

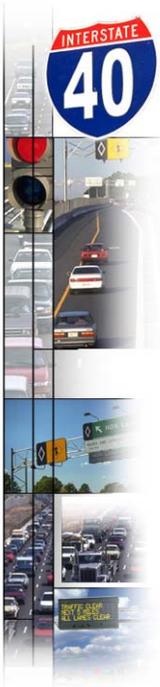


I-40 High Occupancy Vehicle / Congestion Management Study

I-40 HOV Hybrid Configuration Recommendation

December 18, 2003

North Carolina Department of Transportation



I-40 HOV Hybrid Configuration Recommendation

1. EXECUTIVE SUMMARY

Following the comprehensive analysis of four possible HOV configurations for the I-40 corridor between Chapel Hill, Durham and Raleigh, NCDOT evaluated the options for combining the best of each configuration into a hybrid. This recommended Hybrid Configuration seeks to optimize operational benefits, costs and constructability.

The Hybrid Configuration, described in this report, makes use of the Simple Configuration at the outer limits of the corridor where volumes are lower and construction costs can be saved without jeopardizing the overall operations of the HOV facility. The Elevated Configuration is recommended through the RTP-West segment of the corridor where constructability is an issue and where demand for both HOV and express facilities mandate a dedicated, barrier separated structure. The Modified Complex Configuration is recommended where volumes are too great for the efficient operation of the Simple but the Elevated structure is not warranted. The map in Figure 6 on page 9 of this report shows the locations where each configuration is recommended.

With the assumption that implementation moves ahead quickly, this analysis concludes that *full implementation* can be achieved by 2012. This analysis combines costs already estimated by section and configuration to derive a new total estimated and inflated cost of \$1.2 billion for construction of the Full Hybrid Configuration. However, it has been determined that some economies in construction, described in Section 7.2, could result in additional, and possibly considerable, reduced costs.

2. INTRODUCTION

The following describes the recommendations for combining roadway elements of the Simple, Complex, Modified Complex and Elevated Configurations into a Hybrid Configuration that can be assessed in a full NEPA evaluation. This is a cursory assessment, not intended to represent rigorous technical analysis of a single comprehensive configuration. As stated in our Scope of Work, this effort draws from technical analysis previously completed and makes no attempt to evaluate the recommended Hybrid Configuration as a complete comprehensive option.

We were directed to use cross-sections from existing configurations, mixing and matching as seemed appropriate based on geometric and operations technical analyses previously completed. For reference, graphic depictions of the three relevant cross-sections are shown in Figure 1. No environmental baseline input was considered, although an understanding of available right-of-way was applied in development of the Hybrid. Note that HOV demand and traffic operations analyses rely on the overall operation of the entire study area, and results of analyses run on the full Hybrid Configuration are difficult to predict.

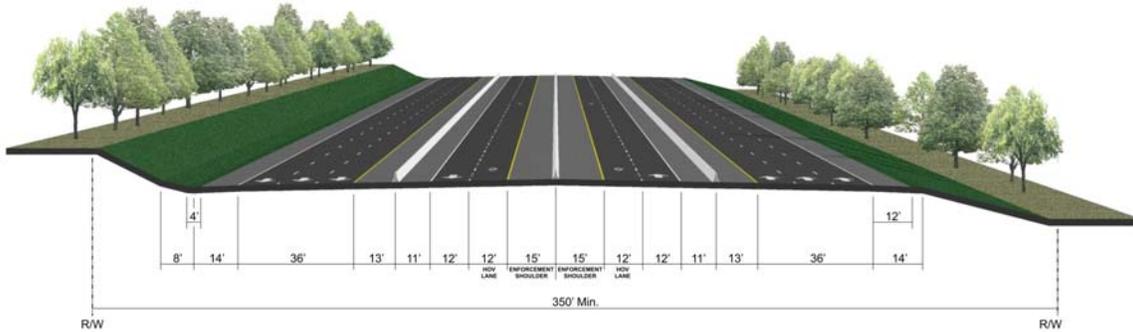


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Figure 1: Sample Typical Cross-Sections



Proposed Simple HOV Design



Proposed Complex HOV Design



Proposed I-40 Barrier-Separated Elevated HOV Design

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3. CRITERIA

The following criteria were used in evaluating and recommending the Hybrid Configuration:

- Must minimize anticipated construction costs while optimizing operational benefits, and
- Must be constructible and able to be phased in a reasonable period of time without extensive disruption to existing traffic.

4. METHODOLOGY

Our evaluation involved three steps:

1. Assess technical demand and traffic analysis data to determine the optimum configuration,
2. Evaluate constructability and phasing
3. Recalculate costs

Since the Simple Configuration is the least expensive and easiest to build, the evaluation began by starting at the outer edges of the corridor to determine how far in towards the RTP the Simple Configuration could remain a viable configuration from a demand and traffic operations perspective. At the points where the Simple Configuration became operationally undesirable other, more expensive and more difficult to build configurations were evaluated.

For purposes of this analysis we used HOV share as a measure of demand. Note that HOV shares are total shares on both the managed lanes facilities and on the general purpose (GP) facilities. LOS on the I-40 mainline is used as a measure of traffic operations quality. This assessment looked solely at AM measures in the inbound (toward RTP) direction. Figures 1 – 4 on the following pages show the HOV shares for each of the configurations in the eastbound and westbound directions respectively, and LOS for each of the configurations in the east and westbound directions respectively. Please refer to these figures for the following discussion.



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Figure 2: Comparison of 2025 HOV Demand by Segment as Measured by AM Peak Hour HOV Mode Share - East Bound

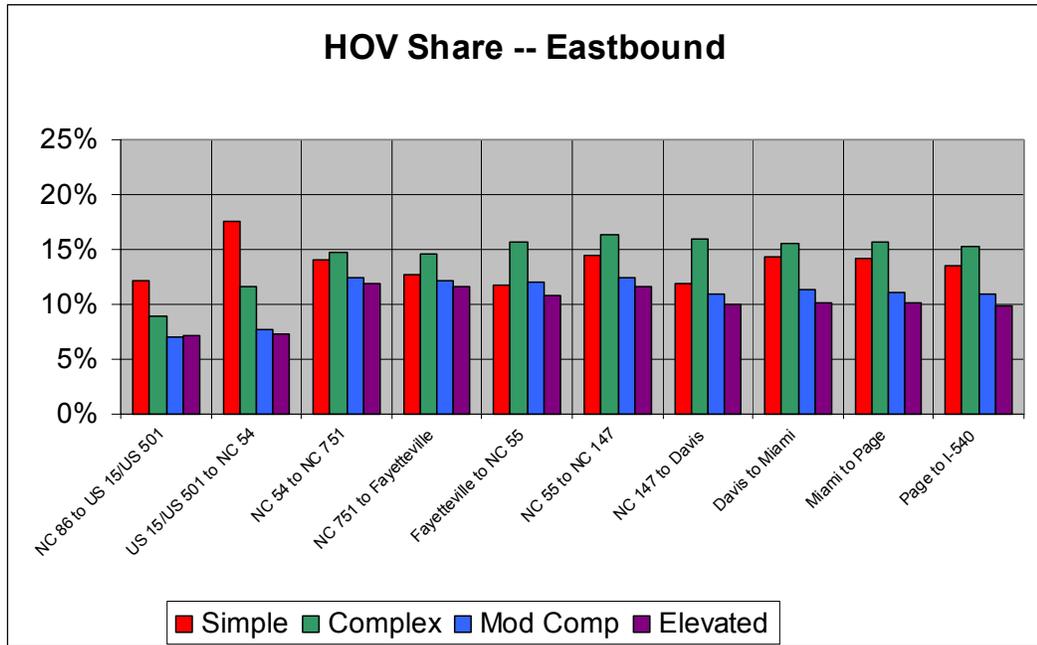
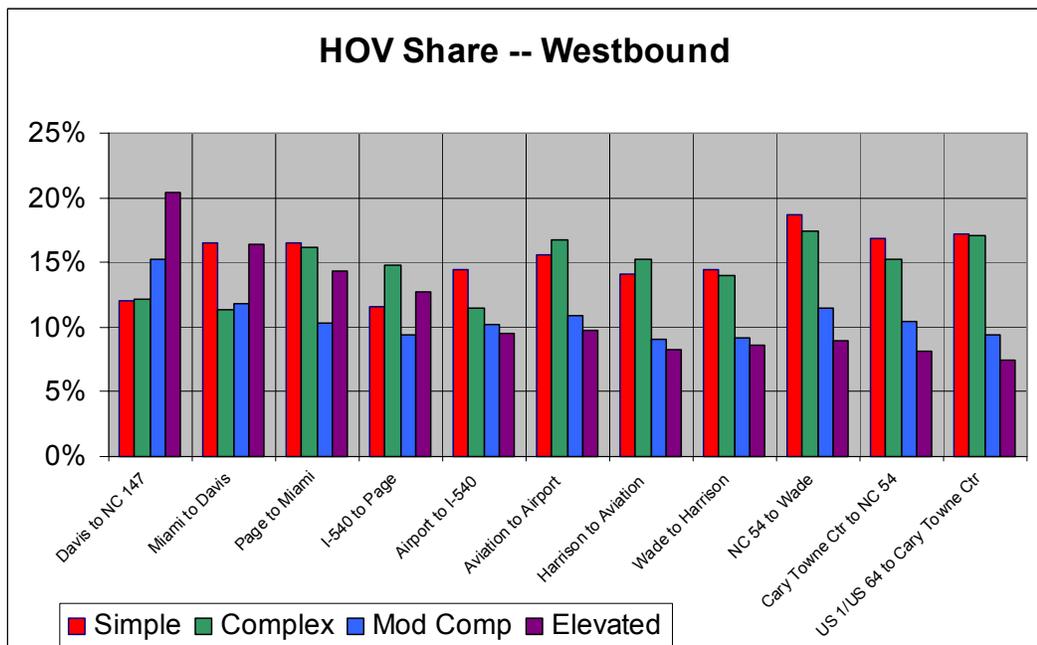


Figure 3: Comparison of 2025 HOV Demand by Segment as Measured by AM Peak Hour HOV Mode Share - West Bound



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Figure 4: Comparison of 2025 AM Peak Hour Level of Service by Section – Eastbound

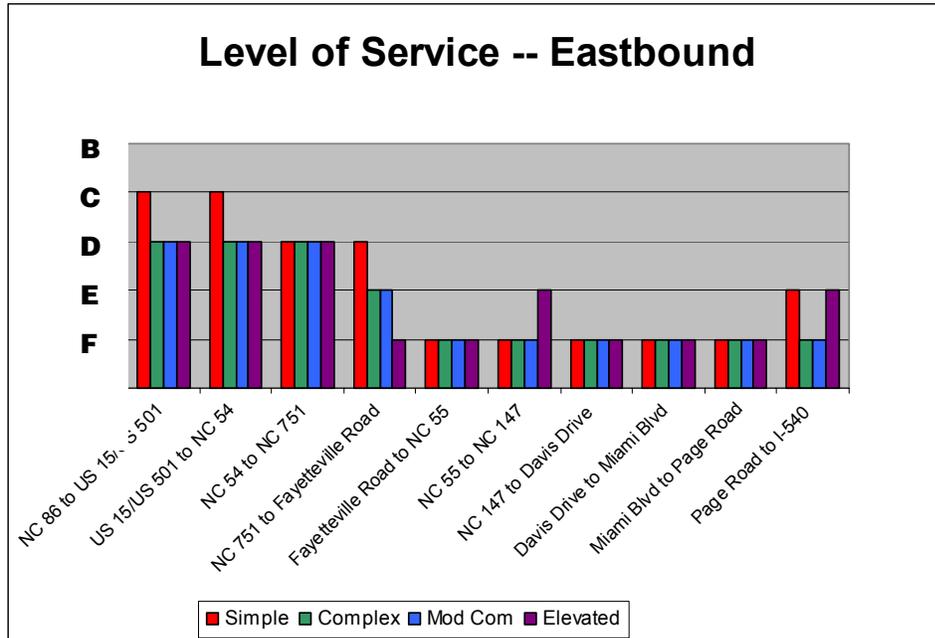
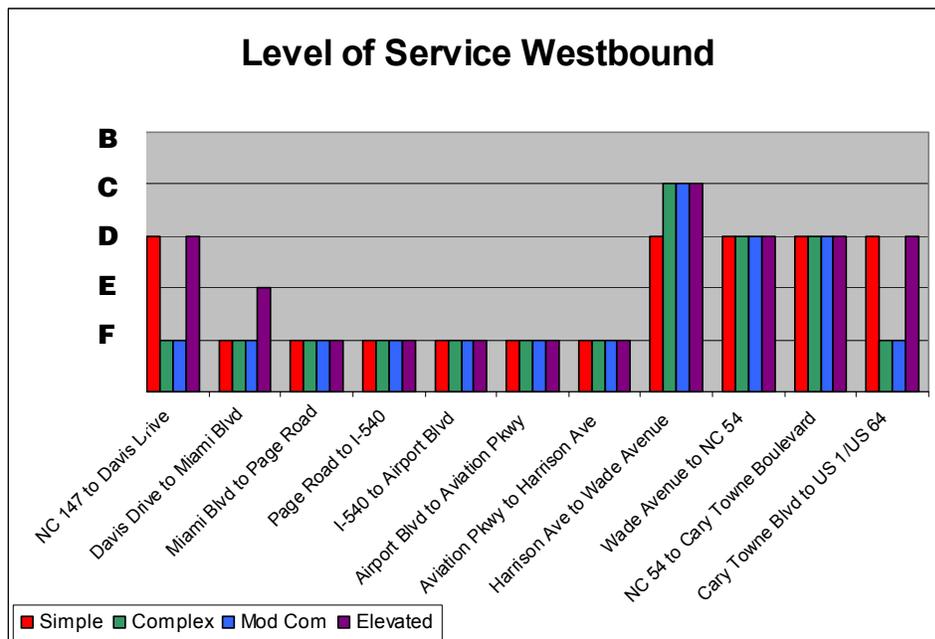


Figure 5: Comparison of 2025 AM Peak Hour Level of Service by Section – Westbound



Note: Level of Service (LOS) is measured on the mainline for the Complex, Modified Complex and Elevated Configurations. The LOS calculations include the HOV lanes for the Simple Configuration since it allows for HOV traffic to change lanes freely.



5. TECHNICAL ASSESSMENT

5.1 Simple

Conceptually, a simple HOV configuration (concurrent, buffer separated lanes) and a complex HOV configuration (barrier separated lanes) should carry the same approximate demand. There have been two primary arguments for choosing a more expensive, Complex Configuration over the cheaper, Simple Configuration. The first is the difficulty of enforcing the Simple Configuration, and the second is the operational problems created by HOVs weaving across general purpose (GP) lanes to get to and from existing, non-dedicated expressway ramps. Recent assessments of emerging technologies indicate that enforcement will not be a major problem for simple configurations in the very near future¹. So to the extent that the Simple Configuration is optimal from a demand and cost perspective, the only reason to choose a more complex option is to avoid the weaving problems in congested conditions. At the outer ends of the I-40 corridor the demand for HOV facilities is low enough that weaving does not create a serious operational problem. As HOV volumes increase operational problems increase and the case for complex configurations with dedicated ramps are warranted.

5.1.1 Eastbound from NC 86

In the eastbound direction the Simple Configuration shows a highest HOV share of all the configurations from NC 86 to NC 54, while at the same time the Simple Configuration shows a LOS C as compared to D for the complex. Volumes are low enough that weaving issues associated with moving HOVs from the inner lanes to the exit ramps does not create a substantial problem. However, east of NC 54 the Complex Configuration shows a higher HOV and the Simple Configuration shows a diminishing of LOS. Therefore, it is recommended that the Simple Configuration be used up to the west side of the NC 54 interchange.

5.1.2 Westbound from US 1

The Simple Configuration shows a higher HOV share than the Complex or Modified Complex Configurations in the westbound direction between US 1 and Wade Avenue. An additional general purpose (GP) lane is added west of the Wade Avenue interchange, but a large number of HOV vehicles access I-40 westbound at this same interchange. In the Simple Configuration these HOV vehicles must weave across the GP lanes to access the HOV lane. So while LOS improves for all other configurations due to the added lane and the dedicated HOV access at Wade Avenue, LOS for the Simple Configuration does not improve due to weaving issues. Therefore it is recommended that the dedicated access/egress ramps at Wade Avenue be the point at which the Simple Configuration transition to some other configuration.

¹ Recent and rapidly developing technologies such as global positioning systems, remote sensing and image interpretation make it extremely likely that non-barrier separated managed lanes will shortly be enforceable entirely through remote, automated technologies. These technologies are currently being employed for enforcement of automated toll collection facilities with good success.



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5.2 Complex and Modified Complex

The difference between the Complex and Modified Complex Configurations is simply the number of HOV access/egress points. The fewer number of access points in the Modified Complex Configuration make it consistent with the Elevated Configuration operationally. The reduced number of access points also reduces over all the number of HOV/Express vehicles that can get to the managed lanes and therefore the overall HOV Share. However, reduced HOV share for the Modified Complex Configuration is across the board, meaning that for most sections of the corridor (RTP westbound excepted), the HOV shares for the Complex and the Modified Complex follow a similar pattern but with the Complex having approximately a 5% higher HOV share throughout the corridor. Since the Modified Complex has fewer interchanges it is cheaper than the Complex Configuration. The change in the number of interchanges affects the total number of HOVs entering the managed lanes system, but operates similarly inside the corridor. So, choosing the Modified Configuration over the Complex Configuration to follow the Simple Configuration as we move toward RTP will result in a less expensive Hybrid and will not diminish the number of HOVs already in the corridor.

5.2.1 Eastbound

The Modified Complex is recommended to follow the Simple Configuration beginning just west of the NC 54 interchange up to just west of NC 147. The only difference between the Modified Complex and the Complex in this section are two HOV access points at Fayetteville Road and Alston Avenue. Neither of these access/egress points are attracting substantial HOV volumes and do not justify their cost.

5.2.2 Westbound

As noted above, a substantial amount of HOV traffic accesses the system at Wade Avenue in all configurations; and, due to weaving issues, in the Simple Configuration the LOS begins to degrade relative to other configurations after Harrison Avenue. It is recommended that the Modified Complex Configuration be used beginning just east of Wade Avenue, where the Simple Configuration becomes less effective. The difference between the Modified Complex and the Complex between Wade and I-540 is the three access/egress points at Harrison, Aviation Parkway and Airport Boulevard. None of these interchange attract significant HOV volumes to warrant the cost of construction or to impact the overall effectiveness of the managed lanes system. Therefore the Complex Configuration is not justified.

Note that the Modified Complex and the Elevated Configurations show the same LOS all the way from Wade Avenue through Miami Boulevard, where the Elevated Configuration begins to show an improvement in LOS over the Modified Complex. However, the Elevated Configuration begins to show improved HOV share after Airport Boulevard. This would imply that the Elevated Configuration should be recommended beginning between Airport Boulevard and I-540. However, due to the grades required to bring the Elevated Configuration up to the required height at I-540, the Elevated Configuration needs to start before Airport Boulevard. Therefore, the recommended transition between the Modified Complex and the Elevated in the westbound direction is between Aviation Parkway and Airport Boulevard.



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5.3 Elevated

The HOV share for the Elevated (and even for the Modified Complex) does not make a strong case for either configuration in the RTP area. However, several points make the case for an Elevated Configuration through RTP:

1. The Elevated Configuration shows some LOS improvements in some sections through RTP.
2. The Modified Complex Configuration requires that every structure within the RTP – East section of the corridor be either widened or totally rebuilt even though there is no HOV/Express access/egress at these interchanges. This is because the typical section width of the at-grade managed lanes cannot pass through existing interchanges without rebuilding the structures. An elevated structure can pass over all these interchanges without having to rebuild them.
3. Construction of an elevated structure through RTP, with narrow rights-of-way and tightly space interchanges would be the easiest way to construct the facility with minimum disruption of traffic. (See constructability discussion below).

5.4 Summary

These sections align with the sections of the corridor defined in the I-40HOV/CMS final report for purposes of summarizing performance measures and costs. Those corridor sections are:

Section of Corridor	Limits	Approximate Length (miles)	Recommended Configuration
Western	west of NC 86 to west of NC 54	7	Simple
RTP – West	west of NC 54 to west of NC 147	6	Modified Complex
RTP – East	west of NC 147 to east of I-540	4	Elevated
Airport	east of I-540 to east of Wade Avenue	6	Modified Complex
Eastern	east of Wade Ave. to east of US 1/US 64	4	Simple

NOTE: Suggested sections are preliminary and subject to further study through the NEPA process.

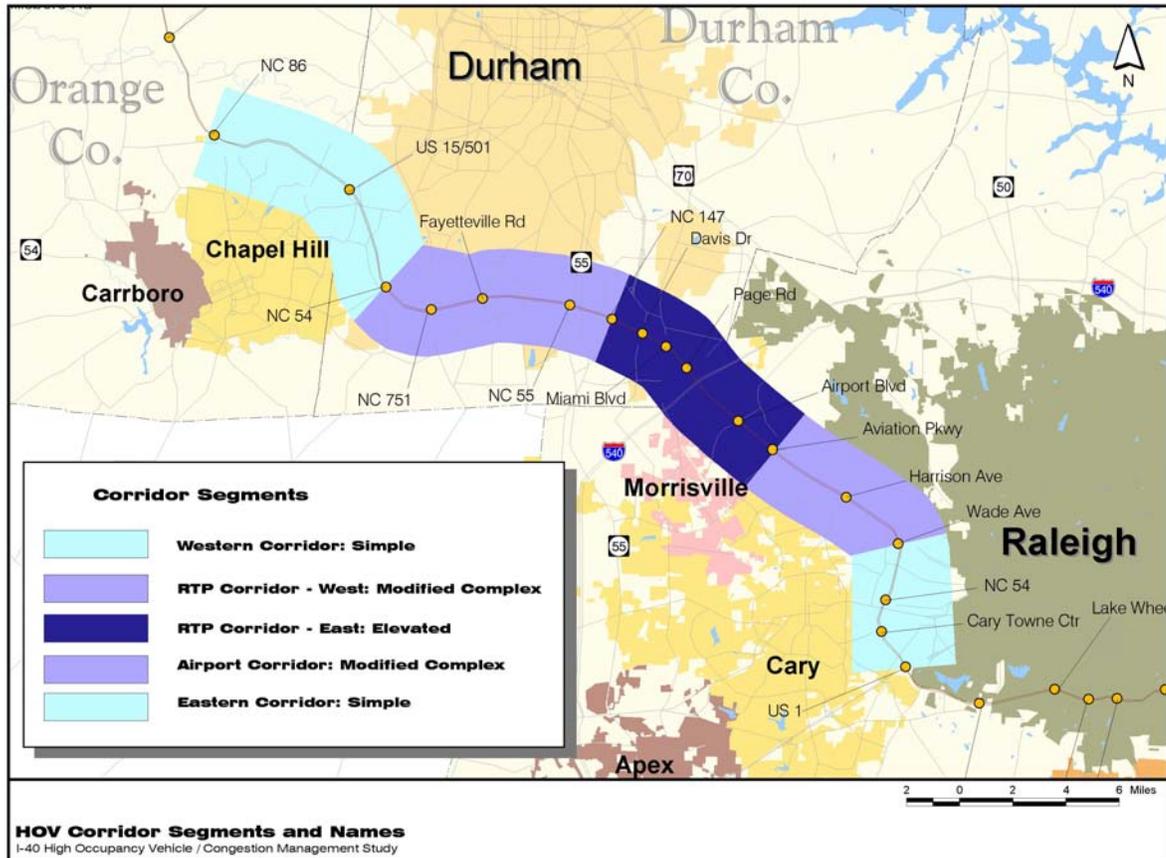
These sections are illustrated in Figure 6 on the following page.

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Figure 6: Map of Proposed Segments and Configurations



NOTE: Suggested sections are preliminary and subject to further study through the NEPA process.

6. CONSTRUCTABILITY AND PHASING

6.1 Construction Issues

Construction of the Simple Configuration sections does not present a substantial problem. Work would progress in much the same way as a simple addition of lanes. Four bridges will need to be widened in the Eastern Corridor where construction is not expected to present unusual difficulties.

Similarly, construction of the Modified Complex sections is not expected to create a particular difficulty. In the RTP – West, 13 bridges will need to be widened, six will need to be reconstructed and one new bridge will need to be constructed.

The challenge for construction is in the dense RTP – East section of the corridor. Challenges stem from the narrow right-of-way, the closeness of the existing ramps, and the highly congested traffic which must be maintained during construction.

Various structural options exist and are feasible for this project setting, including conventional precast concrete and steel beams as used throughout the region. Another

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option relies on the use of pre-cast segmental box girder construction techniques as the method for construction. The study team found that this may have applicability in reducing impacts on traffic. Segmental construction becomes cost effective if the RTP – East section of the corridor is treated as one project. With segmental construction the most expensive part of the cost is in the purchase of the overhead launching truss used for erection of the segments. The cost of setting segments is off-set by minimizing traffic disruption on the existing interchange and materials normally used for scaffolding and underpinning needed for more traditional construction techniques. This method would keep the disruption to a bare minimum on a project of sufficient size, as the RTP – East section of the corridor would be. In addition, casting of the segments could be accomplished in a remote casting yard and brought in for erection by truck. Erection of the structure can commence simultaneously from both ends of the RTP – East section of the corridor, improving the speed with which the entire structure can be completed.

Determination of any structural option is premature at this stage in planning and will likely involve subsequent value engineering investigations and perhaps consideration of structural options in the design/build phase, due to the magnitude of structural work entailed. However, preliminary assessments suggest that by using segmental construction techniques, the design and construction of the RTP – East section of the corridor can be completed within five to seven years from the time that funding is available.

6.2 Phasing

A review of the HOV phasing technical analysis showed that demand for HOVs is sufficient to make HOV lanes feasible throughout the I-40 corridor as early as 2005¹. Demand for HOV facilities in segments of the RTP – East section of the corridor is over 2000 vehicles per hour; over four times that which makes HOV facilities feasible. Therefore, the priorities for phasing should be to implement an interim solution immediately while beginning work on implementation of the Elevated Configuration in the RTP – East section of the corridor.

Pending NEPA approval, the recommendation for phasing is as follows:

1. Implement the Simple Configuration throughout the corridor immediately. Design criteria should fully comply with AASHTO standards in those sections for which the Simple Configuration is the ultimate configuration: NC 86 to NC 54 in Chapel Hill and US 1/64 to Wade Avenue.
2. The remainder of the corridor (Wade Avenue to NC 54 in Chapel Hill) would eventually be upgraded to either the Modified Complex or the Elevated Configuration. Therefore, implementation of the Simple Configuration through these sections of the corridor should be considered an interim solution and tested for cost effectiveness before being implemented. An exemption to AASHTO standards should be considered for interim alignments and treatments so long as a fundable program for graduating to the ultimate configurations could be addressed and approved by local agencies. In this manner, benefits could be provided in the near-term and HOV lane benefits provided while the ultimate project is under

¹ Demand analysis was based on the officially approved Triangle Regional Model which provides forecast years of 2005, 2015 and 2025. HOV lanes may well be shown to be feasible before 2005 were there a forecast model available for earlier years.



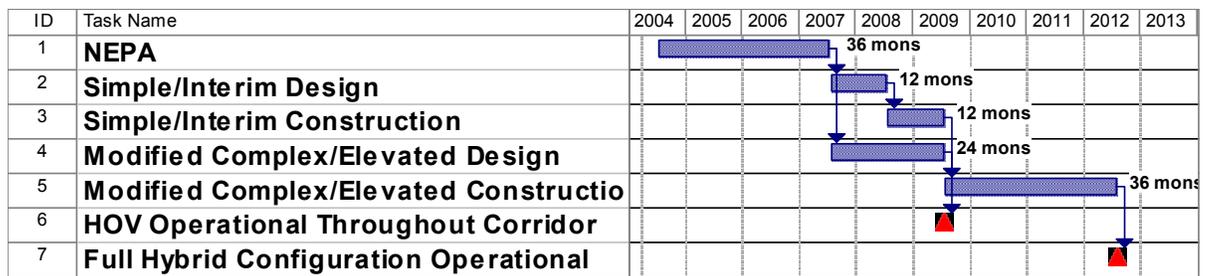
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construction. This approach would require a minimum amount of pavement widening and lane narrowing/restriping for early concurrent HOV lane operation. During this period there would be no enforcement shoulders or buffers along portions of the interim HOV lane alignment. Preliminary analysis has shown that between NC 54 in Chapel Hill and Wade Avenue restriping for HOV lanes within the existing pavement footprint is feasible if travel lanes are allowed to make use of some portion of existing shoulders.

3. Design and construction of the interim Simple Configuration could be completed within two years from the time that NEPA documentation is approved and funding becomes available. This approach has been applied in various other areas and worked satisfactorily from a safety and operation perspective.
4. Work would continue on the design and construction of the Modified Complex (NC 54 to NC 147 and Wade Avenue to I-540) and the RTP elevated sections simultaneously. Design is estimated to take two years with construction requiring three to four years.

This phasing results in the estimated timeline shown in the figure below.

Figure 7: Construction Phasing



Note: Years are representative of Federal fiscal years.

7. COSTS

7.1 Based on Existing Technical Analysis

The costs shown in Tables 1 and 2 below are compiled from the costs that were originally estimated by NCDOT for the I-40 HOV/CMS final report. Costs are first shown in 2002 dollars (Table 1) and then escalated to reflect the year of anticipated construction (Table 2); 2009 for the Simple and an average of 2011 for the Modified Complex/Elevated.

7.2 Anticipated Cost Savings

As noted in the Introduction above, this report draws from existing analyses and does not provide any recalculations of performance measures or costs arising from the Hybrid Configuration. However, it should be noted that through this analysis we have identified some economies that could substantially reduce the overall costs of the proposed Hybrid Configuration. These economies are described below.

1. The interim Simple Configuration that is proposed for the RTP Corridor-West, RTP Corridor-East and the Airport Corridor is proposed to be a less than standard facility



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as prescribed by the NCDOT Highway Design and AASHTO manuals. It would have narrower lanes, buffers and enforcement areas than would be required in the full Simple Configuration. This interim facility would be replaced by the Modified Complex and Elevated Configurations over the course of 2-3 years. This interim Simple Configuration would be much cheaper to build than the full Simple Configuration. The costs shown in Table 2 are those estimated for the full Simple Configuration and are therefore overstated for the segments where the Simple Configuration is proposed to be an interim solution.

2. Options for simplifying the interchanges at I-540 and NC 147 have been identified that could substantially reduce the construction costs of those two interchanges.
3. At the direction of NCDOT, the original Elevated Configuration was designed with a barrier separating the express lanes and the HOV lanes. This was done primarily to prohibit express from accessing the facility at the I-540 and NC147 interchanges, but resulted in additional 16 feet of pavement width for the barrier and its shoulders. With the emerging technologies for enforcement noted above it is possible to enforce the use of the HOV facility without this additional buffer and barrier, thus reducing the costs of both the elevated and modified complex segments of the Hybrid Configuration.

Further analysis will be required to provide a reliable estimate of the extent of the cost savings realized from these changes.

Table 1: 2002 Costs in Millions by Section as Shown in Final Report (March 2003)

Section (approximate miles)	Simple	Complex	Modified Complex	Elevated	Hybrid
Western Corridor (7)	\$29	\$79	\$77	\$232	\$29
RTP Corridor – West (6)	\$68	\$127	\$81	\$465	\$81
RTP Corridor – East (4)	\$59	\$293	\$225	\$617	\$617
Airport Corridor (6)	\$27	\$53	\$52	\$323	\$52
Eastern Corridor (4)	\$54	\$97	\$84	\$324	\$54
Totals	\$237	\$649	\$519	\$1,961	\$833

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Table 2: Phased Costs with 2.7% per Year Inflation Rate

Section (approximate miles)	Simple (2008)	Complex	Modified Complex (2009-2012)	Elevated (2009-2012)	Hybrid
Western Corridor (7)	\$35				\$35
RTP Corridor – West (6)	\$80		\$102		\$182
RTP Corridor – East (4)	\$71			\$786	\$857
Airport Corridor (6)	\$33		\$66		\$99
Eastern Corridor (4)	\$64				\$64
Totals	\$283		\$168	\$786	\$1,237

NOTE: Please note that the inflation rate is compounded over six years for the construction of the Simple Configuration, assuming that it will be constructed in 2008. The construction time frame for the Modified Complex and the Elevated Configuration sections is three years between 2009 (seven years from 2002) and 2012 (10 years from 2002). Therefore the inflation rate for the Modified Complex and Elevated Configurations sections is compounded over and **average** of nine years.

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