NCDOT STIP U-5976
PINEHURST TRAFFIC CIRCLE IMPROVEMENTS

(US 15-501 / NC 211 / NC 2 Intersection)

FINAL - TRAFFIC ANALYSIS TECHNICAL MEMORANDUM 2023 UPDATE

Moore County

Prepared for:

North Carolina Department of Transportation
Transportation Mobility and Safety Division
Congestion Management Unit
&
NCDOT Division 8

Prepared by:

HNTB North Carolina, P.C.
343 East Six Forks Road
Suite 200
Raleigh, NC 27609

NCBELS License #: C-1554

NORTH CAROLINA PROFESSIONAL SEAL 026910 ENGINEER CRAIG R SCHEFFLER

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1. INTRODUCTION / STUDY OBJECTIVES

The North Carolina Department of Transportation (NCDOT) is seeking alternative improvement concepts to the existing Pinehurst Traffic Circle (US 15-501 / NC 211 / NC 2 intersection) to improve traffic operations/safety and increase intersection capacity and efficiency as part of NCDOT State Transportation Improvement Program (STIP) Project U-5976. This report will assist NCDOT by providing traffic projections, capacity analyses and microsimulation visualization of alternative concepts for the intersection for 2050 future year conditions and is an update to previous feasibility studies completed for the Pinehurst Traffic Circle (also noted as "PTC" in this report) by HNTB in 2014, 2017 and 2022. Base Year 2013 "existing" conditions and 2025 future year conditions were previously studied by HNTB in the *Pinehurst Traffic Circle Study – Traffic Analysis Technical Memorandum*, submitted to NCDOT in November 2014. The 2014 study was updated in 2017 to focus on selected alternative concepts with a future design horizon year extended to 2045 and was further refined in 2022 to assess sensitivity analyses of several concepts carried forward into this current study which has a future design year of 2050 and also assesses future short-term improvements for an interim year of 2029.

Detailed capacity analyses were completed to evaluate the network operations and quantify future AM and PM peak hour roadway conditions that compare the impact of Build concepts to each other and to the No-Build Alternative. The analysis evaluated individual intersections, the current PTC, and overall network Measures of Effectiveness (MOE), which include level of service (LOS), delay, queues, vehicle hours traveled (VHT), vehicle miles traveled (VMT) and average network speeds. NCDOT and other stakeholders will use this information to assist in future decisions related to the operations and potential improvements to the Pinehurst Traffic Circle. The analysis results are based upon field-collected traffic data, NCDOT traffic volume information, and traffic projections prepared in this document.

The following sections describe the updates to the existing project study area included in the traffic operations analysis, the updates made to the collection of data for the 2023 Base Year traffic models, and the new traffic crash analysis results.

1.1 Study Area Expansion

Prior to this study, the primary focus of previous traffic analysis studies for the improvements to the PTC were limited to the PTC and upstream roadways up to the next adjacent major intersection – or omitted several stop-controlled minor intersections upstream of the PTC that would not be affected by previous recommended PTC designs. For this study, additional upstream intersections that were included in the 2023 *STIP U-5976 Project Level Traffic Forecast* are now included in the detailed traffic analysis as well to ensure that future traffic growth impacts that extended queues from the existing PTC back past these intersections are now accounted for as a comparison. **Figure 1** in ***Appendix A*** shows the expanded U-5976 traffic analysis study area. ***Appendix A*** contains all figures referenced in this technical memorandum.

1.2 Updated Data Collection

As part of this updated study, new traffic counts were collected as part of the Project Level Traffic Forecast in February 2023. Along with the new traffic counts, a field study was completed in July 2023 to evaluate traffic operations at the PTC with respect to travel speeds around the circle, gap acceptance thresholds for each leg and upstream queue build up and dispersal for both the AM and PM weekday peak hours that were identified in the traffic count data. This information was used to update calibration parameters in the previous base year traffic microsimulation models.

The field study also verified laneage and existing traffic control for upstream intersections included in the expanded project study area. Laneage, geometric and traffic control data is shown in **Figure 2.1.** ***Appendix B*** contains the traffic counts and forecast data, along with the field data collected.

1.3 Updated Crash Analysis

Table 1 provides NCDOT historical crash data for the study area during a five-year time period beginning June 1, 2018 and ending May 31, 2023. The detailed intersection crash analysis data can be found in ***Appendix C***. A total of 840 reported crashes occurred during this five-year period, with 88% of these crashes (739 out of 840) being rear-end (low severity) collisions. Fatal collisions are not included in **Table 1** because there were no fatal collisions during the five-year period 2018-2023. Approximately 85% of the crashes were property damage only (PDO) crashes. ***The five-year cost of property damage in the traffic circle study area was about $31,750,000, or $6,350,000 per year, on average***. ***The average number of crashes per year was nearly 170 crashes***, or one crash almost every two days throughout the five year period in the vicinity of the PTC.

Table 1. Pinehurst Traffic Circle Crash Data 2018-2023

Year	Left Turn	Rear End	Run Off Road & Fixed Object	Angle	Side Swipe	Other	Total	Injury	PDO**	Total Crash Damage Estimate@
2018	0	91	4	2	6	1	104	19	85	$4,416,000
2019	0	154	2	7	6	1	170	23	147	$5,980,800
2020#	0	106	6	4	7	1	124	16	108	$4,243,200
2021	0	167	4	3	16	0	190	33	157	$7,804,800
2022	1	148	2	5	17	0	173	25	148	$6,331,200
2023	0	73	1	1	3	1	79	12	67	$2,980,800
Total	**1**	**739**	**19**	**22**	**55**	**4**	**840**	**128**	**712**	**$31,756,800**
						Rate*	989.29	150.75	2104.84	

* - Crashes per 100 million vehicles entered @ - Based on NCDOT 2022 Standardized Crash Cost Estimates for NC
** - Property Damage Only # - Data Affected by Effects of COVID and Lower Traffic Activity

The crash rate at the PTC is nearly 990 crashes per 100 million vehicles entered. Two previous crash study for the PTC were completed for the period 2007-2011 and 2012-2017. In those studies, the overall PTC crash rate were only 413 and 536 crashes per 100 million vehicles entered, respectively, and the total number of crashes were 309 and 421, respectively. Crash severity and crash patterns between the previous and current studies were very similar – with the primary difference being how much more frequently the same types of crashes are occurring over the 5 and 10 year periods between studies. ***Similar to the 2007-2011 study, a remarkable fact is that 30% of the crashes that occurred within the Village of Pinehurst limits from 2020-2022 occurred at the PTC based on comparative data provided by NCDOT Traffic Safety Unit for municipalities around the state.***

The five year historical crash data at the traffic circle was converted into the collision diagram shown in **Figure 3**, allowing for a detailed view of crash patterns and types at each approach leg and within the circle itself. The NC 211 western leg approach has only 41 rear ends compared to 279 and 139 for US 15-501 northern leg and NC 2 eastern leg (legs with similar AADT), respectively. The NC 211 western leg also has a more perpendicular, tighter radius entry approach compared to all other approaches. No detailed engineering analysis was conducted to address how the change in approach geometry may affect crashes (specifically rear ends), there appears to be a strong correlation between entry radius, approach geometry and rear end crash frequency. This is likely due to the higher entry speeds, stop-and-go approach queues, and driver look-back angles influencing higher rear end crash rates on four of the five approaches. Similar results were noted in the previous crash analysis.

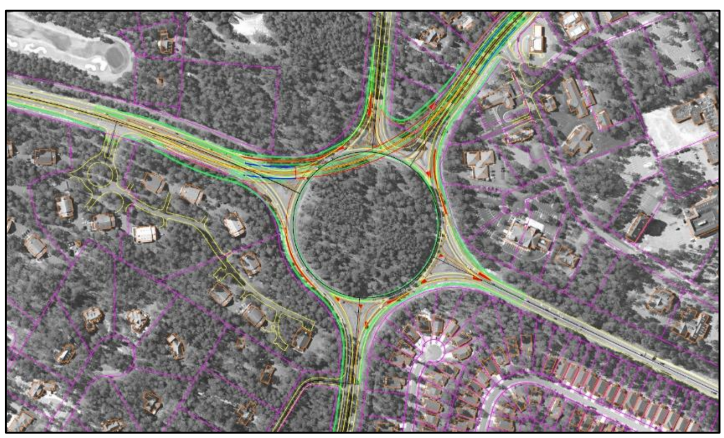
2. NEW ALTERNATIVES ANALYZED

2.1 No-Build Alternative

The PTC, also known as a rotary intersection, has five legs serving three major multilane regional roadways (US 15-501, NC 211 and NC 2) that experience high daily and peak hour traffic volumes. The Circle operates with one continuous circulating lane and a second adjacent auxiliary lane between each approach and departure leg. There are rumble strips between the circulating and auxiliary lane to discourage drivers from changing lanes in the traffic circle. The No-Build Alternative assumes that this configuration, and all adjacent approaching roadway segments from the five existing legs, remain unchanged in the 2050 future analysis year, with the exception of anticipated NCDOT STIP R-5927 roadway widening along US 15-501 to the north of the PTC. No specific final design existing for this project but it was assumed that an additional southbound travel lane would connect to existing laneage through the Memorial Drive / US 15-501 intersection and no lane drop would occur north of this intersection. **Figure 2.1** shows the existing Pinehurst Traffic Circle and nearby intersection laneage, geometrics and traffic control features.

For this study, origin-destination traffic counts were collected February, 2023 to provide an update to the 2013, 2018, and 2021 counts completed for the original feasibility studies and their updates. 2050 projected peak hour traffic volume estimates were also recomputed for the study (see **Section 3** for details) and these peak hour traffic demands were applied to the No-Build Alternative models and all Build Alternative models, as appropriate. **Figures 2.2 and 4** show the existing traffic circle laneage and 2023 and 2050 estimated peak hour origin-destination traffic volumes, respectively. **Figure 4** also shows the assumed laneage improvements provided by the R-5927 project. In previous studies of the PTC, surrounding roads and intersections beyond the existing traffic circle were not specifically analyzed. In this study, additional upstream intersections were included to investigate the effects of upstream queue blockages and impacts on each upstream corridor of the proposed alternatives studied.

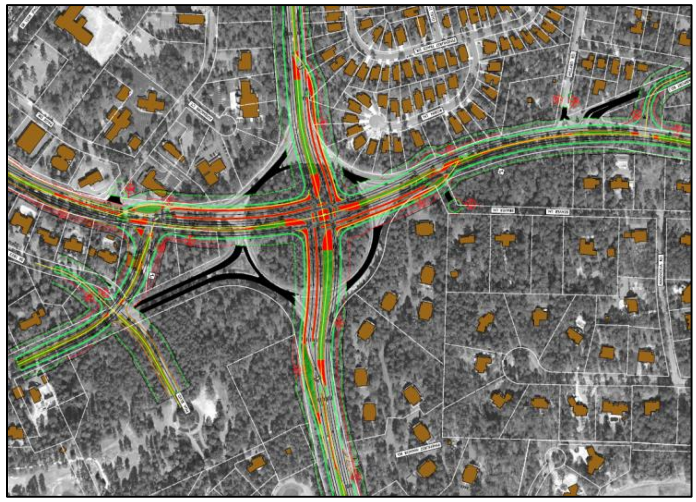
2.2 Alternative Concept 14 - Flyover with Turbo Hybrid Circle



As shown in **Figure 5.1**, Concept 14 provides a free-flowing flyover alignment with a single travel lane in each direction of the heaviest overall peak hour volume movement (NC 211 eastbound to US 15-501 southbound and vice versa). The flyover termini are assumed to be free flow movements that merge/diverge from existing lanes along NC 211 and US 15-501. Adjustments to the horizontal and vertical curvature of the flyover may be possible to avoid impacts to the circle or other private properties. The concept also includes improvements at all existing traffic circle legs that originated previously in Concept 1/3 – Hybrid Modern Traffic Circle and were modified in the traffic modeling process to provide the optimal movement capacity within the circle and at each leg. This generally involved testing combinations of two-lane entry/one-lane circulator and one-lane entry/two-lane circulator combinations. No testing of two-lane entry/two-lane circulator was completed for any Concept.

Initial schematic roadway designs were completed in 2021 for this design concept to assist detailed traffic analyses completed for it at the time and are shown on the image above.

2.3 Alternative Concept 17 – Continuous Flow Intersections (CFI) "Shifted Pillow"



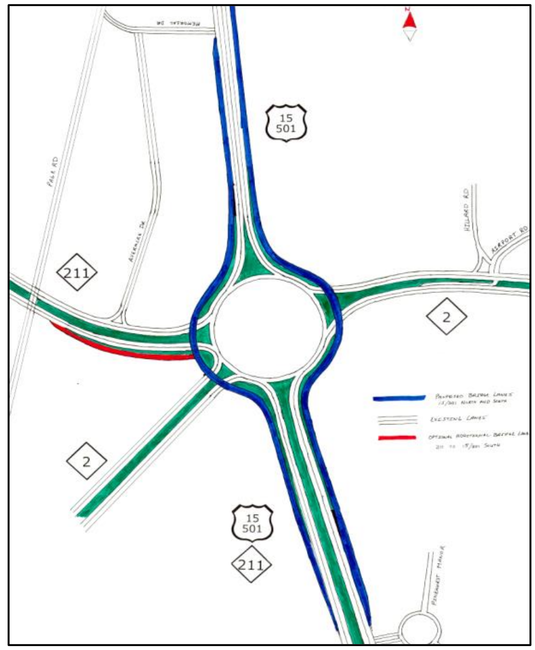
This previously studied concept creates a single major intersection of US 15-501 and NC 211 / NC 2 in the middle of the existing Pinehurst Traffic Circle that separately serves through movements along with bi-directional left-turn and right-turn movements at a single coordinated two-phase traffic signal. Left-turn movements "cross-over" the opposing through travel direction several hundred feet upstream of the main intersection at "half signals" that impact only the crossover movement and opposing through movement. Right-turn movements in the opposite direction of each left-turn movement can either be handled as free-flowing merge lanes or conservatively operate as part of the half signals. The fifth leg of NC 2 from the village core was realigned into the western cross-over at a three phase traffic signal. The geometric changes noted above are shown in **Figure 6.1** and on the image above.

Changes from previous version of the CFI (Original Concept 11) include the following in this design:

- Shifting of the main intersection and adjacent crossover lanes to the east of the "center" of the PTC to allow additional space between this major intersection and the NC 2 realigned intersection.
- Creation of a more circular center island design where the four through roadway legs cross. There is no feasible way to achieve a complete "circle" for this design modification, due to approach speeds and lane separations, along the need to prevent traffic from using this modified "circle" to make left or right turns. The resulting design is a slight "pillow" shape at this location. There is enough area within this "pillow" area to create landscaping that would reflect a circular design.
- Creation of a free-flow southbound merge area for NC 211/NC 2 eastbound to southbound traffic flows that previously was modeled as having traffic signal control.
- Provision of an unsignalized u-turn median break along US 15-501 south of Pinehurst Manor Drive to allow the redirection of southbound lefts seeking to enter Pinehurst Manor subdivision.
- Geometric shift of alignment of the existing NC 2 and Airport Road intersection to provide adequate space from the shifted main CFI intersection, along with signalization of the Airport Road intersection.
- Coordination of signal timing for the new NC 2/Airport road signal, along with coordination of signal timing of the modified US 15-501/Memorial Drive intersection signal.

The major advantage of the CFI design is a large gain in operational capacity through the PTC area without the need for a grade-separated interchange or the need for a large amount of right-of-way. Because this is an unconventional intersection design, it requires additional signage and wayfinding to aid driver familiarity, although all movements occur in "typical directions" in terms of left and right-turns.

2.4 Alternative Concept 18 - US 15-501 "Curved Bridge"



This concept was suggested by a private citizen in Pinehurst and, operationally, closely corresponds to the original Concept 10 – US 15-501 tunnel. As shown in in the drawing to the right, the design would include an outside lane along US 15-501 between Memorial Drive and Pinehurst Manor Drive that would become elevated and extend around the outside of the existing circle traffic lanes on structure to bypass the circulating traffic. There was a notation in the drawing to potentially connect the southbound US 15-501 bridge to another elevated structure originating from NC 211 Eastbound, but physically developing the vertical profile of this connection would prove extremely challenging, so it was not included in the traffic model.

This Concept would be challenging to design and require additional refinements for horizontal curvature in the curved bridge span to produce acceptable design speed and could be considerably costlier than other alternatives to construct. **Figure 7.1** shows the schematic laneage and geometric details for Concept 18.

2.5 2029 Analysis Year "Short-Term" Alternatives

2.5.1 Original Concept 1/3 - Turbo/Hybrid Design

One concept carried forward in an evaluation of short-term/low cost improvements to the Pinehurst Traffic Circle is the Turbo/Hybrid design. This modifies the circle to add an additional circulating lane for much of the circle, where the outside lane drops at each successive leg and the inside lane shifts to redevelop two circulating lanes. An initial study of circulating flows and balancing of one entry/two circulating or two entry/one circulating lane was conducted for the Concept 14 – Flyover with Turbo Hybrid Circle alternative. For this design, the NC 2 westbound approach would feature two entry lanes and one circulating lane. The remaining four legs would have one entry lane and two circulating lanes. Existing right-turn bypass lanes would be maintained and pushed slightly wider than current configuration. **Figure 9.1** shows this concept as applied to the existing PTC study area.

2.5.2 Original Concept 2 – Metering of Existing Circle

Due to public interest in maintaining the existing integrity of the Pinehurst Traffic Circle, while still finding innovative ways to maximize its performance and improve its safety in the short-term, a detailed operational evaluation of signalized metering of the PTC was conducted. The concept of metering the circle would require traffic signals to be placed at or just upstream of circle entry points, along with the possibility of placing signal(s) within the circle itself. The following assumptions were made in the testing of this scenario related to traffic operations changes due to signal "metering":

- The signals were assumed to be activated by sensors upstream that would present red-yellow-green indications at one or more legs to become "active" to temporarily stop traffic flow at that leg, thereby providing gaps in the single lane circulatory flow for other "critical" downstream legs to utilize.

- A "full" signal was modeled at the NC 2 Westbound approach leg and the PTC circulating roadway between this location and the upstream US 15-501 Northbound approach leg was widened two lanes (inner continues to circulate/outer exits to US 15-501 northbound).
- A signal was tested at the US 15-501 Northbound approach leg but was inactive for both peak periods tested as model observation indicated this approach needed to have free entry conditions – still under yield control.
- A 60 second cycle length for all signals was tested, with varying amounts of "green time" allotted to each approach.
- Signal offsets were iteratively modified to provide each approach adequate time for gaps that developed in circulating traffic due to upstream "red" indications for upstream approaches.

3. FUTURE ANALYSIS YEAR TRAFFIC PROJECTIONS

Similar to the previous analyses for design concept evaluation for the PTC, a key purpose of this traffic analysis was to re-examine future traffic volumes (now developed for the 2050 analysis year) from the original studies and provide new peak hour traffic volume estimates for the 2050 horizon year using similar methodologies that include the Moore County Regional Travel Demand model as an input to the process and new traffic volumes for a 2023 base year. The traffic projections also rely on estimated growth rates for each roadway connecting to the PTC, as determined in the *Project Level Traffic Forecast for U-5976* (HNTB, 2023). A 2029 interim year traffic projection is also included for short-term improvement alternatives evaluation for this study.

It was assumed that the traffic volume estimates for 2050 would be applicable to all design concepts in terms of peak hour traffic inflows, outflows and circulation patterns, to provide a consistent comparison of traffic demands between all alternatives. Traffic volumes were estimated for flows at the circle and now include additional key upstream or downstream intersections, but do not include private driveways or low traffic volume access points.

3.1 2050 Design Year Projection Methodology

2023 base year peak period traffic counts at the existing Pinehurst Traffic Circle were collected by NCDOT in February 2023 as an update to recent Project Level Traffic Forecast base year counts completed in 2021. This data collection effort included a detailed origin-destination (O-D) evaluation of traffic patterns through and around the five existing legs of the traffic circle through the use of weekday peak period O-D data from the Streetlight software platform. This information was carried forward in the methodology of projecting 2050 traffic volumes for the traffic circle. Count information was validated by adjusting raw Streetlight O-D flow information and peak period proportions to balance at each leg's entry/exit point in comparison to actual peak period turning movement counts completed at intersections just upstream and downstream of each traffic circle leg. Adjustments to O-D count data were made to minimize count discrepancies for each segment between the circle and upstream/downstream intersections. The overall peak hour for the entire circle was identified and existing base year 2023 AM and PM peak hour traffic volume data is shown in **Figure 2.2**. Raw traffic count data is provided in ***Appendix B***.

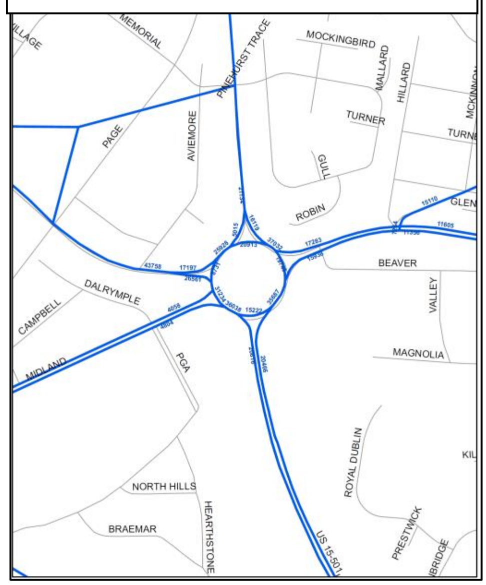
Projections of growth rates applied to the updated 2023 count data were derived from two sources and in a methodology similar to the one used for the *Pinehurst Traffic Circle Study - Supplemental #1 Traffic Analysis Technical Memorandum, 2019,* with the updates to the 2023 base year O-D data affecting previous projected growth rates that utilized the following sources in the previous study :

- NCDOT Historic Average Annual Daily Traffic (AADT) Data – obtained from NCDOT Transportation Planning Division (TPD) Traffic Forecast Utility spreadsheets and updated with 2021-2022 AADT data from NCDOT AADT Web Map (NCDOT GIS On-Line, 2023)
- Moore County Regional Travel Demand Model – obtained from NCDOT Transportation Planning Branch (TPB) in September 2016 for the previous PTC study. No updates to the Travel Demand Model were made for this study. A travel demand model update for Moore County is currently underway.

Historic NCDOT AADT data was analyzed for the five individual traffic circle legs and is shown in **Exhibit 1.** Review of the data points over the last 30 year period shows overall general growth for each leg and a noticeable rebound from the effects of COVID in 2020. The software spreadsheet tool produced future growth estimates for the 2050 analysis year and these are shown in ***Appendix D***. The use of linear regression to estimate future volumes from the historic AADT data set was deemed to be the most appropriate projection of future volumes. Historic growth produced annual growth rates in the range of 0.3 to 1.9 percent per year, depending on intersection leg, when projected from 2023 to 2050. When applied to the 2023 AM and PM peak hour traffic count information, and holding O-D circulating patterns/distributions constant, resulting traffic volumes are shown in ***Appendix D***.

In the previous PTC study, daily traffic assignments from the Moore County Regional Travel Demand Model were analyzed for the five existing traffic circle legs for the loaded 2010 Base Year model run and 2040 Future Year model run. Per year growth rates for each leg were calculated based on the total bidirectional daily traffic assignment information. These rates varied between 1.2 and 3.4 percent per year and represent some significant differences from historic growth patterns for individual legs, as shown in **Table 2**. Potential explanations for these differences include the fact that historic growth is not always a consistent predictor of future growth if land use patterns in a regional context are expected to change or if new regional or local roadway facilities are included in the travel demand model causing reassignment of trips distributed and assigned across the network.

MOORE COUNTY REGIONAL MODEL



The 2023 U-5976 Project-Level Traffic Forecast provides a detailed methodology for accounting for these inputs into the future year traffic projection process, along with other local and regional data sources to ultimately provide future year growth rates that are the best comprehensive estimate of project study area traffic growth. **Table 2** also includes these per year growth rates extracted from the traffic forecast information. These were the per year growth rates utilized to project 2050 and 2029 peak hour traffic volumes.

Exhibit 1. Pinehurst Traffic Circle NCDOT Historic AADT Traffic Volumes

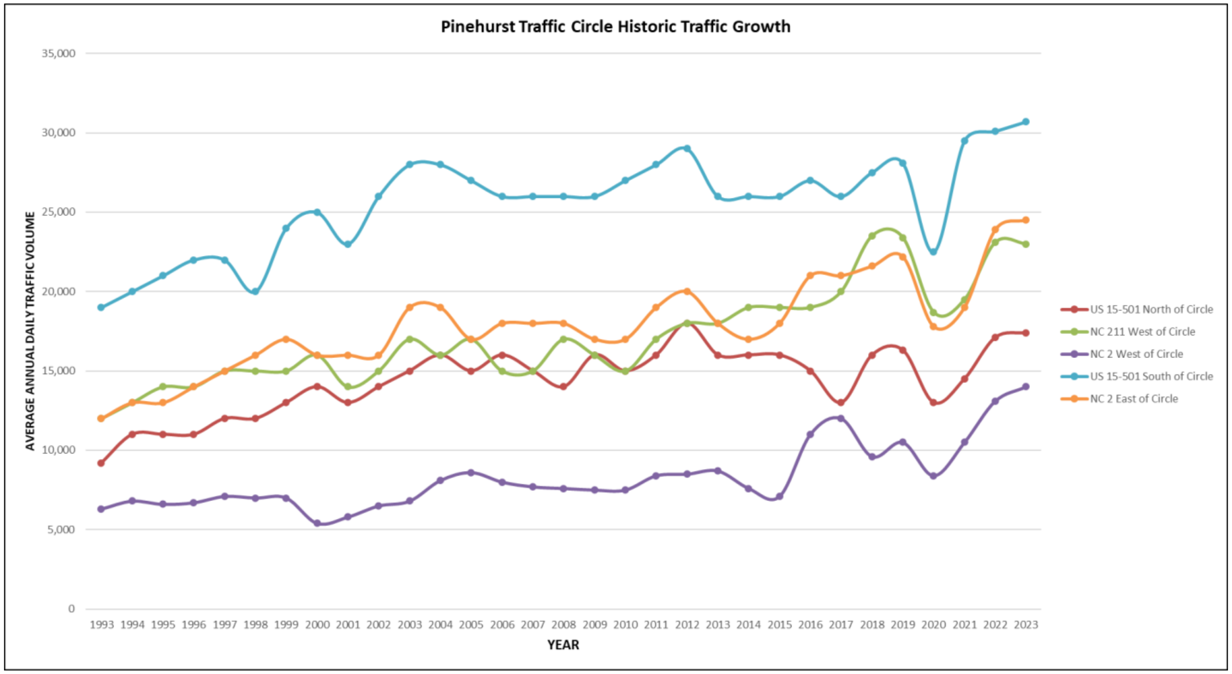


Table 2. Comparison of NCDOT Historic Growth Rates and Moore County Travel Demand Model Growth Rates

ID #	Location Description	NCDOT Historical AADT Data**					Moore County Regional Model Data**					U-5976 Forecast
		2050	2010	Linear Growth %	*Growth %/Yr*	Growth 2023-2050	2040	2010 Base	Linear Growth %	*Growth %/Yr*	Growth 2023-2050	*Growth %/Yr*
1	US 15-501 N OF NC 211	19,545	15,000	30 %	***0.69%***	18.6%	22,329	16,262	37.3%	***1.24%***	*33.6%*	***1.1%***
2	NC 211 E OF SR 1208	30,188	15,000	101%	***1.89%***	51.0%	40,259	25,896	55.5%	***1.85%***	*49.9%*	***1.5%***
3	NC 2 W OF US 15-501	13,517	7,500	80 %	***1.86%***	50.2%	10,051	4,973	102.1%	***3.40%***	*91.9%*	***1.5%***
4	US 15-501 / NC 211 S OF NC 2	34,561	*27,000*	28 %	***0.30%***	8.1%	41,224	26,429	56.0%	***1.87%***	*50.4%*	***1.5%***
5	NC 2 E OF US 15-501	27,050	17,000	59 %	***0.94%***	25.4%	31,500	21,657	45.4%	***1.51%***	*40.9%*	***1.3%***

Blue – Derived Number, No Actual AADT Available

3.2 Development of Modified Growth Rates and Traffic Flow Balancing

Similar to the process used in previous traffic projections for the PTC, to reconcile some of the differences between the 2050 traffic volume projections and growth rates produced by the historic AADT method and the regional travel demand model method, an approach was utilized to initially input the U-5976 Project Level Traffic Forecast per year raw growth rate for each leg and modify existing circulating O-D patterns to produce "balanced" inflows and outflows for each traffic circle leg that correspond to the unique growth rates for each leg. As shown in the data in ***Appendix D***, the application of projected traffic growth rates from each projection method (historic growth, travel demand model or traffic forecast result) to traffic circle inflow results in different growth rate percentages for outflows from the traffic circle. These imbalances needed correction by adjusting key O-D circulating percentages individually and iteratively to produce more reasonable outflow growth rates that would match inflow rates as nearly as possible. The "modified" spreadsheet results in ***Appendix D*** display this process using the traffic forecast growth rates as the selected basis of future growth estimation. Adjusting the circulating O-D distribution patterns for the traffic forecast raw growth rates produces outflow growth rates that are within 0.1% per year of inflow rates for each leg in each peak hour.

The resulting 2050 AM and PM peak hour traffic flow projections for the traffic circle and overall No-Build Scenario for the entire study area are displayed in **Figure 4**. Upstream intersections were also adjusted to keep balanced traffic flows by adjusting upstream intersection growth rates to match the projections for each PTC leg.

3.3 2029 Interim Analysis Year Interpolation

Similar to the process for peak hour traffic projections for the 2050 design year, raw traffic growth estimates for the 2029 interim year were developed by interpolating overall balanced inflow/outflow growth rates for each leg and then making subsequent interpolation adjustments to raw O-D flow percentages to achieve balance between inbound and outbound traffic growth for each leg. Once the growth percentages were arrived at for each leg, upstream intersection volumes for the 2023 Base Year were adjusted by these growth percentages to arrive at 2029 interim year peak hour projections. This approach does not exactly replicate a straight line interpolation between 2023 Base Year data and 2050 projections, but instead accounts for the changes in growth rates for each leg over that time period and assesses the resulting traffic volumes in that manner. ***Appendix D*** contains the 2029 interim year results.

4. ALTERNATIVE CONCEPTS ANALYSIS

Evaluating traffic operations on an urban transportation system is generally done by the determination of level of service (LOS) criteria. The level of service on a freeway segment, arterial corridor, or individual intersection correlates qualitative aspects of traffic flow to quantitative terms. This enables transportation professionals to take the qualitative issues, such as congestion and substandard geometrics, and translate them into measurable quantities, such as operating speeds, flow densities, and vehicular delays. The *2022 Highway Capacity Manual 7th Edition (HCM Version 7)* characterizes level of service by letter designations A through F. Level of service A represents ideal low-volume traffic operations, and level of service F represents over-saturated, high-volume traffic operations. Level of service letter designations and criteria (seconds of delay per vehicle) for arterial signalized controlled, stop controlled intersections and yield controlled roundabouts are described in **Table 3**.

The results of this analysis are based on data compiled for runs in the VISSIM microsimulation software. Per vehicle delay results from VISSIM can be compared to the LOS and delay procedures presented in the *HCM Version 7*, though the methodologies for producing the information (stochastic versus deterministic) are different, so caution should be exercised in interpreting the data. To account for this difference, the term **LOSs** or "simulation Level-of-Service" is shown in all tabular results in this report. In addition, the existing PTC No-Build design does not conform exactly to the parameters of a traditional modern roundabout that would be included in a standard HCM LOS analysis. Thus, the use of the LOSs term provides some flexibility in being able to assess and compare operations from these alternatives.

Table 3. Intersection Level of Service (LOS) Characteristics

Level of Service Description	Intersection	
	Per Vehicle Control Delay - Signal	Per Vehicle Control Delay Stop / Yield
LOS A ➢ Free flow ➢ Freedom to select desired speed / maneuver is extremely high ➢ General comfort level & convenience for motorists is excellent	**< 10.0 seconds**	**< 10.0 seconds**
LOS B ➢ Stable flow ➢ Other vehicles in the traffic stream become noticeable ➢ Reduction in freedom to maneuver from LOS A	**10.0 – 20.0 seconds**	**10.0 – 15.0 seconds**
LOS C ➢ Stable flow ➢ Maneuverability/operating speed are significantly affected by other vehicles ➢ General level of comfort and convenience declines noticeably	**20.0 – 35.0 seconds**	**15.0 – 25.0 seconds**
LOS D ➢ High density but stable flow ➢ Speed and freedom to maneuver are severely restricted ➢ General level of comfort / convenience is poor ➢ Small traffic increases will generally cause operational problems	**35.0 – 55.0 seconds**	**25.0 – 35.0 seconds**
LOS E ➢ Unstable flow ➢ Speed reduced to lower but relatively uniform value ➢ Volumes at or near capacity level ➢ Comfort and convenience are extremely poor ➢ Small flow increases/minor traffic disturbances will cause breakdowns	**55.0 – 80.0 seconds**	**35.0 – 50.0 seconds**
LOS F ➢ Forced or breakdown flow ➢ Volumes exceed roadway capacity ➢ Formation of unstable queues ➢ Stoppages for long periods of time because of traffic congestion	**> 80.0 seconds**	**> 50.0 seconds**

Transportation Research Board, *Highway Capacity Manual Version 7.* Washington, D.C.: National Research Council, 2022.

4.1 Alternative Concepts Assumptions

During the project scoping process for this updated analysis of three new Build Concepts for the PTC, it was agreed by all project stakeholders that the new Alternative Concepts tested would be compared to the Existing (Do Nothing) No-Build scenario for 2050 future year conditions. Models for the Alternative Concepts and Existing/Future No-Build scenarios were created using the same upstream lengths of the five roadways that connect to the Traffic Circle, which initially varied between 1,000 to 1,800 feet but were extended to 5,000 to 8,000 feet in this study to assess future queue spillback comparisons that would not be identified in the previous traffic study models. The primary difference in the design of the 2050 design year alternative concepts is that they may directly impact the existing integrity of the land within the circle and, depending on the horizontal and vertical alignment needs of each design, impact areas outside of the existing right-of-way adjacent to or upstream/downstream of the circle. The following alternative concepts are schematically shown in **Figures 4, 5.1, 6,1, and 7.1** and displayed in screen captures from the VISSIM microsimulation program in **Table 4** below, which were developed by HNTB using preliminary roadway design criteria and basic horizontal/vertical alignment parameters from the previous operational studies and schematic design concepts. **Figures 8.1 and 9.1** display the assumed laneage, geometric and traffic control changes for 2029 Interim Year Build Alternatives, also shown in **Table 4**.

Table 4. VISSIM Model Geometrics

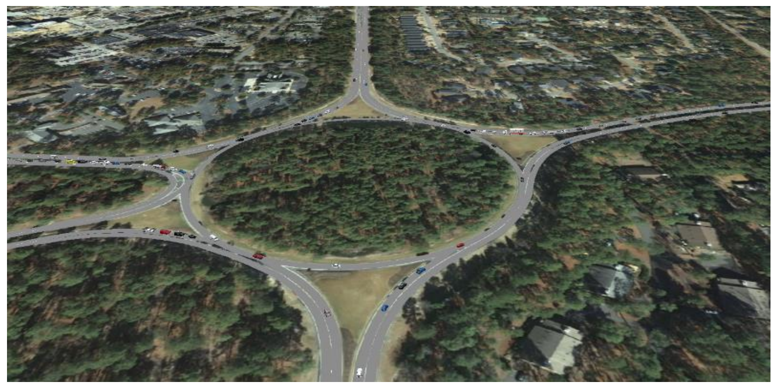
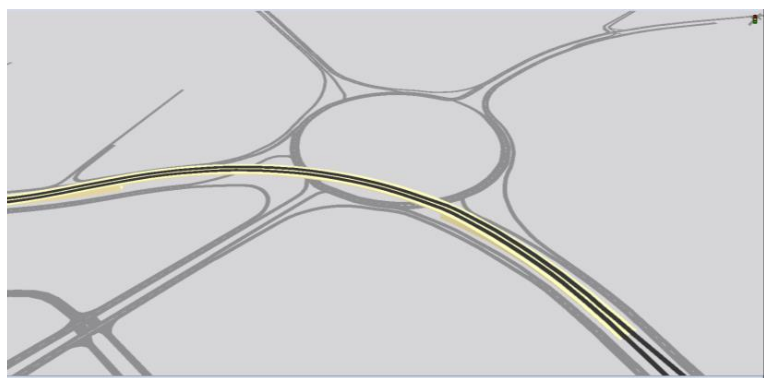
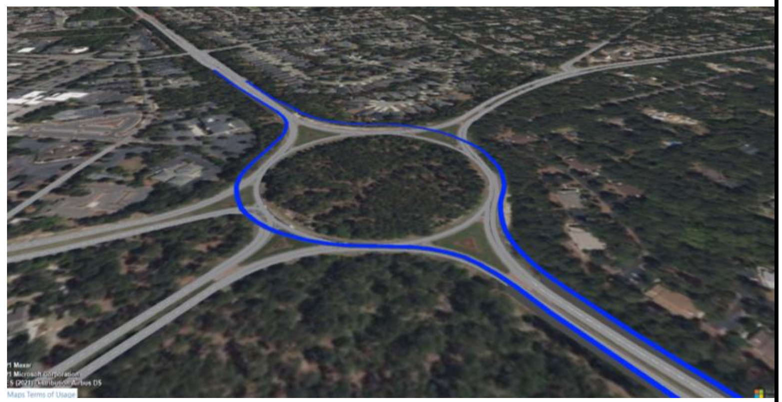
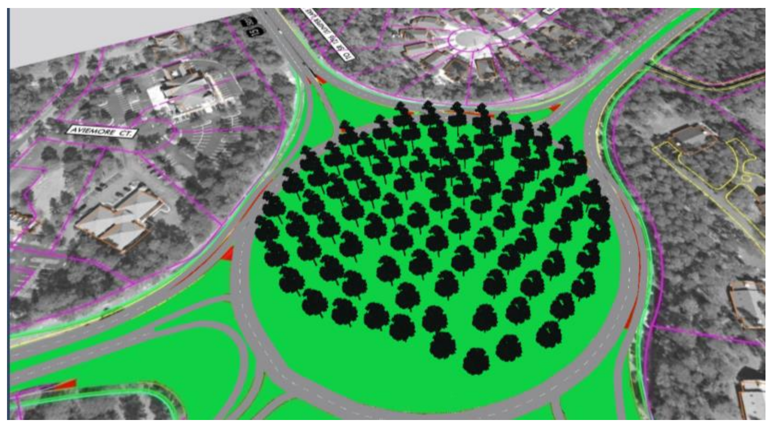
Alternative	VISSIM Model Schematic
No-Build Alternative: Existing Geometrics and operational parameters (speed/gap acceptance, etc.) recalibrated to emulate 2023 Base Year conditions and carried forward for 2029 Short-Term and 2050 Future Year analysis. Model expanded to include nearby upstream intersections. 2050 No-Build model features widened US 15-501 facility north of PTC.	
Concept 14: **Flyover with Turbo Hybrid Circle** Concept 14 model from previous *NCDOT STIP U-5976 Pinehurst Traffic Circle – Concepts 14-16 Traffic Operations Evaluation (March 2022)* was adjusted to include additional upstream intersections, the widening of US 15-501 north of the PTC, and 2050 traffic volume data.	
Concept 17: **CFI – "Shifted Pillow" Design** Updated previous Concept 11 – CFI to shift roadway alignments at the main crossing intersection to move the crossing to the east compared to the original design. Several adjustments to laneage and storage bay lengths were also made, along with addition of upstream intersections, widening of US 15-501 north of the CFI and updates to 2050 traffic volumes.	

Table 4. (Continued) VISSIM Model Geometrics

Alternative	VISSIM Model Schematic
Concept 18: US 15-501 Curved Bridge Concept Created northbound and southbound US 15-501 elevated bridge sections on the outside of the existing PTC. No changes were made to the PTC. Bridge segments were assumed to tie into existing grade using reasonable 4% grade. Similar upstream intersections and network extents were added to match other 2050 models.	
2029 Interim Year Models	
Concept 1/3: Turbo Hybrid PTC Concept Based on original feasibility study hybrid concept 1/3, this design creates “modern roundabout” approach leg geometrics and a “turbo” circulator design where two lanes circulate through most of the existing PTC with exit only outside lanes continuously developing at existing exit legs..	
Concept 2: Metered Signals Concept Added fixed time traffic signals at each approach that feature green-yellow-red standard operation with a 60 second cycle length and a varying amount of time that would be “green” for each leg to enter the PTC. Offsets of the signals were staggered around the circle to provide gaps in traffic flow to allow platoons of traffic from each leg to feasibly enter on green. Added a signal to the PTC circulating roadway at the NC 2 East approach leg and an additional lane of circulating storage back to US 15-501 northbound.	

4.2 Traffic Operations Analysis Methodology

The VISSIM (Version 2020-14) microsimulation software was used to compare vehicle throughput, vehicular delay, vehicle hours traveled (VHT), vehicle miles traveled (VMT), queuing, and vehicle travel times along selected routes through the PTC area between the No-Build scenario and the three build alternative models for 2050 AM and PM peak hours, using the same general methodologies as the original traffic circle studies completed previously. Additional No-Build and Build model scenarios were created for the 2029 Interim Year analyses with the same MOE data collected.

All calibrated model conditions were kept constant from the original study for this analysis, except as described in the following paragraphs. Calibration in the original study traffic models incorporated observed traffic volumes, vehicle mix, approach speeds, circulating speeds, and gap acceptance times. This information was updated with new observations made in July 2023 by HNTB staff, as well as new traffic count data that included vehicle mix updates. VISSIM was also used to evaluate the average and maximum queue lengths on each approach to the intersection and compare to previous and current field observed queue lengths.

The following simulation parameters were used in VISSIM:

- 5 minute "seeding" time prior to Measures of Effectiveness (MOE) collection.
- 60 minute MOE data collection period corresponding to peak hour traffic demands for the entire circle.
- 10 runs of each scenario were conducted with random number seeds.
- Multi-run MOE data collection to produce averaged MOE output.

The following changes were made to default or previous model traffic circle vehicle behavior parameters for the existing PTC evaluated in the 2023 Base Year, 2029 Interim Year No-Build, and 2050 No-Build Alternative Scenarios:

- Minimum Gap Time – adjusted previous model individual leg gap times to a range of 2.5 to 3.2 seconds for single lane approaches at existing traffic circle locations in the 2023, 2029 and 2050 No-Build models to reflect existing conditions and calibrated to match existing queue lengths during peak hours at each of the five approaches. 3.0 - 3.2 second average accepted gaps were field observed in July 2023, with some as low as 2.2 – 2.4 seconds for the second vehicle at an approach that accepted a gap after the first vehicle entered.
- Adjusted speed reduction area locations and speed reduction values upward from previous models to reflect aggressiveness of the follow up vehicles seeking entry gaps.
- PTC circulating roadway speed – field measured in July 2023 for AM and PM peak hour conditions and updated a linear distribution curve of +/- 2mph from mean speed for each peak hour to account for a mean speed of 30 mph in the AM peak hour and 31 mph in the PM peak hour.
- Minimum Gap Time – changed from values in previous Hybrid Turbo design study models to a range of 3.0 to 4.5 seconds reflecting slightly more aggressive future driving behavior, with higher values applied to inner lane of two-lane circulators and lower values to outer lane of the circulating roadway. Visual validation of traffic movements to avoid unrealistic driver behavior causing conflicting entry or not accepting realistic gaps in circulating flow traffic streams.
- No-Build model entry links were modified in previous models to generate traffic for a single (inner) lane, immediately widening to two approach lanes with no lane change allowed from outer lane to inner lane (to avoid standstill traffic waiting to change lanes near the circle and unrealistically causing additional queue and operational issues). This was kept for most future year analyses of No-Build and some Build alternatives in this study where single lane yield-controlled entry points would exist in a proposed scenario design.

For all other No-Build and Build Alternative model areas beyond the PTC, default VISSIM driver behavior parameters were employed, along with consistent applications of appropriate speed distributions for study area roadways, reduced speed areas for left and right-turns and utilization of the RBC signal controller module for existing and proposed traffic signals. Detailed VISSIM output, including network performance statistics, queuing, and delay results by approach for all analyses, is included in ***Appendix E***.

4.3 2050 Network-Wide Operational Analysis Results

Table 5 provides the Future Year 2050 network evaluation MOE results for the 2050 future year No-Build and three Build Concepts, along with a comparison to actual 2023 Base Year No-Build scenario conditions. Network evaluation results capture overall travel effects for vehicles making trips between the five origin-destination PTC points that stay essentially the same, regardless of alternative, as well as all other O-D trips at upstream intersections which do not include travel through the PTC but may be affected by queue spillback issues from the PTC. The table is organized into columns for per vehicle average statistics, overall total aggregate statistics, including network throughput (vehicles arrived) and additional data on vehicles not able to enter the network (latent demand and associated delays for those vehicles). The following conclusions/observations can be made regarding network vehicular performance from the VISSIM model data:

- In general, all the Build alternatives do provide some measurable amount of "total" operational improvement in the vicinity of the Traffic Circle, compared to the 2050 No-Build Alternative. As was found in previous study analysis results, in this evaluation, all Build alternatives are able to "process" more traffic through the circle, due to the No-Build's laneage configuration that forces an outer approach lane to drop at the next circle segment. All of the 2050 Build Alternative results provide general overall network operations related averaged and aggregated performance (whether speeds, delays, stops, VHT or VMT) that are better than 2050 No-Build results.
- The growth in traffic demand between 2023 and 2050 will not be able to be served by the existing PTC design, as network results indicate a tripling of delays with only a slight increase in the overall amount of throughput able to be served. The number of vehicles (latent demand) not even able to be loaded on the model network significantly increases in both peak hours.
- Concept 14 results are generally equivalent to existing 2023 network conditions, with comparable overall averaged delays and speeds, though it does accommodate more throughput, due to higher 2050 travel demand. Its performance compared to the 2050 No-Build Alternative results indicates a measurable benefit of removing the high volume NC 211 – US 15-501 South Leg flows from the PTC and the revisions to the existing PTC geometrics to utilize the "Turbo Hybrid" design. It also consistently outperforms the Concept 18 "Curved Bridge" design concept. However, it does not produce the amount of total network benefit as the Concept 17 – CFI "Shifted Pillow" Concept.
- Concept 17 has the best overall combination of MOE results in the 2050 AM and PM peak hours of any of the Build Alternatives. It vastly improves all measurable categories compared to the 2050 No-Build Alternative and consistently improves travel conditions and mobility in the project study area compared to 2023 Base Year No-Build network averaged and aggregate results – even though it is processing approximately 50% more traffic demand.
- Concept 18 results indicate measurable benefits over the 2050 No-Build Alternative, as the Curved Bridge removes the northbound and southbound US 15-501 flows from the PTC and from conflicting with other movements. However, the network results shown indicate that it doesn't provide nearly the system benefits as Concepts 14 or 17.

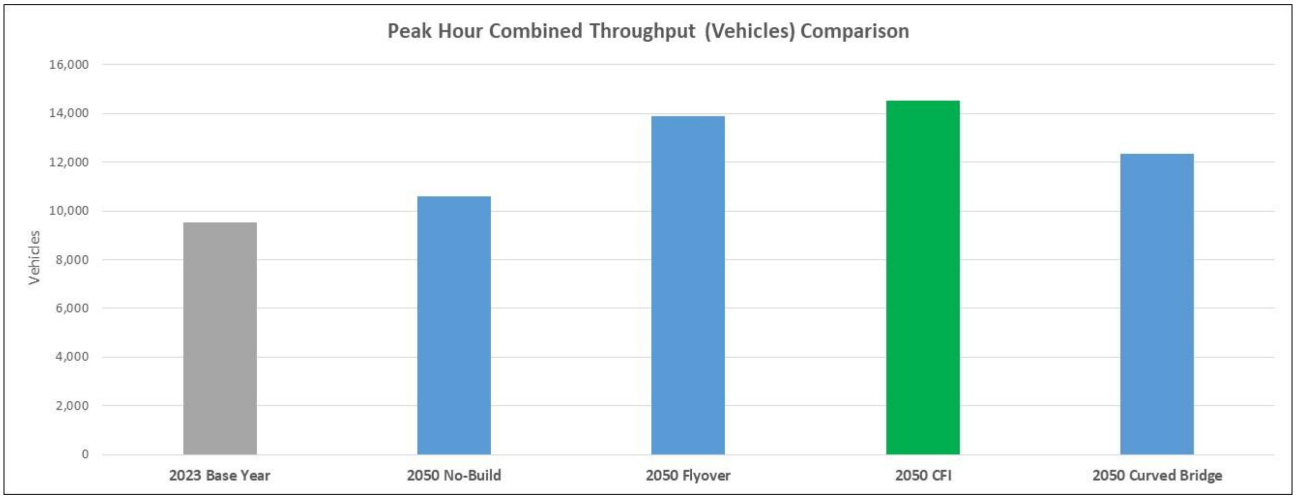
Table 5. 2050 Network MOE Evaluation

	Metric	Average Vehicular Delay	Average Number of Stops	Average Speed	Average Stopped Delay	Total Distance Traveled (VMT)	Total Travel Time (VHT)	Total Delay	Total Number of Stops	Total Stopped Delay	Vehicles Arrived	Latent Total Delay	Latent Demand
	Unit	seconds/ vehicle	stops/ vehicle	miles/ hour	seconds/ vehicle	miles	hours	hours	stops	hours	vehicles	hours	vehicles
AM Peak Hour	2023 Base Year	143	11.1	17.4	49	6,840	395	207	57,888	70	4,728	19	53
	2050 No-Build	400	25.4	8.3	189	7,699	933	722	164,969	341	5,241	469	1,150
	Concept 14 – Flyover with Turbo Hybrid Circle	157	10.2	16.1	69	9,584	599	334	78,186	146	6,867	7	13
	Concept 17 – CFI Shifted Pillow	***52***	***1.7***	***26.1***	***29***	***10,214***	***392***	***110***	***12,949***	***61***	***7,335***	***1***	***0***
	Concept 18 – Curved US 15-501 Bridge	253	17.2	12.0	115	8,931	745	496	121,062	225	6,068	257	599
PM Peak Hour	2023 Base Year	126	9.6	18.0	43	6,396	357	182	49,728	62	4,782	3	9
	2050 No-Build	336	22.6	9.3	159	7,386	797	595	143,921	281	5,337	488	1,130
	Concept 14 – Flyover with Turbo Hybrid Circle	87	5.1	21.1	40	9,047	432	181	38,083	84	7,012	16	26
	Concept 17 – CFI Shifted Pillow	***51***	***1.6***	***25.7***	***29***	***9,349***	***364***	***107***	***12,123***	***61***	***7,185***	***1***	***1***
	Concept 18 – Curved US 15-501 Bridge	163	11.4	15.6	72	8,551	551	312	78,324	138	6,292	246	598
		Averaged Performance MOE Statistics				Aggregated Performance MOE Statistics					Throughput MOE Statistics		

BOLD/ITALIC = Highest MOE Improvement Over 2050 No-Build Conditions

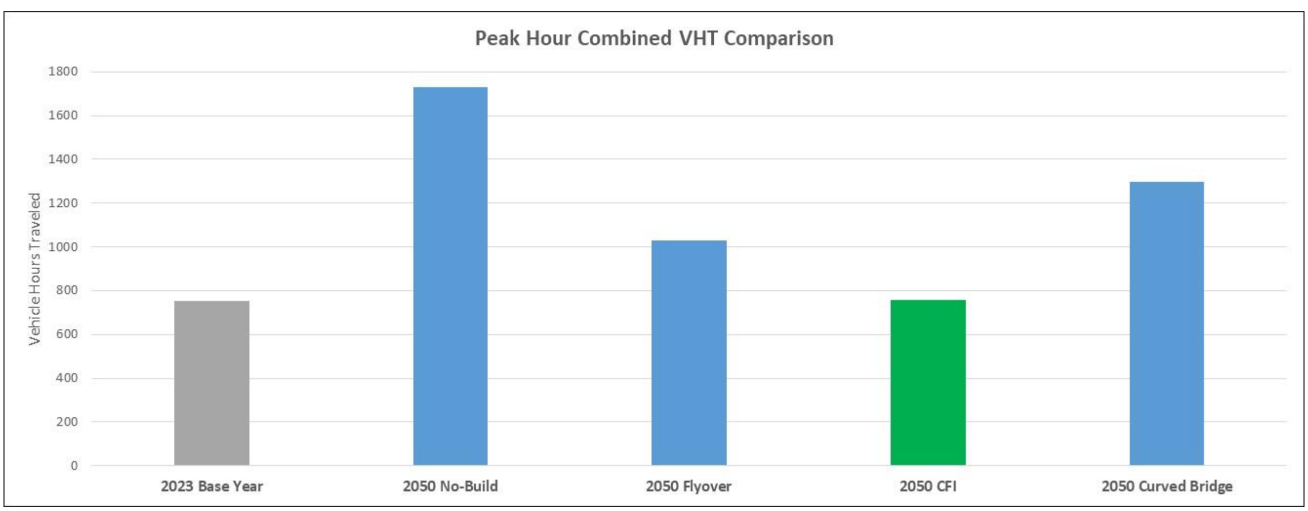
MOE result data shown in **Table 5** was further analyzed for "aggregate" operational statistics that allow visual comparisons of combined 2050 AM and PM peak hour performance between that alternatives and the "No-Build" scenario. **Exhibits 2-4** provide graphical comparisons of combined 2050 AM and PM peak hour Network MOEs for throughput, vehicle hours traveled (VHT), and overall vehicular delay for the 2050 No-Build Alternative and the three alternatives previously described.

Exhibit 2. 2050 AM and PM Peak Hour Combined Network Throughput



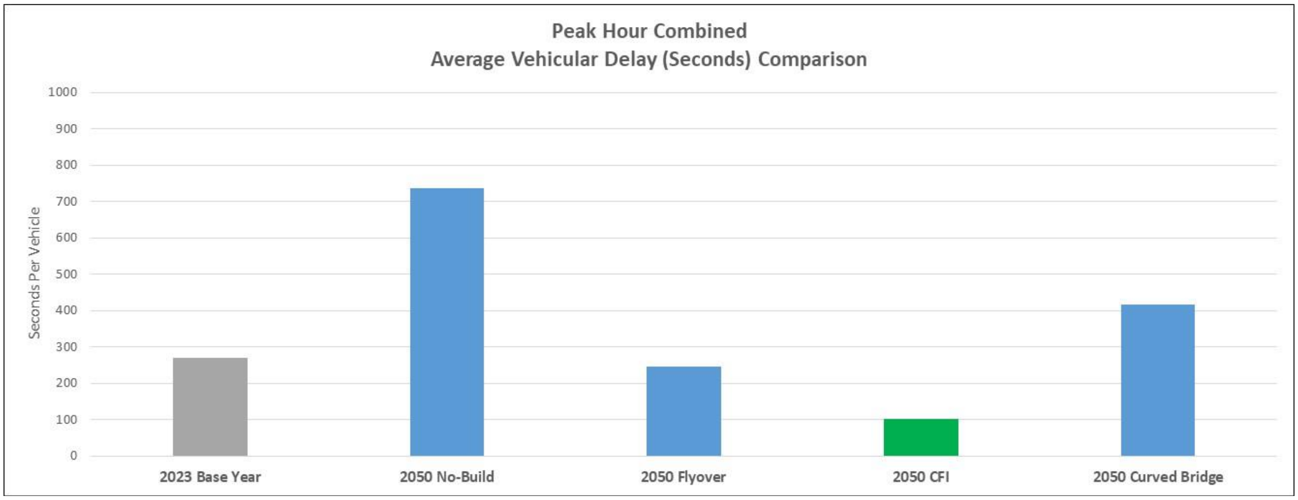
As shown in **Exhibit 2**, combined network throughput is maximized in the alternative shown in green (CFI – "Shifted Pillow" Concept). In the Concept 14 – Flyover and Concept 17 – CFI cases, nearly all aggregate AM and PM peak hour vehicles entering the network can be processed through each Build design, with few vehicles denied entry due to substantial queuing or delay. In the cases of the No-Build and Concept 18 – Curved Bridge Alternatives, throughput is limited due to queue spillback internal to the network that prevents vehicles from reaching their downstream destination in either the AM or PM peak hour, or both.

Exhibit 3. 2050 AM and PM Peak Hour Combined Vehicle Hours Traveled (VHT)



As shown in **Exhibit 3** in green, the CFI – "Shifted Pillow" alternative produces the least amount of combined 2050 peak hour network VHT, correlating with this alternative's efficiency in moving traffic through the network with minimal delays between network origins and destinations. The Flyover alternative is moderately higher (approximately 20 percent more than the CFI), followed by the Curved Bridge alternative and finally the No-Build alternative.

Exhibit 4. 2050 AM and PM Peak Hour Combined Average Vehicular Delay



As shown in **Exhibit 4**, combining the aggregated overall network delay values for the 2050 AM and PM peak hours produces similar results to the VHT data in **Exhibit 3**. The green value indicates the lowest combined delay alternative choice – the CFI "Shifted Pillow" alternative, with approximately 100 seconds averaged delay per vehicle traversing the network when combining AM and PM peak hour results from the 2050 scenarios. The Flyover alternative produces the next relative lowest vehicular delays, with 250 seconds of average vehicle delay when combining AM and PM peak hour simulation run data. Delays for the No-Build and Curved Bridge alternatives are both substantially higher.

4.4 2050 Corridor Travel Time Results

Exhibit 5 shows the comparative results of vehicle travel times for vehicles traveling between selected points on four of the five current approach legs. The results highlight vehicle travel from the following selected points in the study area network:

Travel Time Segment	Origin/Destination Points
NC 211 Eastbound to NC 2 Eastbound	To/From Page Road to the west and Airport Road to the east
NC 2 Westbound to NC 211 Westbound	
US 15-501 Northbound	To/From Memorial Drive to the north and Pinehurst Manor Drive to the south
US 15-501 Southbound	

Exhibit 5. 2050 Design Year Corridor Travel Time Through PTC Performance Comparison

Note – Travel Time Data Only Collected for Vehicles Traveling Continuously Through the Entire Length of the Defined Travel Time Segment . Segment Lengths Vary Depending On Alternative and are Measurably Shorter for the CFI Alternative Where the Circle Geometry is Eliminated.

As shown in **Exhibit 9**, consistently, the CFI – "Shifted Pillow" alternative produces the lowest travel times for each of the four defined travel time segments, regardless of alternative scenario.

The Flyover alternative produces lower travel times than the No-Build Alternative in many cases but not nearly as much as compared to the CFI and Curved Bridge designs. It is worth noting that the Flyover Alternative's primary origin-destination beneficiary – the US 15-501 south leg to/from NC 211 west leg was not included in this travel time test/comparison. However, this movement would be impacted from potential queuing for other movements still utilizing the hybrid/improved existing traffic circle that may block entry/exit from the flyover bridge facility.

The Curved Bridge alternative design produces travel time benefits for the US 15-501 northbound and southbound movements that are relatively similar to the CFI design, as the free flowing bridge sections allow uninterrupted vehicle travel on the elevated sections. However, this benefit only moderately translates into improving overall system operations that improve travel times on the eastbound and westbound NC 211 / NC 2 segments, which are still higher in both peak hours than the CFI.

4.5 2050 Individual Alternative Intersection Operational Analysis Results

Tables 6-11 provide Base Year 2023 and Future Year 2050 intersection capacity analysis results using the VISSIM Node Evaluation MOE for the No-Build and four Build Concepts. Node evaluation results capture overall intersection average delays, approach delays and individual movement or lane group delays. This data is translated into an "HCM Equivalent" or "simulation LOS" (noted as LOS_s) as described in the methodology section previously. The Node Evaluation also provides estimates from maximum queues for each movement/lane group, which are then compared to existing or proposed storages distances for auxiliary turn lanes or distances to the next significant upstream intersection for through travel movements.

Table 6 provides a general comparison for operations at the Pinehurst Traffic Circle for three of the four alternatives where a design concept still includes the Pinehurst Traffic Circle – either with its current lane geometry or a proposed modified geometry to improve operations/safety.

As shown in **Table 6**, the 2050 design year No-Build evaluation of the PTC node shows a reduction in throughput (network demand getting through the PTC to destinations) compared to the 2023 Base Year conditions. Additional demand increases projected vehicular delays and queues from each yield controlled approach at the PTC for both peak hours analyzed. Concept 14 includes the proposed US 15-501 to NC 211 flyover bridged roadway and improvements to the PTC to produce a Turbo Hybrid design. These improvements increase throughput for circle legs and reduces delays and queues to some extent compared to 2050 No-Build conditions, but do not reduce delays to an acceptable LOS for either peak period. No comparison is provided for Concept 17, as the CFI design eliminates the current rotary circle. The proposed "curved bridge" Concept 18 results also show some improvements for the PTC compared to the 2050 No-Build Alternative, but not as robust in terms of delay and queue reduction as the Concept 14 Flyover results.

Table 6. All Scenarios – 2050 Overall PTC Intersection Capacity Analysis Results Comparison

Alternative	Approach	Throughput %		Per Vehicle Delay (sec)		LOSs		Max Queue* (ft.)		Storage (To Next Upstream Intersection)
		AM	PM	AM	PM	AM	PM	AM	PM	
2023 No-Build	**OVERALL**	**93%**	**95%**	**65**	**68**	**F**	**F**			
	NC 211 EB	95%	97%	64	51	F	F	2,879	2,035	1,350
	US 15-501 SB	84%	83%	143	157	F	F	2,815	1,707	1,425
	NC 2 WB	92%	98%	55	52	F	F	754	1,532	600
	NC 2 EB	101%	97%	34	74	D	F	3,394	1,844	1,050
	US 15-501 NB	93%	97%	64	53	F	F	1,924	1,872	750
2050 No-Build	**OVERALL**	**66%**	**70%**	**84**	**81**	**F**	**F**			
	NC 211 EB	75%	88%	159	187	F	F	4,099	3,958	1,350
	US 15-501 SB	65%	62%	70	49	F	E	6,309	5,546	1,425
	NC 2 WB	60%	60%	65	47	F	E	3,605	3,613	600
	NC 2 EB	65%	56%	71	85	F	F	5,608	5,610	1,050
	US 15-501 NB	67%	78%	91	121	F	F	8,024	7,423	750
Concept 14 Flyover – Turbo Hybrid	**OVERALL**	**92%**	**97%**	**53**	**47**	**F**	**E**			
	NC 211 EB	99%	91%	40	97	E	F	5,040	2,431	1,350
	US 15-501 SB	68%	89%	111	92	F	F	390	1,273	875
	NC 2 WB	100%	102%	23	27	C	D	3,519	3,052	600
	NC 2 EB	99%	95%	137	43	F	E	816	892	1,050
	US 15-501 NB	83%	103%	21	22	C	C	4,234	563	750
Concept 17 CFI Shifted Pillow	The PTC is eliminated in this Design Alternative and replaced by the CFI design.									
Concept 18 US 15-501 Curved Bridge	**OVERALL**	**86%**	**83%**	**77**	**68**	**F**	**F**			
	NC 211 EB	88%	97%	50	33	E	D	3,398	1,837	1,350
	US 15-501 SB	70%	75%	256	342	F	F	5,868	2,863	875
	NC 2 WB	67%	70%	58	64	F	F	3,598	3,600	600
	NC 2 EB	71%	68%	79	93	F	F	4,112	1,552	1,050
	US 15-501 NB	91%	100%	68	40	F	E	7,590	5,019	750

The following **Tables 7-11** provide node evaluation data for each scenario, including upstream signalized and unsignalized intersections from the PTC and for Concept 17's individual CFI signalized junctions. The following conclusions/observations can be made regarding intersection vehicular performance for each alternative from the VISSIM model results shown in **Tables 7-11**.

4.5.1 2050 No-Build Alternative

2023 existing PTC traffic circle operations are shown in **Table 7** for each yield-controlled movement through the circle. As shown in the table and field verified, the PTC performs poorly in both the AM and PM peak hours. Almost every approach and overall intersection delay is LOS_S F, indicating excessive congestion in both peak hours. Maximum queue lengths for all approaches spill back past existing upstream signalized intersections, which are also evaluated in the tabular results. Several upstream movements heading towards the circle are negatively impacted (in terms of delay and queuing) by spillback effects from the PTC. In general, the overall signalized intersection results indicate that these intersections operate acceptably but are impacted to some extent by the spillback queues from the PTC. 2023 balanced peak hour traffic volumes and worst-case LOS_S results are shown in **Figure 2.2**.

As shown in **Table 8**, the 2050 No-Build Alternative results indicate that the overall PTC and each individual yield-controlled leg perform poorly in both the AM and PM peak hours, with worsening conditions compared to 2023 Base Year data. Maximum queue lengths for all approaches are projected to spill back past existing upstream intersections and exacerbate delays at these locations – particularly the US 15-501/Memorial Drive intersection. Unsignalized intersections – which are typically evaluated only for critical stop-controlled or left-turn movements – report excessive delays and queues for major street through traffic, due to the spillback effects from the PTC. 2050 balanced peak hour traffic volumes and worst-case LOS_S results are shown in **Figure 4**.

4.5.2 Concept 14 – Flyover with Turbo Hybrid Circle Alternative

As shown in **Table 9**, the overall performance of the Flyover with Turbo Hybrid PTC proposed design is better than the 2050 No-Build Alternative, but still results in a substantial number of LOS_s F results in both peak hours for multiple yield controlled approaches at the modified PTC. **Table 9** data also shows a number of improvements to individual upstream intersection stop-controlled approaches and/or signalized intersection performance. However, there is still incidences of AM or PM peak hour queue spillback from the PTC on a particular leg that affect the upstream intersections – most notably US 15-501 southbound and NC 2 eastbound. 2050 balanced peak hour traffic volumes and worst-case LOS_S results for the Flyover with Turbo Hybrid Circle Alternative are shown in **Figure 5.2**.

4.5.3 Concept 17 – CFI "Shifted Pillow" Alternative

Table 10 shows the individual intersection capacity analysis results from the VISSIM model runs for the proposed Concept 17 design. Overall, all signalized intersections in the design study area operate at an acceptable LOS_s D or better in the 2050 AM and PM peak hours, with most operating at LOS_S A or B. Though more signals are needed for this alternative to function, the ability to simplify signal operation to two phases and to coordinate the operation of the signals in both major directions (US 15-501 and NC 211-NC 2 East) reduces any between intersection queuing and optimizes mobility for the PTC vicinity and upstream intersections.

The NC 211 & NC 2 Realigned intersection (west crossover) is projected to operate at a LOS_s C in the 2050 AM and PM peak hours with potentially some excessive queuing not contained for the realigned NC 2 approach in the current design. Additional refinement of intersection splits and offsets may mitigate this internal queue issue without design modification. No external queue spillback to upstream intersections was noted. 2050 balanced peak hour traffic volumes for the CFI alternative and worst-case LOS_S results are shown in **Figure 6.2**.

4.5.4 Concept 18 – US 15-501 "Curved Bridge"

As shown in **Table 11**, the overall performance of the US 15-501 Curved Bridge proposed design is better than the 2050 No-Build Alternative, but still results in a substantial number of LOS_s F results in both peak hours for multiple yield controlled approaches at the PTC which is assumed to retain its existing configuration for this alternative design concept. **Table 11** data also shows a number of improvements to individual upstream intersection stop-controlled approaches and/or signalized intersection performance compared to the 2050 No-Build Alternative results. However, there is still incidences of AM or PM peak hour queue spillback from the PTC on a particular leg that affect the upstream intersections – most notably for US 15-501 southbound and for NC 2 westbound. 2050 balanced peak hour traffic volumes for the Curved Bridge alternative and worst-case LOS_S results are shown in **Figure 6.2**.

Table 7. 2023 Base Year No-Build – Intersection Capacity Analysis Results

Intersection	Approach	Per Vehicle Delay (sec)		LOSs		Max Queue* (ft.)		Storage (To Next Upstream Intersection)
		AM	PM	AM	PM	AM	PM	
PTC	**OVERALL**	**65.4**	**67.7**	***F***	***F***			
	NC 211 EB	62.8	51.7	***F***	***F***	1,486	436	1,450
	US 15-501 SB	142.8	158.0	***F***	***F***	1,581	245	1,425
	NC 2 WB	55.4	50.3	***F***	***F***	1,290	306	600
	NC 2 EB	37.2	71.8	***E***	***F***	653	336	1,050
	US 15-501 NB	63.5	54.6	***F***	***F***	993	392	800
NC 211 & Page Road	**OVERALL**	**20.9**	**19.2**	**C**	**B**			
	Page Rd SB	23.0	24.2	C	C	203	220	225
	Page Rd NB	27.6	24.4	C	C	226	45	725
	NC 211 WB	12.5	12.2	B	B	206	736	825
	NC 211 EB	25.2	22.4	C	C	1,399	671	725
NC 211 & Aviemore Drive	Aviemore Dr SB	8.2	9.2	A	A	41	106	200
NC 2 & PGA Blvd/Dalrymple	NC 2 WB	0.1	0.1	A	A	87	440	400
	NC 2 EB	6.1	23.1	A	C	192	715	1,250
	Dalrymple SB	12.2	13.4	B	B	47	2	N/A
	PGA Blvd NB	5.2	5.2	A	A	44	20	N/A
US 15-501 & Pinehurst Manor Drive	US 15-501 SB	0.1	0.0	A	A	14	1,130	600
	US 15-501 NB	31.3	22.1	D	C	2,395	903	4,300
	Pinehurst Manor WB	29.6	23.6	D	C	70	13	125
NC 2 & Airport Road	NC 2 WB	13.5	4.6	B	A	457	612	1,450
	Airport Rd SB	138.2	91.4	***F***	***F***	824	324	650
	NC 2 EB	5.2	2.2	A	A	297	478	850
US 15-501 & Memorial Drive/Pinehurst Trace	**OVERALL**	**27.4**	**31.9**	**C**	**C**			
	Pinehurst Trace WB	41.5	21.1	D	C	91	8	200
	US 15-501 NB	6.9	10.7	A	B	184	581	1,250
	US 15-501 SB	52.3	77.3	D	***E***	1,439	289	1,300
	Memorial Dr EB	32.1	32.4	C	C	143	256	250

N/A - Not Applicable, Distance to Upstream Major Intersection Exceeds Model Limits
BOLD/ITALICS – Movement/Approach or overall intersection is at/over Equivalent HCM capacity (***LOS E*** or ***LOS F***)
PURPLE – Maximum Queue May Exceed Storage Bay Distance

Table 8. 2050 No-Build Alternative – Intersection Capacity Analysis Results

Intersection	Approach	Per Vehicle Delay (sec)		LOSs		Max Queue* (ft.)		Storage (To Next Upstream Intersection)
		AM	PM	AM	PM	AM	PM	
PTC	**OVERALL**	**83.1**	**80.9**	***F***	***F***			
	NC 211 EB	68.9	49.3	***F***	***E***	**1,651**	577	1,450
	US 15-501 SB	157.8	184.3	***F***	***F***	**1,584**	262	1,425
	NC 2 WB	70.4	85.2	***F***	***F***	**1,322**	248	600
	NC 2 EB	90.1	118.5	***F***	***F***	788	277	1,050
	US 15-501 NB	65.2	47.3	***F***	***E***	**994**	502	800
NC 211 & Page Road	**OVERALL**	**34.6**	**34.3**	**C**	**C**			
	Page Rd SB	28.1	44.6	C	D	**296**	**316**	225
	Page Rd NB	27.9	24.1	C	C	296	67	725
	NC 211 WB	15.2	15.5	B	B	220	**827**	825
	NC 211 EB	52.0	44.3	D	D	**4,763**	**867**	725
NC 211 & Aviemore Drive	Aviemore Dr SB	8.1	11.0	A	B	43	159	200
NC 2 & PGA Blvd/Dalrymple	NC 2 WB	0.1	0.1	A	A	90	**621**	400
	NC 2 EB	61.7	78.2	***F***	***F***	**2,972**	603	1,250
	Dalrymple SB	19.3	12.9	C	B	51	3	N/A
	PGA Blvd NB	80.6	59.8	***F***	***F***	160	27	N/A
US 15-501 & Pinehurst Manor Drive	US 15-501 SB	0.1	0.1	A	A	17	**1,214**	600
	US 15-501 NB	42.3	29.3	***E***	D	**4,669**	1,069	4,300
	Pinehurst Manor WB	39.3	32.9	***E***	D	92	23	125
NC 2 & Airport Road	NC 2 WB	58.4	68.9	***F***	***F***	**7,262**	680	1,450
	Airport Rd SB	331.1	347.5	***F***	***F***	**847**	142	650
	NC 2 EB	11.0	4.8	B	A	404	426	850
US 15-501 & Memorial Drive/Pinehurst Trace	**OVERALL**	**51.7**	**70.8**	**D**	***E***			
	Pinehurst Trace WB	56.8	28.8	***E***	C	106	11	200
	US 15-501 NB	9.4	13.2	A	B	230	571	1,250
	US 15-501 SB	90.2	118.6	***F***	***F***	**2,556**	327	1,300
	Memorial Dr EB	75.5	122.3	***E***	***F***	**297**	242	250

N/A - Not Applicable, Distance to Upstream Major Intersection Exceeds Model Limits
BOLD/ITALICS – Movement/Approach or overall intersection is at/over Equivalent HCM capacity (***LOS E*** **or** ***LOS F***)
PURPLE – Maximum Queue May Exceed Storage Bay Distance

Table 9. 2050 Build Concept 14 – Flyover with Turbo Hybrid Intersection Capacity Analysis Results

Intersection	Approach	Per Vehicle Delay (sec)		LOSs		Max Queue* (ft.)		Storage (To Next Upstream Intersection)
		AM	PM	AM	PM	AM	PM	
PTC	**OVERALL**	**52.8**	**47.1**	***F***	***E***			
	NC2 EB	39.7	42.5	***E***	***E***	713	714	1,450
	US 15-501 SB	136.9	93.4	***F***	***F***	**1,522**	**1,505**	1,425
	NC 211 EB	23.5	93.8	C	***F***	392	**1,063**	600
	US 15-501 NB	111.2	24.9	***F***	C	949	602	1,050
	NC 2 WB	21.1	25.7	C	D	**820**	775	800
NC 211 & Page Road	**OVERALL**	**23.1**	**26.4**	**C**	**C**			
	NC 211 EB	19.8	22.7	B	C	**622**	**528**	225
	NC 211 WB	19.8	18.3	B	B	622	566	725
	Page Rd NB	19.2	36.1	B	D	447	135	825
	Page Rd SB	39.7	45.1	D	D	367	**808**	725
NC 211 & Aviemore Drive	Aviemore Dr SB	2.9	9.6	A	A	27	138	200
NC 2 & PGA Blvd/Dalrymple	NC 2 WB	0.5	0.5	A	A	103	104	400
	NC 2 EB	22.7	22.4	C	C	**2,877**	**2,302**	1,250
	Dalrymple SB	18.4	13.3	C	B	46	46	N/A
	PGA Blvd NB	10.9	10.5	B	B	74	73	N/A
US 15-501 & Pinehurst Manor Dr	Pine Hurst Manor WB	8.9	8.6	A	A	67	57	600
	US 15-501 NB	36.8	0.2	***E***	A	3,355	5	4,300
NC 2 & Airport Road	**OVERALL**	**16.9**	**19.2**	**B**	**B**			
	NC 2 WB	21.4	17.9	C	B	431	353	1,450
	Airport Rd SB	24.6	44.1	C	D	460	**672**	650
	NC 2 EB	10.0	8.0	A	A	349	252	850
US 15-501 & Memorial Drive/Pinehurst Trace	**OVERALL**	**39.9**	**39.9**	**D**	**D**			
	Pinehurst Trace WB	51.6	24.7	D	C	99	68	200
	US 15-501 NB	10.7	13.5	B	B	189	245	1,250
	US 15-501 SB	78.5	65.5	***E***	***E***	**3,609**	998	1,300
	Memorial Dr EB	45.4	62.2	D	***E***	193	**583**	250

N/A - Not Applicable, Distance to Upstream Major Intersection Exceeds Model Limits
BOLD/ITALICS – Movement/Approach or overall intersection is at/over Equivalent HCM capacity (***LOS E*** **or** ***LOS F***)
PURPLE – Maximum Queue May Exceed Storage Bay Distance

Table 10. 2050 Concept 17 – CFI Shifted Pillow – Intersection Capacity Analysis Results

Intersection	Approach	Per Vehicle Delay (sec)		LOSs		Max Queue* (ft.)		Storage (To Next Upstream Intersection)
		AM	PM	AM	PM	AM	PM	
CFI NC 211 & NC 2 Realigned	**OVERALL**	**20.5**	**22.4**	**C**	**C**			
	NC 2 NB	25.1	22.7	C	C	454	379	400
	NC 211 EB	12.6	20.4	B	C	507	636	1050
	NC 211 WB	22.1	23.4	C	C	522	378	600
	US 15-501 SB	29.4	28.3	C	C	162	117	350
CFI MAIN INTERSECTION	**OVERALL**	**9.5**	**9.4**	**A**	**A**			
	NC 2 WB	9.5	10.6	A	B	236	287	500
	US 15-501 SB	16.5	17.4	B	B	315	279	750
	US 15-501 NB	9.7	8.2	A	A	342	317	800
	NC 211 EB	2.2	2.9	A	A	213	166	675
CFI NORTH CROSSOVER	**OVERALL**	**13.2**	**12.6**	**B**	**B**			
	US 15-501 SB	12.8	16.3	B	B	241	144	850
	NC 2 WB	22.3	25.1	C	C	380	306	700
	US 15-501 NB	7.3	5.2	A	A	205	186	550
CFI EAST CROSSOVER	**OVERALL**	**8.8**	**8.5**	**A**	**A**			
	NC 2 WB	5.9	6.5	A	A	189	234	900
	NC 2 EB	8.1	6.3	A	A	270	182	475
	US 15-501 NB	28.7	27.9	C	C	282	265	625
CFI SOUTH CROSSOVER	**OVERALL**	**18.7**	**17.4**	**B**	**B**			
	US 15-501 SB	8.0	7.5	A	A	139	171	550
	US 15-501 NB	25.3	25.8	C	C	281	271	350
NC 211 & Page Road	**OVERALL**	**19.1**	**19.6**	**B**	**B**			
	Page Rd SB	22.2	19.9	C	B	236	517	225
	Page Rd NB	26.7	20.1	C	C	319	109	725
	NC 211 WB	17.8	17.1	B	B	461	475	1,000
	NC 211 EB	17.8	21.6	B	C	501	436	725
NC 2 & PGA Blvd/Dalrymple	NC 2 EB	2.0	0.7	A	A	504	106	1,250
	PGA Blvd NB	33.0	15.3	D	C	82	68	N/A
	NC 2 WB	0.7	0.9	A	A	93	83	400
	Dalrymple SB	12.1	12.6	B	B	71	70	N/A
US 15-501 & Pinehurst Manor Dr	US 15-501 NB	0.2	0.2	A	A	0	0	775
	Pinehurst Manor WB	9.2	9.1	A	A	90	80	125
NC 2 & Airport Road	**OVERALL**	**18.2**	**18.0**	**B**	**B**			
	NC 2 WB	23.3	18.3	C	B	408	332	1,450
	Airport Rd SB	22.8	38.6	C	D	498	626	650
	NC 2 EB	12.5	8.4	B	A	482	298	900
US 15-501 & Memorial Drive/Pinehurst Trace	**OVERALL**	**12.9**	**17.0**	**B**	**B**			
	Memorial Dr EB	23.3	28.4	C	C	141	532	200
	Pinehurst Trace WB	32.4	15.8	C	B	78	56	250
	US 15-501 NB	7.9	10.6	A	B	262	242	900
	US 15-501 SB	15.7	14.9	B	B	282	207	1,300
US 15-501 SB Median U-Turn	US 15-501 SB U-Turn	7.4	11.8	A	B	23	36	200

N/A - Not Applicable, Distance to Upstream Major Intersection Exceeds Model Limits
PURPLE – Maximum Queue May Exceed Storage Bay Distance

Table 11. 2050 Concept 18 – US 15-501 Curved Bridge – Intersection Capacity Analysis Results

Intersection	Approach	Per Vehicle Delay (sec)		LOS$_S$		Max Queue* (ft.)		Storage (To Next Upstream Intersection)
		AM	PM	AM	PM	AM	PM	
PTC	**OVERALL**	**77.0**	**67.6**	***F***	***F***			
	NC 211 EB	49.3	32.7	***E***	D	**1,631**	**1,538**	1,450
	US 15-501 SB	258.3	331.1	***F***	***F***	**1,571**	**1,463**	1,425
	NC 2 WB	58.6	63.9	***F***	***F***	**1,325**	**1,309**	600
	NC 2 EB	80.5	93.4	***F***	***F***	785	783	1,050
	US 15-501 NB	66.2	40.5	***F***	***E***	**997**	**930**	800
NC 211 & Page Road	**OVERALL**	**26.2**	**22.2**	**C**	**C**			
	Page Rd SB	25.8	27.1	C	C	**285**	**555**	225
	Page Rd NB	27.8	24.1	C	C	298	119	725
	NC 211 WB	16.6	16.7	B	B	258	312	825
	NC 211 EB	32.7	24.2	C	C	**4,309**	**1,443**	725
NC 211 & Aviemore Drive	Aviemore Dr SB	9.0	12.9	A	B	44	130	200
NC 2 & PGA Blvd/Dalrymple	NC 2 WB	0.1	0.2	A	A	94	99	400
	NC 2 EB	51.0	58.2	***F***	***F***	**2,974**	**2,933**	1,250
	Dalrymple SB	20.0	12.1	C	B	51	50	N/A
	PGA Blvd NB	7.6	7.4	A	A	62	65	N/A
US 15-501 & Pinehurst Manor Dr	US 15-501 SB	0.1	0.1	A	A	18	19	600
	US 15-501 NB	25.4	7.8	D	A	2,896	678	4,300
	Pinehurst Manor WB	141.8	39.5	***F***	***E***	**145**	76	125
NC 2 & Airport Road	NC 2 WB	47.5	50.5	***E***	***F***	**6,685**	**3,740**	1,450
	Airport Rd SB	299.1	276.5	***F***	***F***	**855**	**851**	650
	NC 2 EB	21.8	7.5	C	A	685	319	850
US 15-501 & Memorial Drive/Pinehurst Trace	**OVERALL**	**37.3**	**29.3**	**D**	**C**			
	Pinehurst Trace WB	60.2	27.2	***E***	C	102	0	200
	US 15-501 NB	7.7	13.5	A	B	188	69	1,250
	US 15-501 SB	57.1	20.0	***E***	B	**1,851**	268	1,300
	Memorial Dr EB	104.3	59.0	***F***	***E***	**293**	205	250

N/A - Not Applicable, Distance to Upstream Major Intersection Exceeds Model Limits
BOLD/ITALICS – Movement/Approach or overall intersection is at/over Equivalent HCM capacity (***LOS E*** **or** ***LOS F***)
PURPLE – Maximum Queue May Exceed Storage Bay Distance

4.6 2029 Network-Wide Operational Analysis Results

Table 12 provides the Interim Year 2029 network evaluation MOE results for the 2029 Interim Year No-Build and two Build Concepts, along with a comparison to actual 2023 Base Year No-Build scenario conditions. Similar to the 2050 design year data, network evaluation results capture overall travel effects for vehicles making trips between the five origin-destination points that stay essentially the same, regardless of alternative and then other movements at upstream intersections that do not include trips through the PTC. The following conclusions/observations can be made regarding network vehicular performance from the VISSIM model data for the 2029 Interim Year scenarios:

- In general, the two Build alternatives do NOT provide measurable amounts of “total” operational improvement in the vicinity of the Traffic Circle, compared to the 2029 No-Build Alternative. The 2029 No-Build Alternative does show network operational degradation in terms of delays, speeds, VMT and VHT from 2023 Base Year levels, with little additional throughput attainable though traffic demands do show measurable increase from 2023 levels.
- The Concept 1/3 Turbo Hybrid design slightly worsens network operations in the 2029 AM peak hour and more markedly worsens operations in the PM peak hour compared to the No-Build Alternative. Even though there is more “lane capacity” within the PTC circulating roadway, the usage of two lanes by circulating vehicles does not in reality add additional gaps for single lane entry traffic in most cases. Several designs for the “Turbo Hybrid” concept have been tested in the past and consistent with past findings, the difference in AM and PM peak traffic patterns will result in one turbo design working more efficiently in one peak and a different design in the other peak. The design changes in these cases are focused on which approach(es) can have a two lane approach and a one lane circulator versus which approach(es) then have single lane entry and two lane circulators. Also, the adjustment of gap acceptance times to emulate usable gaps in this design may, in reality, not be as efficient as some of the current gap acceptances at certain approaches – though the design should produce safer conditions at entry.
- The Concept 2 – Signalized Metering results indicate that, operationally, it outperforms the Concept 1/3 Turbo Hybrid design in both peak hours but does not match 2029 No-Build Alternative overall averaged and aggregated network operational results for either AM or PM peak hour. The concept design was iteratively tested to assess which approaches should have active signalization in a given peak hour and what the effects would be of signalizing the circulating PTC roadway. The most feasible option is to widen the PTC roadway to two lanes between the US 15-501 northbound and NC 2 westbound legs and signalize that two-lane segment with NC 2 westbound and make that approach two lane in the vicinity of the circulating roadway. This configuration sets the offset pattern for downstream approach legs. Through testing, it was found that de-activating the US 15-501 northbound signal in both peak hours produced the most beneficial overall results. However, even with signals providing some more sustained gaps that subsequent coordinated signals could utilize, the overall network-wide effects are still not as efficient as the current PTC operation.

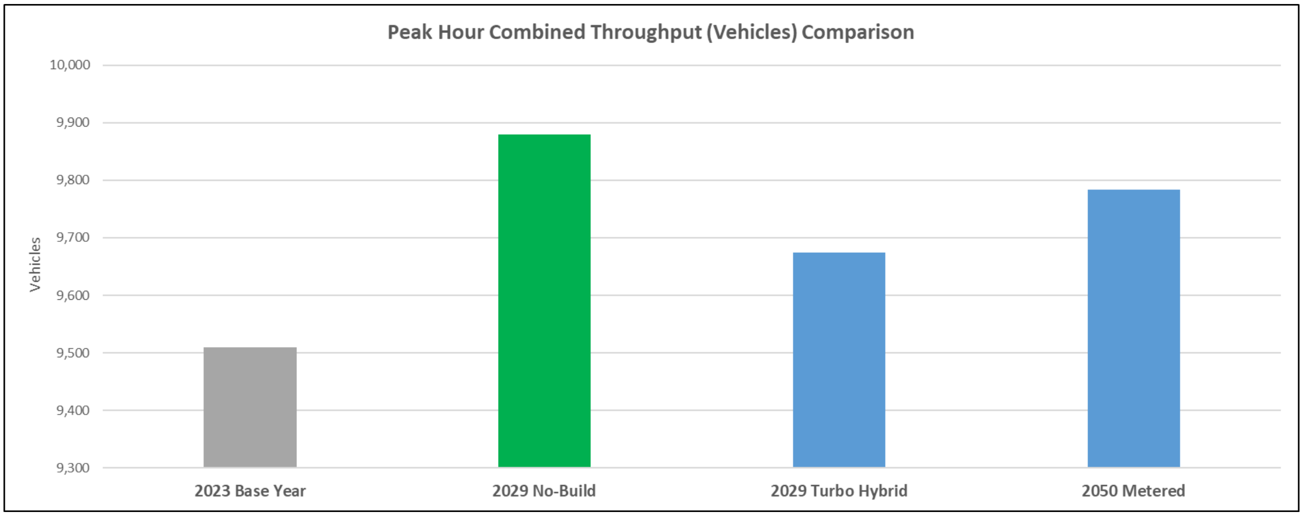
Table 12. 2029 Network MOE Evaluation

	Metric	Average Vehicular Delay	Average Number of Stops	Average Speed	Average Stopped Delay	Total Distance Traveled (VMT)	Total Travel Time (VHT)	Total Delay	Total Number of Stops	Total Stopped Delay	Vehicles Arrived	Latent Total Delay	Latent Demand
	Unit	seconds/ vehicle	stops/ vehicle	miles/ hour	seconds/ vehicle	miles	hours	hours	stops	hours	vehicles	hours	vehicles
AM Peak Hour	**2023 Base Year**	143	11.1	17.4	49	6,840	395	207	57,888	70	4,728	19	53
	2029 No-Build	196	14.8	14.4	76	7,182	500	303	82,138	117	4,914	55	157
	2029 Turbo Hybrid	229	16.4	12.9	93	7,118	556	360	92,888	147	4,888	17	53
	2050 Metered	228	13.5	13.0	118	7,071	546	352	74,900	182	4,828	62	164
PM Peak Hour	**2023 Base Year**	126	9.6	18.0	43	6,396	357	182	49,728	62	4,782	3	9
	2029 No-Build	151	11.2	16.3	61	6,698	413	230	60,947	92	4,965	46	115
	2029 Turbo Hybrid	223	14.9	12.5	102	6,447	520	341	82,092	156	4,786	19	60
	2050 Metered	182	9.7	14.4	104	6,654	463	280	53,857	161	4,955	19	41
		Averaged Performance MOE Statistics				**Aggregated Performance MOE Statistics**					**Throughput MOE Statistics**		

BOLD/ITALIC = Highest MOE Improvement Over 2050 No-Build Conditions

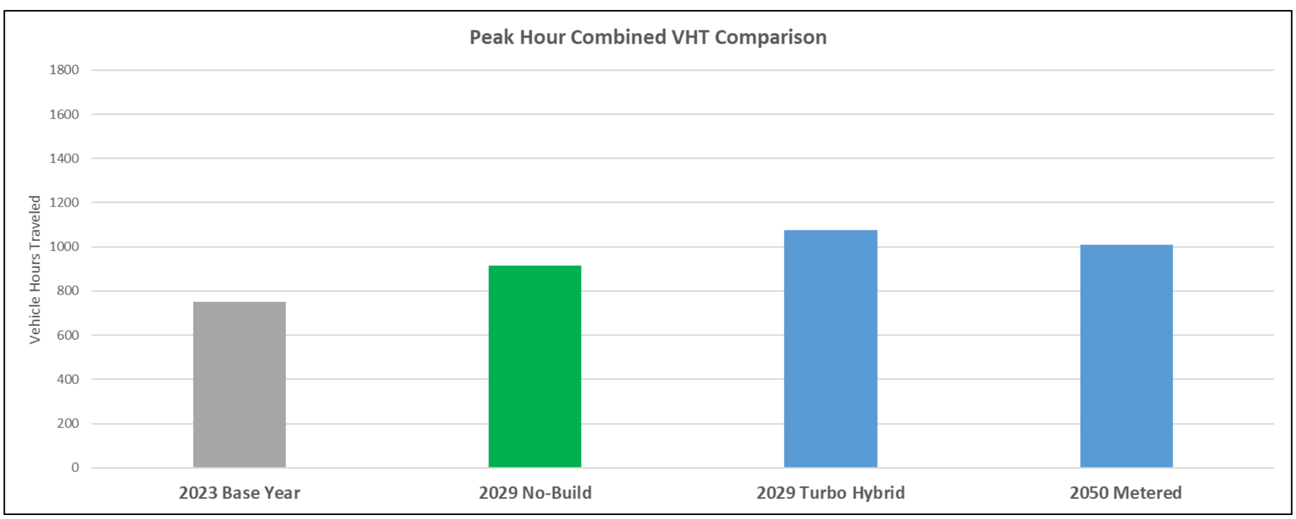
MOE result data shown in **Table 12** was further analyzed for "aggregate" operational statistics that allow visual comparisons of combined 2029 AM and PM peak hour performance between the two Build alternatives and the "No-Build" scenario. **Exhibits 6-8** provide graphical comparisons of combined 2029 AM and PM peak hour Network MOEs for throughput, vehicle hours traveled (VHT), and overall vehicular delay for the 2029 No-Build Alternative and the Turbo Hybrid and Metered Signal Build Alternatives.

Exhibit 6. 2029 AM and PM Peak Hour Combined Network Throughput



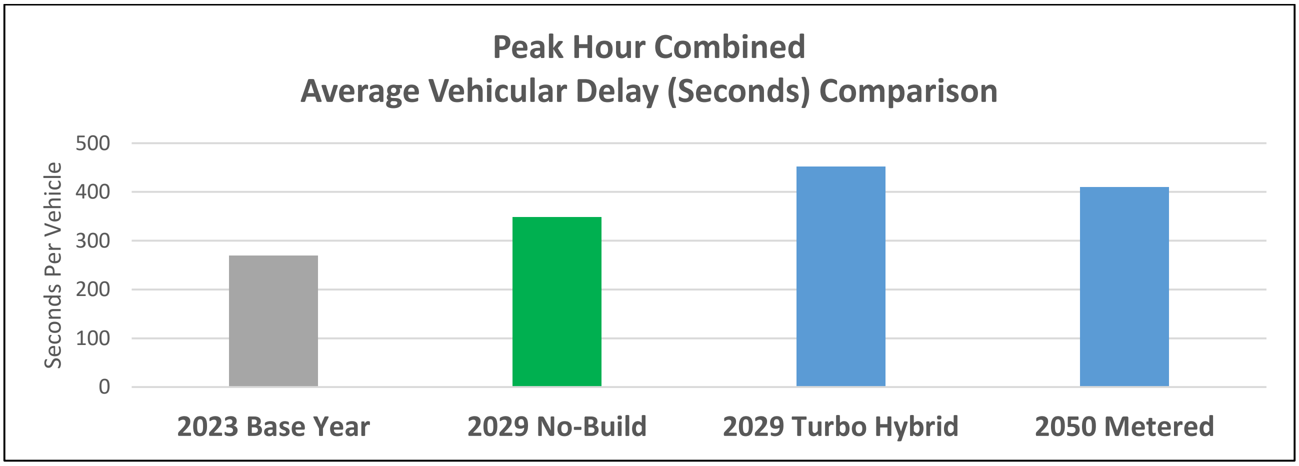
As shown in **Exhibit 6**, combined network throughput is maximized in the alternative shown in green (No-Build Alternative). This represents the highest number of vehicles that can processed through the network but also is capped by the capacity through the PTC and indicates that overall only about 400 more combined AM and PM peak hour vehicles are able to get through the network over the 2023 Base Year scenario. In the cases of the Turbo Hybrid and Metered Signal alternatives, combined peak hour throughput over the entire network is slightly lower than the No-Build results.

Exhibit 7. 2029 AM and PM Peak Hour Combined VHT



As shown in **Exhibit 7** in green, the 2029 No-Build alternative produces the least amount of combined VHT, correlating with this alternatives' efficiency in moving traffic through the network with slightly less (5-10%) delay compared to the Turbo Hybrid and Metered Signal alternatives. Between 2023 Base Year conditions and the 2029 No-Build conditions, VHT is expected to rise network-wide over the two combined peak hours by approximately 20 percent.

Exhibit 8. 2029 AM and PM Peak Hour Combined Average Vehicular Delay



As shown in **Exhibit 8**, combining the aggregated overall network delay values for the 2029 AM and PM peak hours produces similar results to the VHT data in **Exhibit 7**. The green value indicates the lowest combined delay alternative choice – the No-Build Alternative, with the two short-term Build alternatives producing some measurable increased vehicular delays. The exhibit also shows the relative increase in network average delay for all vehicles between the 2023 Base Year and the 2029 alternatives.

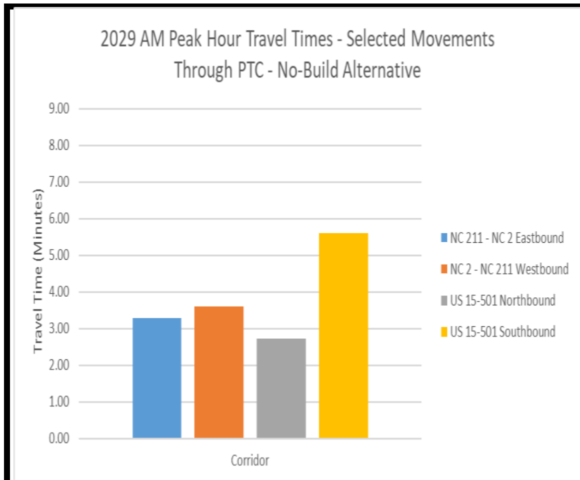
4.7 2029 Corridor Travel Time Results

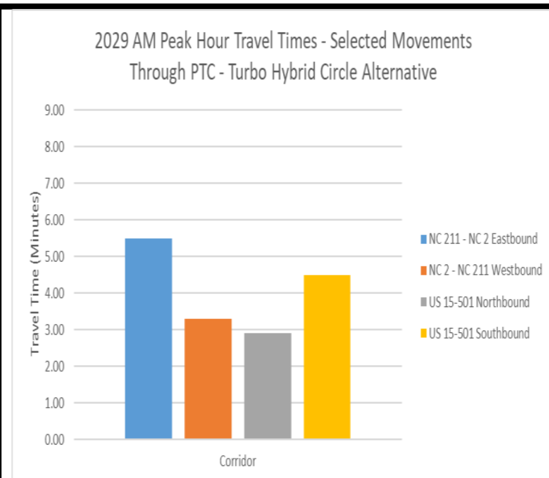
Exhibit 9 shows the comparative results of vehicle travel times for vehicles traveling between selected points on four of the five current approach legs. The results highlight vehicle travel from the same selected points in the study area network that were previously done for the 2050 design year evaluation – US 15-501 northbound and southbound through the PTC area and also NC 211 – NC 2 eastbound and westbound through the PTC. **Exhibit 9** provides separate AM and PM peak hour graphical results that compare the travel times produced by each alternative. There is wide variation in the results by travel time corridor direction and by peak hour when comparing each alternative's results to the other alternatives.

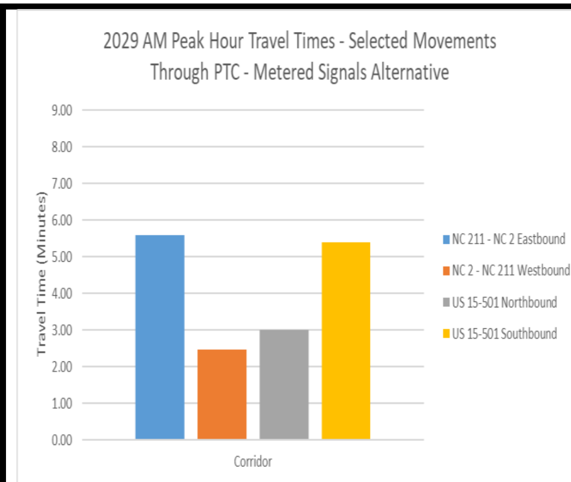
The Concept 1/3 Turbo Hybrid alternative increases travel times compared to the No-Build scenario for NC 211-NC2 eastbound but substantially reduces travel times for US 15-501 southbound. Overall, it performs collectively quite similar to the results for the Concept 2 – Metered Signals alternative for the 2029 AM peak hour but performs worse for two corridor directions in the PM peak hour while vastly better for the US 15-501 southbound corridor through the PTC.

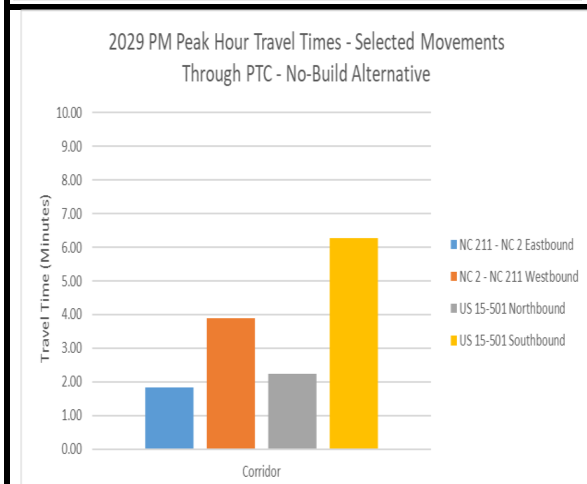
The Concept 2 – Metered Signals results are, collectively over all directions and the two peak hours, somewhat worse than the 2029 No-Build Alternative results. Again, certain travel time directions are marginally better for a given peak hour being compared, but overall there is no clear indication that this Build Concept provides any measurable and consistent improvement.in travel time through the immediate PTC area over No-Build conditions.

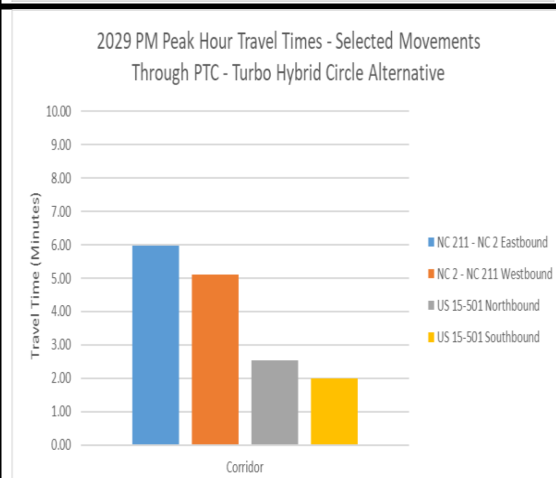
Exhibit 9. 2029 Interim Year Corridor Travel Time Through PTC Performance Comparison

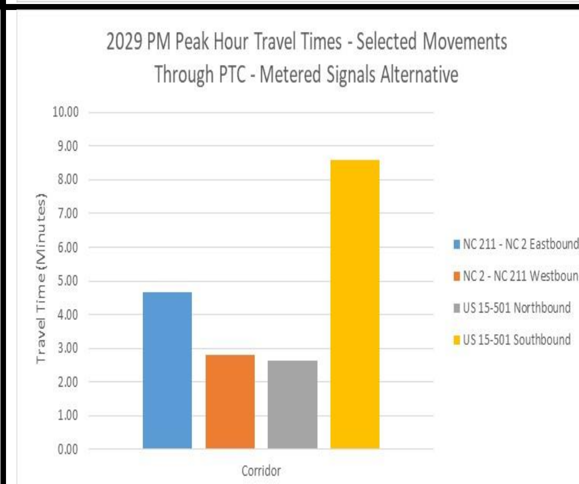












4.8 2029 Individual Alternative Node/Link Capacity Analysis Results

Tables 13-17 provide Base Year 2023 and Interim Year 2029 intersection capacity analysis results using the VISSIM Node Evaluation MOE for the No-Build and two Build Concepts. **Table 13** provides a general comparison for operations at the Pinehurst Traffic Circle for all three alternatives – either with its current lane geometry or a proposed modified geometry to improve operations/safety.

As shown in **Table 13**, the 2029 interim year No-Build evaluation of the PTC node shows a slight reduction in throughput percentage compared to the 2023 Base Year conditions. Additional demand in most cases increases projected vehicular delays and queues from each yield controlled approach at the PTC for both peak hours analyzed. Concept 1/3 Turbo Hybrid results indicate that the proposed changes to the PTC do not provide any consistent operational benefit over No-Build results, though for some approaches, there are changes that do produce some shorter delays or maximum queues. Similar results are indicated in the table for the Metered Signal alternative.

Table 13. All Scenarios – 2029 Overall PTC Intersection Capacity Analysis Results Comparison

Alternative	Approach	Throughput % (Processed/Demand)		Per Vehicle Delay (sec)		LOSs		Max Queue* (ft.)		Storage (To Next Upstream Intersection)
		AM	PM	AM	PM	AM	PM	AM	PM	
2023 Existing	**OVERALL**	**93%**	**95%**	**65**	**68**	**F**	**F**			
	NC 211 EB	95%	96%	63	52	F	F	2,974	2,717	1,350
	US 15-501 SB	84%	83%	143	158	F	F	2,678	2,129	1,425
	NC 2 WB	91%	98%	55	50	F	F	793	1,488	600
	NC 2 EB	100%	98%	37	72	E	F	3,336	2,423	1,050
	US 15-501 NB	94%	97%	64	55	F	F	2,027	1,754	750
2029 No-Build	**OVERALL**	**88%**	**91%**	**73**	**64**	**F**	**F**			
	NC 211 EB	98%	99%	147	168	F	F	3,921	3,654	1,350
	US 15-501 SB	80%	77%	52	23	F	C	2,145	786	1,425
	NC 2 WB	83%	85%	63	44	F	E	3,397	3,056	600
	NC 2 EB	88%	91%	62	69	F	F	4,874	2,406	1,050
	US 15-501 NB	89%	98%	76	77	F	F	2,510	2,124	750
2029 Concept 1/3 Turbo Hybrid	**OVERALL**	**88%**	**87%**	**85**	**86**	**F**	**F**			
	NC 211 EB	86%	81%	84	93	F	F	2,686	924	1,350
	US 15-501 SB	88%	97%	113	48	F	E	4,294	4,572	875
	NC 2 WB	91%	83%	85	136	F	F	3,516	3,287	600
	NC 2 EB	84%	85%	77	85	F	F	3,983	3,603	1,050
	US 15-501 NB	88%	93%	75	58	F	F	2,542	3,009	750
2029 Concept 2 Metering	**OVERALL**	**86%**	**91%**	**81**	**73**	**F**	**F**			
	NC 211 EB	85%	90%	86	76	F	F	3,861	5,654	1,350
	US 15-501 SB	82%	61%	141	232	F	F	4,880	3,307	875
	NC 2 WB	95%	95%	38	49	E	E	3,593	1,136	600
	NC 2 EB	72%	97%	110	49	F	E	4,073	2,110	1,050
	US 15-501 NB	93%	99%	76	59	F	F	1,862	1,850	750

BOLD/ITALICS – Movement/Approach or overall intersection is at/over Equivalent HCM capacity (***LOS E* or *LOS F***)
PURPLE – Maximum Queue May Exceed Storage Bay Distance

4.8.1 2029 No-Build Alternative

As shown in **Table 14**, the 2029 No-Build Alternative shows slight to moderate degradation of operations at the PTC from the 2023 Base Year scenario AM and PM peak hour results. Since throughput is not improved from at/above capacity existing conditions, the results in the table show the effects of additional upstream queue spillback impacting through movements on the major roadway approaches at adjacent signalized and unsignalized intersections. Some approaches do not exhibit an excessively poor LOS_S but do show the upstream "rolling" queues that can cause operational and safety problems when queuing spills through an intersection. 2029 balanced peak hour traffic volumes for the No-Build alternative and worst-case LOS_S results are shown in **Figure 8**.

4.8.2 Original Concept 1/3 – Turbo Hybrid Design

As shown in **Table 15**, the Turbo Hybrid PTC design modifications do not improve overall or approach leg PTC delay or LOS_S in any consistent manner. The design does improve the operations of certain legs in one peak hour but then add more delay and worsen LOS_S in the other peak hour. Upstream queue spillback also is expected to cause operational issues at intersections within the project study area for unsignalized through movements in particular. 2029 balanced peak hour traffic volumes for the Turbo Hybrid alternative and worst-case LOS_S results are shown in **Figure 9.2**.

4.8.3 Original Concept 2 – Signalized Metering of Existing Circle

As shown in **Table 16**, the signalized metering alternative does not mitigate congestion to a substantial degree for the overall PTC or any of the approach legs compared to the 2029 No-Build Alternative, with the exception of the NC 2 WB leg that features the signalization of both a widened two-lane approach to the circle and a widened two-lane cross-section within the circle. Queue spillback from the metered circle is evident in intersection approach delays and LOS_S upstream of the PTC for critical movements the approach the circle for multiple legs, particularly US 15-501 southbound and NC 211 eastbound in both peak hours. 2050 balanced peak hour traffic volumes for the Signalized Metering alternative and worst-case LOS_S results are shown in **Figure 10**.

Table 14. 2029 No-Build Alternative – Intersection Capacity Analysis Results

Intersection	Approach	Per Vehicle Delay (sec)		LOSs		Max Queue* (ft.)		Storage (To Next Upstream Intersection)
		AM	PM	AM	PM	AM	PM	
PTC	**OVERALL**	**73.1**	**64.4**	***F***	***F***			
	NC 211 EB	52.3	22.6	***F***	C	**1,474**	787	1,450
	US 15-501 SB	146.7	168.3	***F***	***F***	**1,565**	**1,565**	1,425
	NC 2 WB	61.9	69.3	***F***	***F***	**1,319**	**1,317**	600
	NC 2 EB	76.5	76.6	***F***	***F***	781	776	1,050
	US 15-501 NB	63.2	44.1	***F***	***E***	**1,000**	**979**	800
NC 211 & Page Road	**OVERALL**	**18.1**	**15.2**	**B**	**B**			
	Page Rd SB	22.5	22.7	C	C	**234**	**295**	225
	Page Rd NB	27.7	25.2	C	C	211	97	725
	NC 211 WB	13.2	12.2	B	B	222	242	825
	NC 211 EB	18.1	12.8	B	B	**948**	451	725
NC 211 & Aviemore Drive	Aviemore Dr SB	7.5	9.6	A	A	42	105	200
NC 2 & PGA Blvd/Dalrymple	NC 2 WB	0.1	0.2	A	A	88	104	400
	NC 2 EB	41.9	41.7	***E***	***E***	**2,717**	**2,377**	1,250
	Dalrymple SB	16.5	12.2	C	B	47	47	N/A
	PGA Blvd NB	52.4	34.6	***F***	D	92	67	N/A
US 15-501 & Pinehurst Manor Drive	US 15-501 SB	0.1	0.0	A	A	17	17	600
	US 15-501 NB	34.8	18.0	D	C	3,933	1,465	4,300
	Pinehurst Manor WB	33.5	24.4	D	C	75	61	125
NC 2 & Airport Road	NC 2 WB	37.0	28.9	***E***	D	1,228	786	1,450
	Airport Rd SB	213.4	200.7	***F***	***F***	**844**	**852**	650
	NC 2 EB	9.3	4.3	A	A	417	256	850
US 15-501 & Memorial Drive/Pinehurst Trace	**OVERALL**	**32.7**	**40.1**	**C**	**D**			
	Pinehurst Trace WB	45.6	22.5	D	C	85	53	200
	US 15-501 NB	7.2	11.2	A	B	194	176	1,250
	US 15-501 SB	63.9	102.9	***E***	***F***	**2,380**	**2,113**	1,300
	Memorial Dr EB	35.2	41.5	D	D	157	**535**	250

N/A - Not Applicable, Distance to Upstream Major Intersection Exceeds Model Limits
BOLD/ITALICS – Movement/Approach or overall intersection is at/over Equivalent HCM capacity (***LOS E*** or ***LOS F***)
PURPLE – Maximum Queue May Exceed Storage Bay Distance

Table 15. 2029 Concept 1/3 – Intersection Capacity Analysis Results

Intersection	Approach	Per Vehicle Delay (sec)		LOSs		Max Queue* (ft.)		Storage (To Next Upstream Intersection)
		AM	PM	AM	PM	AM	PM	
PTC	**OVERALL**	**84.9**	**86.0**	***F***	***F***			
	US 15-501 SB	113.3	48.3	***F***	***E***	**1,475**	877	1,450
	NC 211 EB	83.7	93.2	***F***	***F***	**1,645**	**1,651**	1,425
	US 15-501 NB	75.3	58.1	***F***	***F***	**937**	**926**	600
	NC 2 EB	76.9	84.8	***F***	***F***	715	710	1,050
	NC 2 WB	85.4	135.9	***F***	***F***	**1,193**	**1,204**	800
NC 211 & Page Road	**OVERALL**	**29.4**	**36.2**	**C**	**D**			
	NC 211 EB	43.9	61.7	D	***E***	**2,737**	592	725
	NC 211 WB	14.2	13.2	B	B	240	747	825
	Page Rd NB	28.2	24.9	C	C	229	48	725
	Page Rd SB	25.2	38.9	C	D	230	228	225
NC 211 & Aviemore Drive	Aviemore Dr SB	0.4	5.9	A	A	0	15	200
NC 2 & PGA Blvd/Dalrymple	NC 2 WB	0.2	0.2	A	A	86	97	400
	NC 2 EB	46.7	48.7	***E***	***E***	**2,874**	**2,645**	1,250
	Dalrymple SB	26.1	24.4	D	C	42	42	N/A
	PGA Blvd NB	40.8	29.3	***E***	D	82	67	N/A
US 15-501 & Pinehurst Manor Drive	Pinehurst Manor WB	38.8	25.3	***E***	D	78	60	125
	US 15-501 SB	0.1	0.1	A	A	22	21	600
	US 15-501 NB	40.5	29.5	***E***	D	3,132	2,752	4,300
NC 2 & Airport Road	NC 2 WB	30.1	65.8	D	***F***	**1,420**	**1,901**	1,450
	Airport Rd SB	118.1	134.9	***F***	***F***	**824**	**831**	650
	NC 2 EB	7.0	13.4	A	B	413	790	850
US 15-501 & Memorial Drive/Pinehurst Trace	**OVERALL**	**24.6**	**15.6**	**C**	**B**			
	Pinehurst Trace WB	39.8	19.2	D	B	87	60	200
	US 15-501 NB	7.7	9.9	A	A	141	141	1,250
	US 15-501 SB	41.8	17.0	D	B	**1,308**	292	1,300
	Memorial Dr EB	32.4	21.3	C	C	145	441	250

N/A - Not Applicable, Distance to Upstream Major Intersection Exceeds Model Limits
BOLD/ITALICS – Movement/Approach or overall intersection is at/over Equivalent HCM capacity (***LOS E* or *LOS F***)
PURPLE – Maximum Queue May Exceed Storage Bay Distance

Table 16. 2029 Concept 2 – Intersection Capacity Analysis Results

Intersection	Approach	Per Vehicle Delay (sec)		LOSs		Max Queue* (ft.)		Storage (To Next Upstream Intersection)
		AM	PM	AM	PM	AM	PM	
PTC	**OVERALL**	**81.1**	**72.6**	***F***	***F***			
	NC 211 EB	85.9	76.0	***F***	***F***	**1,645**	**1,633**	1,450
	US 15-501 SB	140.6	232.3	***F***	***F***	**1,558**	**1,559**	1,425
	NC 2 WB**	38.1	48.9	D	D	**1,204**	**1,224**	600
	NC 2 EB	110.4	49.4	***F***	***E***	771	700	1,050
	US 15-501 NB	76.2	59.0	***F***	***F***	**973**	**924**	800
NC 211 & Page Road	**OVERALL**	**30.0**	**27.9**	**C**	**C**			
	Page Rd SB	24.7	30.8	C	C	**234**	**410**	225
	Page Rd NB	27.7	24.8	C	C	211	97	725
	NC 211 WB	13.4	12.8	B	B	236	263	825
	NC 211 EB	46.8	43.2	D	D	**3,328**	**1,822**	725
NC 211 & Aviemore Drive	Aviemore Dr SB	7.8	10.3	A	B	41	111	200
NC 2 & PGA Blvd/Dalrymple	NC 2 WB	0.1	0.2	A	A	88	96	400
	NC 2 EB	66.6	12.5	***F***	B	**2,913**	477	1,250
	Dalrymple SB	15.1	13.1	C	B	47	47	N/A
	PGA Blvd NB	55.5	18.0	***F***	C	90	59	N/A
US 15-501 & Pinehurst Manor Drive	US 15-501 SB	0.1	0.1	A	A	17	20	600
	US 15-501 NB	30.5	16.2	D	C	3,131	1,196	4,300
	Pinehurst Manor WB	30.2	23.0	D	C	74	61	125
NC 2 & Airport Road	NC 2 WB	4.2	6.9	A	A	211	234	1,450
	Airport Rd SB	110.4	101.9	***F***	***F***	**797**	**777**	650
	NC 2 EB	3.3	2.6	A	A	211	177	850
US 15-501 & Memorial Drive/Pinehurst Trace	**OVERALL**	**32.8**	**59.2**	**C**	***E***			
	Pinehurst Trace WB	45.2	33.0	D	C	95	56	200
	US 15-501 NB	8.9	13.1	A	B	228	213	1,250
	US 15-501 SB	62.6	175.9	***E***	***F***	**2,321**	**4,114**	1,300
	Memorial Dr EB	36.1	76.6	D	***E***	155	**590**	250

N/A - Not Applicable, Distance to Upstream Major Intersection Exceeds Model Limits
BOLD/ITALICS – Movement/Approach or overall intersection is at/over Equivalent HCM capacity (***LOS E*** **or** ***LOS F***)
PURPLE – Maximum Queue May Exceed Storage Bay Distance
** - Approach is Controlled by Two Phase Signal for Both NC 2 WB and PTC legs

5. ANALYSIS CONCLUSIONS AND RECOMMENDATIONS

5.1 2050 Design Year Preferred Alternative Concept

Similar to previous design concept operational analyses completed for the U-5976 project, the goal of this alternative concepts study is to assist and guide NCDOT and stakeholders in decisions related to the selection of a preferred alternative design concept for STIP U-5976, based on operations and safety implications of the three currently analyzed Build Alternative Concepts contained in this report, along with the No-Build Alternative. The three current alternatives were included, based on direction from NCDOT Division 8 staff.

To provide the most recent and accurate data for PTC operations and projection of future traffic volumes, traffic count data and field operations studies were conducted in 2023 to inform the analytic models created for this study. In addition, the study area was expanded to account for traffic operations effects at upstream intersections for each of the five legs of the PTC.

To summarize the pros and cons related to design details, potential effects on safety, and operational results from this study, the three new or updated Build Alternative concepts analyzed in this report are shown in **Table 17**. This general summary table provides a general qualitative comparison of the five proposed design alternative concepts – with considerations related to design, safety and 2050 traffic operations, based on microsimulation operational results from this study.

The operational results clearly indicate that the Concept 17 – CFI "Shifted Pillow" design provides the highest levels of mobility through the U-5976 study area compared to the other Build Alternatives under study and in agreement with previous alternative analysis comparison with other previously considered designs. It provides long term safety benefits by reducing congestion and facilitating orderly traffic flow between the five major roadways. Its design can also provide areas for aesthetic treatments to create a sense of "gateway" into the Village that the current PTC provides.

The two other Build Alternatives that were studied do improve traffic mobility from the 2050 design year No-Build Alternative, but still result in excessive queuing and delays for the existing or modified PTC that remains in each Alternative. The designs do avoid direct conflict with the existing interior of the PTC but also create construction impacts outside of the circle and would not be as cost-effective as the CFI design.

5.2 2029 Interim Year Preferred Alternative Concept

Table 17 also contains an evaluation of the two Interim Year Build Alternatives in comparison to the No-Build Alternative. The intent of the Interim Year study was to identify and test feasible/low cost options for improving mobility and safety in the existing PTC area, with the knowledge that a long-term option was still needed and may not be constructed until after 2029, the year chosen for the interim analysis. In general, based on the results of the capacity analyses and design/safety issues, neither Interim Year Build Alternative produces any substantial benefit to merit a recommendation for implantation at this time.

Table 17. Overall Concept Comparisons

2050 Design Year Alternatives			
Alternative	**Design Considerations**	**Safety Considerations**	**2050 Operational Performance**
No-Build Alternative	• Maintain existing two-lane entry pattern with each outer lane functioning as a right-turn lane for adjacent downstream leg. • No geometric changes to the existing PTC.	• Current high crash pattern of rear-end, angle and sideswipe crashes likely to continue and potentially increase as congested conditions increase. • More conflicts/crashes likely at blocked upstream intersections.	• 2050 projected traffic demands will increase existing delays and queues which are above capacity during existing peak hours. • More off-peak hours during the day likely to face congestion. • More traffic will "cut through" other local roadways not designed for high volume traffic conditions.
Concept 14: **Flyover – with Turbo Hybrid PTC Design**	• Horizontal and vertical alignment of elevated roadway can be achieved to connect at grade along NC 211 and US 15-501 without major right-of-way issues. • Existing PTC could be upgraded to Turbo Hybrid design as part of the project.	• Reduction in congestion for the PTC and implementation of the Turbo Hybrid design should reduce crash frequency. • May be issues with weaving immediately downstream of Flyover at-grade connection points. • Current two-lane bridge design may have operational issues if a crash occurs on the elevated bridge section.	• Some network, corridor and local intersection improvements were noted compared to the 2050 No-Build Alternative but none to the degree where Concept 14 eliminates congestion in and around the PTC area other than for the movements directly associated with the Flyover.
Concept 17: **Continuous Flow Intersections – "Shifted Pillow" Design**	• Reduces potential ROW impacts and does not require a grade separation. • Should not have substantial constructability or MOT issues. • May require additional signing and public information campaign to help drivers understand the correct ways to drive through the area. • Will impact aesthetics by eliminating the current circle but provides additional land in outside quadrants for vegetation and grassed median areas for landscaping. • Eliminates Aviemore Drive connection to NC 211 and limits Pinehurst Manor Drive to a RIRO along US 15-501.	• Unconventional design requires appropriate signage, pavement markings to guide traffic at crossovers. • No "unexpected" movements and reduction of conflict points with the reduction in congested conditions should provide a large safety benefit. • Crossing pedestrians through the CFI could be challenging.	• Best network and individual intersection performance for 2050 traffic demands among any alternative tested. • Flexibility in designing signal progression schemes in all four directions of the main intersection. • Can extend signal coordination and progression to adjacent traffic signals at Page Road on NC 211 and Memorial Drive at US 15-501 and new signalized intersection at NC 2 and Airport Drive.
Concept 18: **US 15-501 "Curved Bridge" Concept**	• US 15-501 curved bridges would be challenging to properly design and construct over the existing PTC configuration. • There is adequate upstream and downstream spacing to provide necessary connection points along US 15-501. • Will impact aesthetics by featuring large bridge span structures in the immediate PTC vicinity as well as retaining wall features and bridge piers along sections of US 15-501.	• Existing PTC approaches not associated with the US 15-501 bridged sections still expected to be congested with associated safety issues at each PTC leg. • Curved bridge design creates upstream/downstream weaves to access the bridge connection points, potentially causing safety issues. • Creating appropriate design speeds on the curved bridge and clearing any crashes that occur on a single lane bridge may be problematic.	• Only improves operational performance for the US 15-501 traffic stream. Existing issues would still remain at other approach legs. • Does not provide overall mobility improvements compared to the other two Build Alternatives.
2029 Interim Year Alternatives			
Alternative	**Design Considerations**	**Safety Considerations**	**2029 Operational Performance**
Concept 1/3: **PTC Turbo Hybrid Design**	• Could generally be designed and constructed without major impacts to existing PTC operation. • The implementation of "modern roundabout" design criteria on the PTC is unconventional.	• The design changes to have traffic streams enter at a larger approach angle for each PTC leg should allow more consistent and safer judgement of acceptable gaps and reduce "rolling" higher speed entry patterns that cause safety problems at the existing PTC. • Turbo design could help eliminate internal circulating roadway safety issues.	• Operational results do not indicate any consistent improvements for throughput, delay, or queuing reduction from the 2029 No-Build Alternative.
Concept 2: **PTC Metered Traffic Signals**	• Implementation of traffic signals and proposed minor PTC circulating roadway widening should cause little design and construction issues. • Actual field implementation of signal operations in this unconventional scenario may require additional evaluation of field performance and changes to optimize operations throughout peak and off-peak periods where traffic flows vary considerably.	• Driver understanding and adherence to signalized operation and compliance with no entry on "red' may be challenging. • Non-compliance may cause safety issues. • Providing "green" on an approach only indicates that yield-controlled entry is allowed which could be a major safety concern. • The circulating roadway signal at NC 2 Westbound in unconventional and may need upstream signage/warning signals to safely stop vehicles given limited sight distance.	• Operational results do not indicate any consistent improvements for throughput, delay, or queuing reduction from the 2029 No-Build Alternative. • The effects of metering will cause start-up delays for each leg getting "green" indications, potentially inhibiting the maximum amount of circulating vehicles.