as discussed at the Brainstorming meeting (WM-1) with a more refined review based upon the screening review explained above. This comparison is shown in Figure C-18.

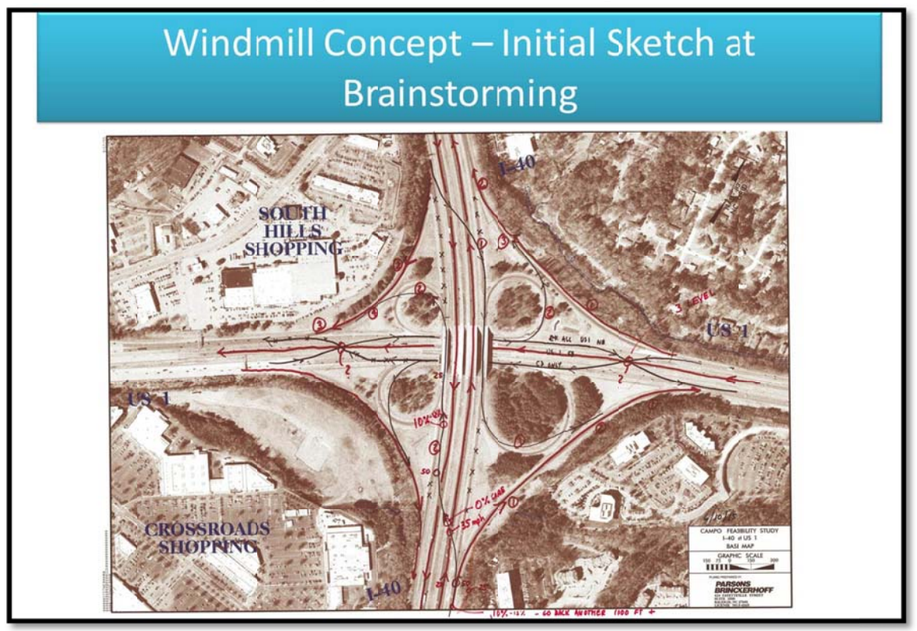
Note that no formal CADD drawings were created for the Windmill concept. For this reason the hand-drawn sketch from the Brainstorming meeting is provided as shown in Figure C-19. As noted above, the actual limits of a refined design would have pulled back approach lanes more than one-half mile instead of as sketched.

Based on this review, the Windmill interchange concept was not examined in more detail.

Figure C-18. Windmill Concept Comparison Matrix

Alt #	Interchange Concept	Source	Traffic Patterns	Crossroads Access	ROW/ Impacts	Structure Requirements	MOT Issues	Implementation of Future Managed Lanes	Score
WM-1	**Shifted DDI Windmill Interchange - Initial Sketch**		Low speed ramps at CD approaches. All turns at 30 mph or less. Left exits from CD ramps.	Crossroads flyover maintained but no direct access from US 1.	Minimal ROW impacts.	Walls and 5 structures required for shifting CDs. Maximum grades exceeded. Structure will require S-curve alignments.	Will require closure of certain ramps and CDs in both directions simultaneously.	Structure construction will be more complicated. Median on I-40 is utilized for overpass transitions.	4.0
WM-2	**Shifted DDI Windmill Interchange - Refined**		Low speed ramps at CD approaches. All turns at 30 mph or less. Left exits from CD ramps.	Crossroads flyover removed due to bridge grades & horizontal shift & overlaps.	ROW impacts to all 4 quadrants. Walnut Creek severely impacted. South Hills Mall & Plaza impacted.	Walls and 5 structures required for shifting CDs. Maximum grades exceeded. Structure will require S-curve alignments. Reconstruct 3rd level at 4 local bridges (Walnut, Buck Jones, & both Jones Franklin.	Will require closure of certain ramps and CDs in both directions simultaneously. MOT issues at 4 adjacent local street bridges.	Bridges shifting over from CD conflict with potential managed lanes ramps. Managed lanes would likely be 4th level at 4 adjacent local street bridges.	4.8

Figure C-19. Windmill Concept



C.2.6. Summary of Concepts from Brainstorming

Based upon the analysis conducted for the Brainstorming, a summary comparison of the top scoring interchanges from the four concepts examined beforehand was presented. (The Windmill was not presented in this format at the Brainstorming since it was developed during the Brainstorming.) Using the same scoring system as presented for each concept type, Figure C-20 was presented.

Figure C-20. Top Interchange Options

Alt #	Interchange Concept	Source	Traffic Patterns	Crossroads Access	ROW/ Impacts	Structure Requirements	MOT Issues	Phasing of Future Managed Lanes	Score
S-2	**Stacked 4 level with 3 flyovers & 1 loop**	NCDOT FS-1005A	Fully directional ramps except 1 loop.	Crossroads flyover & slip closed. Jones Franklin interchange likely required.	ROW needed in all 4 quadrants. South Hills Mall & Plaza likely impacted. Walnut Creek impacted.	3 major curved bridge flyovers. High cost, but less restricted than flyovers to/from median.	Longer bridges allow for loops to operate for MOT. New ramp alignments to outside should allow for construction to outside.	Managed lanes likely must use median area with 174 ft cross section for managed lanes at tie-in to US 1. Major phasing & reconstruction issues.	**3.5**
B-2	**Box with 2 GP flyovers tying to US 1 median only**	PB Variation	Left exit & entrance unconventional, but does split 2 heaviest turns. Flyovers provided for major moves.	Crossroads flyover & slip closed. Jones Franklin interchange likely required. May be possible to connect local CD access.	Reduced impacts with no alignment changes to outermost ramps. South Hills Mall & Plaza not impacted.	Most difficult structure option with walls & long flyovers.	Flyover from US 1 north simplified. Allows for more flexibility.	Future managed lanes to median would need to share flyovers & shift GP to new outside flyovers. Eliminating median ramp to north simplifies future managed lanes compared with Box #1.	**3.5**
T-2A w/o CD	**1/2 Turbine without Local loops**	PB variation	Lower speed flyovers - check capacity, 2 loops with LOS C weave.	Crossroads flyover serves I-40. No access from US 1. 1800 ft weave across 4 lanes. US 1 traffic can use existing Jones Franklin at US 1.	Minimal South Hills Mall & Plaza impact. Potential Walnut Creek impacts, near building in SE quadrant.	Multiple flyover ramps but lower level with turbine.	MOT simplified & constructible. Some tight spaces, but no high level structures.	Managed lanes simpler with removal of 3rd turbine and keeping NW loop. Opportunity to shift managed lanes to vacant land.	**2.8**
T-2B with CD	**1/2 Turbine with Local loops & CD**	PB variation	Lower speed flyovers, 4 loops with LOS C weave, removing local traffic improves major merge in NW quadrant.	Crossroads flyover access provided with CD & local loops.	Minimal South Hills Mall Plaza impact. Potential Walnut Creek impacts, near building in SE quadrant.	Multiple flyover ramps but lower level with turbine.	MOT simplified & constructible. Some tight spaces, but no high level structures.	Managed lanes simpler with removal of 3rd turbine and keeping NW loop. Opportunity to shift managed lanes to vacant land.	**2.7**
T-3	**Higher Speed 1/2 Turbine with Local loops & CD**	PB variation	Higher speed flyovers, 4 loops with LOS C weave, removing local traffic improves major merge in NW quadrant.	Crossroads flyover access provided with CD & local loops.	Improved ramp angle & reduced traffic allow NW merge to be shifted away from South Hills Mall & Plaza. CD can fit into ROW.	2 flyovers span loops and need 3rd level.	MOT simplified & constructible. Some tight spaces, but no high level structures.	Managed lanes simpler with removal of 3rd turbine and keeping NW loop. Opportunity to shift managed lanes to vacant land.	**2.7**

D. Comparison and Refinement of Key Design Features

As part of the Brainstorming Meeting, a major focus was evaluating how each interchange concept was able to allow for two critical design elements: (1) the provision of future access for Managed Lanes, and (2) maintaining access for local trips to Crossroads and Walnut Street. Section 4 examines these issues in terms of the interchange concepts under consideration.

D.1 Comparison of Managed Lane Access Options

Managed lanes have been identified as a future improvement for increasing capacity and trip reliability along I-40. CAMPO's current 2040 Metropolitan Transportation Plan (MTP) includes the provision of two managed lanes along I-40 (project F41 in the CAMPO MTP for 2030). In addition, the NCDOT has conducted a feasibility study (FS-1005A) examining the provision of managed lanes along I-40 (considering both 2 and 4 lanes). As part of this study, US 1 from Apex and Cary was identified as a key high volume access point to an I-40 managed lane system. The study included direct ramp access to a managed lane system located in the median of I-40. An overview of the managed lane system identified by NCDOT is shown in Figure D-1.

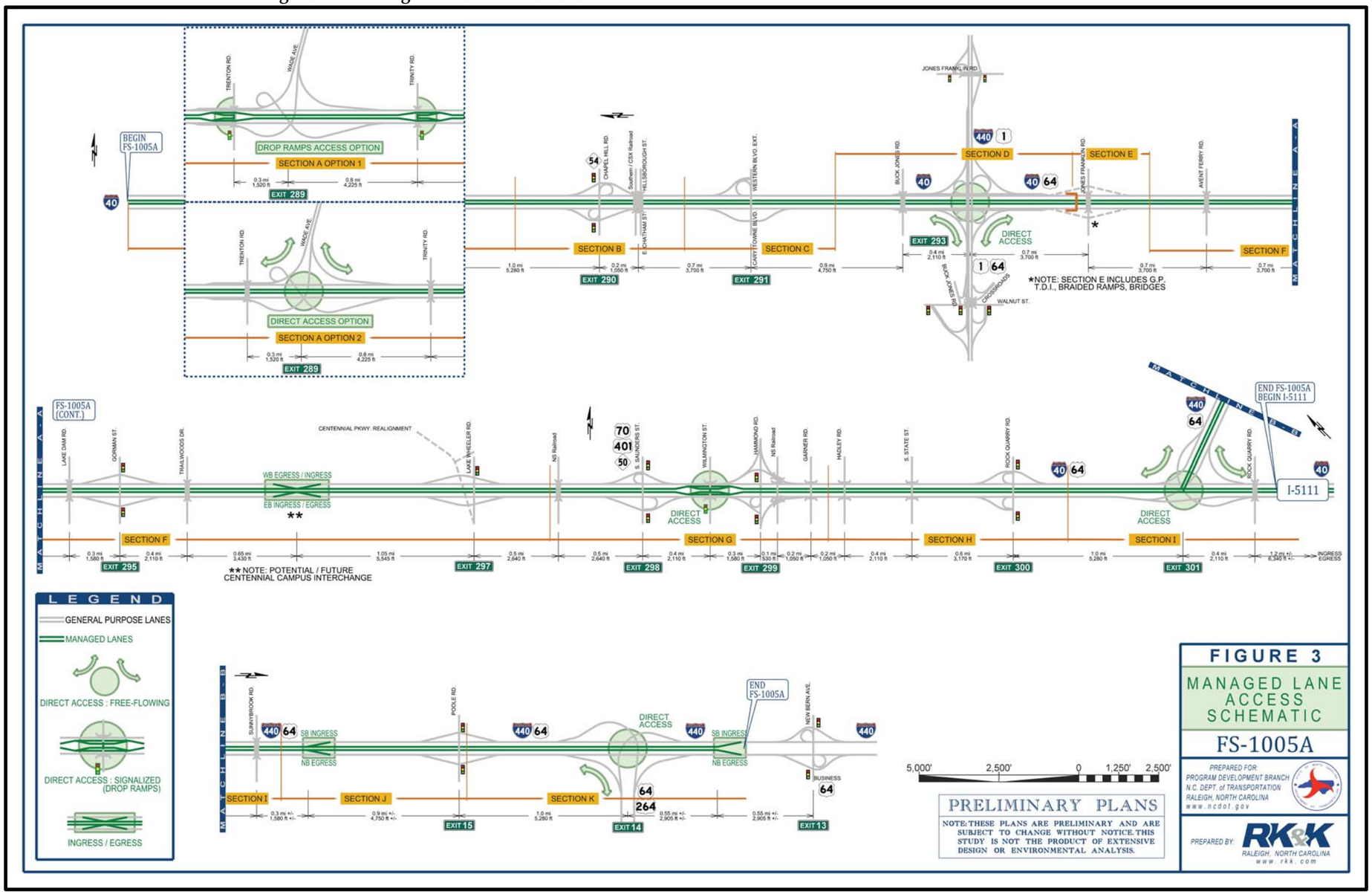
As identified in the comparison of interchange alternatives, a key factor in identifying a preferred interchange concept is design flexibility to allow for future managed lane access between US 1 to the south and I-40 in both directions. At the same time, this study assumed that adding provision of managed lane access would be a future project and not included as part of the current interchange improvements under consideration. Therefore, the study was conducted to identify challenges that could preclude future managed lanes.

In examining each of the interchange concepts, alternative concepts for inclusion of managed lanes were identified that could work with each interchange type (i.e. the Stack, the Box, and the Turbine). Key assumptions included:

- Direct ramp access was preferred between US 1 and I-40. No stops or low speed movements were allowed. Merging across I-40 general purpose lanes into the managed lanes was not considered.
- Managed lanes along I-40 would be in the median. Therefore, the direct access ramps would need to tie into the median.
- Access would only be provided to/from US 1 to the south. Managed lane access was not provided to/from US 1 and I-440 to the north.
- Managed lane access would be provided for 4 movements – US 1 northbound to I-40 westbound and I-40 eastbound as well as from I-40 westbound and I-40 eastbound to US 1 south.
- Managed lanes are not to be provided along US 1. Access should be provided to/from US 1 which could be accomplished from either a managed lane approach or directly from general purpose lanes on US 1.
- In comparing options, it is noted that in all cases the managed lane sections along I-40 may vary to include 2 or 4 lanes. In addition, the tie ins and adjacent access points along I-40 may vary. In any event, the exact laneage and tie ins along I-40 will require improvements along I-40. For this study, it is assumed that the specific impacts will be identified as part of future studies.

After review, multiple types of access were identified that could potentially be applied. These are examined in greater detail in the following sections.

Figure D-1. Managed Lanes Plan FS-1005A



- Managed Lanes have been identified as potential long term treatment for I-40 through Chapel Hill, Durham, RTP, Cary, and Raleigh by NCDOT, DCHC, & CAMPO
- CAMPO 2040 MTP has single managed lanes on I-40 in both directions. Identified as a second phase to initial GP widening on I-40
- NCDOT evaluating managed lanes throughout the Triangle through series of feasibility studies. FS-1005A is for I-40 from Wade Avenue to US 64/ 264
- US 1 is identified as a direct access system level access point. Access is provided to/from US 1 south of I-40 only

D.1.1. Managed Lane Option 1: Access to/from Managed Lane Flyovers in the median of US 1 (ML-1):

The FS-1005A interchange study by NCDOT assumed that managed lane traffic would use left exits and entrances to and from the US 1 median area to connect three direct access ramps to the I-40 managed lanes. The use of the median for these flyovers is very similar to a Box concept for managed lanes only with the general purpose Stack interchange built around the managed lane Box style ramps. An illustration of ML-1 is shown in Figure D-2 with additional detail in Figure D-3.

The primary issue with this option is that the tie in of four managed lane ramps and three flyovers at the US 1 median requires a width of approximately 174 feet. In effect, the US 1 general purpose lanes must be moved outward to allow for the 174 feet wide tie in. This is illustrated in Figure D-2. The impacts of this widening include ROW issues at the South Hills Mall and Plaza. In addition, phased construction likely requires reconstruction of US 1 in both directions if initial construction is centered on the existing 46 foot median.

After review, it was identified that this access type could be applied with both a Stack and Turbine interchange configuration. It could not be applied directly to a Box interchange configuration without conversion of Phase 1 general purpose flyovers to managed lanes and constructing new general purpose lanes.

Figure D-2. Alternative ML-1. Alt. S-3 from FS-1005A

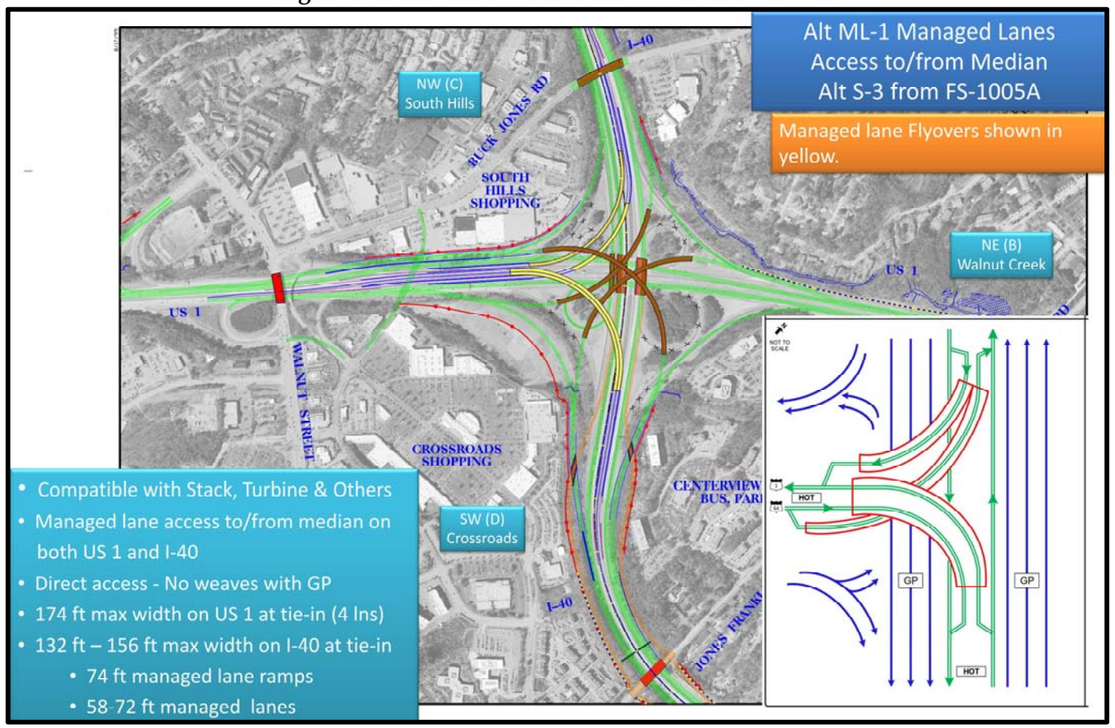
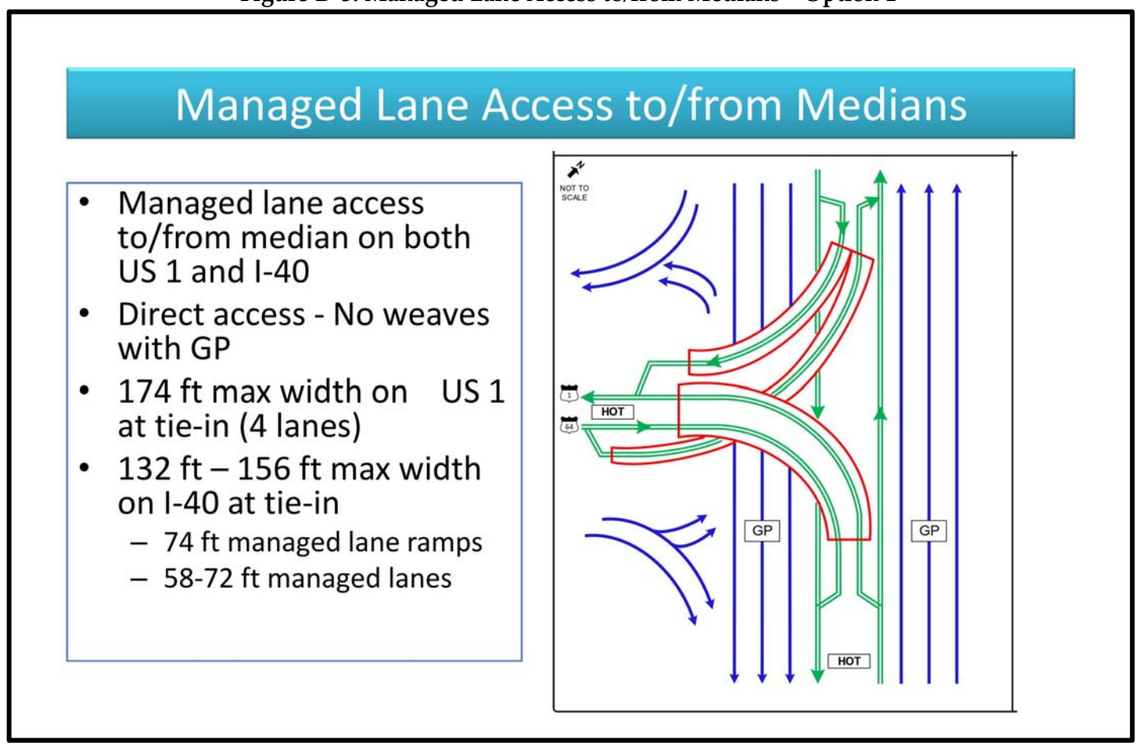


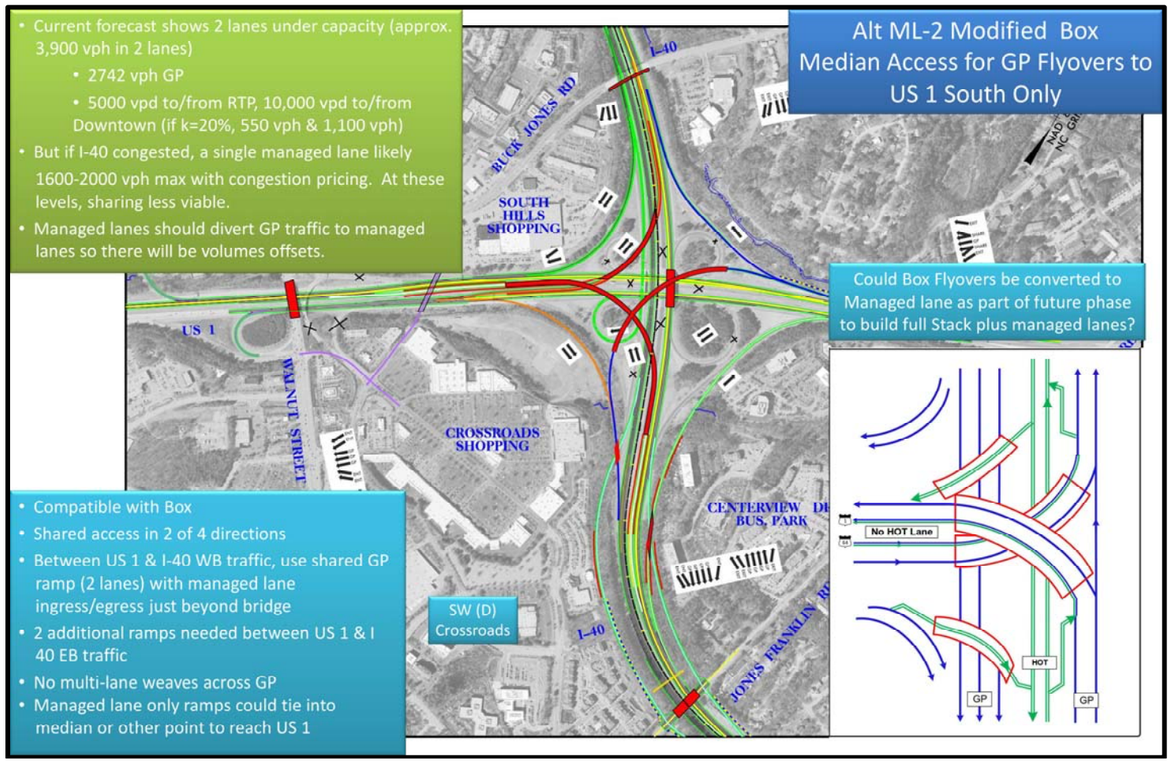
Figure D-3. Managed Lane Access to/from Medians – Option 1



D.1.2. Managed Lane Option 2: Shared Use of Box-Type Median Flyovers for General Purpose and Managed Lane Traffic (ML-2):

With the Box interchange type, direct flyovers are provided from the median of US 1 to the median of I-40 for general purpose traffic. An analysis was conducted to identify options whereby the Box flyovers could be built in an initial phase for general purpose traffic and then converted to carry a combination of general purpose and managed lane traffic. A scheme was developed that allowed for traffic from US 1 northbound to I-40 west as well as I-40 westbound to US 1 south to share the major two-lane flyovers in the Box. Option ML-2 is illustrated in Figure D-4.

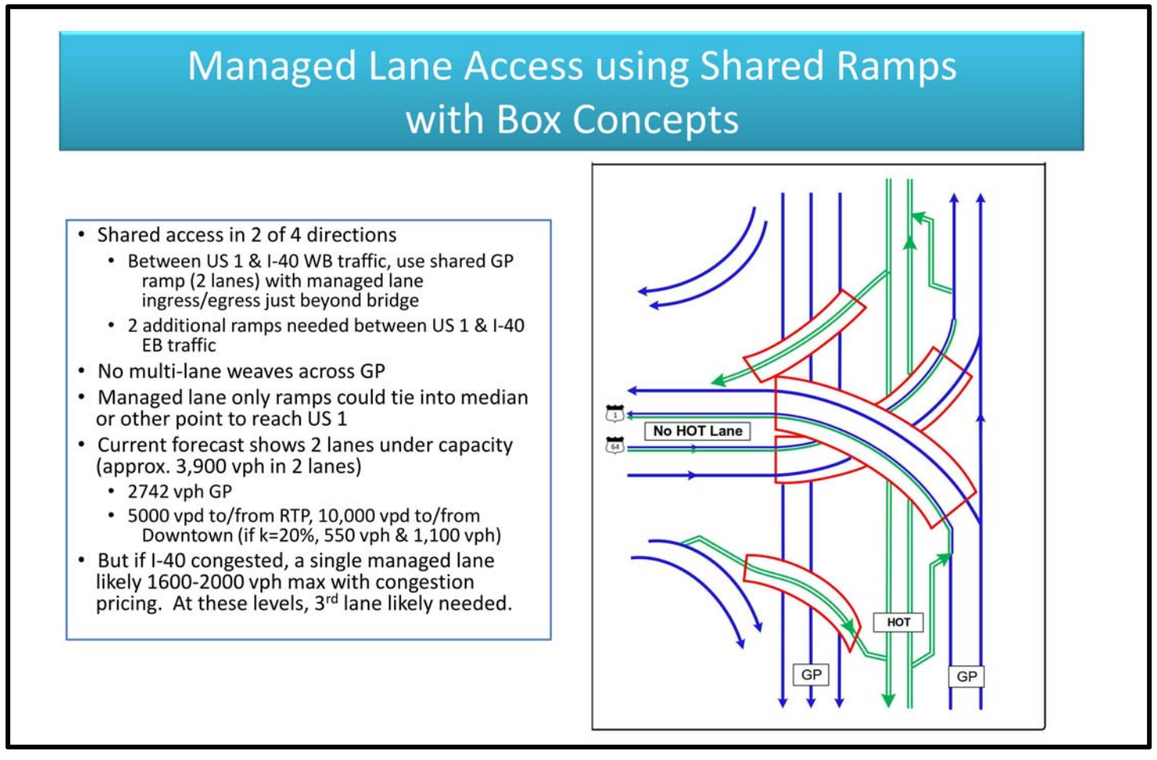
Figure D-4. Alt. ML-2 Modified Box with Median Access for GP Flyovers to US 1 South



To make this option work, however, two additional managed lane only ramps would need to be constructed. In addition, the tie-ins to I-40 would require a longer transition section along I-40 both north and south of the managed lane merge/diverge points increasing the future ROW width and impacts along I-40. A volume to capacity review of the capacity indicates that there would likely be adequate capacity for shared access to the two lane flyovers, but during periods where an incident increases managed lane demand there may be restricted flow to/from the managed lanes. Figure D-5 examines the ramp capacity issues from a planning level perspective, but a more detailed traffic operations analysis would be required as part of future implementation of shared use of lanes by both managed lane and general purpose traffic,

Also note that median flyovers would be set in a permanent location and any future improvements or additional connections would move outward requiring the widening of US 1 to both the north and south of the corridor. Overall, however, the ability to eliminate two flyovers (as compared with ML-1) and the reduced ROW width along US 1 (due to the shared flyover), resulted in this alternative appearing to be a feasible long term managed lanes solution with a Box type interchange alternative. To be most effective, any structures to be shared with managed lanes must begin and end in the median area to directly tie into managed lanes.

Figure D-5. Managed Lane Access using Shared Ramps with Box Concepts – Option 2



D.1.3 Managed Lane Option 3: Utilize Vacant Land near Crossroads (ML-3):

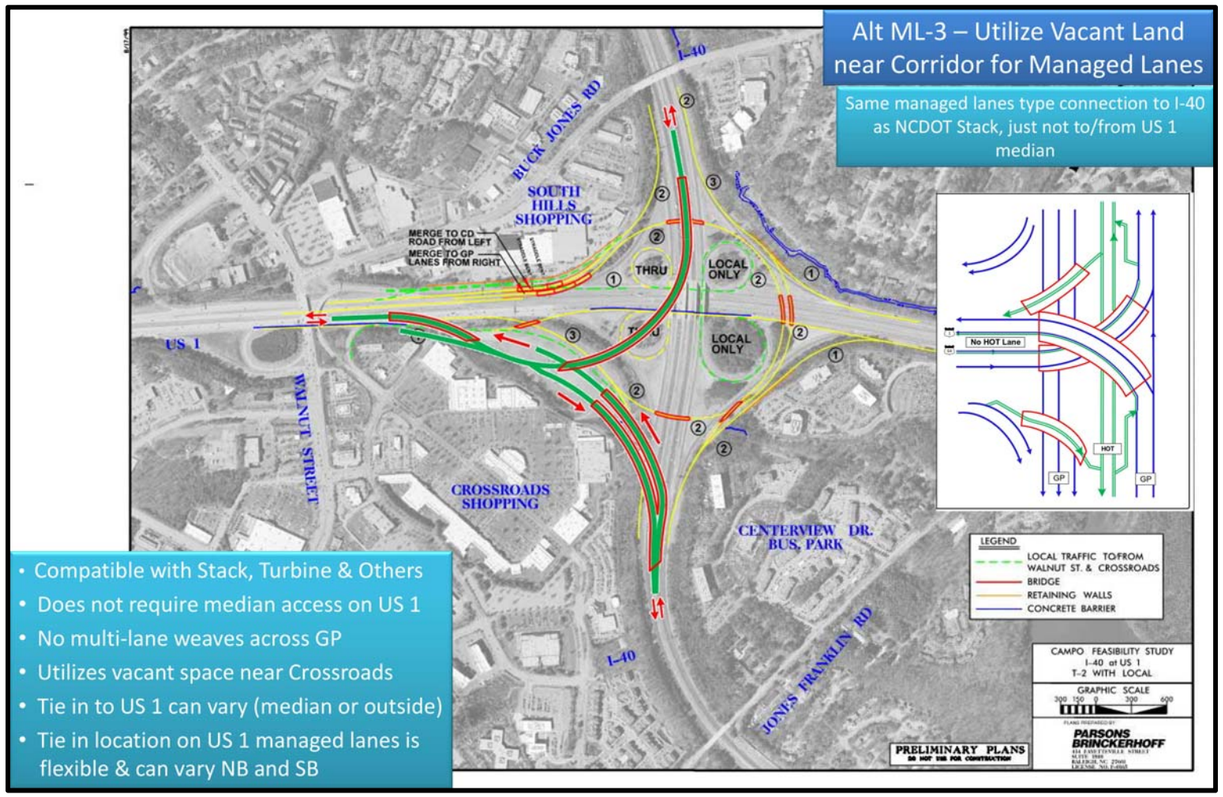
As part of the original assessment of issues within each quadrant, a vacant section of land was identified in the southwest quadrant between the existing US 1 and Crossroads. Although considered in developing the basic interchange concepts, no initial interchange concept was identified that could effectively utilize this full area. In reviewing managed lane options, however, a concept was identified whereby the I-40 managed lanes could be fed by an access point utilizing ramps from this takeoff point instead of the median. ML-3 is illustrated in Figure D-6.

This option has the primary advantage of allowing for the main interchange to be constructed and then maintained during a future managed lane project. By constructing the access outside the main footprint of the interchange, maintenance of traffic issues would be greatly reduced in a managed lane phase and impacts to the north of US 1 (including replacement of the four I-40 interchange bridges over US 1) could be eliminated as part of a second phase. Instead, most construction would occur to the south of US 1. In general, the tie-ins to I-40 would be very similar to the ML-1 concept tie-ins with high speed direct access to the managed lanes in the median.

Access to and from US 1, however, would be modified. Instead of coming into the US 1 median with 4 lanes, it would be possible to tie the managed lanes together in the adjacent land, merge the 4 lanes (2 in each direction) into 2 lanes (1 in each direction), and then tie into US 1. Although further study is needed, the tie-in to US 1 could occur at the median or into the outside of US 1 depending upon access needs. Note that it is likely that the ultimate tie-in to US 1 may need to extend south of Walnut Street, but this has the benefit of reducing the width needed on US 1 immediately adjacent to Crossroads, the cost of replacing the Walnut Street and Crossroads ramp bridges, the cost of replacing the four I-40 interchange bridges over US 1, and the cost and maintenance of traffic difficulties of relocating NB US 1, which would be required if the managed lanes were directed down the US 1 median. Access to and from Crossroads and South Hills can be maintained, but an expensive structure would be required to span over Walnut Street and several ramps before connecting into the US 1 median.

Based on the review, this type of access would be feasible with both a Stack and Turbine interchange configuration. Application with a Box concept would require additional analysis of horizontal and vertical clearance issues between the shifted managed lane ramps and the median based general purpose lane flyovers and require a fifth level to the interchange.

Figure D-6. Alt. ML-3 Utilize Vacant Land near Corridor for Managed Lanes



D.1.4. Managed Lane Option 4 – Build the Box and Convert to Stack Interchange:

Converting the Box type interchange to provide managed lane access was initially assumed to require shared access ramps (ML-2). After additional review, it was also determined that a possible long term solution would be to convert the median ramps to managed lane traffic only and construct new general purpose lanes to convert the Box concept into a Stack Concept (similar to NCDOT's original Stack concept).

Review of this concept indicated that this conversion may be possible. In the future, the Box flyover bridges could be widened and reconfigured to accommodate managed lanes but NB US 1 would need to be shifted to create a wider median. This would likely require replacement of the four I-40 interchange bridges over US 1, as well as the Walnut Street and Crossroads ramp bridges, and leading to a more complex traffic control plan. In addition, two new bridges would be constructed with the Box conversion – a NB US 1 to WB I-40 flyover for the new general purpose lanes and a NB US 1 to EB I-40 flyover for the managed lanes.

One design change to the NCDOT Box interchange resulted from the brainstorming meeting – shifting the flyover bridge from WB I-40 to SB US 1 from the median to the outside. In the future, if this bridge were converted from general purpose lane to also accommodate managed lanes, traffic in the managed lanes would be required to weave across multiple general purpose lanes to exit. An alternative is to revise this bridge to tie into the median, per the original Box design.

In addition to construction costs, the wider sections would effectively increase the width of the managed lane section on US 1 from 174 feet (ML-1) to more than 200 feet (ML-4) resulting in ROW impacts to the Crossroads area. While it appears that the Box could be converted into a Stack with managed lanes, the phasing costs would exceed the anticipated costs of building a Stack from the outset and adding median based managed lanes.

D.2 Preserving Local Access to Crossroads

Access to the Crossroads shopping area is also a key criterion for the I-40 at US 1 interchange. Daily traffic volumes show that roughly 16,000 vpd currently and upwards of 25,000 vpd in the future utilize the section of US 1 between Walnut Street and I-40 for local access at Walnut Street and Crossroads. This traffic uses a combination of the existing flyover and slip ramp that directly access Crossroads Blvd as well as the half-clover at Walnut Street.

The interchanges examined by NCDOT as part of the FS-1005A study removed the Crossroads flyover and rerouted all local traffic to the Walnut Street interchange. An intersection analysis was conducted as part of FS-1005A that indicated delays would more than double at the Walnut Street interchange with average intersection delays reaching a very poor LOS F at two intersections. Recognizing that significant increase of congestion would occur at Walnut Street, alternative access options were considered. The option selected as part of the FS-1005A study was a new I-40 interchange at Jones Franklin Road. In general, it has been recognized that some type of alternate access would be needed to mitigate the increases in congestion that would result from removing the existing Crossroads ramps.

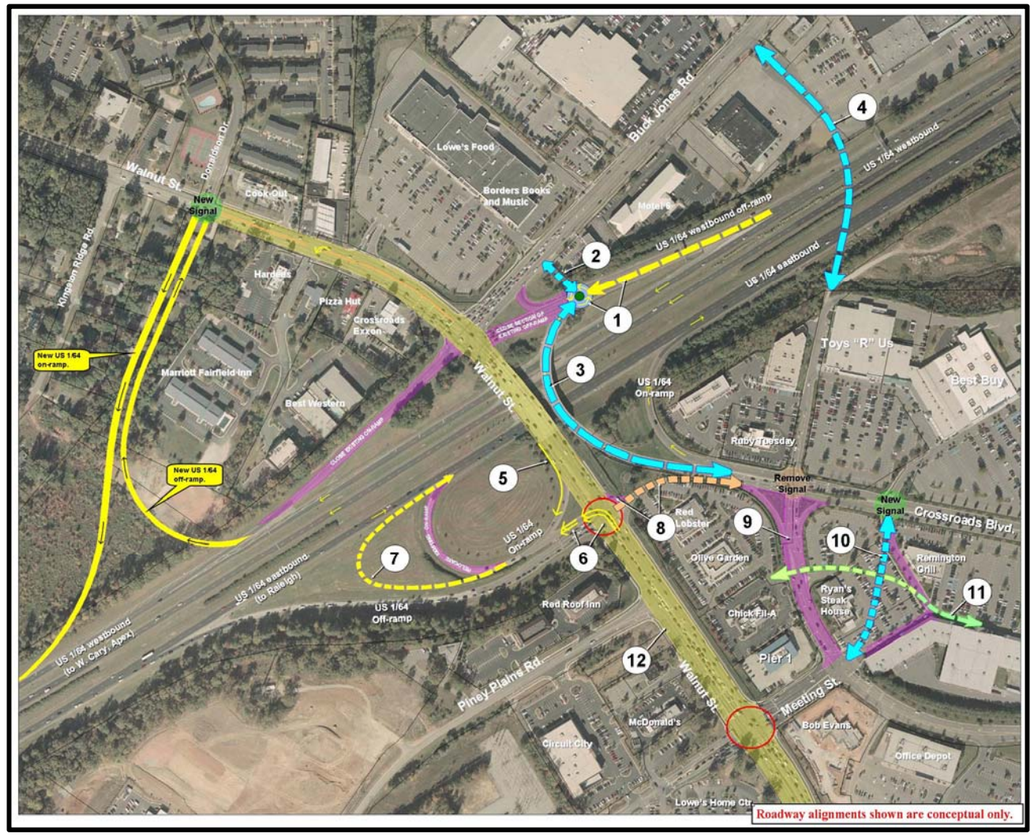
D.2.1. Crossroads Option 1: Divert all traffic to Walnut Street and implement Improvements

As noted, if all traffic is diverted to the existing six-lane Walnut Street, very poor LOS F operations would occur at the two intersections where ramps to and from US 1 connect with Walnut Street. Widening of Walnut Street could reduce these delays, but even with the widening LOS F signal operations and queuing would occur at the I-40 ramp intersections with Walnut Street (more than double the delays anticipated with the Crossroads ramps in place). In addition, it is likely that the main entrance to Crossroads would require reconstruction to allow for an increase of almost 1,000 vehicles per hour in left turns. Widening of Walnut to 8 or 10 lanes was not viewed as a preferred mitigation.

The Southeast Area Plan was proposed in 2004 by the Town of Cary and discussed during the brainstorming session. Illustrated in Figure D-7, the plan has been partially implemented at the Walnut Street interchange. The Town of Cary is currently updating its Comprehensive Plan and additional changes in this area are likely to be addressed in the new plan. The 2004 plan includes some elements that could be considered (such as a fourth leg at the US 1 southbound ramps), but in general this option was deemed to potentially increase congestion rather than decrease it at the most congested intersection at the Walnut Street interchange. No formal traffic analysis was conducted.

It was generally concluded at the Brainstorming meeting that relying exclusively on Walnut Street for access is not acceptable.

Figure D-7. Southeast Area Plan



Southeast Area Plan
Map 3 of 4: Recommended Roadway Improvements, Crossroads Area
Adopted by the Town Council on September 9, 2004

D.2.2. Crossroads Option 2: Provide I-40 interchange at Buck Jones Road

Although considered, this option has not been identified as a particularly viable solution. Key issues are that it may require revisions to the Cary Town Center interchange for spacing, diverting traffic to Buck Jones Road still requires an additional overpass of US 1, and this route would likely not be the preferred route. Due to these issues, this option was not pursued.

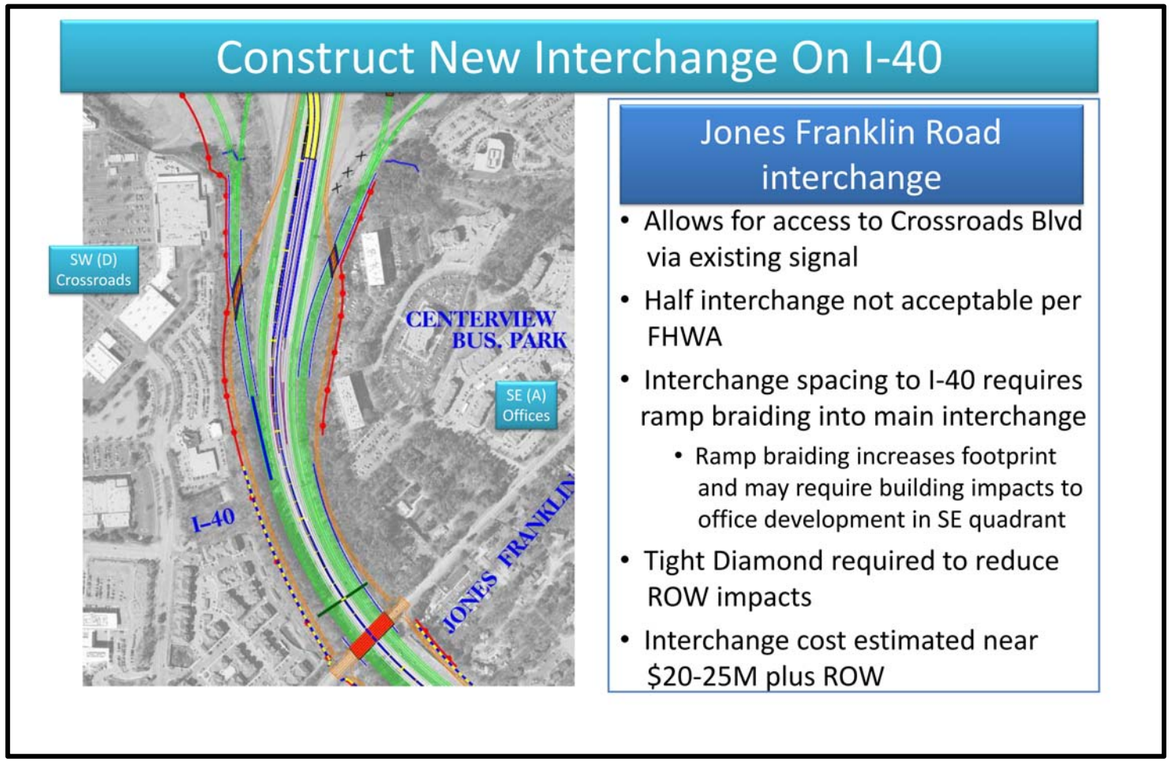
D.2.3. Crossroads Option 3: Provide I-40 interchange at Jones Franklin Road

As part of the FS-1005A study, the provision of a new interchange at Jones Franklin Road was selected as the preferred method to mitigate congestion at Walnut Street resulting from the closure of the Crossroads access ramps. Due to close spacing with the I-40 at US 1 interchange, ramp braiding was proposed which prevent traffic from exiting US 1 onto I-40 to exit at Jones Franklin Road (and vice-versa). The braiding requires additional structures, ROW, and ramp construction which increases the cost of a diamond interchange at Jones Franklin Road to approximately $22 million plus potential ROW in the vicinity of the office buildings in the southeast quadrant. An example connection from FS-1005A is shown in Figure D-8.

While this access point would provide an alternate access route from both directions of I-40, multiple concerns have been raised as to whether this is a preferred solution. These concerns range from local concerns as to congestion on Jones Franklin Road and consistency with the long range vision for the area to engineering focused concerns related to the need for ramp braiding due to minimal spacing on I-40, additional cost and ROW impacts due to ramp braiding, and uncertainty as to FHWA's approval of a local access interchange immediately adjacent to a major freeway to freeway interchange.

Although compatible with proposed interchange concepts for the main interchange, a secondary interchange is not required as a long term solution for Crossroads access. Instead, additional options for local access to the Crossroads area are examined in the remaining sections.

Figure D-8. Construct New Interchange on I-40 – Option 3



D.2.4. Crossroads Option 4: Allow for some traffic to access Crossroads flyover (but not all)

Depending upon the specific movement this may be acceptable, but would still result in increasing congestion on Walnut Street. To be viable, a minimum requirement is to provide access from I-40 West and I-40 East. Crossroads bound traffic from US 1 could theoretically be signed to utilize the US 1 at Jones Franklin Road interchange to leave US 1, travel on Jones Franklin Road south, and enter the back access to Crossroads from Jones Franklin Road.

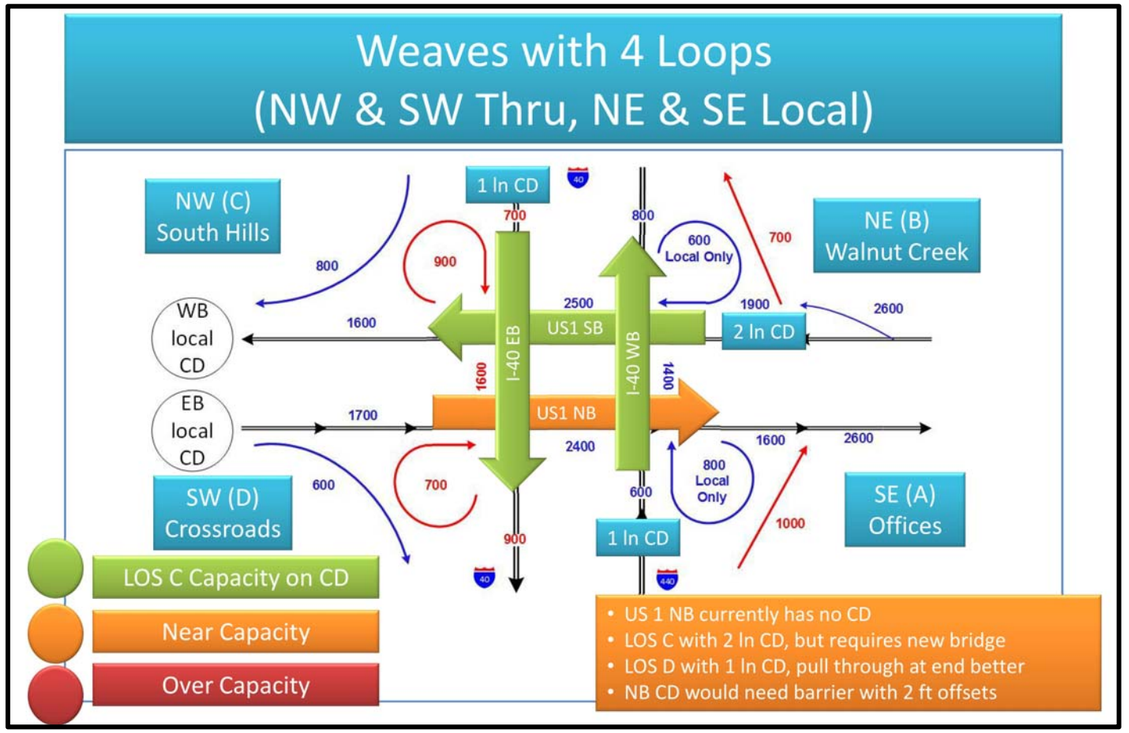
D.2.5. Crossroads Option 5: Provide for Local movements by using the existing loops with a CD on US 1 (both SB and NB)

In the US 1 southbound direction, the CD system is in place and can be readily utilized. Local traffic from I-40 westbound can be directed to use the existing loop (instead of a flyover serving through traffic). This solution requires ramp braiding for the US 1 southbound CD to cross over the conflicting flows from major through ramps.

In the US 1 northbound direction, a CD can be constructed to separate the traffic entering US 1 from Walnut Street and Crossroads from the through traffic on US 1 using barriers and ramp braiding. The key challenge is addressing how the US 1 northbound traffic passes under the existing I-40 bridges. Alternatives were considered that separated three through lanes from one CD lane. With the loop/weave, a fifth lane was added to the section under the bridge. As a longer term solution, it may be possible to direct the I-40 westbound traffic to a separate ramp to merge into the flyover carrying the heavy volume through lanes.

A key feature to providing full local access is maintaining all four loops in the existing cloverleaf. For both the post-Brainstorming refinements, the Turbine and Box utilized the NW (South Hills) and SW (Crossroads) loops for through traffic. The higher volume NE (Walnut Creek) and SE (Offices) loops will be replaced by dual lane flyovers of varying configurations. By diverting local trips to the NE and SE loops, it is possible to maintain existing access to Crossroads. An updated HCS analysis was conducted for the four weaves at the existing cloverleaf with the reduced local volumes (assuming through traffic bypasses the NE and SE loops on a flyover). This analysis showed LOS C operation on 3 of the 4 weaves. The US 1 northbound weave could operate at LOS D if a one lane CD were provided. (See Figure D-9).

Figure D-9. Weaves with 4 Loops with Local Crossroads Movements (based on 2035 operations)



D.3. Refinement of CD Options to Preserve Crossroads Access

Based on these findings, there was general consensus that it could be acceptable to continue to utilize the four loops into the future. Therefore, after the Brainstorming session, additional review of how to provide local access with both a Turbine and a Box concept was conducted. For these reviews, it was identified that a CD system on both US 1 southbound and US 1 northbound were a key element of a successful concept. Therefore, additional review on both southbound and northbound CD operations was conducted.

D.3.1. CD operation on US 1 Southbound

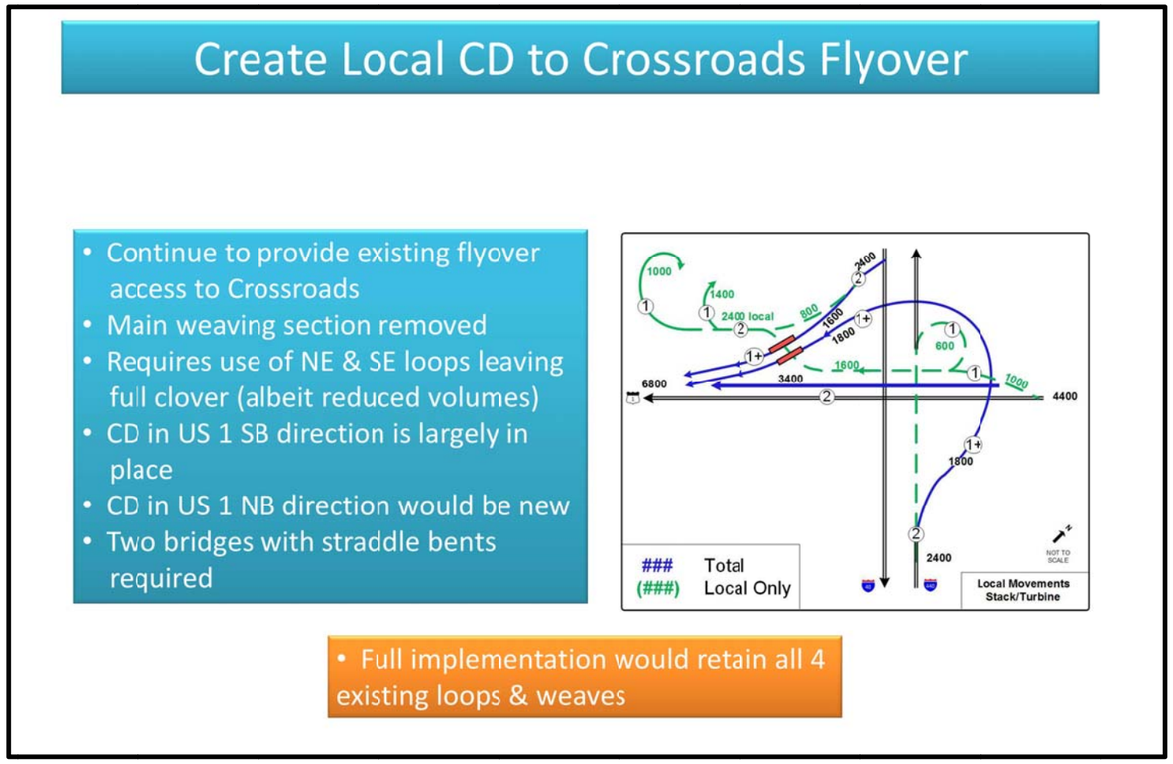
In reviewing local flows on US 1 southbound, a method to combine local flow from I-40 eastbound, US 1 southbound, and I-40 westbound into a single CD is necessary. With the Turbine it is relatively simple to use the existing CD system on US 1 southbound to combine the local traffic from US 1 with the I-40 westbound local traffic using the existing loop ramp in the northeast quadrant. After consideration of alternatives, it was identified that in order to shift this traffic over to the right side, the CD road would need to be braided under bridges serving the through movements crossing the CD. Once the freeway traffic passes over the CD connection, the CD system would provide direct access to both the existing Crossroads and Walnut Street exits. (See Figure D-10).

As originally envisioned in the FS-1005A interchange concepts, the CD for US 1 southbound was removed and combined with the US 1 through movement into a single section. Removing the CD was acceptable since the existing weave on US 1 SB was not required with the removal of the loop in the NE quadrant. Preserving local access to the Crossroads area requires keeping the NE loop open for local Crossroads traffic from I-40 westbound which preserves the existing weave on US 1 southbound between the NE and NW loops. With the weave in place, it is necessary to maintain a separated CD from the mainline US 1 southbound traffic.

With the Turbine concept, the existing US 1 southbound mainline can be maintained on existing alignment. With a Box concept, however, the existing US 1 mainline alignment cannot be maintained because the flyovers in the median area overlap with the existing US 1 mainline alignment. In order to provide local Crossroads access with the Box, it was identified that a 60 mph design could be maintained, but would require an S-curve alignment for the US 1 southbound alignment.

Based on this review, both the Box and the Turbine concepts can be designed to allow for a separated movement for local Crossroads traffic by retaining the NE quadrant loop and a separated southbound CD system.

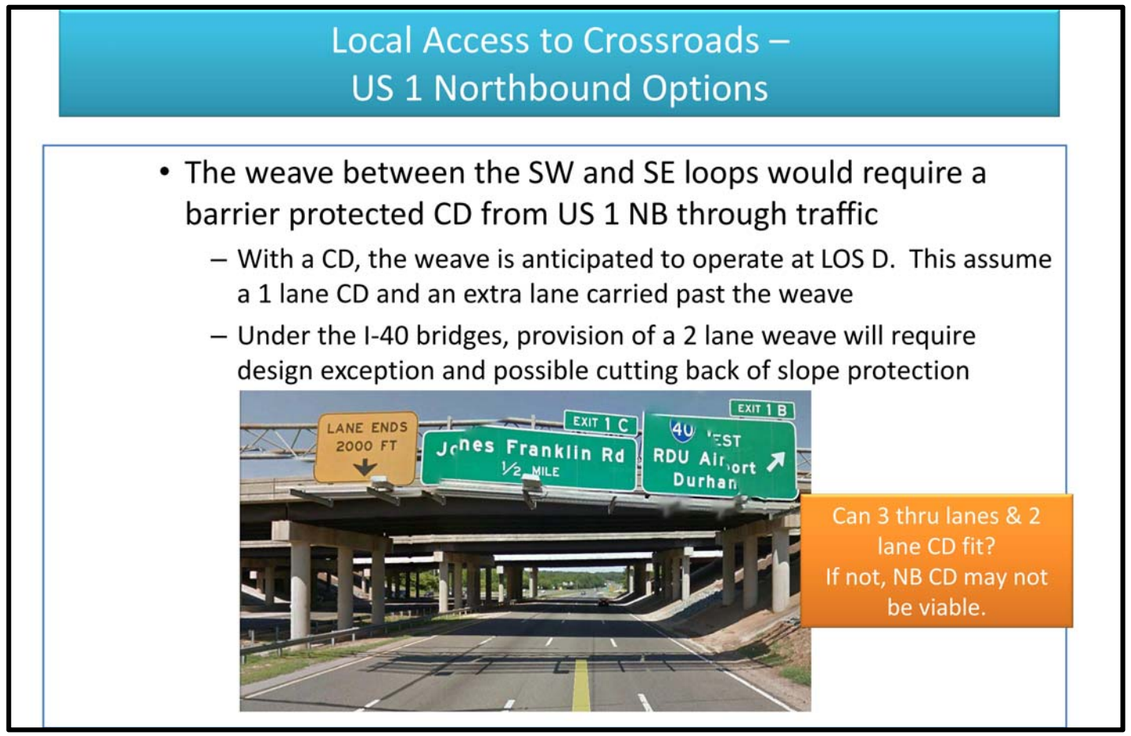
Figure D-10. Southbound US 1 CD to Crossroads Flyover



D.3.2. CD operation on US 1 Northbound

The provision of a northbound CD along US 1 is more problematic because no northbound CD is currently provided. Although the CD can be readily constructed from the Walnut Street loop north to I-40, carrying the CD under the I-40 bridge is a challenge since both through and CD lanes must pass under the same existing bridge span (see Figure D-11). The span currently serves 4 lanes (three US 1 through lanes and one weave lane). A preliminary assessment of the horizontal clearance indicates that a maximum of 5 lanes could be provided with design exceptions required for shoulder widths and barrier offsets. Since a five lane section is required to provide a minimally acceptable LOS D operations for a US 1 northbound weave, approval of reduced shoulder widths and barrier offsets is required under the I-40 bridge spans. Note that to obtain LOS C weave operations, a two lane CD plus weave lane is required. This would require replacement of the I-40 bridges over US 1 to provide a wider span and is not recommended.

Figure D-11. Local Access to Crossroads – US 1 Northbound Issue at I-40



To examine operational options, four treatments for the US 1 northbound movement were identified and are illustrated in Figure D-12. These options include:

US 1 NB CD Option 1: This is the base option with three through lanes, one CD lane and a weave lane. At the end of the weave the rightmost lane would operate as an option lane allowing both a through movement and a right turn onto the loop in the SW quadrant. As noted, LOS D can be provided in the loop, but it should be noted that the single lane CD is nearing capacity in the design year approaching the weave area. After review, this option seemed to be the best solution for the B-4 Box interchange concept with a CD system for local traffic.

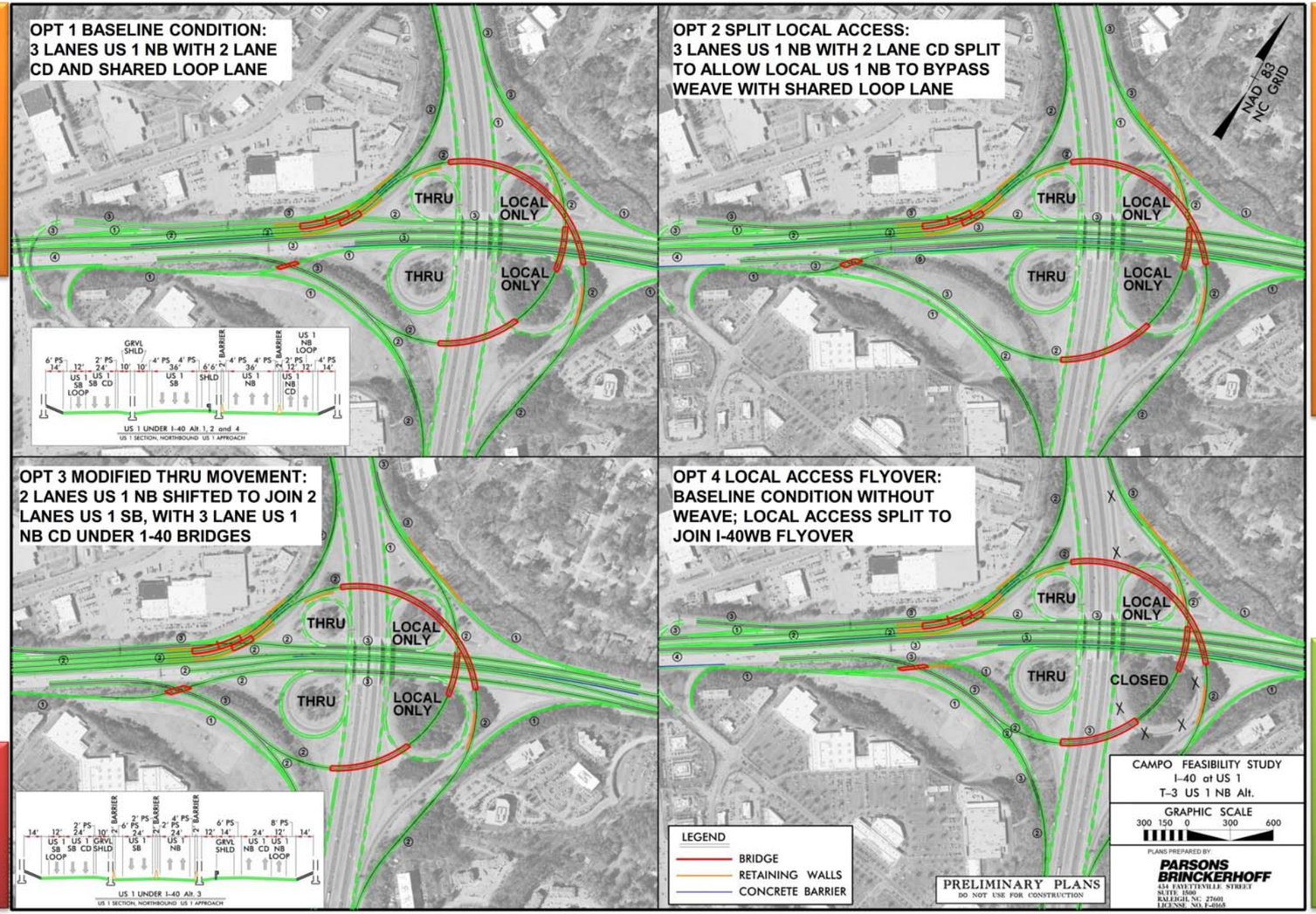
US 1 NB CD Option 2: Recognizing that a single lane CD would operate at LOS D, this option drops a merge lane into the US northbound flow prior to SE loop. By merging this traffic into US 1 earlier, the CD volume is reduced and a LOS C weave operation can be provided between the loops in the SW and SE quadrants. Design exceptions would still be required under the I-40 bridge spans. As with Option 1, however, at the end of the weave the rightmost lane would operate as an option lane allowing both a through movement and a right turn onto the loop in the SW quadrant. Also note that in order to merge one lane into US 1 prior to the weave, the alignment of the CD is shifted and reduces the available vacant land that could be used as a future managed lanes connection.

US 1 NB CD Option 3: This option was developed to identify whether a standard two lane CD could be provided on US 1 northbound. In order to do this, the center span on I-40 was evaluated as to whether both northbound and southbound through lanes could utilize the same span. To do this, however, it was determined that instead of three lanes per direction, only two through lanes could be provided on US 1 in each direction. This is inconsistent with the planned widening of US 1 to six total lanes. Although it was determined that a four lane section would be adequate based on the 2035 forecasts (because greater than one-third of traffic is diverted to the CD system in each direction), it would not meet the basic lane requirements. Therefore Option 3 was not considered.

US 1 NB CD Option 4: This option eliminates the need for the SE quadrant loop to serve local traffic bound for I-40 westbound. Instead this traffic is split off the basic CD and directed onto the main flyover. The design speed of the connector ramp is 30 mph and additional structure costs are incurred on the flyover ramp, but there are significant traffic flow advantages. The primary advantage is the elimination of two weaves in the interchange area. Specifically the US 1 northbound and the I-40 westbound weaves are eliminated since there is not a loop in the SE quadrant. The removal of this weave also eliminates the need for a formal CD system underneath the I-40 bridges (instead three through lanes, a merge lane from the CD, and a merge lane from the SW loop are needed). This option was selected for application with the T-3 Turbine option with the CD connection. Note that it cannot be applied with the Box since the CD cannot be merged onto the key flyover from US 1 to I-40 westbound with the Box.

Figure D-12. Options for Connecting US 1 NB CD

- Works with Turbine or Box
- Merge US 1 NB before CD
- LOS D on US 1 NB weave
- Requires multiple design exceptions under I-40 bridge



- Works with Turbine only
- Reduces US 1 to 4 thru lanes
- US 1 NB CD optimal

- US 1 NB Weave used in Alt B-4 Modified Box (Fig. ES-2)
- Works with Turbine or Box
- Merge US 1 NB before CD
- LOS C on US 1 NB weave
- Limits Vacant Land for Managed Lanes

- Used in Alt T-3 Flyover Version of Turbine (Fig. ES-3)
- Works with Turbine only
- Only needs 3 loops with 2 weaving areas

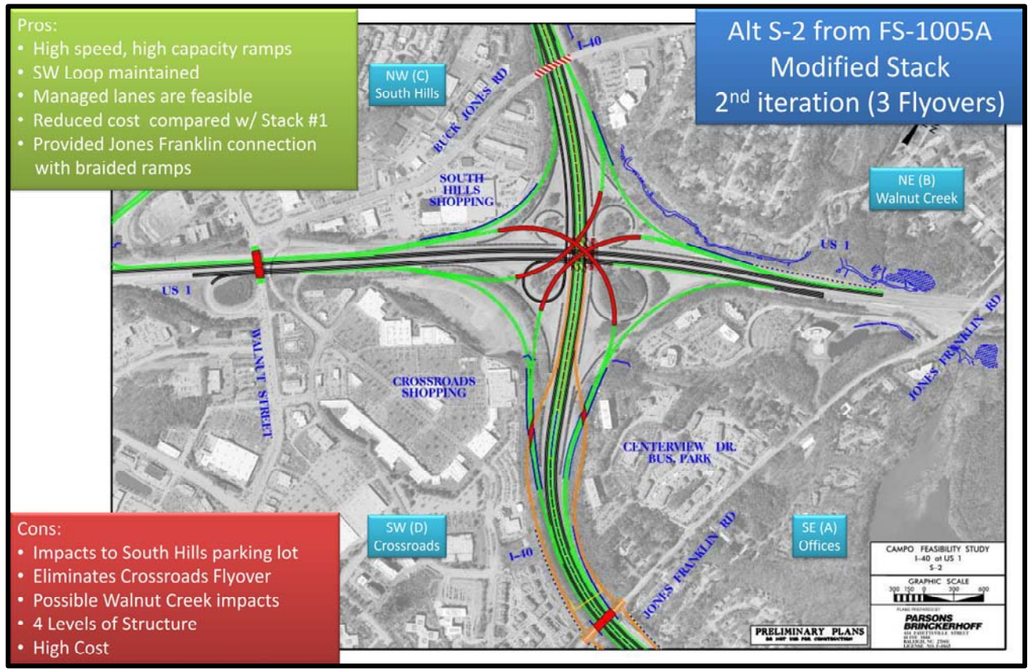
D.4. Comparison of Brainstorming Options

Based on the feedback from the Brainstorming, three alternatives were identified for further review and comparison:

- Stack Concept S-2 (see Figure D-13)
- Box Concept B-2 & B-3 (combination) (see Figure D-14 and D-15)
- Turbine Concept T-3 with Local Access via CD systems (see Figure D-15)

For the Stack concept, no additional refinements were to be applied. Instead it was recognized that the FS-1005A feasibility study had already refined this alternative to more detail than allowed by the current study.

Figure D-13. Alternative S-2 from FS-1005A



For the Box Concept, the committee wanted refinements to include:

- Eliminate left exits off I-40 similar to B-3.
- Examine options to maintain access to Crossroads flyover

Figure D-14. Alternative B-2 Modified Box

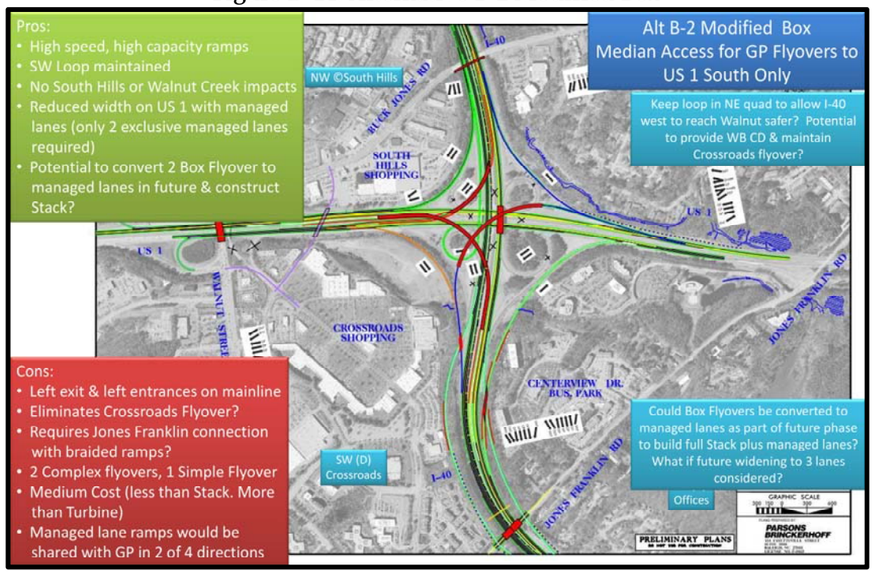
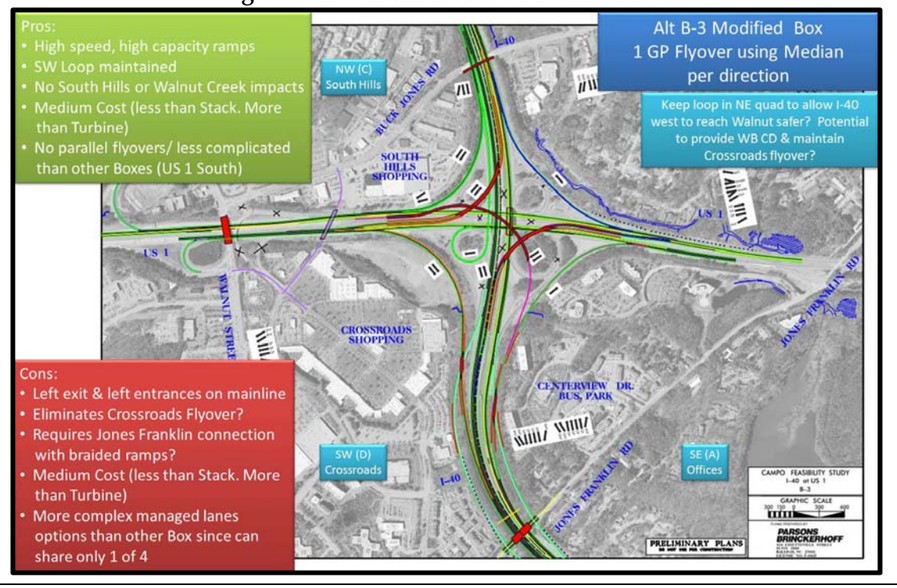


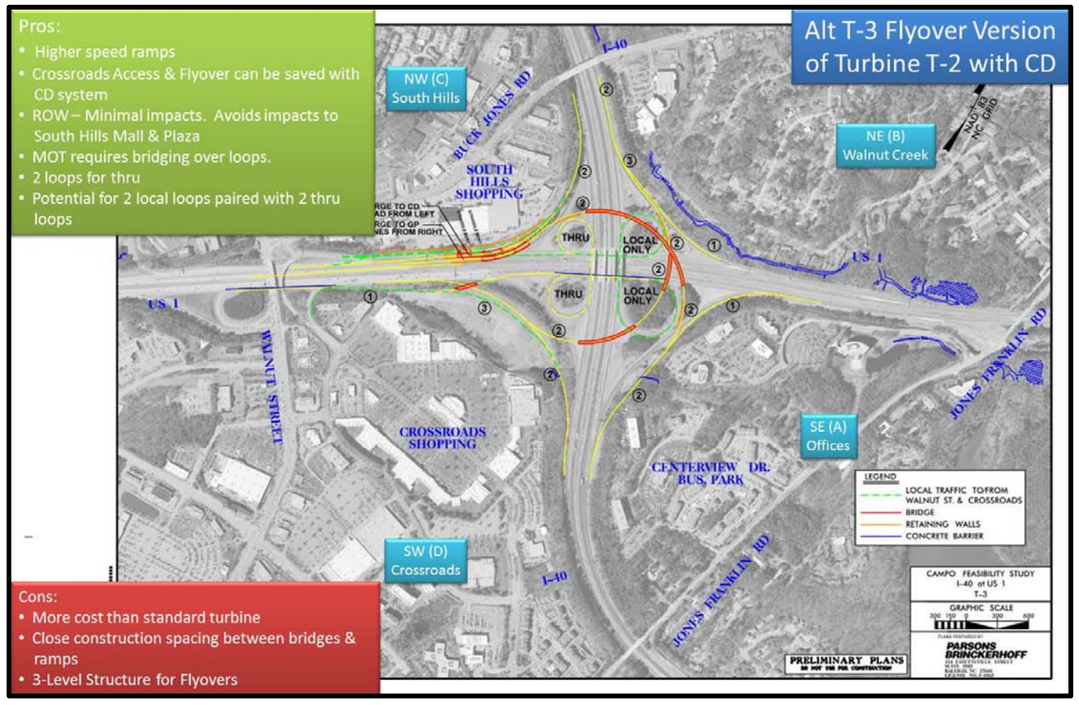
Figure D-15. Alternative B-3 Modified Box



For the Turbine Concept, direction included:

- Preference for more conventional flyovers with 3 levels
- Examine options to maintain access to Crossroads flyover

Figure D-16. Alternative T-3



As noted in Section C, post-Brainstorming review of the horizontal and vertical grades associated with a Windmill type intersection were also examined after the Brainstorming meeting. Based on the initial findings, however, this option was not pursued further.

E. Examination of Refined Alternatives

E.1. Refined Alternatives for Evaluation & Comparison

Based on the feedback from the Brainstorming, further refinements were made to the Box and Turbine concepts for comparison with the Stack interchange developed as part of the FS-1005A study. The three concepts for final evaluation as part of this feasibility study are identified in Table 3 and illustrated in Figures E-1, E-2, and E-3.

Table 3. Refined Alternatives for Evaluation

Concept	Figure	Refinements Considered in Layout
Alternate S-2 Stack Concept	E-1	None. Based on FS-1005A preferred layout without managed lanes. Used for comparison only.
Alternate B-4 Box Concept	E-2	Modify Box to utilize CD system for exits from I-40 (similar to B-3) while identifying method to access Crossroads. Replace US 1 SB to I-40 WB with loop.
Alternate T-4 Turbine Concept	E-3	Utilize higher speed flyover type ramps (instead of 2-level turbine) and utilize existing loops for local traffic to Crossroads.

The three refined alternatives were then examined in greater detail using seven key criteria. These seven factors included:

- ***Traffic Patterns***: Focused on I-40 and US 1 through traffic and high volume ramps. (Section E.2)
- ***Crossroads Access***: Evaluated how well and in what manner access to Crossroads is maintained. (Section E.3)
- ***ROW and Related Impacts***: Identified likely impacts to South Hills Mall and Plaza in the northwest quadrant, office buildings in the southwest quadrant, and other impacts. (Section E.4)
- ***Natural System Impacts***: Potential impacts to Walnut Creek introduce additional steps and challenges regarding getting project approval through the NEPA planning process. For the construction, walls will be required to minimize or prevent impacts to Walnut Creek. (Section E.5)
- ***Structure Requirements***: Structural challenges considered in the evaluation include the overall lengths and complexity of structural elements as well as the need for three or four-level structures. (Section E.6)
- ***Maintenance of Traffic Issues***: A planning level assessment of the viability and ease of MOT during construction. (Section E.7)
- ***Implementation of Future Managed Lanes***: Key challenges and opportunities as well as the overall scale of providing a future managed lanes connection to US 1 from I-40 managed lanes. (Section E.8)

The discussion of these criteria is summarized in the remaining seven sub-sections of this report. Within each sub-section, a summary matrix is presented for each of the seven key factors broken down to examine multiple elements affecting the key factor.

As noted in the brainstorming comparison, a numeric scoring system was utilized for the comparison of specific types of alternatives, but is less applicable in comparing different types of alternatives. (In other words, the Brainstorming used a scoring system to compare variations of the Box type interchanges, but not for comparing a Box concept with a Turbine concept).

In order to prepare a more valid comparison between alternative types, the analysis for each of the seven factors was subdivided to focus on specific elements within each factor. By focusing on smaller issues, it is possible to more effectively compare the three different alternatives. Discrepencies between alternative types are reduced since the same sub-elements are compared within each of the seven major factors.

Figure E-1. Alternative S-2 from FS-1005 Modified Stack 2nd iteration (3 Flyovers)

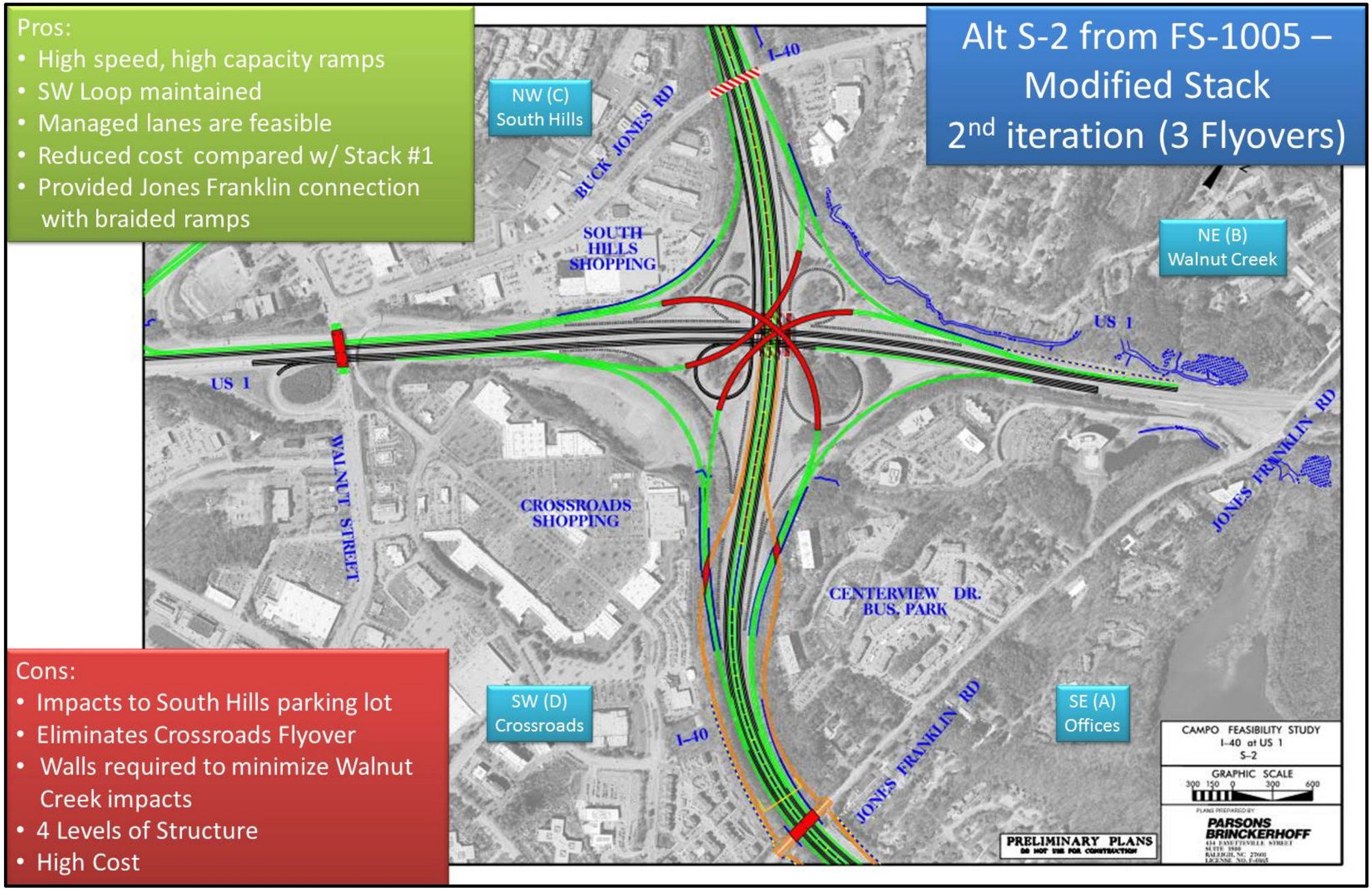


Figure E-2. Alternative B-4 Modified Box with CD & 4 Loops for Crossroads Access

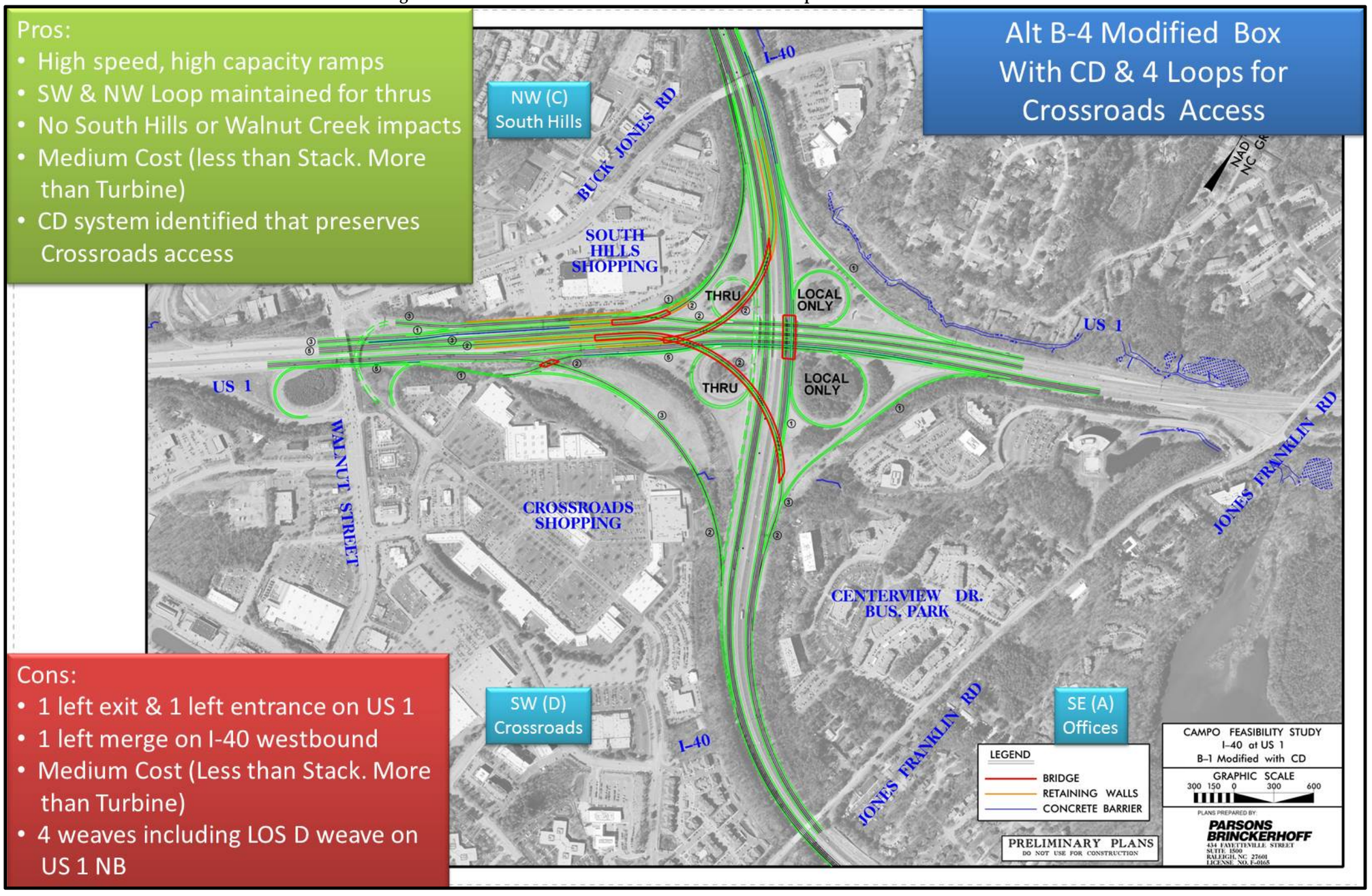
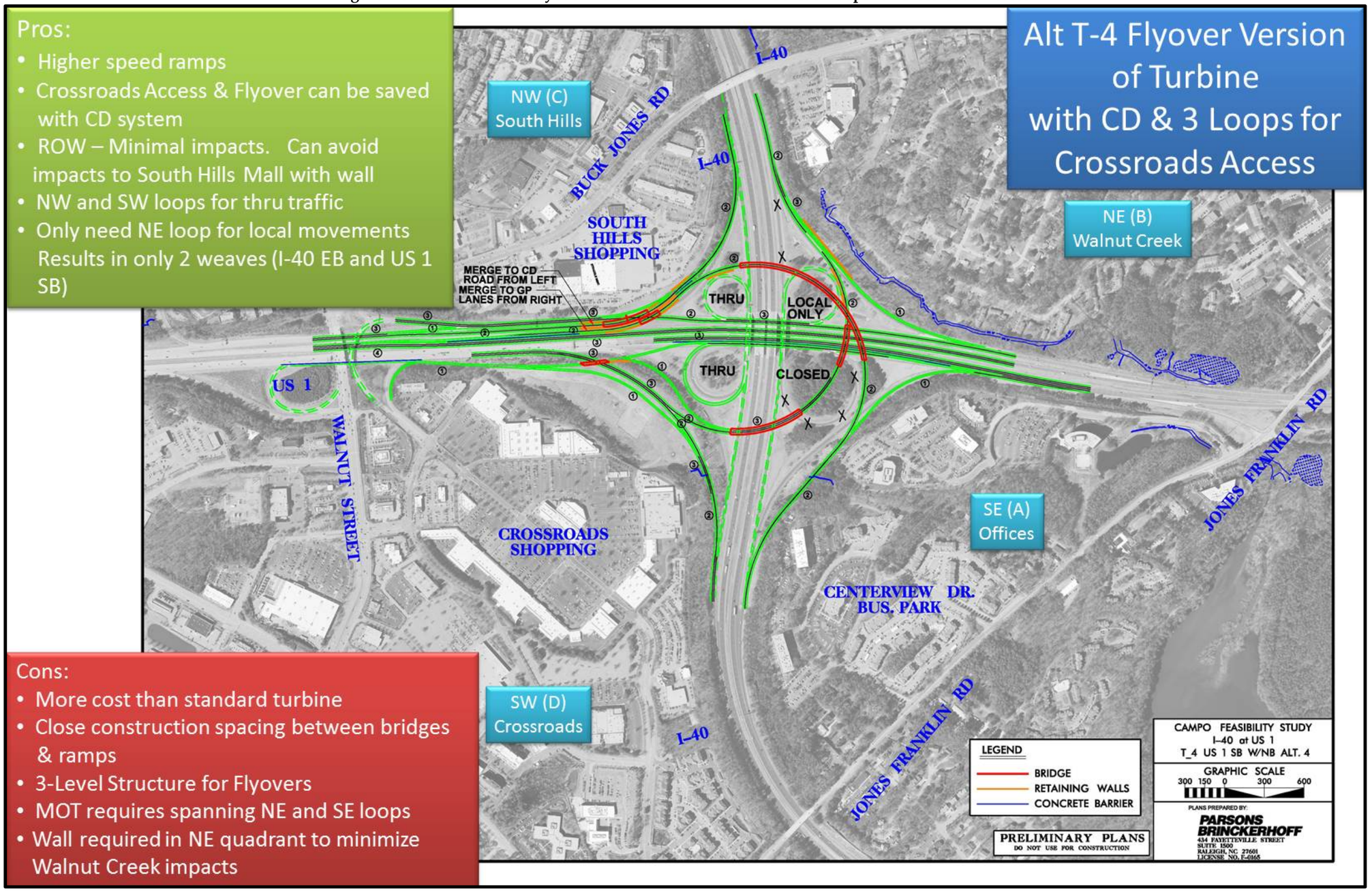


Figure E-3. Alternative T-4 Flyover Version of Turbine with CD & 3 Loops for Crossroads Access



E.2. Traffic Operations

More detailed traffic analysis was conducted for the Turbine and Box options to most efficiently refine the designs. The analysis was conducted using two primary software – Highway Capacity Software and Transmodeler.

The primary input into this analysis was the 2035 traffic forecast. Using the same trip matrix as the 2035 No Build analysis, the Transmodeler software was used to estimate trip volumes. Note that when testing variations regarding local traffic, additional refinements were employed. In addition, as a simulation software, each iteration of the model runs slightly different combination. Nevertheless, Figures E-5 and E-6 provide a summary of the trip assignment analyzed for the Turbine and Box individually.

E.2.1 Interchange Efficiency and Crossroads Access

A key decision to be made was to determine the method to follow to maintain existing access to Crossroads. A review of vehicle hours travelled for the combined AM and PM peak period traffic was performed for both the Turbine and the Box options and compared with the 2035 No Build scenario. The analysis is summarized in Table 4. For each scenario 10 iterations of the Transmodeler software was run.

For this analysis, comparisons were made for the Turbine and the Box concept with different levels of access to Crossroads. For the Turbine, the most restrictive access examined assumed that the Crossroads flyover would be in place but can only be accessed by I-40 traffic. For the Box, the most restrictive access assumes that the Crossroads flyover is removed. These assumptions are based on the initial reviews prior to the Brainstorming.

Key findings from the analysis include:

- Access to Crossroads is critical to maximizing network wide reductions in congestion and improving efficiency (measured by vehicle hours travelled).
- Both the Turbine and Box concepts can provide a very similar 33% network reduction in delay and congestion compared with the No Build.
- Based on 2035 Box scenario with Crossroads closed, the 33% network reduction in freeway operations is almost totally offset by increases in VHT related to delays on Walnut Street and spillover onto the freeway network.
- The provision of a Jones Franklin interchange will offset some of the Walnut Street delays due to the closure of Crossroads, but overall delay is still higher than with full access.

Based on this review, the post-Brainstorming refinements focused on finding methods to maintain access to the Crossroads flyovers.

Table 4. Network Vehicle Hours Traveled by Concept & Crossroads Access

Scenario	2035 Vehicle Hours Travelled	Percent Reduction
2035 No Build	4,864	
Box Concepts		
2035 Box with Crossroads flyover closed and no Jones Franklin interchange	4,843	1% less congestion than No Build (due to congestion on Walnut Street)
2035 Box with Crossroads flyover closed and Jones Franklin interchange added	4,120	15% less congestion than No Build 15% less congestion than Base Turbine
2035 Box with Full Access to Crossroads Flyover (CD and 4 loops)	3,243	33% less congestion than No Build 33% less congestion than Base Turbine
Turbine Concepts		
2035 Turbine with Partial Access to Crossroads Flyover (US 1 southbound diverted to Walnut) No local loops (BASE TURBINE)	3,745	23% less congestion than No Build
2035 Turbine with Full Access to Crossroads Flyover (CD and 3 or 4 loops)	3,321	32% less congestion than No Build 12% less congestion than Base Turbine

Note that modeling was not performed for the Stack interchange concept. Based on an overview of the above scenarios, however, it is likely that the proposed Stack interchange would be most similar to the Box with Crossroads flyover closed and Jones Franklin interchange added. For comparison purposes, it is therefore assumed that the Stack interchange concept would have approximately 4,100 vehicle hours travelled.

Figure E-4. 2035 Peak Hour Demand for Modified Turbine: T-3

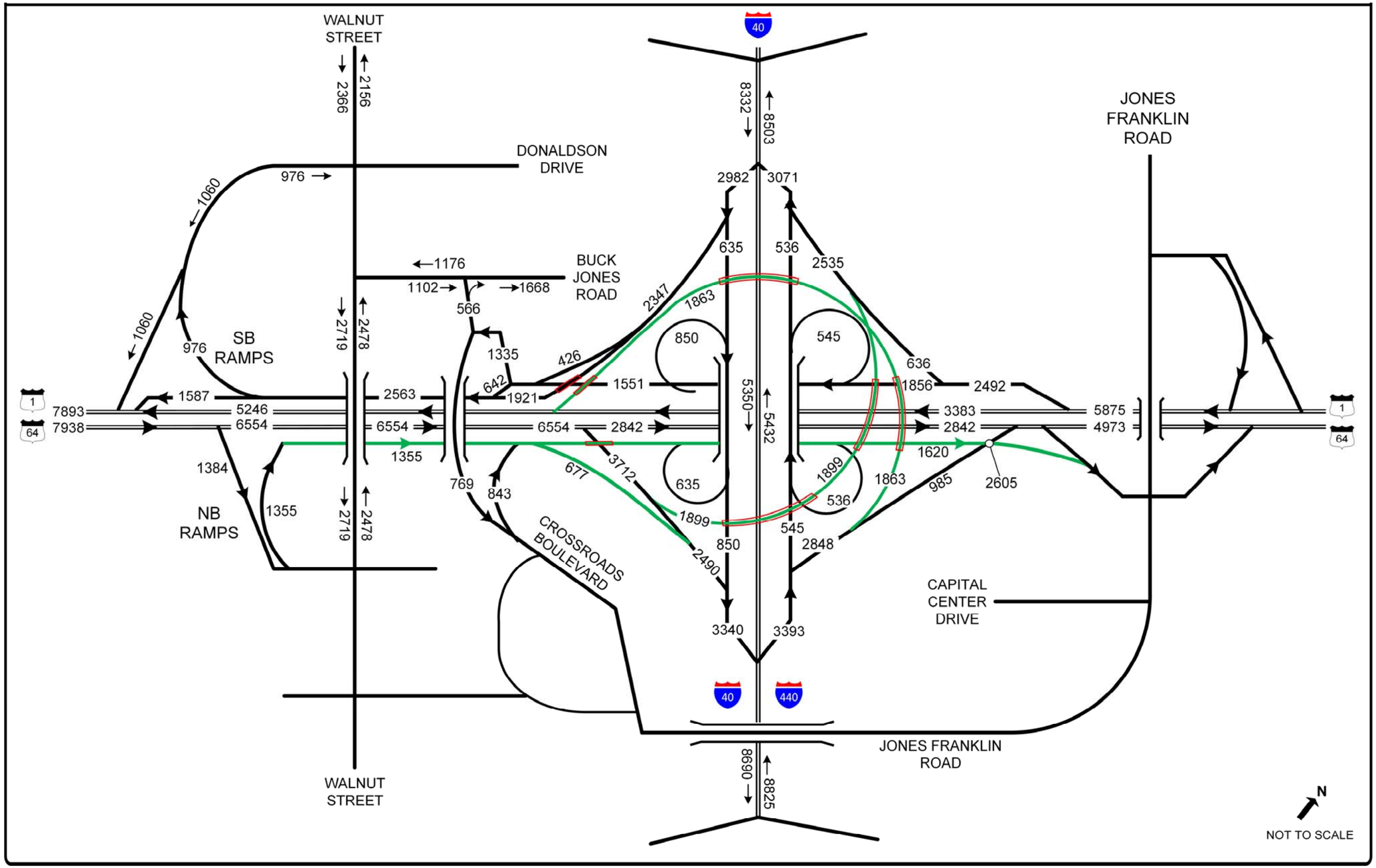
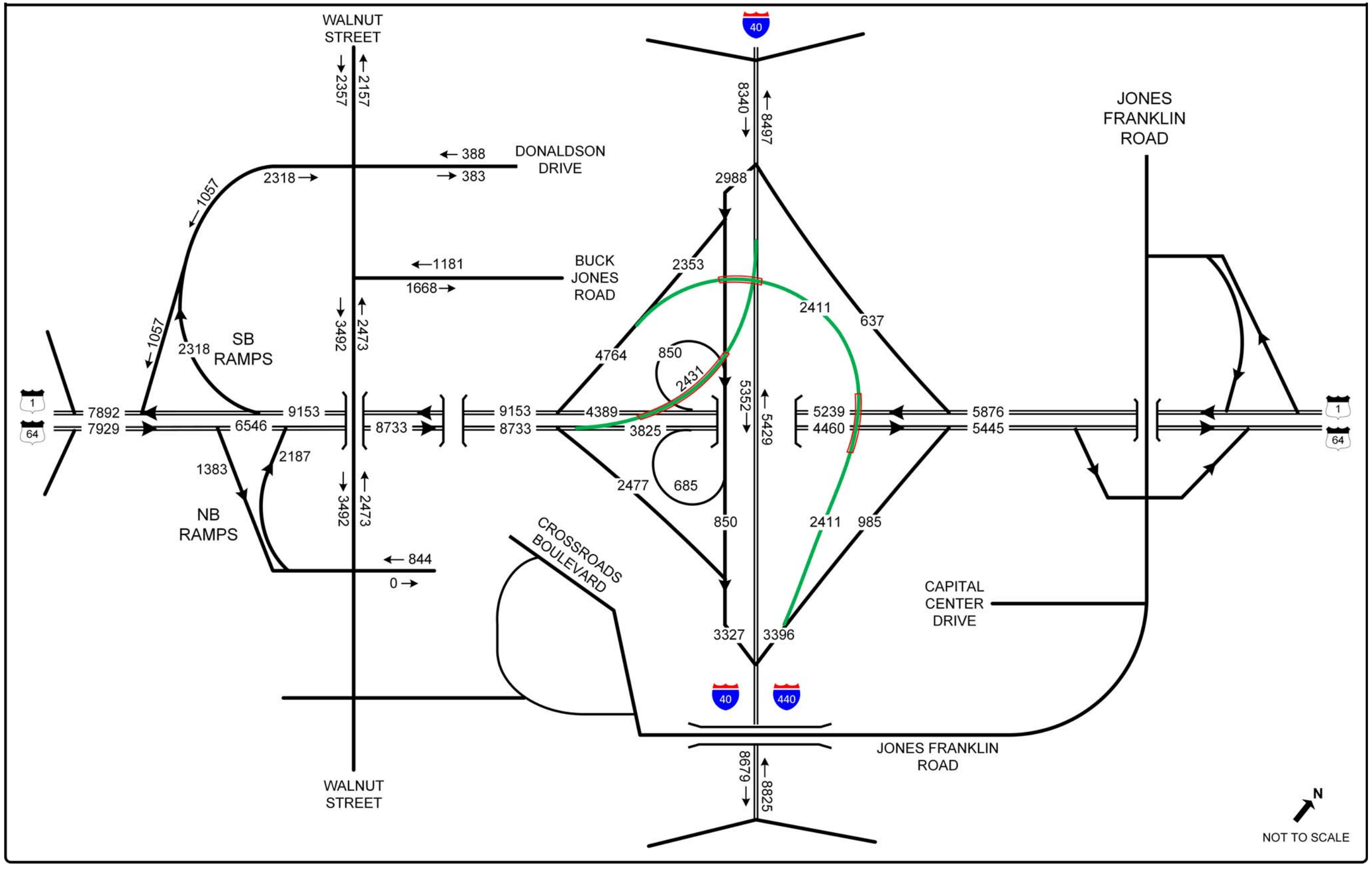


Figure E-5. 2035 Peak Hour Demand for Box



E.2.2 Transmodeler Comparison of Interchanges

In addition to providing network level statistics, Transmodeler can be used to demonstrate operations on a network. Utilizing the same trip tables, more detailed modeling was done for the 2035 No Build, Turbine with Local CD, and the Box with Local CD. The Box and Turbine match with the refined versions used in the overall analysis. As noted in the previous section, it is important from a systems operation persepective to maintain the existing flyover to Crossroads.

For each alternative a color scheme was used to illustrate Level of Service, Volume to Capacity ratios, and Average Speed on links. In general, green was utilized to represent lower levels of congestion with red used for high levels of congestion and delay. Key observations include:

No Build (See Figure E-7)

- LOS F operations are noted in many locations within the full cloverleaf of the main Interchange. Three of the four CD approaches are at LOS F with the approach to the weave also congested. For the two Build options, LOS within the interchange area is typically at LOS C or LOS D with some exceptions.
- Even with the Crossroads flyover in place, delays and congestion are anticipated along Walnut Street.

Turbine with Local CD Access (See Figure E-8)

- LOS E shown on the US 1 northbound approach to the split with I-40 exit lanes to the right.
- Weave operations shown at LOS C or better. Only two weaves are in this scenario (US southbound and I-40 eastbound) since the southeast loop is removed. Note that the northeast loop is open only to local traffic.

Box with Local CD Access (See Figure E-9)

- LOS E shown on the US 1 northbound approach to the split with I-40 exit lanes to the left and right
- Four weaves are in this scenario. Weave operations on US 1 southbound and northbound shown at LOS D. Note that the northeast and southeast loops are open only to local traffic.

In addition to the color diagrams, a visual simulation of the three options was developed.

Figure E-6. No Build LOS, Volume/Capacity and Average Speed Results (2035)

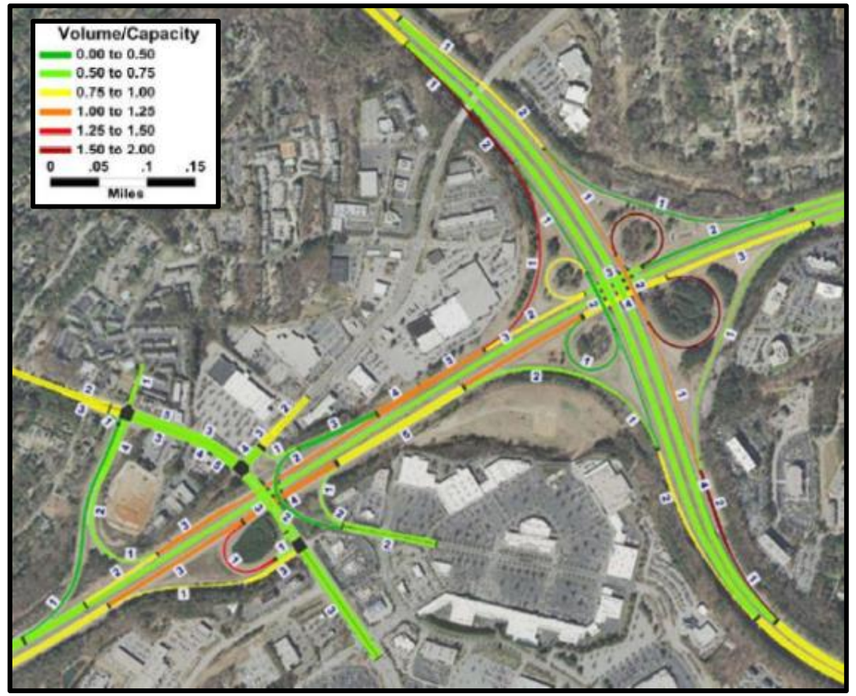


Figure E-7. Turbine T-4 LOS, Volume/Capacity and Average Speed Results (2035)

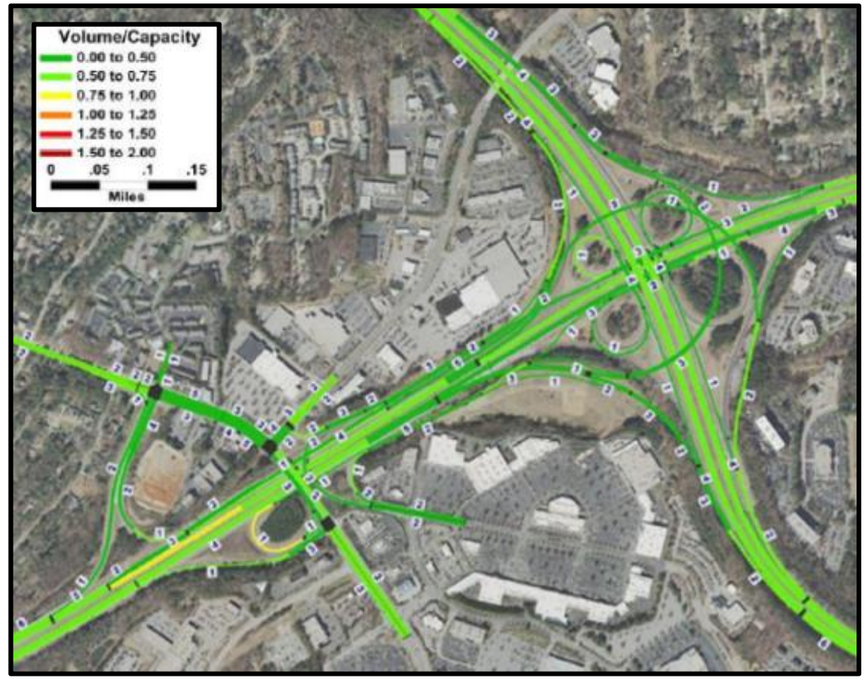
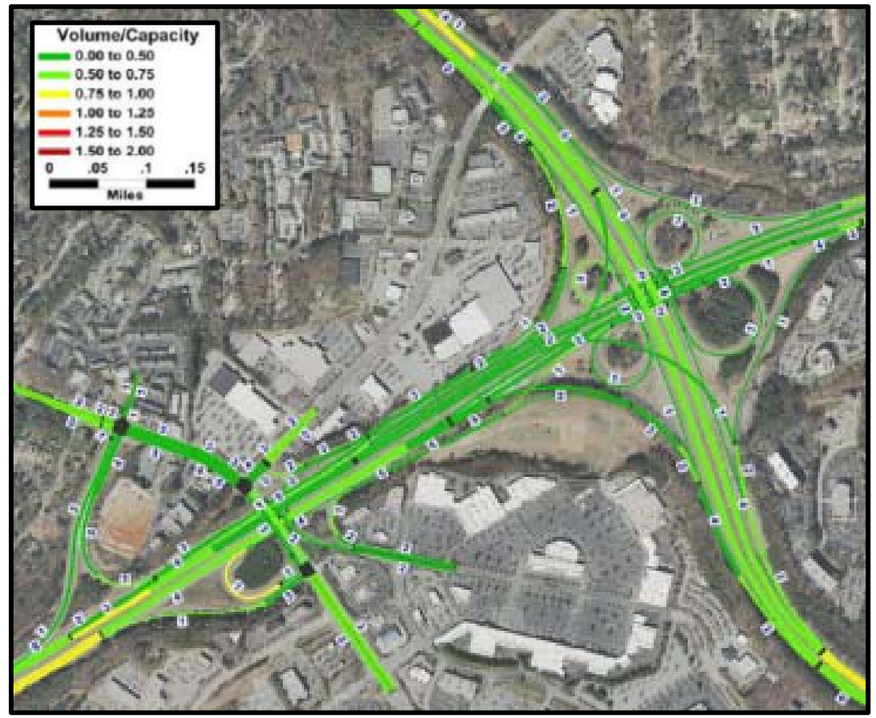
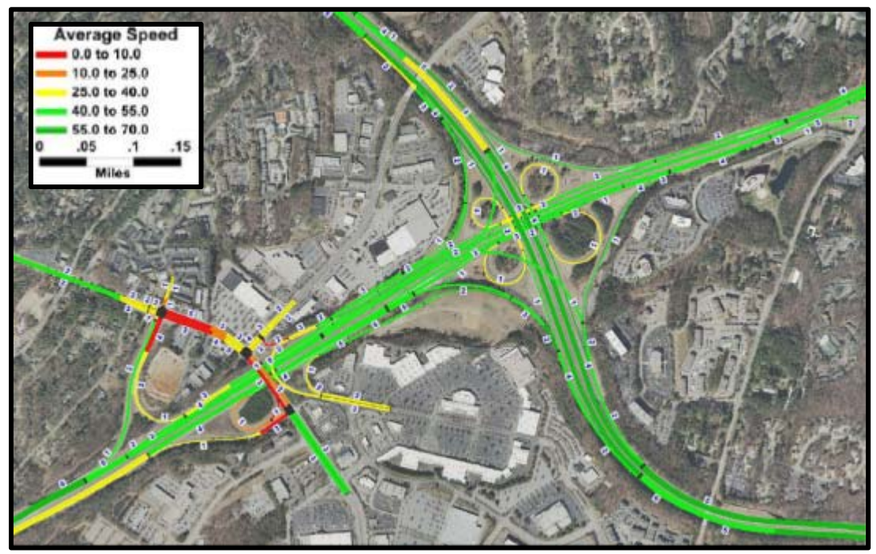


Figure E-8. Box B-4 LOS, Volume/Capacity and Average Speed Results (2035)





E.2.3 Comparison of Concepts – Traffic Operations

In order to compare Traffic Operations between the three interchange concepts (the Stack, the Box, and the Turbine), a comparison matrix was developed examining eight distinct elements. Key findings for each concept are shown in Table 4 and include:

- Stack: Generally performed very effectively for major through and turn movements. The primary drawback of the Stack is the impact on local traffic caused by the elimination of the existing ramps to/from the Crossroads area resulting in lower network efficiency (i.e. higher vehicle hours travelled (VHT) is indicative of more delay.
- Box: Overall efficiency is greater than the Stack, but similar to the Turbine. Nevertheless, this alternative has the highest number of loops and weaves (4 each). The primary operational difference is the use of a left exit from US 1 NB which has a slightly improved operation for traffic exiting onto I-40, but also introduces congestion at the left merge onto I-40 WB as well as signing and driver expectancy issues. Traffic operations are also negatively impacted by the need to introduce an S-curve onto the mainline US 1 SB movement.
- Turbine: Similar to the Box, keeping the existing ramps to/from the Crossraods area results in a more efficient network as compared with the Stack. By allowing for the elimination of the loop in the SE quadrant, only 2 weaves are needed and US 1 NB does not require design exceptions under the I-40 bridges.

Based on the Table 5 ratings, the Stack is the highest rated for overall Traffic operations with the Turbine slightly lower. The Box appears to rank lowest in this comparison primarily due to weaving areas and the left merge on I-40 NB.

Table 5. Traffic Operations Comparison

OVERALL	STACK	BOX	TURBINE
Network Efficiency (VHT)*	4120 Primarily due to local traffic congestion related to Crossroads	3,243	3,321
Number of Loops at Main Interchange	1 - SW loop to serve through traffic	4 - NW & SW loops serve throughs, and NE and SE loops serve local only.	3 - NW & SW loops serve throughs, NE loop serves local only, & SE loop eliminated.
Weaves at Main Interchange	0 - No weaves & existing CDs eliminated at existing loops.	4 weaves. 3 operate at LOS C using existing CDs. US 1 NB will operate at LOS D if barrier separated CD provided.	2 weaves would remain (US 1 SB and I-40 EB). Both have existing CDs.
Design Exceptions	None	Shoulder & barrier offsets reductions required on US 1 NB under I-40 bridge. Other minor items.	Slight speed reduction on I-40 WB to US 1 SB flyover to minimize ROW take. Other minor items.
US 1 NB Approach to I-40 Ramps	Both I-40 exits on the right. Results in queuing prior to Walnut Street exit in rightmost lanes. Left lane operates without queuing for US 1 NB traffic.	I-40 west exit on the left and I-40 east on the right. Less queuing on US 1 NB approach from Cary Parkway. Reduced speed flow noted in both left and right lanes, however.	Both I-40 exits on the right. Results in queuing prior to Walnut Street exit in rightmost lanes. Left lane operates without queuing for US 1 NB traffic.
Merge of US 1 Ramps onto I-40 WB	Both US 1 movements merge onto single ramp before dual lane merge onto from right side onto I-40.	Two separate merges onto I-40 WB - two lanes from the left (from the US 1 NB flyover) and one lane on the right (from the CD). Transmodeler shows turbulaence & reduced speed at the combined merge area affecting all lanes.	Both US 1 movements merge on CD system before dual lane merge from right side onto I-40.
Other Traffic Operations Issues	Weaves between Walnut & main interchange require multiple lane changes.	Left exits and entrances for major movements. S-curve required for mainline US 1 SB alignment due to structures in median of US 1.	Slight speed reduction on I-40 WB to US 1 SB flyover
Signing Issues	Layout reflects preferred practice for signing with single right exits from mainline freeway on all approaches. Requires additional signs for new Jones Franklin interchange.	Layout introduces separate left exit from US 1 NB and additional decision points on US 1 NB mainline. Requires additional signs for local traffic to/from Crossroads.	Layout reflects preferred practice for signing with single right exits from mainline freeway on all approaches. Requires additional signs for local traffic to/from Crossroads.

* Network efficiency measured in vehicle hours travelled as summarized in Section E.2.1 and Table 4.

E.3. Local Access to Crossroads, Buck Jones Road, & Walnut Street

In developing the refined Box and Turbine options considerable effort went into finding solutions that could maintain the existing flyover into Crossroads and slip ramp out of Crossroads. Multiple challenges were identified including:

- Interchange spacing between I-40 and the Crossroads ramps is inadequate
- Heavy traffic volumes from all 3 facilities to the north (i.e. I-40 from the west, I-40 from the east, and US 1 from the north resulted in major merges requiring local traffic to exit across multiple lanes of traffic.
- Retaining the Crossroads overpass and Walnut Street bridges require that US 1 southbound traffic be in two parallel sections (i.e. a CD and the mainline).

E.3.1 Stack Treatment

For comparison purposes, it is noted that the Stack concept combines both local and through traffic on major flyovers. When the different movements make grade at the end point of the bridges, multi-lane merges occur. For the Stack concept developed for the FS-1005A study, it was concluded that the existing flyover providing access to Crossroads would be removed as well as access to Buck Jones Road. Instead all traffic would need to utilize the Walnut Street ramps resulting in unacceptable traffic congestion on Walnut Street. In order to mitigate the increased congestion on Walnut Street, the Stack Treatment proposed a new interchange of I-40 at Jones Franklin Road.

E.3.2 Box Treatment

The Box concepts initially combined all US 1 northbound traffic into a single section eliminating the split between mainline and CD traffic. This treatment was provided since the Box flyovers from the US 1 median area south of I-40 prevent US 1 from proceeding straight. Merging all the traffic together, while effective for through vehicles, eliminated opportunities for saving the Crossroads flyover due to both traffic operations (weaves across multiple lanes) and physical geometrics (the elimination of the CDs required reshifting of lanes and reconstruction of the I-40 bridges as well as Walnut Street and Crossroads.

Investigation was conducted as to whether a CD system similar to the Turbine could be implemented. In the US 1 southbound direction, the key tool is to go back to a separated thru and CD section on US 1. The NE loop can be used for local access from I-40 westbound and US 1 southbound. These movements can then be braided under the heavy volume ramps from I-40 to the existing CD.

In the northbound direction, a CD system can also be provided to serve local traffic. At the I-40 bridge over US 1, a weave section must be carried through on US 1 northbound between the SW and SE loops. This weave can operate at LOS D in 2035 but would require design exceptions for reduced shoulder and barrier offsets with a restricted CD section in order to fit five lanes under the bridge.

With the proposed Box concept, there are four loops – the NW and SW quadrant loops serving through trips and the NE and SE quadrant loops serving local traffic to/from the Crossroads and Walnut Street ramps. As a result there are 4 weave sections at the Interchange serving the four loops. Three of the weaves operate at LOS C and one weave (US 1 northbound) operates at LOS D and requires geometric design exceptions.

E.3.3 Turbine Treatment

In developing solutions for the Turbine, the US 1 southbound traffic was located on the left of the major southbound merge. To allow traffic from the existing CD to access the right exits at Crossroads, a ramp braid is proposed that takes the US 1 northbound CD under the I-40 eastbound and I-40 westbound ramps. In order to make this work, the loop in the northeast quadrant loop is retained to allow local traffic from I-40 westbound to directly access Crossroads.

In the northbound direction on US 1, a CD ramp is proposed linking the Walnut Street loop and Crossroads slip ramp to the main Interchange. Some ramp braiding is necessary past the main ramp of I-40 traffic exiting US 1 northbound. The CD then runs parallel to US 1 northbound with a barrier. The initial approach had been to divert the local traffic under the I-40 bridges and exit onto the existing loop from US 1 northbound to I-40 westbound. Analysis indicated this weave could operate at LOS D but would require design exceptions for the shoulders and barrier offsets under the I-40 bridge over US 1. After more detailed review, however, the northbound CD Option 4 (see Figure D-12) was selected, because it diverted the same movement onto the main flyover. This treatment allows the removal of the southeast loop eliminating weaves on US 1 northbound and I-40 westbound.

With the proposed Turbine concept, there are three loops - the NW and SW quadrant loops serving through trips and the NE loop serving local traffic to the Crossroads and Walnut Street ramps. The SE loop serving local traffic from the Crossroads and Walnut ramps to I-40 westbound are directed onto the main flyover. As a result there are only two weave sections at the Interchange for I-40 eastbound and US 1 southbound. Both of these weaves occur on existing CD systems and will operate at LOS C in 2035.

E.3.4 Local Access to Crossroads Comparison

In order to compare issues related to local access issues related to the existing Crossroads access ramps between the three interchange concepts (the Stack, the Box, and the Turbine), a comparison matrix was developed examining five distinct elements. These elements focus on local traffic not just to Crossroads, but also Buck Jones Road and Walnut Street. Key findings for each concept are shown in Table 5 and include:

- Stack: The removal of the existing Crossroads ramps results in high levels of congestion on the local streets in addition to eliminating existing access patterns. The provision of a new interchange at Jones Franklin Road partially mitigates the local traffic, but substantial congestion levels are still observed in terms of overall network efficiency as well as congestion on Walnut Street.
- Box: The proposed Box configuration addresses local traffic access by maintaining the the US 1 southbound CD and allowing for a new US 1 NB CD. The existing four loops are retained with the NW and SW loops serving through traffic and the SE and NE loops serving local traffic only. The primary drawbacks in comparison with the Turbine concept is that the loop in the SE quadrant must be retained resulting in a LOS D weave and the need for design exceptions on US 1 NB under the existing I-40 bridges. In addition, an "S" curve must be introduced on the US 1 SB mainline movement due to the ramps utilizing the US 1 median just past the I-40 bridges.
- Turbine: The proposed Turbine concept preserves the existing Crossroads ramps by maintaining the the US 1 southbound CD and allowing for a new US 1 NB CD. Three of the existing four loops are retained with the NW and SW loops serving through traffic and the NE loop serving local traffic only. The SE loop is replaced by a direct connector for local traffic on the US 1 NB CD to access the mainline flyover to I-40 WB. By allowing for the elimination of the loop in the SE quadrant, only 2 weaves are needed and US 1 NB does not require design exceptions under the I-40 bridges.

Based on the Table 6 ratings, the Turbine appears to be slightly better than the Box for providing Local Access to Crossroads. The Stack is ranked lowest due to the elimination of the Crossroads ramps and resulting congestion.

Table 6. Local Traffic Access to Crossroads Comparison

OVERALL	STACK	BOX	TURBINE
Network Efficiency (VHT)*	4120 Primarily due to local traffic congestion related to Crossroads	3,243	3,321
Into Crossroads from Interchange (i.e. on US 1 Southbound)	Crossroads ramps removed. Traffic must utilize Walnut Street. New interchange proposed for Jones Franklin Road at I-40 to mitigate.	Southbound CD to Crossroads flyover provided with major braid under I-40 WB to US 1 SB ramp. NE loop retained to serve local traffic only. Requires S-curve for US 1 southbound mainline.	Southbound CD to Crossroads flyover provided with major braid under I-40 WB to US 1 SB ramp. NE loop retained to serve local traffic only.
From Crossroads to Interchange (i.e. on US 1 Northbound)	Crossroads ramps removed. Traffic must utilize Walnut Street.	Northbound CD serving Walnut & Crossroads exit to be constructed. SE loop retained to serve local traffic only. Weave under existing I-40 bridge requires CD with barrier & design exceptions to operate at LOS D.	Northbound CD serving Walnut & Crossroads exit to be constructed. Instead of using SE loop, local traffic diverted onto main flyover from CD. This eliminate US 1 NB weave issue.
Walnut Street Congestion	Signal delays with V/C over 150%.	LOS F delays will occur with V/C less than 120%	LOS F delays will occur with V/C less than 120%
New Jones Franklin Road Interchange	New interchange proposed to mitigate removal of Croosroads ramps & resulting Walnut Street congestion.	Not required.	Not required.

* Network efficiency measured in vehicle hours travelled as summarized in Section E.2.1 and Table 4.

E.4 Right of Way & Impacts Comparison

In order to compare issues related to Right of Way and Impacts between the three interchange concepts (the Stack, the Box, and the Turbine), a comparison matrix was developed examining six distinct elements. Key findings for each concept are shown in Table 6 and include:

- Stack: The proposed FS-1005A design of the Stack identified the impacts and right of way requirements in all four quadrants. A total of $48 million in ROW was identified by NCDOT including substantial takings in the NW quadrant including the South Hills Shopping Plaza. In addition, building impacts are anticipated in the SE quadrant and probable impacts to Walnut Creek in the NE quadrant.
- Box: The proposed Box configuration has the lowest ROW impacts of any of the three concepts. The primary impacts are along US 1 in both the NW and SW quadrants. Nevertheless, it is anticipated that impacts in the NW quadrant can be minimized by constructing a wall to preserve the existing parking at South Hills Shopping Plaza.
- Turbine: The proposed Turbine concept requires ROW from all four quadrants, but is not anticipated to impact any existing buildings. Walls are required in three of four quadrants to reduce the footprint. In addition, the flyover from I-40 WB to US 1 SB likely requires a design exception for a slight design speed reduction to avoid impacts to parking in the NE quadrant.

Based on the Table 7 ratings, the Box is preferred from a Right of Way and Impacts overview. The Stack has much greater impacts and anticipated ROW costs as compared with the Box and Turbine and is ranked lowest.

Table 7. Right of Way & Impacts Comparison

OVERALL	STACK	BOX	TURBINE
Estimated ROW Cost	$48M	$7M	$14M
Building Impacts	Up to 6	0 (highly confident)	0 (confident)
NW Quadrant - South Hills	Realignment of outside ramp and widening of US 1 results in possible take of main building plus up to 3 additional buildings. Major parking impacts anticipated even if buildings saved.	Realignment limited to CD system parallel to US 1 & not outside ramp. ROW impacts avoided with wall.	Realignment limited to CD system parallel to US 1. Ramp from I-40 WB to US 1 SB likely requires design speed reduction to avoid impacts to South Hills parking. Short wall proposed to avoid ROW impacts.
SW Quadrant - Crossroads	ROW required from adjacent land near Crossroads. Ramp braids for Jones Franklin interchange increase ROW take, but no building impacts anticipated.	Outside ramp from US 1 NB to I-40 EB realigned to allow for CD. ROW taking from vacant land adjacent to Crossroads is anticipated.	Outside ramp from US 1 NB to I-40 EB realigned to allow for CD. ROW taking from vacant land adjacent to Crossroads is anticipated.
SE Quadrant - Office Park	Combination of realigning outside ramp & braiding for Jones Franklin interchange result in impacts up to 2 office buildings.	Outside ramp from I-40 WB to US 1 NB remains on existing alignment. Minimal/ no ROW anticipated.	Realignment of outside ramp for flyover requires ROW. No building impacts anticipated.
NE Quadrant - Walnut Creek	Realigning of outer ramp requires 2 large walls (2400 lf) to mitigate impacts of Walnut Creek & church/school	No ramp realignments. No ROW takes.	Flyover tie-in at outside ramp results of realignment toward Walnut Creek. 1 large wall (800 lf) to mitigate impact to Walnut Creek.

E.5 Natural Systems Impacts

Although originally considered as part of the Right of Way and Impacts category, Natural Systems impacts were pulled out for separate review since Natural Syatems impacts have the potential of introducing higher levels of analysis requirements and approval steps as part of the NEPA process. As determined in the initial project phases, impacts to Walnut Creek in the NE quadrant are the primary issue from a Natural Systems perspective. Therefore the three interchange concepts (the Stack, the Box, and the Turbine) were evaluated separately for Natural Systems impacts using a similar comparison matrix to the other study elements. Key findings for each concept are shown in Table 7 and include:

- Stack: This alternative has the highest level of anticipated impacts to the NE quadrant based upon the identification of two walls with a length of approximately 2400 feet.
- Box: The proposed Box configuration has the lowest ROW impacts of any of the three concepts. In the NE quadrant no construction or resulting impacts to Walnut Creek are anticipated.
- Turbine: In the NE quadrant, the T-4 Turbine concept will likely require one 800 foot long wall to allow for the US 1 NB to I-40 WB flyover to merge into the existing US 1 SB to I-40 WB ramp. This wall could likely be built outside Walnut Creek. Alternatively, it may be possible to reduce the design speed on the flyover slightly, but that is not desired for a direct ramp onto I-40.

Based on the Table 8 ratings, the Box has no impacts to Walnut Creek and is the highest rated from a Natural Systems Impact perspective. The Turbine option, however, also has relatively minor impacts that could likely be mitigated. The Stack Turbine has the greatest impacts on the Walnut Creek resources and would be the most difficult to get through the NEPA process.

Table 8. Natural System Impacts Comparison

OVERALL	STACK	BOX	TURBINE
Likely Impacts to Walnut Creek	Moderate impacts to Walnut Creek mitigated by 2 walls (2400 lf)	No impacts to Walnut Creek	Minor impacts to Walnut Creek mitigated by 1 wall (800 lf). Wall may be able to be built outside of Walnut Creek limits.
NEPA Requirements	Mitigation for impacts will likely be required. Walls will be longer and higher. More difficult to avoid construction impacts.May be possible to minimize/ eliminate impacts with the use of walls.	Documentation would still be required to examine potential construction impacts.	Mitigation for impacts may be required. May be possible to minimize/ eliminate impacts with the use of walls.

E.6 Structural Requirements Comparison

Structure cost and complexity are key drivers for cost and engineering between the three interchange concepts (the Stack, the Box, and the Turbine). As with other key factors, a comparison matrix was developed examining ten distinct elements related to Structural Requirements. Key findings for each concept are shown in Table 9 and include:

- Stack: The proposed FS-1005A design of the Stack requires extensive structural elements including three major flyovers, replacement of five existing bridges, and three bridges for the new Jones Franklin interchange. This is reflected in the higher structural cost of $51 million.
- Box: The proposed Box configuration has two major flyovers, but also requires extensive MSE wall construction related to both flyovers tying into the US 1 median. In addition, two straddle bent bridges are likely required (for the US 1 SB braid and at the US 1 median connection). The total anticipated structural cost is $34 million.
- Turbine: The proposed Turbine configuration has two major flyovers, one of which requires three lanes for a portion as part of eliminating the loop in the SE quadrant. In addition, one straddle bent bridge is likely required for the US 1 SB braid. The total anticipated structural cost is $26 million.

Based on the Table 9 ratings, each of the alternative concepts include expensive and complex structures. In general, the Turbine is the highest rated based on the lower overall structural costs. The Box is similar, but is more expensive and has challenges related to multiple bridge alignments focused within the median areas. The Stack is rated lowest since it is the most expensive and requires replacement of multiple existing bridges.

Table 9. Structural Requirements Comparison

OVERALL	STACK	BOX	TURBINE
Estimate Structure Cost	$51M	$34M	$26M
Number of multi-level flyover bridge structures	3 1 4th level curved flyover (2 lane) 2 3rd level curved flyovers (1 & 2 lane)	2 1 4th level curved flyover (2 lane) 1 3rd level curved flyovers (2 lane)	2 1 3rd level curved flyover (2 lane) 1 2nd level curved flyovers (2 lane)
Number of Bridges for braid over US 1 SB CD	0 bridges	1 I-40 EB to US 1 SB ramp	2 I-40 EB to US 1 SB ramp & I-40 WB flyover over NB CD
Number of simple two-level bridge structures	0 bridges	1 (braid of I-40 EB to US 1 SB ramp over NB CD)	2 (braid of I-40 EB to US 1 SB ramp over NB CD and I-40 WB flyover over NB CD
Reconstruction/ replacement of existing bridges	5 4 bridges carrying I-40 & CDs over US 1 Walnut Street Bridge	2 I-40 WB and I-40 WB CD over US 1	0 bridges
Bridges required for new Jones Franklin Interchange	3 2 for ramps plus replace Jones Franklin bridge	0 bridges	0 bridges
Bridges Removed & Not Replaced	2 Crossroads Flyover & US 1 NB CD	0 bridges	0 bridges
Walls between traffic lanes (MSE)	4 walls (900 lf)	7 walls (5200 lf)	6 walls (1500 lf)
Walls to minimize ROW & cut/fill impacts	3 walls (3700 lf)	1 wall (1200 lf)	4 walls (1600 lf)
Walls due to new Jones Franklin interchange	9 walls (6200 lf)	0 walls	0 walls

E.7 Maintenance of Traffic & Constructability Comparison

Maintenance of Traffic (MOT) and Constructability are key factors in identifying a preferred design between the three interchange concepts (the Stack, the Box, and the Turbine). As with other key factors, a comparison matrix was developed examining ten distinct elements related to Maintenance of Traffic. Key findings for each concept are shown in Table 10 and include:

- Stack: The proposed design of the Stack requires reconstruction of the four existing I-40 bridges over US 1. This construction will require shifting of mainline I-40 traffic to/from CD bridges depending upon phase of construction. These shifts will result in LOS F weaves between loops. It is also noted that MOT congestion related to construction activities will likely overlap with increase in severe congestion on Walnut Street due to early closure of Crossroads ramps.
- Box: The proposed Box configuration requires extensive construction in the median areas of US 1 and I-40. This introduces additional traffic shifts compared with outside widening as well as elevation differences between traffic and construction areas.
- Turbine: The proposed Turbine configuration has minimal impact on I-40 traffic operations. Key issues are along US 1 including the construction of two ramp braiding structures on US 1 southbound.

Based on the Table 10 ratings, each of the alternative concepts include complex MOT provisions and constructability challenges. In general, the Turbine is the highest rated based on the simplest MOT provisions on I-40 and US 1. Both the Box and the Stack have issues with replacing existing bridges on I-40, but the Stack replaces all 4 bridges resulting in weaving issues for the duration of construction. Also note that the Box and the Turbine both maintain the majority of the existing loops which provides increased flexibility in MOT.

Table 10. MOT & Constructability Comparison

OVERALL	STACK	BOX	TURBINE
MOT on I-40	Requires replacement of 4 bridges on I-40 over US 1 (the I-40 mainline & CDs) 4 bridges (including 3 flyovers) to be constructed over I-40 possibly requiring temporary closures	Requires replacement of I-40 WB bridge and I-40 WB CD bridge over US 1 Requires median construction with walls & elevation differences at connection of proposed flyover from US 1 NB to I-40 WB 2 flyover bridges to be constructed over I-40 possibly requiring temporary closures	In general, improvements will occur to outside with minimal impact to I-40. 2 flyover bridges to be constructed over I-40 possibly requiring temporary closures
MOT on US 1	Phasing will focus construction to the outside and then shift traffic to the new pavement. Median construction would not include elevation differences & walls.	US 1 SB will need to be diverted to US 1 SB CD to allow for realignment with S-curve to avoid US 1 NB ramp to I-40 WB to be constructed in median Requires construction with walls & elevation differences at median connection of proposed flyover from US 1 NB to I-40 WB & at braid of 1 ramp over US 1 SB	Likely phasing would widen to the south first, divert US 1 SB to new pavement, and then construct median area. Median construction would not include elevation differences & walls. Requires construction with walls & elevation differences at braid of 2 ramps over US 1 SB.
Loop Operations during MOT	3 flyovers extended over 3 loops (NW, NE, & SE) that will be removed in final phase for MOT purposes. All loops will remain open during majority of MOT until no longer needed. LOS F weave operations likely due to replacement of I-40 bridges, however. Short term structural closures of all 4 loops required.	0 flyovers extended only for MOT reasons. All loops will remain open during majority of MOT. Short term structural closures of lower volume NW & SW loops required.	1 flyover extended over SE loop solely for MOT reasons All loops will remain open during majority of MOT. Once the US 1 NB to I-40 WB flyover is completed, the SE loop can be removed. Short term structural closures of higher volume NE & SE loops required.
Access To Crossroads during MOT	Crossroads flyover & slip ramp to be permanently closed. Walnut Street exit will be only access during construction to/from I-40.	Possible closure of US 1 SB CD required for 1 bridge being braided over CD. US 1 NB CD will likely be late phase during construction. During CD closures, Walnut Street will be primary access to/from I-40.	Possible closure of US 1 SB CD required for 2 bridges being braided over CD. US 1 NB CD will likely be late phase during construction. During CD closures, Walnut Street will be primary access to/from I-40.

E.8. Provision for Future Managed Lanes

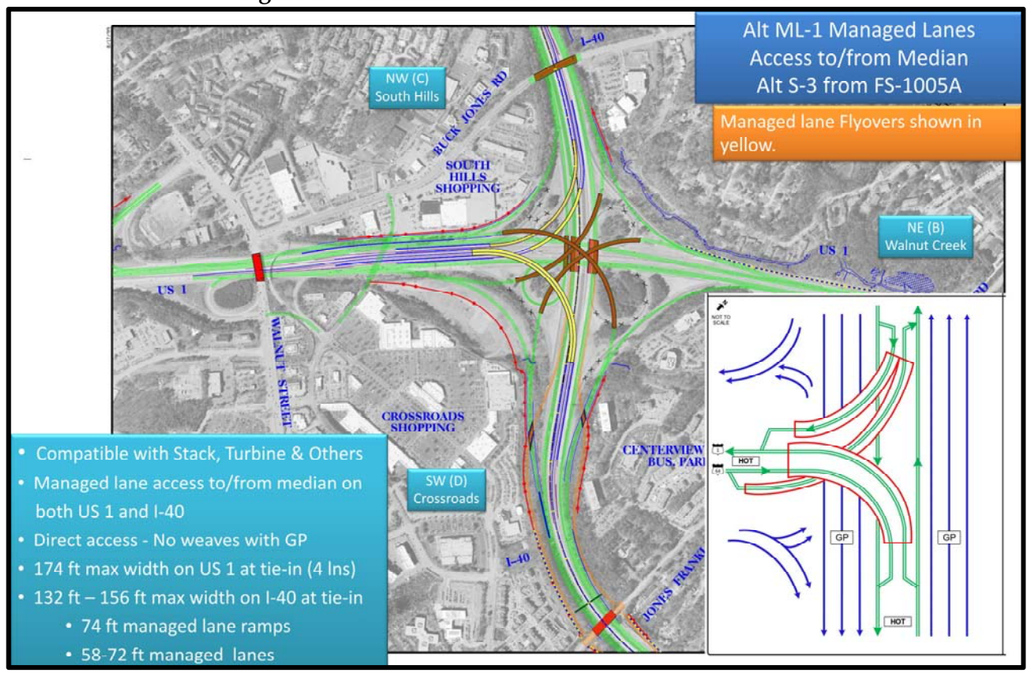
The development of alternatives considered the provision for providing access from US 1 to an I-40 managed lane system. The following identified the proposed managed lane treatments for each concept considered. Note that no cost estimates were developed as part of this comparison of managed lane treatments. Section D.1 provides a more detailed description of the specific treatments.

E.8.1 Stack Treatment

An illustration of potential managed lane connection with the Stack interchange is shown in Figure E-9.

The final output from the FS-1005A study was the presentation of the Stack interchange with managed lanes connectors to/from US 1 south of I-40. The design utilized the median of US 1 for all managed lane movements to access I-40 in both directions. This was accomplished with 3 managed lane flyovers (one dual direction and two single direction ramps). The primary issue in this treatment is the requirement for a 174 foot wide section of median to bring the four ramps together onto US 1 due to shoulders, barrier offsets, and structure walls. The existing median is only 46 feet thereby requiring significant widening on both sides of US 1 and associated ROW impacts. Note that this widening would be in addition to any additional general purpose or CD lanes.

Figure E-9. Alternative ML-1. Alt. S-3 form FS-1005A



E. 8.2 Box Treatment

An illustration of potential managed lane connection with the Box interchange is shown in Figure E-10.

Providing future managed lane access for the Box treatment is more difficult than with the Stack. This is because the Box concept uses the median area for general purpose lane flyovers which conflicts with using the median area for managed lane connections. Although initial considerations were to allow for shared lane treatments, this became problematic after the Brainstorming session due to the connector ramp between I-40 westbound to US 1 south pulling off on the right side as opposed to the median. In order to share this ramp, managed lane traffic would be forced to merge across multiple general purpose lane to exit to US 1. This is not desirable. Nonetheless, this option has been illustrated in Figure E-10.

Although not illustrated, the Box interchange was also considered with the use of and adjacent parcel of land between US 1 and the Crossroads development in the SW quadrant as discussed in Section D.1.3. While it is possible to utilize this approach, it is noted that a fifth level to interchange structure would likely be required. (Note that although this concept is not illustrated, Figure E-11 for the Turbine concept illustrates the concept as described in the next section.)

Other access alternatives would require additional flyovers and roadway width along US 1. Specifically, a flyover is needed from the median of I-40 westbound managed lanes to US 1 southbound. Alternatively, the general purpose ramp from I-40 westbound to US 1 southbound could be tied into the median to allow sharing of the flyover. Even with a shared managed lane/general purpose lane flyover from I-40 westbound, an extended approach will be needed to allow the managed lane traffic to merge into the left most general purpose lane before the exit point.

E.8.3 Turbine Treatment

An illustration of potential managed lane connection with the Turbine interchange is shown in Figure E-11.

In reviewing managed lane options, a concept was identified that utilized a section of vacant land near Crossroads to develop an an access point utilizing ramps from this takeoff point instead of the median. This option has the primary advantage of allowing for the main interchange to be constructed and then maintained during a future managed lane project. Instead of construction occurring in a median, maintenance of traffic issues would be greatly reduced in a managed lane phase and impacts to the north of US 1 could be eliminated as part of a second phase.

Access to and from US 1, however, would be modified for managed lane traffic. Instead of coming into the US 1 median with 4 lanes, it would be possible to tie the managed lanes together in the adjacent land, merge the 4 lanes (2 in each direction) into 2 lanes (1 in each direction), and then tie into US 1. Although further study is needed, a potential connection is illustrated in Figure E-11. It is likely that overall costs for implementation of managed lanes may be higher than using the median, but this may be more than offset by the simplicity in allowing for the primary interchange to operate with minimal changes during construction and into the future.

Figure E-10. Modified Box with Managed Lanes

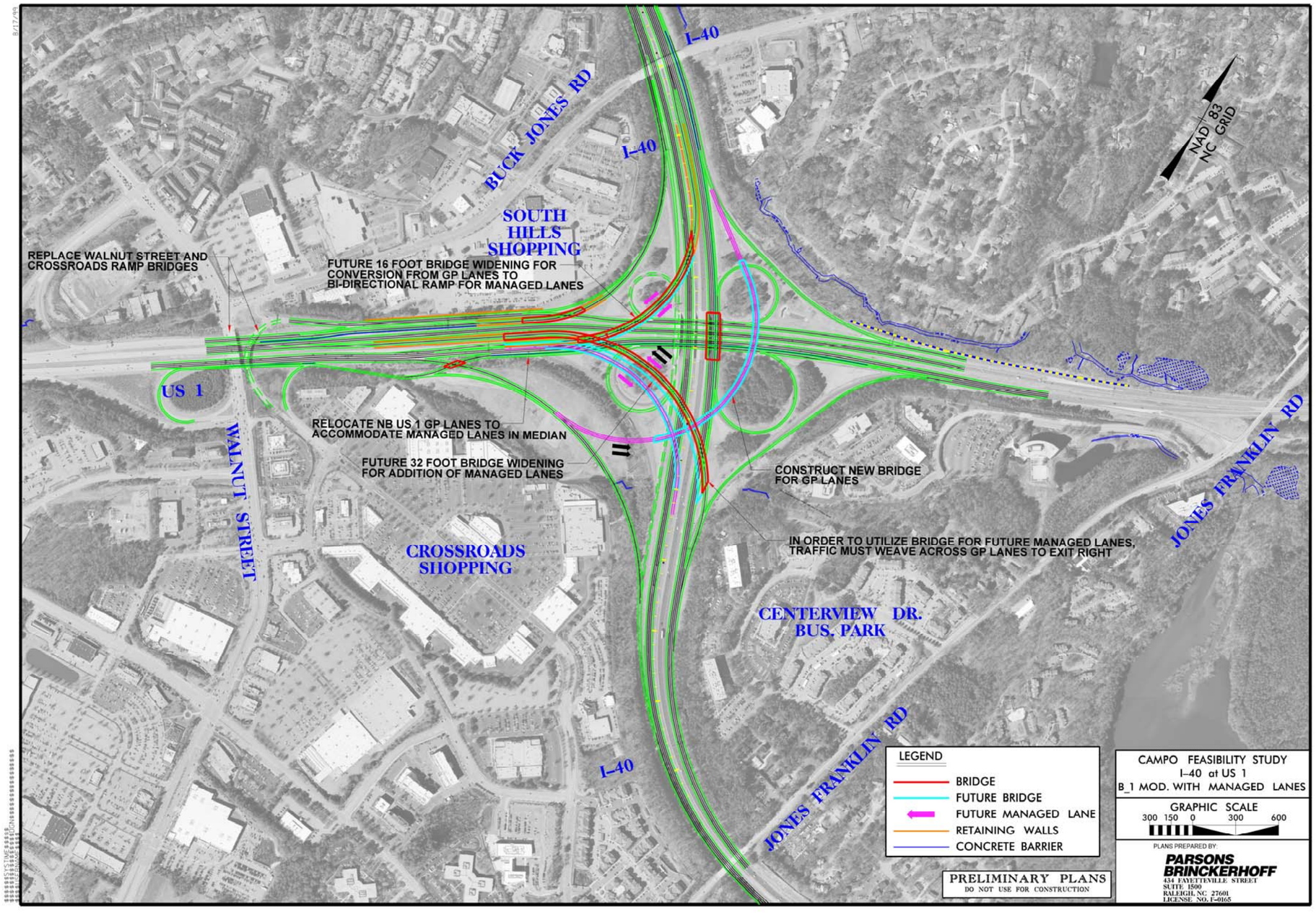
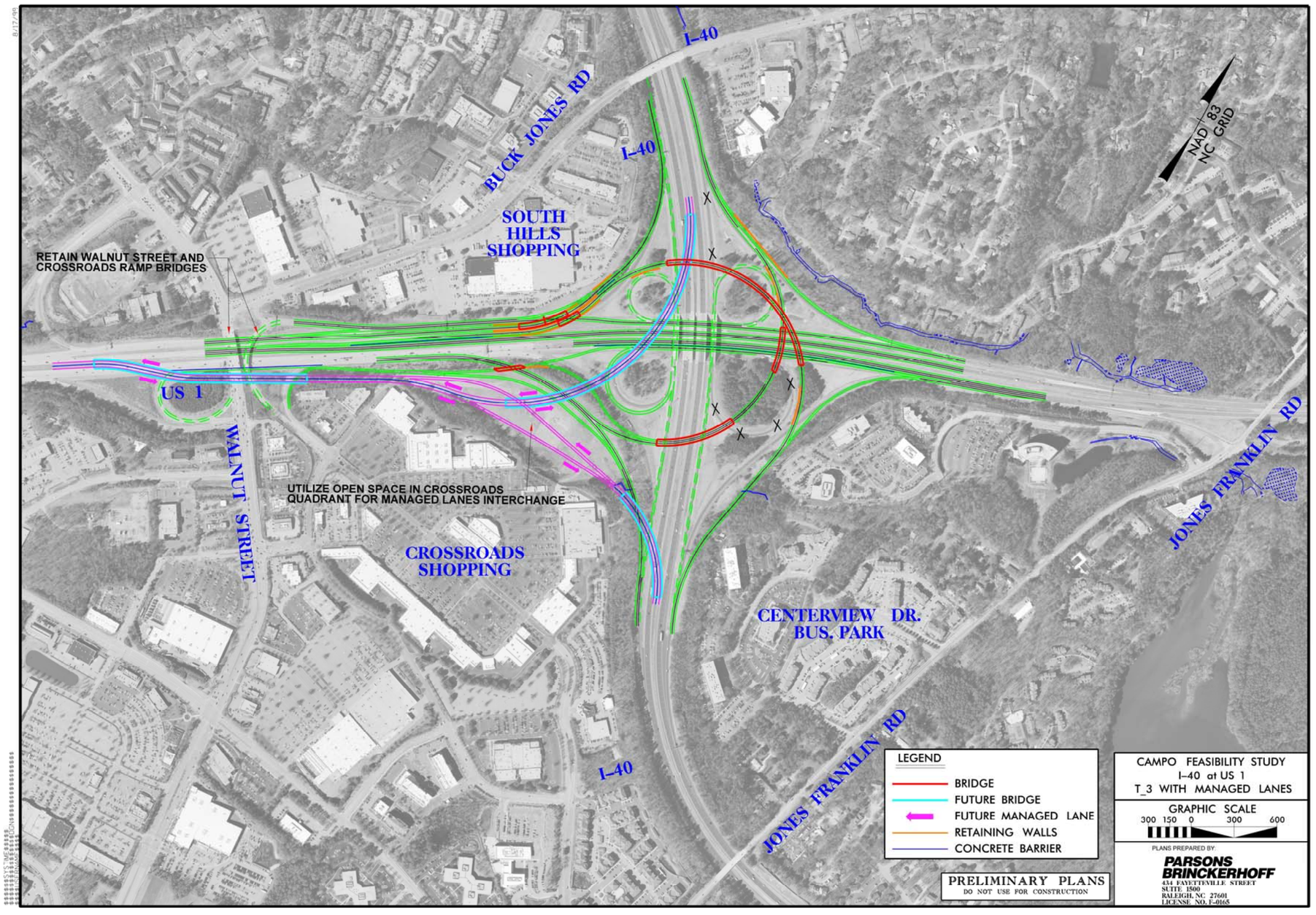


Figure E-11. Modified Turbine T-4 with Managed Lanes



E.8.4 Provision of Future Managed Lanes Comparison

The provision of managed lanes as part of a future improvement is planned at the subject interchange. Although the related costs and effort would be part of a separate project, the ability of the proposed interchange concept to be modified in the future to provide managed lanes is a key factor in identifying a preferred design between the three interchange concepts (the Stack, the Box, and the Turbine). As with other key factors, a comparison matrix was developed examining ten distinct elements related to Provision of Future Managed Lanes. Key findings for each concept are shown in Table 10 and include:

- Stack: The Stack interchange concept was developed allowing for all managed lane movements to occur between the US 1 median and I-40 medians. While this is optimal for managed lane operations, it does introduce substantial impact issues, particularly along US 1 where four managed lanes require up to 174 feet of future median.
- Box: The proposed Box configuration includes a combination of median to median movements and direct connectors for managed lane traffic. There is some potential for shared bridges serving both managed lane and general purpose traffic, but this opportunity require left hand exits and entrances on both I-40 and US 1 for each shared structure. As shown, the managed lane scheme also includes a major weave along I-40 that would require an additional flyover to address the weave.
- Turbine: The proposed Turbine configuration utilizes a parcel of vacant land adjacent to the Crossroads shopping center. Utilizing this land has the major advantage of allowing for managed lanes to be added in the future with reduced shifting of traffic and simpler maintenance of traffic. This approach would still require extensive structure investment including a connection of the managed lanes to US 1 south of the Walnut Street bridge.

Each of the alternative concepts should be designed to allow for potential managed lane improvements in the future. Based on Table 11, the Turbine is likely the easiest to plan for and design a future managed lane connection. Both the Box and Stack, however, have multiple challenges and drawbacks. The Box has challenges related to the managed lane weave across I-40 which would require additional structures and ROW to address. The primary drawback of the Stack is the width of the median section on US 1 and the resulting impacts to South Hill.

Table 11. Provision of Future Managed Lanes Comparison

OVERALL	STACK	BOX	TURBINE
Required Median Area on US 1 for Future Connection of Managed Lanes	Managed lanes connect directly with 4 ramps into US 1 median. Required width for future Managed Lanes is 174 feet.	Managed lanes connect directly into US 1 median with 2 ramps and converting 1 GP ramp. Required additional width for the future managed lanes is approx. 44 feet. Could increase substantially if I-40 WB to US 1 SB movement is new flyover.	Managed lanes concept utilizes vacant land adjacent to Crossroads in SW quadrant. No median connections required.
Required Median Area on I-40 for Future Connection of Managed Lanes	Similar requirements in all scenarios.	Similar requirements in all scenarios.	Similar requirements in all scenarios.
Utilization of Vacant Land Near Crossroads	Not included as part of proposed interchange, but modifications may allow.	Not included as part of proposed interchange, but modifications may allow.	Assumed as part of proposed interchange.
Likely ROW Impacts	Major impact to NW Quadrant including South Hills Shopping Center.	Impact to NW Quadrant includes a wall to preserve South Hills Shopping Center parking. Could increase substantially if I-40 WB to US 1 SB movement is new flyover.	Impact to NW Quadrant includes a wall to preserve South Hills Shopping Center parking
New structures required	3 managed lane flyovers (3rd or 4th level) required in Phase 2 implementation. - US 1 south to/from I-40 east (both US 1 NB to I-40 EB & I-40 WB to US 1 SB) - 2 ML - US 1 NB to I-40 WB - 1 ML - I-40 EB to US 1 SB - 1 ML	2 flyovers required (3rd & 4th level) in Phase 2 implementation. - US 1 NB to I-40 EB - 1 ML - US 1 NB to I-40 WB - 2 GP to replace converted flyover Also note that if ramp added for I-40 WB to US 1 SB managed lane movement (to eliminate weave across I-40), an additional managed lane flyover would need to be constructed.	3 managed lane flyovers (2nd or 3rd level) required in Phase 2 implementation - US 1 NB toI-40 WB & I-40 WB to US 1 SB - 2 ML - I-40 WB to US 1 SB & US 1 NB to I-40 EB - 2 ML - US 1 NB and SB to ML take off point at vacant land
Shared Ramps	No shared ramps required.	Managed lanes would require conversion of Phase 1 GP ramp from US 1 NB to I-40EB to be converted to two-way managed lane ramp. New flyover would be reconstructed to carry GP traffic. I-40 WB to US 1 SB shown with shared ramp. Shared ramp could be eliminated, but would require new median to median ramp from I-40 WB to US 1 SB.	No shared ramps required.
Weaving Issues	Managed lanes and general purpose lane traffic fully separated.	Modified Box concept with Managed Lanes (Figure E-12) requires I-40 WB managed lane traffic to weave across 4 lanes of I-40 to utilize right exit to US 1 SB. Weave could be eliminated, but would require new median to median ramp from I-40 WB to US 1 SB.	Managed lanes and general purpose lane traffic fully separated.

E.9. Cost Estimates

Planning level cost estimates have been prepared for the key alternatives and are shown in Table 12. These estimates are based on conceptual interchange concepts only and are not intended to serve as an accurate project cost or for allocation of funds. The primary purpose at this level of planning is for comparison between alternatives.

The cost estimates were developed using the spreadsheets from the FS-1005A interchange cost estimation as a base. Key inputs were bridge and retaining wall structures. For other items, percentage estimates were made on a case-by-case basis for specific quantities as compared with the Stack interchange. Lump sum costs (such as mobilization and utilities) were assumed to be equal between options. In addition, mileage differences were calculated as appropriate to factor quantities.

The unit costs in the FS-1005A spreadsheet were then applied. Miscellaneous and Mobilization was assumed to be 15 percent of structural and 45 percent of roadway costs and used in computing Contract cost. An engineering and construction inspection (E&C) allowance of 15 percent was then added to reach the Construction Cost. A 10 percent contingency was then added to Construction Cost.

In preliminary analysis, it was identified that the Jones Franklin interchange was estimated to cost $22 million based on the same FS-1005A spreadsheet. For alternatives with this in place, the cost was added separately.

Right of Way cost has also been prepared. This estimate has not been vetted by NCDOT and is not representative of any specific impacts or takings. Instead it is based more on a qualitative review.

The high point of the estimate ($48 million) was estimated by NCDOT as part of FS-1005A for the ultimate Stack interchange configuration identified. This included substantial ROW impacts to the South Hills Mall and Plaza area in the NW quadrant. In addition, there were ROW impacts in the SE quadrant to the Center Drive Business Park.

Using this limited information as a worst case, the potential impacts for each of the concepts was compared to the FS-1005A Stack concept ROW impacts. It was estimated that severe impacts to the NW quadrant resulted in $30 million in ROW and severe impacts to the SE quadrant required $15 million in ROW. Minor impacts to these quadrants were estimated to be two-thirds of these levels. For the other two quadrants, ROW costs were estimated to range from $5 million to $10 million.

Table 12. Conceptual Cost Estimates

Alternative	Construction Cost plus 10% Contingency	ROW	Total I-40 at US 1	Jones Franklin at I-40	ROW Impacts
S-2 Stack	$130 M	$48 M	$178 M	$22	South Hills, Office
B-4 Box with with Local CD Access	$127 M	$5 M	$132 M	$0	minimal
T-4 Turbine with Local CD Access	$94 M	$15 M	$109 M	$0	minimal

As initially stated, multiple assumption have gone into these cost estimates. More detailed analysis will result in changes. These costs are planning level only and are intended primarily for comparison of alternatives.

- The cost estimate figures included in this report were calculated strictly as a comparison tool to evaluate alternatives, and not intended as an accurate project cost or for allocation of funds.
- The cost estimate figures included in this report were developed using the baseline estimate developed for the FS-1005 Feasibility Study 4-level stack with 3 flyovers at the US 1/I-40 interchange. Bridge and retaining wall costs were calculated based on the actual design alternatives under consideration, but all other quantity/cost calculations used engineering judgment to apply an estimated percentage factor to the baseline 4-level stack estimate.
- Costs for Managed Lanes are not included in the estimate.
- Costs for a Jones Franklin Road interchange is not included in the estimate.
- Bridges estimated at $160/SF, regardless of bridge height, complexity, or use of straddle bents.
- Retaining walls estimated applying engineering judgment for wall heights but comprehensive determination of locations and limits not based on vertical profiles.