RESEARCH & DEVELOPMENT

Comparing Intersection Safety Performance using the "20-Flags" Method and Crash Data

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The 20-Flags method supplied through NCHRP Research Report 948 is a way to assess bicycle and pedestrian safety at intersections. These design flags and their thresholds were built from data ,expert input, and previous research; however the resultant outcomes in flags from using this method had not been compared to crash data to determine how well it predicted associated crash patterns. This project sought to understand corollary relationships between the flags and crashes by applying the method to 300 intersections of state roads in North Carolina and comparing the resultant red and yellow design flags to the historical crash data from 2010-2019 for each. The objective was to determine if crashes and flags generally trended in the same direction (i.e., do intersections with more flagged elements or more red flags result in higher numbers or rates of pedestrian or bicyclist crashes.) At a subset of 100 intersections, video camera footage was collected and processed to extract pedestrian crossing movement counts, bicyclist through and turning movement counts (TMCs), and motor vehicle (MV) TMCs. The 20-Flags method was re-applied using MV TMC volume for this subsample of sites to compare how the flags changed when observational volume was used in lieu of estimated proxy volumes. The pedestrian and bicycle counts were used to generate crash rates to compare with resultant flags, which was important given that sites with zero crashes may not necessarily mean they are safe sites. Analyzing the full 300-intersection set, six flags were present for at least one movement at almost every intersection, which could indicate a systemic safety concern or lack of safe pedestrian or bicyclist infrastructure at similar state owned sites. Given that red design flags indicate a safety concern while yellow flags relate more to comfort, and upon inspecting the correlations between red flags and crashes, the most frequently correlated flags to pedestrian crashes are 1 (motor vehicle right turns), 4 (crossing yield- or uncontrolled vehicle paths), and 13 (grade change) while those to bicyclist crashes are 11 (intersection driveways and side streets), and 16 (lane change across motor vehicle lane.) Summary variables, such as total number of red flags, almost always negatively correlated with crash variables, suggesting that summing the flags per intersection may be less effective in analyzing pedestrian and bicyclist safety concerns as inspecting each design flag raised individually.</td></tr>
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Executive Summary

Research Report 948: *Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges* supports the intersection control evaluation (ICE) process by offering a 20-Flags method as a sketch-level evaluation specifically to assess bicycle and pedestrian safety of a design plan (2020). This method is intended to aid transportation professionals in assessing the safety performance of different intersection designs for pedestrians and bicyclists. While the 20-Flags method was based on data, expert input, and thresholds adapted from prior research and guidance documents, resultant outcomes in flags had not been compared to crash data to determine how well the method predicted associated crash patterns. The North Carolina Department of Transportation (NCDOT) needs a way to objectively assess intersections and interchanges for pedestrian and bicyclist quality and is interested in the potential usefulness of the 20-Flags method; however, there is also concern about how well the trend in flags raised for a given intersection relates to poor safety performance based on crash evidence.

This project sought to understand the relationship between the 20-Flags method and crash data by applying the method to a sample of intersections and then comparing the resultant red and yellow design flags to the historical crash data for those intersections. The objective was to determine if the crashes and flags generally trended in the same direction – in other words, do intersections with more flagged elements result in higher numbers or rates of pedestrian and/or bicyclist crashes than those intersections with fewer flags?

Site Selection

Three hundred intersections were identified within the top 15 largest population municipalities and/or the top 15 municipalities for pedestrian and bicycle intersection crashes between 2010-2019. These sites included 4-way intersections of two state roads, including ramp terminals or alternative intersections. Within this set of 300 intersections, a subset of 100 sites were selected to collect pedestrian, bicyclist, and motor vehicle turning movement volumes via a video footage reduction process. This allowed for an assessment of the flags and their correlation to crash data on a subset of intersections for two reasons: (1) to determine if observed turning volumes are needed to more accurately reflect design flags raised or if proxy volumes based on AADTs are sufficient; and (2) to understand how flags may correlate to crash rates. This second aspect is important, given that sites with zero crashes may not necessarily mean they are safe; it may simply reflect that no one walks or bicycles there due to an intersection's design and/or the perception that they are unsafe. The 100-intersection subset of sites were selected due to their location in a Census tract with high or medium population density as a proxy estimation of walking and bicycling activity.

Each site was screened via a desktop review using Google Maps historical Street View imagery to determine if any geometric or design changes were made between the 2010-2019 study period, and the "version" of the intersection found with at least three consecutive years with no construction disruptions moved forward for evaluation using the 20-Flags method and the corresponding years of crash data.

Data Collection

Data collection consisted of two primary components: 1) a desktop review process using Google Maps or Google Earth aerial and street views to collect data needed to evaluate each site using the 20-Flags method, and 2) collecting appropriate crash data for each site. At the 100-intersection subset of sites, exposure data were also collected using video cameras and a coding process to count pedestrians,

bicyclists, and turning movements. Hourly turn volumes, vehicle turning speed, delay, and sight distance needed as inputs for the 20-Flags method were derived, estimated, or calculated based on existing data sources or standard methods (e.g., NCDOT Road Characteristics Arcs GIS file) or methods (e.g., NCHRP Report 672 method to estimate fastest path). For the 100-intersection subset, observed hourly volumes were used and the 20-Flags method was re-run for comparison.

Pedestrian and bicycle crashes that occurred between 2010-2019 were pulled from the NCPedBikeCrashes feature layer that were within the sphere of influence for each intersection. That area was defined as being within 150 ft. from the near side edge of the curb or roadway edge, or from the start of a turn bay if that distance is greater. Only crashes for the specific years associated with the correct version of the intersection were included.

Based on the guidance of NCHRP Research Report 948, each pedestrian and bicycle movement was assessed individually such that at a standard intersection 4 pedestrian crossing movements and 12 bicycle movements are evaluated under the 20-Flags method. Therefore, the exposure data collected at the 100-intersection subset was predicated on this same assumption: cameras captured pedestrians crossing at crosswalks and bicyclist left-right-thru movements through the intersection assuming they operated motorists where no dedicated bicycle facilities existed.

Flag Frequency Results

The distribution of flags (i.e., present on at least one movement) across the intersection sample was examined to determine any high-level links between design flags and safety concerns. Several flags were frequently raised, such as Yellow Flag 8 (long red times), or rarely raised, such as Flag 5 (indirect paths) and Flag 6 (executing unusual movements), which may be a reflection of the types of sites assessed. The frequency of certain flags may lack statistically significant correlations to crash data but may indicate near ubiquitous safety concerns for pedestrians and bicyclists at intersections of state roads.

The frequency of flags increased for Flag 1 (motor vehicle right turns), Flag 4 (crossing yield- or uncontrolled vehicle paths), and Flag 10 (motor vehicle left-turns) in the 100-intersection subsample when the 20-Flags method was re-done using observed turning movement volumes rather than proxy volumes, with some movements that previously were indicated as yellow flags upgraded to red flags. None of the flag frequencies went down.

Crash Correlation Results

To evaluate the correlations between the flags and pedestrian- and bicycle-involved crashes, multiple rounds of analyses were performed. These separate analyses considered the different ways to measure safety, and these were: total crashes over the analytical period, average crashes per year, and crash rates in the case of the 100-intersection subsample. All correlations were generated using the Pearson Correlation procedure PROC CORR in SAS 9.4. Only those correlations that were statistically significant at the 95% level are reported.

Ultimately, some rules were developed to streamline the analysis and to eliminate statistically significant but analytically meaningless correlations from the results, including:

- Correlations were only tested by mode based on the current framework of the design flags laid out in NCHRP Report 948. Only flags for pedestrian movements (e.g., Flags 1 through 13) were

tested for correlations to pedestrian crashes. Only flags for bicycle safety concerns (Flags 4-20) were tested for correlations to bicycle crashes.
- Separate correlations were tested for red, yellow, and the combined sum of flags. For example, in the case of Flag 4, the separate correlations for red flags, yellow flags, and red and yellow flags were all tested.
- Summary flags (e.g., total pedestrian yellow flags) were also tested for correlations, as appropriate by mode.
- While several flags related to both pedestrian and bicyclist movements, correlations were not tested for combined pedestrian and bicyclist crashes because the frequency of bicyclist crashes was too small, leading to pedestrian crashes dominating the correlations.

In general, correlations tend to be consistent regardless of using total crashes over the analytical period or average crashes per year as the crash variable of concern and between the 300-intersection sample, the 100-intersection subsample using the proxy volume data, and the subsample using the observed volume data. Correlations of crash rates to flags seemed to capture slightly different pedestrian risk in the 100-intersection subsample than either total or average crashes. While using observed turning movements may provide more accurate outputs of flagged movements, using the proxy volumes are likely sufficient to identify the key safety risks with exception of Flag (crossing yield- or uncontrolled vehicle paths).

Conclusions

From the basic summary of flag frequencies after using the 20-Flags method to process the 300 intersections, it was found that six flags were present for at least one movement at nearly every intersection:

- Flag 14 (N=299): Riding in mixed traffic
- Flag 8 (N=297): Long red times
- Flag 1 (N=296): Motor vehicle right-turns
- Flag 16 (N=296): Lane change across motor vehicle travel lane(s)
- Flag 7 (N=295): Multilane crossings
- Flag 15 (N=295): Bicycle clearance times

This may indicate the potential for systemic safety concerns for pedestrian and bicyclists at intersections similar to those studied here (e.g., where two state roads meet), or may suggest that safe infrastructure for active travelers is not present at most state-owned intersections in North Carolina. This finding does not, however, take into account historical crash data. Upon inspecting correlations between flags and total or average crashes across the 300 intersections, it was found that:

- Flag 1 (motor vehicle right turns) is positively correlated to fatal and severe pedestrian crashes.
- Flag 16 (lane change across motor vehicle lanes) is positively correlated to fatal and severe bicycle crashes.

For the 100-intersection subsample, when inspecting correlations between flags and crashes:

- Flag 4 (uncontrolled crossings) positively correlates to fatal and severe or evident average pedestrian crashes per year.
- Flag 7 (multilane crossings) positively correlates to total pedestrian crash rates.

- Flag 13 (grade change) positively correlates to fatal and severe or evident injury pedestrian crash rates.
- Flag 16 (lane change across motor vehicle lanes) positively correlates to fatal and severe injury bicyclist crash rates.

Red design flags are intended to indicate a safety concern, while yellow flags relate more to pedestrian or bicyclist comfort. Therefore, the most critical correlations may be those between crash data and red flags. Synthesizing the various analyses conducted, the most flags most frequently positively correlated to pedestrian crash variables are:

- Flag 1 (motor vehicle right turns)
- Flag 4 (crossing yield- or uncontrolled vehicle paths)
- Flag 13 (grade change)

For bicyclist crash variables, the most frequently positively correlated flags are:

- Flag 11 (intersection driveways and side streets)
- Flag 16 (lane change across motor vehicle lane)

Several flags were often found to be negatively correlated across the different analyses conducted, and others had both positive and negative correlations depending on the crash variable used or the flag color, which may mean these flags provide less utility in identifying actual crash risk or could be the result of the sites evaluated, particularly in relation to bicycle safety given that the sites had a low frequency of bicycle crashes overall.

Summary variables, such as total number of red flags, or total number of pedestrian flags, were consistently negatively correlated to crash variables across all of the analyses, with the exception of total yellow flags, which was occasionally positively correlated to pedestrian crashes. This finding suggests that summing the flags per intersection may be less effective for analyzing pedestrian and bicyclist safety concerns rather than inspecting them individually.

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1 Introduction

Historically, research on how to address bicyclist and pedestrian safety at intersections primarily focused on retrofitting existing locations through countermeasure treatments rather than providing tools to evaluate for an optimum design of a new or rebuilt location. The objective of NCHRP project 07-25 was to develop a methodology to allow the comparison of the expected safety performance of alternative intersections and interchanges (A.I.I.s) relative to conventional intersections for pedestrians and bicyclists. The resultant Research Report 948: *Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges* supports the intersection control evaluation (ICE) process by offering a 20-Flags method as a sketch-level evaluation specifically to assess bicycle and pedestrian safety of a design plan (2020). While intended to be used to compare conventional to different A.I.I. designs, the 20-Flags method can be applied to any intersection type, is easy to apply, and could be useful to screen NCDOT projects during the design process. The 20-Flags method was based on some data and expert input, but most of the thresholds were adapted from prior research and guidance documents like the Highway Capacity Manual (HCM) and the AASHTO Green Book.

Specifically, the 20-Flags method has not been compared to crash data to determine if the flags correlate with associated crash patterns. In the method, red flags directly relate to a safety concern, and yellow flags point to design aspects associated with user comfort. To build confidence in the method, research is needed to validate the work against crash data.

Project teams at NCDOT currently do not have a good way to objectively evaluate intersections and interchanges for bicyclist and pedestrian quality. Crash modification factors (CMFs) exist for some of the flags but may not directly correspond to the thresholds given in Research Report 948 or may be derived from poor-quality crash models; however, 12 design flags have no corresponding CMFs. Other indices or checklists are subjective, and microscopic simulation is too expensive to use in early stages of project development.

Given the lack of other safety screening tools readily available to assess intersection safety at the early concept development and design stage, the 20-Flags method provides a potentially useful tool for engineers and designers. To build further confidence in the method, there is a need to determine if the trend in flags raised relates to poor safety performance based on crash evidence. The authors expect that, as flags increase for a given intersection, bicycle and pedestrian crash risk increases; however, without analyzing actual crash data, it is unclear if the flags accurately predict crash outcomes. Further, this research is needed to confirm that reducing the number of elements flagged (i.e., reducing the number of flags raised for a given intersection design) will reduce the number of pedestrian or bicyclist crashes. Confirming a positive corollary relationship between the 20-Flags method and crash outcomes will build confidence in the method, and thereby open up the opportunity for NCDOT’s project planning and design teams to apply the 20-Flags method when designing intersections that are safe for bicyclist and pedestrian activity.

1.1 Research Objective

When applying the 20-Flags method to a sample of intersections and comparing the resultant yellow and red design flags raised to the historical crash data for these intersections, do the existing bicycle and pedestrian crash patterns confirm the poor safety performance measures flagged? The research team tested the hypothesis that crash data and flags will generally trend in the same direction. In other words, intersections with more elements flagged result in higher rates of bicycle and/or pedestrian crashes than intersections with fewer flags. Strictly comparing raised flags with crash numbers may be misleading, as intersections with zero crashes do not necessarily mean they are safe for bicyclists and pedestrians. Therefore, observed pedestrian and bicycling activity at a subset of intersections provides added context to the crash numbers.

1.2 Review of NCHRP Research Report 948

NCHRP Report 948 provides guidance for assessing pedestrian and bicyclist safety at alternative and conventional intersections. The project was originally focused on providing guidance for alternative intersections and interchanges only, with a specific emphasis on four intersection forms: Median U-Turn (MUT), Restricted Crossing U-Turn (RCUT), Displaced Left Turn (DLT), and Diverging Diamond Interchange (DDI). For these four intersection and interchange forms, the report provides specific design guidance and recommendations for improving multimodal safety. The report further includes an assessment method for evaluating pedestrian and bicyclist safety, referred to as the 20-Flags methods. This methodology was specifically developed to work for both the alternatives designs and conventional designs, as well as other (future) designs for intersections. The motivation for structuring the method in this way was to allow for a direct comparison of alternatives, including in an ICE analysis. The method is able to do this as it evaluates each intersection or interchange based on the pedestrian and bicyclist travel paths and evaluates the specific crossings and design elements encountered by a pedestrian or cyclist.

Chapter 4 of NCHRP Research Report 948 explains how intersections are to be assessed using the 20-Flags method. These design flags consist of two types: red flags that relate to design elements that impact safety or accessibility concerns for bicyclists or pedestrians, and yellow flags generally related to design elements that impact delay and travel time or other user comfort aspects. Flags may be specific for both pedestrian and bicyclist movements or may only relate to one of the modes. Each movement is assessed individually such that at a standard intersection 4 pedestrian crossing movements and 12 bicycle movements are evaluated. (2020)

Table 1 shows each design flag, which mode it is relevant to, how it is measured, and what the measurement thresholds are for the red and/or yellow flags. When assessing an intersection:

- 13 flags apply to pedestrian movements for a total of 52 possible flags.
- 17 flags apply to bicyclist movements for a total of 204 possible flags.

Table 1. Design Flags and Thresholds (compiled from Exhibits 4-4 through 4-76 of NCHRP Report 948)

No.	Flag Name	Description	Mode	Measure of Effectiveness	Yellow Flag Threshold	Red Flag Threshold
1	MV Right Turns	Permissive MV right-turns across ped paths	Ped	Vehicle turning speed & volume	≤ 20 mph & ≤ 50 vph	>20 mph OR >50 vph
2	Uncomfortable/Tight Walking Environment	Ped facilities of narrow width	Ped	Walkway width	<5 ft if traffic present on one side; <10 ft if traffic present on two sides	N/A
3	Nonintuitive MV Movements	MV movements arriving from an unexpected direction	Ped	Vehicle acceleration profile	Vehicle decelerating	Vehicle accelerating or free-flowing
4	Crossing Yield-Controlled or Uncontrolled Vehicle Paths	Yield or uncontrolled ped crossings	Ped & Bike	Vehicle speed & volume	≤ 20 mph & ≤ 50 vph	>20 mph OR >50 vph
5	Indirect Paths	Paths resulting in out-of-direction travel	Ped & Bike	Out of direction travel distance	90 ft (ped) 450 ft (bike)	135 ft (ped) 675 ft (bike)
6	Executing Unusual Movements	Movements that are unexpected given local context	Ped & Bike	Local expectation	Path does not match expectation	N/A
7	Multilane Crossing	Crossing distances of significant length across multiple lanes	Ped & Bike	Number of lanes without refuge	2-3 lanes (ped) 4-5 lanes (bike)	>3 lanes (ped) >5 lanes (bike)
8	Long Red Times	Excessive stopped delay at signalized crossings	Ped & Bike	Delay	30 sec	45 sec
9	Undefined Crossings at Intersections	Unmarked paths through intersections	Ped & Bike	Path markings	Unmarked crossing	N/A

10	MV Left Turns	Permissive and protected left-turns across ped and bike paths	Ped & Bike	Vehicle turning speed & volume	≤ 20 mph & ≤ 50 vph	>20 mph OR >50 vph
11	Intersecting Driveways & Side Streets	Driveways or streets within intersection area of influence	Ped & Bike	# of access points in areas of influence	1-2 (ped) 1-2 (1-way bikes)	>2 (ped) >2 (1-way bikes) >0 (2-way bikes)
12	Site Distance for Gap Acceptance Movements	Providing adequate sight distance to conflict points	Ped & Bike	Sight distance	N/A	Less than required for vehicle speed
13	Grade Change	Vertical curves adjacent to intersections	Ped & Bike	Percent grade	±3-5%	>±5%
14	Riding in Mixed Traffic	On-Street bike facilities on high-speed/volume roads	Bike	Vehicle speed & volume	25-35 mph OR 3,000-7,000 vpd	>35 mph OR >7,000 vpd
15	Bicycle Clearance Times	Bikes require longer clearance times than MVs at signals	Bike	Vehicle speed & clearance zone length (ft)	≤35 mph & 36-72 ft OR ≤35 mph & 24-60 ft	≤35 mph & ≥72 ft OR >35 mph & ≥60 ft
16	Lane Change Across MV Travel Lane	Lane changes by bikes across MV lanes	Bike	Vehicle speed & volume	25-35 mph OR 3,000-7,000 vpd	>35 mph OR >7,000 vpd
17	Bicyclist Crossing MV Channelized Travel Lane	Bike traveling in channelized lane adjacent to MVs	Bike	Vehicle speed & volume	25-35 mph OR 3,000-7,000 vpd	>35 mph OR >7,000 vpd
18	Turning MV Crossing Bike Path	Lane changes by MVs across bike facility	Bike	MV lane configuration	Exclusive turn lane	Shared thru & turn lane
19	Riding Between Lanes	Bike lanes with MV lanes on both sides	Bike	MV lane configuration	MV lanes remain parallel or diverge	MV lanes merge

20	Off-Tracking Trucks in Multi-Lane Curves	The tendency of trucks to swing into bike lanes while turning	Bike	Turn Angle	Curve ≤ 60°	Curve > 60°

Note: MV = Motor Vehicle; Ped = Pedestrian; Bike = Bicycle; mph = miles per hour; vph = vehicles per hour; vpd = vehicles per day; ft = feet

2 Methodology

2.1 Site Selection

The scope for this project called for analyzing 300 intersections in North Carolina using the 20-Flags methodology. Several criteria were compiled to determine which intersections to include in the study. Since the aim was to correlate a 20-Flags index with pedestrian and bicycle crashes, which are relatively rare events, intersections needed to have adequate pedestrian and bicycle activity and thus the potential for these crashes. Therefore, the first step was to identify target municipalities in North Carolina based on two criteria:

- The top 20 largest municipalities based on 2019 population.
- The top 20 municipalities for pedestrians and bicycle intersection crashes between 2010-2019.

This resulted in identifying 23 municipalities. Within these jurisdictions, specific intersections were identified that were 4-way intersections of two state roads, including ramp terminals, or alternative intersections, resulting in 356 candidate sites for potential study (see Table 1).

After reviewing the candidate list of sites, the NCDOT steering and implementation committee requested that we include 38 specific intersections that they felt would have higher pedestrian and bicyclist activity. In order to include these, Wilson, New Bern, Hickory, Kinston, Apex, and Huntersville sites were removed from the list, resulting in a list that represented the top 15 cities based on population size and/or crash counts.

Within this list, the research team selected a subset of 100 intersections where observed volume data of pedestrians, bicyclists, and motor vehicle turning movements was collected through video camera footage. Having observed volume data is useful particularly at locations where there may be no crashes to determine if there are none because people are not walking or bicycling there. This subset was selected by categorizing the sites by high (4,179 – 8,660 people per square mile), medium (1,567 – 4,178 people per square mile) and low (44 – 1,567 people per square mile) population density based on the population density in the Census tract within which each intersection is located. The population density categories were selected based on the Geometrical Interval method using ArcGIS. It was assumed that more people would be walking and bicycling in areas with higher population density, and thus, all the "high" (42 intersections) and "medium" (58 intersections) sites were selected for a total of 100 sites. This subset was relatively representative of the larger set of 356 intersections based on the maximum number of lanes of any leg, highest AADT of any leg, sum of the AADT of both intersecting roads, and the geographic distributions of each intersection.

Table 2. Top 20 municipalities in North Carolina with the highest pedestrian and bicycle crashes and/or largest population.

City	Population (2019)	Number of Pedestrian and Bicyclist Crashes (2010-2019)	Number of Candidate Intersections	NCDOT Added (+) or Removed (-) Intersections
Charlotte	863,985	2,552	38	11
Raleigh	471,745	1,493	45	8
Greensboro	293,726	835	7	5
Durham	269,339	820	41	5
Wilmington	122,891	556	23	
Fayetteville	208,878	429	20	
Asheville	93,413	396	11	3
Winston-Salem	244,737	331	11	3
Greenville	92,105	258	14	
High Point	113,446	196	15	
Cary	167,223	194	18	
Chapel Hill	63,634	187	5	3
Gastonia	76,930	187	21	
Rocky Mount	54,916	133	15	
Burlington	54,147	109	12	
Wilson	49,384	108	14	-14
New Bern	*30,010**	90	4	-4
Hickory	*41,407**	88	8	-8
Kinston	*20,154**	87	2	-2
Jacksonville	80,328	*85**	7	
Concord	95,453	*72**	15	
Apex	61,212	*47**	2	-2
Huntersville	62,582	*45**	8	-8

*Population or crash count is outside of top 15 for its category.

The research team further screened each site to determine if any geometric or design changes were made between the study period of 2010-2019. Sites were ultimately dropped if there was not at least three (3) consecutive years of the intersection without construction disruptions. Analysts used Google Maps historical Street View imagery to assess for any construction changes within the study period such as addition or removal of lanes, addition or removal of channelized turns, addition of sidewalk, etc. Given these are snapshot images, and the actual construction periods were unknown, the year(s) in which changes were observed was dropped as a possible study year(s) for a given intersection. The before and after conditions were compared and the longer period was used for evaluation. For example, if a site was observed with no bicycle lanes between 2010-2015 and then bicycle lanes were observed in a historical Street View image in June of 2016, then two different versions of the intersection were possible to evaluate further: the 2010-2015 version without bicycle lanes, or the 2017-2019 version with bicycle lanes. Since the before version includes 7 years and the after version includes 3 years, the before version of the intersection and its characteristics was used for the 20-Flags assessment along with the corresponding crash data from those same years. The 300 sites with the most years of data eligible to use were selected for data collection as described below.

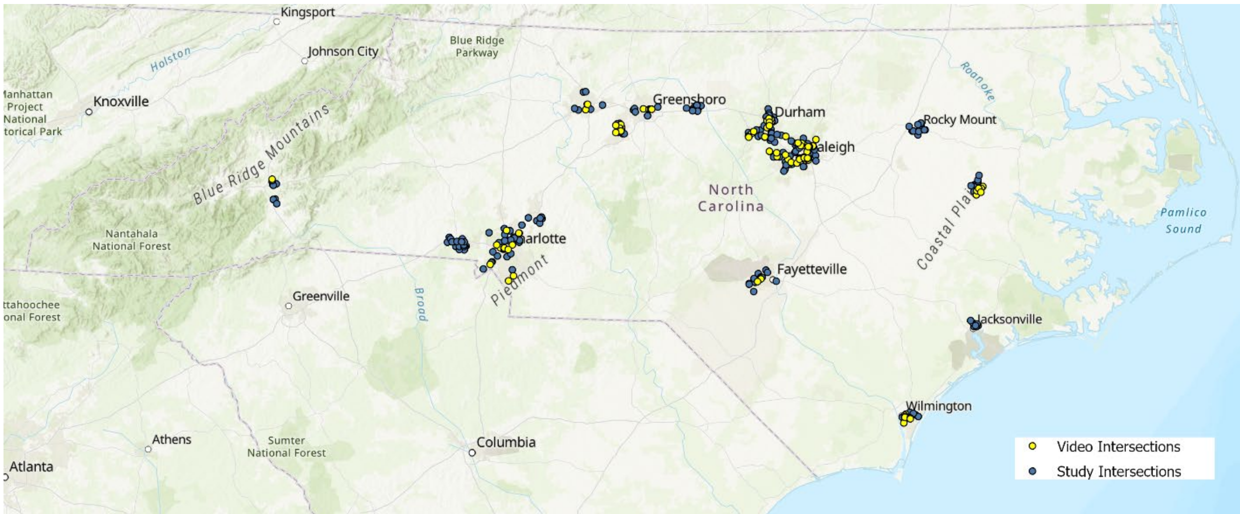


Figure 1. Map showing the locations of the study intersections with the subset of video intersections.

The sites that were ultimately evaluated varied in terms of numbers of crashes, AADTs, number of lanes, posted speed limits, and other characteristics that were used as data inputs for running each through the 20-Flags method. Across the 300 sites:

- 23 are alternative intersection or interchanges (3 RCUT, 1 Roundabout, 4 SPUI).
- 3 are unsignalized.
- 67 include a channelized turn lane.
- The maximum AADT for either street by site ranges from 3,600 to 66,000 vehicles per day with an average of 24,921.
- The maximum lane count for any approach by site ranges from 2 to 11 lanes, with an average of 5.6.
- The number of relevant years of crash data used by site ranged from 3 to 10 years, with an average of 9.58.
- The total number of crashes ranged from 0 to 27 by site, with an average of 3 crashes. (71 sites had 0 crashes.)
- The total number of red flags ranged from 6 to 76 by site, with an average of 48.99.
- The total number of yellow flags ranged from 16 to 70, with an average of 35.54.

Figure 1 is a map of where the intersections are located across NC; Appendix 7.1 contains the full list of intersections and those indicated for exposure data collection.

2.2 Data Collection

Data collection consisted of two primary components: 1) a desktop review process using Google Maps or Google Earth aerial and street views to collect data needed to evaluate each site using the 20-Flags method, and 2) collecting appropriate crash data for each site. At a subset of sites, exposure data were also collected using video cameras and a coding process to count pedestrians, bicyclists, and turning movements. Each of these efforts are described further below.

2.2.1 20-Flags Data Collection

For each intersection at each identified time period, desktop data was collected as needed to apply the 20-Flags method. Google Earth and Google Street View were used as outlined in Table 3. For observations, the intersection area of influence was considered 150 ft from the near side edge of the curb or edge of the roadway or from the start of a turn bay if that distance is greater.

Table 3. Means of Collection for Data Needed for 20 Flags Method

Data Type	Impacted Flag(s)	Means of Collection
Posted Speed Limit + 5 mi/hr	14, 15, 16, 17	Desktop observation
Hourly turn volumes	1, 4, 10, 14, 16	Derived from NCDOT Road Characteristics Arcs GIS file
Sidewalk width	2	Desktop measurement
Vehicle acceleration profile	3	Desktop observation
Vehicle turning speed	1, 4, 10	Estimated fastest path using NCHRP Report 672 method
Extra distance traveled	5	Desktop measurement
Vehicle movement direction	6	Desktop observation
Lane count	7	Desktop measurement
Delay	8	Derived from NCHRP Report 948 equation
Crosswalk and bike lane markings	9	Desktop observation
Driveway count	11	Desktop measurement
Sight distance	12	Desktop measurement & AASHTO Greenbook
Grade	13	Desktop measurement
Clearance zone length	15	Desktop measurement
Channelization length	17	Desktop measurement
Motor vehicle lane configuration	18, 19	Desktop observation
Turn angle	20	Desktop measurement

Before beginning, data collectors defined the assumed pedestrian and bicycle paths to be used in the analysis. Generally, pedestrians were expected to move from one quadrant directly to an adjacent quadrant. For no intersections did signage prohibit such a movement. For bicycles, it was assumed that riders would use the facilities provided. Therefore, movements were assumed to be made in the same manner as a motor vehicle unless a shared use path, bicycle cut through at a median, or two-stage bicycle box were provided.

To facilitate the data collection process, the team built a data collection tool. The tool presents the analyst with a series of questions to gather the required input data for the 20-Flags method in a consistent manner. The tool was then used to populate a database with all input data for all intersections that could be used to process the 20-Flag outcomes. The data collection tool was designed to make the data entry process intuitive and consistent, and provided opportunities for quality control testing of the data. The team conducted several internal training sessions to make sure that data collectors were trained both in the 20-Flagd method and in the use of the tool. Analysts beta-tested the data entry tool and helped develop the training process. Once the process was established, new analysts were trained on three “test” intersections 7, 319, and 344. Analysts created a running list of questions and answers and other notes to ensure consistency in how they used the data entry tool.

For some data types, assumptions were made as stated below.

Vehicle Speeds

The 20-Flags method uses two types of speed data for entry. For some of the flags, the posted speed limit is used as a proxy measure for vehicle (through) speeds. The proxy speed was estimated by adding 5 mi/h to the posted speed limit obtained through desktop observation using Google Street View. This measure applies to Flags 14, 15, 16, and 17.

For other flags, the vehicle turning speed in approach of a crosswalk is needed, which has been linked to driver yielding behavior and safety outcomes. Vehicle turning speeds were estimated using the fastest path method from NCHRP Report 672, which uses the same speed-radius relationship that is given in the AASHTO Policy on Geometric Design of Highways and Streets (Green Book). The radius of the fastest path was measured in Google Earth and Equation 6.1 of NCHRP Report 672 was used to convert the radius to a speed. The turning speeds are needed for Flags 1 and 10 (right and left turns), but also frequently applies to Flag 4 (crossing a yield-controlled movement). For cases where the yield-controlled movement in Flag 4 is on a straight approach (as opposed to a curve/turn), the posted speed limit is used to approximate speeds.

Hourly Turn Volumes

Two methods were used to collect turning volumes. For all intersections, AADT were gathered from NCDOT’s AADT Mapping Application. From those values, it was assumed that the directionality factor was 0.5 and the daily right turn and left turn volumes were each 20% of the approach volume. To generate the hourly turn volumes, it was assumed the peak hour had 9% of the daily turn volume.

For the subset of 100 intersections where exposure data was collected (see section 2.2.3), the observed volume data were used for a comparative analysis of flags.

Vehicle Acceleration Profile

Vehicle Acceleration profile was observed in Google Earth. If the pedestrian or bicycle crossing was located upstream of the midpoint of a curve, the acceleration profile was assumed to be decelerating. If the crossing was located on a tangent section, the vehicle was assumed to be free-flowing or accelerating. A distinction between the two was not necessary as Flag 3 categorizes both as red.

Clearance Zone Length

The clearance zone length was measured per NCDOT Signal Timing Manual (July 2021) standard number 5.2.2.

Sight Distance

The Stopping Sight Distance was calculated as below:

$$SSD = 1.47ut + 1.075 * \frac{u^2}{a}$$

Where:
u = the speed (assumed as speed limit) in miles per hour

t = perception reaction time (assumed to be 2.5 seconds)
a = deceleration rate (assumed to be 11.2 feet per second squared)

Delay

Pedestrian and bicycle delay were estimated using the method provided in NCHRP Report 948, Section 4.4.8. Cycle lengths were gathered for each intersection either through signal timing sheets or from email interviews with city staff responsible for signal timing in the respective jurisdiction. The AM, PM, and weekday mid-day were collected for most intersections. In some cases, only the peak hour cycle length was provided. The maximum cycle length collected was used for analysis. The red time was calculated using Exhibit 4-34 of Report 948. The number of critical phases were assumed as shown in Table 4.

Table 4. Assumed Number of Critical Phases by Intersection Form

Intersection Form	Assumed Number of Critical Phases
Conventional 3 Leg	3
Conventional 4 Leg	4
Single Point Interchange	3
Diverging Diamond Interchange	3
Restricted Crossing U-Turn	2
Median U-Turn	2

Lane Count

To determine the number of lanes crossed without refuge by a left-turning bicycle, the number of lanes on the approach immediately adjacent clockwise to the bicycle's approach lane was added to the number of lanes on the approach directly opposite the bicycle's approach lane. (See Figure 2.) If a two-stage bicycle box was used, the number of approach lanes immediately adjacent clockwise to the bicycle's approach lane was added to the number of approach lanes immediately adjacent counterclockwise to the bicycle's approach lane. This was compared to the number of approach lanes for the bicycle's approach plus the number of approach lanes directly opposite the bicycle's approach lane. The larger of the two values was used. For example, for a bicycle making a northbound-to-westbound left turn without a two-stage left turn box, the eastbound and southbound approach lane count would be added together. If a two-stage box was provided, the eastbound and westbound approach lane count would be added together and compared to the combined northbound and southbound approach lane count.

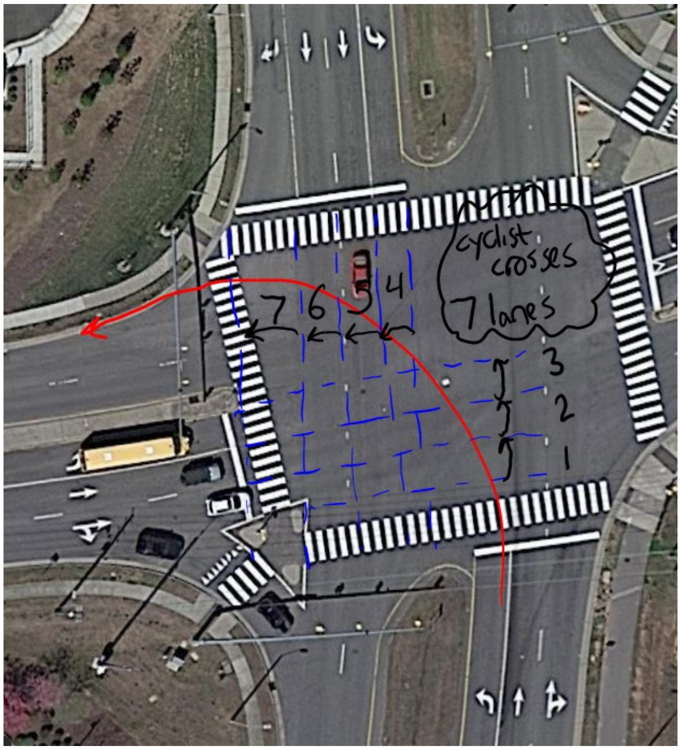


Figure 2. Diagram showing how to count the number of lanes for a traditional left-turning bicyclist.

2.2.2 Crash Data Collection

Crash data were pulled from the NCPedBikeCrashes feature layer provided by NCDOT. Crashes relevant to each intersection were identified in the 2010-2019 period by using ArcGIS Desktop to create a 150 ft. buffer around each intersection and spatially joining the intersections to the pedestrian and bicycle crash feature class. Once crashes were associated with intersections for each year, the crash set was further refined to include only the specific years associated with the correct version of the intersection.

2.2.3 Exposure Data Collection

From the 300 intersections selected, a subset of 100 of them were chosen as described in Section 2.1 to collect pedestrian, bicycle, and motor vehicle turning movement counts (TMCs). This allowed for an assessment of the flags and their correlation to crash data on a subset of intersections for two reasons: (1) to determine if observed turning volumes are needed to more accurately reflect design flags raised or if proxy volumes based on AADTs are sufficient; and (2) to understand how flags may correlate to crash rates. This second aspect is important, given that sites with zero crashes may not necessarily mean they are safe; it may simply reflect that no one walks or bicycles there due to an intersection's design and/or the perception that they are unsafe. A list of the 100-subset intersections included in the study can be found in Appendix 7.1. Cameras were installed to collect at least two days of video footage at each intersection for the video data reduction process. Footage from each intersection was processed to extract pedestrian, bicycle, and motor vehicle movements between 7am-7pm on one of the selected days of video. Counts were binned into 1-hour intervals with TMCs only collected for the first 15 minutes of each hour and the bicyclist and pedestrian counts collected for the full hourlong interval. Some intersections required multiple cameras to collect each desired movement, meaning that coders had to process more than one file of video footage in order to comprehensively extract all the counts for the intersection. Each camera view associated with each intersection is also shown in the appendix. Additional details on how each coding analyst was trained and the process used to code the counts and track progress are further provided in Appendix 7.3.

The events for all motor vehicles were combined into one spreadsheet and the pedestrian crossing and bicyclist through and turning movement events were combined into another spreadsheet. After this the data were cleaned, errors in coding resolved with the individual coders, and incorrect time stamps and codes fixed such that for every event there was an intersection number, an event code (as described in Appendix 7.3), a correct hour in which the event took place, mode of travel (for pedestrian or bicyclists), intersection approach, and turning movement. After these data were summarized in Excel using Pivot Tables, filtering out blanks, and hours not within the counting window. Data were summarized first by hour, such that peak hours could be identified for each intersection, and then by average hourly volume during the count period. To get daily volumes for use in analysis, factors were applied as shown in Equation 2 in Section 3.

For motor vehicles, average and peak hour counts were provided for each of the right and left turning movement for each approach for each intersection. The 15-minute motor vehicle count collected at the beginning of each hour was multiplied by four to give an estimated hourly count.

For pedestrians, total pedestrian crossings during the count period and average hourly pedestrian crossings for each intersection were summarized. Note that this is not the same as total pedestrian traffic passing through the intersection because some pedestrians cross the intersection multiple times during their turning movement, while others may turn at a corner and never cross a leg of the intersection and are thus not counted.

For bicyclists, total bicyclists passing through the intersection during the count period and average bicyclists passing through the intersection per hour were summarized. Note that bicyclists who crossed the intersection using the crosswalks were only counted once, not by crossing movement. This required coders to watch the bicyclist's entire movement through the intersection before coding their movement type.

See the appendix for details of coding, including how micromobility devices were included in the count.

2.3 Evaluation of Flags

Following collection of the data, a python script was used to evaluate each of the 20 design flags for each of the applicable pedestrian movements or bicycle paths. It was assumed bicycles were not allowed on limited access roadways or the ramps leading to those roadways unless the ramps also provided access to non-restricted facilities (e.g., a frontage road).

Approximately 25% of the output from the python script was then reviewed by a second set of data collectors to address any errors, hand evaluate unique geometric features (e.g., channelized left turn lane), and verify the original data collection.

3 Results and Findings

To evaluate the correlations between the flags and pedestrian- and bicycle-involved crashes, multiple rounds of analyses were performed. These separate analyses considered the different ways to measure safety, and these were total crashes over the analytical period, average crashes per year, and crash rates in the case of the 100-intersection subsample. Different methods of summing flags per intersection were also considered, and a variety of different numerical flag variables were tested. For example, at any intersection, each approach could have multiple Flag 4 flags (Crossing Yield-Controlled or Uncontrolled Vehicle Paths), both red and yellow, per pedestrian movement. So at any intersection, there could be separate variables for the sum of red pedestrian Flag 4 flags, yellow pedestrian Flag 4 flags, red bicyclist Flag 4 flags, yellow Flag 4 bicyclist flags, red and yellow pedestrian Flag 4 flags, red and yellow bicyclist Flag 4 flags, or even total red and yellow flags or total flags. Ultimately, some rules were developed to streamline the analysis and to eliminate statistically significant but analytically meaningless correlations from the results, including:

- Correlations were only tested by mode based on the current framework of the design flags laid out in NCHRP Report 948. Only flags for pedestrian movements (e.g., Flags 1 through 13) were tested for correlations to pedestrian crashes. Only flags for bicycle safety concerns (Flags 4-20) were tested for correlations to bicycle crashes.
- Separate correlations were tested for red, yellow, and the combined sum of flags. For example, in the case of Flag 4, the separate correlations for red flags, yellow flags, and red and yellow flags were all tested.
- Summary flags (e.g., total pedestrian yellow flags) were also tested for correlations, as appropriate by mode.
- While several flags related to both pedestrian and bicyclist movements, correlations were not tested for combined pedestrian and bicyclist crashes because the frequency of bicyclist crashes was too small, leading to pedestrian crashes dominating the correlations.

All correlations were generated using the Pearson Correlation procedure PROC CORR in SAS 9.4. Only those correlations that were statistically significant at the 95% level are reported in this chapter. A summary of the flag variables tested for correlations is shown in Table 5.

Table 5. Flag Variable Names and Descriptions

Flag Number	**Pedestrian Flag Variable Names**	**Pedestrian Flag Variable Definition**	**Bicyclist Flag Variable Names**	**Bicyclist Flag Variable Definition**
1	Flag_1_R_P	Flag 1 for pedestrians, red	-	-
	Flag_1_Y_P	Flag 1 for pedestrians, yellow	-	-
	Flag_1_RY_P	Flag 1 for pedestrians, red and yellow summed	-	-
2	Flag_2_Y_P	Flag 2 for pedestrians, yellow	-	-
3	Flag_3_R_P	Flag 3 for pedestrians, red	-	-
	Flag_3_Y_P	Flag 3 for pedestrians, yellow	-	-
	Flag_3_RY_P	Flag 3 for pedestrians, red and yellow summed	-	-
4	Flag_4_R_P	Flag 4 for pedestrians, red	Flag_4_R_B	Flag 4 for bicyclists, red
	Flag_4_Y_P	Flag 4 for pedestrians, yellow	Flag_4_Y_B	Flag 4 for bicyclists, yellow

Flag Number	Pedestrian Flag Variable Names	Pedestrian Flag Variable Definition	Bicyclist Flag Variable Names	Bicyclist Flag Variable Definition
	Flag_4_RY_P	Flag 4 for pedestrians, red and yellow summed	Flag_4_RY_B	Flag 4 for bicyclists, red and yellow summed
5	Flag_5_R_P	Flag 5 for pedestrians, red	Flag_5_R_B	Flag 5 for bicyclists, red
	Flag_5_Y_P	Flag 5 for pedestrians, yellow	Flag_5_Y_B	Flag 5 for bicyclists, yellow
	Flag_5_RY_P	Flag 5 for pedestrians, red and yellow summed	Flag_5_RY_B	Flag 5 for bicyclists, red and yellow summed
6	Flag_6_Y_P	Flag 6 for pedestrians, yellow	Flag_6_Y_B	Flag 6 for bicyclists, yellow
7	Flag_7_R_P	Flag 7 for pedestrians, red	Flag_7_R_B	Flag 7 for bicyclists, red
	Flag_7_Y_P	Flag 7 for pedestrians, yellow	Flag_7_Y_B	Flag 7 for bicyclists, yellow
	Flag_7_RY_P	Flag 7 for pedestrians, red and yellow summed	Flag_7_RY_B	Flag 7 for bicyclists, red and yellow summed
8	Flag_8_R_P	Flag 8 for pedestrians, red	Flag_8_R_B	Flag 8 for bicyclists, red
	Flag_8_Y_P	Flag 8 for pedestrians, yellow	Flag_8_Y_B	Flag 8 for bicyclists, yellow
	Flag_8_RY_P	Flag 8 for pedestrians, red and yellow summed	Flag_8_RY_B	Flag 8 for bicyclists, red and yellow summed
9	Flag_9_Y_P	Flag 9 for pedestrians, yellow	Flag_9_Y_B	Flag 9 for bicyclists, yellow
10	Flag_10_R_P	Flag 10 for pedestrians, red	Flag_10_R_B	Flag 10 for bicyclists, red
	Flag_10_Y_P	Flag 10 for pedestrians, yellow	Flag_10_Y_B	Flag 10 for bicyclists, yellow
	Flag_10_RY_P	Flag 10 for pedestrians, red and yellow summed	Flag_10_RY_B	Flag 10 for bicyclists, red and yellow summed
11	Flag_11_R_P	Flag 11 for pedestrians, red	Flag_11_R_B	Flag 11 for bicyclists, red
	Flag_11_Y_P	Flag 11 for pedestrians, yellow	Flag_11_Y_B	Flag 11 for bicyclists, yellow
	Flag_11_RY_P	Flag 11 for pedestrians, red and yellow summed	Flag_11_RY_B	Flag 11 for bicyclists, red and yellow summed
12	Flag_12_R_P	Flag 12 for pedestrians, red	Flag_12_R_B	Flag 12 for bicyclists, red
13	Flag_13_R_P	Flag 13 for pedestrians, red	Flag_13_R_B	Flag 13 for bicyclists, red
	Flag_13_Y_P	Flag 13 for pedestrians, yellow	Flag_13_Y_B	Flag 13 for bicyclists, yellow
	Flag_13_RY_P	Flag 13 for pedestrians, red and yellow summed	Flag_13_RY_B	Flag 13 for bicyclists, red and yellow summed
14	-	-	Flag_14_R_B	Flag 14 for bicyclists, red
	-	-	Flag_14_Y_B	Flag 14 for bicyclists, yellow

Flag Number	Pedestrian Flag Variable Names	Pedestrian Flag Variable Definition	Bicyclist Flag Variable Names	Bicyclist Flag Variable Definition
	-	-	Flag_14_RY_B	Flag 14 for bicyclists, red and yellow summed
15	-	-	Flag_15_R_B	Flag 15 for bicyclists, red
	-	-	Flag_15_Y_B	Flag 15 for bicyclists, yellow
	-	-	Flag_15_RY_B	Flag 15 for bicyclists, red and yellow summed
16	-	-	Flag_16_R_B	Flag 16 for bicyclists, red
	-	-	Flag_16_Y_B	Flag 16 for bicyclists, yellow
	-	-	Flag_16_RY_B	Flag 16 for bicyclists, red and yellow summed
17	-	-	Flag_17_R_B	Flag 17 for bicyclists, red
	-	-	Flag_17_Y_B	Flag 17 for bicyclists, yellow
	-	-	Flag_17_RY_B	Flag 17 for bicyclists, red and yellow summed
18	-	-	Flag_18_R_B	Flag 18 for bicyclists, red
	-	-	Flag_18_Y_B	Flag 18 for bicyclists, yellow
	-	-	Flag_18_RY_B	Flag 18 for bicyclists, red and yellow summed
19	-	-	Flag_19_R_B	Flag 19 for bicyclists, red
	-	-	Flag_19_Y_B	Flag 19 for bicyclists, yellow
	-	-	Flag_19_RY_B	Flag 19 for bicyclists, red and yellow summed
20	-	-	Flag_20_R_B	Flag 20 for bicyclists, red
	-	-	Flag_20_Y_B	Flag 20 for bicyclists, yellow
	-	-	Flag_20_RY_B	Flag 20 for bicyclists, red and yellow summed
Total Flags	Flag_Ped_R_Tot	Total pedestrian flags, red	Flag_Bike_R_Tot	Total bicycle flags, red
	Flag_Ped_Y_Tot	Total pedestrian flags, yellow	Flag_Bike_Y_Tot	Total bicycle flags, yellow
	Flag_Ped_Tot	Total pedestrian flags	Flag_Bike_Tot	Total bicycle flags
	Flag_Tot_R	Total flags, red		
	Flag_Tot_Y	Total flags, yellow		
	Flag_Tot	Total flags		

The crash variables used in the correlation analysis are depicted in Table 6. All variables in this analysis are numeric.

Table 6. Crash Variables in Correlation Analysis

Pedestrian Crash Variable Name	Pedestrian Crash Variable Description	Bicycle Crash Variable Name	Pedestrian Crash Variable Description
Ped_Tot	Total pedestrian crashes	Bike_Tot	Total bicycle crashes
Ped_K	Fatal pedestrian crashes	Bike_K	Fatal bicycle crashes
Ped_KA	Fatal and severe injury pedestrian crashes	Bike_KA	Fatal and severe injury bicycle crashes
Ped_KAB	Fatal, severe, and evident injury pedestrian crashes	Bike_KAB	Fatal, severe, and evident injury bicycle crashes
Ped_KABC	Fatal and injury pedestrian crashes	Bike_KABC	Fatal and injury bicycle crashes
Ped_Tot_Avg	Total average pedestrian crashes per year	Bike_Tot_Avg	Total average bicycle crashes per year
Ped_K_Avg	Fatal average pedestrian crashes per year	Bike_K_Avg	Fatal average bicycle crashes per year
Ped_KA_Avg	Fatal and severe injury average pedestrian crashes per year	Bike_KA_Avg	Fatal and severe injury average bicycle crashes per year
Ped_KAB_Avg	Fatal, severe, and evident injury average pedestrian crashes per year	Bike_KAB_Avg	Fatal, severe, and evident injury average bicycle crashes per year
Ped_KABC_Avg	Fatal and injury average pedestrian crashes per year	Bike_KABC_Avg	Fatal and injury average bicycle crashes per year
Ped_Tot_R	Total pedestrian crash rate	Bike_Tot_R	Total bicycle crash rate
Ped_K_R	Fatal pedestrian crash rate	Bike_K_R	Fatal bicycle crash rate
Ped_KA_R	Fatal and severe injury pedestrian crash rate	Bike_KA_R	Fatal and severe injury bicycle crash rate
Ped_KAB_R	Fatal, severe, and evident injury pedestrian crash rate	Bike_KAB_R	Fatal, severe, and evident injury bicycle crash rate
Ped_KABC_R	Fatal and injury pedestrian crash rate	Bike_KABC_R	Fatal and injury bicycle crash rate

The crash rates mentioned in Table 6 (e.g., Ped_KAB_R) were developed exclusively for the 100-intersection subsample using the exposure data discussed in Section 2.2.3. The crash rates were calculated using the general intersection crash rate formula shown in Equation 1:

Equation 1. Crash Rate

$$R = \frac{1{,}000{,}000 * C}{365 * N * V}$$

where:
R = the crash rate per intersection as the number of crashes per million entering vehicles
C = the total number of intersection crashes during the analysis period
N = the number of years in the analysis period
V = the total intersection volume per day, including motor vehicles, pedestrians, and bicyclists

The volume was calculated using Equation 2:

Equation 2. Intersection Volume Per Day

$$V = (PHV_{veh} * 10) + \left(\frac{Avg_{peds}}{0.21}\right) + (\frac{Avg_{bikes}}{0.17})$$

Where:
PHV_{veh} = the vehicle peak hour volume
Avg_{peds} = the average count of pedestrians per hour
Avg_{bikes} = the average count of bicyclists per hour

Following typical traffic volume estimation, it was assumed that vehicular peak hour volume was one tenth of the AADT, so an expansion factor of 10 was applied. Using the 2017 Non-Motorized Volume Data Program (NMVDP) count station data summary, conversion factors of 0.21 and 0.17 were calculated to convert average hourly pedestrians and average hourly bicyclists to daily pedestrians and daily bicyclists, respectively. Then, these three volumes were summed per intersection to provide the daily traffic volume per intersection.

3.1 Overview of Flags Distribution

Although a correlation analysis can reveal potential connections between the design flags and crash frequencies, the correlation methodology may not indicate statistical significance if certain flags are too frequently distributed or relatively absent. Therefore, there is value in examining the distribution of flags as binary variables (i.e., present or not present on at least one approach) across the entire sample of intersections to determine if there is a high-level link between design flags and safety concerns for pedestrians and bicyclists. The distribution of each flag, both red and yellow, across the entire sample of intersections is shown in Table 7. There are several flags in this table for which red and or yellow flags are either almost always flagged, such as Yellow Flag 8 (long red times), or never flagged, such as Flags 5 (indirect paths), 6 (executing unusual movements), and 19 (riding between lanes), which may be a reflection of the types of sites evaluated. For this reason, caution should be used when evaluating results from these flags as discussed below.

Table 7. Frequency of Each Flag Across 300 Intersection Sample

Flag Number	**Flag Name**	**Number of Intersections with at Least One Flag This Number**	**Number of Intersections with This Red Flag**	**Number of Intersections with This Yellow Flag**
1	MV Right Turns	296	287	39
2	Uncomfortable/Tight Walking Environment	177	-	177
3	Nonintuitive MV Movements	21	20	1
4	Crossing Yield-Controlled or Uncontrolled Vehicle Paths	33	32	1
5	Indirect Paths	12	9	3
6	Executing Unusual Movements	6	-	6
7	Multilane Crossing	295	264	172

8	Long Red Times	297	0	297
9	Undefined Crossings at Intersections	161	-	161
10	MV Left Turns	284	279	30
11	Intersecting Driveways & Side Streets	226	99	219
12	Site Distance for Gap Acceptance Movements	53	53	-
13	Grade Change	129	42	114
14	Riding in Mixed Traffic	299	280	88
15	Bicycle Clearance Times	295	279	82
16	Lane Change Across MV Travel Lane	296	276	62
17	Bicyclist Crossing MV Channelized Travel Lane	43	43	2
18	Turning MV Crossing Bike Path	248	201	98
19	Riding Between Lanes	8	8	1
20	Off-Tracking Trucks in Multi-Lane Curves	84	82	3
Note: (-) indicate where either a yellow or red design flag does not exist to be evaluated.				

As can be seen in Table 7, the six flags with the greatest frequency of at least one approached flagged red or yellow at an intersection are:

- Flag 14 (N=299): Riding in mixed traffic
- Flag 8 (N=297): Long red times
- Flag 1 (N=296): Motor vehicle right-turns
- Flag 16 (N=296): Lane change across motor vehicle travel lane(s)
- Flag 7 (N=295): Multilane crossings
- Flag 15 (N=295): Bicycle clearance times

These flags were so frequently indicated on approaches across the entire intersection sample that, as will be seen in Section 3.2, they often lacked statistically significant correlations to the crash data. However, it is important to consider these flags in addition to statistically significant correlated flags because they may indicate near-ubiquitous safety concerns for pedestrians and bicyclists within the 300-intersection sample. Of these flags, one is pedestrian specific (Flag 1); two apply to either pedestrians or bicyclists (Flag 7 and Flag 8); and three apply only to bicyclists (Flag 14, Flag 15, and Flag 16).

Table 7 also indicates the frequency of red flags compared to the frequency of yellow flags. The five most frequently indicated red flags include:

- Flag 1 (N=287): Motor vehicle right-turns
- Flag 14 (N=280): Riding in mixed traffic
- Flag 10 (N=279): Motor vehicle left-turns
- Flag 15 (N=279): Bicycle clearance times
- Flag 16 (N=276): Lane change across motor vehicle travel lane(s)

Notably, there were no approaches flagged red for Flag 8 (long red times) in the 300-intersection sample. Instead, Flag 10 had a substantial number of red-flagged motor vehicle left-turns across the entire intersection sample, indicating safety concerns with motor vehicle movements intersecting pedestrian and bicyclist movements at nearly every intersection in the sample. Comparatively, the five most common yellow flags at intersections in the full sample were:

- Flag 8 (N=297): Long red times
- Flag 11 (N=219): Intersection driveways and side streets
- Flag 2 (N=177): Uncomfortable/tight walking environment
- Flag 7 (N=172): Multilane crossings
- Flag 9 (N=161): Undefined crossings at intersections

Flag 11, Flag 2, and Flag 9 were not some of the most frequently observed flags overall, but their high frequency as yellow flags specifically may indicate consistent concerns across intersections in the sample that decrease the comfort and usability of these intersections for pedestrians and bicyclists. Interestingly, Flag 3 (nonintuitive motor vehicle movements), Flag 4 (crossing yield-controlled or uncontrolled vehicle paths), Flag 5 (indirect paths), Flag 6 (executing unusual movements), Flag 17 (bicyclist crossing motor vehicle travel lane), and Flag 19 (riding between lanes) were rarely indicated at any intersections; this may reflect the limited number of alternative intersections included in the study where these design flags may be more common than at traditional, four-leg intersections, so this study cannot conclude that they lack utility in the method.

3.1.1 Changes in Flag Indications

For the subsample of 100 intersections, the 20 Flags analysis was performed again using the observed turning movement volume data. This reassessment resulted in new flags being identified at different intersections and, in some cases, movements previously indicated with yellow flags upgraded to red flags. The additional analysis resulted in new flag indications for:

- Flag 1: Motor vehicle right-turns
- Flag 4: Crossing yield- or uncontrolled vehicle paths
- Flag 10: Motor vehicle left-turns

In no cases were flags downgraded from red to yellow, and in no cases did the revised volumes result in fewer flag indications per intersection. These results are noteworthy for demonstrating that an accurate assessment of exposure can highlight additional design risks for pedestrians and bicyclists that were previously missed when proxy volumes were used. In particular, Flag 4, which relates to exposed crossings for pedestrians and bicyclists, was not previously identified as a common concern in the full sample where only 33 intersections had either a red or yellow Flag 4 for at least one movement. While the proportion of sites with Flag 4 remained roughly the same across the full sample (11%) and the subsample (12%) using proxy volumes; the proportion increased to 25% of the 100-subset sample with Flag 4 when observed turning volumes were used. The frequency of flags across the 100-intersection sample before and after flag reassignments is shown in Table 8. A full summary of the changes in flags for the 100-intersection subsample can be found in Table 11 in the appendix.

Table 8. Frequency of Each Flag Across 100-intersection subsample before and after Volume Reassignments

	Before Flag Reassignment	**After Flag Reassignment**

Flag Number	Number of Intersections with at Least One Flag This Number	Number of Intersections with This Red Flag	Number of Intersections with This Yellow Flag	Number of Intersections with at Least One Flag This Number	Number of Intersections with This Red Flag	Number of Intersections with This Yellow Flag
1	97	92	12	100	98	7
2	27	-	27	27	-	27
3	5	5	0	5	5	0
4	12	12	0	25	25	0
5	6	3	3	6	3	3
6	5	-	5	5	-	5
7	98	85	60	98	85	60
8	99	0	99	99	0	99
9	37	-	37	37	-	37
10	94	92	9	99	99	8
11	80	35	77	80	35	77
12	16	16	-	16	16	-
13	50	17	42	50	17	42
14	100	90	32	100	90	32
15	97	91	31	97	91	31
16	99	91	17	99	91	17
17	11	11	1	11	11	1
18	65	51	23	65	51	23
19	6	6	1	6	6	1
20	25	24	25	25	24	2

3.2 Crash Correlations Results

Multiple correlation matrices were generated to identify statistically significant correlations between the crash variables highlighted in Table 6 and the flag variables highlighted in Table 5. This section presents summary tables for each intersection sample and method of crash summarization. Both positive and negative correlations are summarized for pedestrian crashes and bicyclist crashes. Correlation coefficients (r) and p-values are shown for each statistically significant correlation. Each table is accompanied by a summary of key findings per each analysis.

3.2.1 Full Dataset

The following tables (Table 9 and Table 10) show the statistically significant positive and negative correlations for total crashes and average crashes for the full 300-intersection sample, respectively. Note that these correlations were generated without using the proxy turning movement volumes estimated as explained in Section 2.2.1 above, so the correlations do not take the updated flag frequencies of the 100-intersection subsample into account.

Table 9 presents the positively and negatively correlated flag variables for **total crashes** over the analysis period. This table reveals some potentially important correlations between crash totals and the 20-Flags method. The only statistically significant and positively correlated flag variable for pedestrian fatal and severe injury crashes (Ped_KA) was Flag 1 (motor vehicle right-turns). This result is interesting given that, as seen in Table 7, this flag was indicated on at least one approach at 287 intersections. These results may indicate the importance of addressing permissive motor vehicle right turns to improve pedestrian safety. Flag 11 (access points) is correlated with both pedestrian crashes (Ped_Tot) and bicycle crashes (Bike_KABC). These results may indicate that access points within the intersection area should be more carefully considered for their effect on crash frequencies.

For bicyclists, Flag 16 was the only statistically significant and positively correlated flag to fatal and severe injury crashes. Flag 16 corresponds to lane changes for bicyclists, so this result may indicate the importance of minimizing conflicts between motor vehicles and bicycles to the extent possible. This flag is also indicated at 276 of the 300 intersections, demonstrating its ubiquity within the sample. Flag 20 (off-tracking trucks in multilane curves) is also positively correlated to total and all fatal or injury bicyclist crashes. This flag was only indicated on at least one approach at 84 of the intersections in the sample, but the correlation may indicate the potential effect that exposure to truck traffic can have on bicyclist safety.

If the goal of using the 20-Flags method is to identify safety concerns for pedestrians and bicyclists, the negative correlations in Table 9 may indicate that the summary flag variables (e.g., Flag_Tot_R, Flag_Ped_Tot, Flag_Ped_Y_Tot) provide less utility in predicting where crashes may occur than single red or yellow flags. Additionally, Flag 12 (sight distance for gap acceptance movements), Flag 2 (uncomfortable/tight walking environment), and Flag 9 (undefined crossings) were consistently negatively correlated to pedestrian crashes, while Flag 10 (motor vehicle left-turns) was negatively correlated to total and all fatal and injury bicyclist crashes. Note that Flag 2, Flag 9, and Flag 10 were indicated at over half of all of the intersections, which again, likely reflects the types of intersections selected for evaluation, so these negative correlations may not necessarily mean these flags are not associated with pedestrian and bicyclist crashes.

Table 10 shows the correlations between **average crashes** over the analysis period and the various flag variables. As with the total crash correlations, the average crash correlation results seem to indicate that the summation variables (e.g., Flag_Tot_R) are less useful for predicting crashes than individual flag variables, although Flag_Tot_Y was statistically and positively correlated to total pedestrian crashes and fatal and all injury pedestrian crashes. The results for pedestrian crashes shown in Table 10 are similar to those shown in Table 9. Flag 1 (motor vehicle right-turns) is again positively correlated to fatal and severe injury pedestrian crashes, and Flag 11 (access points) is correlated to total pedestrian crashes. For bicyclist crashes, Flag 16 (lane change across motor vehicle lane(s)) is again correlated to fatal and severe injury bicycle crashes, while Flag 20 (off-tracking trucks in multilane curves) is again correlated to total bicycle crashes. When examining Flag 20, only 3 yellow flags were indicated at any intersection, so the effects of the combined summation of red and yellow flags (Flag_20_RY_B) may be more important for predicting bicyclist crashes, as indicated by the correlations between this variable and fatal and all injury bicyclist crashes for both the total crash analysis and the average crash analysis. The negative correlations are also similar to those calculated for the total crash set.

Tables 9 and 10, taken together, seem to indicate that Flag 1 (motor vehicle right-turns) and Flag 11 (access points) provide the most utility in predicting pedestrian crashes, while Flags 16 (lane change across motor vehicle(s)) and 20 (off-tracking trucks in multilane curves) provide the most utility in predicting bicyclist crashes. Flags 1, 11, and 16 were indicated at 296, 226, and 296 intersections, respectively. These flags are largely ubiquitous in the dataset and positively correlated to pedestrian and/or bicyclist crashes. Flag 20 is only indicated at 84 intersections but was consistently correlated to bicyclist crashes. These results may indicate that, if proxy traffic volumes are used in the 20-Flags method, these flags indicate consistent safety concerns for pedestrian and bicyclist maneuvers. Conversely, Flags 2 (uncomfortably tight walking environment), 7 (multilane crossings), 9 (undefined crossings at intersections), 10 (motor vehicle left-turns), and 12 (sight distance for gap acceptance movements) were consistently negatively correlated to pedestrian and bicyclist crashes in the 300-intersection sample. All of those flags except Flag 12 were indicated at over half of the intersections in the sample, perhaps indicating consistent safety concerns but less utility for predicting where crashes may occur.

Although all of the correlations shown in Tables 9 and 10 are statistically significant, none of the correlation coefficients exceed 0.5. This may indicate that none of the correlations are particularly strong.

Table 9. Statistically significant correlations between total crashes (summed over N years) for all 300 intersections and flag variables.

Pedestrian Crashes	**Positively Correlated Flags**	**Negatively Correlated Flags**	**Bicycle Crashes**	**Positively Correlated Flags**	**Negatively Correlated Flags**
Ped_Tot	Flag_11_Y_P (r=0.13, p=0.0239); Flag_11_RY_P (r=0.12, p=0.045)	Flag_12_R_P (r=-0.14, p=0.019); **Flag_2_Y_P (r=-0.21, p=0.0003)**; **Flag_9_Y_P (r=-0.30, p<0.0001);** Flag_Tot_R (r=-0.14, p=0.015); **Flag_Tot (r=-0.17, p=0.0025); Flag_Ped_Tot (r=-0.22, p=0.0001); Flag_Y_Ped_Tot (r=-0.21; r=0.0002)**	Bike_Tot	Flag_20_Y_B (r=0.13, p=0.0215)	Flag_10_R_B (r=-0.12, p=0.034); **Flag_10_RY_B (r=-0.16, p=0.0042)**
Ped_K	-	**Flag_7_RY_P (r=-0.24, p<0.0001)**	Bike_K	-	-
Ped_KA	Flag_1_R_P (r=0.12, p=0.036)	Flag_Ped_Y_Tot (r=-0.12, p=0.0433); **Flag_7_RY_P (r=-0.19, p=0.0009)**	Bike_KA	**Flag_16_R_B (r=0.16, p=0.007);** Flag_16_RY_B (r=0.15, p=0.0111)	-
Ped_KAB	-	**Flag_2_Y_P (r=-0.20, p=0.0007); Flag_9_Y_P (r=-0.22, p=0.0002);** Flag_Tot (r=-0.13, p=0.0241); **Flag_Ped_Tot (r=-0.17, p=0.0033); Flag_Ped_Y_Tot (r=-0.19, p=0.0013); Flag_7_RY_P (r=-0.15, p=0.0076)**	Bike_KAB	Flag_20_Y_B (r=0.13, p=0.0235)	Flag_Tot_Y (r=-0.13, p=0.027)
Ped_KABC	-	Flag_12_R_P (r=-0.13, p=0.0279); **Flag_2_Y_P (r-0.22, p=0.0002); Flag_9_Y_P (r=-0.30, p<0.0001); Flag_Tot_R (r=-0.17, p=0.003); Flag_Tot (r=-0.20, p=0.0005); Flag_Ped_Tot (r=-0.23, p<0.0001); Flag_Ped_Y_Tot (r=-0.21, p=0.0002);** Flag_7_RY_P (r=-0.12, p=0.0412)	Bike_KABC	Flag_11_RY_B (r=0.11, p=0.0467)	Flag_10_RY_B (r=-0.14, p=0.0155)
Note: (-) indicates no statistically significant correlation between any flag and crash data. Bolded flags: p<0.01; Grey highlight: r ≥ absolute value of 0.30					

Table 10. Statistically significant correlations between average crashes (averaged over N years) for all 300 intersections and flag variables

Pedestrian Crashes	**Positively Correlated Flags**	**Negatively Correlated Flags**	**Bicycle Crashes**	**Positively Correlated Flags**	**Negatively Correlated Flags**
Ped_Tot_Avg	Flag_11_Y_P (r=0.12, p=0.0325)	Flag_12_R_P (r=-0.14, p=0.0162); **Flag_2_Y_P (r=-0.21, p=0.0002); Flag_9_Y_P (r=-0.31, p<0.0001); Flag_Tot_R (r=-0.15, p=0.0097); Flag_Tot (r=-0.18, p=0.0016); Flag_Ped_Tot (r=-0.23, p<0.0001); Flag_Ped_Y_Tot (r=-0.22, p=0.0002**)	Bike_Tot_Avg	Flag_20_Y_B (r=0.12, p=0.0337)	Flag_10_R_B (r=-0.14, p=0.0151); **Flag_10_RY_B (r=-0.18, p=0.0015)**
Ped_K_Avg	-	Flag_7_RY_P (r=-0.23, p<0.0001)	Bike_K_Avg	-	-
Ped_KA_Avg	Flag_1_R_P (r=0.12, p=0.0413)	Flag_Ped_Y_Tot (r=-0.12, p=0.0385); **Flag_7_RY_P (r=-0.19, p=0.001**)	Bike_KA_Avg	**Flag_16_R_B (r=0.16, p=0.0064); Flag_16_RY_B (r=0.15, p=0.0099)**	-
Ped_KAB_Avg	-	**Flag_2_Y_P (r=-0.20, p=0.0006); Flag_9_Y_P (r=-0.22, p<0.0001);** Flag_Tot (r=-0.13, p=0.022); **Flag_Ped_Tot (r=-0.18, p=0.0023); Flag_Ped_Y_Tot (r=-0.19, p=0.001); Flag_7_RY_P (r=-0.15, p=0.0093)**	Bike_KAB_Avg	Flag_20_Y_B (r=0.12, p=0.032)	Flag_Tot_Y (r=-0.12, p=0.0345)
Ped_KABC_Avg	-	Flag_12_R_P (r=-0.13, p=0.0224); **Flag_2_Y_P (r=-0.22, p<0.0001); Flag_9_Y_P (r=-0.30504, p<0.0001); Flag_Tot_R (r=-0.18, p=0.0018); Flag_Tot (r=-0.21, p=0.0003); Flag_Ped_Tot (r=-0.24, p<0.0001); Flag_Ped_Y_Tot (r=-0.22, p=0.0002);** Flag_7_RY_P (r=-0.12, p=0.0464)	Bike_KABC_Avg	Flag_11_RY_B (r=0.12, p=0.0465)	Flag_10_RY_B (r=-0.14, p=0.0126); Flag_15_RY_B (r=-0.12, p=0.044)
Note: (-) indicates no statistically significant correlation between any flag and crash data. Bolded flags: p<0.01; Grey highlight: r ≥ absolute value of 0.30					

3.2.2 Subsample Dataset

As mentioned, a subset of intersections was examined for statistically significant correlations to crash data. At these 100 intersections, pedestrian, bicyclist, and motor vehicle volumes were counted, so crash rates were calculated. Certain movements were also reassigned yellow or red flags in this subsample using observed motor vehicle turning movements in lieu of the proxy volume data. The following tables highlight the correlations between the crash rates and the flag assignments using proxy volumes for the 100-intersection subset (Table 11), the crash rates and the updated flag assignments based on observed volumes (Table 12), total crashes over the analysis period and the updated flag assignments (Table 13), and average crashes per year and the updated flag assignments (Table 14). Tables 11 and 12 were generated to highlight the importance (if any) of using actual volume data rather than proxy data in the flag calculations. Tables 13 and 14 were generated to assess any potential differences in flag correlations between rates and total and average crashes, as well as to provide a potential point of comparison between the full intersection sample and the 100-intersection subset.

Flag Data with Proxy Volumes

Compared to the correlations to total or average crashes in the full intersection sample, the correlations to **crash rates** shown in Table 11 highlight slightly different findings. Of note for pedestrians are Flag 7 (multilane crossings) and Flag 13 (grade change). While Section 3.2.1 pointed out that Flag 7 may not be useful for predicting pedestrian crashes based on the consistently negative correlation, Table 11 shows that yellow indications of Flag 7 are positively correlated to total pedestrian crash rates and fatal and all injury pedestrian crash rates. Conversely, red indications of Flag 7 are negatively correlated with those two crash rate variables. The same relationship between the crash rate variables and yellow and red indications are also evident for Flag 1 (motor vehicle right-turns). Taken together, these results may indicate that Flags 1 and 7 are less reliable (despite Flag 1's near ubiquity [N=97] across the 100-interserction subset) in predicting crash rates. For pedestrian crashes, Flag 13 (grade change) is positively correlated with total and fatal and severe or evident injury pedestrian crash rates. This flag may indicate potential risks to pedestrian safety within this subset of intersections. Flag 9 (undefined crossings at intersections) is again negatively correlated to pedestrian crash rates.

For bicyclists, Flag 16 (lane change across motor vehicle travel lane(s)) and Flag 11 (access points) are positively correlated to crash rates. Flag 15 (bicycle clearance times) was found to be negatively correlated to average bicycle crashes in the full dataset, but now Flag 20 (off-tracking trucks in multilane curves) is negatively correlated with total bicyclist crash rates, as is Flag 7. As with the correlations to total and average crashes in the full dataset, the correlations to crash rates in the 100-intersection subsample seems to indicate that summary flag variables (e.g., Flag_Tot) provide less utility in predicting crashes, aside from Flag_Tot_Y, which does have a positive correlation to total pedestrian crash rate.

Flag Data with Observed Volumes

Table 12 shows the correlations between the flag variables and **crash rates** in the 100-intersection subsample, but with the flags updated to reflect the counted traffic volumes (see Table 8 and Table 19 for more information on flag updates). The revised crash rate correlations do not differ significantly from those shown in Table 11. For pedestrian crash rates, Flag 13 (grade change) remains a positively correlated variable, as does Flag_Tot_Y; the same differences between yellow and red indications for Flag 7 (multilane crossings) are also repeated. Flags 1 (motor vehicle right-turns) and 9 (undefined crossings at intersections) are again negatively correlated with pedestrian crash rates. For bicyclists, Flags 16 (lane change across motor vehicle travel lane(s)) and 11 (access points) are again positively correlated to crash rates, while Flags 7 (multilane crossings), 10 (motor vehicle left-turns), and 20 (off-tracking trucks in multilane curves) are again negatively correlated to crash rates. These results indicate that while the addition of the counting data may reveal differences in the total flags across the entire intersection set, revising the analyses with counts and using crash rates as the safety variables primarily provides consistent findings to the analysis using proxy data.

Table 11. Statistically significant correlations between crash rates for 100-intersection subset and original flag variables

Pedestrian Crashes	Positively Correlated Flags	Negatively Correlated Flags	Bicycle Crashes	Positively Correlated Flags	Negatively Correlated Flags
Ped_Tot_R	Flag_1_Y_P (r=0.20, p=0.0495); Flag_7_Y_P (r=0.23, p=0.0223); Flag_Tot_Y (r=0.25, p=0.0111); Flag_13_RY_P (r=0.20, p=0.0458)	**Flag_1_R_P (r=-0.28, p=0.0052);** Flag_7_R_P (r=-0.24, p=0.0162); **Flag_9_Y_P (r=-0.30, p=0.0028);** **Flag_Tot_R (r=-0.35, p=0.0003);** **Flag_Ped_Tot (r=-0.26, r=0.0097);** **Flag_Ped_R_Tot (r=-0.28, p=0.0046)**	Bike_Tot_R	N/A	**Flag_7_R_B (r=-0.33, p=0.0009);** **Flag_15_R_B (r=-0.26, p=0.0080);** **Flag_20_R_B (r=-0.20, p=0.0454);** **Flag_Tot_R (r=-0.30, p=0.0024);** Flag_Tot (r=-0.25, p=0.0139); Flag_Bike_Tot (r=-0.20, p=0.0417); **Flag_Bike_R_Tot (r=-0.30, p=0.0024);** Flag_7_RY_B (r=-0.24, p=0.0146); Flag_10_RY_B (r=-0.25, p=0.0137), **Flag_15_RY_B (r=-0.26, p=0.0082**), Flag_20_RY_B (r=-0.20, p=0.0495)
Ped_K_R	-	-	Bike_K_R	-	-
Ped_KA_R	-	-	Bike_KA_R	Flag_16_R_B (r=0.20, p=0.0430); Flag_16_RY_B (r=0.21, p=0.0401)	-
Ped_KAB_R	Flag_13_R_P (r=0.21, p=0.0320); Flag_1_Y_P (r=0.20, p=0.0478); Flag_13_RY_P (r=0.24, p=0.0177)	Flag_2_Y_P (r=-0.20, p=0.0471), Flag_9_Y_P (r=-0.25, p=0.0115)	Bike_KAB_R	Flag_11_R_B (r=0.20, p=0.0485)	-
Ped_KABC_R	Flag_7_Y_P (r=0.22, p=0.0245); Flag_Tot_Y (r=0.22, p=0.0291)	Flag_1_R_P (r=-0.25, p=0.0115); Flag_7_R_P (r=-0.24, p=0.0162); **Flag_9_Y_P (r=-0.29, p=0.0034);** **Flag_Tot_R (r=-0.34, p=0.0005);** Flag_Tot (r=-0.20, p=0.0419); Flag_Ped_Tot (r=-0.26, p=0.0090); Flag_Ped_R_Tot (r=-0.26, p=0.0119)	Bike_KABC_R	Flag_11_R_B (r=0.20, p=0.0430	**Flag_7_R_B (r=-0.31, p=0.0015**); Flag_15_R_B (r=-0.20, p=0.0500), Flag_7_RY_B (r=-0.23, p=0.0229)
Note: (-) indicates no statistically significant correlation between any flag and crash data. Bolded flags: p<0.01; Grey highlight: r ≥ absolute value of 0.30					

Table 12. Statistically significant correlations between crash rates for 100-intersection subset and updated flag variables.

Pedestrian Crashes	Positively Correlated Flags	Negatively Correlated Flags	Bicycle Crashes	Positively Correlated Flags	Negatively Correlated Flags
Ped_Tot_R	Flag_7_Y_P (r=0.23, p=0.0223); Flag_Tot_Y (r=0.24, p=0.0154); Flag_13_RY_P (r=0.20, p=0.0458)	**Flag_1_R_P (r=-0.29, p=0.0039);** Flag_7_R_P (r=-0.24, p=0.0162); **Flag_9_Y_P (r=-0.30, p=0.0028); Flag_Tot_R (r=-0.28, p=0.0056); Flag_1_RY_P (r=-0.27, p=0.0039)**	Bike_Tot_R	-	**Flag_7_R_B (r=-0.33, p=0.0009);** Flag_10_R_B (r=-0.20, p=0.0425); Flag_15_R_B (r=-0.25, p=0.0109); Flag_20_R_B (r=-0.20, p=0.0454); **Flag_Tot_R (r=-0.27, p=0.0055); Flag_Bike_R_Tot (r=-0.28, p=0.0049);** Flag_7_RY_B (r=-0.24, p=0.0146); **Flag_15_RY_B (r=-0.26, p=0.0082);** Flag_20_RY_B (r=-0.20, p=0.0495)
Ped_K_R	-	-	Bike_K_R	-	-
Ped_KA_R	-	-	Bike_KA_R	Flag_16_R_B (r=0.20, p=0.043); Flag_16_RY_B (r=0.21, p=0.0401)	-
Ped_KAB_R	Flag_13_R_P (r=0.21, p=0.032); Flag_13_RY_P (r=0.24, p=0.0177)	Flag_2_Y_P (r=-0.20, p=0.0471); Flag_9_Y_P (r=-0.25, p=0.0115)	Bike_KAB_R	Flag_11_R_B (r=0.20, p=0.0485)	-
Ped_KABC_R	Flag_7_Y_P (r=0.22, p=0.0245); Flag_Tot_Y (r=0.21, p=0.0397)	Flag_1_R_P (r=-0.24, p=0.0159); Flag_7_R_P (r=-0.24, p=0.0153); **Flag_9_Y_P (r=-0.29, p=0.0034);** Flag_Tot_R (r=-0.25, p=0.0133); **Flag_1_RY_P (r=-0.25, p=0.0106)**	Bike_KABC_R	Flag_11_R_B (r=0.20, p=0.043)	**Flag_7_R_B (r=-0.31, p=0.0015);** Flag_15_R_B (r=-0.20, p=0.05); Flag_7_RY_B (r=-0.22, p=0.0229)
Note: (-) indicates no statistically significant correlation between any flag and crash data. Bolded flags: p<0.01; Grey highlight: r ≥ absolute value of 0.30					

Tables 13 and 14 show the correlations between the updated flag variables (using observed volumes) and the total and average crashes in the 100-intersection subsample. Notably, these tables do show some different correlations than those captured in Table 12. In Table 13, Flag 4 (crossing yield- or uncontrollable vehicle paths) is positively correlated to total and fatal and injury pedestrian crashes, while the yellow Flag 9 (undefined crossings at intersections) indication is negatively correlated to total and fatal and injury pedestrian crashes. This analysis is the first instance of Flag 4 being correlated to pedestrian crashes. In particular, Flag 4 was one of those updated after the traffic volumes were used in the intersection assessments and new movements were assigned this flag. It is therefore possible that the inclusion of actual traffic volumes can help identify risks posed by uncontrolled crossings. Table 13 reinforces Flags 16 (lane change across motor vehicle travel lane(s)) and 20 (off-tracking trucks in multilane curves) for bicycle crashes, both of which were also positively correlated in the full dataset analyses. There were no flag variables negatively correlated to bicycle crashes in the 100-intersection subsample.

The correlations shown in Table 14 are effectively identical to those shown in Table 13. Flag 4 (crossing yield- or uncontrolled vehicle paths) is positively correlated to average pedestrian crash variables, and Flags 16 (lane change across motor vehicle travel lane(s)) and 20 (off-tracking trucks in multilane curves) are positively correlated to average bicycle crash variables. This table confirms a previous finding seen in Tables 9 and 10, namely that the correlations tend to be consistent regardless of total crashes or average crashes being the crash variable of concern.

Generally, the correlated flags remained mostly consistent when examining the 100-intersection subset compared to the full intersection sample. The two key differences are: 1) more movements were indicated as flagged when observed turning volumes were used, and 2) the use of crash frequencies or averages seems to capture slightly different pedestrian risk than the use of crash rates. The consistency between the results for when crash rates were used for the 100-intersection subset and the results for the crash frequencies and averages in the 300-intersection set may indicate that while collecting turning movements may provide a more realistic scope of flagged movements, the proxy volumes used in the 20-Flags method are likely sufficient for identifying the key safety risks to pedestrians and bicyclists, with the exception of perhaps Flag 4 (crossing yield- or uncontrolled vehicle paths), which was only flagged when examining crash frequencies and averages in the 100-intersection subset. If uncontrolled paths are a concern for practitioners, there may be benefit to using observed data rather than proxy data.

Table 13. Statistically significant correlations between crash totals for 100-intersection subset and updated flag variables.

Pedestrian Crashes	Positively Correlated Flags	Negatively Correlated Flags	Bicycle Crashes	Positively Correlated Flags	Negatively Correlated Flags
Ped_Tot	Flag_4_R_P (r=0.22, p=0.0259); Flag_4_RY_P (r=0.22, p=0.0259)	Flag_9_Y_P (r=-0.25, p=0.0110)	Bike_Tot	Flag_20_Y_B (r=0.24, p=0.0162)	-
Ped_K	-	-	Bike_K	N/A	-
Ped_KA	-	-	Bike_KA	Flag_16_R_B (r=0.20, p=0.0430); Flag_16_RY_B (r=0.24, p=0.0155)	-
Ped_KAB	Flag_4_R_P (r=0.21, p=0.0338); Flag_4_RY_P (r=0.21, p=0.0338)	-	Bike_KAB	Flag_20_Y_B (r=0.24, p=0.0151)	-
Ped_KABC	Flag_4_R_P (r=0.26, p=0.0100); Flag_4_RY_P (r=0.26, p=0.0100)	Flag_9_Y_P (r=-0.24, p=0.0169)	Bike_KABC	-	-
Note: (-) indicates no statistically significant correlation between any flag and crash data. Bolded flags: p<0.01; Grey highlight: r ≥ absolute value of 0.30					

Table 14. Statistically significant correlations between crash averages for 100-intersection subset and updated flag variables.

Pedestrian Crashes	Positively Correlated Flags	Negatively Correlated Flags	Bicycle Crashes	Positively Correlated Flags	Negatively Correlated Flags
Ped_Tot_Avg	Flag_4_R_P (r=0.22, p=0.0273)	**Flag_9_Y_P (r=-0.26, p=0.0080)**	Bike_Tot_Avg	Flag_20_Y_B (r=0.23, p=0.0232)	-
Ped_K_Avg	-	-	Bike_K_Avg	-	-
Ped_KA_Avg	-	-	Bike_KA_Avg	Flag_16_R_B (r=0.23, p=0.0187); Flag_16_RY_B (r=0.24, p=0.0155)	-
Ped_KAB_Avg	Flag_4_R_P (r=0.21, p=0.0333); Flag_4_RY_P (r=0.21, p=0.0333)	-	Bike_KAB_Avg	Flag_20_Y_B (r=0.24, p=0.0164)	-
Ped_KABC_Avg	Flag_4_R_P (r=0.25, p=0.0109); Flag_4_RY_P (r=0.25, p=0.0109)	Flag_9_Y_P (r=-0.25, p=0.0124)	Bike_KABC_Avg	-	-
Note: (-) indicates no statistically significant correlation between any flag and crash data. Bolded flags: p<0.01; Grey highlight: r ≥ absolute value of 0.30					

4 Conclusions

The goal of this project was to assess the capacity of the 20-Flags method prescribed in NCHRP Report 948 for identifying pedestrian and bicyclist safety concerns by validating it with pedestrian and bicyclist crash data. To accomplish this goal, multiple analyses were undertaken to link the design flags discussed in NCHRP 948 to a sample of intersections in North Carolina and to identify any statistically significant correlations between the design flags and crash data.

The procedure discussed throughout this document included a high-level summary of the frequency of design flags across a 300-intersection sample, the calculation of Pearson correlation coefficients between those design flags (summarized per intersection) and crash data (tabulated as total crash frequency over an analysis period and average crashes per year). The procedure also included a reevaluation of the design flags after pedestrian, bicyclist, and motor vehicles were counted from video footage at a subset of 100 intersections, and the calculation of Pearson correlation coefficients between the revised design flag sums and crash frequencies, average crashes, and crash rates at the 100-intersection subset.

The first layer of analysis, the **basic summary of flag frequencies**, serves as a sort of global assessment of the utility of the 20-Flags method to identify pedestrian and bicyclist safety concerns. In this level of analysis, it was found that six flags were present for at least one movement at nearly every intersection in the sample. These flags include:

- Flag 14 (N=299): Riding in mixed traffic
- Flag 8 (N=297): Long red times
- Flag 1 (N=296): Motor vehicle right-turns
- Flag 16 (N=296): Lane change across motor vehicle travel lane(s)
- Flag 7 (N=295): Multilane crossings
- Flag 15 (N=295): Bicycle clearance times

This finding alone points to potential systemic safety concerns for pedestrians and bicyclists, where the possible risks denoted by these flags are found at the majority of tested intersections. These intersections likely represent similar locations where two state roads meet, which suggests that safe basic pedestrian and bicyclist infrastructure may not be present at most state-owned intersections in NC.

The ubiquity of these flags alone does not necessarily correspond to crash frequencies, so the second level of analysis - an inspection of the **correlations between the flag variables and total and average crashes**, was performed to determine if any flags are also correlated with crash data. For pedestrians, Flag 1 (motor vehicle right turns) was positively correlated to fatal and severe pedestrian crashes, while Flag 16 (lane change across motor vehicle lanes) was positively correlated to fatal and severe bicycle crashes. This was true regardless of whether or not total crashes or average crashes were examined. It also remained somewhat consistent when examining the crash rates at the subset of 100-intersections using the original flag variable sums. Flag 1 was positively correlated to pedestrian fatal and severe or evident injury crashes (but not fatal and severe injury crashes), and Flag 16 was again correlated to fatal and severe injury bicycle crashes.

After comparing the full sample to the 100-intersection subset, the **flag variables were updated for the 100-intersections subset** using the study's collected traffic volume data, and the Pearson correlation coefficients were recalculated. This analysis highlighted that Flags 7 (multilane crossings) and 13 (grade change) were positively correlated to total pedestrian crash rates and fatal and severe or evident injury pedestrian crash rates, respectively. Flag 16 (lane change across motor vehicle lanes) remained the consistent positive correlation to fatal and severe injury crash rates for bicyclists. However, when examining crash frequencies or average crashes per year for the subset of 100 intersections, Flag 4 (uncontrolled crossings) was the only positively correlated flag variable to fatal and severe or evident injury crashes for pedestrians, while Flag 16 remained correlated for bicyclists.

When considering the most critical correlations between the design flags and pedestrian and bicycle crashes in this sample of intersections in North Carolina, it is likely most appropriate to focus primarily on the red flags, as the red flags were originally intended to indicate safety concerns. Considering this emphasis on red flags and the various analyses discussed throughout this report, the most important flags for identifying pedestrian safety concerns at intersections are likely Flag 1 (motor vehicle right turns), Flag 4 (crossing yield- or uncontrolled vehicle paths), and Flag 13 (grade change). Flag 7 (multilane crossings) and Flag 11 (intersecting driveways and side streets), while frequently positively correlated to pedestrian crashes, were typically correlated as yellow flags rather than red flags. For bicyclists, the most important design flag for identifying bicyclist safety concerns is likely Flag 16 (lane change across motor vehicle lanes). Other flags that were relatively frequently positively correlated to bicyclist crash variables include Flags 11 (intersecting driveways and side streets) and 20 (off-tracking trucks in multi-lane curves), although these flags tended to be correlated as yellow flags rather than red flags. These flags, the number of statistically significant positive correlations identified in Tables 9 through 14 between the red version of these flags and various crash variables, and potential design implications, are summarized in Table 15.

Table 15. Summary of Frequently Correlated Flags

Flag Number	Flag Description	Frequency of (+) Correlations to Pedestrian Crash Variables	Frequency of (+) Correlations to Bicyclist Crash Variables	Design Implications for Red Flags
1	Motor Vehicle Right-Turns	2	N/A	Right hook crashes with pedestrians
4	Crossing Yield-or Uncontrolled Vehicle Paths	6	-	Inadequate signal protection for pedestrian movements
11	Intersection Driveways and Side Streets	-	4	Access control
13	Grade Change	2	-	Differences in velocity for motor vehicles and crossing speed for pedestrians
16	Lane Change Across Motor Vehicle Travel Lane(s)	N/A	6	Crashes during bicyclist lane changes due to vehicle speeds and/or volumes
Note: (-) indicates no statistically significant correlation found.				

Table 15 shows the five most frequently positively correlated red flags to pedestrian and bicyclist crash variables across each of the correlation analyses summarized in Tables 9 through 14. Several pieces of information should be considered when interpreting this table. First, only the correlations between the red versions of these flags (e.g., Flag_16_R_B) were counted in this summary, so although some flags would have higher correlation frequencies—Flag_13_RY_P was also correlated to pedestrian fatal and severe or evident injury crashes several times, for example—this summary focuses only on those direct links between safety concerns (red flags) and crashes. Second, the flags were counted each time they correlated to a crash variable, so it is possible that one flag was correlated multiple times in the same analysis. For example, in the 100-intersection subset correlation analysis between crash frequencies and the flag variables that considered observed volumes, Flag_4_R_P was correlated to total pedestrian crashes, fatal and severe or evident injury crashes, and fatal and all severity injury crashes.

Under those conditions, the analyses performed in this study validate that motor vehicle right-turns, uncontrolled crossings, access points, grade changes, and necessary lane changes are key safety concerns for pedestrians and bicyclists. All of these design concerns, with the exception perhaps of grade changes, are linked to conflicts between pedestrian and bicyclist movements and motor vehicle traffic and therefore make sense practically. Practitioners should assess designs for these safety concerns to minimize the risks to pedestrians and bicyclists at intersections. Other flags, such as those relating to multilane crossings and off-tracking trucks in multilane curves, may help practitioners identify intersection designs where pedestrians and bicyclists feel uncomfortable and may be unlikely to walk or bike, although further research on that topic is needed.

Several flags were relatively frequently negatively correlated with pedestrian and bicycle crashes. These correlations include Flag 9 (undefined crossings at intersections) and Flag 12 (sight distance for gap acceptance) for pedestrians, and Flag 10 (motor vehicle left-turns) and Flag 15 (bicycle clearance time) for bicyclists. Flags 9 and 12 are only indicated at 161 and 53 intersections, respectively. Flags 10 and 15 were indicated far more frequently at 284 and 295 intersections, respectively, so while they are present on a global level at many intersections, they may provide less utility in identifying actual crash risk for bicyclists.

Somewhat confoundingly, some flags had both positive and negative correlations to crash variables, depending on the crash variable in question and the flag color (red or yellow) indication. For the 100-intersection subset, the yellow indications of Flag 1 (motor vehicle right turns) (for the flag summaries using proxy volumes) and for Flag 7 (multilane crossings) (for both the proxy and observed volume flag summaries) was positively correlated with pedestrian crash rates, while both red indications were correlated negatively with pedestrian crash rates. The red and yellow summary indications for Flag 7 were also regularly negatively correlated for bicyclist crash rates. These results may indicate that for these design flags, the yellow indication is sufficient for identifying crash risks. However, the results may also be connected to the low frequency of bicycle crashes overall.

Throughout all of the analyses, the summary variables—e.g., Flag_Tot_R, Flag_Tot_Y, Flag_Ped_Tot—generated to test the correlations between total flags and the crash variables were consistently negatively correlated with the crash variables, with the exception of Flag_Tot_Y, which was occasionally correlated positively to pedestrian crashes. These results may indicate that summing the flags at each intersection, rather than inspecting them individually, is less effective for analyzing pedestrian and bicyclist safety concerns.

There are some limitations to the analyses performed. Principally, while the correlations do indicate relationships between variables, they do not indicate causality. While the relationships discussed throughout Section 3 are periodically described as having the potential to predict pedestrian and bicyclist crashes, this terminology is functionally a shorthand for describing that the flag variables that are positively correlated may indicate safety problems that can be used to determine where crashes might occur.

A future direction of this research may be to generate regression models that would allow crashes to actually be predicted using the flag variables, but that analysis is beyond the scope of this project. Additionally, all of the correlations identified in this study are below r=0.5 and are therefore relatively weak correlations. They are statistically significant, but any one flag is not a strong predictor of where crashes may occur.

Additionally, NCHRP Report 948 instructs practitioners to evaluate intersections for bicycle movements based on the facilities provided or included in the design. For intersections with no dedicated bicycle facilities or shared-use paths, the assumption is that bicyclists maneuver through the intersection just as motorists would – an assumption that may be misleading. Of the 100 intersections for which bicycle and pedestrian movements were counted for this study, at 51 of these intersections more than half of bicyclists were observed riding on the sidewalk (see Table 19 in the Appendix). The average percentage of bicyclists on sidewalks is 52% across all 100 intersections. Intersections with higher bicycle traffic (over 90 bicyclists observed passing through the intersection in the 12-hour time period) had less than 50% bicycles on sidewalks. Thus, of the 2,480 bicyclists observed, 38% were riding on sidewalks, but these sidewalk riders were more commonly observed riding on sidewalks at intersections with less than 90 bicyclists in 12 hours. It should also be noted that some of the intersections do not have sidewalks, in which case, no bicyclists could have been observed riding on a sidewalk. The high percentage of bicyclists riding on sidewalks should be noted, since this is not usually where road designers assume bicyclists will ride, and bicyclists riding on sidewalks is associated with higher crash risk.

Finally, while the design flags can be used to assess traditional or alternative intersection and interchanges per NCHRP Report 948, certain flags are more relevant to alternative intersection designs. Given that only 8% of the intersections studied here were not traditional 4-leg intersections, there was insufficient sample to test correlations of flags to crashes to draw any meaningful conclusions of this subset.

Despite these limitations, the analysis described in this report provides an important validation of at least some components of the 20-Flags Method and provides possible directions for refinement to improve its usefulness to practitioners.

5 Implementation & Technology Transfer Plan

The findings from this project are not as satisfyingly clear-cut to solidly demonstrate how effective the 20-Flags method may be at predicting crashes based on corollary relationships between flags and crash data. Due to weak correlations, small crash numbers and/or low pedestrian and bicyclist volumes, and the types of intersections evaluated, it is unclear if certain flags are more or less “important” to consider when applying the 20-Flags method. That said, some insights were learned and could be considered as NCDOT utilizes this method to evaluate intersection designs for pedestrian and bicyclist considerations:

- Reducing the total number of flagged design elements may not be as relevant as which design elements are flagged.

- Particular attention should be paid to redesigning an intersection if red Flags 1 (motor vehicle right turns), 4 (crossing yield-or uncontrolled vehicle paths), 11 (intersection driveways and side streets), 13 (grade change), or 16 (lane change across motor vehicle travel lanes) are found, as these were more consistently correlated with crashes. Modified designs should attempt to reduce vehicle speeds and/or volumes, limit driveway or side street access, and/or reduce the grade within the intersection's sphere of influence to reduce the number or severity of conflicts.
- Where AADTs are known, estimating turning volume is likely sufficient; collecting local observed counts may not be necessary, but doing so may provide additional insights into risks posed by uncontrolled crossings (Flag 4).

Should NCDOT formalize the integration and use of the 20-Flags method into its planning and design process, pertinent staff should be notified through training presentations and memos to ensure it is understood and consistently applied. NCDOT can also consider training municipal staff, private consultants, and others on how to incorporate the 20-Flags method into current intersection control evaluation procedures. Nuances in understanding each flag relative to crash risk based on this project may also aid staff in a deeper understanding of the design options to be considered and may help when facilitating discussion with communities about a new intersection project's impact on bicycling and walking.

Finally, the summary of the flags found for each of the 300 intersections assessed in this study will be provided to NCDOT. Sites with red flags that also have known crash histories could be targeted for reconstruction to address specific design or operational aspects to improve safety for pedestrians and bicyclists and reduce the risk of future crashes.

6 Appendices

6.1 Study Sites

Int. No.	Intersection Name	Intersection Type	Signalized	Channelized Lane	Max AADT	Max Lane Count	Number of Relevant Years	Number of Ped/Bike Crashes	Total Red Flags	Total Yellow Flags
1	W Sugar Creek Rd & Reagan Dr	4-leg	Yes	No	36,000	5	10	23	44	37
2	Freedom Dr & Tuckaseegee Rd/Ashley Rd	4-leg	Yes	No	43,000	9	10	17	37	30
3	N Columbia/S Columbia St & E Franklin St/W Franklin St	4-leg	Yes	No	14,000	5	10	10	42	20
4	E Millbrook Rd/W Millbrook Rd & Six Forks Rd	4-leg	Yes	No	39,500	6	10	8	44	17
5	Eastway Dr & The Plaza	4-leg	Yes	No	36,000	6	10	14	40	22
6	Market St & N 16th St/S 16th St	4-leg	Yes	No	17,500	5	10	6	30	22
7	N Gregson St/S Gregson St & W Main St	4-leg	Yes	No	12,000	3	10	6	8	50
8	NC 54 E Hwy & NC 55 Hwy	4-leg	Yes	No	38,000	7	10	7	44	33
9	Cliffdale Rd & Skibo Rd	4-leg	Yes	No	43,000	9	10	7	49	34
10	E Six Forks Rd & Wake Forest Rd	4-leg	Yes	No	34,000	7	10	7	49	35
13	Martin Luther King Jr Bv & S Person St	4-leg	Yes	No	24,500	5	10	5	34	22
14	Monroe Rd & N Wendover Rd	4-leg	Yes	No	41,000	8	10	8	44	23
15	S Duke St & W Chapel Hill St	4-leg	Yes	No	13,000	4	10	5	22	39
16	S Gregson St & W Chapel Hill St	4-leg	Yes	No	15,500	3	10	5	17	52
17	Carolina Beach Rd & Shipyard Bv	RCUT	Yes	Yes	36,000	8	10	7	49	62
18	E 10th St & Greenville Bv NE/Greenville Bv SE	4-leg	Yes	Yes	40,000	7	10	5	45	42
19	E Edenton St & N Person St	4-leg	Yes	No	9,400	3	10	4	26	20
20	E Green Dr & S University Pkwy	4-leg	Yes	No	8,700	5	7	3	43	42
21	Holloway St & N Alston Ave	4-leg	Yes	No	15,500	3	10	6	44	45
22	Independence Bv & Oleander Dr	4-leg	Yes	No	27,500	7	10	5	62	36
23	Market St & S Kerr Ave/N Kerr Ave	4-leg	Yes	No	37,500	8	7	4	64	32

25	N McDowell St & W Edenton St	4-leg	Yes	No	25,000	4	10	5	40	26
26	N Raleigh Bv & New Bern Ave	4-leg	Yes	No	20,000	7	10	7	65	35
27	N Tryon St & W Mallard Creek Church Rd/E Mallard Creek Church Rd	4-leg	Yes	No	26,000	7	10	4	64	32
28	S 16th St & Dawson St	4-leg	Yes	No	19,000	5	10	4	42	27
29	S Wilmington St & Tryon Rd	4-leg	Yes	No	66,000	11	10	6	54	35
30	W Franklin Bv & N Myrtle School Rd/S Myrtle School Rd	4-leg	Yes	No	21,500	5	7	3	54	50
31	Billy Graham Py & West Bv	4-leg	Yes	No	50,000	6	10	4	58	24
32	Brier Creek Pkwy & Glenwood Ave	4-leg	Yes	No	58,500	9	10	4	60	25
33	Capital Bv & E Millbrook Rd/N New Hope Rd	4-leg	Yes	No	50,000	10	10	6	62	21
34	Creedmoor Rd & Lynn Rd	4-leg	Yes	No	33,500	8	10	4	58	24
36	E Martin Luther King Jr Dr & N University Pkwy/S University Pkwy	4-leg	Yes	No	16,000	5	10	3	56	19
37	E Ozark Ave & N New Hope Rd	4-leg	Yes	No	24,000	5	10	4	62	36
38	E Raleigh Bv & E Grand Ave/N Fairview Rd	4-leg	Yes	No	13,000	5	10	3	60	32
40	Estes Dr/N Estes Dr & Martin Luther King Jr Bv	4-leg	Yes	No	27,500	5	10	3	58	31
41	Falls Of Neuse Rd & Spring Forest Rd	4-leg	Yes	No	34,500	8	10	3	62	17
42	Gaston Ave/Linwood Rd & W Franklin Bv	4-leg	Yes	No	16,000	5	10	3	59	33
43	Horton Rd & N Duke St	4-leg	Yes	No	27,500	5	10	8	59	36
44	Martin Luther King Jr Bv & S Blount St	4-leg	Yes	No	25,000	5	10	3	44	30
45	Martin Luther King Jr Bv & S Raleigh Bv	4-leg	Yes	No	20,500	6	10	3	59	16
46	Murchison Rd & Pamalee Dr/Country Club Dr	4-leg	Yes	No	31,000	7	10	12	65	24
47	N 23rd St & Princess Place Dr	4-leg	Yes	Yes	19,500	4	4	1	53	37
48	N Marine Bv & Onslow Dr	4-leg	Yes	No	21,000	7	10	5	60	28
49	Old Statesville Rd & W W T Harris Bv	4-leg	Yes	No	38,000	7	10	3	62	19
50	S 17th St & Wooster St	4-leg	Yes	No	18,500	4	10	4	43	24

51	S Dawson St & W Morgan St	4-leg	Yes	No	26,000	4	8	4	40	35
52	S Memorial Dr & W 5th St	4-leg	Yes	No	28,000	7	10	6	66	26
53	S Tryon St & W Woodlawn Rd	4-leg	Yes	Yes	47,000	6	10	4	59	31
54	Alamance Rd & S Mebane St	4-leg	Yes	No	16,000	6	10	3	60	30
55	Bell Fork Rd & Country Club Rd/Hargett St	4-leg	Yes	No	49,000	5	10	2	67	25
56	Bellhaven Bv/Rozzelles Ferry Rd & Mt Holly-Huntersville Rd	4-leg	Yes	Yes	17,500	5	10	2	60	39
57	Benvenue Rd & Jeffreys Rd	4-leg	Yes	No	27,500	6	10	2	59	42
58	Bessemer City Rd & Dallas Bessemer City Hwy/Oates Rd	4-leg	Yes	Yes	14,500	5	10	2	52	49
59	Capital Bv & Durant Rd/Perry Creek Rd	4-leg	Yes	Yes	65,500	9	10	4	69	28
60	Carpenter Fire Station Rd & Green Level Church Rd	4-leg	Yes	Yes	14,500	6	10	3	76	22
61	Cary Towne Bv & SE Maynard Rd	4-leg	Yes	No	20,000	6	10	2	60	28
62	Cliffdale Rd & Glensford Dr	4-leg	Yes	No	38,000	8	4	1	62	18
63	Cottonwood St & N Graham St	4-leg	Yes	No	33,500	4	10	2	44	51
64	Davis Dr & High House Rd	4-leg	Yes	Yes	27,500	6	5	1	64	24
65	Davis Dr & Morrisville Pkwy	4-leg	Yes	No	31,000	6	10	3	66	25
66	E Cornwallis Rd & NC 55 Hwy	4-leg	Yes	Yes	24,000	6	7	2	64	38
67	E Fire Tower Rd/W Fire Tower Rd & Evans St/Old Tar Rd	4-leg	Yes	No	41,500	6	10	2	56	23
68	E Franklin St & N Estes Dr/S Estes Dr	4-leg	Yes	No	22,500	5	10	3	52	44
69	E Geer St & N Roxboro St	4-leg	Yes	No	10,000	3	10	2	42	43
70	E Lexington Av & N University Pkwy	4-leg	Yes	No	13,000	7	10	2	56	36
71	E Martin Luther King Jr Dr/W Kivett Dr & N Main St	4-leg	Yes	No	16,000	5	10	2	35	43
72	E Morgan St & S Blount St	4-leg	Yes	No	9,500	3	8	1	35	26
73	E Ramseur St/W Ramseur St & S Mangum St	4-leg	Yes	No	12,500	4	10	4	22	50
75	Freedom Dr & W Morehead St	4-leg	Yes	Yes	33,000	6	10	2	49	56
76	Gaston Day School Rd & Kendrick Rd	Roundabout	No	No	8,800	2	10	2	14	35

77	Graham Rd/71st School Rd & Raeford Rd	4-leg	Yes	No	32,500	6	10	3	56	28
78	Gum Branch Rd & Henderson Dr	4-leg	Yes	No	23,500	6	10	2	55	27
80	Independence Bv & Wrightsville Ave	4-leg	Yes	Yes	31,500	7	10	4	64	28
81	Kildaire Farm Rd & SE Cary Pkwy/SW Cary Pkwy	4-leg	Yes	No	28,000	6	10	2	60	20
82	Lead Mine Rd & Lynn Rd	4-leg	Yes	Yes	18,000	6	10	2	63	16
84	Market St & N 17th St/S 17th St	4-leg	Yes	No	21,000	4	10	2	49	28
85	N Dawson St & W Edenton St	4-leg	Yes	No	25,000	4	10	2	52	39
86	N Duke St & W Morgan St	4-leg	Yes	No	11,000	3	9	2	14	48
88	N Gregson St & W Morgan St	4-leg	Yes	No	11,000	3	10	2	25	47
90	NC 54 E Hwy & S Alston Ave	4-leg	Yes	No	22,000	5	10	6	48	38
91	Page Rd & T W Alexander Dr	4-leg	Yes	No	26,000	7	10	3	59	26
92	Peters Creek Pkwy & Silas Creek Pkwy	4-leg	Yes	Yes	41,000	9	10	4	59	29
93	S 3rd St & Dawson St	4-leg	Yes	No	19,500	6	10	2	49	34
94	S Chester St & W Franklin Bv	4-leg	Yes	No	15,000	5	10	3	42	44
95	S College Rd & Wrightsville Ave	4-leg	Yes	No	46,000	6	10	3	60	30
96	S McDowell St & W Morgan St	4-leg	Yes	No	21,500	4	8	4	45	27
97	Armstrong Park Rd/Cox Rd & E Franklin Bv	4-leg	Yes	Yes	38,500	8	10	1	73	36
98	Beechwood Dr & Bethlehem Rd	4-leg	Yes	No	10,500	5	10	1	53	47
99	Biltmore Ave & S Charlotte St	4-leg	Yes	Yes	16,000	5	7	2	65	52
100	Biltmore Ave & Bryson St/Meadow Rd	4-leg	Yes	No	22,500	5	10	1	60	41
101	Branchview Dr NE/Branchview Dr SE & Cabarrus Av E/Old Salisbury-Concord Rd	4-leg	Yes	No	22,000	4	10	1	49	44
102	Bridford Pkwy & Guilford College Rd	4-leg	Yes	No	21,000	7	10	1	67	22
103	Cabarrus Av E & Church St S	4-leg	Yes	No	11,500	4	10	1	36	65
104	Capital Bv & Spring Forest Rd	4-leg	Yes	No	50,500	10	10	3	61	32
106	Chapel Hill Rd & Trinity Rd	4-leg	Yes	Yes	28,000	5	10	1	43	50
107	Cliffdale Rd & S Reilly Rd	4-leg	Yes	No	40,000	8	6	2	59	33

108	College Rd/Guilford College Rd & W Market St	4-leg	Yes	No	22,000	5	10	1	59	35
109	Country Club Rd & Western Bv	4-leg	Yes	Yes	40,500	7	10	6	67	27
110	Creedmoor Rd & Glenwood Ave	4-leg	Yes	Yes	53,000	9	10	3	64	30
111	Creedmoor Rd & W Millbrook Rd	4-leg	Yes	Yes	33,500	6	10	1	72	30
112	Dillard Dr & Walnut St	4-leg	Yes	No	32,000	8	10	1	63	20
113	Duraleigh Rd/W Millbrook Rd & Glenwood Ave	4-leg	Yes	No	33,000	9	10	1	61	26
114	E 14th St & Greenville Bv SE	4-leg	Yes	No	38,000	5	10	1	65	25
115	E Edenton St & N Blount St	4-leg	Yes	No	9,500	3	10	1	46	33
116	E Hudson Bv/W Hudson Bv & S York Rd	4-leg	Yes	No	22,000	6	10	2	59	32
117	E Millbrook Rd & Old Wake Forest Rd	4-leg	Yes	No	19,500	5	10	1	49	38
119	Eastchester Dr/Westchester Dr & N Main St	4-leg	Yes	Yes	27,000	6	9	3	71	23
120	Evans St & SE Greenville Bv/SW Greenville Bv	4-leg	Yes	No	34,000	8	10	4	67	27
121	Fayetteville Rd & NC 54 E Hwy/NC 54 W Hwy	4-leg	Yes	No	33,000	8	10	2	62	27
122	Garrett Rd & Old Chapel Hill Rd	4-leg	Yes	No	28,000	7	9	1	63	36
124	Gum Branch Rd & Western Bv	4-leg	Yes	No	29,500	6	10	1	58	24
125	Hogan St/Shaw Mill Rd & Murchison Rd	4-leg	Yes	No	20,000	5	10	2	54	42
126	Hope Valley Rd/NC 751 Hwy & NC 54 W Hwy	4-leg	Yes	No	21,500	6	10	1	58	32
127	Jones Franklin Rd & Tryon Rd	4-leg	Yes	No	33,000	6	10	1	58	21
128	Kildaire Farm Rd & Ten-Ten Rd	4-leg	Yes	No	22,500	5	10	2	60	21
129	Lakeview Rd & W W T Harris Bv	4-leg	Yes	No	27,500	6	10	1	37	52
130	Lakewood Dr/King Rd & Rockfish Rd/Stoney Point Rd	4-leg	Yes	Yes	13,500	4	10	1	33	57
131	Latta Rd/Infinity Rd & N Roxboro St	4-leg	Yes	No	31,500	5	10	2	51	58
132	Lead Mine Rd & W Millbrook Rd	4-leg	Yes	No	22,000	5	10	1	68	23
133	Long Shoals Rd & Overlook Rd	4-leg	Yes	No	32,500	5	10	1	62	48

134	Louisburg Rd & N New Hope Rd	4-leg	Yes	No	31,500	9	8	2	61	36
135	Lynn Rd & Ray Rd	4-leg	Yes	No	20,500	5	10	1	42	41
137	Martin Luther King Jr Pkwy & N Kerr Ave	4-leg	Yes	Yes	45,500	8	10	1	63	16
138	Morganton Rd & Skibo Rd	4-leg	Yes	No	43,500	9	10	4	60	38
139	N Church St & N Graham Hopedale Rd/S Graham Hopedale Rd	4-leg	Yes	No	20,000	7	10	8	62	33
140	N Church St & W Thomas St	4-leg	Yes	No	3,700	3	10	1	6	42
141	N Duke St & W Carver St	4-leg	Yes	No	34,500	5	10	1	58	37
142	N Fisher St & Rauhut St/W Holt St	4-leg	Yes	Yes	12,000	4	10	1	58	41
143	N Fisher St/S Fisher St & W Webb Ave	4-leg	Yes	No	13,000	5	10	1	42	38
144	N Franklin St & W Thomas St	4-leg	Yes	No	3,600	3	10	1	9	42
145	N Marine Bv & Western Bv	4-leg	Yes	No	37,000	9	10	4	60	20
146	N Memorial Dr & W Belvoir Rd/Belvoir Hwy	4-leg	Yes	No	20,000	6	10	1	49	35
147	N New Hope Rd & New Bern Ave	4-leg	Yes	No	33,500	10	10	2	60	35
148	N Wesleyan Blvd & Jeffreys Rd	4-leg	Yes	No	15,000	6	10	2	54	46
149	NC 55 Hwy & Riddle Rd	4-leg	Yes	No	20,500	5	10	2	53	44
150	S 16th St & Wooster St	4-leg	Yes	No	18,500	4	10	2	33	31
151	S 17th St & Dawson St	4-leg	Yes	No	22,500	4	10	1	49	29
153	S Church St & N Oneal St/S Oneal St	4-leg	Yes	No	26,000	5	10	1	53	56
154	S Kerr Ave & Wilshire Bv	4-leg	Yes	No	13,500	4	10	5	43	47
155	S Memorial Dr & Stantonsburg Rd/Farmville Bv	4-leg	Yes	Yes	28,000	10	6	2	67	37
156	S Memorial Dr & SW Greenville Bv	4-leg	Yes	Yes	36,500	7	10	1	64	29
157	S Stratford Rd & Hanes Mall Bv	4-leg	Yes	No	40,500	8	10	1	43	37
158	S Tryon St & Steele Creek Rd	4-leg	Yes	No	34,000	7	10	3	54	17
159	S Tryon St & W Arrowood Rd	4-leg	Yes	No	33,500	7	10	5	56	21
160	S Tryon St & Westinghouse Bv	4-leg	Yes	No	45,000	7	10	2	57	26
161	S Tunnel Rd & Swannanoa River Rd & Wood Ave	4-leg	Yes	No	16,500	5	10	1	51	32
162	S York St & W Franklin Bv	4-leg	Yes	No	16,500	5	10	2	46	27
163	Santa Fe Dr & Yadkin Rd	4-leg	Yes	No	22,000	6	10	4	67	32

164	Skycrest Dr & Trawick Rd	4-leg	Yes	No	17,000	4	10	1	48	42
165	W Franklin Bv & Edgewood Rd/Archie Whitesides Rd	4-leg	Yes	No	14,000	5	10	2	47	47
167	W Lexington Av & Westchester Dr	4-leg	Yes	Yes	26,000	6	10	1	61	33
168	W Main St & Broad St/Swift Ave	4-leg	Yes	Yes	22,500	5	10	1	36	56
169	W Sugar Creek Rd & W W T Harris Bv	4-leg	Yes	No	36,500	6	6	1	57	39
170	Providence Rd & S Wendover Rd	4-leg	Yes	No	32,000	5	10	0	59	31
171	Providence Rd & Pineville-Matthews Rd	4-leg	Yes	Yes	37,000	9	10	0	73	22
172	Providence Rd & Ballantyne Commons Pkwy/McKee Rd	4-leg	Yes	Yes	44,000	7	10	0	59	32
173	Ardrey Kell Rd & Rea Rd	4-leg	Yes	No	31,500	6	8	0	54	18
174	E WT Harris Bv & Grier Rd	4-leg	Yes	No	50,000	6	10	1	57	36
175	E WT Harris Bv & Rocky River Rd	4-leg	Yes	No	48,500	7	10	0	61	31
176	W WT Harris Bv & Statesville Rd	4-leg	Yes	No	45,500	6	8	0	61	26
177	Statesville Rd & Sunset Rd/Old Statesville Rd	4-leg	Yes	Yes	40,000	7	10	1	70	28
178	E Millbrook Rd & Falls of Neuse Rd	4-leg	Yes	No	34,500	8	10	2	60	27
179	Six Forks Rd & Strickland Rd	4-leg	Yes	Yes	31,500	7	10	1	75	27
180	Leesville Rd & Lynn Rd	4-leg	Yes	No	17,000	6	10	0	58	22
181	Glenwood Ave & Ebenezer Church Rd	4-leg	Yes	No	39,000	6	10	0	65	34
182	Duraleigh Rd & Edwards Mill Rd	4-leg	Yes	No	29,500	7	10	0	58	23
183	Reedy Creek Rd & Edwards Mill Rd	4-leg	Yes	No	29,500	5	10	0	53	33
185	Poole Rd & S New Hope Rd	4-leg	Yes	No	25,000	7	7	0	59	17
186	Buffaloe Rd & N New Hope Rd	4-leg	Yes	No	28,500	6	10	0	57	33
187	E Wendover Ave & Penry Rd	4-leg	Yes	No	21,500	6	10	0	46	40
188	N Roxboro St & Horton Rd/Denfield St	4-leg	Yes	No	18,000	4	10	0	48	50
189	E Club Blvd & Dearborn Dr/Midland Ter	4-leg	Yes	No	10,000	2	10	0	48	50
190	Cheek Rd & Midland Ter/Muldee St	4-leg	Yes	No	17,500	5	10	1	50	47
191	N Alston Ave & E Geer St	4-leg	Yes	No	13,000	3	10	0	43	49
192	S Alston Ave & E Cornwallis Rd	4-leg	Yes	Yes	15,000	3	10	0	38	37

193	TW Alexander Dr & S Miami Blvd	4-leg	Yes	No	32,000	7	7	0	57	22
195	Davis Dr & Hopson Rd	4-leg	Yes	No	21,500	8	10	0	61	16
196	NC 55 & Sedwick Rd	4-leg	Yes	No	24,500	6	10	0	57	23
197	Academy Rd & W Cornwallis Rd	4-leg	Yes	No	11,000	3	10	0	48	34
198	S Roxboro St & W Cornwallis Rd	4-leg	Yes	No	13,000	5	10	0	51	40
199	Old Chapel Hill Rd & Farrington Rd/SW Durham Dr	4-leg	Yes	No	15,000	4	8	0	63	51
200	NC 54 & Farrington Rd	4-leg	Yes	No	46,000	8	10	0	59	32
201	Germanton Rd & Oak Summit Rd	4-leg	Yes	No	16,000	2	10	0	43	57
202	University Pkwy & Oak Summit Rd	4-leg	Yes	Yes	37,500	6	10	0	55	36
203	S Martin Luther King Jr Dr & Waughtown St	4-leg	Yes	No	7,900	3	10	2	47	52
204	Kernersville Rd & Sedge Garden Rd	4-leg	Yes	No	14,000	2	10	0	36	63
206	Cedar Creek Rd & Clinton Rd	4-leg	Yes	Yes	15,000	6	10	0	65	38
208	Raeford Rd & Bunce Rd	4-leg	Yes	No	40,000	9	7	0	60	24
209	S Raeford Rd & Gillis Hill Rd	4-leg	Yes	No	22,000	7	10	0	56	26
210	Raeford Rd & Rim Rd/Gillis Hill Rd	4-leg	Yes	No	12,500	3	10	0	49	47
213	NW Maynard Rd/NE Maynard Rd & N Harrison Ave	4-leg	Yes	No	22,000	7	10	1	57	36
214	SE Cary Pkwy & Tryon Rd	4-leg	Yes	No	25,500	7	10	0	60	24
215	Kildaire Farm Rd & Tryon Rd	4-leg	Yes	Yes	34,500	7	10	0	68	22
216	Kildaire Farm Rd & Penny Rd	4-leg	Yes	No	25,000	6	10	0	63	23
218	SW Cary Pkwy/NW Cary Pkwy & High House Rd	4-leg	Yes	No	29,000	5	10	0	60	16
219	NC 55 & High House Rd/Green Level West Rd	4-leg	Yes	No	26,000	7	10	0	57	23
220	NW Cary Pkwy & Evans Rd	4-leg	Yes	No	11,000	5	10	0	60	23
221	Martin Luther King Jr Pkwy & Market St	4-leg	Yes	Yes	39,000	8	10	1	66	25
222	Eastwood Rd & Military Cutoff Rd	4-leg	Yes	Yes	45,500	7	10	1	65	22
224	S Kerr Ave & Wrightsville Ave	4-leg	Yes	No	13,500	5	10	1	59	36
225	Eastchester Dr & N University Pkwy/E Hartley Dr	4-leg	Yes	No	24,500	7	10	0	51	37

226	N Main St & E Lexington Ave/W Lexington Ave	4-leg	Yes	Yes	26,000	5	10	2	60	42
227	S Main St & E Green Dr/W Green Dr	4-leg	Yes	No	14,000	5	10	0	27	42
228	S Main St & E Market Center Dr/W Market Center Dr	4-leg	Yes	No	25,500	4	10	0	34	37
229	S Main St & S University Pkwy/College Dr	4-leg	Yes	No	27,500	5	10	0	27	61
230	W Green Dr & W Market Center Dr	4-leg	Yes	No	11,000	6	10	0	42	55
231	W English Rd & Westchester Dr/W Market Center Dr	4-leg	Yes	Yes	20,500	7	10	0	69	36
232	E Fairfield Rd/W Fairfield Rd & S Main St	4-leg	Yes	Yes	23,000	7	10	3	65	36
233	E Fairfield Rd & Baker Rd	4-leg	Yes	No	10,000	3	10	0	31	58
234	Warren C Coleman Bv N & Cabarrus Ave W	4-leg	Yes	No	21,000	5	10	1	57	23
235	George W Liles Pkwy NW & Poplar Tent Rd	4-leg	Yes	No	34,000	8	10	1	68	37
238	Warren C Coleman Bv & Wilshire Ave SW	4-leg	Yes	No	17,000	4	10	0	51	40
239	Branchview Dr SE & Corban Ave SE	4-leg	Yes	No	21,000	4	10	0	48	40
240	Lodge St & Hendersonville Rd	4-leg	Yes	No	23,500	5	10	1	14	59
242	Hendersonville Rd & Long Shoals Rd/Miller Rd S	4-leg	Yes	No	34,000	6	10	1	63	38
243	Hendersonville Rd & Sweeten Creek Rd/Airport Rd	4-leg	Yes	No	26,000	7	10	1	61	37
244	S Memorial Dr & Dickinson Ave	4-leg	Yes	Yes	20,500	7	10	0	64	36
245	Stantonsburg Rd & Allen Rd	4-leg	Yes	No	32,500	6	10	0	53	33
246	N Memorial Dr & Briley Rd	4-leg	Yes	Yes	22,000	6	10	0	49	36
247	N Greene St & Airport Rd/Mumford Rd	4-leg	Yes	No	12,500	5	10	0	57	38
248	Greenville Bv SE & Charles Bv	4-leg	Yes	Yes	32,000	6	10	0	63	29
249	Charles Bv & E Fire Tower Rd	4-leg	Yes	No	34,000	5	10	0	63	28
250	N Marine Bv & Gum Branch Rd/Bell Fork Rd	4-leg	Yes	No	28,500	6	10	6	63	28

251	E Franklin Bv & N New Hope Rd/S New Hope Rd	4-leg	Yes	No	24,500	8	10	2	64	43
253	S New Hope Rd & Armstrong Park Rd	4-leg	Yes	Yes	22,000	5	10	1	68	27
254	E Hudson Bv & Armstrong Park Rd/Gaston Day School Rd	4-leg	Yes	No	14,500	5	10	1	60	27
255	E Hudson Bv & Redbud Dr/Hoffman Rd	4-leg	Yes	No	15,000	7	10	0	59	23
256	S New Hope Rd & E Hudson Bv/Titman Rd	4-leg	Yes	Yes	18,000	5	7	0	55	36
257	E Hudson Bv & Robinwood Rd	4-leg	Yes	No	17,000	5	7	0	67	30
258	Union Rd & E Hudson Bv	4-leg	Yes	No	17,000	7	7	0	58	21
259	Union Rd & Neal Hawkins Rd/Robinwood Rd	4-leg	Yes	Yes	22,500	5	10	0	61	31
261	Bessemer City Rd & Shannon Bradley Rd/Jenkins Dairy Rd	4-leg	Yes	Yes	23,000	5	8	0	43	58
263	Chapel Hill Rd & S Mebane St	4-leg	Yes	Yes	13,000	6	8	0	61	44
264	S Fisher St & W Front St	4-leg	Yes	No	12,000	3	10	0	30	46
265	Chapel Hill Rd & Tucker St	4-leg	Yes	Yes	11,500	4	10	0	38	51
266	Maple Ave & Chapel Hill Rd/Harden St	4-leg	Yes	Yes	23,000	5	10	0	73	32
267	S Church St & S Williamson Ave/St Marys Church Rd	4-leg	Yes	No	19,500	5	9	1	60	26
268	Sunset Ave & N Halifax Rd/S Halifax Rd	4-leg	Yes	No	22,500	5	10	0	50	39
269	Bethlehem Rd & Old Mill Rd	4-leg	Yes	No	12,500	5	10	0	43	58
270	S Franklin St & W Raleigh Bv	4-leg	Yes	No	9,900	4	10	0	32	38
271	E Grand Ave & Atlantic Ave	4-leg	Yes	No	10,000	4	10	1	49	42
272	N Church St & Airport Rd	4-leg	Yes	Yes	11,500	5	10	0	57	37
273	S Church St & Kingston Ave	4-leg	Yes	No	5,000	3	10	0	37	47
274	US 64 Alt & Springfield Rd	4-leg	Yes	No	12,000	5	10	0	51	46
275	I-85 & University City Bv	SPUI	Yes	Yes	37,000	4	10	1	23	25
276	I-85 & W Sugar Creek Rd	Diamond interchange	Yes	No	36,000	6	10	8	25	31
278	I-85 & Statesville Rd	Diamond interchange	Yes	No	29,500	6	10	3	17	37

279	I-85 & Brookshire Bv	SPUI	Yes	No	64,000	6	10	6	54	26
280	I-85 & Freedom Dr	SPUI	Yes	No	43,000	8	10	6	54	24
281	I-485 & S Tryon St	Partial clover diamond interchange	Yes	Yes	50,500	6	7	3	21	31
282	I-40 & Gorman St	Diamond interchange	Yes	Yes	20,000	6	10	1	17	34
286	I-40 & Randleman Rd	Unusual Interchange	Yes	Yes	31,000	6	10	9	22	39
287	W Wendover Ave SB & W Market St	Interchange	Yes	No	12,000	6	6	2	37	35
288	I-40 & W Wendover Ave	Diamond interchange with single clover	Yes	Yes	55,500	10	10	3	31	38
290	I-85 & N Roxboro St	Two diamond interchanges	Yes	Yes	19,000	7	10	5	45	37
291	I-85 & N Duke St	Partial Clover Interchange	Yes	Yes	36,500	6	10	1	15	46
292	I-85 & Guess Rd	Diamond interchange	Yes	Yes	29,000	8	10	4	26	35
293	I-40 & Durham Chapel Hill Bv	Diamond interchange	Yes	Yes	52,500	10	10	1	29	30
294	I-40 & Fayetteville Rd	SPUI	Yes	No	34,000	6	10	2	31	27
296	US 421 & Jonestown Rd	Unusual interchange	Yes	Yes	21,500	4	10	3	31	54
298	All American Exp & Morganton Rd	Diamond interchange	Yes	No	35,000	9	9	4	31	28
300	I-85 & Bruton Smith Bv	Partial clover diamond interchange	Yes	No	45,000	7	10	2	25	29
302	I-40/I-85 & Maple Ave	4-leg	Yes	Yes	23,000	8	10	2	23	37
303	I-40/I-85 & Alamance Rd	4-leg	Yes	No	21,500	6	10	1	19	34
304	US 64 & E Raleigh Bv	Diamond interchange	Yes	Yes	12,000	5	10	1	13	38
308	Eastwood Rd & Tanbridge Rd/Carolina Bay Dr	RCUT	No	No	33,000	6	10	1	32	30
318	US 15/501 & Erwin Rd/Europa Dr	RCUT	Yes	Yes	49,500	4	10	1	48	51
319	E 4th St & S College St	4-leg	Yes	No	14,500	3	10	12	24	42
321	E Trade St & N College St/S College St	4-leg	Yes	No	14,500	3	10	27	37	53
322	E Stonewall St & S College St	4-leg	Yes	No	13,000	4	7	9	29	38
323	E 6th St & N College St	4-leg	Yes	No	9,500	3	7	5	27	33
324	E 7th St & N College St	4-leg	Yes	No	6,400	3	10	1	17	57
325	W 6th St & N Church St	4-leg	Yes	No	7,800	3	10	2	19	61
326	W 7th St & N Church St	4-leg	Yes	No	5,600	3	10	0	31	50

327	Central Ave & The Plaza	4-leg	Yes	No	25,500	5	10	11	50	40
330	E Chapel Hill St & Foster St/Corcoran St	4-leg	Yes	No	4,500	2	10	4	21	70
331	W Morgan St & Rigsbee Ave	4-leg	Yes	No	5,300	2	7	2	17	59
332	N Roxboro St & Holloway St	4-leg	Yes	Yes	10,000	3	7	1	41	39
333	N Roxboro St & E Club Blvd	4-leg	Yes	No	31,000	5	10	4	67	24
334	Fayetteville St & E Lawson St	4-leg	Yes	No	15,000	3	10	3	26	61
335	S Columbia St & E Cameron Ave/W Cameron Ave	4-leg	Yes	No	12,500	5	10	3	13	50
336	N Columbia St & E Rosemary St/W Rosemary St	4-leg	Yes	No	14,000	5	10	6	63	41
337	S Columbia St & South Rd/McCauley St	4-leg	Yes	Yes	9,200	3	10	4	30	47
338	Western Blvd & Avent Ferry Rd/Morrill Dr	4-leg	Yes	No	36,500	7	10	9	58	32
339	Western Blvd & Dan Allen Dr	4-leg	Yes	No	34,000	6	10	8	49	35
340	Avent Ferry Rd & Varsity Dr	4-leg	Yes	No	21,000	6	5	2	45	37
341	Glenwood Ave & W Johnson St	4-leg	Yes	No	9,800	2	10	3	36	45
342	N West St & W Jones St	4-leg	No	No		2	10	1	27	46
344	New Bern Ave & N Tarboro St/S Tarboro St	4-leg	Yes	No	11,500	4	3	1	25	33
345	E Edenton St & N Tarboro St	4-leg	Yes	No	9,400	4	10	4	38	31
347	E Friendly Ave/W Friendly Ave & N Elm St	4-leg	Yes	No	12,500	4	10	5	30	39
348	E Market St & N Dudley St/S Dudley St	4-leg	Yes	No	15,500	6	10	2	59	27
349	E Market St & Laurel St	4-leg	Yes	No	15,500	5	10	4	31	31
350	E Market St & N Benbow Rd/S Benbow Rd	4-leg	Yes	No	15,500	5	10	6	35	41
351	W 4th St & N Cherry St	4-leg	Yes	No	7,300	2	10	1	25	49
352	W 4th St & N Liberty St	4-leg	Yes	No	7,300	2	6	0	24	44
353	Reynolds Blvd & Whitaker Park	4-leg	Yes	No	5,000	5	10	0	39	42
354	Merrimon Ave & Chestnut St	4-leg	Yes	No	24,500	4	10	7	21	54

355	Biltmore Ave/Broadway St & Patton Ave	4-leg	Yes	No	11,000	3	7	1	18	61
356	Broadway St & College St	4-leg	Yes	No	9,900	3	7	3	20	59

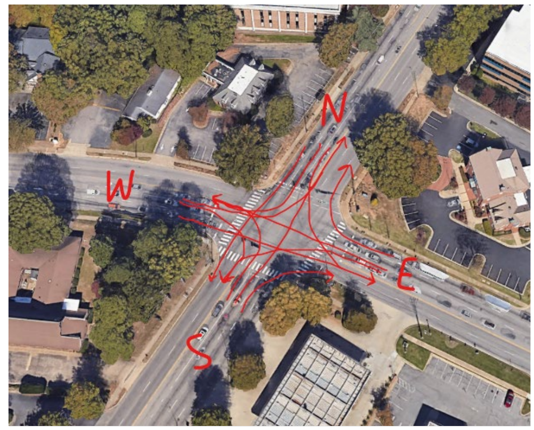
Note: Int = Intersection; SPUI = single point urban interchange; RCUT = Restricted Crossing U-Turn; bolded intersection numbers = site included in subsample for observed pedestrian movement, bicycle movement, and motor vehicle turning movement counts.

6.2 Subset of 100 Study Sites

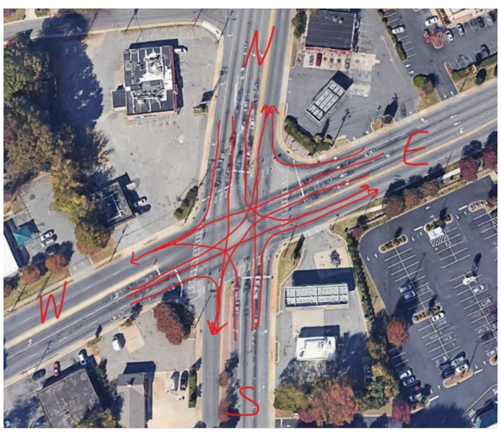
The following shows an aerial view from Google Maps for each of the 100 intersections that were coded. The bicycle movement paths and cardinal directions assigned to each leg are overlaid for reference.

Int 3: N Columbia/S Columbia St & E Franklin St/W Franklin St, Chapel Hill

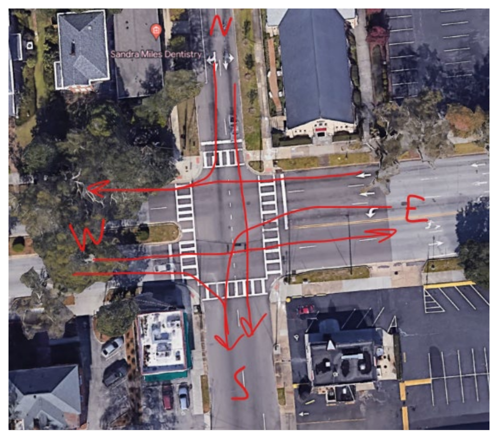
Int 4: E Millbrook Rd/W Millbrook Rd & Six Forks Rd, Raleigh



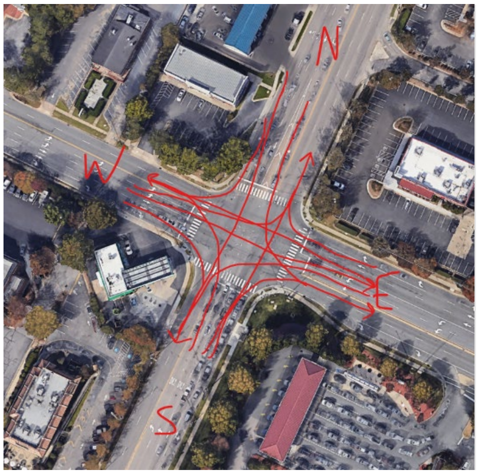
Int 5: Eastway Dr & The Plaza, Charlotte



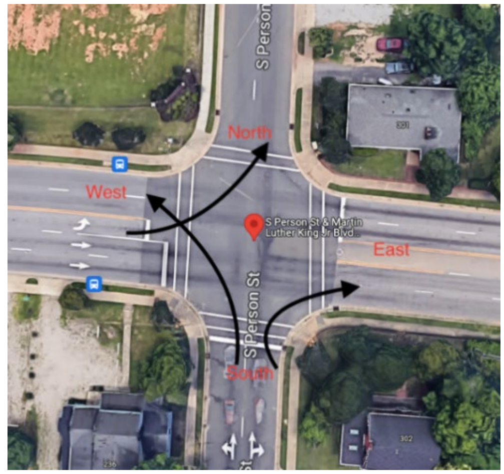
Int 6: Market St & N 16th St/S 16th St, Wilmington



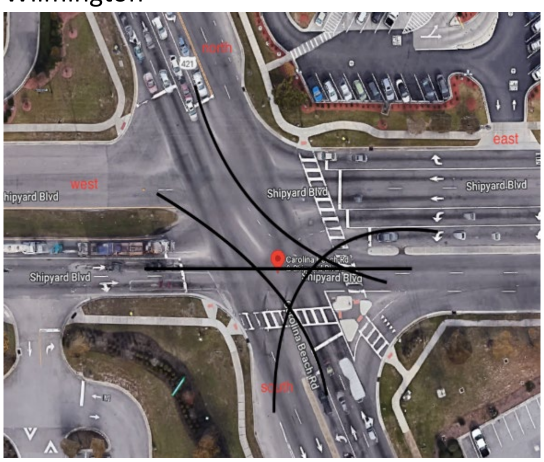
Int 10: E Six Forks Rd & Wake Forest Rd, Raleigh



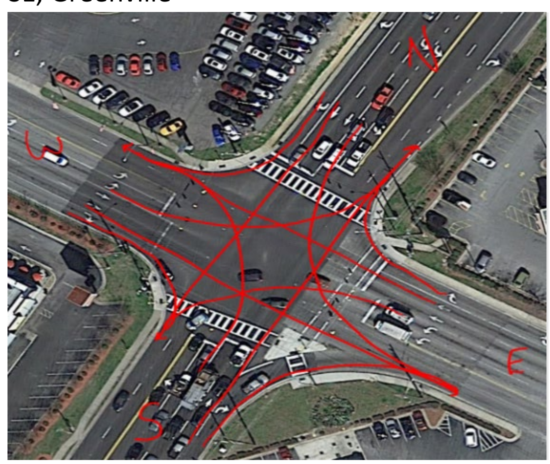
Int 13: Martin Luther King Jr Bv & S Person St, Raleigh



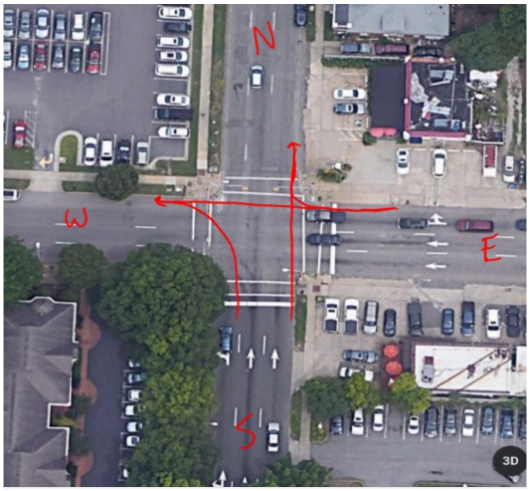
Int 17: Carolina Beach Rd & Shipyard Bv, Wilmington



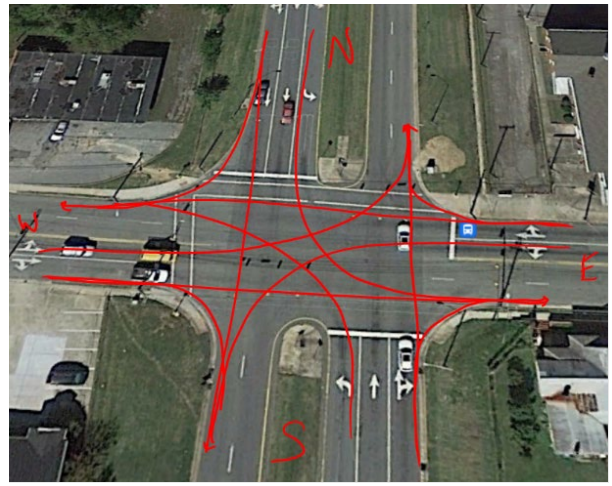
Int 18: E 10th St & Greenville Bv NE/Greenville Bv SE, Greenville



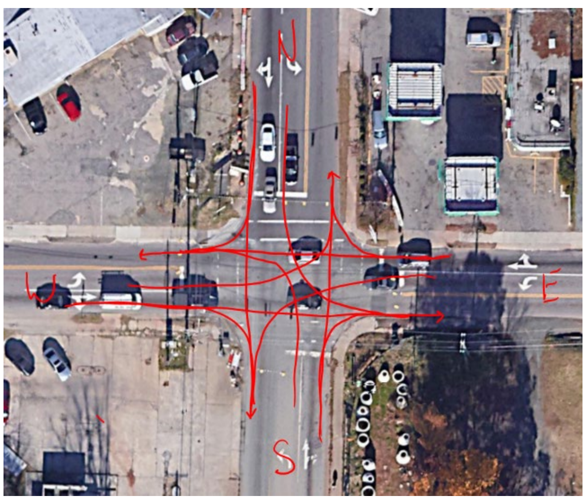
Int 19: E Edenton St & N Person St, Raleigh



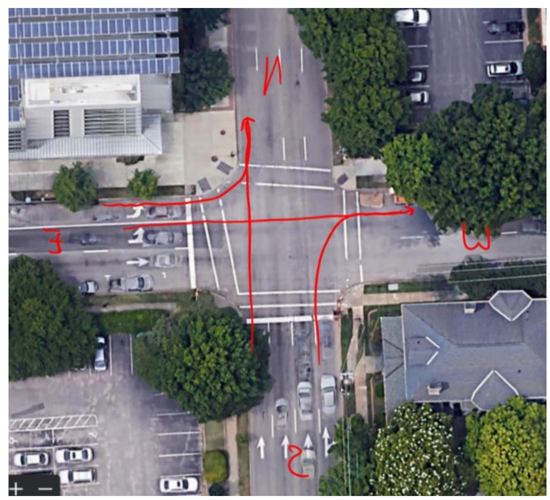
Int 20: E Green Dr & S University Pkwy, High Point



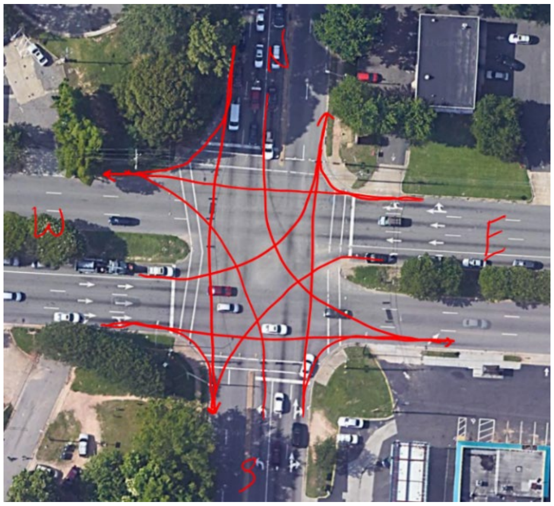
Int 21: Holloway St & N Alston Ave, Durham



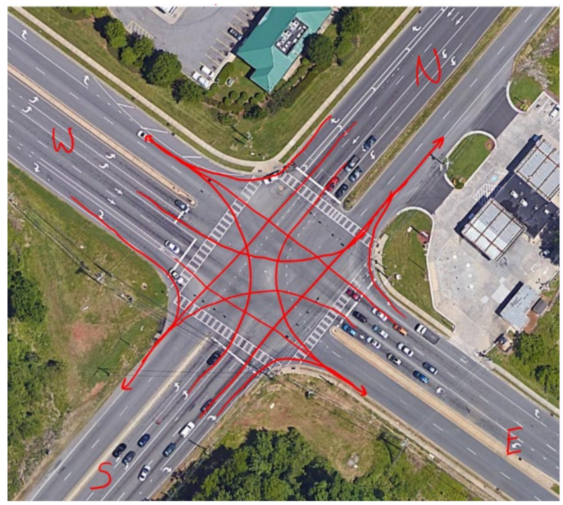
Int 25: N McDowell St & W Edenton St, Raleigh



Int 26: N Raleigh Bv & New Bern Ave, Raleigh

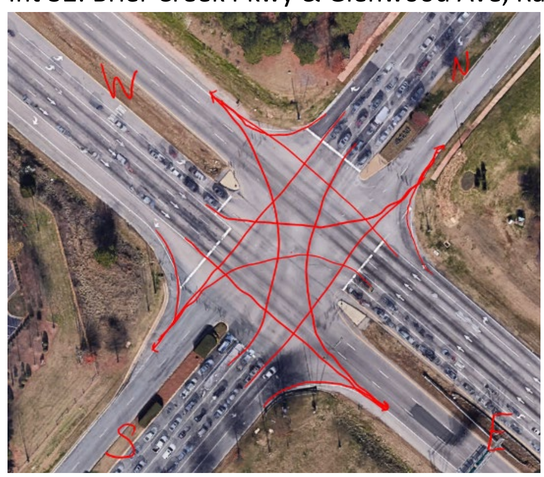


Int 27: N Tryon St & W Mallard Creek Church Rd/E Mallard Creek Church Rd, Charlotte

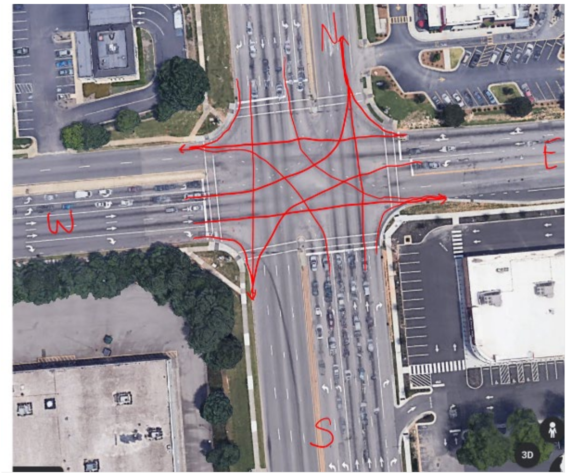


Int 28: S 16th St & Dawson St, Wilmington

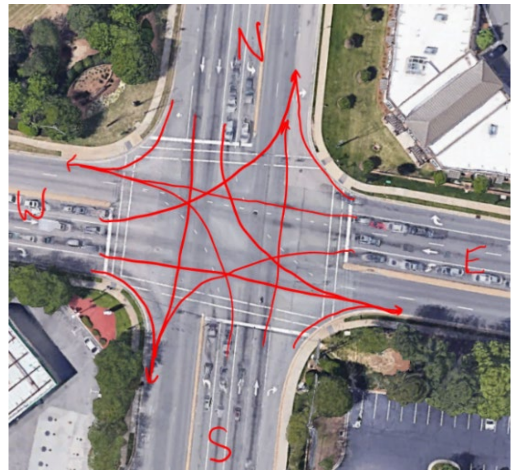
Int 32: Brier Creek Pkwy & Glenwood Ave, Raleigh



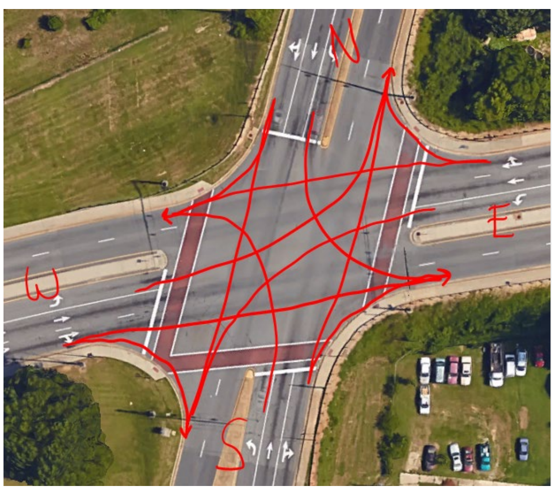
Int 33: Capital Bv & E Millbrook Rd/N New Hope Rd, Raleigh



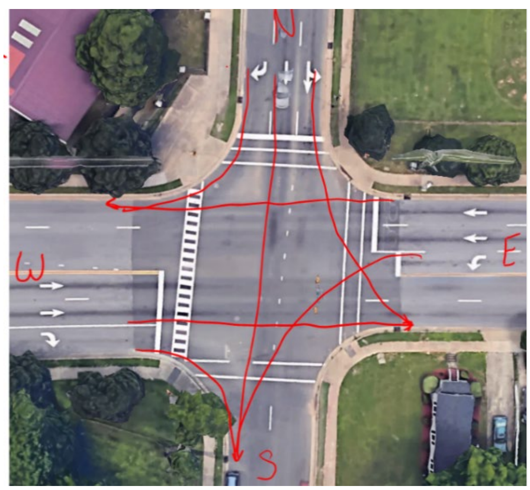
Int 34: Creedmoor Rd & Lynn Rd, Raleigh



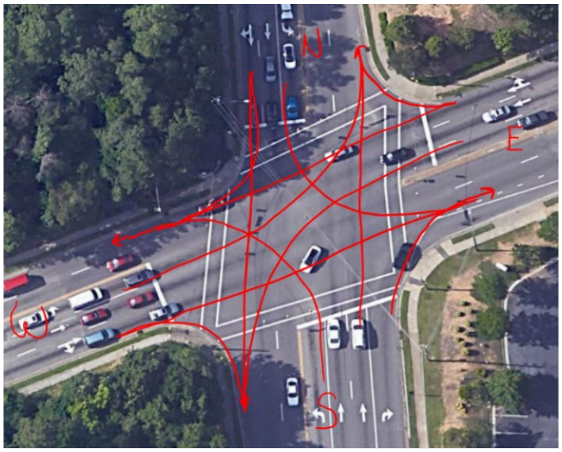
Int 36: E Martin Luther King Jr Dr & N University Pkwy/S University Pkwy, High Point



Int 44: Martin Luther King Jr Bv & S Blount St, Raleigh

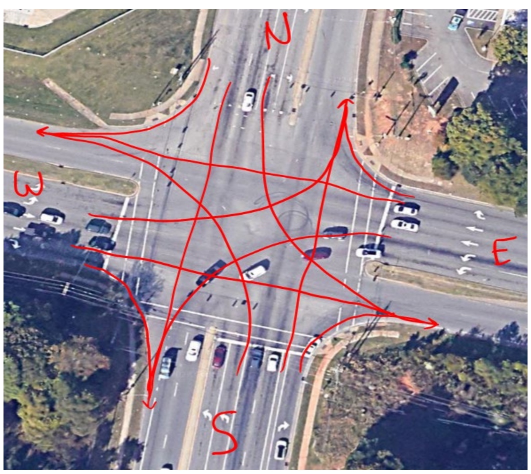


Int 45: Martin Luther King Jr Bv & S Raleigh Bv, Raleigh

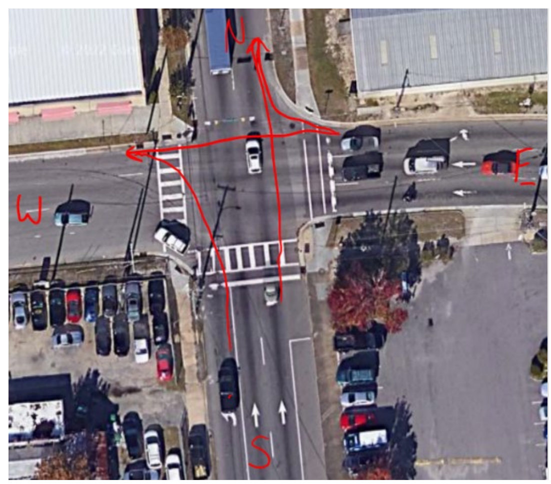


Int 47: N 23rd St & Princess Place Dr, Wilmington

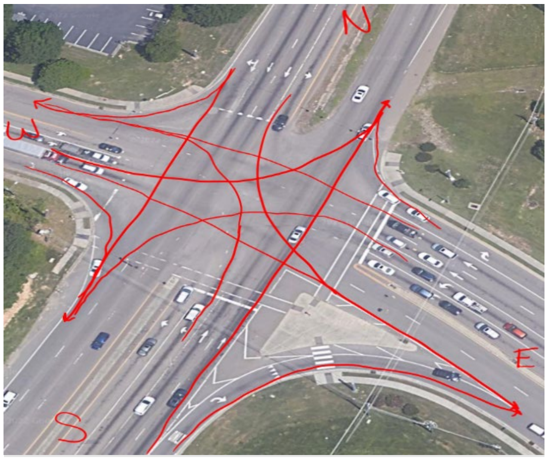
Int 49: Old Statesville Rd & W W T Harris Bv, Charlotte



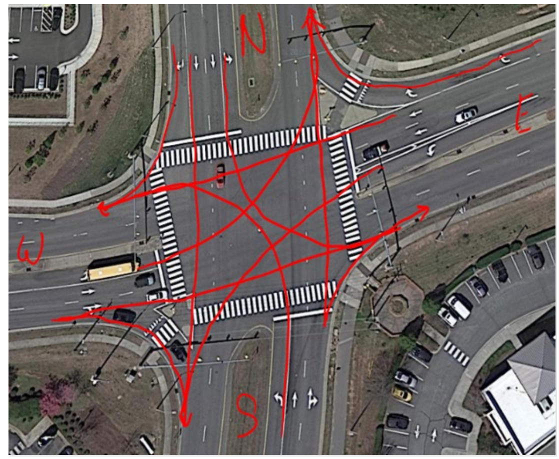
Int 50: S 17th St & Wooster St, Wilmington



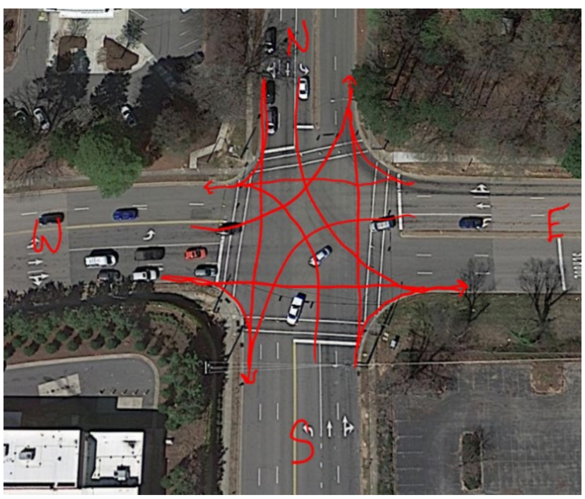
Int 59: Capital Bv & Durant Rd/Perry Creek Rd, Raleigh



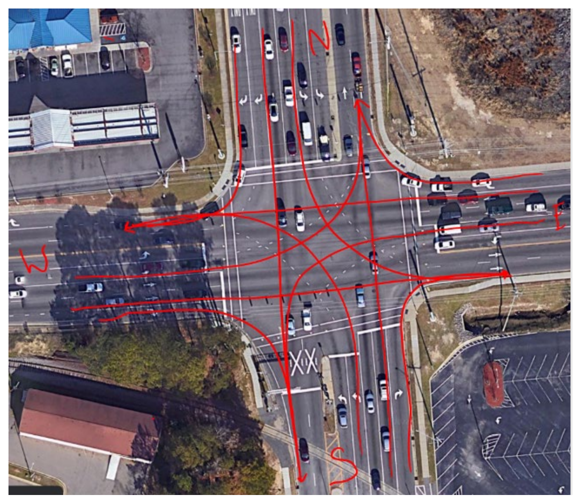
Int 60: Carpenter Fire Station Rd & Green Level Church Rd, Cary



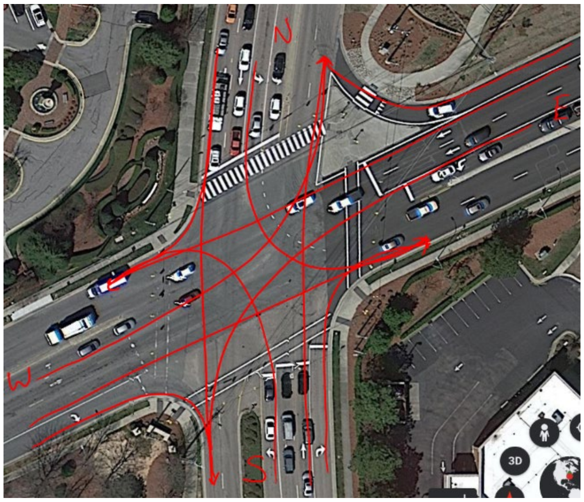
Int 61: Cary Towne Bv & SE Maynard Rd, Cary



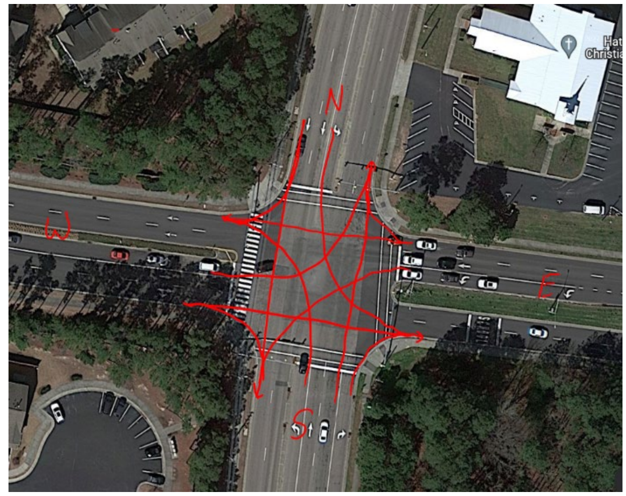
Int 62: Cliffdale Rd & Glensford Dr, Fayetteville



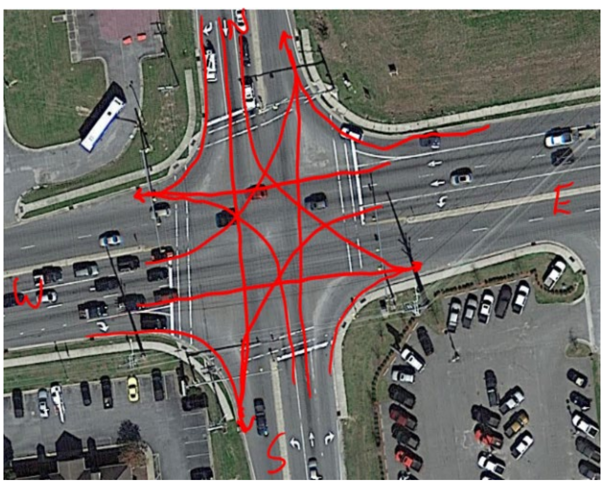
Int 64: Davis Drive & High House Road, Cary



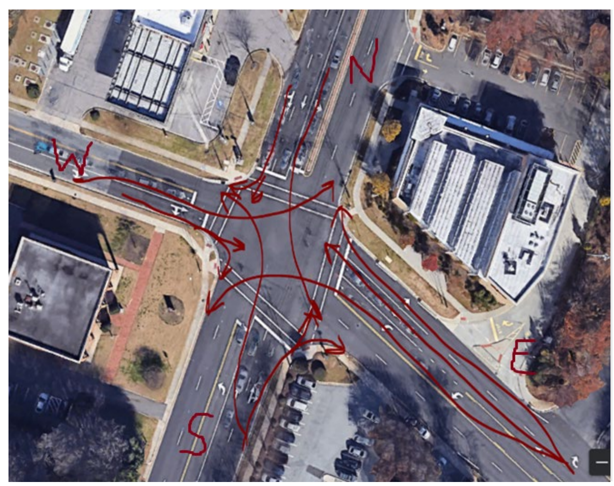
Int 65: Davis Drive & Morrisville Parkway, Cary



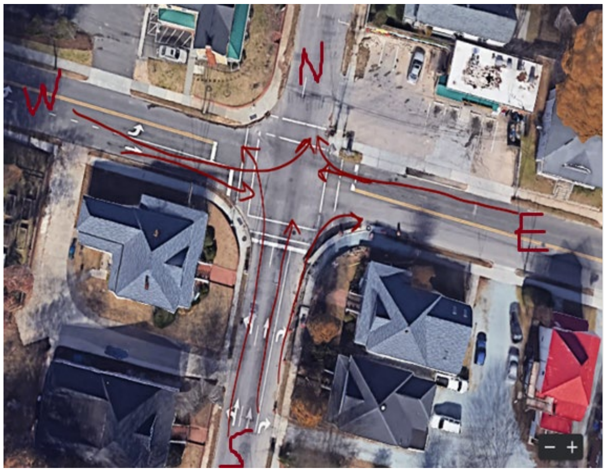
Int 67: E Fire Tower Rd/W Firetower Rd & Evans St/Old Tar Rd, Greenville



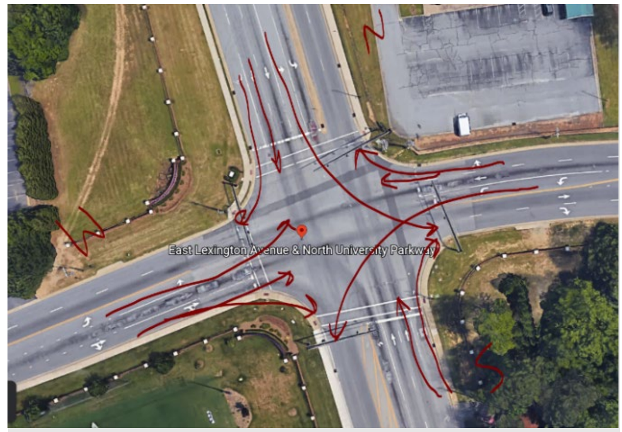
Int 68: E Franklin St & N Estes Dr/S Estes Dr, Chapel Hill



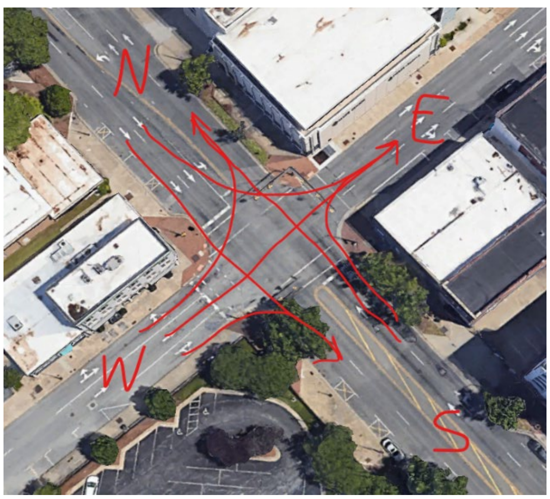
Int 69: E Geer St & N Roxboro St, Durham



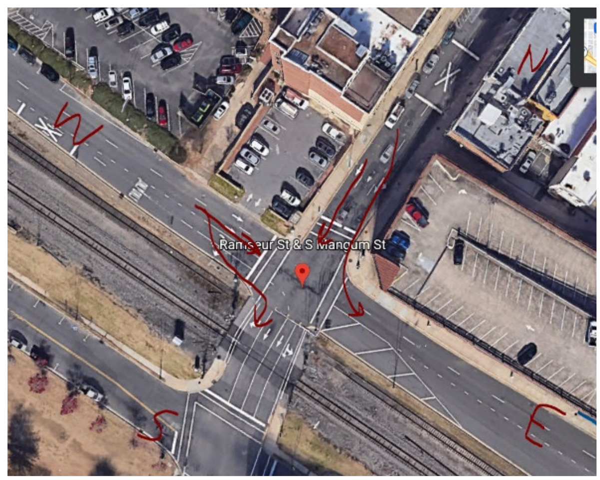
Int 70: E Lexington Av & N University Pkwy, High Point



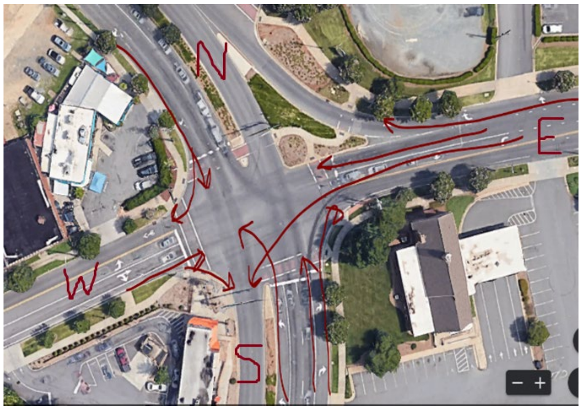
Int 71: E Martin Luther King Jr Dr/W Kivett Dr & N Main St, High Point



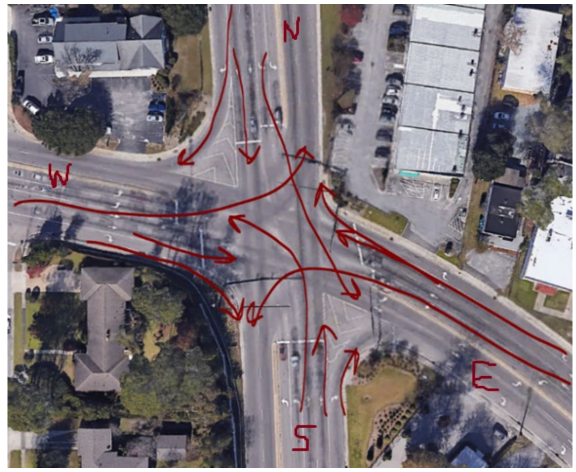
Int 73: E Ramseur St/W Ramseur St & S Mangum St, Durham



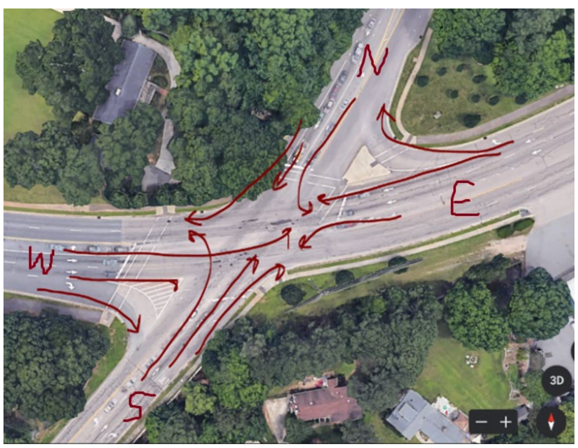
Int 75: Freedom Dr & W Morehead St, Charlotte



Int 80: Independence Bv & Wrightsville Ave, Wilmington

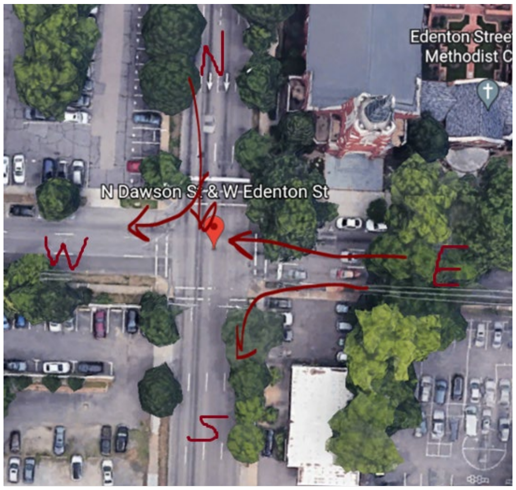


Int 82: Lead Mine Rd & Lynn Rd, Raleigh



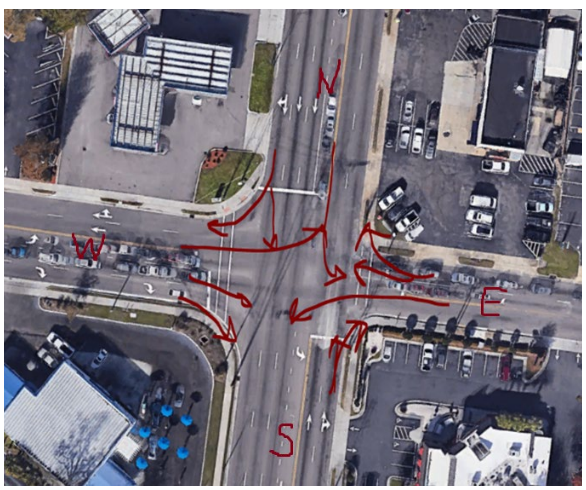
Int 84: Market St & N 17th St/S 17th St, Wilmington

Int 85: N Dawson St & W Edenton St, Raleigh

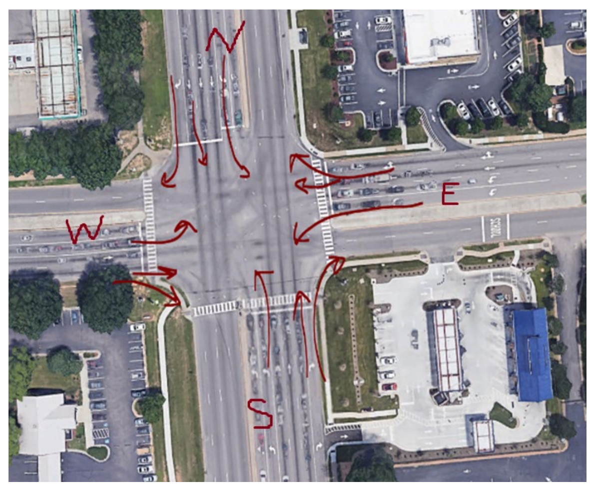


Int 92: Peters Creek Pkwy & Silas Creek Pkwy, Winston-Salem

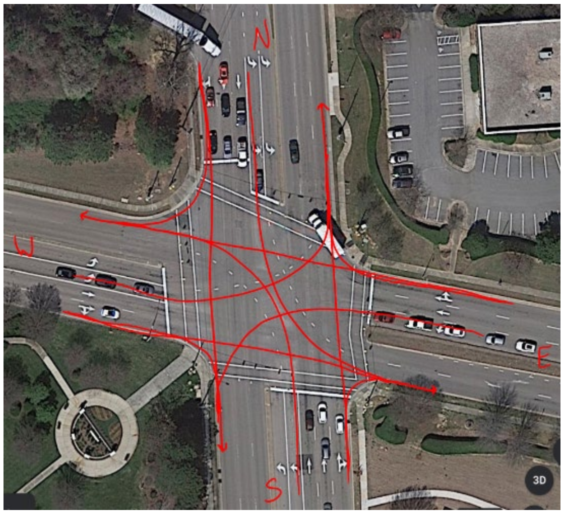
Int 95: S College Rd & Wrightsville Ave, Wilmington



Int 104: Capital Bv & Spring Forest Rd, Raleigh



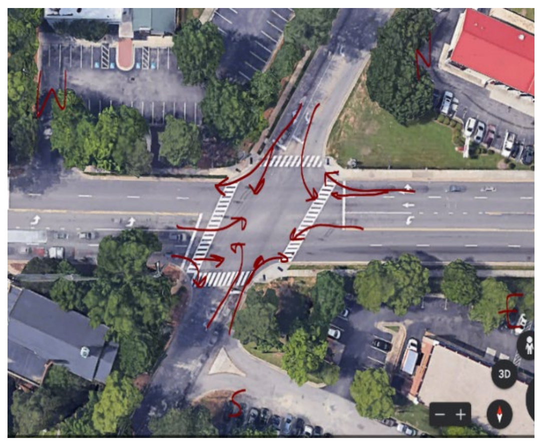
Int 112: Dillard Dr & Walnut St, Cary



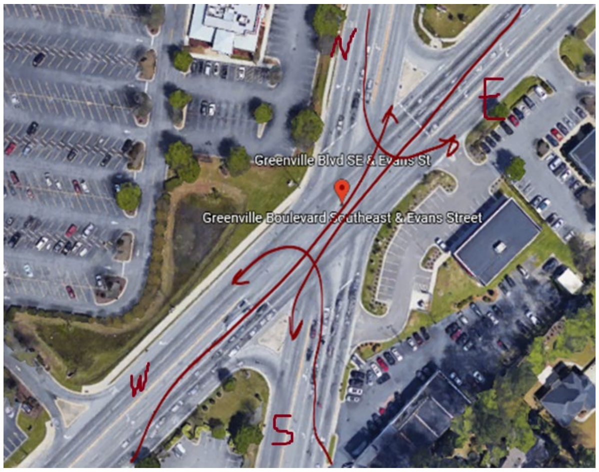
Int 114: E 14th St & Greenville Bv SE, Greenville

Int 115: E Edenton St & N Blount St, Raleigh

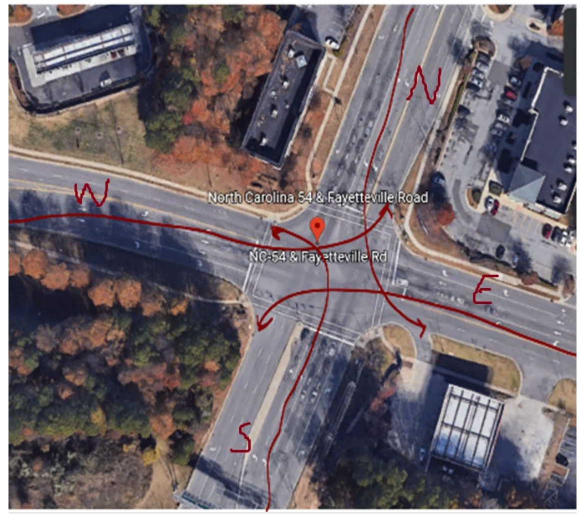
Int 117: E Millbrook Rd & Old Wake Forest Rd, Raleigh



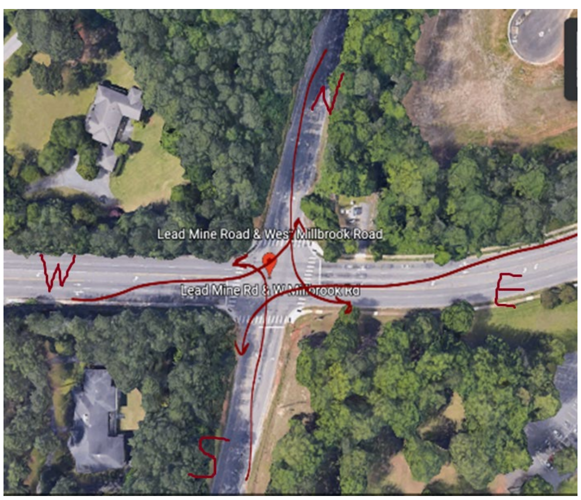
Int 120: Evans St & SE/SW Greenville Blvd, Greenville



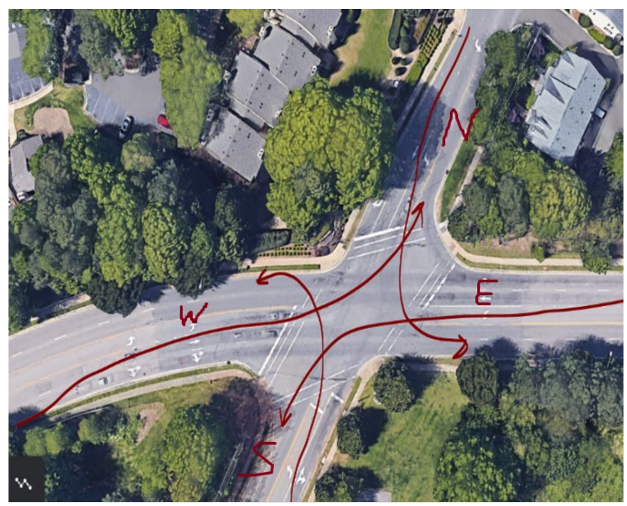
Int 121: Fayetteville Rd & NC 54, Durham



Int 132: Lead Mine Rd & W Millbrook Rd, Raleigh

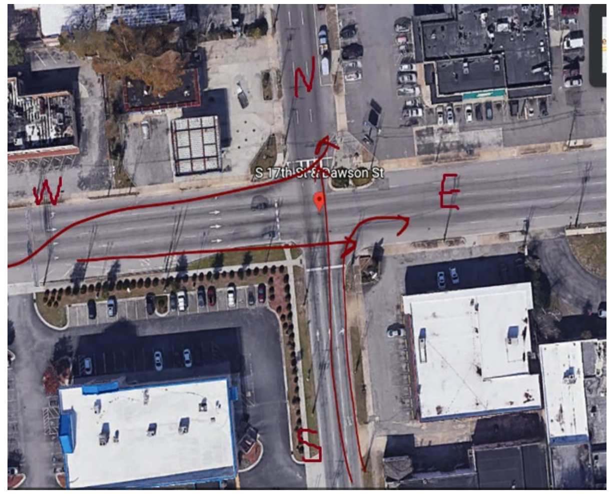


Int 135: Ray Rd & Lynn Rd, Raleigh

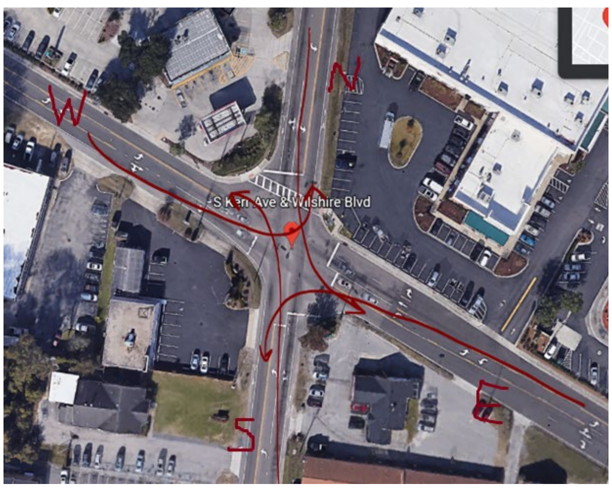


Int 150: S 16th St & Wooster St, Wilmington

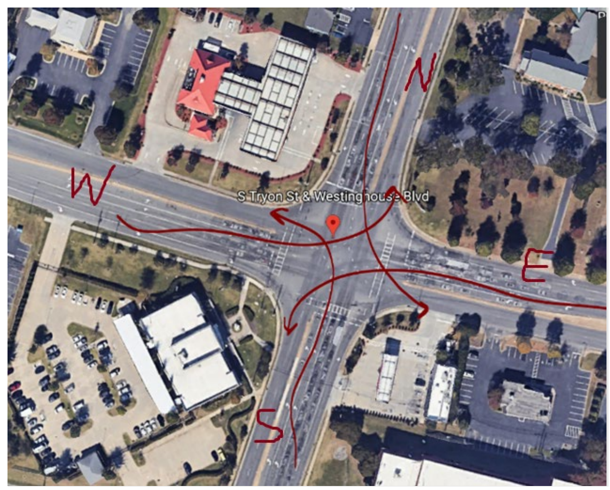
Int 151: S 17th St & Dawson St, Wilmington



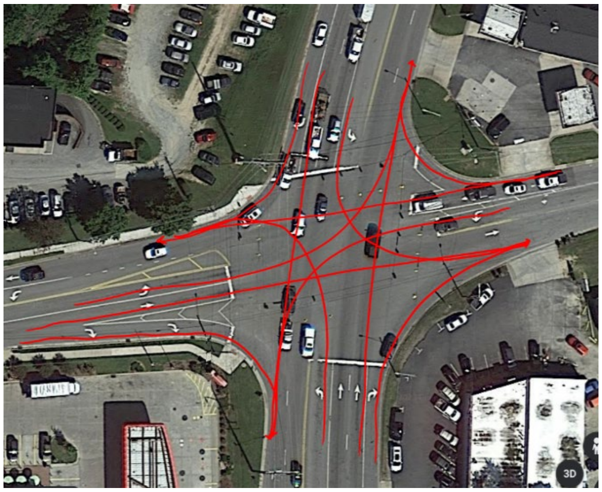
Int 154: S Kerr Ave & Wilshire Bv, Wilmington



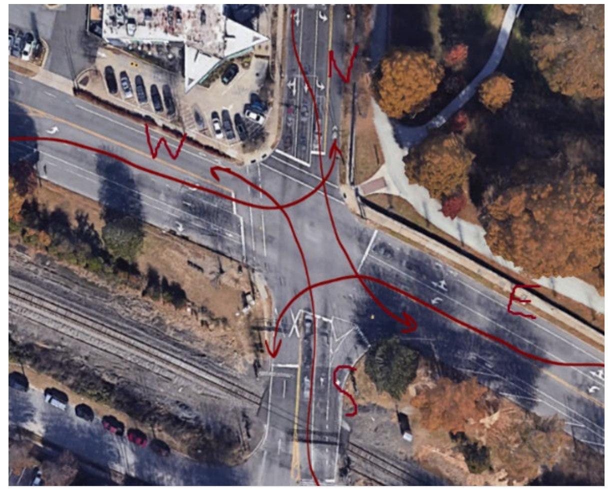
Int 160: S Tryon St & Westinghouse Bv, Charlotte



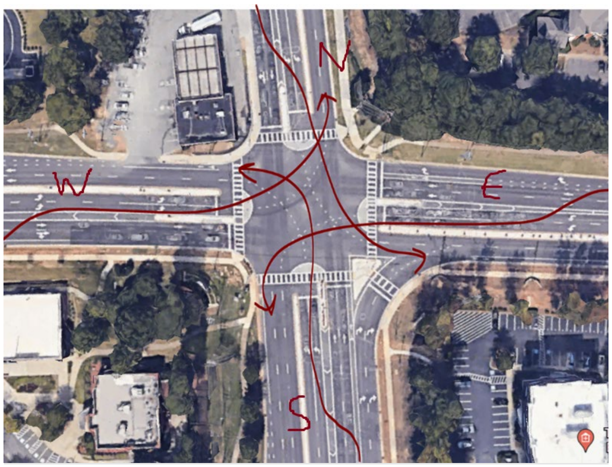
Int 167: W Lexington Av & Westchester Dr, High Point



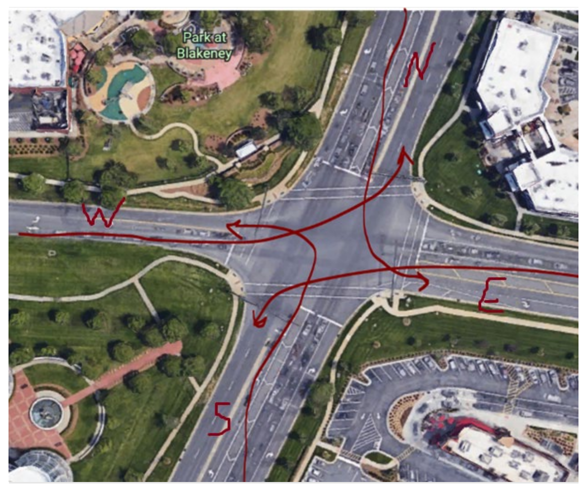
Int 168: W Main St & Broad St/Swift Ave, Durham



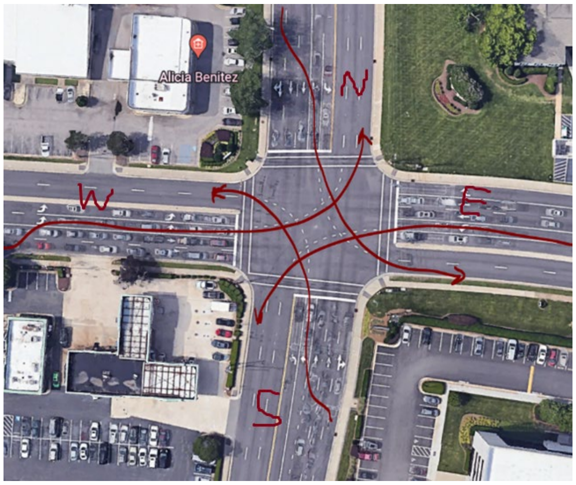
Int 172: Providence Rd & Ballantyne Commons Pkwy/McKee Rd, Charlotte



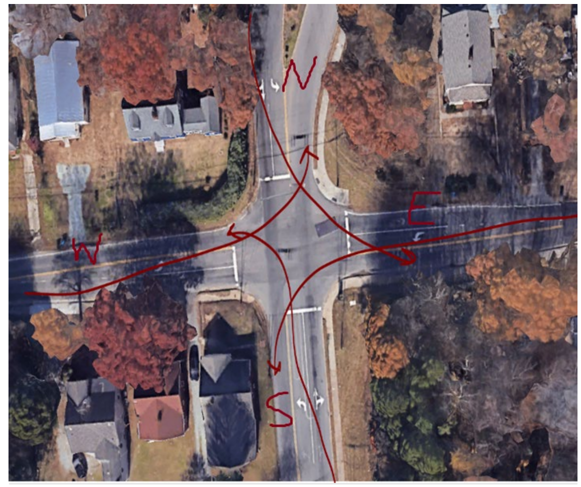
Int 173: Ardrey Kell Rd & Rea Rd, Charlotte



Int 178: E Millbrook Rd & Falls of Neuse Rd, Raleigh

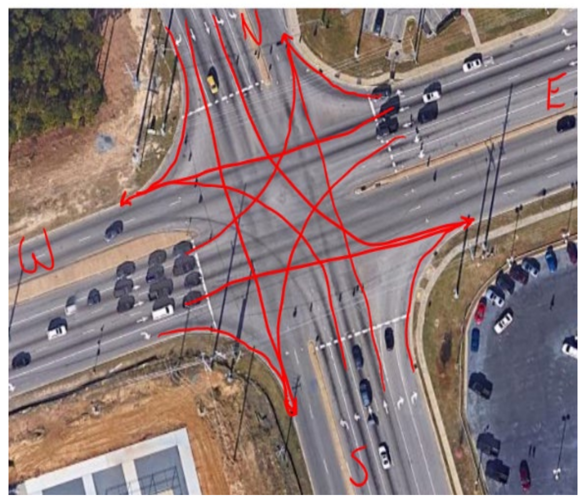


Int 191: N Alston Ave & E Geer St, Durham

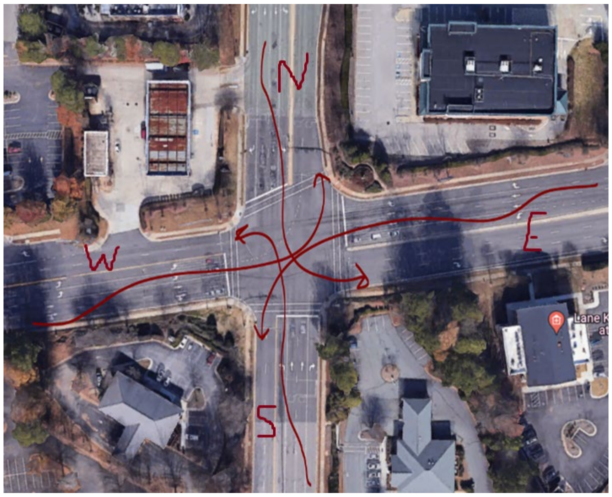


Int 198: S Roxboro St & W Cornwallis Rd, Durham

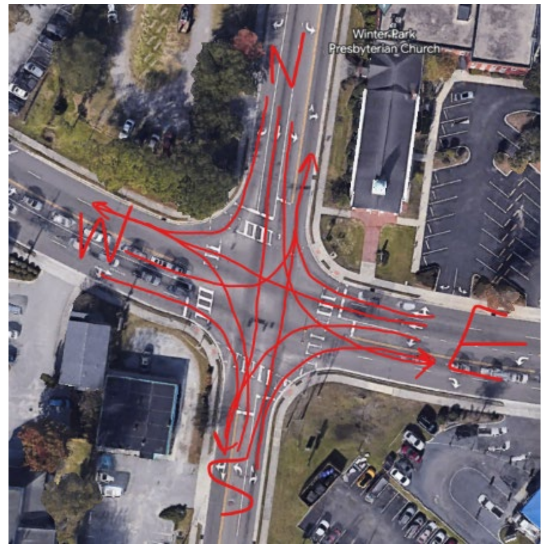
Int 208: Raeford Rd & Bunce Rd, Fayetteville



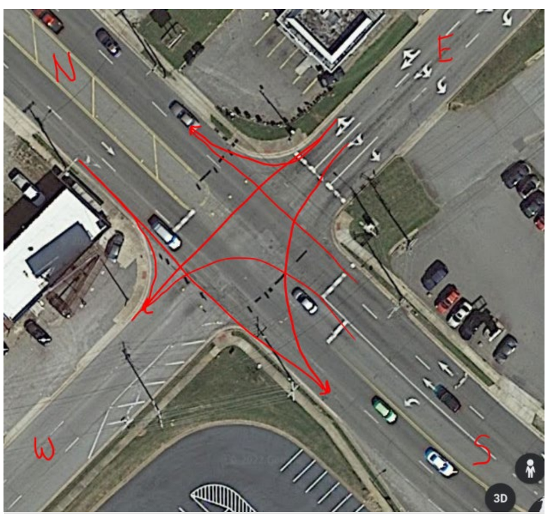
Int 213: NW Maynard Rd/NE Maynard Rd & N Harrison Ave, Cary



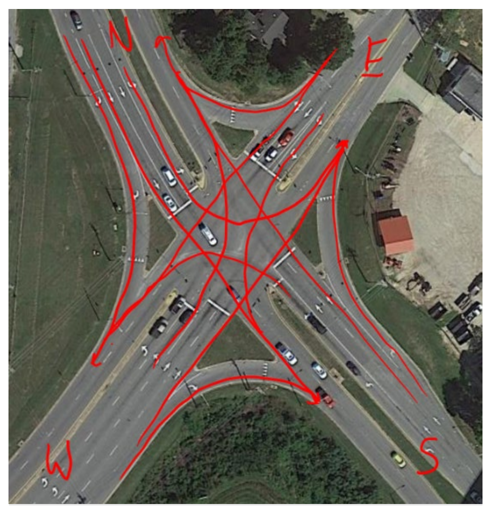
Int 224: S Kerr Ave & Wrightsville Ave, Wilmington



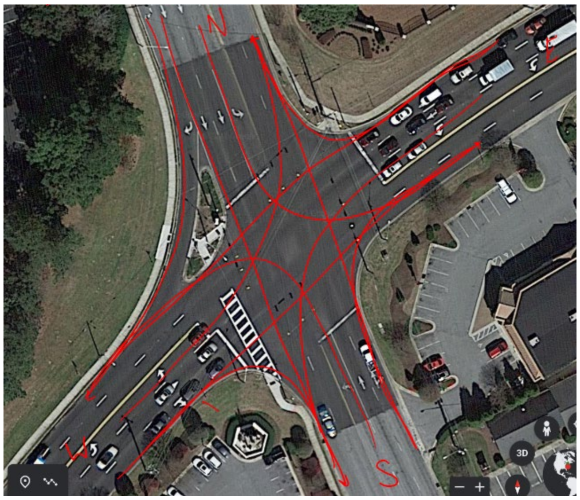
Int 228: S Main St & E Market Center Dr/W Market Center Dr, High Point



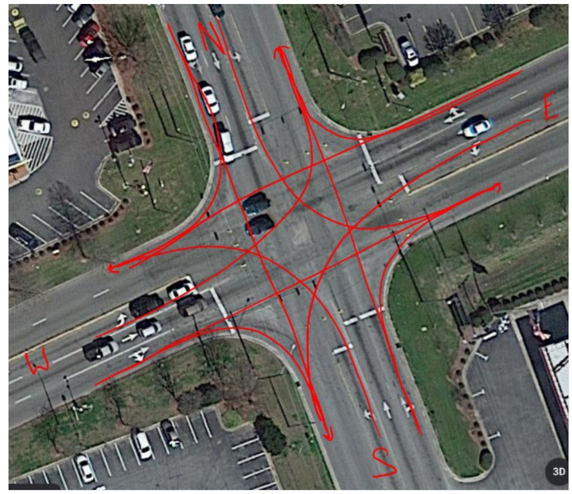
Int 231: W English Dr & Westchester Dr/W Market Center Dr, High Point



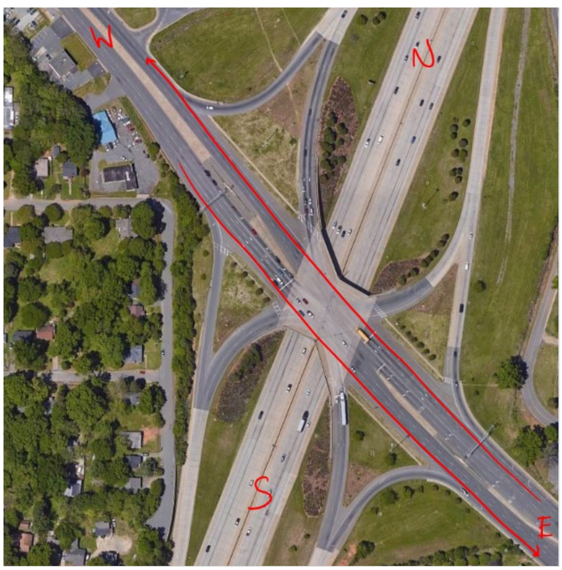
Int 248: Greenville Bv SE & Charles Bv, Greenville



Int 249: Charles Bv & E Fire Tower Rd, Greenville

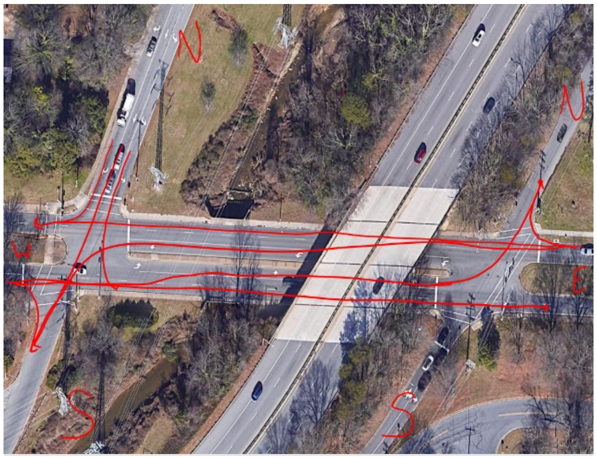


Int 280: I-85 & Freedom Dr, Charlotte

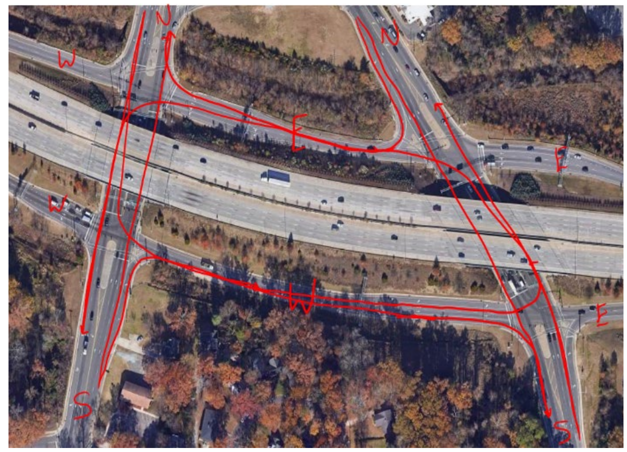


Int 282: I-40 & Gorman St, Raleigh

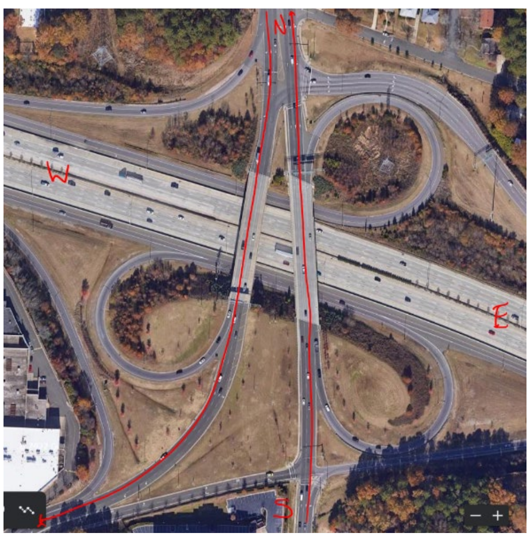
Int 287: W Wendover Ave SB & W Market St, Greensboro



Int 290: I-85 & N Roxboro St/Avondale Dr, Durham

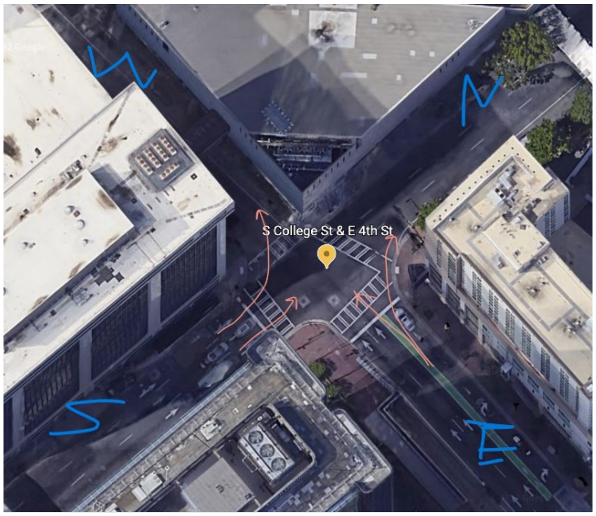


Int 291: I-85 & N Duke St, Durham

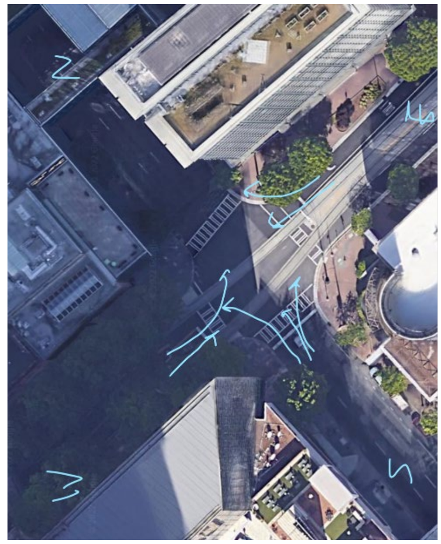


Int 318: US 15/501 & Erwin Rd/Europa Dr, Chapel Hill

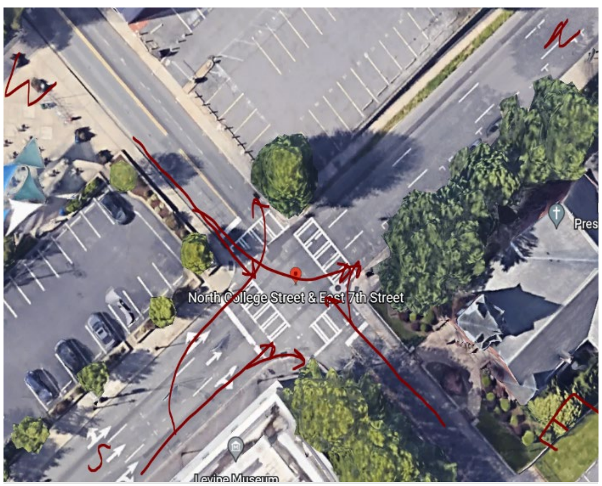
Int 319: E 4th St & S College St, Charlotte



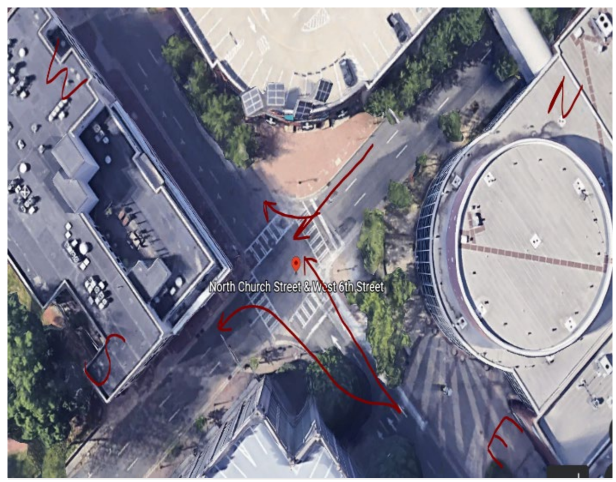
Int 321: E Trade St & N College St/S College St, Charlotte



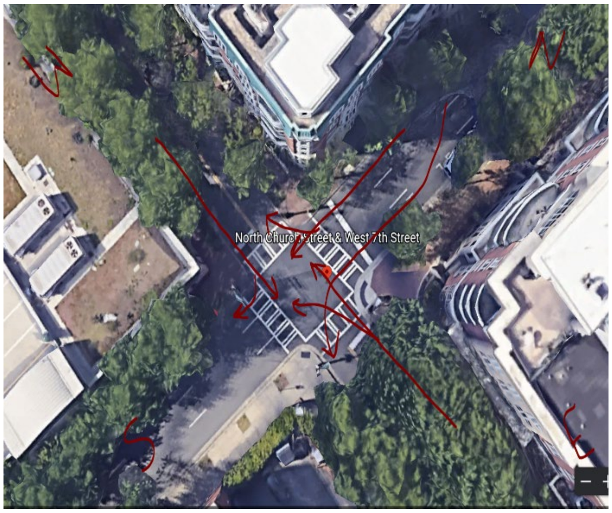
Int 324: E 7th St & N College St, Charlotte



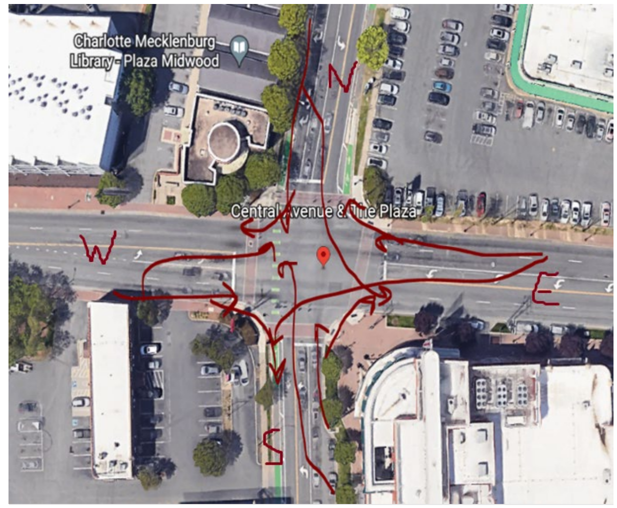
Int 325: W 6th St & N Church St, Charlotte



Int 326: W 7th St & N Church St, Charlotte

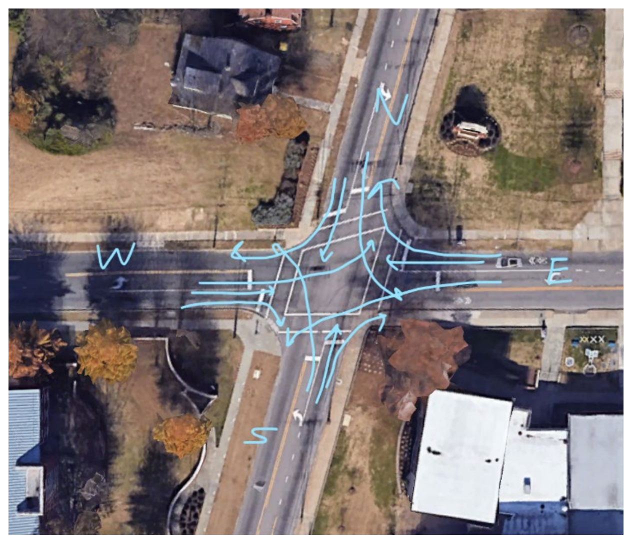


Int 327: Central Ave & The Plaza, Charlotte

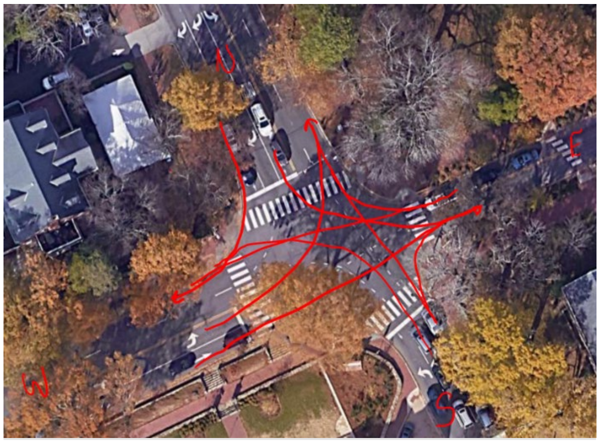


Int 330: E Chapel Hill St & Foster St/Corcoran St, Durham

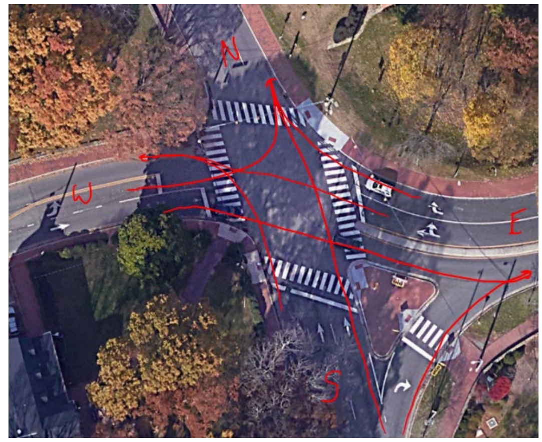
Int 334: Fayetteville St & E Lawson St, Durham



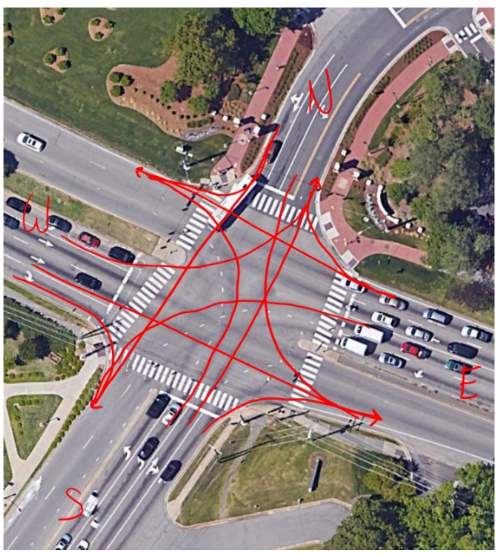
Int 335: S Columbia St & E Cameron Ave/W Cameron Ave, Chapel Hill



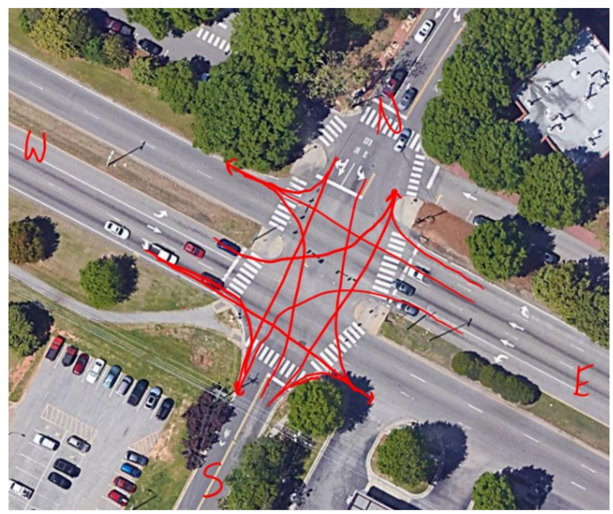
Int 337: S Columbia St & South Rd/McCauley St, Chapel Hill



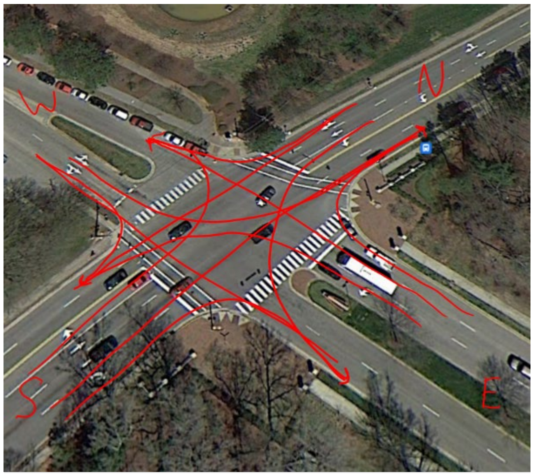
Int 338: Western Blvd & Avent Ferry Rd/Morrill Dr, Raleigh



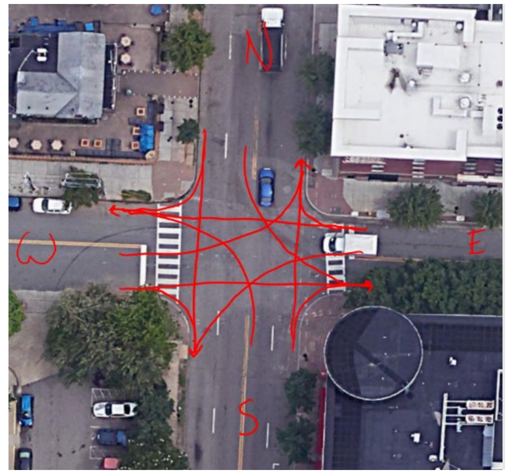
Int 339: Western Blvd & Dan Allen Dr, Raleigh



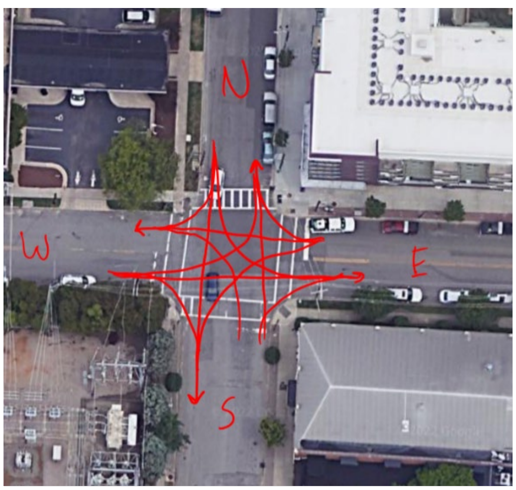
Int 340: Avent Ferry Rd & Varsity Dr, Raleigh



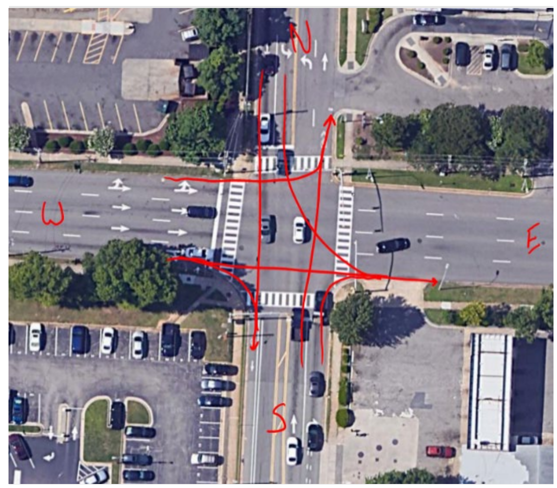
Int 341: Glenwood Ave & W Johnson St, Raleigh



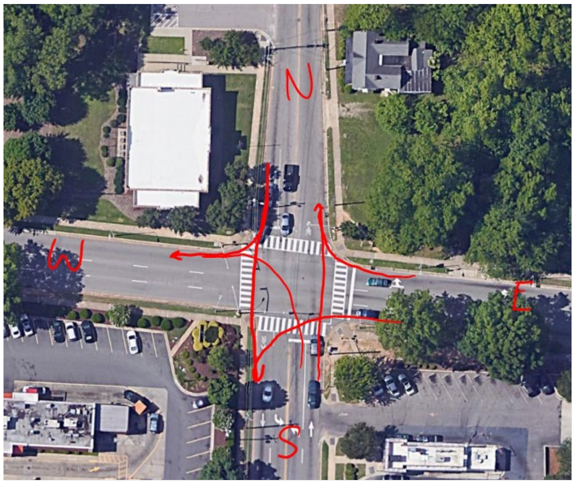
Int 342: N West St & W Jones St, Raleigh



Int 344: New Bern Ave & N Tarboro St/S Tarboro St, Raleigh

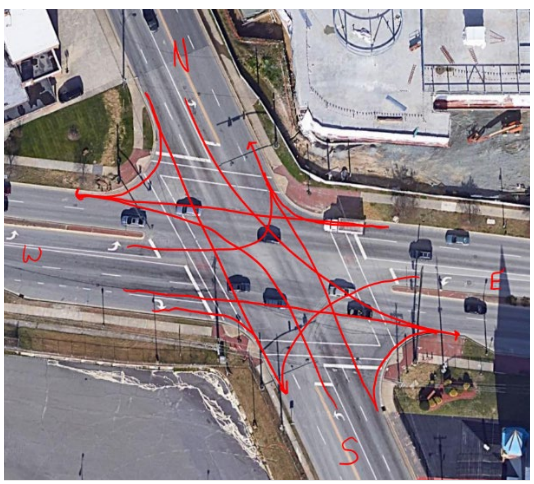


Int 345: E Edenton St & N Tarboro St, Raleigh

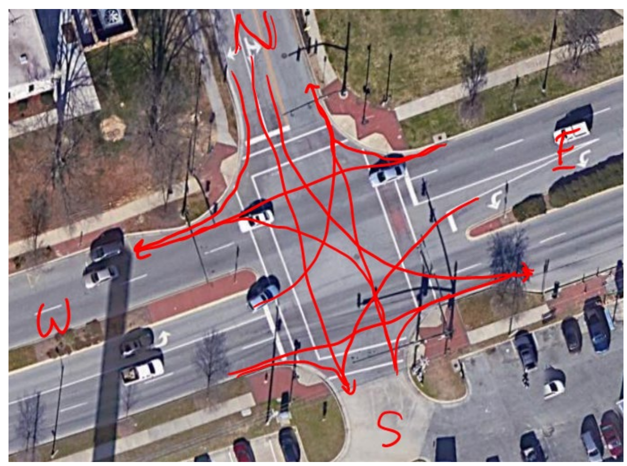


Int 347: E Friendly Ave/W Friendly Ave & N Elm St, Greensboro

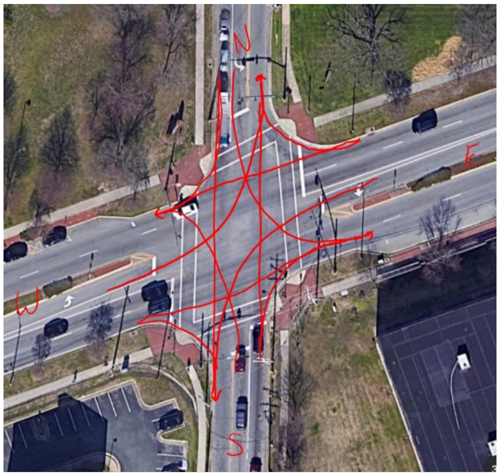
Int 348: E Market St & N Dudley St/S Dudley St, Greensboro



Int 349: E Market St & Laurel St, Greensboro

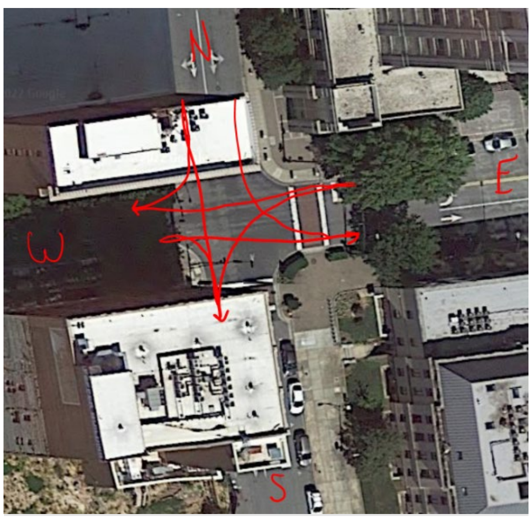


Int 350: E Market St & N Benbow Rd/S Benbow Rd, Greensboro

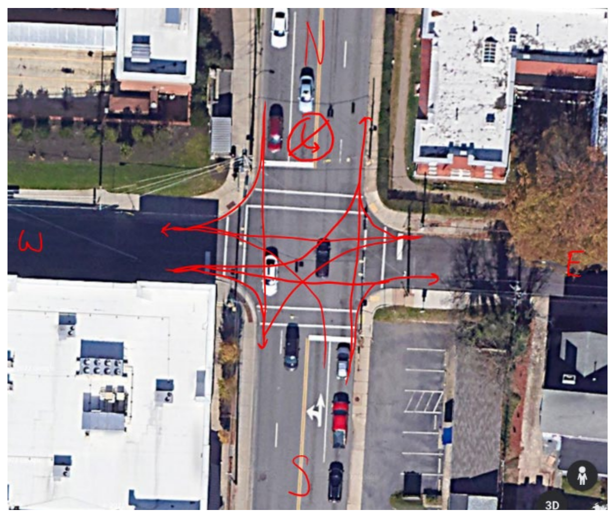


Int 351: W 4th St & N Cherry St, Winston-Salem

Int 352: W 4th St & N Liberty St, Winston-Salem



Int 354: Merrimon Ave & Chestnut St, Asheville



6.3 Video Reduction Protocol

Before starting the video coding, every analyst met with the study team for an orientation to the project and watched a training video explaining the coding process. Next, each analyst coded pedestrian, bicycle, and motor vehicle maneuvers over two separate periods (a training hour and a test hour) for a total of three hours on the same intersection (May 18, 2022 at Intersection 168: Broad St/Swift Ave & W Main St, Durham) beforehand to ensure uniformity. This intersection was selected because it has significant bicycle-pedestrian traffic and has two-way motor vehicle traffic on all four legs. The training hour was 8am-9am: bicycle-pedestrian movements were coded for the full hour on one macro-enabled Excel workbook, and motor vehicles were coded for the first 15 minutes on a separate macro-enabled workbook. After coding the hour, the workbooks were reviewed and compared to the count of movements derived from a careful review of the video by the study team to check for discrepancies and make sure there was sufficient agreement between the training hour and the "ground truth" counts. The comparison was done using a statistical test to determine if the mean of the two distributions (the analyst's and the study team's) of coded movements were the same. Analysts then coded the next two test hours, 4pm-6pm: a full two hours for bicycle-pedestrian movements and the first 15 minutes of each hour for motor vehicles in separate workbooks. Again, the test hours were compared to the ground truth counts of movements as established by the study team.

6.3.1 Tracking Coding Progress

Progress in coding was tracked in a master spreadsheet listing the 100 sites as well as relevant information on each such as the city and county it was within, a link to the intersection on Google Maps, cross street names, latitude/longitude, and a notes field to note anything unusual about the intersection if needed. Analysts chose and documented which intersection they were working on or had completed. This information was also used to fill out the header information in each macro-enabled Excel Workbook used for the coding.

Study:	20-Flags
Site:	Intersection 345
City:	Raleigh
Date:	May 25, 2022
Time:	7am-7pm
Analyst:	
Corner:	SPECIFY IN COLUMN J
N-S Road:	N Tarboro St
E-W Road:	E Edenton St

Figure 3. Example of header information for each intersection, to be entered before starting coding process (Taken from Intersection 345: E Edenton St & N Tarboro St, Raleigh)

6.3.2 Coding Process Steps

Step 1: Match Camera View(s) to Site's Cardinal Orientation

Properly identifying the North-South and East-West roads in an intersection was particularly important to be able to correctly align cardinal directions to the legs of an intersection before starting to code movements. To do so, analysts used the information provided in the master intersection list, as well as Google Maps and Google Earth to compare to the intersection's corresponding videos (See Figure 4 and Figure 5). In some cases, one camera captured all four legs of an intersection, and therefore all the movements were pulled from one video (See Figure 4).

Figure 4. Example view of "typical" Intersection 345 in VLC Media Player: An intersection with only one camera angle, SW corner facing NE.

Figure 5. Google Street View of Intersection 345 from the SW corner to depict the process of confirming the correct cardinal directions to be coded from provided video shown in Figure 2.

Typically, movements were recorded only for the legs closest to the camera when more than one camera was used. For example, north and west leg movements were usually recorded using a video from a camera that was placed at the NW corner, but this could vary on factors such as visibility, types of turns being made, and how many camera angles were available for the intersection. An example of a complex intersection is shown in Figure 6 and in Table 16 that required 8 camera angles to capture all the required movements.

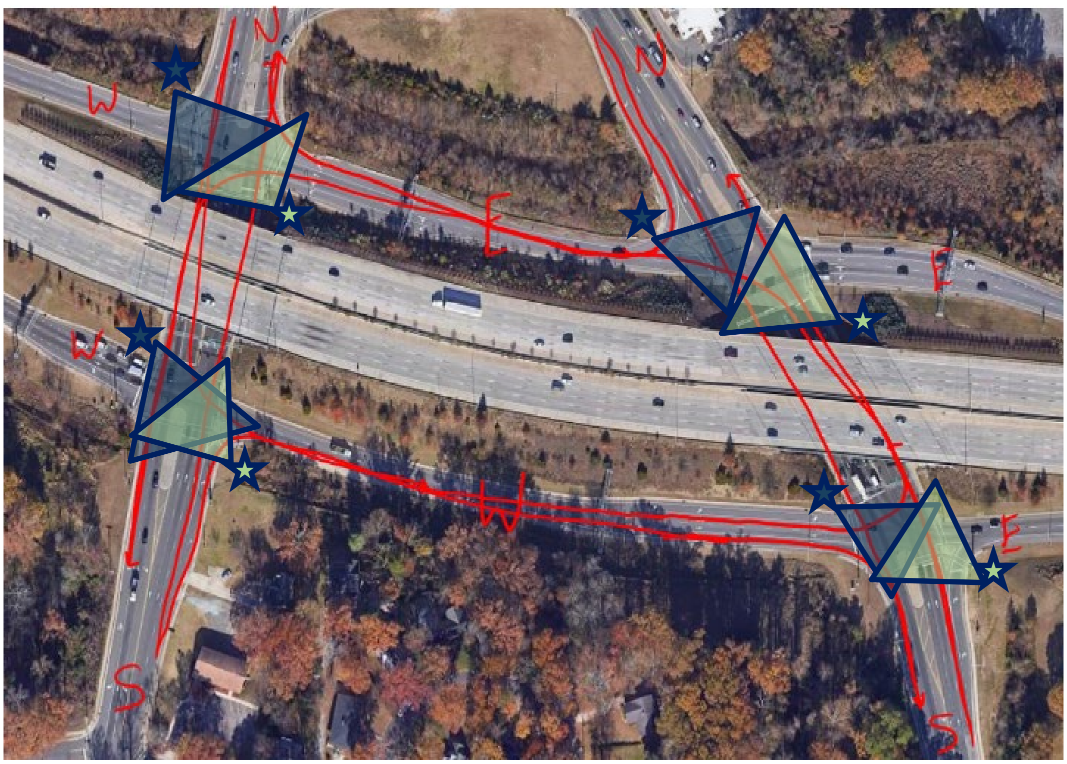


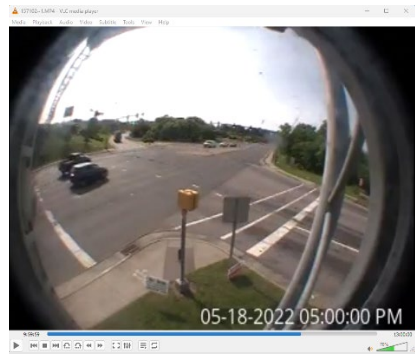
Figure 6. Google Maps aerial view of Int. 290: I-85 & N Roxboro St/Avondale Dr, Durham showing the placement of 8 cameras needed to capture all required movements.

Table 16. Depiction of the 8 camera views for complex intersection, Int 290: I-85 & N Roxboro St/Avondale Dr, Durham.

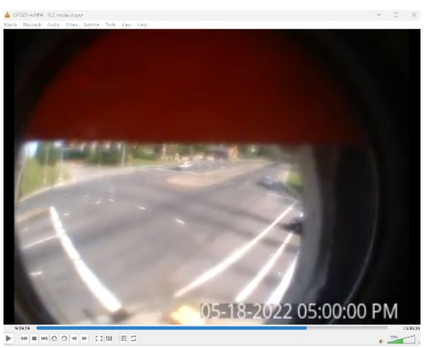
Avondale Dr and I-85 EB Ramps - NW Corner facing SE

Avondale Dr and I-85 EB Ramps - SE Corner facing NW

Avondale Dr and I-85 WB Ramps - NW Corner facing SE



Avondale Dr and I-85 WB Ramps - SE Corner facing NW



N Roxboro St and I-85 EB Ramps - NW Corner facing SE

N Roxboro St and I-85 EB Ramps - SE Corner facing NW

N Roxboro St and I-85 WB Ramps - NW Corner facing SE

N Roxboro St and I-85 WB Ramps - SE Corner facing NW

Step 2 – Sync Timestamps Across Videos

VLC Media Player was used to view videos. This software has capabilities to speed up and slow down videos; go backwards and forwards in ten second increments; and shows the hour, minutes, and seconds, which allows for accurately recording movements down to the second. For intersections with more than one video, it was important to make sure time stamps matched up correctly between videos and adjusted accordingly. This was done by selecting one corner as the correct time and adding or subtracting the number of seconds that the second corner was discrepant to the start and end periods of each 15-minute bin.

Step 3 – Enter Data into Excel Workbook

The hours coded for the purpose of this study were 7am-7pm, hours were manually entered in the "time stamp" fields in the Excel workbooks, corresponding to the hour of video being viewed while coding movements. For motor vehicle movements, the 7am-7pm period was divided into hours because only the movements from the first 15 minutes of every hour were coded – 7am, 8am, and so on. For bicycle-pedestrian movements, the whole hour was coded, divided into 15-minute bins – 9:00am-9:15am, 9:15am-9:30am and so on. The "corner" field was filled out manually to reflect the camera angle being used to record movements, i.e., if an analyst was coding movements viewing the SW corner, then they would record "SW", and change description as needed if coding movements with more than one camera angle. The comment field was used to make note of anything unusual or to indicate a micromobility device.

11	Event	Bike on Sidewalk = 1	Time Stamp	Comments	Approach	Turning Movement	Hour	Start time of 15-min time period	Mode	Corner
13			17:00:00.00							
14	A		28:21.7		West Side	Crossing	7	7:00:00 AM	Pedestrian	SW
15	Q		29:34.8		North Side	Crossing	7	7:00:00 AM	Pedestrian	SW

Figure 7. Example of the fields in the bicycle-pedestrian macro-enabled Excel workbook.

11	Event	Time Stamp	Comments	Approach	Turning Movement	Hour	15-min	Corner
13		17:00:00.00						
14	R	49:15.0		SB	Right	7	7:00:00 AM	SW
15	J	49:19.0		WB	Left	7	7:00:00 AM	SW

Figure 8. Example of the fields in the motor vehicle macro-enabled Excel workbook.

Movements were coded by starting the Excel macro, clicking on the "Start Recording" box in the macro, and entering the movement's corresponding keyboard key in the "event" field (See Table 17 and Table 18 for the list of key codes.) The macro would then automatically fill out the "approach," "turning movement," "mode" (Bike-Ped macro only), and "time stamp" (not used in analysis) fields. Turning movements were recorded as the direction of their approach from their point of origin -- where in an intersection a motor vehicle or bicycle originated based on what could be seen in the camera's field of view- and what direction they were headed in. For example, a motor vehicle on the north leg of the intersection that turned right would be recorded as a "North Side – Southbound right turn." The following movements were coded:

- Motorists: left and right turn movements.
- Bicyclists: left turns, right turns, and through movements.
- Pedestrians: crossings where pedestrian used crosswalk. Where crosswalks were unmarked, analysts estimated the location where markings would be to determine if observed pedestrians were crossing inside or outside of a crosswalk location.
- Micromobility device users: People riding micromobility devices were coded according to behavior and a note was provided with details of the device and movement as needed.

- If a rider was travelling along a sidewalk and used a crosswalk they were coded as a pedestrian.
- If a rider was travelling in a bike lane or motor vehicle lane they were coded as a bicycle.
- Examples of micromobility devices – electric scooters, seated e-scooters, electric skateboards, etc.

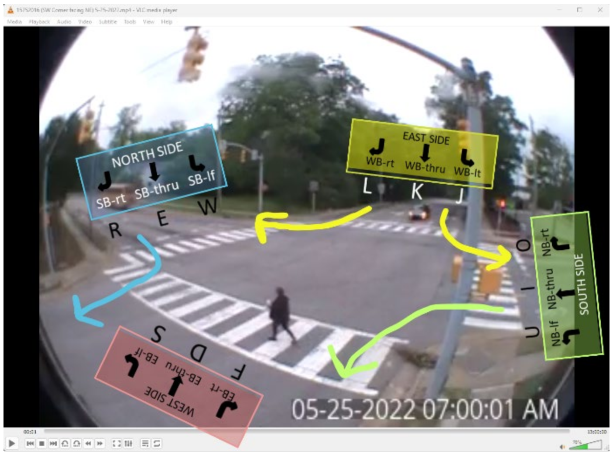
Table 17. Motor vehicle and bicycle movement codes used for this study and their corresponding keyboard keys. Note that motor vehicle and bicycle turning movements use the same codes.

Vehicle Keys	Code
W	North Side - SB left
E	North Side - SB thru
R	North Side - SB right
U	South Side - NB left
I	South Side - NB thru
O	South Side - NB right
S	West Side - EB left
D	West Side - EB thru
F	West Side - EB right
J	East Side - WB left
K	East Side - WB thru
L	East Side - WB right

Table 18. Pedestrian movement codes used for this study and their corresponding keyboard keys.

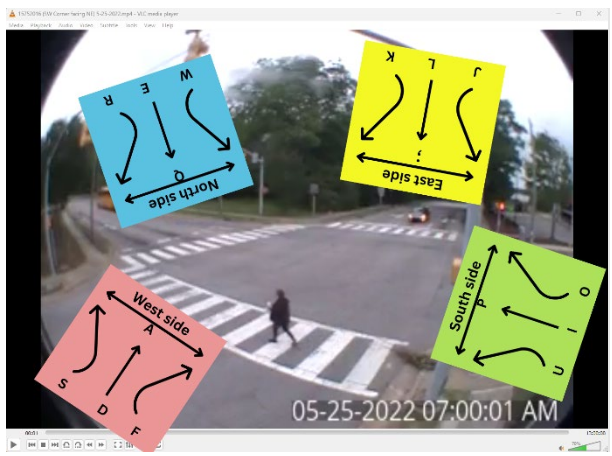
Pedestrian Keys	Code
Q	North Side - Pedestrian Crossing E-W
P	South Side - Pedestrian Crossing E-W
A	West Side - Pedestrian Crossing N-S
;	East Side - Pedestrian Crossing N-S

To correctly code movements, the keyboard diagrams were aligned with the intersection video. Different methods were used to align the legs of intersections (north, south, east, west) with the videos, such as printing out the diagrams to reference while coding or placing sticky notes with keyboard codes on computer screens.



(A) Vehicle movements

(B) Pedestrian movements

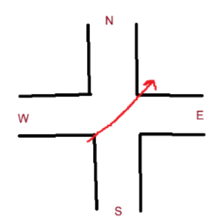
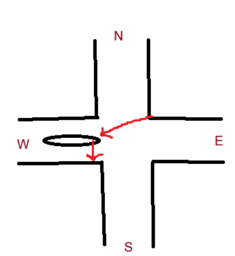
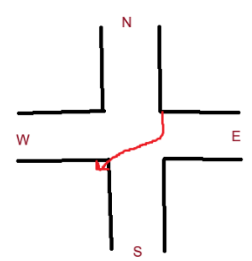


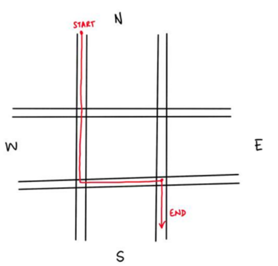
(C) Sticky note method.

Figure 9. Intersection 345 showing three different examples of how the keyboard diagram was aligned with the correct legs of the intersection. (A) shows application of keyboard diagram for bicyclist movements and arrows depicting motor vehicle turning movements NB-left, WB-right, WB-left, and SB-right; (B) shows application of diagram with pedestrian movements; (C) shows application of sticky note method depicting pedestrian, bicycle, and motor vehicle movement keys.

Besides traditional turning and through movements, there were many special cases the team came across while coding intersections. A complete list with rules on how to handle the cases was compiled throughout the coding process.

Special Case	**Solution**
Bicycle on the sidewalk or in crosswalk for at least a part of the crossing Ex. Starting on sidewalk and ending on the road	Recorded a “1” in the “Bike on Sidewalk = 1” field in the bicycle-pedestrian Excel workbook for every instance of a bike on sidewalk. For micromobility devices such as e-scooters, only a note was made in the comment field.
Pedestrian or bicyclist crossing outside of the crosswalk or intersection box	Not coded even if visible from certain cameras to provide uniformity

Pedestrian not completing a crossing Ex. Pedestrian crossed halfway and walked out of crosswalk	Pedestrians were only counted if they crossed over a quarter of the length of the crosswalk Ex. Pedestrian that crossed halfway across intersection and walked out of crosswalk is counted as one pedestrian crossing
Motor Vehicle U-Turns	Coded as a left turn
Pedestrian U-Turn: pedestrian crossed in crosswalk and crossed back again across the same intersection	Coded as two crossings -- two pedestrians, on the same crosswalk
Bicyclist U-turn	Bicyclists in a crosswalk who made a U-turn like a pedestrian were counted as two through bicyclists. Bicyclists who made a U-turn like a motor vehicle were counted as a left turn.
Diagonal crossing 1: Exactly in the middle of an intersection  	Coded as two crossings: arbitrarily decided which crosswalk to code and added the opposite leg
Diagonal crossing 2: Into a median and straight across or vice versa  	Coded as two crossings
Diagonal crossing 3:  	Coded as two crossings: determined what side pedestrian or cyclist was closest to and added the opposite leg

Bicyclist crossing one leg of an intersection and dismounting to walk second leg of intersection	Coded as two movements: one through bicycle movement and a second pedestrian crossing
Person walking bicycle partway across an intersection and getting on to ride bicycle still in the intersection and vice versa	Coded based on the action occurring for the majority of the crossing Ex. A person who walked a bike a quarter of the way across an intersection and rode the rest of the way would be coded as a bicyclist because more than half the intersection was crossed while riding
Camera resolution making it difficult to determine a bicycle from a moped or motorcycle	Movement coded as a bicycle if analyst was at least 50% sure that device was a bicycle, considering factors such as speed relative to other traffic when making determinations
Riding lawn mowers	Not coded
Golf Carts	Not coded but added to notes column for particular 15 minute bin
A bicyclist completing a through movement by crossing an intersection: a bicyclist crosses one leg of an intersection, turns left/right and crosses a perpendicular leg, and then turns left/right to continue in the same direction on the opposite side of the street 	Coded the first turn movement as the bicyclist movement
Bicycle with two or more riders	Coded as one bicycle
Micromobility device with two or more riders	Coded depending on action -- if travelling as a pedestrian, coded the number of riders and if travelling as a bicycle, coded as one device

6.3.3 Summary of Observed Bicycle and Pedestrian Movements

Video coders noted that several bicyclists rode on the sidewalk and crossed using pedestrian movements. The table below summarizes the number of bicyclists and pedestrians counted per intersection for this subsample dataset and the portion of sidewalk-riding cyclists.

Table 19. Subsample Data: Number of Observed Bicyclists and Pedestrians, and Percent of Bicyclists Riding on Sidewalk by Intersection

Intersection Number	Bicyclists Observed in 12-hour period	Number of Bicycles Observed on Sidewalk	Pedestrian Crossings Observed in 12-hr period	% Bikes on Sidewalk
3	198	93	3864	47%
4	5		169	0%
5	18	11	80	61%
6	38	33	126	87%
10	16	13	183	81%
13	10	1	63	10%
17	18	16	74	89%
18	17	12	54	71%
19	54	2	428	4%
20	31	22	169	71%
21	19	11	140	58%
25	23	6	357	26%
26	7		141	0%
27	8	4	40	50%
28	30	28	73	93%
32	4		22	0%
33	11	9	163	82%
34	11	8	35	73%
36	6	5	7	83%
44	19	7	86	37%
45	10	9	45	90%

Intersection Number	Bicyclists Observed in 12-hour period	Number of Bicycles Observed on Sidewalk	Pedestrians Crossings Observed in 12-hr period	% Bikes on Sidewalk
60	41	14	115	34%
61	16	10	260	63%
62	9	8	22	89%
64	25	15	61	60%
65	61	23	31	38%
67	1		5	0%
68	73	24	247	33%
69	19	4	81	21%
70	7	4	66	57%
71	15	11	91	73%
73	36	8	592	22%
75	19	11	209	58%
80	11	6	8	55%
82	12	7	24	58%
84	22	18	52	82%
85	27	8	312	30%
92	6		17	0%
95	25	14	22	56%
104	6	6	99	100%
112	9	7	47	78%
114	9	7	47	78%

Intersection Number	Bicyclists Observed in 12-hour period	Number of Bicycles Observed on Sidewalk	Pedestrian Crossings Observed in 12-hr period	% Bikes on Sidewalk
47	18	15	15	83%
49	15	11	24	73%
50	31	26	98	84%
59	3	3	43	100%
132	10	6	35	60%
135	7	5	30	71%
150	23	21	48	91%
151	26	25	60	96%
154	33	12	39	36%
160	6	4	28	67%
167	15	4	6	27%
168	231	17	275	7%
172	8	4	58	50%
173	29	23	118	79%
178	6	6	46	100%
191	5	2	30	40%
198	6	0	26	0%
208	4	3	8	75%
213	17	14	73	82%
224	39	31	50	79%
228	10	8	44	80%
231	2	0	1	0%
248	6	5	8	83%
249	0	0	4	0
280	13	11	70	85%
282	0	0	1	0
287	14	5	91	36%

Intersection Number	Bicyclists Observed in 12-hour period	Number of Bicycles Observed on Sidewalk	Pedestrians Crossings Observed in 12-hr period	% Bikes on Sidewalk
115	81	7	896	9%
117	5	3	34	60%
120	7	4	14	57%
121	3	1	23	33%
321	153	61	5330	40%
324	72	20	1568	28%
325	119	10	1434	8%
326	36	8	793	22%
327	98	37	800	38%
330	290	31	1930	11%
334	12	6	369	50%
335	285	51	1928	18%
337	493	175	4139	35%
338	75	56	405	75%
339	60	43	226	72%
340	89	39	259	44%
341	35		864	0%
342	60	4	529	7%
344	44	18	213	41%
345	24	9	101	38%
347	79	38	2354	48%
348	13	11	51	85%
349	21	17	198	81%
350	32	22	207	69%
351	88	42	2834	48%
352	67	24	1793	36%
354	57	16	390	28%

Intersection Number	Bicyclists Observed in 12-hour period	Number of Bicycles Observed on Sidewalk	Pedestrian Crossings Observed in 12-hr period	% Bikes on Sidewalk
290	12	10	68	83%
291	3	2	23	67%
318	13	6	24	46%
319	136	39	3157	29%

Intersection Number	Bicyclists Observed in 12-hour period	Number of Bicycles Observed on Sidewalk	Pedestrians Crossings Observed in 12-hr period	% Bikes on Sidewalk
Total	**4,141**	**1,566**	**43,010**	**52%**

6.4 Flag Reassignments following Volume Calculation for 100-Intersection Subsample

As mentioned, the flags were reassessed for the 100-intersection subsample after pedestrian, bicyclist, and motor vehicle volumes were recalculated. The flag changes per intersection are documented in Table 20.

Table 20: Changes in Flags after Volume Revision

Intersection Number	Changes in Flags	Intersection Number	Changes in Flags	Intersection Number	Changes in Flags	Intersection Number	Changes in Flags
3	+4 Flag_4_R_P +12 Flag_4_R_B +12 Flag_10_R_B	60	+10 Flag_4_R_B	132	N/A	318	+4 Flag_10_R_P
4	+3 Flag_4_R_P +7 Flag_4_R_B +12 Flag_10_R_B	61	N/A	135	+3 Flag_10_R_P -3 Flag_10_Y_P +11 Flag_10_R_B -11 Flag_10_Y_B	319	+2 Flag_1_R_P +3 Flag_4_R_P +4 Flag_4_R_B
5	+12 Flag_10_R_B	62	N/A	150	+2 Flag_10_R_P +6 Flag_10_R_B	321	+3 Flag_1_R_P +4 Flag_4_R_P +9 Flag_4_R_B
6	+3 Flag_1_R_P +10 Flag_10_R_B	64	+4 Flag_4_R_P +7 Flag_4_R_B	151	+2 Flag_1_R_P	324	+3 Flag_1_R_P
10	+12 Flag_10_R_B	65	N/A	154	N/A	325	+2 Flag_1_R_P
13	+3 Flag_4_R_P +6 Flag_4_R_B +10 Flag_10_R_B	67	N/A	160	N/A	326	N/A
17	+4 Flag_4_R_P +11 Flag_4_R_B +12 Flag_10_R_B	68	N/A	167	N/A	327	N/A
18	+4 Flag_1_R_P +4 Flag_4_R_P +7 Flag_4_R_B +12 Flag_10_R_B	69	N/A	168	N/A	330	+2 Flag_1_R_P -2 Flag_1_Y_P +3 Flag_4_R_P +2 Flag_10_R_P -2 Flag_10_Y_P +7 Flag_4_R_B +6 Flag_10_R_B -6 Flag_10_Y_B
19	+2 Flag_1_R_P +6 Flag_10_R_B	70	N/A	172	N/A	334	+4 Flag_4_R_P +11 Flag_4_R_B

20	+11 Flag_10_R_B	71	M/A	173	N/A	335	+2 Flag_1_R_P +2 Flag_1_Y_P +2 Flag_10_R_P +8 Flag_10_R_B
21	+8 Flag_10_R_B	73	+2 Flag_1_R_P -1 Flag_1_Y_P +3 Flag_10_R_P +10 Flag_10_R_B	178	+4 Flag_1_R_P	337	+3 Flag_1_R_P +4 Flag_4_R_P +3 Flag_10_R_P +1 Flag_10_Y_P +6 Flag_4_R_B +11 Flag_10_R_B -3 Flag_10_Y_B
25	+2 Flag_1_R_P	75	+4 Flag_4_R_P +7 Flag_4_R_B	191	N/A	338	N/A
26	N/A	80	+4 Flag_4_R_P +10 Flag_4_R_B	198	N/A	339	N/A
27	N/A	82	+10 Flag_4_R_B	208	N/A	340	+4 Flag_1_R_P -2 Flag_1_Y_P
28	+2 Flag_1_R_P	84	+3 Flag_1_R_P	213	N/A	341	N/A
32	N/A	85	+2 Flag_1_R_P	224	N/A	342	+6 Flag_10_R_B -6 Flag_10_Y_B
33	N/A	92	+4 Flag_4_R_P +10 Flag_4_R_B	228	+2 Flag_1_R_P +3 Flag_10_R_P +1 Flag_10_Y_P +11 Flag_10_R_B -3 Flag_10_Y_B	344	+3 Flag_1_R_P -1 Flag_1_Y_P +3 Flag_10_R_P +6 Flag_10_R_B
34	N/A	95	N/A	231	+4 Flag_4_R_P +11 Flag_4_R_B	345	N/A
36	N/A	104	N/A	248	+3 Flag_4_R_P +7 Flag_4_R_B	347	+3 Flag_1_R_P
44	+3 Flag_1_R_P	112	N/A	249	N/A	348	N/A
45	N/A	114	N/A	280	+4 Flag_4_R_P +12 Flag_4_R_B	349	+3 Flag_1_R_P -1 Flag_1_Y_P +3 Flag_10_R_P -1 Flag_1_Y_P +11 Flag_10_R_B -5 Flag_10_Y_B
47	+3 Flag_4_R_P	115	+2 Flag_1_R_P	282	+4 Flag_1_R_P	350	+4 Flag_10_R_P

	+7 Flag_4_R_B				+4 Flag_4_R_P +4 Flag_10_R_P +10 Flag_4_R_B +12 Flag 10_R_B		-2 Flag_10_Y_P +12 Flag_10_R_B -6 Flag_10_Y_B
49	N/A	117	N/A	287	+4 Flag_1_R_P -1 Flag_1_Y_P +4 Flag_10_R_P +11 Flag_10_R_B	351	+3 Flag_1_R_P -1 Flag_1_Y_P +4 Flag_10_R_P -1 Flag_10_Y_P +8 Flag_10_R_B -2 Flag_10_Y_B
50	+2 Flag_1_R_P	120	+4 Flag_4_R_P +10 Flag_4_R_B	290	+4 Flag_1_R_P +4 Flag_10_R_P +10 Flag_4_R_B +12 Flag_10_R_B	352	+3 Flag_1_R_P -1 Flag_1_Y_P +4 Flag_10_R_P -1 Flag_10_Y_P +8 Flag_10_R_B -2 Flag_10_Y_B
59	+4 Flag_4_R_P +7 Flag_4_R_B	121	N/A	291	+4 Flag_1_R_P +4 Flag_4_R_P +4 Flag_10_R_P +9 Flag_4_R_B +8 Flag_10_R_B	354	+4 Flag_1_R_P -3 Flag_1_Y_P +4 Flag_10_R_P +12 Flag_10_R_B