NCDOT Capacity Analysis Guidelines

Best Practices

NCDOT Congestion Management Section

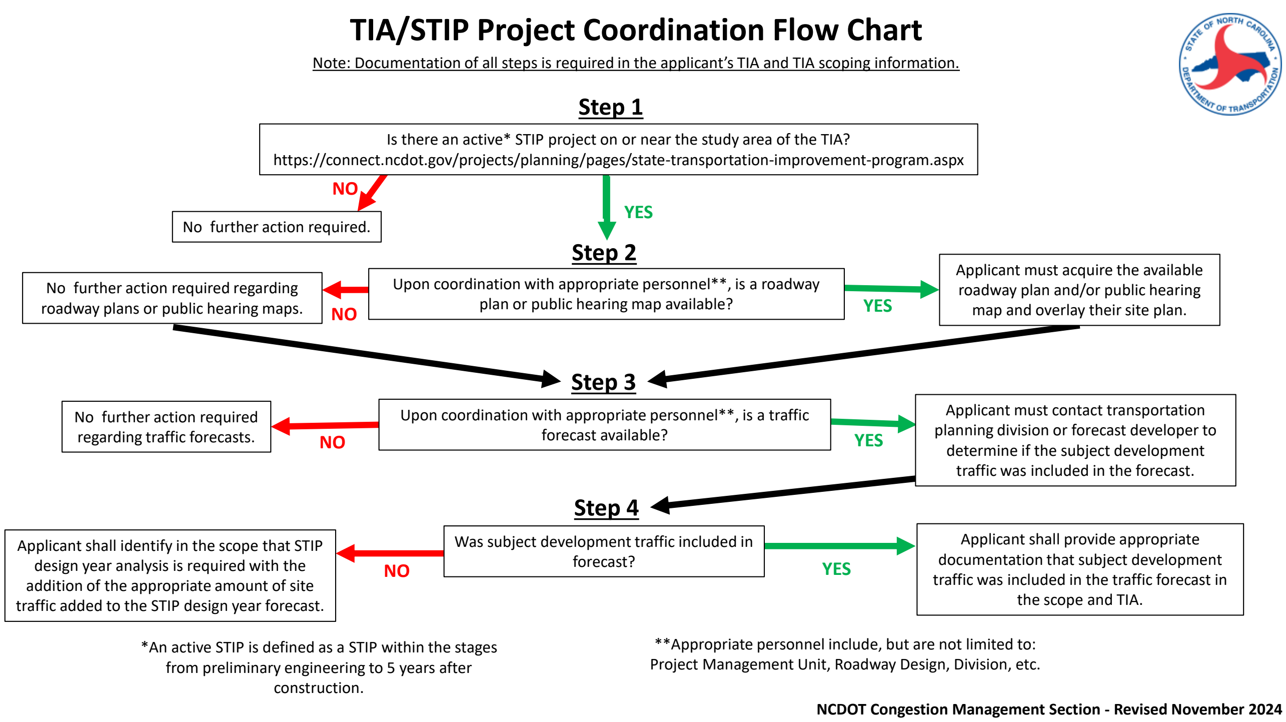
This document provides Best Practices that should be followed for capacity analysis submittals to NCDOT. Standard values for capacity analysis are provided in the NCDOT Capacity Analysis Guidelines Standards document.

Contents

Best Practices for Traffic Impact Analyses Submitted to NCDOT

The Driveway Manual Policy indicates that a coordination with appropriate NCDOT Transportation Improvement Program (STIP) personnel is required for proposed developments on an active STIP project (i.e., STIP project is in the planning phase, in the design phase, in the construction phase, or within 5 years after construction). The applicant should determine if the proposed site is on an active STIP project at the scoping stage of Traffic Impact Analysis (TIA) development. If it is determined that a development is on or near an active STIP project, the applicant should coordinate with appropriate Project Management Unit and/or Division personnel and provide a site plan overlay over the most current STIP design (public hearing map, roadway design, etc.). This is especially important in coordinating proposed access points with the current STIP design. A STIP design year analysis may be needed if the TIA is proposing a new and/or modified driveway along the STIP project corridor.

It is the applicant's responsibility to next see if there is a STIP traffic forecast developed and if/when a forecast has been developed. It is the applicant's responsibility to reach out to who developed or approved the forecast to determine if the subject development traffic was included in the forecast or not. If the proposed site traffic was included in the forecast, the applicant/PEF needs to document this in the scoping document and TIA. If the proposed site traffic was not included in the forecast for a given parcel/zone, then a STIP design year analysis should be included with the TIA with the proposed additional site traffic added to the STIP design year forecast volumes. The following chart details this process.



Applicants should include the Traffic Safety Unit on TIA and TIA scoping submittals that could include safety concerns.

Unadjusted daily trips (without modal splits, pass-by trips, internal capture rates) should be provided in the Trip Generation tables as required in the Policy on Street and Driveway Access to North Carolina Highways (Driveway Manual).

If local data is intended to be used for trip generation, proper justifications should be provided in the scoping document and in the TIA. Local trip generation studies should follow ITE Trip Generation Procedures.

For retail developments, trip generation for individual outparcels should be calculated separately from the remainder of the development. Similarly, trip generation for the same land use across different buildings should be calculated separately unless the same parking area is intended to be used, and public streets are not crossed.

When zoning is nonspecific, the highest peak hour generating land use should be used. One example for this would be Land Use Code (LUC) 945 – Convenience Store/Gas Station. This 945 LUC allows for the independent variable to either be Vehicle Fueling Position or GFA. Both options need to be checked and the highest peak hour generating one should be used.

For multi-use developments, pass-by percentages should be applied to the retail and services component only. Total pass-by trips (sum of entering and exiting) should not exceed 10% of the volume on the adjacent street.

The applicant should provide origin/destination distribution points in the trip distribution diagram. In addition to the origin/destination points, please provide the trip distribution movements for entering and exiting site trips during the AM and PM peak hours and any other study period being analyzed. The TIA should include trip distribution figure, site trip figures for primary trips and for pass-by trips.

Intersections in the proposed study area should be included if site trips are expected to add 10 percent or more to the expected background volumes for any approach/movement or at the discretion of NCDOT or local authorities.

Approved or planned (not yet approved) development traffic in this area should be included in background traffic based on coordination with district and local authorities. The background traffic should also include potential growth in the study area, which can be determined using a growth factor that is calculated based on the long term AADT data trends, traffic forecast data. Both the growth factor and the background approved development should be discussed in the scoping document, prior to TIA submittal. For developments that are planned to be built out over multiple phases, it should be noted that the site trips generated from a previous phase should NOT be added to the background traffic volumes of the subsequent phases. The build out volumes for every phase should include the site trips generated by what is planned to be constructed during this phase as well as the site trips of everything that was constructed in the frame of this project in all previous phases.

The provided site plan/map in the scope and in the TIA shall include an appropriate scale and shall clearly show the location and type of each access point, internal street network, proposed buildings/parcels with their anticipated uses and sizes at full build-out and, if applicable, any nearby interstate, US, NC, or Secondary Roads (SR) in conformance with requirements in the Driveway Manual.

A comparison table across analysis scenarios should be provided in the TIA to identify roadway network improvements based on level of service, delay and queuing requirements detailed in the Policy on Street and Driveway Access to North Carolina Highways. Comparison tables should include both the 95th percentile queue from Synchro analysis and the maximum observed queue from Simtraffic simulation. Please note that a Signal Timing modification is not considered a mitigation.

Capacity Analysis Guidelines should be followed consistently between Future no build Synchro files and future build Synchro files for a fair comparison between both files. An example among others, the cycle length in the future no build should not be unnecessarily higher than the cycle length in future build as this will not allow for an accurate comparison of both files.

If the Developer wishes the TIA information to remain confidential, they need to clearly mark the document CONFIDENTIAL. It will remain confidential until a formal Driveway Permit has been requested or upon which time the Department knows that a public announcement *has been made about the development.*

It is the PEF responsibility to identify control-of-access breaks that occur in the area that is being studied for the TIA. These identified control-of-access breaks need to be clearly marked on the TIA recommendation diagram.

Best Practices for all Capacity Analyses Submitted to NCDOT

General Project Information

This information applies to State Transportation Improvement Projects (STIP) and TIA studies.

Project Coordination

For TIA's, complete the NCDOT TIA Checklist which is referenced on the Congestion Management Website.

The NCDOT TIA Checklist is a group of three sets of standard forms designed to facilitate the TIA need determination, project scoping, and TIA submittals. The objective is to improve TIA consistency and streamline the review and approval process statewide.

When schools are in the vicinity of a STIP project or new development; coordination with the Municipal and School Transportation Assistance Section (MSTA) is required.

All intersections within the study area should be evaluated unless otherwise justified. For STIP projects, analyze all roadways with an anticipated design year Annual Average Daily Traffic (AADT) of over 1,000 vehicles per day.

For STIP projects, the traffic analysis scope should be discussed with the NCDOT project manager along with the Congestion Management Section, and if applicable, the Transportation Planning Division.

Strategic Transportation Corridors and Comprehensive Transportation Plans (CTP)

NCDOT places highest priority in the planning and long-term improvement of safe, highly reliable, and efficient multimodal Strategic Transportation Corridors (STC). The STC identify a network of critical multimodal transportation corridors considered the backbone of the state's transportation system. These 25 corridors move most of our freight and people, link critical centers of economic activity to international airports and seaports, and support interstate commerce. They must operate well to help North Carolina attract new businesses, grow jobs and catalyze economic development. A Comprehensive Transportation Plan (CTP) is a long-range multimodal plan that identifies transportation improvement need and proposes solutions for the next 50 years. CTP facilities are broken down into the following facility types: freeway, expressway, boulevard, major thoroughfare, minor thoroughfare. Metropolitan Transportation plan (MTP) identifies how the multi-modal transportation system will be managed and operated to meet the region's economical, sustainability goals for the upcoming 20 years while remaining fiscally constrained.

All projects must conform to the vision of the STC and CTP to protect the safety, mobility and traffic carrying capacity of these corridors. In addition, if a project is in an urban area, it must conform to the vision of the MTP. The project must support the proposed facility type and allowed access types recommended in the CTP/MTP.

Median and Control-of-Access Breaks

Changes in Control-of-Access (C/A) will require approval from the NCDOT Right-of-Way Disposal and Control-of-Access Committee. New or modified median crossovers must be approved by the State Traffic Engineer or designee for existing roadways, the Roadway Design Project Engineer for active STIP projects, and the State Highway Design Engineer for exceptions to the Median Crossover Guidelines on active STIP projects. These requests must be initiated by the District Engineer.

For driveway requests that require a change in C/A, a new median crossover, or both, the benefit to the travelling public should be demonstrated. To provide a basis for comparison, analysis should demonstrate the benefit along the following hierarchy: no access, right-in/right-out, directional crossover, unconventional intersection designs, and full access.

Interchanges

New and modified interchanges along interstate routes may require an Interchange Access Report (IAR) that requires approval by Federal Highway Administration (FHWA). Control-of-access is recommended for at least 1,000 feet beyond the nearest ramp terminal. If this is not feasible, full C/A will extend for a minimum of 350 feet and a raised island will be installed to a point a minimum of 1,000 feet beyond the ramp terminals.

Best Practices for Synchro/SimTraffic

The remainder of this document provides Best Practices to ensure that consistent traffic analysis is done by/for the North Carolina Department of Transportation (NCDOT) Congestion Management Section using Synchro/SimTraffic software. Traffic analysis requires an understanding of traffic engineering principles and the ability to make sound engineering judgments.

Strict adherence to the Guidelines is not an explanation as to why something was, or was not, done during the development of an analysis. By reviewing reports, plans, and submittals, the NCDOT in no way relieves the analyst of possible claims or additional work resulting from errors or omissions.

These Guidelines are limited to capacity analysis studies only. Detailed operational studies, such as field signal timing, may have different requirements. These Guidelines may be utilized for projects that are not being prepared for the NCDOT Congestion Management Section, such as projects at the Division level, at the discretion of the responsible NCDOT Business Unit. For Non-Congestion Management Section projects, substitution of the responsible NCDOT Business Unit throughout these Guidelines where NCDOT Congestion Management Section approval is required is acceptable.

Synchro/SimTraffic Software

Synchro is a macroscopic (deterministic) analysis and optimization software application that supports the latest Highway Capacity Manual's (HCM) and previous versions for signalized intersections, unsignalized intersections and single lane roundabouts. SimTraffic is an accompanying software application that performs micro-simulation and animation of vehicular and pedestrian-related traffic. Synchro does not provide performance data for freeways, multilane highways, or two-lane rural roads; therefore, alternative analysis methodologies should be used for these road classes. NCDOT utilizes Synchro and SimTraffic to evaluate the performance of urban streets, signalized intersections and unsignalized intersections (two-way stop, all-way stop and single lane roundabouts). Therefore, these guidelines only apply to the aforementioned types of analyses.

General Synchro Information/Project Setup

NCDOT is currently utilizing Synchro 11 and recommend that Synchro files submitted in the frame of any capacity analysis to be compatible with Synchro 11. Please note that the guidelines discussed in this document apply for Synchro 11. For additional details on Synchro 11 usage, please refer to the Synchro Studio 11 User Guide.

File Naming Conventions

This section includes file naming conventions for Synchro projects. Each scenario should be stored in its own separate set of folders and the files should follow the following standard naming conventions:

{STIP or Project No.}_{Analysis Year}_{Scenario}_{Alternative (if applicable)}

With:

STIP or Project No.: STIP, Special Project (SP) or SPOT ID

Analysis Year: Analysis Year for Model

Scenario: No-Build, Build or some other special scenario

Alternative: Alternative name/number or additional information to distinguish between differing options or scenarios

For Example: U-0000_20XX_No-Build

R-0000_20XX_No-Build

I-0000_20XX_Build_Alternative 1

Background Images for Model Development

The development of models is typically done utilizing aerial imagery for existing conditions models and GIS shapefiles for proposed designs. The following file formats can be attached in Synchro: DXF, GIS, Bitmap, JPEG and Shapefile (*.dxf, *.bmp, *.jpg, *.jpeg and *.shp). There are several sources and methods for utilizing aerial imagery in Synchro as detailed in the Synchro User Guide.

Previously Developed Models

Check with the appropriate NCDOT Congestion Management Section staff member to determine if existing models are available for the project study area. If an existing model is available, the previous model may be used as a starting point or merged into a single model with the same file name as the new model. Please refer to the Synchro User Guide for more information on procedures that can be followed to merge files in Synchro.

Fiscal Constraint for Future Year Models

When developing future year models, review the pertinent plans listed below to determine if any additional reasonably foreseeable projects, beyond the subject project being modeled, are located within the model study area. Any project that is reasonably foreseeable should be included in the future year model(s). Use the following criteria to determine if a project is reasonably foreseeable:

- For model study areas located within the boundaries of a Metropolitan Planning Organization (MPO), review the currently adopted Comprehensive Transportation Plan (CTP) or Metropolitan Transportation Plan (MTP) to determine if any projects within the model study area are included on the fiscally constrained list of projects. This link could be utilized as a starting point: https://connect.ncdot.gov/projects/planning/Pages/Comprehensive-Transportation-Plans.aspx
- For a non-MPO area, determine if any project located within the model study area that has construction funding in the current STIP. This link could be utilized as a starting point: https://ncdot.maps.arcgis.com/home/webmap/viewer.html?webmap=cb02f4f828974670ad01bb83be91b18c

Node Numbering

Node numbering should be done in a consistent manner across all projects. The main corridor should be numbered starting in either the southern or western part of the corridor depending on the orientation of the project and increase in reasonable increments (1, 2, 3, 4… or 10, 20, 30, 40…). For projects where there is more than one major corridor, each corridor should be numbered in a similar manner with each corridor progressing with the next set of logical numbers.

Node numbers can be changed by double clicking on a node, which opens the Node Settings panel on the left side of the screen. In the Node Settings panel, select the top row (Node #) and type in the desired number. Synchro prevents duplicate node numbers, and the analyst will be prompted to overwrite the existing node number if duplicated.

Zones

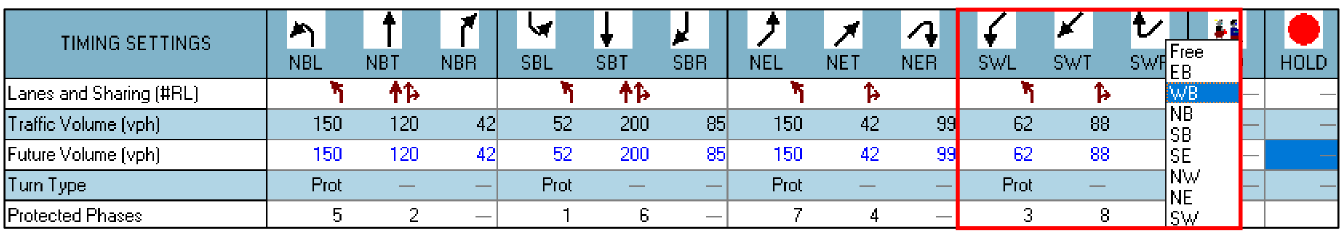
Synchro allows for the creation of zones where intersections can be grouped together (assigned in the Timing Settings tab). Zones are helpful when there is a need to analyze a specific corridor of the network. The analyst can create zones to have different cycle lengths for a section of a network or to change the timings of a specific corridor while keeping the remaining parts of the network constant. Zones can be beneficial for the following features:

- Optimization of network cycle lengths
- Optimization of network Offsets
- Output Reports

Cardinal Directions

Intersection approaches should only be coded by cardinal directions (north, south, east, and west) as other approach directions (northeast, southeast, northwest, and southwest) may prevent Synchro from discerning turn movements from through movements resulting in inaccurate capacity and queuing results.

To adjust directions, right click over the direction wanting to be changed and a drop-down list will appear, then select the correct cardinal direction for that approach. Note that each leg may have to be manually adjusted to get all cardinal directions correct. The directions can be revised in any of the setting windows.



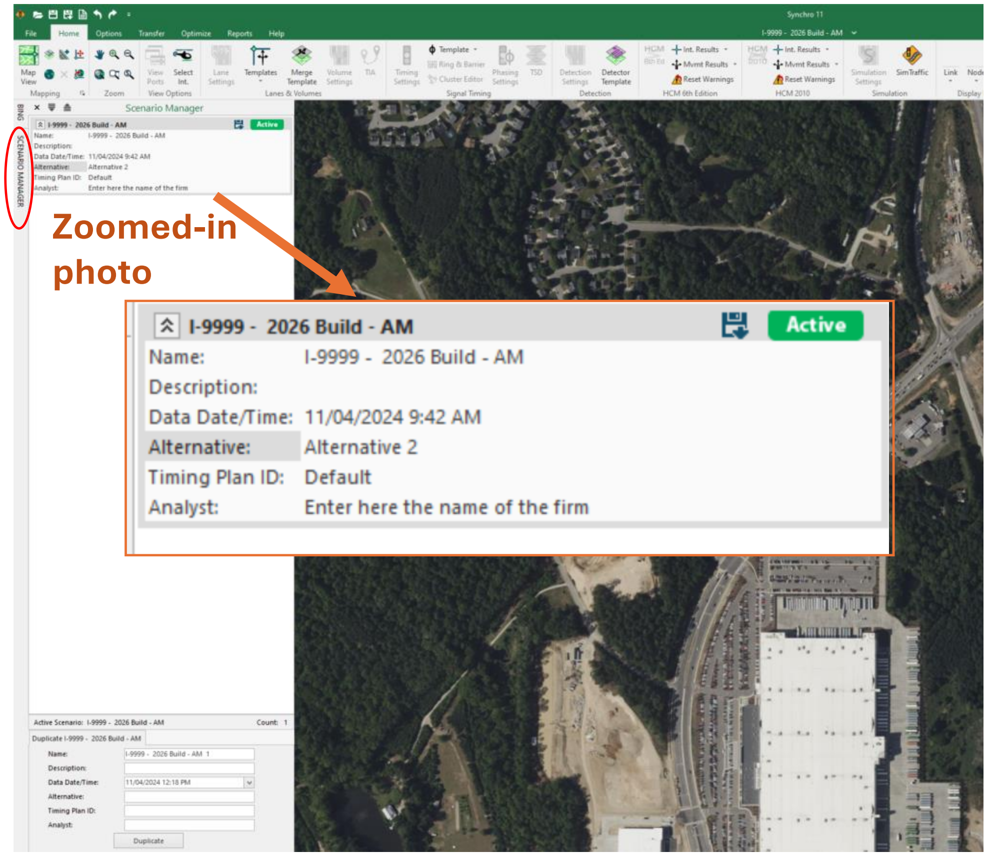
TIMING SETTINGS	NBL	NBT	NBR	SBL	SBT	SBR	NEL	NET	NER	SWL	SWT	SWR		HOLD
Lanes and Sharing (#RL)													—	—
Traffic Volume (vph)	150	120	42	52	200	85	150	42	99	62	88		—	—
Future Volume (vph)	150	120	42	52	200	85	150	42	99	62	88		—	—
Turn Type	Prot	—	—	Prot	—	—	Prot	—	—	Prot	—		—	—
Protected Phases	5	2	—	1	6	—	7	4	—	3	8			

Cardinal directions may not be feasible for atypical intersections and alternative intersection designs such as diverging diamond interchanges and continuous flow Intersections. In the case of atypical intersections and alternative designs, the project analyst should use best judgment when coding approach directions.

Scenario Manager

The Scenario Manager allows the user to track scenarios and enter project information which is shown on output reports. The Scenario Name should provide the STIP/Project Number and analysis period (year and time of day). The Alternative should be a description of the scenario being analyzed and the Analyst should provide the name of the firm performing the work. If helpful to the analyst, the Time and Timing Plan ID information may also be included.

It is important to update this information for each Synchro file to avoid confusion when output is provided. The Scenario Manager can be found in the vertical left banner of Synchro.



VOLUME DEVELOPMENT AND INPUT

Volume Development

The development of traffic volumes is one of the most important elements of an analysis project. Typically, volumes for TIA's will be developed from existing traffic counts and volumes for STIP projects will be developed from an approved traffic forecast. The following sections include Best Practices for developing project level traffic volumes.

Existing Traffic Counts

Take traffic turning movement counts at each existing intersection in the project area, which should reflect normal daily and/or peak hour traffic conditions for each individual intersection in the network. Each individual intersection in a network may exhibit different peak hours within a counted peak period (e.g., 5:00-6:00 PM and 5:15-6:15 PM within the 5:00-7:00 PM peak period) throughout the network. When submitting a traffic analysis document for review, the traffic counts used for capacity analysis purposes should have been taken no more than one year prior to the submittal date of the document. When using traffic count data to predict future year volumes an appropriate growth rate should be applied. Growth rates should be consistent with historical growth rates in the study area. Heavy vehicles and pedestrians should be included in all traffic counts and may be used in the traffic analysis.

Normally, counts should be taken during the following weekdays: Tuesday, Wednesday, or Thursday. In areas with high seasonal traffic variations, counts should be taken during peak seasonal conditions or appropriate seasonal factors should be applied to the traffic count volumes. Counts should not be taken on holidays, when school is not in session, or when a significant weather event or traffic incident occurs.

For developments near schools or for school developments, refer to MSTA guidelines to determine the existing traffic counts collection procedure.

StreetLight data cannot be used for count data. StreetLight data may be used in a similar nature as travel demand models, forecast data, AADT maps, etc. to assist with volume balancing or in certain circumstances to help estimate existing traffic volumes when traffic counts are not feasible due to temporary changes in traffic patterns (e.g, construction detours, significant weather impacts, schools being out of session). Usage of StreetLight data requires prior approval from Congestion Management Section, District and/or Local authorities.

Traffic Breakouts

Traffic forecasts for STIP projects should be completed or approved by the NCDOT Transportation Planning Division (TPD) before performing traffic analysis work. To perform the traffic volume breakouts, traffic forecasts should provide the following information:

- Annual average daily traffic volume (AADT)
- Percent of trucks (duals, TTST) on a facility
- Directional split (D)
- Percent of traffic during the peak hours K (DHV)
- The direction of D during the AM and PM peak hours

The Intersection Analysis Utility (IAU), originally developed by TPD, should be used to convert forecasted AADT to Peak Hour Volumes. IAU's are available to break out traffic forecast volumes displayed with both one-way and two-way arrows and included in the NCDOT Traffic Engineering Suite which is available at the Congestion Management Website.

If this spreadsheet is not used, justification should be provided for any alternate method chosen.

Interpolations

An interpolation spreadsheet is included in the NCDOT Traffic Engineering Suite for direct interpolation of Traffic Forecast Scenarios. The interpolation spreadsheet entitled "spreadsheet to assist in the interpolation of traffic volumes" can be found on the Congestion Management Website and can be utilized to interpolate between hourly volumes of different years. . This interpolation is based on a straight-line calculation method and used for hourly volumes. Please refer to the forecast document for information on how to properly determine intermediate year volumes.

When determining intermediate traffic year volumes, the appropriate traffic breakout spreadsheet should be applied to the Base and Future Year AADT forecasts first, and then the interpolation spreadsheet should be used.

Traffic Adjustments

The analyst should provide documentation and methodology for all traffic adjustments and rerouting. The NCDOT Traffic Engineering Suite spreadsheet is available to assist in converting a "standard" intersection traffic volume layout to layouts for unconventional intersection designs. (Examples include Reduced Conflict Intersections, quadrant designs, etc.)

Volume Balancing

Typically, a network should not need to be balanced if only minor differences exist from traffic forecast breakouts or traffic counts. In real word conditions there are typically minor intersections or driveways between intersections, which would create an imbalance. If large differences exist between intersections, it may be necessary to balance the network or add source/sink nodes to account for these imbalances. If a network is balanced, documentation regarding the balancing methodology should be provided.

Volume Settings and Inputs

Volume Settings

The volume settings tab is used to enter/edit traffic volumes and related information. Each scenario models hourly volumes for one design hour/peak period (ex. 7:00 – 8:00 AM or 5:00 – 6:00 PM). Note the absence of traffic volumes on some movements that are allowed at one or more intersections may cause Synchro to incorrectly calculate one or more movements as being prohibited. It is recommended to code zero, one, two, or three volume movements to four vehicles (minimum) per hour for allowable movements.

Heavy Vehicles

The modeling of heavy vehicles (duals and TTST's) can have substantial effects on the operations of the model. Therefore, heavy vehicle percentages should be included under the volume settings tab in Synchro. If the percentage of duals and TTST's are available from a traffic forecast, their average value should be used. For example, if an intersection leg has 3% duals and 4% TTST's, the percentage entered into Synchro would be, (3+4)/2 = 3.5, rounded up to 4 percent.

If a forecast is not available and traffic counts are, the percentage of trucks from the counts should be used.

A minimum of 2% should be used for the percentage of heavy vehicles.

Peak Hour Factor

The peak hour factor accounts for the fluctuation in traffic arrivals during the peak hour and is used to convert the hourly traffic volume into the flow rate that represents the peak fifteen minutes. The analyst should use a peak hour factor of 0.90 unless the analysis requires a specific peak hour factor that was agreed on after a coordination with MSTA/Congestion Management. If traffic counts are available, the resulting PHF should only be used for existing conditions and any future analyses should use a PHF of 0.90. In the event PHF adjustments are allowed, the adjustments should be consistent across all future analysis scenarios and consistent across all intersection movements per intersection.

If a school is in the vicinity of the project, coordination with the MSTA group is necessary to determine the appropriate peak hour factor that needs to be used.

Pedestrians and Bicycles

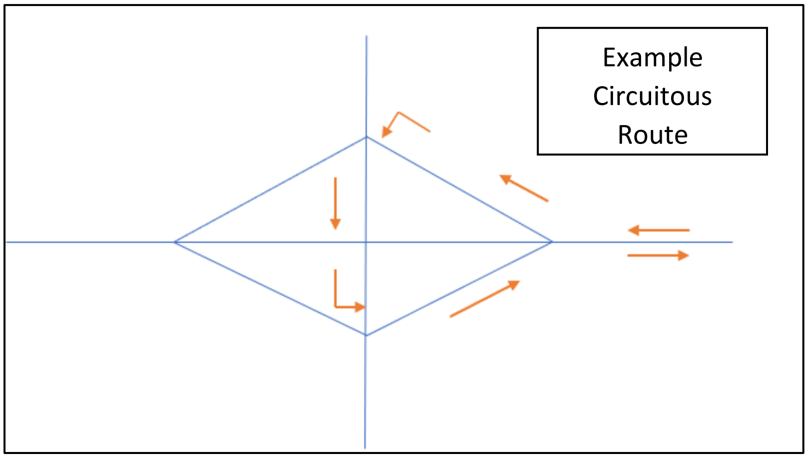
The modeling of pedestrians and bicycles at intersections can influence the operation of the model and may be included in the analysis on a project-by-project basis. Typically, this data is not included in the model unless there is a specific reason, such as in a downtown area or other area with higher pedestrian and bicycle conflicts.

If it is determined that pedestrians will be included in the model, they should be added to the network under the "volume settings" tab as conflicting pedestrians (#/hr). This value is the number of pedestrians conflicting with the right-turns and permitted left-turns (separate entries). Additionally, for a signalized intersection, the number of pedestrian calls per phase should be included under "phasing settings" tab. The number of pedestrian calls represents the number of pedestrians activating the phase, which is typically the same number as the conflicting pedestrians' number.

If it is determined that bicycles will be included in the model, they should be added to the network under the "volume settings" tab as conflicting bicycles (#/hr). This value is the number of bicycles that conflict with right-turns. Conflicts with permitted left-turns can be ignored since Synchro assumes bicycles clear during the queue clearance time for vehicles.

Link OD's (Origins/Destinations)

Synchro does not provide for complete network OD's; however, it does allow the analyst to adjust OD's between adjacent intersections. This can be helpful to prevent vehicles from making circulatory route choices, such as at interchanges or closely spaced intersections. These circulatory routes may not affect Synchro outputs; however, they may influence the simulation in SimTraffic.



The Link OD Volumes allows the analyst to adjust the OD's between the intersections to prevent these circulatory movements. The analyst should review the entire network for these movements and adjust the Link OD accordingly. Refer to the Synchro User Guide for a detailed explanation of this procedure.

VOLUME SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)												
Traffic Volume (vph)	150	42	99	62	88	99	150	120	42	52	200	85
Development Volume (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Combined Volume (vph)	150	42	99	62	88	99	150	120	42	52	200	85
Future Volume (vph)	150	42	99	62	88	99	150	120	42	52	200	85
Conflicting Peds. (#/hr)	0	—	0	0	—	0	0	—	0	0	—	0
Conflicting Bicycles (#/hr)	—	—	0	—	—	0	—	—	0	—	—	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Growth Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adjusted Flow (vph)	167	47	110	69	98	110	167	133	47	58	222	94
Heavy Vehicles (%)	2	2	2	2	2	2	2	2	2	2	2	2
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Adj. Parking Lane?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Parking Maneuvers (#/hr)	—	—	—	—	—	—	—	—	—	—	—	—
Traffic from mid-block (%)	—	0	—	—	0	—	—	0	—	—	0	—
Link OD Volumes	—	—	—	—	WB	—	—	NB	—	—	—	—
Traffic in shared lane (%)	—	—	—	—	—	—	—	—	—	—	—	—
Lane Group Flow (vph)	167	157	0	69	208	0	167	180	0	58	316	0

NETWORK CODING

Link Speed

For arterials, collectors and local roadways, the link speed should be selected based on the posted speed limit of the facility. For roadways that do not have a posted speed limit, an appropriate speed limit should be selected and documented in the model documentation. Ensure that the speed limit is uniform across a link length (unless posted speed limit indicates differently). In addition, ensure that the speed limit of each link is uniform between various scenarios for an accurate comparison between different Synchro files (unless justification is provided).

For freeway ramps, the default speed limit should be 45 mph.

For freeway loops the default speed limit should be 25 mph.

If detailed design information is available, then deviation from the default speed is acceptable, if properly documented in the model documentation.

Link Names

All roadways' links should be named for the reviewer to identify which roadways are being analyzed. Link names (i.e., Steet Name) are input in the Lane Settings tab at each intersection node so they can be included on the headings of the output reports.

Link Lengths

It is preferred that all links be a minimum of 100' to avoid simulation issues in SimTraffic. Additionally, all boundary nodes should extend a reasonable distance beyond the last intersection node (typically 1,000') to ensure adequate queuing can be calculated in SimTraffic.

Bend Nodes

Bend nodes connect two links traversing the same directions and are typically used to create lane additions/drops or to assist the analyst in visually matching the network to aerial photography. Volume data is not a required input for a bend node; however, laneage data is required input. The analyst should minimize the use of bend nodes which increase the time for SimTraffic calculations and excessive bends and short links cause SimTraffic to model vehicles at slower speeds and can result in reduced capacities.

Lane Width

Use the default width of 12 feet for all lanes being coded. On a project-by-project basis, it may be determined that the additional effort associated with coding lane widths is critical to adequately evaluate the operations and requires approval from the NCDOT Congestion Management Section. If it is determined that lane widths will be modeled, the lane widths (rounded to the nearest foot) will be coded for all roadways within the model according to their actual width.

Grades

The grade of a roadway has an impact on a vehicle's ability to accelerate and decelerate and is accounted for in the model. The effect of grades needs to be balanced against the level of effort required to obtain and add them to the model. Two potential options are available and should be determined on a project-by-project basis:

- Option 1: No Modeling of Grades – Due to minimal variations in topography or the level of analysis being completed; it is not critical to model the effect of grades on the operations. Therefore, develop the model with an elevation and grade of zero for all links.
- Option 2: Modeling of Grades – Develop the model to include the approximate grade, taken from an appropriate data source (e.g., signal plan), for each link within the model.

It is also possible that the level of detail for coding grades and elevations in the model may vary between the existing model data and the proposed design depending on the level of design. Determine the need for coding grades into models on a case-by-case basis during the scoping process.

Saturation Flow Rate

The saturation flow rate is the maximum flow through a signalized intersection if the signal were to stay green for an entire hour and the flow of traffic through the intersection were as dense as possible. The default value in Synchro is 1,900 veh/hr/ln and is typically not modified. Any variation to the default value should be done in accordance with the HCM and should be justified in the documentation.

Lane Utilization Factor

The lane utilization factor determines how the traffic volumes assigned to a lane group are distributed across each lane. Synchro automatically selects this factor based on the type of lanes input. This field can be overridden and may be justified in certain situations. One example would be dual turn lanes where one lane is used much more than the other. If this situation occurs, the lane utilization factor may be adjusted accordingly and should be done in accordance with the HCM and should be justified in the documentation. NCDOT Research Project HWY-2003-07 entitled “False Capacity for Lane Drops” presents various lane utilization factor models that can be utilized to predict lane utilization factor for lane drop at different intersection types. These models can be found in Table 18 of this study. The computational tool developed in NCHRP 3-98 can be utilized to determine the upstream and downstream auxiliary through lane length at a signalized intersection. This computational tool was developed based on NCHRP 707 that introduced the guidelines for safe and effective implementation of auxiliary through lanes at signalized intersections.

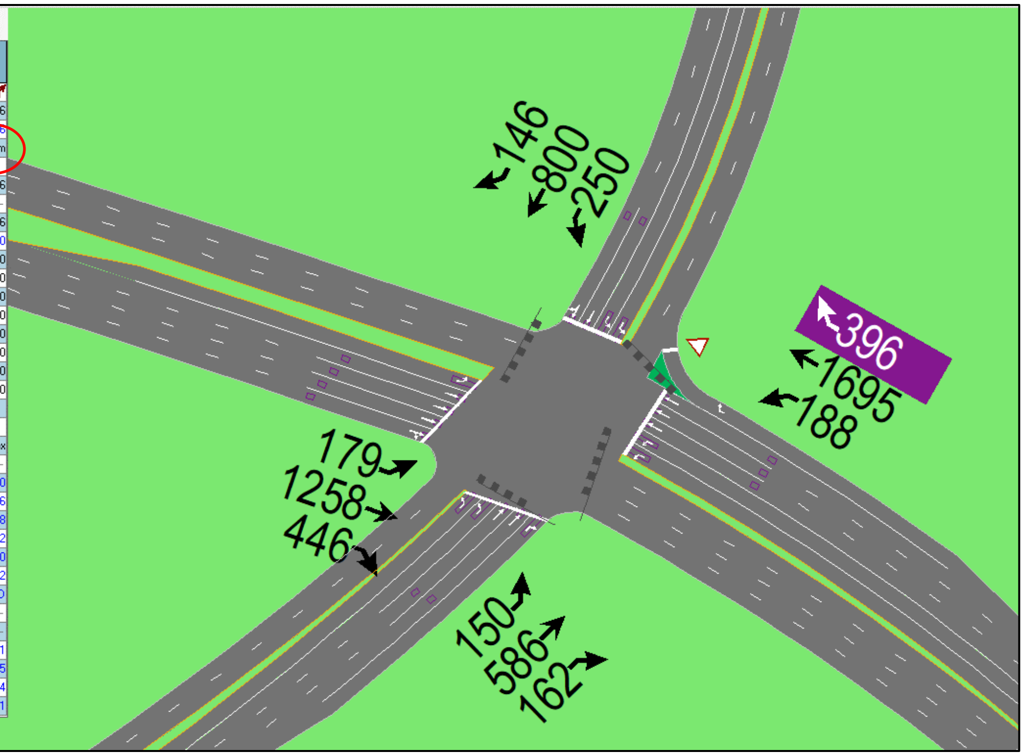
Intersection Geometric Coding

The coding of intersections in a consistent manner is a goal that will allow for the most reliable comparison of alternatives and allow for the re-use of model networks. The following sections include Best Practices that should be adhered to as much as possible when developing intersections within the model.

Channelized Movements

Model channelized right turn lanes as part of the same link as the through traffic and included in the main intersection node. Right turn movements may be coded with an overlap phase when appropriate. The latest Highway Capacity Manual adopted for use by NCDOT does not include any means of determining delay or Level of Service for yield movements; therefore, include yield-controlled right turn movements in the signal operations as a permitted phase. For yield-controlled movements, Right Turn on Red (RTOR) may be used for the right turns to emulate the yield-controlled conditions.

TIMING SETTINGS	WBL	WBT	WBR
Lanes and Sharing (#RL)			
Traffic Volume (vph)	188	1695	396
Future Volume (vph)	188	1695	396
Turn Type	Prot	—	Perm
Protected Phases	1	6	
Permitted Phases			6
Permitted Flashing Yellow	—	—	—
Detector Phases	1	6	6
Switch Phase	0	0	0
Leading Detector (ft)	20	100	20
Trailing Detector (ft)	0	0	0
Minimum Initial (s)	7.0	12.0	12.0
Minimum Split (s)	14.0	19.0	19.0
Total Split (s)	16.0	48.0	48.0
Yellow Time (s)	5.0	5.0	5.0
All-Red Time (s)	2.0	2.0	2.0
Lost Time Adjust (s)	-2.0	-2.0	-2.0
Lagging Phase?	☑	☑	☑
Allow Lead/Lag Optimize?	☑	☑	☑
Recall Mode	None	C-Max	C-Max
Speed limit (mph)	—	45	—
Actuated Effct. Green (s)	11.0	43.0	43.0
Actuated g/C Ratio	0.09	0.36	0.36
Volume to Capacity Ratio	0.67	1.03	0.78
Control Delay (s)	63.7	68.3	45.2
Queue Delay (s)	0.0	0.0	0.0
Total Delay (s)	63.7	68.3	45.2
Level of Service	E	E	D
Approach Delay (s)	—	63.9	—
Approach LOS	—	E	—
Queue Length 50th (ft)	81	~573	301
Queue Length 95th (ft)	123	#670	435
Stops (vph)	179	1519	344
Fuel Used (g/hr)	6	54	11



Right turn channelization options are available under the Lane Settings tab including control type, curb radius and lane additions. These functions are used to visually match existing field conditions and control simulation operations only.

LANE SETTINGS	WBL	WBT	WBR
Lanes and Sharing (#RL)			
Traffic Volume (vph)	188	1695	396
Future Volume (vph)	188	1695	396
Street Name	Glenwood Ave		
Link Distance (ft)	—	1062	—
Link Speed (mph)	—	45	—
Set Arterial Name and Speed	—	WB	—
Travel Time (s)	—	16.1	—
Ideal Satd. Flow (vphpl)	1900	1900	1900
Lane Width (ft)	12	12	12
Grade (%)	—	0	—
Area Type CBD	—	☐	—
Storage Length (ft)	400	—	250
Storage Lanes (#)	2	—	1
Right Turn Channelized	—	—	Yield
Curb Radius (ft)	—	—	50
Add Lanes (#)	—	—	0
Lane Utilization Factor	0.97	0.91	1.00
Right Turn Factor	1.000	1.000	0.850
Left Turn Factor (prot)	0.950	1.000	1.000
Saturated Flow Rate (prot)	3433	5085	1583
Left Turn Factor (perm)	0.950	1.000	1.000
Right Ped Bike Factor	1.000	1.000	1.000
Left Ped Factor	1.000	1.000	1.000
Saturated Flow Rate (perm)	3433	5085	1583
Right Turn on Red?	—	—	☐
Saturated Flow Rate (RTOR)	0	0	0
Link Is Hidden	—	☐	—
Hide Name in Node Title	—	☐	—

May be checked

For channelized free flow movements, the right turn can be removed from signal operations and set at free when a dedicated lane addition is included downstream.

Offset Left Turn Lanes

The modeling of offset left turns (those with the left turn separated from the adjacent through lanes to improve sight distance at the intersection) should be modeled as part of the same link as the adjacent through lanes. This methodology will likely not visually match field conditions; however, operations will be the same.

Coding of Turn Lanes

When coding turn lanes, the available storage is often a critical component of the analysis and should be modeled at a level that allows for the accurate analysis of the operations. The storage length of a turn lane should not include the taper length and should be measured from the stop bar to the beginning of the taper.

Synchro only allows one length to be entered for the storage length, which is usually an issue for dual turn lanes because they are often not the same length. In this situation, the average of the two turn lane lengths should be used.

It is important to note that if a turn lane does not include a storage length, it is assumed to be a full lane which will extend the length of the link. The storage length does not affect Synchro output results; however, it will have considerable effect on any simulation results.

Modeling Wide Medians and Two-Stage Crossing

The modeling of wide medians and two-stage crossings at unsignalized intersections can have a noticeable effect on operations and require special consideration when coding the model. If the model is coded with a two-stage crossing but the median width is not wide enough to store a truck, the truck will block through traffic until it finds a gap. Conversely, if it is coded as a single node then vehicles must find gaps in both directions of traffic before making the turn, causing the side street delay to be much higher than expected. Therefore, a balance is required to allow the model to produce realistic results.

If a roadway has a median width greater than 50 feet, it should be modeled as a two-stage crossing with nodes being located on each side of the median and a separate link representing the median refuge area between them. If the median width is 24-50 feet in width the intersection should be coded in the same manner; however, the intersections should be coded with a minimum link length of 48 feet by moving the intersection nodes out slightly to accommodate truck storage within the median link. For median widths less than 24 feet, it should be coded as a single intersection node and vehicles must clear both directions of traffic in a single movement to make a left turn.

Roundabouts

The design of a roundabout should be based on projected traffic 20 years after the completion of construction.

A flow-scale analysis determining the expected failure year of the proposed roundabout based on a maximum v/c ratio (degree of saturation) of 0.85 should be provided. A peak hour v/c ratio greater than 0.85 in the future design year does not absolutely remove a roundabout from consideration as a solution.

Analysis for roundabouts has been updated in the HCM 6th Edition. These updates have increased the capacity of roundabouts when compared to the HCM 2010. It is acceptable for single lane roundabouts to use the HCM 6th Edition for reporting roundabout MOE’s. Include roundabouts in SimTraffic outputs as well. For dual lane roundabouts, it is recommended that Sidra Intersection software package be utilized for roundabout operations.

If a dual-lane roundabout is needed for the design year, consider construction as a single-lane roundabout designed for simple expansion to a dual-lane design. The interaction between the proposed roundabout and adjacent intersections should be considered. Roundabouts should not be constructed where queues from adjacent intersections restrict the flow of vehicles leaving the roundabout.

For single-lane roundabout analysis, use a minimum 120 feet for the roundabout inscribed diameter, with 16-foot lanes, and an 88 foot inside diameter. For dual-lane roundabout analysis, use a minimum 150 feet for the roundabout inscribed diameter, with 15-foot lanes, and a 90 foot inside diameter. The speed of the roundabout should be restricted to a maximum of 25 mph. For mini roundabout analysis, consult with Congestion Management staff.

Signalized Intersection Coding

The coding of signalized intersections in Synchro requires a basic understanding of signal design and operations. The following section includes the default values and basic coding requirements for signalized intersections. More detailed coding of signalized intersections may be allowable on a project-by-project basis if they are warranted by the project scope or the nature of the improvement. Discuss deviation from the default values with the NCDOT Congestion Management Section and document, if approved. For additional guidance on the design of signalized intersections, please refer to the *NCDOT Traffic Management and Signal System Unit Design Manual*

Code all existing signalized intersections in Synchro as shown on a verified signal plan from the NCDOT or local municipality. If a signal plan is unavailable, obtain phasing and timings from a field visit or by contacting the maintaining authority for verification. NCDOT signal plans can be found at https://connect.ncdot.gov/site/tmsd/SignalPlans/Pages/default.aspx.

Timing and Phasing Settings

The coding of signalized intersections is completed by utilizing the Timing and Phasing Settings tabs. The following sections include the process for coding signalized intersections in the model.

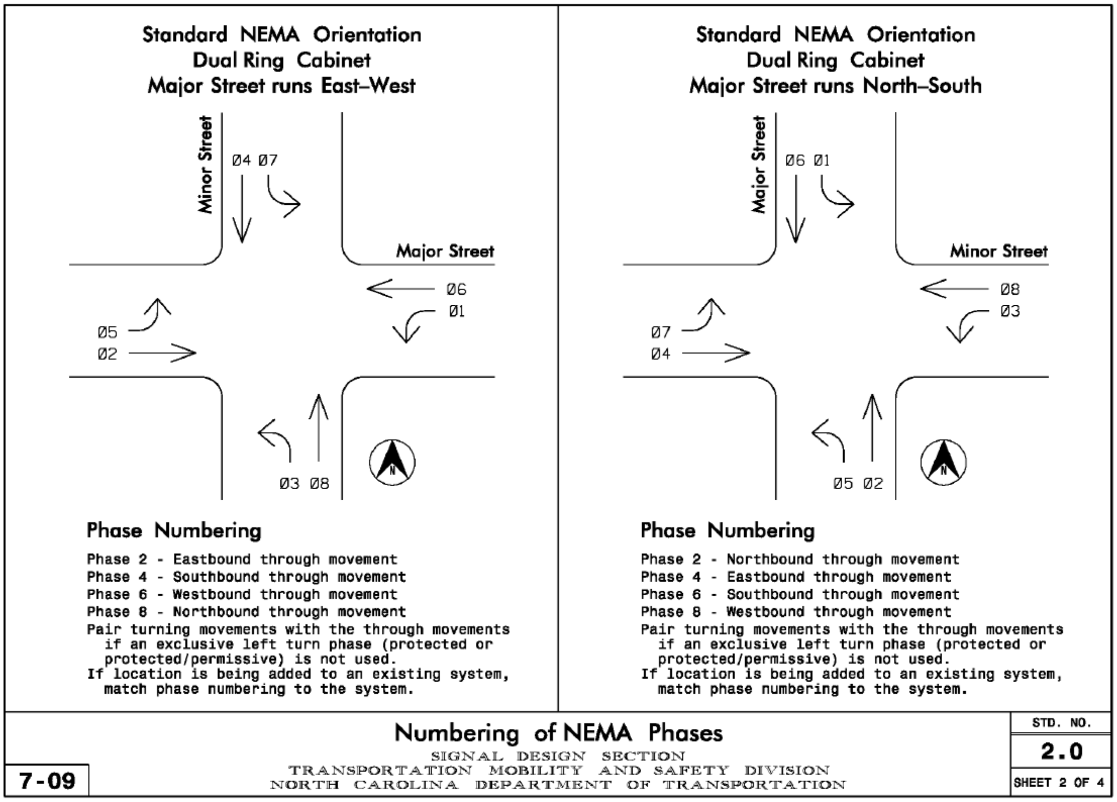
Control Type

The Control Type is a dialog box of intersection control options such as pretimed, actuated uncoordinated, semi actuated uncoordinated, actuated coordinated, unsignalized, and a roundabout. The signal plan should inform the analyst to whether the signal is actuated or semi actuated and coordinated or uncoordinated. For analyses, it is acceptable (and recommended) to assume that signals are actuated coordinated unless specific information is available. It is NCDOT standard practice for future analysis, to analyze signals as coordinated when they are within ½ mile from each other.

Phasing Settings

For any existing signals, the use of the Table of Operations and Phasing Diagram on the existing signal design plans should be utilized as a basis for determining the phasing for the signal. In the absence of an existing signal plan, engineering judgment and/or field visit observations should be utilized to determine the most appropriate phase settings.

For new or proposed signals, set the phase IDs based on the NEMA phase numbering system included in the following figure.



Turn Phasing (Turn Type)

The turn type in the timing settings tab should be set to correct states by using the drop-down list to properly define turning movements as split, permitted, protected, protected + permitted (pm+pt), Dallas Protected+ Permitted (D.P+P) with a Flashing Yellow Arrow, or overlap.

Combined lanes should not be analyzed with a right-turn overlap.

Default Timing Settings

The default timing settings in Synchro are described along with guidance on how each parameter should be implemented beyond the default settings below.

- Coordinated Phases
  - Default = No (Uncoordinated)
  - Modified to yes for any coordinated phases, typically phases 2+6
- Coordination Referenced to
  - Default = Begin of Green
- Coordination Mode
  - Default = Fixed
- Yield Point
  - Default = Single
- Minimum Initial
  - For Major Street Through Movements, based on the posted speed along the approach, with ≥50 mph = 14 seconds, 40-45 mph = 12 seconds and ≤35 mph = 10 seconds.
  - For Protected Left Turns and All Side Street Movements, 7 seconds.
- Yellow Time

    - Default = 5 seconds
- All Red Time
    - Default = 2 seconds
- Lost Time Adjust
    - Default = -2 seconds
- For actuated signals under recall, "none", "min", or "C-Max" should be specified for the main street, and "none" should be specified for minor streets or movements.
- RECALL MODES
    - Pretimed: All Phases MAX Recall
    - Actuated-Uncoordinated: Phase 2+6, use MIN Recall, all other phases use NONE (no recall)
    - Actuated-Coordinated (to Phase 2+6): Phase 2+6, use CMAX Recall, all other phases use NONE (no recall)

Pedestrian Timing Settings

If it is determined during scoping that the model will include the analysis of pedestrians at intersections, then use the following settings:

- Walk Time + Flash Don't Walk (W + FDW) is defined as:
    - W + FDW = 7 seconds + Crossing Width (ft) / 3.5 ft/sec

If it is determined that the model will not include the analysis of pedestrians at intersections, then the pedestrian phase box will be unchecked.

Lagging Phases

The Lagging Phase check box indicates if the phase in question is a lagging or leading phase. This box should only be checked if the corresponding phase is a lagging phase.

Flashing Yellow Arrow

Flashing Yellow Arrows (FYA's) have become preferred to protected + permitted (pm+pt) signals for left-turn traffic at signalized intersections. FYA's provide operational improvements and eliminate the "yellow trap" where drivers may make a left turn movement as their signal turn transitions to red assuming the opposite direction is transitioning to red at the same time.

D.Pm (Dallas Permitted) left-turn type phase type can be used to model existing permitted left-turns with flashing yellow arrow in the field.

Synchro does not provide a specific turn type for FYA's; however, Dallas Protected-Permitted (D.P+P) phasing can be utilized since phasing and operations are similar.

Reviews have shown only minimal differences in total delay when comparing D.P+P to the traditional pm+pt phasing in Synchro. The primary difference in the timing settings is that the permitted phases select the opposing through phase rather than the concurrent one, which matches controller settings. Use Dallas phasing for existing conditions where a four-section head with a FYA has been installed. If a five-section "doghouse" signal head is used, then use the traditional pm+pt phasing.

Please note that when pm+pt or D.P+P are selected, a Permitted Flashing Yellow checkbox appears in the timing settings window. This checkbox is only used if a simulation within SimTraffic is conducted. The Permitted Flashing Arrow checkbox does not affect the analysis results in Synchro.

Allow Lead/Lag Optimize

During signal optimization, Synchro can select the most efficient order of phases. If the allow lead/lag optimize box is checked, Synchro will optimize all combinations to choose the most efficient phase order (lead or lag). If this tool is utilized, avoid the "yellow trap" scenario.

Right Turn on Red (RTOR)

Do not model Right Turn on Red (RTOR) for signalized intersections in a future year analysis, except where explicitly allowed (see below). If RTOR are used in the future year, code the base year model to match for a more reliable comparison of the results. RTOR can be found under the Lane Settings tab.

The use of RTOR is permitted when coding channelized right turns with yield-controlled movements that can be modeled as part of the signal. Refer to Channelized Movements section for additional details. On a project-by-project basis, the use of RTOR for signals that currently allow RTOR and are not modified as part of the build improvements, may be allowed, if approved by the NCDOT Congestion Management Section.

U-Turn Conflicts with Overlapping Right

If U-turn volumes are nominal, then U-turn volumes can be coded as left turns. Otherwise, if the U-turn volumes are high, they must be coded as U-turn. In this case, at signalized intersections in Synchro, a conflict may exist between a protected U-turn phase and a right-turn overlap phase. It is unacceptable to retain this conflict coding in a Synchro model. The analysis should match expected field conditions. Either the U-turn must yield to the protected right-turn, or the right turns must yield to the protected U-turn. Under field conditions, if a "U-Turn Must Yield", a "U-Turn Yield to Right Turn" sign will be posted.

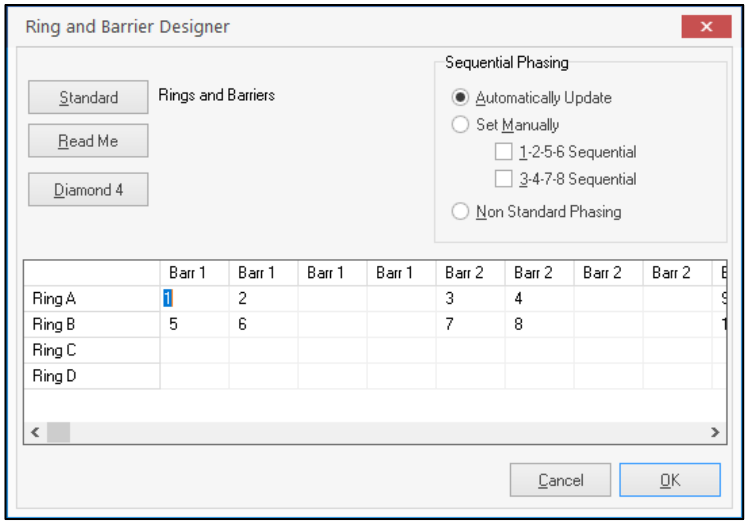
Detector Placement and Settings

Typically, the default detector placement and settings in Synchro are utilized for analyses. It is not recommended to revise the default detector phases, because if overridden the detector phases will not update if the phase numbers are changed.

Ring and Barrier

Once the phases for a traffic-actuated timing plan have been defined, a phase order and transition scheme with a ring-and-barrier table can be defined as well. The ring-and-barrier table is a common method for illustrating the phase transition logic for actuated controllers and is shown on the bottom of the Timing Settings window.

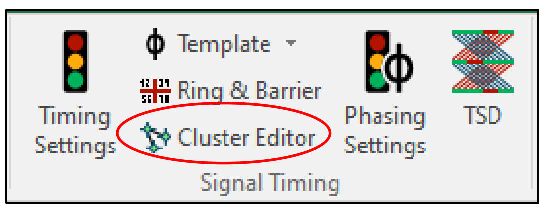
The block of phases between any two consecutive barriers is referred to as a barrier and the sequence of phases in a single row – which may span multiple barriers – is referred to as a ring. Dual ring, two-barrier designs are common; however, Synchro allows more complex designs with as many as 4 barriers and 4 rings and can be revised using the Ring and Barrier Designer tab on the main toolbar.



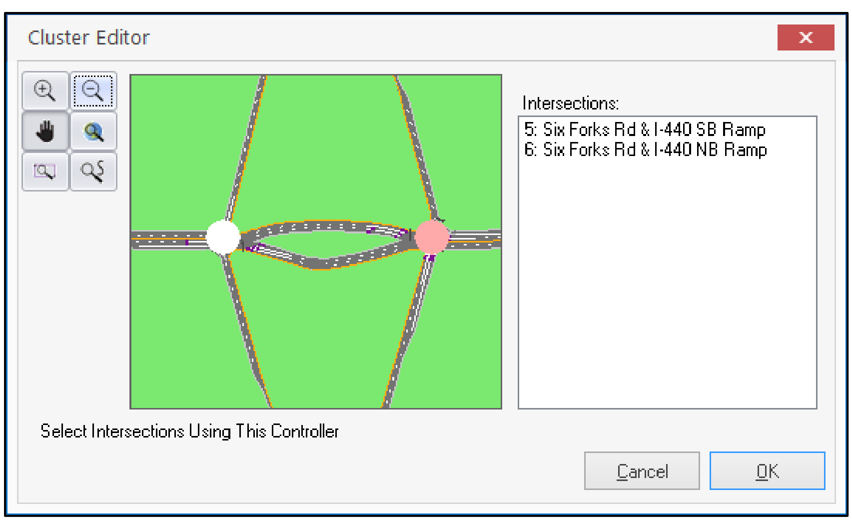
The ring and barrier for existing signals is defined based on the Phase Diagram from the existing signal design plan. For modified or new signals, the ring and barrier table is set up based on engineering judgment.

Cluster Editor

It is becoming more common, especially with alternative intersection designs, to have a single signal controller controlling multiple intersections (nodes). Synchro can group multiple nodes into a single signal controller by using the Cluster Editor tool on the main toolbar.



The Cluster Editor allows the analyst to select each node that you want grouped together on a single controller. For additional information on this, please refer to the Synchro Studio User Manual.



Signal Recommendations

Consider monitoring for signalization when peak hour warrants are met. Poor LOS on a side street does not always result in a recommendation for signalization if v/c ratios and queuing are acceptable. The following list indicates when signals are less desirable:

- Strategic Transportation Corridors
- In close proximity to other signals
- When the signal creates operational and queuing problems greater than it solves

When signals are warranted, consider every option to reduce phasing, especially on a Strategic Transportation Corridor.

General Signalized Intersection Best Practices

The phasing and timing settings for signalized intersections require the analyst to review the volumes, Synchro results, and SimTraffic simulation to determine the most appropriate signal operations.

- Signal phasing should remain consistent for all time periods. As an example, if split phasing is used for the AM peak, it must be used for the PM peak. Changing the phasing sequence, such as altering left-turn phasing from leading left to lagging left, is dependent on the traffic signal controller equipment.
- Dual left turns should be used cautiously due to:
  - Turn Conflicts requiring split phasing
  - Protected Phasing (see signal plans)
  - Driveways in close proximity to the intersection on the receiving lanes can lead to erratic movements
  - Merges on the receiving lanes can create false capacity in the analysis
- Dual right turns with one lane sharing a through movement perform poorly in overlap and RTOR conditions.
- Through movements on highway ramps should not be combined with right turns for three phase signals or standard diamond configurations. The through movement should be shared with the left-turn lanes.
- For analysis of future operations, use protected-only phasing, not protected/permitted phasing. This analysis will identify the required storage if protected-only phasing is found to be necessary in the field in future.
- Intersections with combination through/left-turn lanes should have either permitted-only left-turn treatment or split phase left-turn treatment for that approach. This is not a recommended geometric configuration and should be avoided if there is an opposing movement.
- Lane configuration for opposing side streets should match, when possible, to avoid driver confusion (for example: avoid a combination through/left-turn and right-turn lane on one approach opposite a combination through-right-turn and left-turn lane on the opposite approach).
- For analysis, generally use protected left-turn treatment instead of permitted when:
  - Dual left-turn lanes are present
  - Hourly volume exceeds 240 cars
  - Left-turn lanes are crossing 3 or more opposing through lanes of traffic
  - When a condition is satisfied in the table below:

Number of Opposing Lanes (Through and Right)	Condition
1	Left-Turn Volume * Opposing Volume > 50,000
2	Left-Turn Volume * Opposing Volume > 90,000
3 or more	Left-Turn Volume * Opposing Volume > 110,000

- Use overlapping right-turn phasing where appropriate. Use of a shared through-right turn lane limits the effectiveness of the right-turn overlap, especially where volumes require dual right turns.
- Cycle lengths for individual intersections in coordinated systems should be equal. Double or half cycles can be used if the minimum cycle lengths, defined below, are accommodated.
- It should not be the intent of capacity analysis for planning purposes of a project to fully design and optimize a coordinated traffic signal system.
- Generally, the minimum cycle lengths are shown in the table below. Deviation from these minimum values is acceptable if justified in the model documentation.

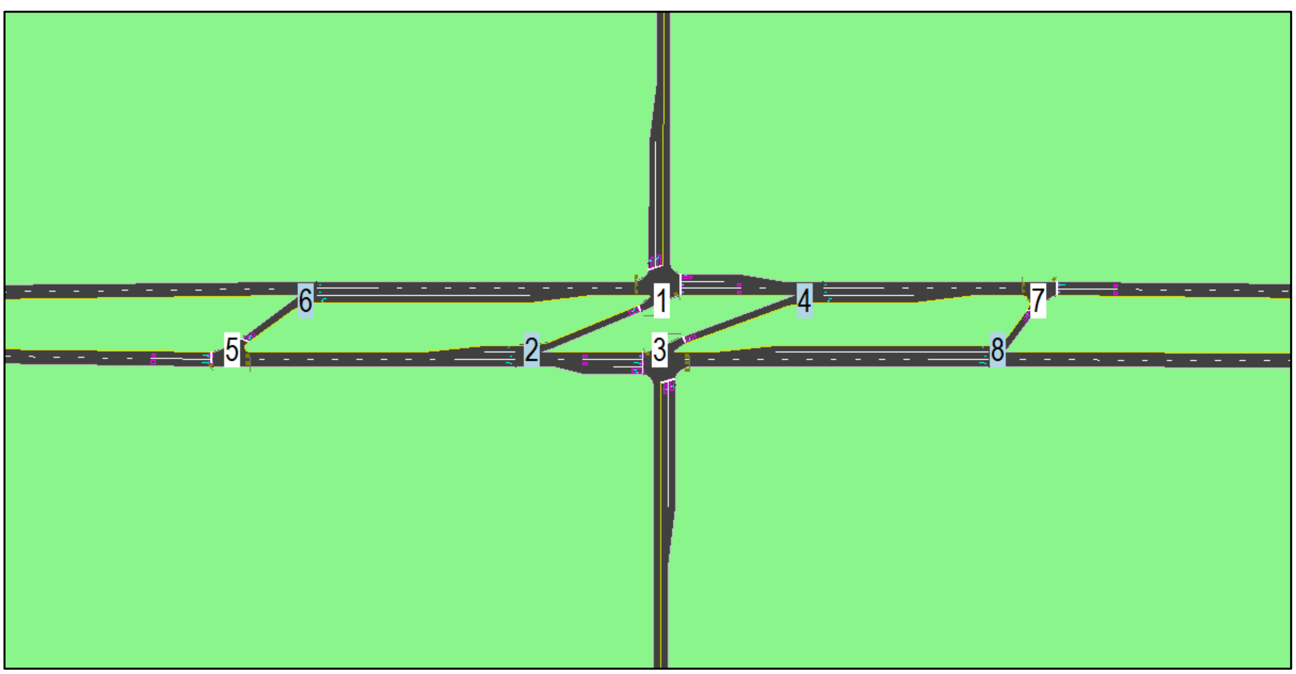
Number of NEMA Phases	Minimum Cycle Length
2	60 seconds
3	90 seconds
4 or more	120 seconds

- Generally, the maximum cycle length should not exceed 180; however, cycle lengths up to 240 seconds are acceptable if justified in the model documentation.
- Overall cycle lengths should be rounded to the nearest 5 seconds increment.

ALTERNATIVE INTERSECTION CODING

Restricted Crossing U-Turn (RCUT) Coding

The proper coding of Restricted Crossing U-Turns (RCUT's) in Synchro allows for the accurate modeling of the operations and optimization of the corridor with full one-way progression. The preferred method for coding RCUT's is to develop them as one-way links in each direction along a roadway as shown in the Synchro file below:

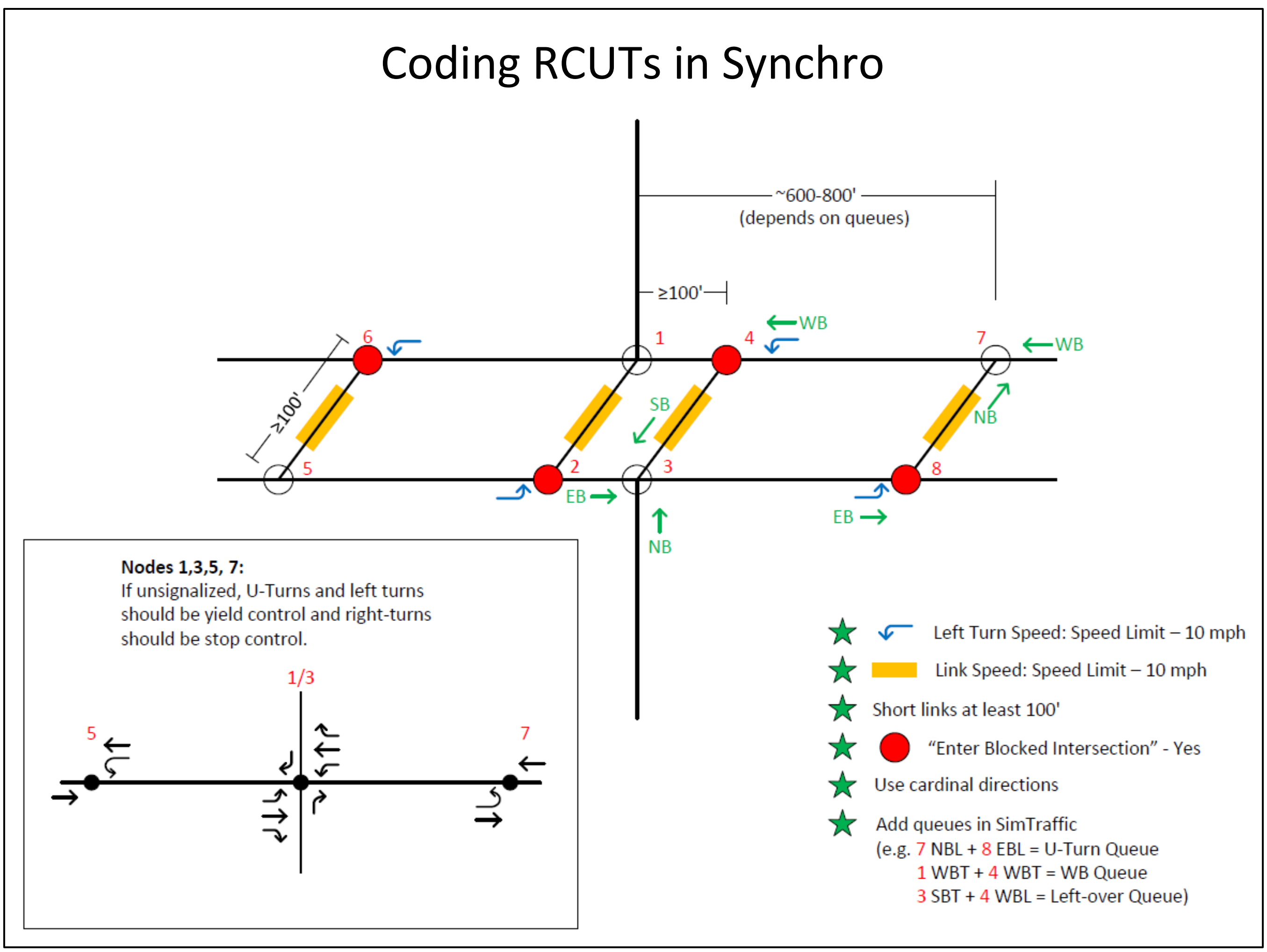


The main street should be analyzed as parallel one-way streets, rather than a single facility, because each two-phase signal impacts only one direction of traffic on the main street. U-turn crossovers should be located approximately 600-800 feet from the side street. Spacing may also be determined by the U-turn queuing.

The coding of the main intersection should be such that each direction of travel has its own node. If the main intersection includes directional left turn lanes from the mainline onto the side street, they should be coded as separate links with the link beginning approximately at the point where the monolithic island would begin. Consideration should be given to adding a segment break and short additional lane on the mainline link in advance of the left turn lane splitting from the mainline roadway to better model the transition into the left turn storage bay.

Caution should be exercised when coding RCUT intersections to ensure appropriate lane continuity.

The coding of the U-turn locations should include creating a short link between each direction of traffic with either unsignalized or signalized control at the downstream node (the odd numbered nodes in the schematic below) where the vehicles are turning. If a traffic control device is not placed on the U-turn link, it will not be possible to collect delay or LOS at the node; therefore, all U-turn nodes must have a traffic control device defined. The upstream node for the U-turn links (the even numbered nodes below) operates as a dummy node; it should have no traffic control, and the “Enter Blocked Intersection” setting should be changed to Yes under “simulation settings” tab. See the schematic below additional guidance on coding of RCUTs (Reduced Conflict Intersections).



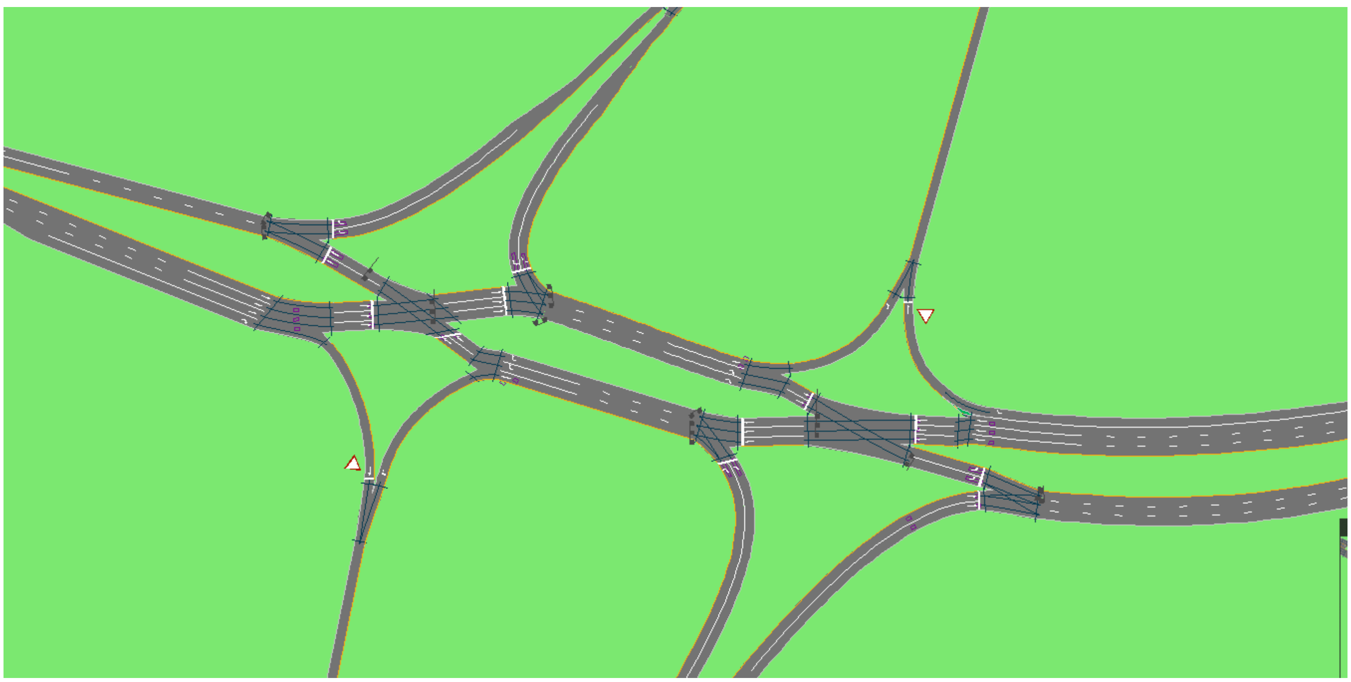
Diverging Diamond Interchange Coding

A Diverging Diamond Interchange (DDI) interchange allows two directions of traffic to temporarily cross to the left side of the road. The DDI increases access to the interstate by moving high volumes of traffic through an intersection without increasing the number of lanes and traffic signals. It should be noted, when the interchange has heavy through movements, a DDI may not be the best configuration to service the traffic demand.

DDI's should be considered at locations:

- With heavy left-turn traffic volumes onto and off the freeway ramps
- Without adjacent traffic signals or nearby driveways
- Where there is limited roadway width for left-turn lanes between ramp intersections and limited right-of-way to expand

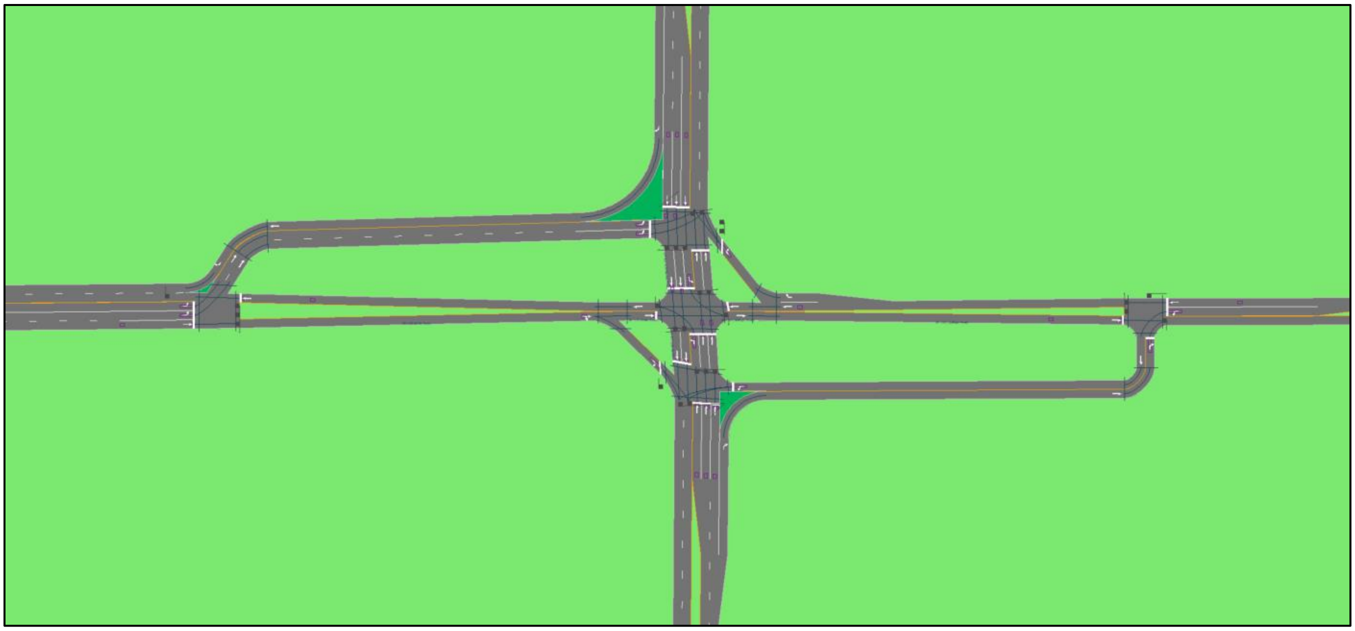
The coding of Diverging Diamond Interchanges (DDI) in Synchro allows for a high-level evaluation of the operations of the interchange. Below is a Synchro screenshot of a DDI.



Continuous Flow Intersection Coding (CFI)

A continuous flow intersection (sometimes referred to as a displaced left-turn intersection) improves traffic flow and reduces delays by allowing left turns and through movements of one or both approaches to occur at the same time. The left-turns from the main intersection are moved to cross the mainline several hundred feet upstream of the main intersection which reduces delays and improves capacity.

If displaced left turns are only used in one direction, it is recommended to use a single signal controller. If all four legs have displaced left turns, use of a single controller is still recommended but dual controllers are also allowable. Below is a Synchro screenshot of a CFI with displaced left-turns on the northbound and southbound approaches only.



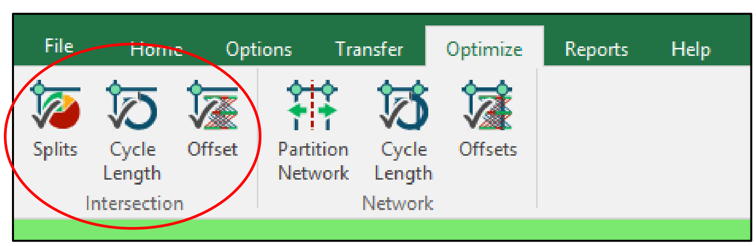
Signal phasing and timing for a CFI can be complex. As indicated in the FHWA Displaced Left Turn Informational Guide, "*the multiple signalized intersections within a [CFI] are usually coordinated so certain movements at separate intersections essentially operate during the same phase*." Ideally, timing should allow for displaced left-turning traffic and parallel through movements to "continuously flow" through the intersection without stopping or queuing on displaced left turn lane. Additional guidance on phasing for CFI is provided in the FHWA Displaced Left Turn Informational Guide.

Signal Optimization

The optimization of signalized intersections is vital to accurately model the traffic operations of both isolated signals and coordinated corridors. The optimization of signals in Synchro is completed in two different manners depending on the number of signals being analyzed, with isolated signals (those that are not coordinated with other signals in a signal system) and multi-signal corridors (those that are coordinated as part of a signal system) being optimized with separate methods.

Isolated Signal Optimization

If the signal is an isolated signal, click on the signal to be optimized and use the Intersection signal feature under the Optimize Tab to optimize either the intersection splits or cycle length.

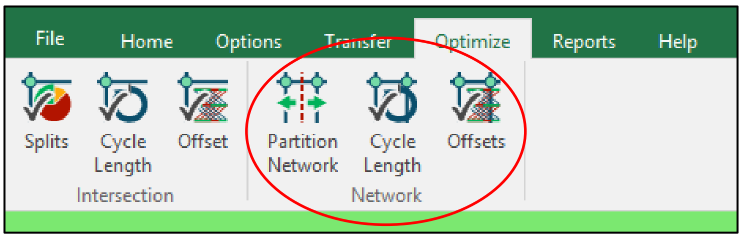


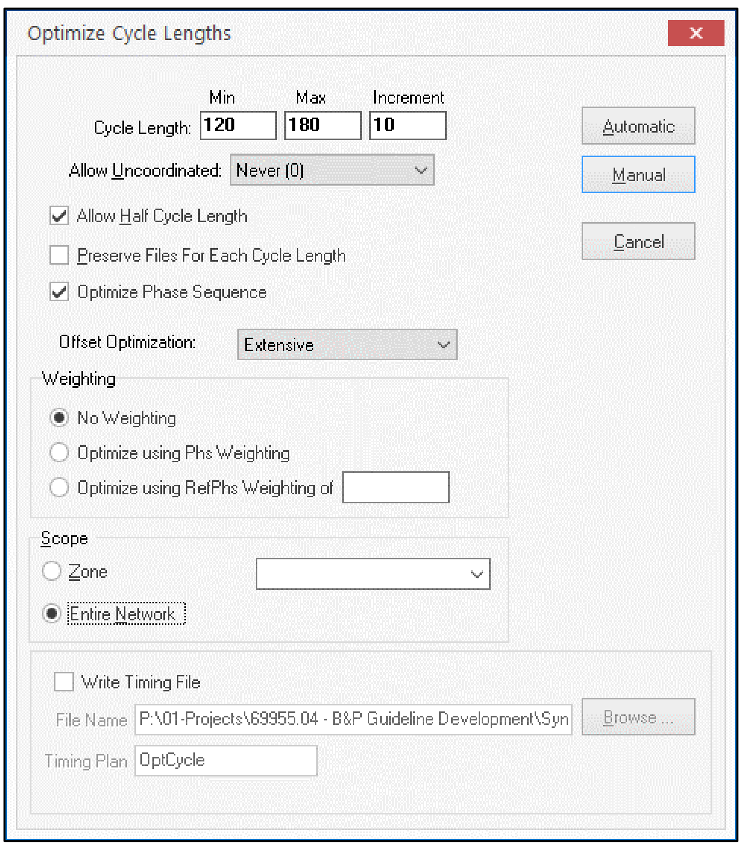
The Splits command will select the optimal split for each phase based on each lane groups volume divided by its adjusted saturation flow rate. This is a good exercise when looking to have a good and quick indication how certain laneages or cycle lengths will work for any given volume. If two or more lane groups move concurrently, the highest volume to saturation flow rate will be used to set the phase time.

The Cycle Length command will set the intersection to its natural cycle length. It is worth noting that in certain instances longer cycle lengths will provide better performance measures. When optimizing, Synchro tries to determine the shortest cycle length with acceptable performance while conforming to the recommended minimum cycle lengths stated in the NCDOT Capacity Analysis Guidelines standards and in the General Signalized Intersection Best Practices section of this document

Multi-Signal Corridor Optimization

To optimize the cycle length for multiple signalized intersections that are located along a corridor, utilize the Network signal optimization tool. This tool allows the analyst to optimize the cycle length for the entire network or a corridor by selecting a specific zone.





The following are recommendations for optimizing cycle lengths using the Network Cycle Length command box.

- Allow Uncoordinated = Never
- Allow Half Cycle Length = Checked
- Preserve Files for Each Cycle Length = Unchecked unless a specific need is identified
- Optimize Phase Sequence = Checked
- Offset Optimization = Extensive

- Weighting = No Weighting
- Scope = Set to Zone if the analyst is performing optimization of a specific corridor and that zone should then be selected in the drop down. If the entire network is to be optimized, the analyst should select Entire Network.
- Write Timing File = Unchecked, unless a specific need is identified

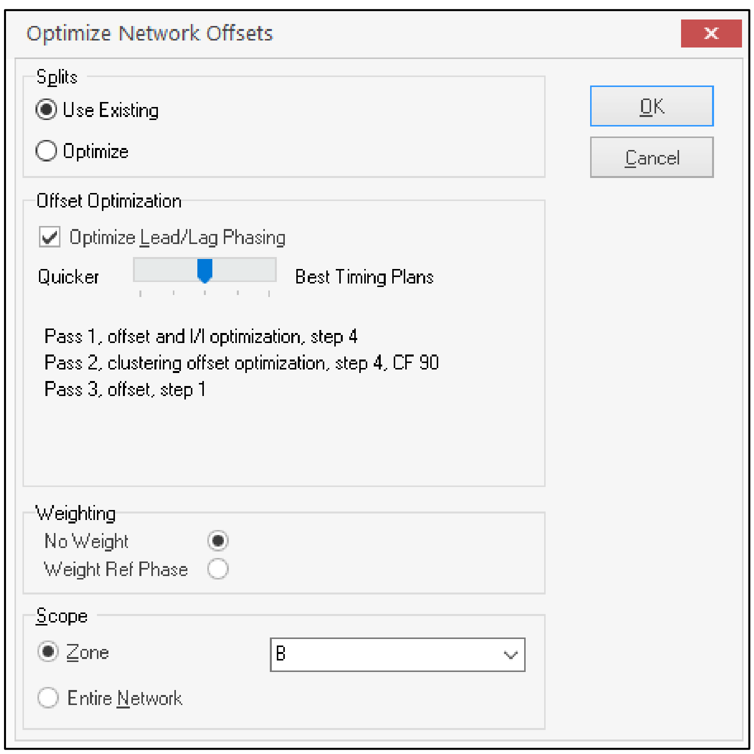
When performing the optimization, the analyst can choose between Manual or Automatic to run the optimization. The analyst should choose Automatic to let Synchro chose the best timings combination. If the analyst uses the Manual option, they must justify that in the traffic report and provide detail on the steps taken to choose the timing data used in the Synchro file.

Intersection Offset Optimization

To optimize the offset for a single intersection, the analyst should select the intersection to be optimized and then select the Intersection Offset Optimization tab. When selecting the Offset button Synchro will test all possible offsets and lead/lag optimizations to minimize delay between this intersection and its immediate neighbors.

Optimize Network Offsets

To optimize the offset for multiple signalized intersections that are located along a corridor, the analyst should select the Offset Optimization on the Network Tab. This tool allows the analyst to optimize the offset for the entire network or a corridor by selecting a specific zone. It is important to note that this step should be completed after the cycle length has been optimized. The Offset Optimization will not affect the cycle length.



The following are recommendations for optimizing offsets using the Network Offsets command box.

- Splits = Use existing should be selected (Only select Optimize if there has been a change in volume or geometry)
- Optimize Lead/Lag Phasing = Checked

- For early runs and option testing, the user may use a Quicker optimization (more in the middle of the scale as shown above) but for final analysis and results that will be reported, use the Best Timing Plan optimization.
- Weighting = No Weight
- Scope = Set to Zone if the analyst is performing offset optimization of a specific corridor and that zone should then be selected in the drop down. If the entire network is to be optimized, the analyst should select Entire Network.

Best Practices for Signal Optimization

The optimization of signalized intersections requires experience in traffic operations and basic knowledge of signal design; however, the optimization methods in Synchro should be considered a tool that assists the analyst in developing the signal timing and offsets for a given project; therefore, fine tuning may be required following the completion of the optimization task in Synchro.

The coordination of grids and other networks where major corridors intersect may require optimizing both the east-west and north-south routes separately. The best way to coordinate this type of system is to first optimize the major route that includes the coordinated phases, then each perpendicular route should be reviewed, and the cycle length set to the same (or a compatible variation of the) major corridor cycle length with each signal's splits being optimized individually.

Optimization of RCUT corridors should be done individually for each direction of travel along the corridor.

Please note that if you see a grey bar in the phasing diagram under "timing settings" tab, this means that the splits of the signal were not optimized. If this signal is in a coordinated system, please optimize the splits for this intersection, and then optimize the cycle length and offset for the entire network or zone as described in the previous sections.

SIMULATION SETTINGS

The Simulation Settings tab allows the analyst to enter SimTraffic specific parameters that will be used in the SimTraffic simulation. Changes to simulation settings will not affect the Synchro outputs but will have a considerable effect on any simulation results.

Two-Way Left Turn Lane Coding

Synchro can model two-way left turn lanes (TWLTL) under the Simulation Settings tab. The median will be colored with the pavement markings and dashed yellow lines; however, the TWLTL is for visualization purposes and has no effect on MOE's or simulation outputs. The vehicles in the simulation will only use the available storage length input in the lane settings tab.

Taper Lengths

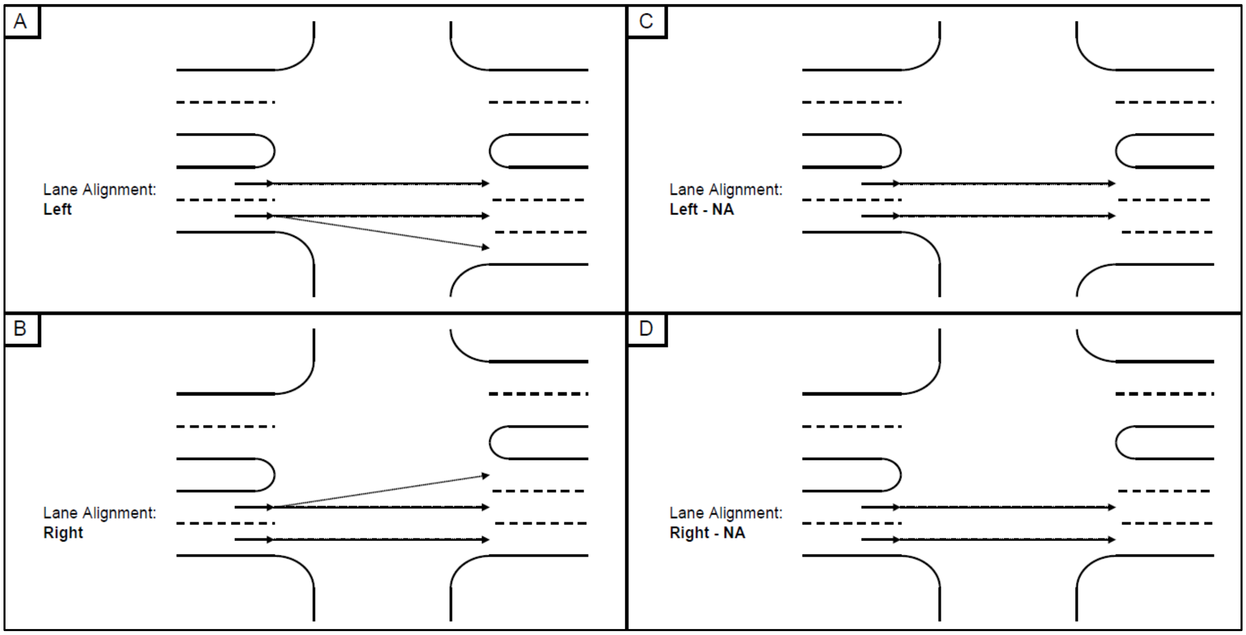
The default taper length in Synchro is 25 feet which allows a maximum of one queued vehicle to be stored in the taper. The taper length does not affect Synchro output results; however, it will have considerable effect on any simulation results. All taper lengths in the model should be set to 100 feet, which allows additional vehicles to store in the taper length.

Lane Alignment

The Lane Alignment controls how lanes align when adding a lane downstream as shown below:

A. Left
B. Right

C. L-NA (left, no add)
D. R-NA (right, no add)



Lane alignment Figure copied from the Synchro Studio User Manual Guide

Lane alignments for each movement should be reviewed to ensure they connect to the appropriate receiving lanes that are likely to be utilized under real world conditions. The Intersection Paths tool can be used to review the lane alignments and can be found on the Map Settings tool under Options tab.

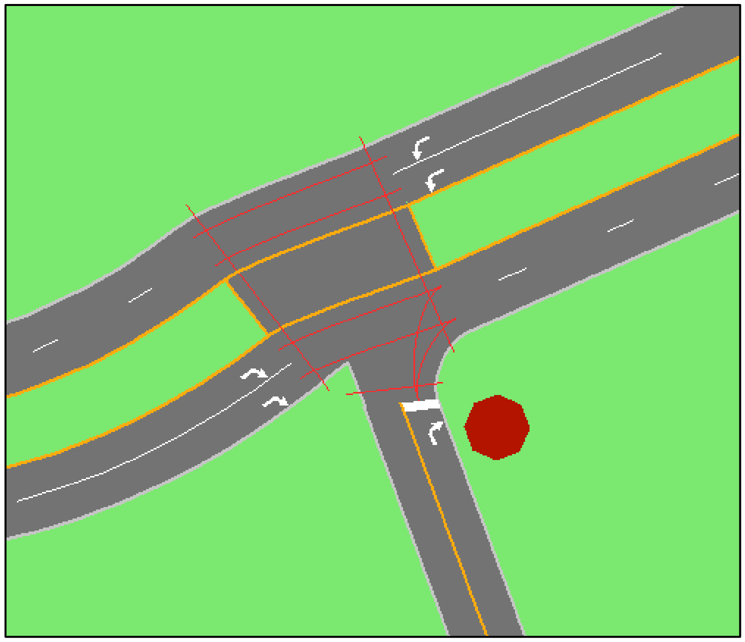
Enter Blocked Intersection

The Enter Blocked Intersection setting controls how queued vehicles perform at intersections to prevent gridlock conditions. A value of “No” does not allow vehicles to block an intersection and should be the default setting. A value of “Yes” should be entered for bend nodes, where queued vehicles will not affect the intersection.

For side streets at unsignalized intersections the value can be set to one (1) or two (2) which will allow one or two vehicles to enter the intersection. Allowing one (1) or two (2) vehicles to enter the intersection from the side street can help the capacity of driveways. There may be other cases that warrant entering a blocked intersection and should be justified in the documentation.

Turning Speed

This entry is used to define the speed at which vehicles make a turning maneuver in SimTraffic and does not affect Synchro output results. Typically, this value should not be modified; however, there are a few instances in which it is appropriate (e.g., when coding a reduced conflict intersection, or a diverging diamond interchange). In addition, sometimes a through movement is shown as turning movement due to geometric design constraints as shown below:



This issue can typically be resolved by changing the link to a cardinal direction or by shifting nodes and/or adding curvature. If this in not feasible, the turning speed for this movement should be changed to match the speed limit of the road. It is also important to note that if this occurs at an intersection instead of a bend node, the left-turn and right-turn factors along with the lane utilization factors should be modified as well.

The analyst should address any modifications to the default turning speeds in the documentation.

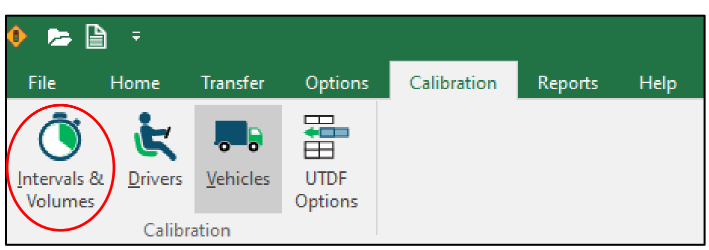
SimTraffic Simulation

As previously mentioned, SimTraffic is an accompanying software with Synchro that performs micro-simulation and animation of vehicular and pedestrian-related traffic. SimTraffic should not be used to provide performance data for freeways, multilane highways, or two-lane rural roads; therefore, use alternative methodologies for these road classes. To run a simulation, the SimTraffic button should be selected on the main toolbar, which will open SimTraffic in another window.

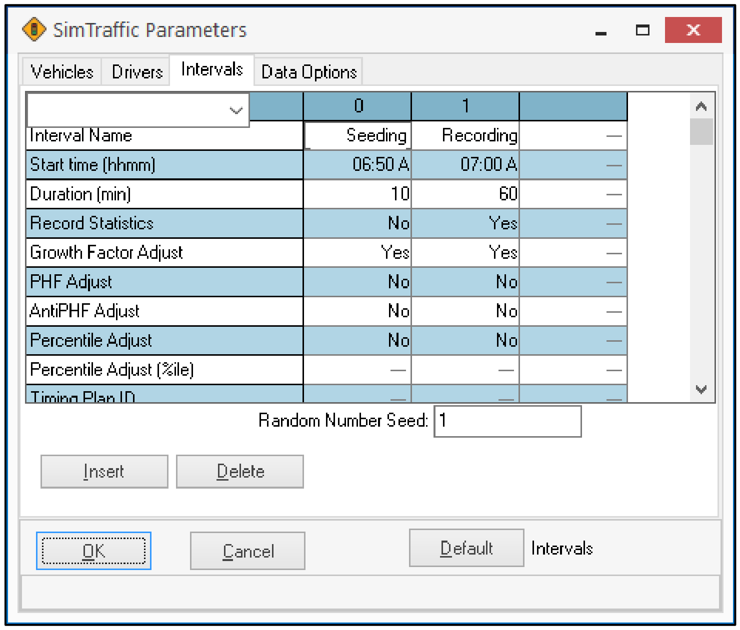
Overall network operations should be reviewed during the simulation, and any significant queuing, starvation, spillback, or gridlock should be addressed.

Intervals and Volumes

Before running a simulation in SimTraffic, the Intervals and Volumes tab should be selected under the Calibration toolbar.



The seeding duration should be set to a minimum of 10 minutes, or the time needed to traverse the corridor. The recording duration should be set to 60 minutes. The start time should be set to match the peak hour selected (i.e., 7:00 to 8:00 AM or 5:00 to 6:00 PM). This will not have any effect on the simulation results, but the hours will align for reporting purposes. Statistics should only be recorded for the analysis hour and not for the seeding period.



Random Seed

Typically, the random number seed should be set to 1; however, the random number seed may be changed, if the same seed number is consistent for all analyses on the project (i.e., Existing, No-Build, Build Alternatives).

PHF Adjust

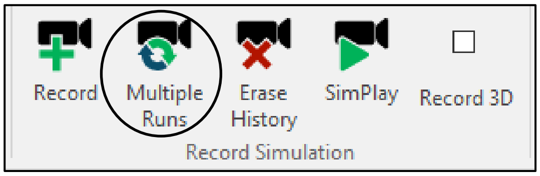
Typically, the PHF Adjust is set to "No". In certain instances, such as analyzing school operations or an area adjacent to a school, the PHF adjust may be set to "Yes". "Requirements for School Studies" included in the MSTA School Traffic Calculator should be followed.

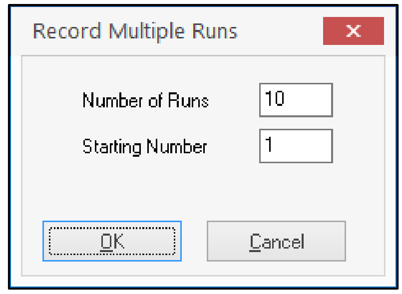
Visual Validation

In most situations, the SimTraffic default settings for driver and vehicle behaviors are adequate for planning level studies. There may be instances where the default settings do not always capture location specific operations; therefore, visual validation should be considered as a means of better replicating the real-world operations. Further refinement of the model, through varying driver and vehicle behaviors, can be undertaken to develop the model to a level where it better replicates the operations of the actual network. Any variance from the default settings should be discussed with Congestion Management before proceeding and any changes to default settings should be justified and documented.

Number of Runs

When performing simulation runs for outputs and MOEs, a minimum of ten (10) runs should be performed. This is done by selecting Multiple Runs and choosing 10 for the number of run and the Starting Number should be 1. Select Multiple runs on the main SimTraffic toolbar and then enter the number of runs and starting number in the appropriate boxes. SimTraffic will provide a summary of all intervals run; however, it is good practice to review the results of all runs to ensure there are no outliers that need to be addressed.

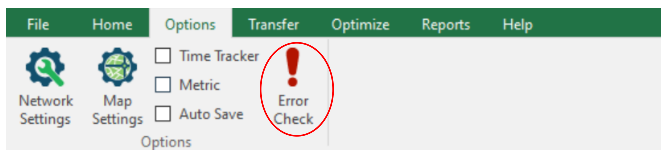




Error Checking and Quality Control

Network Error Check in Synchro

Following the development of the model and prior to running any output or submitting for review, the analyst should utilize the Error Check tool under the options tab to review the model coding. It is possible, that the error check will identify items that are not actually errors or will not influence model results. Therefore, if after running the error check, it is determined that items are identified that are not actual errors, they should be documented in the model documentation.



Quality Control

Perform Quality Control of the model prior to submittal to NCDOT. A detailed review of the model for quality control should be done by an individual with a thorough understanding of Synchro and these Guidelines. A second, independent review of the model by an individual who has expertise in traffic operations but was not involved in the development of the model is also recommended prior to running any outputs.

Output Reports

Output reports from Synchro and SimTraffic for all intersections analyzed should be included in the documentation for review. To generate output reports, the analyst should go to File and select the create report button. Report headers for each report should include the intersection number, roadway names, description of scenario and the alternative analyzed. Additionally, the footer of each report should include the date, report type and firm performing the work.

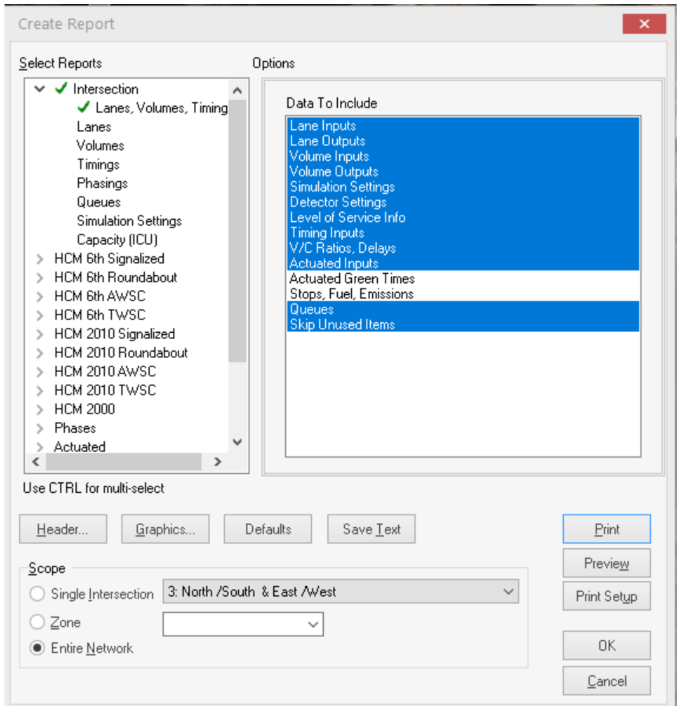
Synchro Reports

Signalized Intersections

Output reports for signalized intersections should use the Lanes, Volumes, and Timings report and include the following from the data to include list:

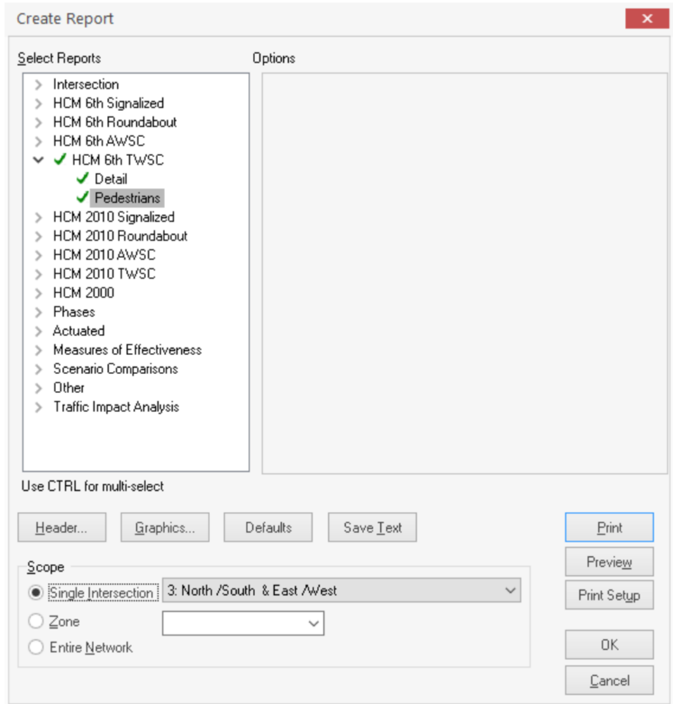
- Lane Inputs
- Lane Outputs
- Volumes Inputs
- Volume Outputs
- Simulation Settings
- Detector Settings

- Level of Service Info
- Timing Inputs
- V/C Ratios, Delays
- Actuated Inputs
- Queues
- Skip Unused Items



Unsignalized Intersections

Unsignalized intersections should use the HCM 6th Edition detailed output report when reporting MOEs for two-way or all-way stopped controlled intersections. Unsignalized intersections do not report an overall intersection level of service. In the traffic technical memorandum, the analyst should report the delay and level of service for all movements that have conflicting movements. The traffic technical memorandum should also include the 95th percentile queue for all conflicting movements. It should be noted that the HCM 6th Edition queue lengths are reported in vehicles, not feet. In this situation, the analysis should multiple the number of vehicles by 25 feet to determine the estimated queue length.



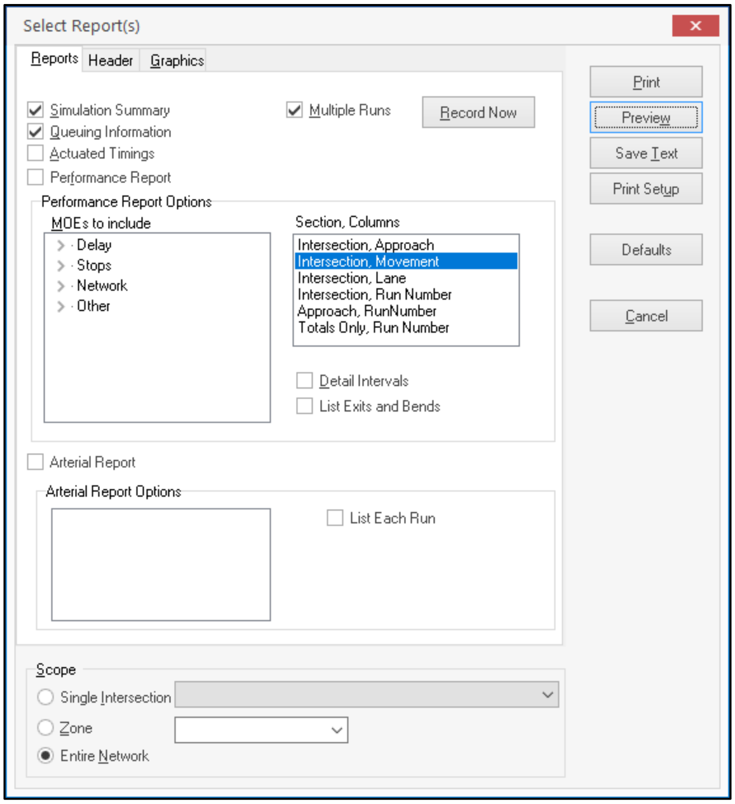
Roundabouts

As previously noted, it is acceptable for single lane roundabouts to use the HCM 6th Edition for reporting roundabout MOE's. For dual lane roundabouts, it is recommended that Sidra Intersection be utilized for roundabout MOE's.

SimTraffic Reports

A SimTraffic "Queuing and Blocking Report" should be provided for all intersections analyzed. The report should include the Simulation Summary and Queuing Information and be a summary of the 10 runs. It is recommended that before submitting any simulation outputs, they should be evaluated for reasonableness. For example, there could be outlier results that need to be explained. Outlier or unexpected results can come from multiple factors. A truck could become stuck making a turning maneuver locking down a network for example. Also turning queues may seem to be unrepresentative of the queues seen or provided by Synchro. At times, a turning vehicle may become caught in the queue for the through movement and the resulting maximum queue may be unrealistic. In this case, the geometrics may need to be modified or perhaps the 95^{th} percentile queue could be used.

Also, the analysis document must note when the maximum SimTraffic queue spills back onto the next link SimTraffic reports shows a maximum queue that only measures how long the queue is to the end of the link segment (queuing may go beyond the end of the link and this should be identified). If queuing extends beyond the length of a link, such as the entire length of a freeway ramp, the upstream block percentage should be identified.



MEASURES OF EFFECTIVENESS

Interrupted Flow Measures of Effectiveness

The evaluation of MOE's for interrupted flow facilities is primarily based on the delay, LOS and queue length at each intersection.0 When performing analyses, providing an adequate overall intersection LOS alone is not sufficient. Items such as queuing, individual movement level of service, and volume–to capacity ratio should be evaluated and addressed. Additional measures of effectiveness beyond level of service should be reported for near or over capacity conditions.

Include the data in the following sections for all intersections within the model network. Arrange the output in a reasonable manner to allow for an orderly review. In general, the network should be presented along each corridor from west to east and from south to north along the corridor. The outputs should also be labeled based on the cardinal directions (Northbound, Eastbound, Southbound and Westbound) unless there is justification for varying from this requirement.

For reporting purposes, the approaches of the intersection should be ordered beginning with the Eastbound direction and continuing as Westbound, Northbound, Southbound while movements at each intersection should be listed from left to right in the direction oriented toward the intersection (for example: EB Left, EB Through then EB Right).

Signalized Intersections

Report the control delay by intersection and control delay by lane group and their corresponding LOS for the overall intersection and each individual lane group.

For approach based and intersection wide assessments, LOS is defined solely by control delay. However, there may be individual movements (lane groups) where the v/c ratio is greater than one. If this occurs, the movement (lane group) is considered LOS F, even if the control delay is below the LOS F threshold, and this can be footnoted in the table. Further evaluation is needed at these locations and additional improvements may be necessary to achieve acceptable operations.

Analysts work for a variety of sponsors and clients who have a variety of motives. Sometimes sponsors and clients want a certain alternative to succeed (perform well in the design year) and sometimes they want a certain alternative to fail (perform poorly on the design year). However, the objective of any analyst using these Guidelines in any NCDOT context should be to provide all stakeholders with an honest assessment of the performance of an alternative under conditions that follow these Guidelines and mimic those that would occur if the alternative were to be built as closely as possible. Analysis should demonstrate an effort to provide acceptable and functional movement to all lane groups. For example, queue lengths for all movements should not exceed available storage lengths. Significant deviations in analysis input or output from those honest conditions should be approved by all major stakeholders and highlighted in any reports.

Queue Lengths

Report the queue length utilizing both the Synchro 95th percentile queue length and the maximum queue length from SimTraffic. Base all maximum queue lengths on an average of all simulation runs (minimum of ten model runs) for the one-hour peak period simulated. For the analysis of Build designs, the length of turn bays should accommodate the greater of the 95th percentile queue length from Synchro or the max queue length from SimTraffic. Storage recommendations for queue lengths should be rounded up to the nearest 25 feet with a minimum of 100 feet for both right-turn and left-turn lanes. Recommended storage lengths are considered "Variable Storage Lengths" as referenced in the NCDOT Roadway Design Manual and in the NCDOT Policy on Street and Driveway Access to North Carolina Highways, which also provides details on calculating deceleration and taper distances.

For Synchro 95th percentile queue lengths, any movement that is flagged (~, #, or m) should be reviewed in further detail and more reliance should be placed on SimTraffic outputs. A ~ indicates that the volume exceeds capacity, and the queue length could be much longer than reported. A # indicates that compound queuing may occur over multiple cycles and exceed the reported 95th percentile queue length. If the v/c ratio for the movement is less than one, then the reported queue length may be acceptable for design of storage bays. The m indicates traffic is being metered from upstream and could also indicate a volume or signal coding issue.

Queue lengths for through lanes should also be reviewed to ensure that they don't extend beyond the taper of the adjacent turn lanes. If this occurs, engineering judgment should be used to adjust storage lengths accordingly.

It should be noted that the max queue length in SimTraffic will only be reported for the length of the link or storage lane and does not account for queuing that may extend beyond adjacent nodes. This can be an issue where closely spaced intersections exist or bend nodes are present, such as DDI, RCI, or RCUT designs. The simulation should be reviewed and if queuing extends beyond an adjacent node the queue lengths should be added together to report the max queue for that lane.

Sample Signalized Intersection Performance Measure Table

Signalized Intersections											
Intersection No.	**Intersection**	**Approach**	**Lane Group**	**Delay (sec)**		**LOS**		**95th % Queue**		**Max Queue**	
				AM	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**
1	Lake Boone Trl at Wycliff Rd	**Overall**		**16.6**	**15.1**	**B**	**B**				
		Lake Boone Trl Eastbound	LT	40.3	8.8	D	A	#242	38	200	225
			TH	2.7	10.4	A	B	52	165	201	1484
		Lake Boone Trl Westbound	TH	15.3	9.6	B	A	376	156	299	133
			RT	11.7	8.8	B	A	m202	60	259	96
		Wycliff Rd Southbound	LT	44.4	38.1	D	D	84	#313	141	896
			RT	24.4	21.2	C	C	122	187	146	500

Unsignalized Intersections (Stop or Yield Controlled)

Report the Control Delay by Lane Group and their corresponding LOS for any individual lane group that has a conflicting movement.

Note there is not an overall LOS for unsignalized intersections in the HCM methodology; therefore, do not report overall Intersection Control Delay or LOS for unsignalized intersections. There is currently no methodology for determining the control delay or LOS for yield-controlled movements (except for roundabouts); therefore, for those near signals, model as part of the signal (as noted in the ***Intersection Coding*** section). For yield-controlled intersections that are not near a signalized intersection, report Queue Length for each yield-controlled approach with a note that delay and LOS are not reported for yield controlled intersections.

Sample Unsignalized Intersection Performance Measure Table

Unsignalized Intersections											
Intersection No.	**Intersection**	**Approach**	**Lane Group**	**Delay (sec)**		**LOS**		**95th % Queue**		**Max Queue**	
				AM	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**
2	Lake Boone Trl at Shopping Center Dwy/Myron Dr	Lake Boone Trl Westbound	LT	10.4	18.3	B	C	16	5	100	24
		Myron Dr Northbound	RT	10.5	12.2	B	B	6	23	56	115
		Shopping Center Dwy Southbound	RT	18.3	11.9	C	B	57	11	333	74

The analyst should review level of service and queuing outputs to determine if turn lanes are required for unsignalized intersections. An additional tool can be found on the nomograph provided in Attachment A. For school developments, contact MSTA to determine the adjustment needed for the nomograph in Attachment A – Warrant For Left and Right-Turn Lanes – Unsignalized Intersections.

Roundabouts

The HCM 6th Editions detailed report should be used for the approach/lane group LOS and delay which should be documented in the traffic technical memorandum. Queue lengths and v/c ratios should be documented and any movement with a v/c ratio greater than 0.85 should be considered for additional improvements.

TECHNICAL DOCUMENTATION

Technical documentation of traffic analysis consists of a report, with appendices as necessary, along with a listing and justification for any variance from these guidelines. In the future, a sample technical report will be provided as a go-by. In the interim, technical reports should consist of the following sections:

1. **Executive Summary** – Provide a summary of project purpose, results for each analysis scenario, and any recommendations made.
2. **Project Background** – Briefly describe the purpose of memo and project description.
3. **Description of Scenarios Analyzed** – Provide a description of each scenario analyzed.
4. **Methodology** – Describe the methodology for the capacity analysis, including the Synchro release version and build number. A brief description of any project anomalies may be included here along with whether previous Synchro models were used to develop this analysis.
5. **Measures of Effectiveness** – Provide a description of the measures of effectiveness (MOEs) selected for the project. The MOEs to be provided are detailed in these guidelines.
6. **Volume Development** – Provide a description of volume development methodology and any unconventional treatment to the development of volumes.
7. **Deviations from Default Values** – Provide a list of any default values that were modified in the analysis, including a brief justification for the deviation. Include approval of the deviations in an Appendix to the report.
8. **Base Year No-Build Analysis** – Provide a description of Base Year No-Build scenario and analysis results, including any notable concerns that arose during visual validation.
9. **Future Year No-Build Analysis** – Provide a description of Future Year No-Build scenario and analysis results, including any notable concerns that arose during visual validation.
10. **Future Year Build Analysis** – Provide a description of Future Year Build scenario and analysis results, including any notable concerns that arose during visual validation. If multiple build alternatives were analyzed, include description and results for each.
11. **Base Year Build Analysis (if applicable)** – Provide a description of Base Build scenario and analysis results, including any notable concerns that arose during visual validation. Also include illustrations of the signal timings used for each intersection in each peak period. If multiple build alternatives were analyzed, include description and results for each.
12. **Conclusions and Recommendations** – Provide a brief description of the conclusions and any recommendations developed based on the analysis results. Discuss any counterintuitive results. A recommendation diagram figure needs to be provided in the Capacity Analysis Document.

The following tables should be provided in the technical report:

1. Base Year No-Build Measures of Effectiveness
2. Future Year No-Build Measures of Effectiveness
3. Future Year Build Measures of Effectiveness (include tables for each build alternative analyzed)
4. Base Year Build Measures of Effectiveness, if applicable (include tables for each build alternative analyzed)

The following figures should be provided in the technical report or appendices of the technical report:

1. Project and Model Study Area (distinguish between the project study area limits of the analysis model)

2. Base Year No-Build Volumes
3. Base Year No-Build Laneage
4. Base Year No-Build MOEs
5. Future Year No-Build Volumes
6. Future Year No-Build Laneage
7. Future Year No-Build MOEs
8. Future Year Build Volumes (for each build alternative)
9. Future Year Build Recommended Laneage (for each build alternative)
10. Future Year Build MOEs (for each build alternative)
11. Base Year Build Volumes (if applicable)
12. Base Year Build Recommended Laneage (if applicable)
13. Base Year Build MOEs (if applicable)

SUBMITTAL REQUIREMENTS

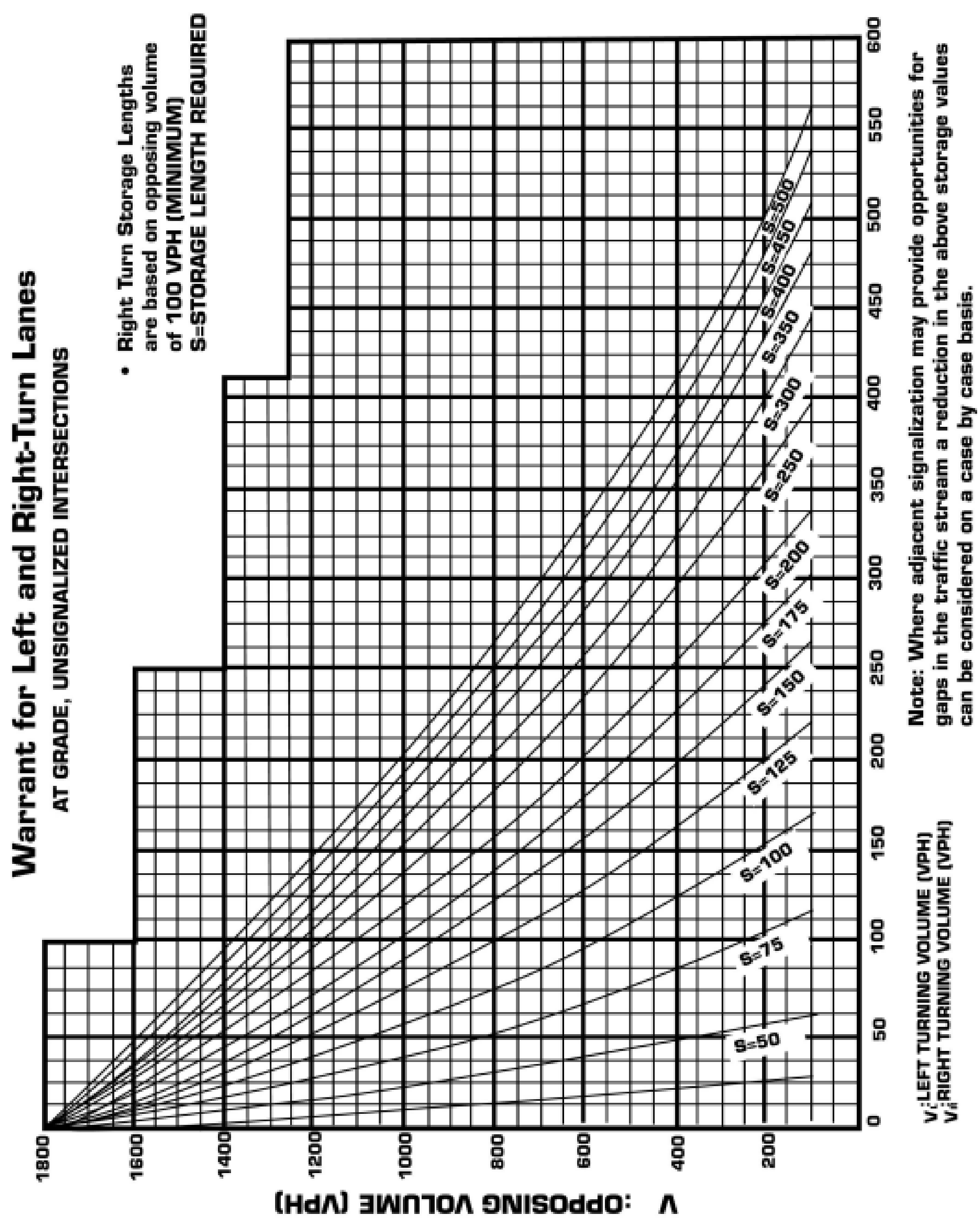
The following items should be included in a submittal package:

- Synchro models following the naming convention outlined in the ***File Naming Conventions*** section.
- MOE Spreadsheets
- Technical Documentation

For review purposes, a printable digital copy of the report/documentation submittal is preferable, although NCDOT may require hard copies as well. The number of hard copies will be determined during the scoping process of each project. For plan sheets, such as site plans, the digital submittal should be legible and to scale when printed as a 22” x 34” sheet. Use of the Portable Document Format (PDF) is preferred.

ATTACHMENT A – WARRANT FOR LEFT AND RIGHT-TURN LANES – UNSIGNALIZED INTERSECTIONS

Policy On Street And Driveway Access to North Carolina Highways



LINKS

- NCDOT Congestion Management Section website: *https://connect.ncdot.gov/resources/safety/Pages/Congestion-Management.aspx*
- NC OneMap Aerial Photography: NC OneMap
- NCDOT Functional Classification Map : *http://ncdot.maps.arcgis.com/home/webmap/viewer.html?layers=029a9a9fe26e43d687d30cd3c08b1792*
- NCDOT Congestion Management Guidelines -Standards

  https://connect.ncdot.gov/resources/safety/Congestion%20Mngmt%20and%20Signing/Standards%20-%20Capacity%20Analysis%20Guidelines.pdf
- NCDOT signal plans: https://connect.ncdot.gov/site/tmsd/SignalPlans/Pages/default.aspx.
- MSTA website: Municipal School Transportation Assistance (MSTA)
- Synchro Studio 11 – User Guide https://support.gridsmart.com/support/solutions/articles/69000541835-synchro-studio-11-user-guide