RED Priority Bus Lanes Study

RED Lanes Evaluation Methodology (Report 4)

June 2020

CAMPO
NC Capital Area Metropolitan Planning Organization

RENAISSANCE PLANNING

WSP

CONTENTS

1 OVERVIEW – OBJECTIVES AND APPROACH

OBJECTIVES

For a given location, assign a value that reflects its suitability for RED Lanes, differentiated by travel demand, transportation system operations, and area design/context characteristics.

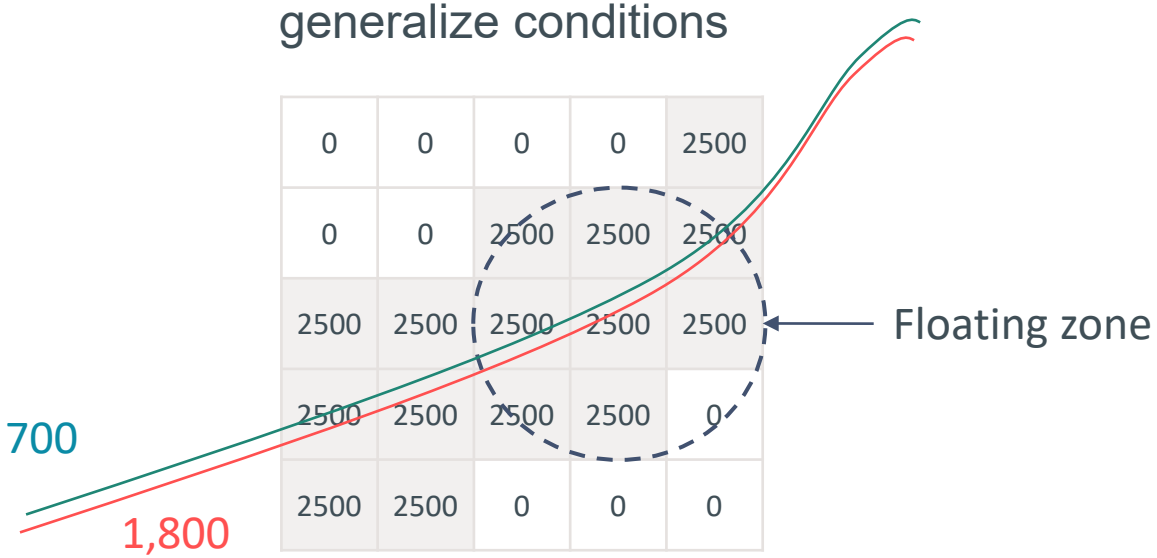
1. Major dimensions of RED Lanes suitability.
   - Travel demand
   - Transit operations
   - Highway operations
   - Contexts and design
2. Analyze conditions on an “areawide” basis to address inconsistencies in the details of line geometries.
3. Create a consistent, predictable, and replicable process.
   - Facilitate testing of measures
   - Simplify updates to accommodate new/fresh data
   - Allow CAMPO and partner agencies to engage with and revise the RED Lanes Suitability process

APPROACH – DIMENSIONS

1. Major dimensions of RED Lanes suitability.
   a. Identify data sources and potential measures that define and describe these dimensions.
      - Reference earlier study reports for recommended measures.
        - RED Lanes Fundamentals
        - Existing Conditions Report
      - Utilize feedback from CTT workshops to set weighting of variables in the suitability analysis process.

APPROACH – METHODS FOR MEASURING DIMENSIONS

2. Account for areawide conditions when measuring each dimension.
   a. Utilize spatial analysis to estimate typical conditions in a given area revealed by various linear datasets.
      - Since not all lines are digitized consistently, it is important to consider all lines within a small area to combine measures from diverse datasets.
      - Define “floating zones” as areas for which all available data points will be aggregated to generalize conditions



The blue line and the red line represent the same facility but have inconsistent GIS representation.

The blue line shows 700 transit riders on route A; the red 1,800 riders on route B.

The total ridership within the floating zone is… 2,500.

APPROACH – STREAMLINING PROCESSES

3. Create a consistent, predictable, and reliable process.
   a. Utilize standard geo-processing tools to develop measures.
      - ArcGIS's Spatial Analyst extension
   b. Develop scripted process to sequence geo-processing tasks and minimize the effort required to (re)run, modify, and update suitability estimates
      - Python (arcpy)
   - Provide a simple interface for ease of use
      - ArcMap geoprocessing script interfaces

APPROACH FOR DATA DRIVEN RED LANES SUITABILITY

- Quantitatively assess suitability “tier”
  - Travel demand
  - Transportation system operations
  - Contexts
- “Tiers” are scaled from 0 (no suitability) to 10 (max suitability)
- Qualitatively embellish tiers with additional information
  - Peak-hour vs full-time RED Lanes (full time suitability)
  - TSP suitability
  - Non-motorized demand
  - Design constraints/feasibility
  - Communities of Concern served

RED LANES FUNDAMENTALS – BEST PRACTICES FOR PLANNING

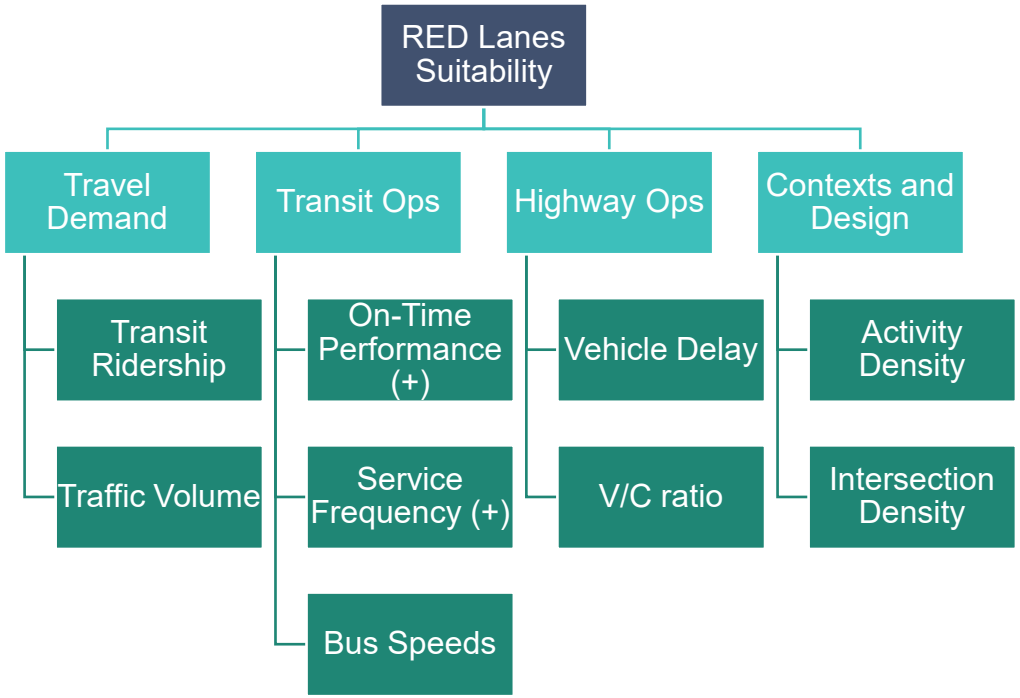
- Commonly cited key metrics listed in RED Lanes Fundamentals Report.
  - Transit vehicle volume
  - Person throughput by all modes
  - Volume-to-capacity (v/c) ratio and highway level of service
  - Reliability, travel time variability, delay
  - Safety
  - Available right of way and physical/spatial constraints
- Each of these measures (except safety) was addressed in the Existing Conditions Report (ECR).
  - The ECR measures are being used as inputs to the suitability analysis.
  - Safety will be assessed for priority corridors as a consideration informing appropriate RED Lane design.

ECR MEASURES BY TOPIC

- Hierarchical approach
  - Topics help create natural groupings of measures such that distinctive dimensions of RED Lanes suitability can be assessed using a small collection of variables.
  - Once each dimension has been assessed, they can be combined/overlaid to understand the complete picture of RED Lanes suitability.
  - Some factors are better utilized for implementation guidance rather than suitability analysis. These can be operationalized in the same way.

TOPIC AREA Indicator	Metric	CTT Priority	Literature Priority
DEMAND			
Transit Ridership (p. 8)	Forecasted daily route-level transit passengers by segment in 2045	High	High
	Forecasted peak-hour route-level ridership as a share of daily route-level ridership by segment in 2045	High	High
Transit Mode Share (p. 12)	Transit commute (journey to work) mode share in 2015	Low	Low
Traffic Volume (p. 14)	Forecasted daily bi-directional traffic volume by segment in 2045	Low	High
	Forecasted PM peak hour volume-to-capacity ratio by direction in 2045	Low	Medium
Non-motorized Users (p. 18)	Walk access to jobs (proxy for non-motorized trip demand) in 2014	Low	Low
Person throughput *(p. 20)*	*To be addressed at a project level*	*High*	*High*
OPERATIONS			
Transit on time performance/reliability (p. 21)	On time performance rates by route in 2018/19	High	High
Transit service frequency (p. 25)	Transit vehicles per hour (bi-directional) by segment in 2019	Low	High
	Future RED Lanes-supportive frequency by segment by planning horizon year.	Low	High
Transit Signal Priority *(p. 29)*	*To be addressed at a project level*	*Medium*	*NA*
Person/vehicle delay (p. 30)	Forecasted AM peak hour congested-to-free-flow-speed ratio by direction in 2045	Low	Medium
Average travel speed (p. 33)	Forecasted peak hour bus travel speed by direction in 2045	Low	Medium
CONTEXTS			
Adjacent land uses (p. 35)	Activity unit density by TAZ in 2013	Medium	Low
	Intersection density by block group in 2011	Medium	Low
Context classification/ complete streets (p. 39)	*To be addressed at a project level*	*Medium*	*NA*
Parking/curb space (p. 41)	*To be addressed at a project level*	Low	Low
Accessibility (p. 43)	Transit-to-auto access to jobs ratio in 2013	Medium	NA
	Communities of concern by block group in 2012	Medium	Low
Functional/access class (p. 47)	Functional class by segment in 2045	Low	Low
DESIGN/OTHER			
Number of lanes (p. 50)	Segment lane count by direction in 2013	Medium	Medium
	Buildings intersected (within potential ROW buffer) per mile by segment in 2018	Medium	Medium
Intersection design, separation of traffic, safety, enforcement, maintenance, cost, and project length to be addressed at a project level, following best practices findings from RED Lanes Fundamentals *report.*			

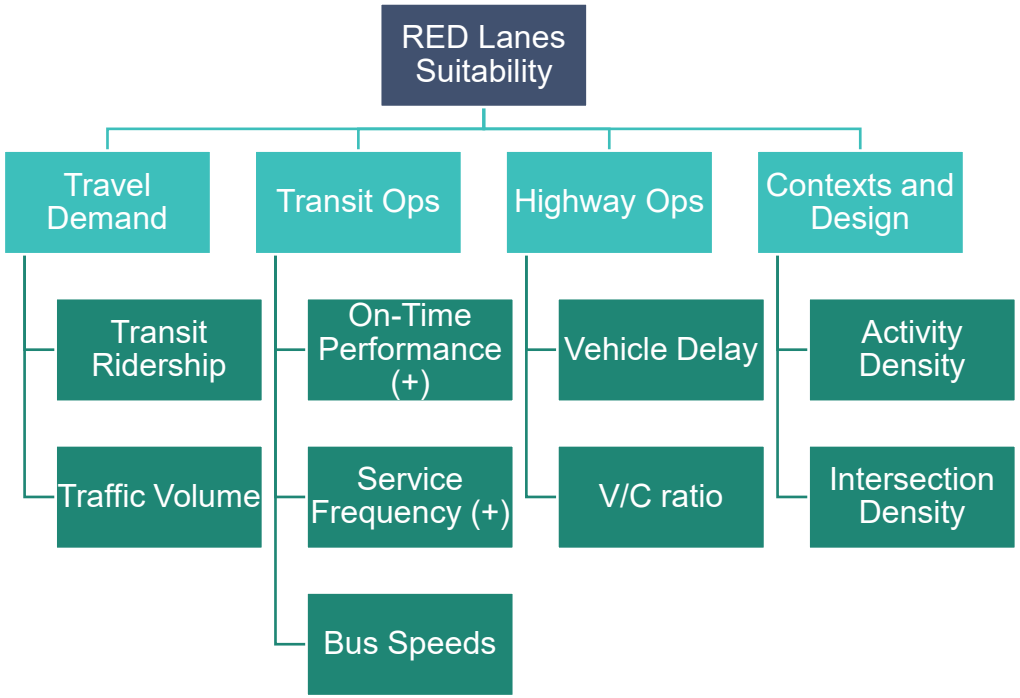
DATA DRIVEN PRIORITIZATION BASED ON DATA DEVELOPED IN ECR



Combine the ECR measures into a holistic understanding of suitability and implementation guidance (this section focuses on suitability).

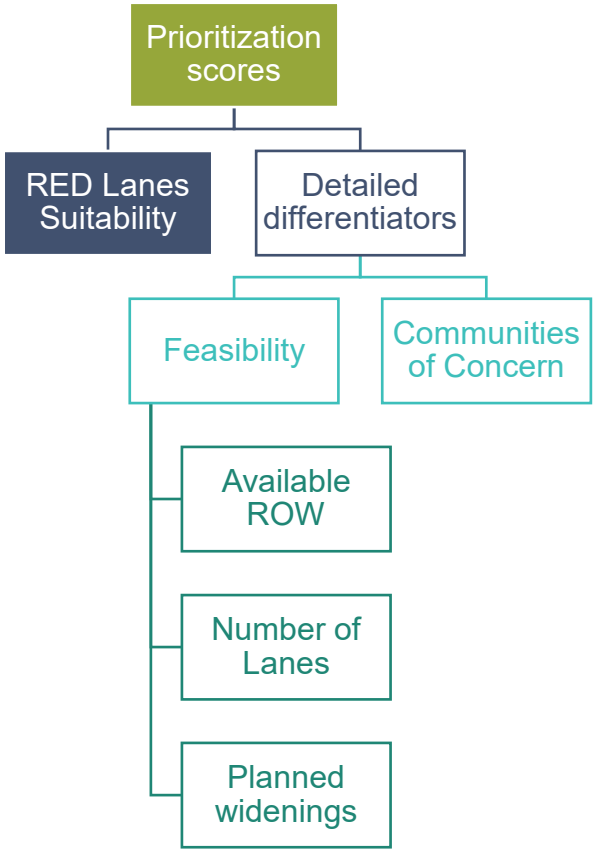
- Hierarchically address key dimensions of suitability
  - Travel Demand
  - Transit Operations
  - Highway Operations
  - Contexts and Design

TRAVEL DEMAND ANALYSIS



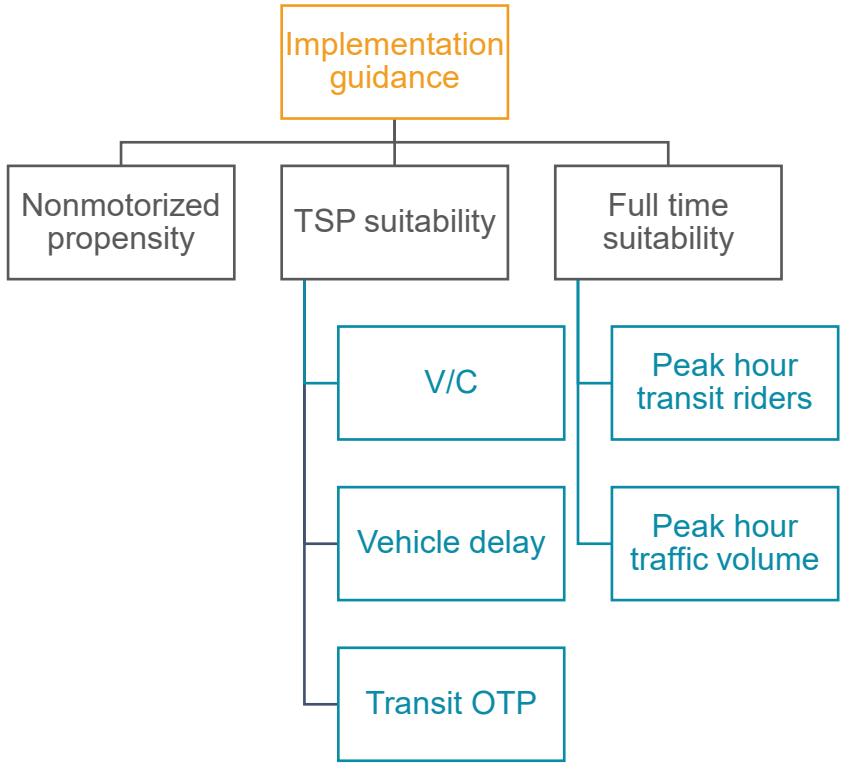
- Assess expected suitability tier on a dimension-by-dimension basis
- Overlay all dimensions to determine tier based on combined measures
  - Weight each dimension's influence on final suitability score
- Embellish raw suitability score with other scores derived using the same approach.

DATA DRIVEN PRIORITIZATION BASED ON DATA DEVELOPED IN ECR



- Enrich raw suitability scoring with other measures
- Some variables provide detailed differentiation among segments with similar RED Lanes Suitability scores
  - Feasibility – segments with adequate ROW, suitable number of lanes, or planned widenings
  - Communities of concern – segments serving neighboring areas with transportation disadvantaged populations.

DATA DRIVEN PRIORITIZATION BASED ON DATA DEVELOPED IN ECR

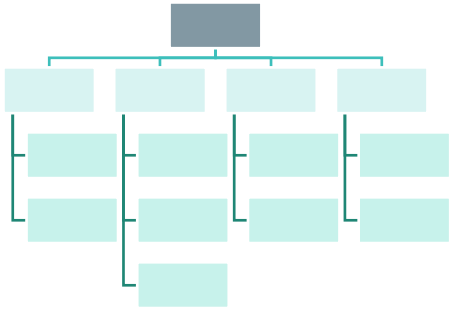


- Enrich raw suitability scoring with other measures
- Implementation guidance
  - Measures indicating how a RED Lane should be designed/implemented.
  - These are generated by the tool but not incorporated in the corridor ranking

2 WALKTHROUGH OF SUITABILITY ELEMENTS

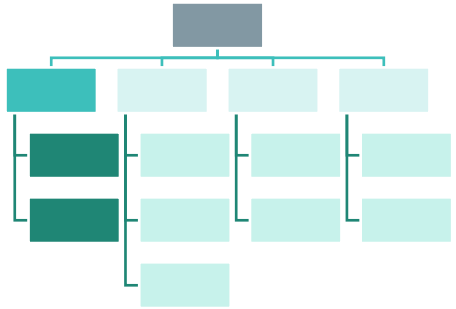
WALKTHROUGH OF SUITABILITY ELEMENTS

- The following slides provide details of how each component of the RED Lanes Suitability process is developed, including data sources, analysis parameters, scoring rubrics and maps.
- The diagram in the lower left corner indicates which components of the scoring process are depicted in each slide.



TRAVEL DEMAND – SCORING DIMENSIONS

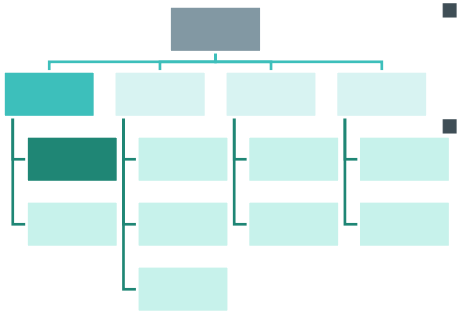
- Measures:
  - Forecasted (2045) Daily Transit Ridership
  - Forecasted (2045) Daily Traffic Volume



TRAVEL DEMAND – TRANSIT RIDERSHIP

Measure: Daily Transit Ridership

- Rationale:
  - RED Lanes are most effective in high ridership corridors, providing transit travel time savings to the greatest number of users.
  - Daily demand reveals overall utilization of the corridor by transit patrons. Peak-hour ridership will be considered for full-time vs. part-time implementation considerations.
- Sources:
  - TRM transit ridership forecasts (2045) – forecasts are available at a route level rather than a segment level.
- Methods:
  - For a defined floating zone area, summarize the daily transit ridership on routes using an adjacent facility.
  - Define thresholds to set “suitability tiers” based on ridership forecasts

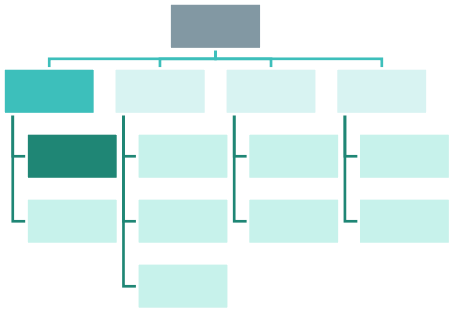


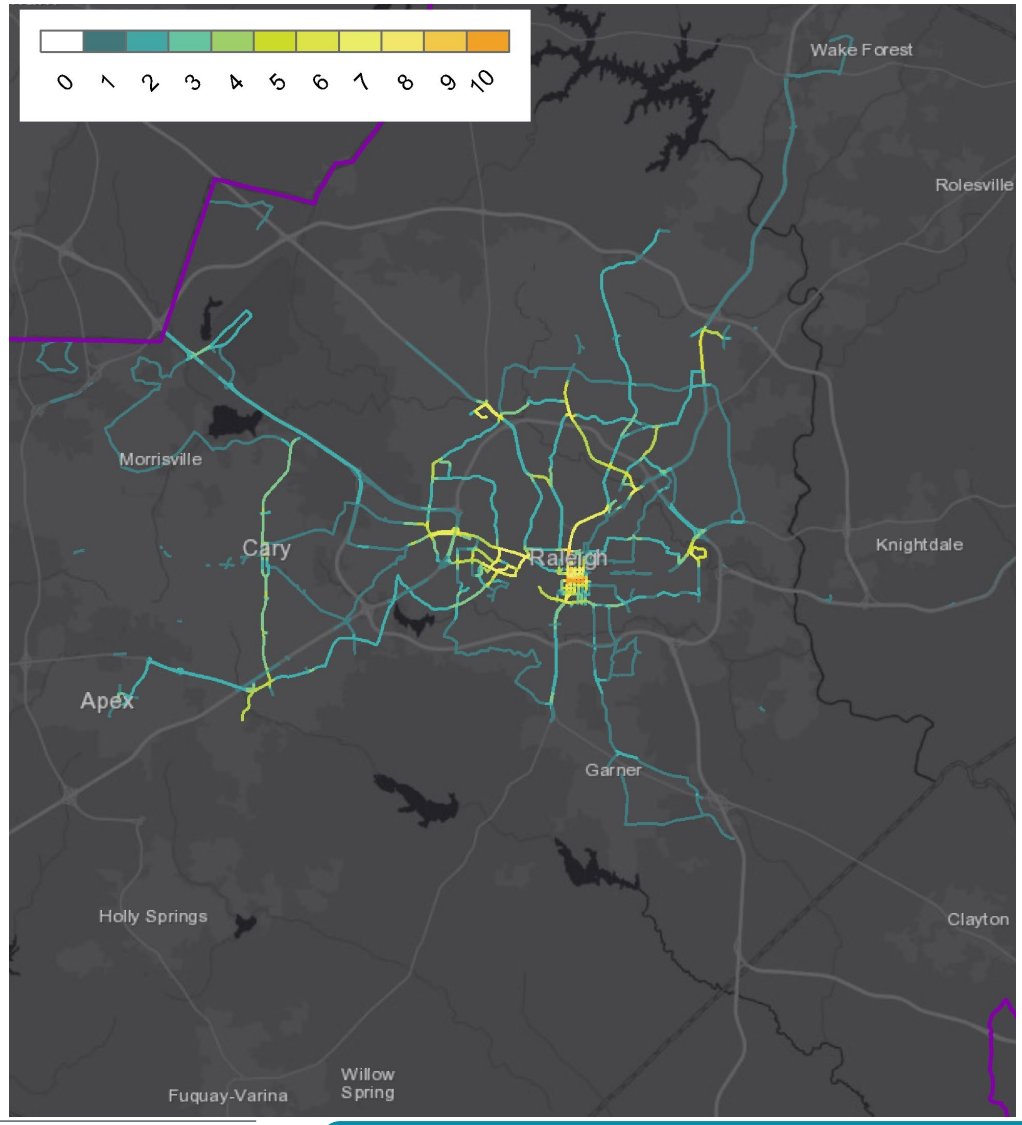
TRAVEL DEMAND – TRANSIT RIDERSHIP

Measure: Daily Transit Ridership (2045)

- Analysis specs:
  - Floating zone: Circle with 200' radius

Ridership Range	Suitability Score
0 – 1,000	1
1,000 – 2,500	2
2,500 – 4,000	3
4,000 – 6,000	4
6,000 – 8,000	5
8,000 – 10,000	6
10,000 – 15,000	7
15,000 – 20,000	8
20,000 – 35,000	9
35,000+	10

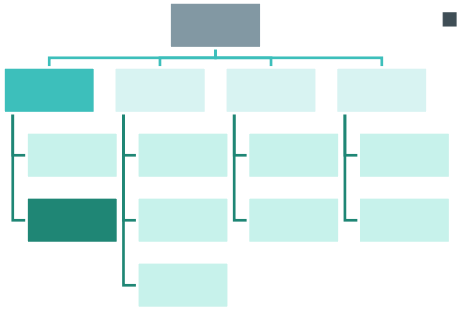




TRAVEL DEMAND – TRAFFIC VOLUME

Measure: Daily Traffic Volume

- Rationale:
  - RED Lanes should facilitate timely connections along well-traveled corridors, enhancing multimodal options for the greatest number of travelers.
  - Daily demand reveals overall utilization of the corridor. Peak-hour demand will be considered for full-time vs. part-time implementation considerations.
- Sources:
  - TRM traffic forecasts (2045)
- Methods:
  - For a defined floating zone area, summarize the daily traffic volume on an adjacent facility (exclude limited access highways).
  - Define thresholds to set “suitability tiers” based on traffic volume forecasts

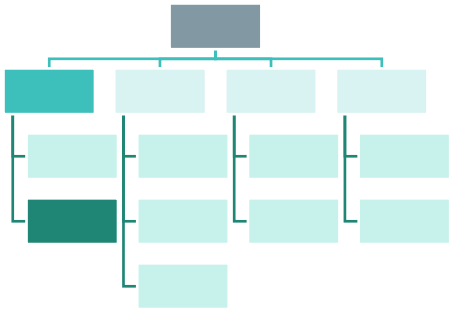


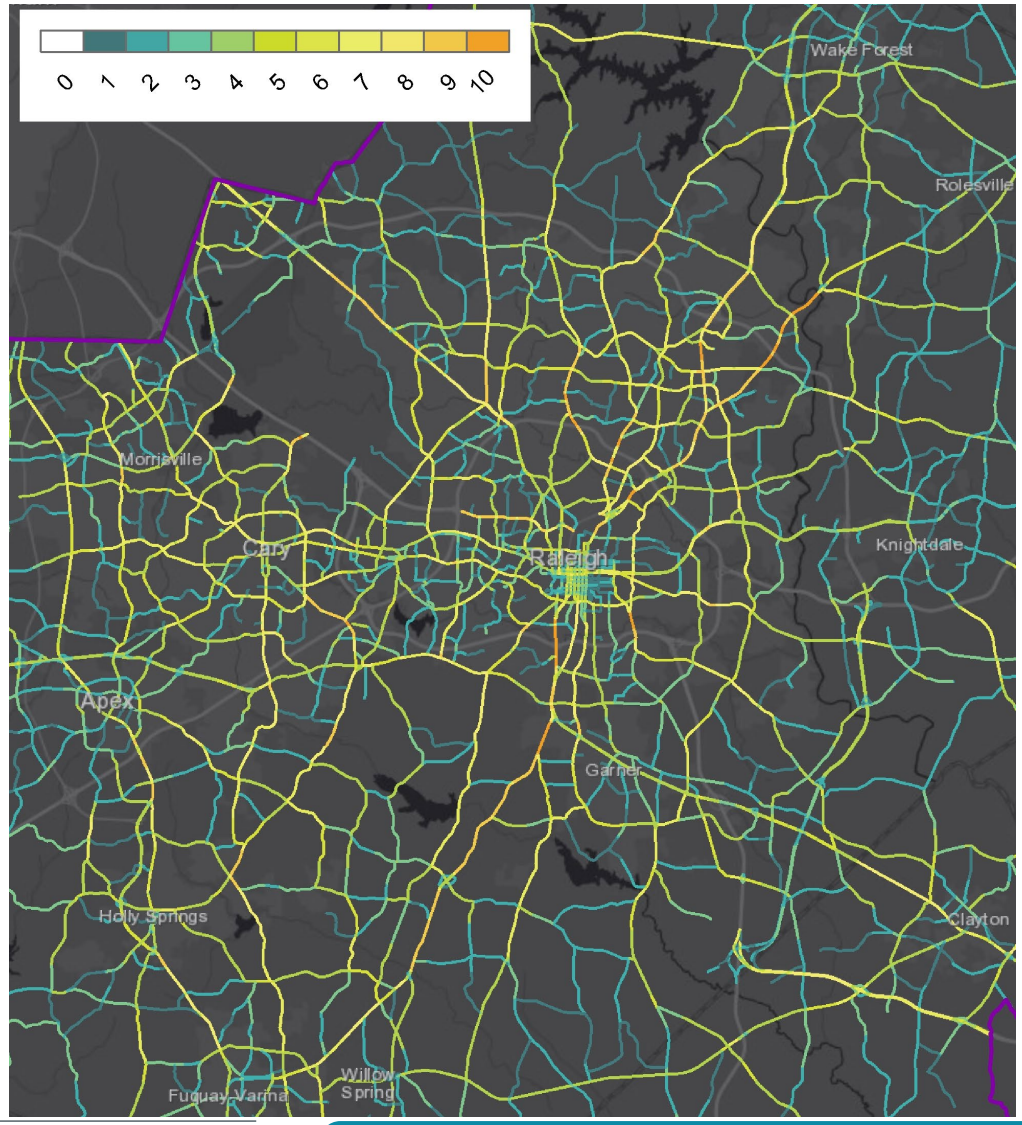
TRAVEL DEMAND – TRAFFIC VOLUME

Measure: Daily Traffic Volume (2045)

- Analysis specs:
  - Floating zone: Circle with 200' radius

Volume Range	Suitability Score
0 – 5,000	1
5,000 – 10,000	2
10,000 – 15,000	3
15,000 – 20,000	4
20,000 – 25,000	5
25,000 – 30,000	6
30,000 – 40,000	7
40,000 – 50,000	8
50,000 – 70,000	9
70,000+	10

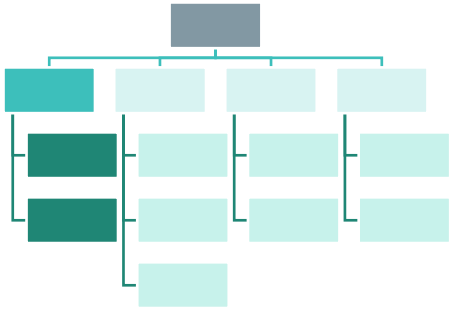


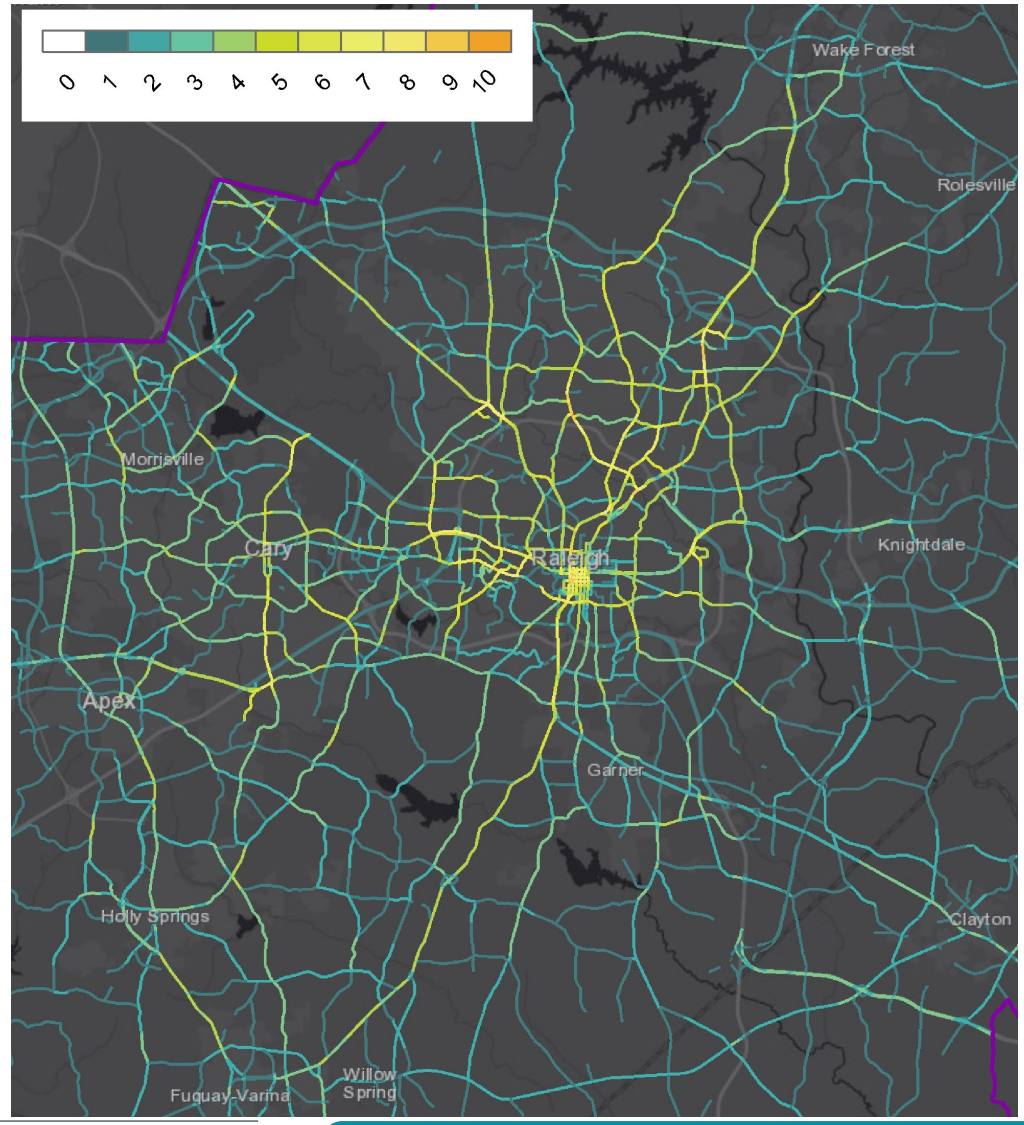


TRAVEL DEMAND – OVERLAY

Measure: Travel Demand Suitability

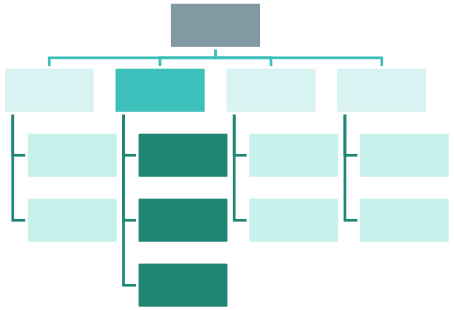
- Methods:
  - Overlay the transit ridership and traffic volume suitability maps and take a weighted average.
    - Transit ridership weight: 60%
    - Traffic volume weight: 40%

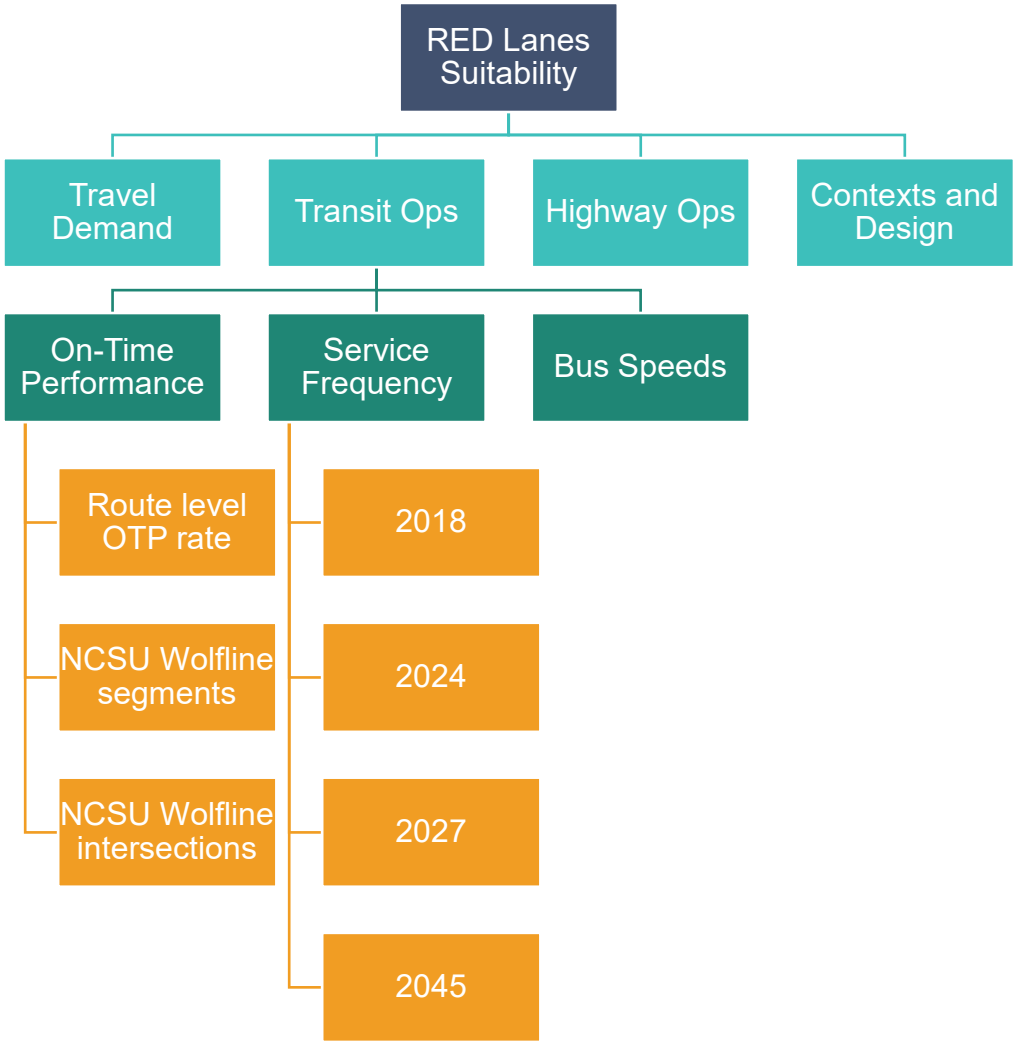




TRANSIT OPERATIONS – SCORING DIMENSIONS

- Measures:
  - On-Time Performance
  - Service frequency
  - Transit travel speed

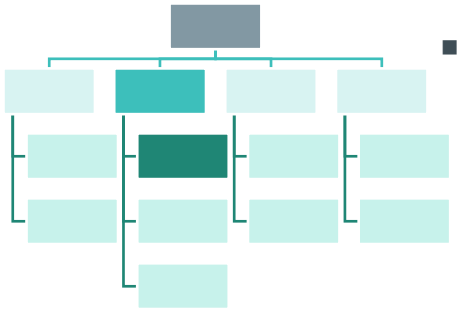




TRANSIT OPERATIONS – ON-TIME PERFORMANCE

Measure: On-Time Performance (OTP)

- Rationale:
  - RED Lanes provide more consistent travel conditions for transit vehicles, helping alleviate schedule adherence issues.
- Sources:
  - Route-level OTP statistics from transit agencies.
  - Segments that pose on-time performance difficulties for NCSU routes.
  - Intersections that pose on-time performance difficulties for NCSU routes.
- Methods:
  - For a defined floating zone area, summarize the average route-level OTP rate.
  - Define thresholds to set “suitability tiers” based on OTP rates.
  - Combine route-level OTP tiers with NCSU flagged features.



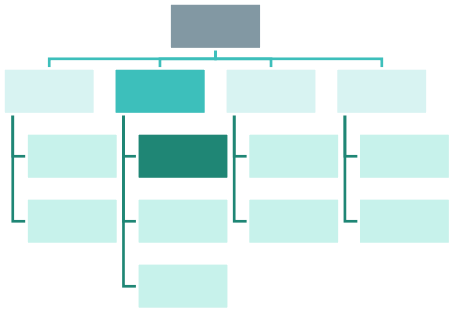
TRANSIT OPERATIONS – ON-TIME PERFORMANCE

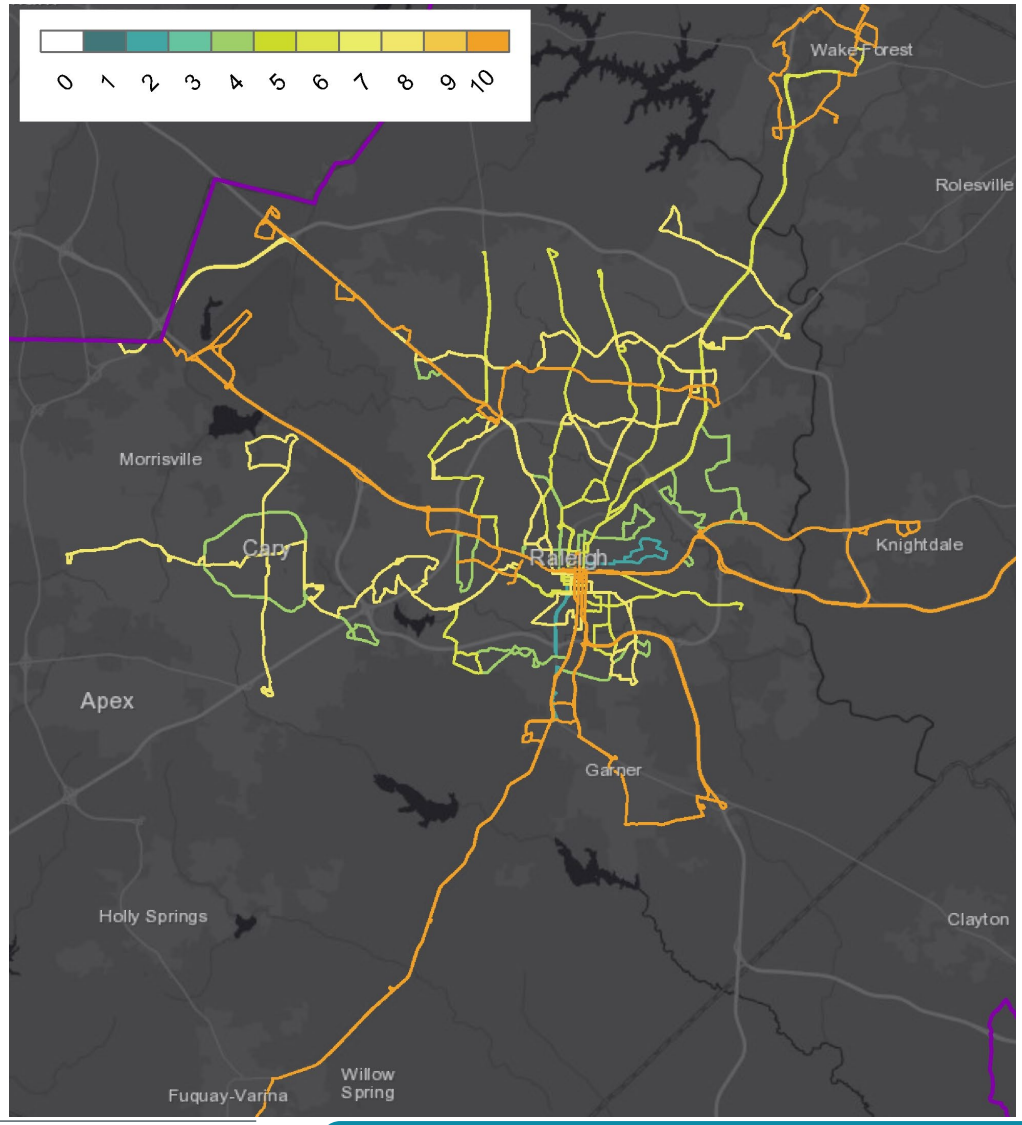
Measure: On-time performance (c. 2019)

- Analysis specs:
  - Floating zone: Circle with 200' radius

OTP rate	Suitability Score
0 – 75%	10
75% - 80%	8
80% - 85%	6
85% - 90%	4
90%- 95%	2
95% - 100%	0
If NCSU segment*	10
If NCSU intersection*	10

*Segments and intersections identified by Wolfline staff as posing reliability issues.

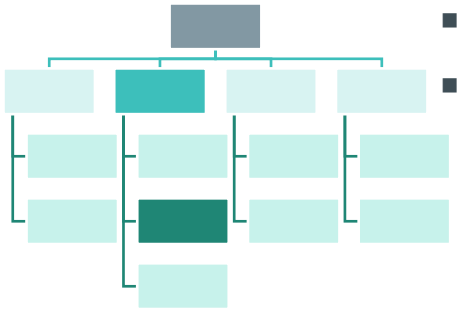




TRANSIT OPERATIONS – SERVICE FREQUENCY

Measure: Service Frequency

- Rationale:
  - RED Lanes are most effective on segments with frequent bus service, justifying the designation of the priority lane and making the lane effectively self-enforcing.
- Sources:
  - Wake Bus Plan routes and headways
  - MTP routes and headways
- Methods:
  - For a defined floating zone area, summarize the total buses per hour in the peak period (by horizon year).
  - Define thresholds to set “suitability tiers” based on frequency.
  - Overlay existing and planned service frequencies.

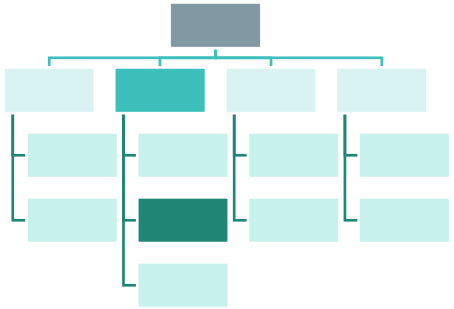


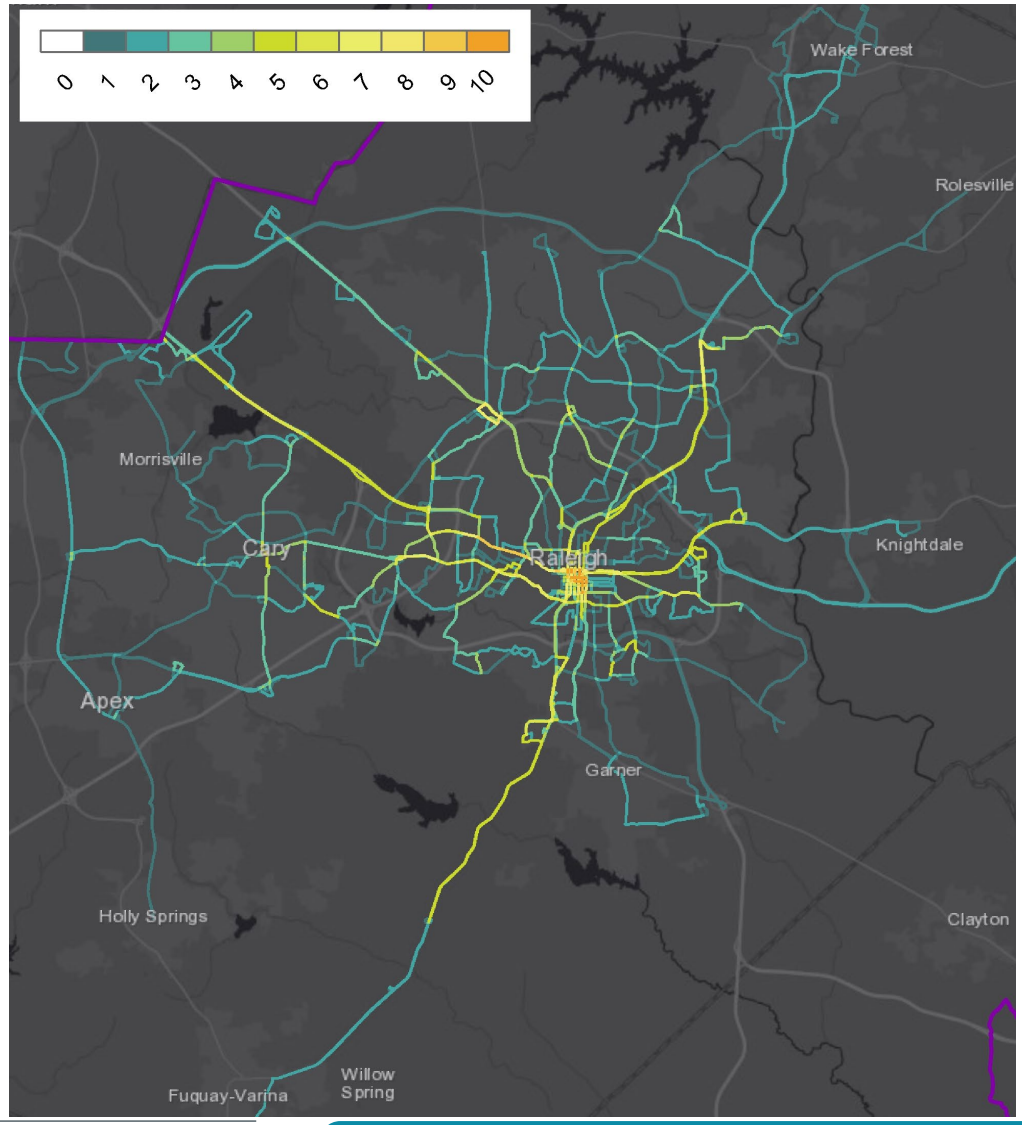
TRANSIT OPERATIONS – SERVICE FREQUENCY

Measure: Service Frequency (composite by year – see weights below)

- Analysis specs:
  - Floating zone: Circle with 200' radius
  - Overlay weights
    - 2018 (40%)
    - 2024 (30%)
    - 2027 (20%)
    - 2045 (10%)

Buses per hour	Suitability Score
0	0
Up to 2	2
2 – 4	4
4 – 8	6
8 – 12	8
12+	10

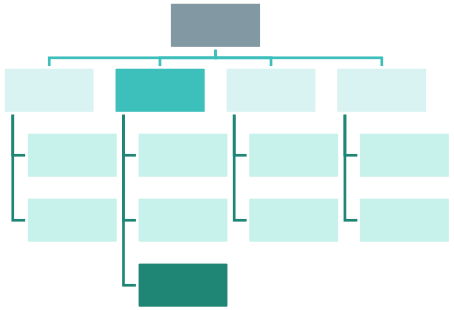




TRANSIT OPERATIONS – BUS SPEED

Measure: Average Bus Speed

- Rationale:
  - RED Lanes can increase bus speeds, making service more convenient and competitive. Thus, they are appropriate on segments where bus speeds are typically slow.
- Sources:
  - TRM highway network bus speed forecasts (2045)
- Methods:
  - For a defined floating zone area, summarize the average bus speed.
  - Define thresholds to set “suitability tiers” based on estimated speeds.

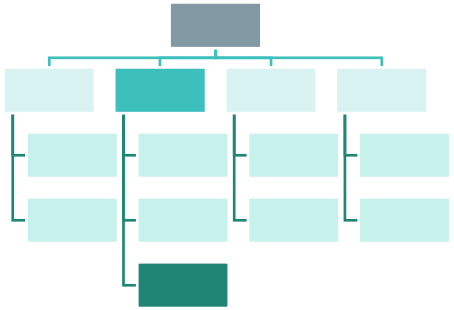


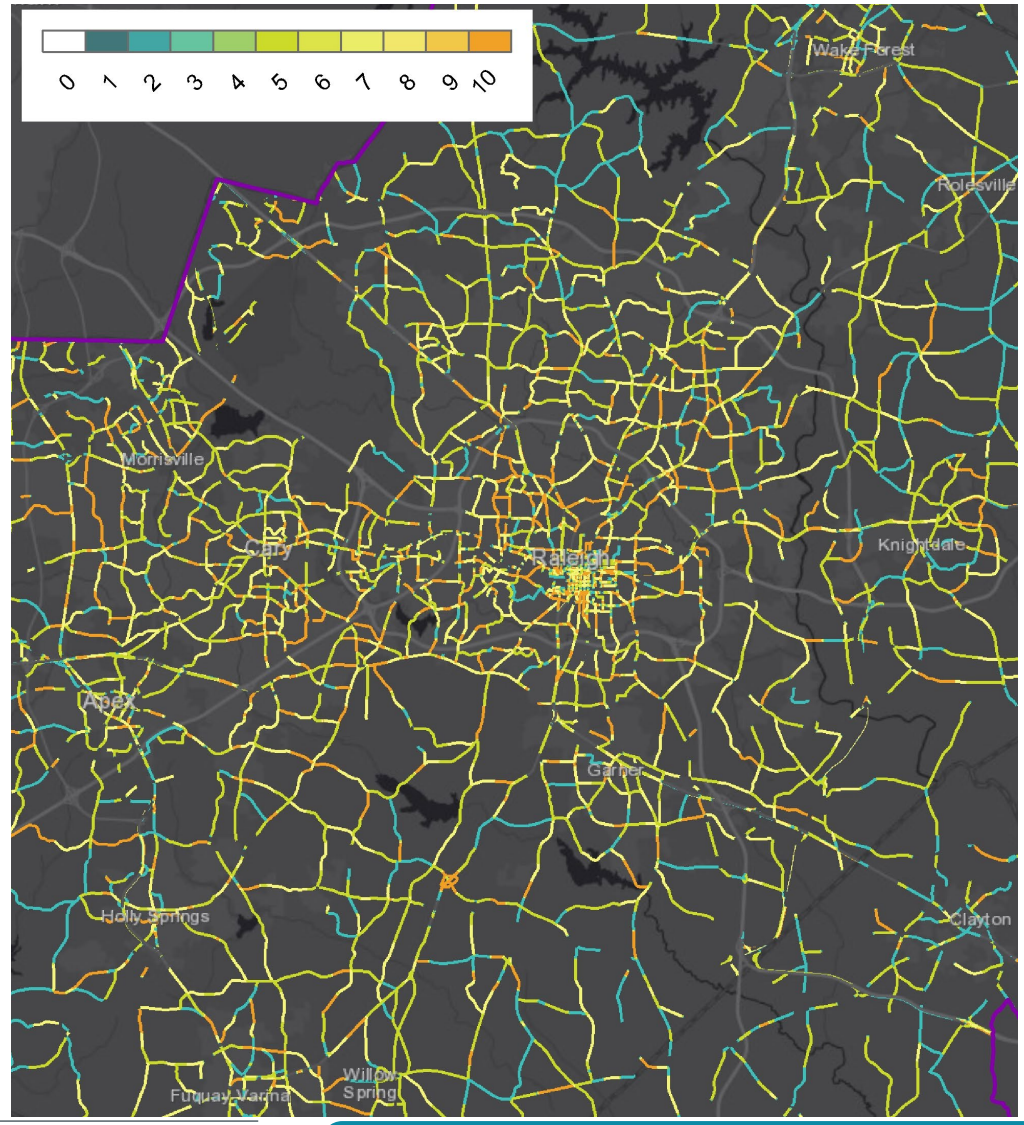
TRANSIT OPERATIONS – BUS SPEED

Measure: Average Bus Speed (2045)

- Analysis specs:
  - Floating zone: Circle with 200’ radius

Estimated bus speed	Suitability Score
0 – 8	10
8 – 12	8
12 – 16	5
16 – 20	2
20+	0

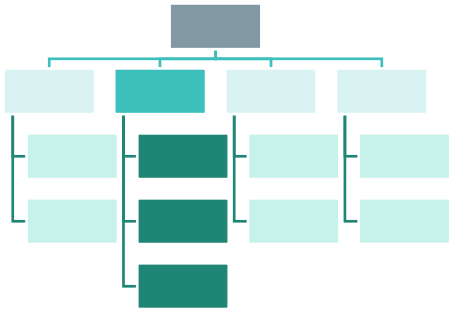


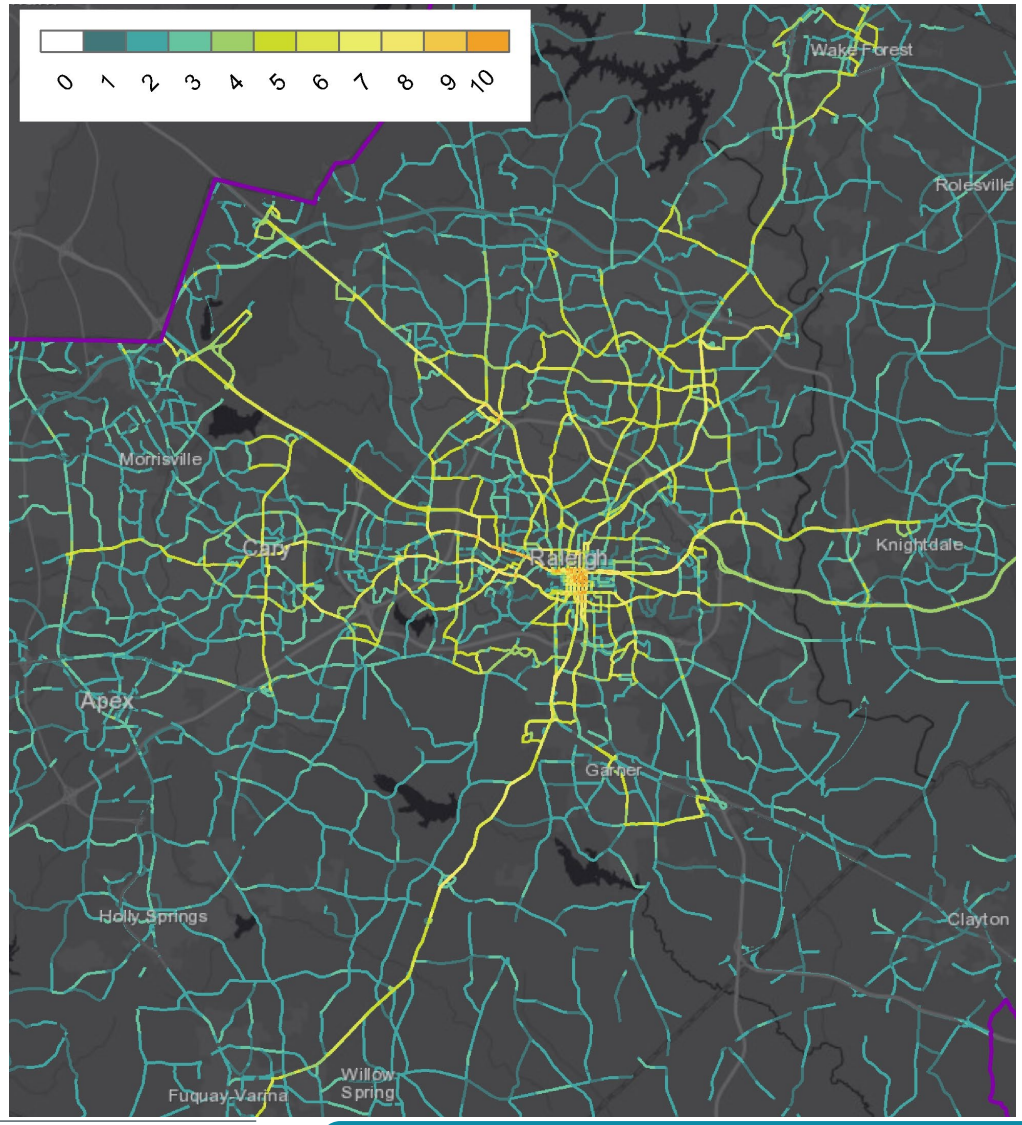


TRANSIT OPERATIONS – OVERLAY

Measure: Transit Operations Suitability

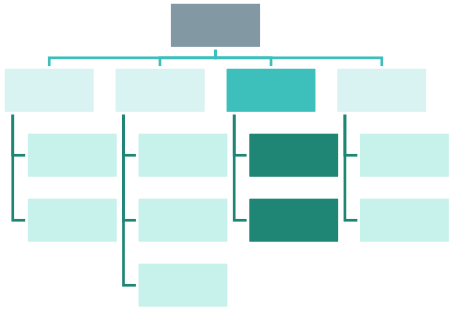
- Methods:
  - Overlay the on-time performance combo, service frequency overlay, and bus speed and take a weighted average.
    - On-Time Performance: 25%
    - Service Frequency: 50%
    - Bus Speed: 25%





HIGHWAY OPERATIONS – SCORING DIMENSIONS

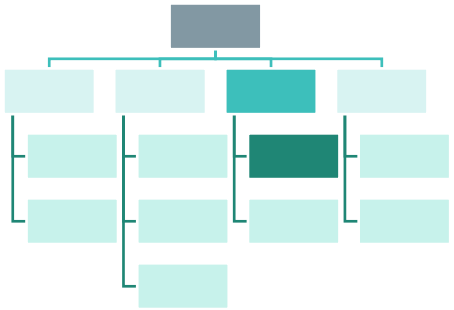
- Measures:
  - Vehicle Delay
  - V/C Ratio



HIGHWAY OPERATIONS – VEHICLE DELAY

Measure: Vehicle Delay

- Rationale:
  - RED Lanes provide more consistent travel conditions for transit vehicles in congested corridors and should be added to corridors where congestion impacts travel speeds.
- Sources:
  - TRM loaded highway network (2045)
- Methods:
  - For a defined floating zone area, summarize the minimum congested: free-flow speed ratio in the PM peak period.
  - Define thresholds to set “suitability tiers” based on congested: free-flow speed ratios.

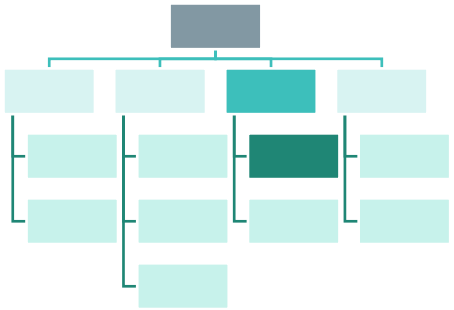


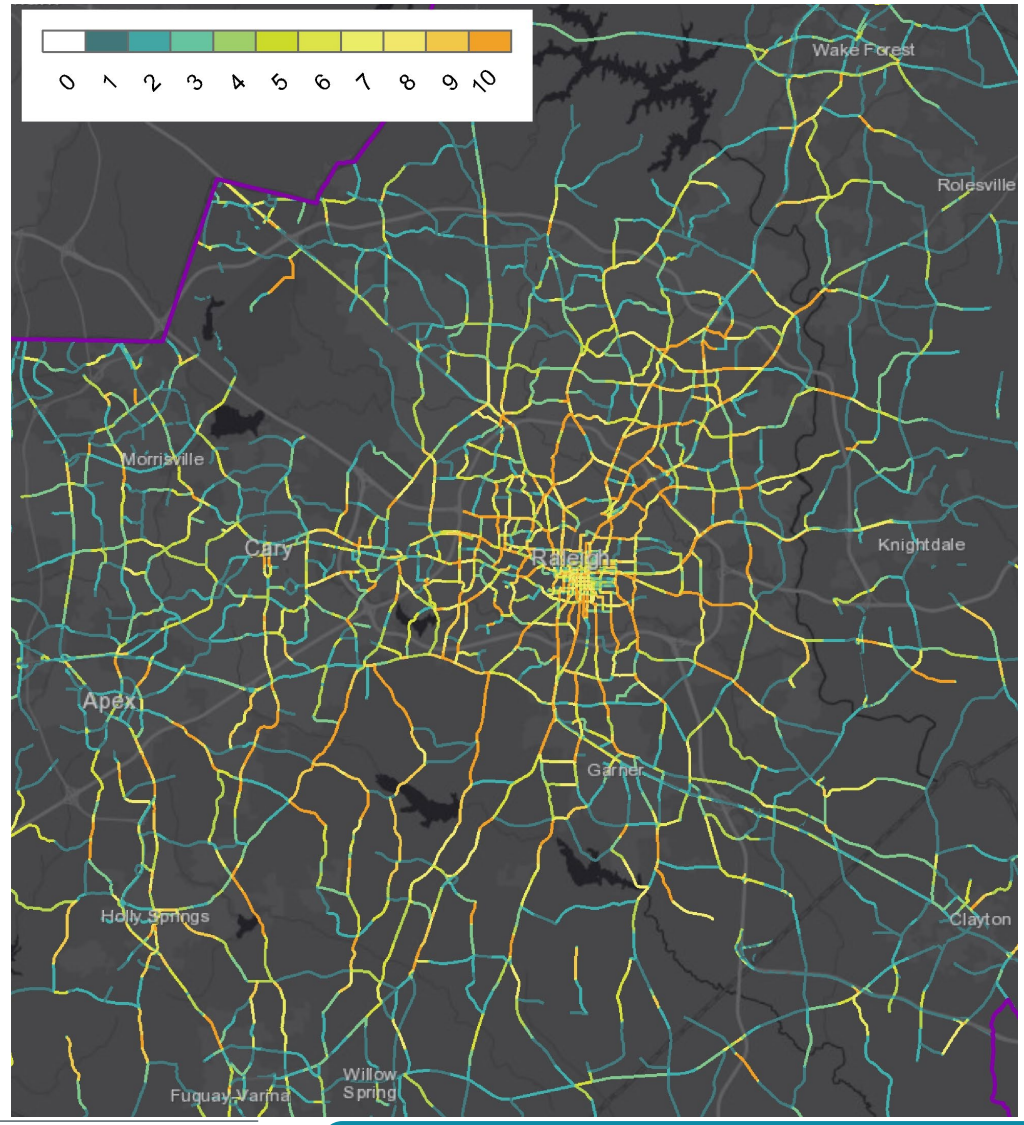
HIGHWAY OPERATIONS – VEHICLE DELAY

Measure: Vehicle delay (2045)

- Analysis specs:
  - Floating zone: Circle with 200' radius

Congested: Free-flow speed ratio	Suitability Score
0.00 – 0.50	10
0.50 – 0.60	9
0.60 – 0.65	8
0.65 – 0.70	7
0.70 – 0.75	6
0.75 – 0.80	5
0.80 – 0.85	4
0.85 – 0.90	3
0.90 – 0.95	2
0.95 – 1.00	1

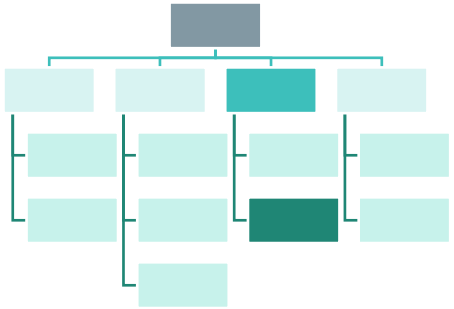




HIGHWAY OPERATIONS – V/C RATIO

Measure: V/C Ratio

- Rationale:
  - RED Lanes are most effective on segments where traffic congestion affects bus operations. However, extremely congested conditions call for general use capacity rather than transit priority lane investments.
- Sources:
  - TRM loaded highway network (2045)
- Methods:
  - For a defined floating zone area, summarize the maximum v/c ratio.
  - Define thresholds to set “suitability tiers” based on v/c ratios.

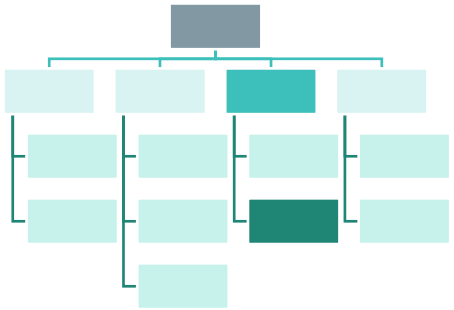


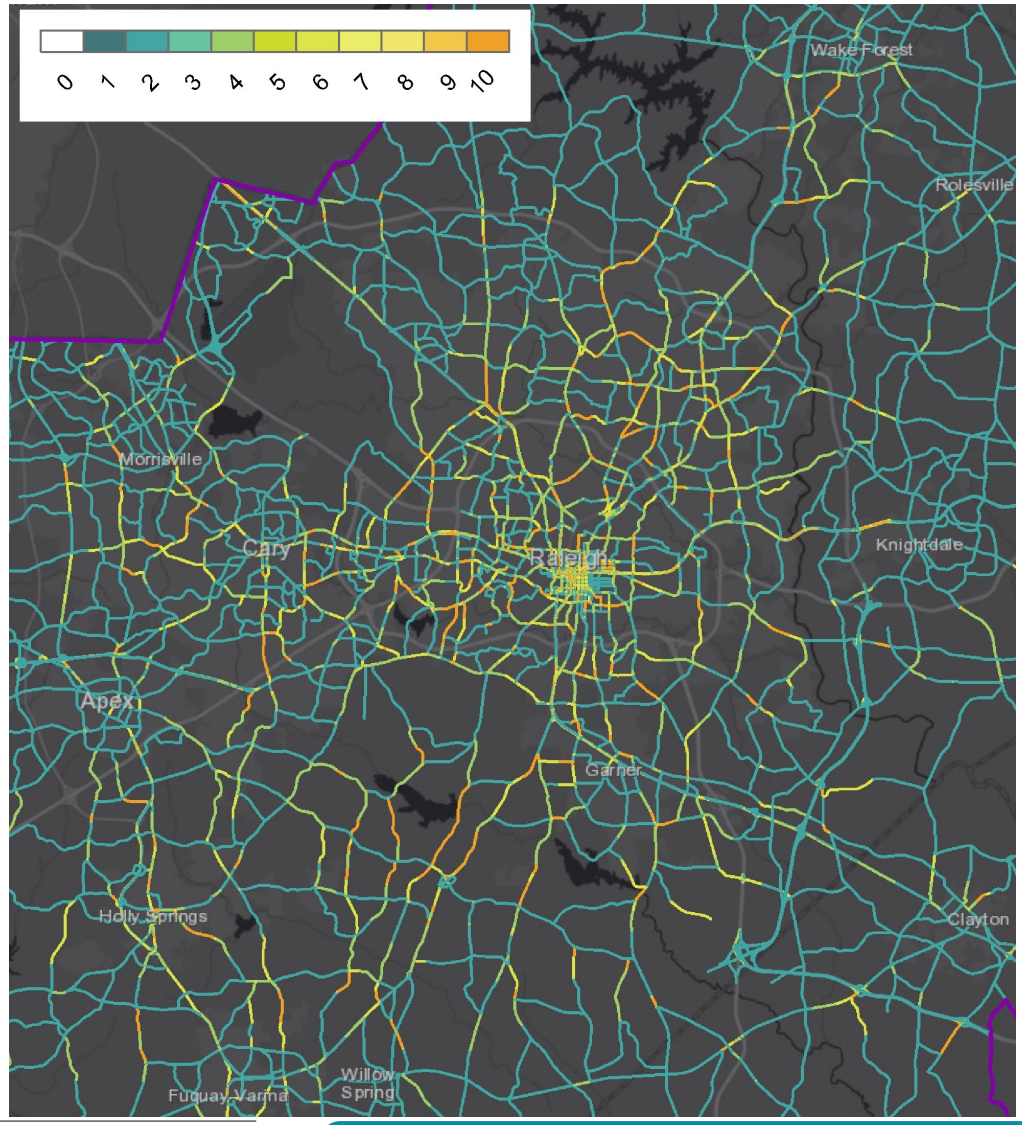
HIGHWAY OPERATIONS – V/C RATIO

Measure: V/C Ratio (2045)

- Analysis specs:
  - Floating zone: Circle with 200' radius

V/C Ratio	Suitability Score
0 – 0.75	2
0.75 – 0.85	6
0.85 – 0.95	8
0.95 – 1.05	10
1.05 – 1.20	6
1.20 +	2

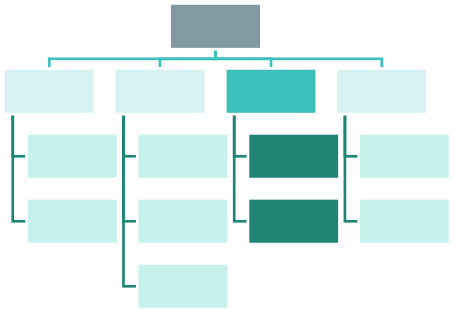


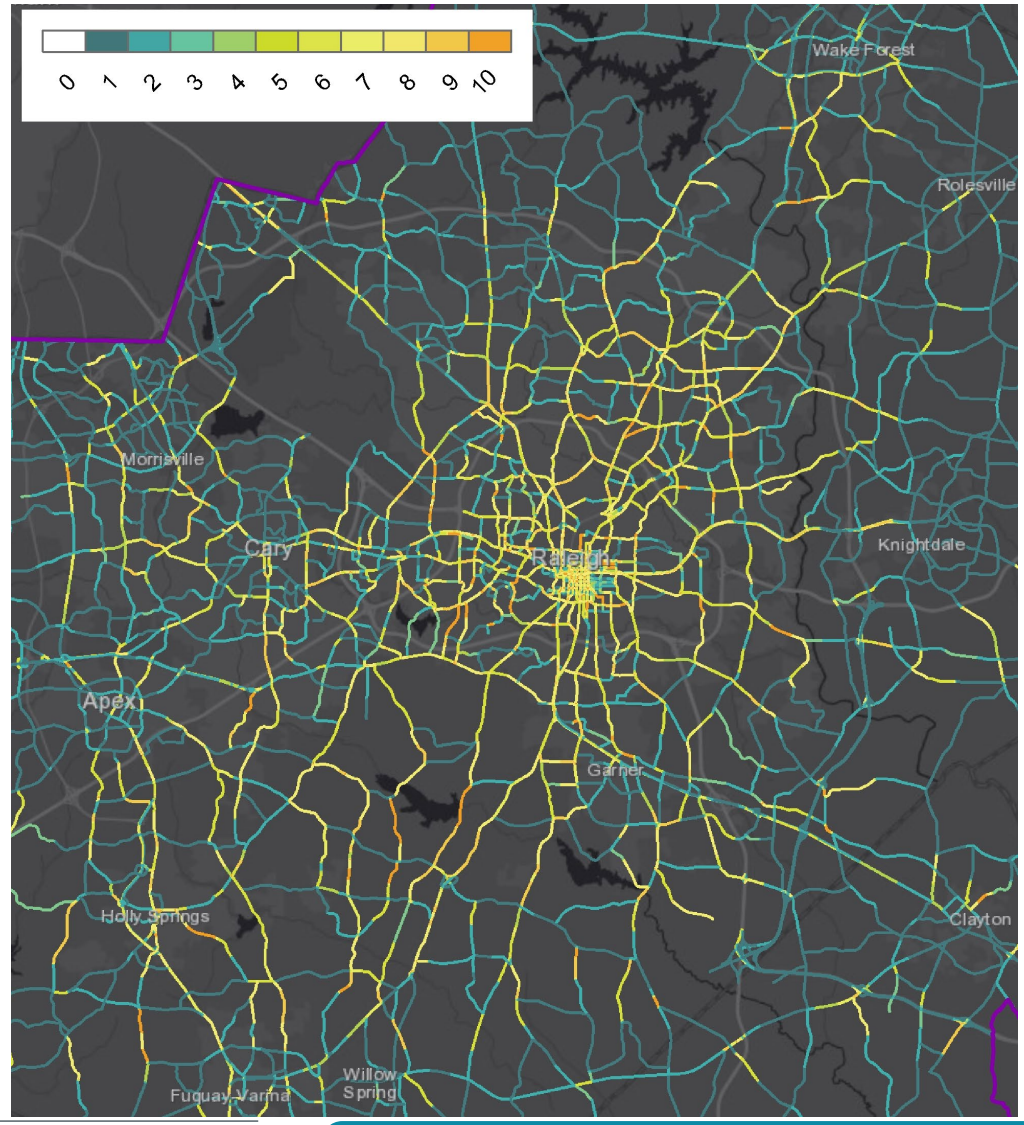


HIGHWAY OPERATIONS - OVERLAY

Measure: Highway Operations Suitability

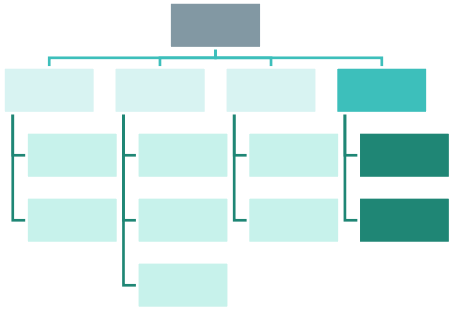
- Methods:
  - Overlay the vehicle delay and v/c ratio scores and take a weighted average
    - Vehicle delay: 50%
    - V/C ratio: 50%





CONTEXT AND DESIGN– SCORING DIMENSIONS

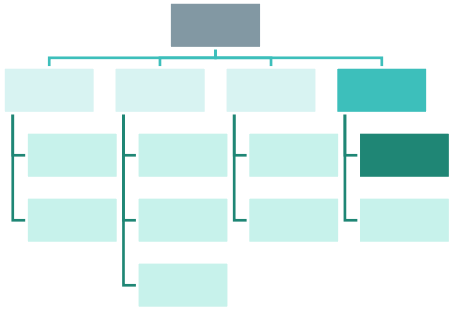
- Measures:
  - Activity unit density
  - Intersection density



CONTEXT AND DESIGN – ACTIVITY UNIT DENSITY

Measure: Activity Unit Density

- Rationale:
  - Activity unit density (jobs + dwellings per acre) is a common component of "transit readiness" analyses. RED Lanes can be incorporated in complete streets designs and are generally appropriate in transit-supportive contexts.
- Sources:
  - TRM zonal data (2013)
- Methods:
  - Find the activity unit density for the zone(s) adjacent to each segment.
  - Define thresholds to set "suitability tiers" based on activity unit density.

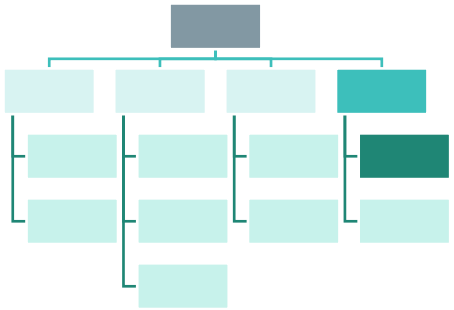


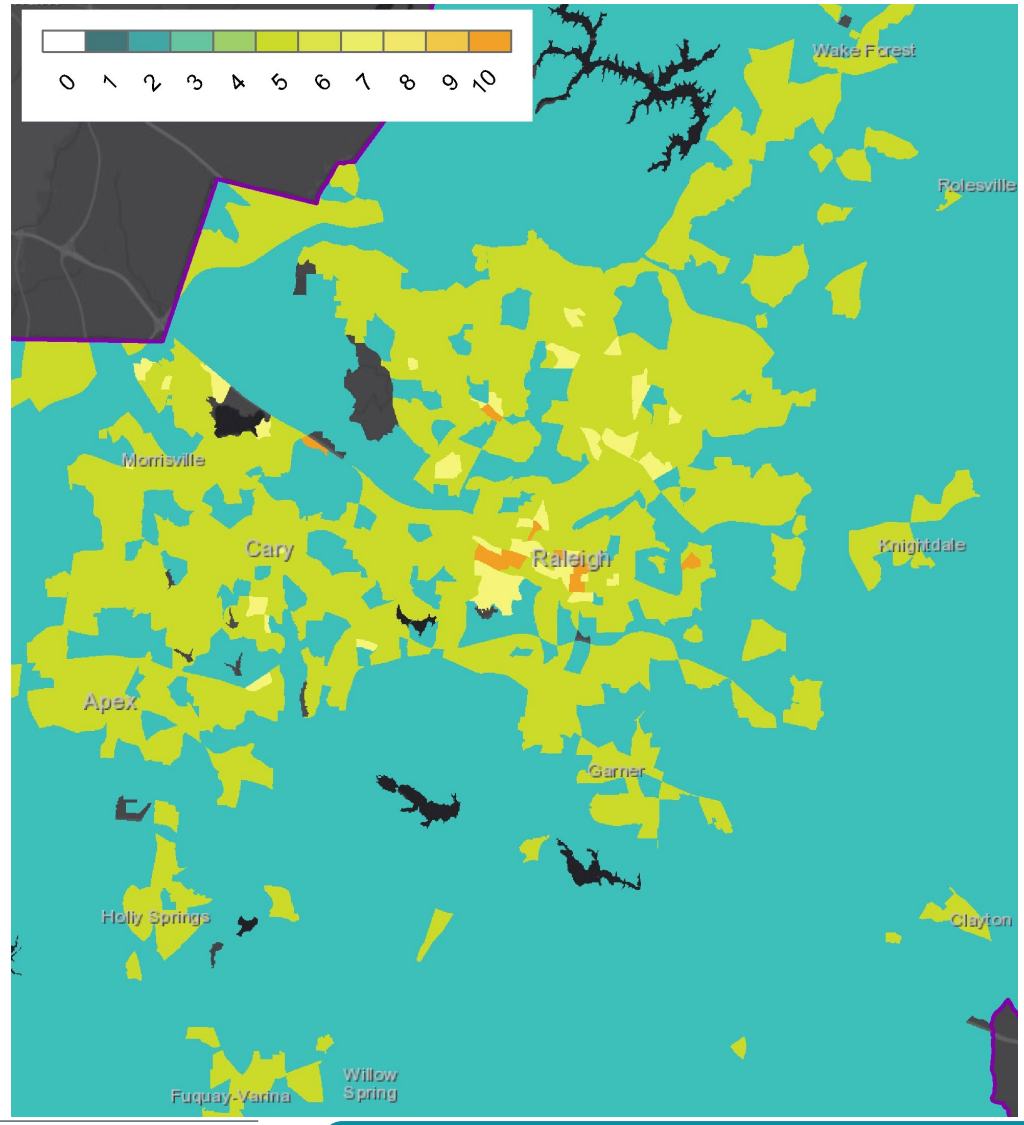
CONTEXT AND DESIGN – ACTIVITY UNIT DENSITY

Measure: Activity Unit Density (2013)

- Analysis specs:
  - Adjacent zone activity density

Activity Unit Density	Suitability Score
0	0
0 – 5	2
5 – 21	5
21 – 49	8
49+	10

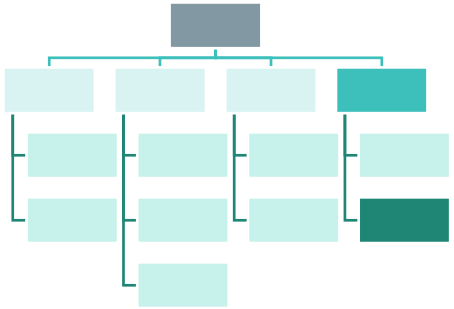




CONTEXT AND DESIGN – INTERSECTION DENSITY

Measure: Intersection Density

- Rationale:
  - Intersection density (intersections per square mile) is a common component of "transit readiness" analyses. RED Lanes can be incorporated in complete streets designs and are generally appropriate in transit-supportive contexts.
- Sources:
  - EPA Smart Location Database (variable D3b, circa 2010)
- Methods:
  - Find the intersection density for the zone(s) adjacent to each segment.
  - Define thresholds to set "suitability tiers" based on intersection density.

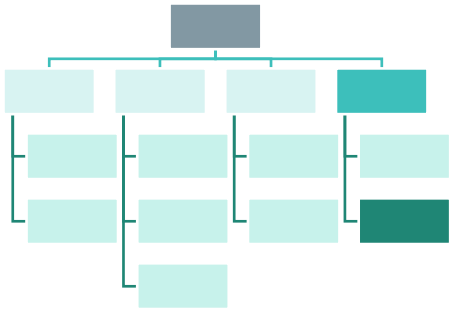


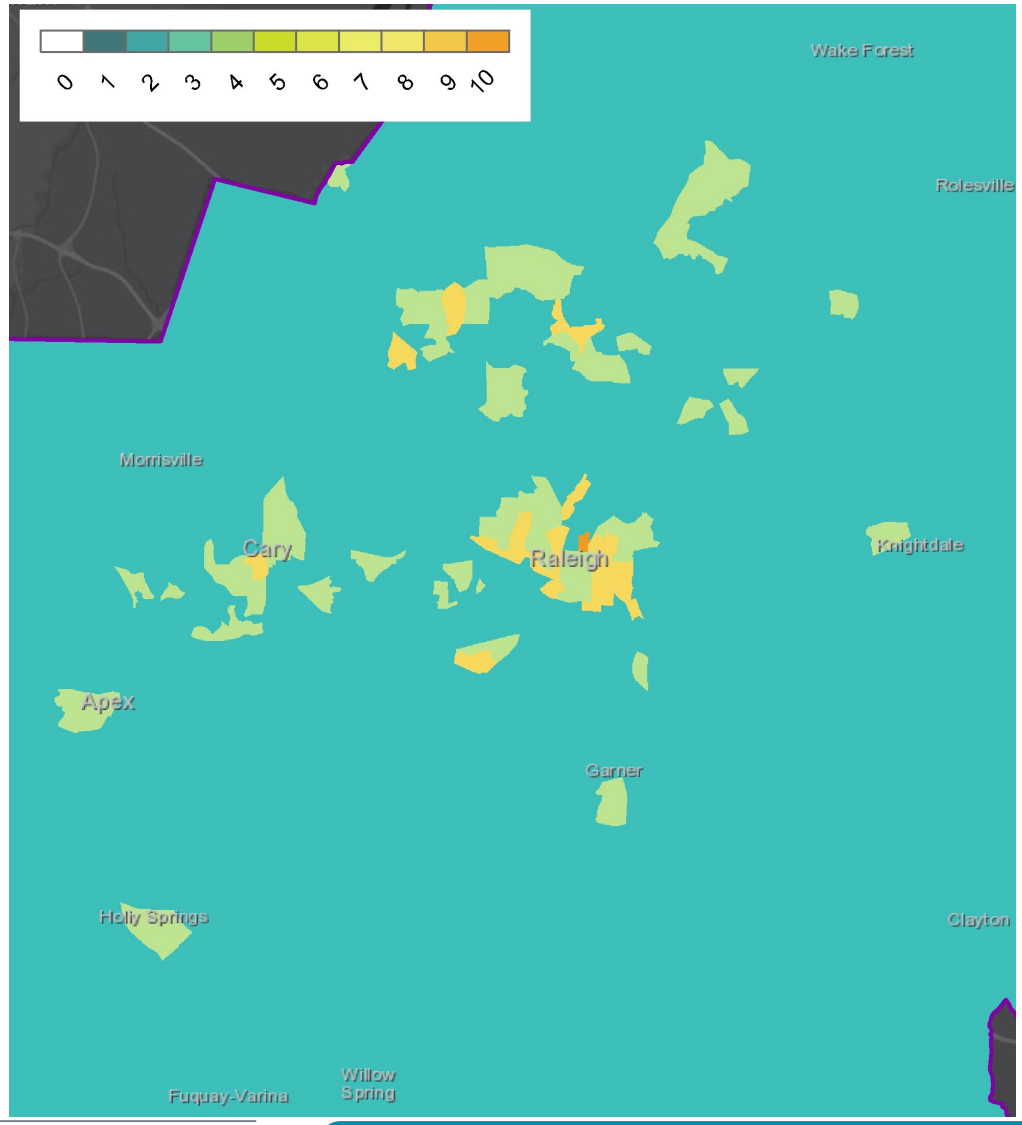
CONTEXT AND DESIGN – INTERSECTION DENSITY

Measure:
Intersection Density (c. 2010)

- Analysis specs:
  - Adjacent zone intersection density

Intersection Density	Suitability Score
0	0
0 – 70	2
70 – 100	5
100 – 226	8
226 +	10

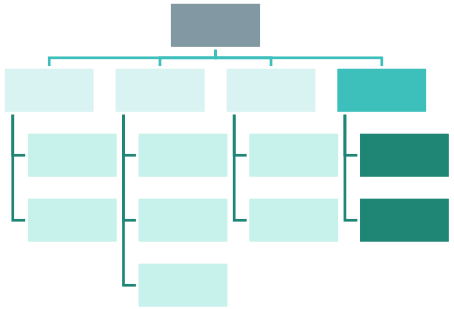


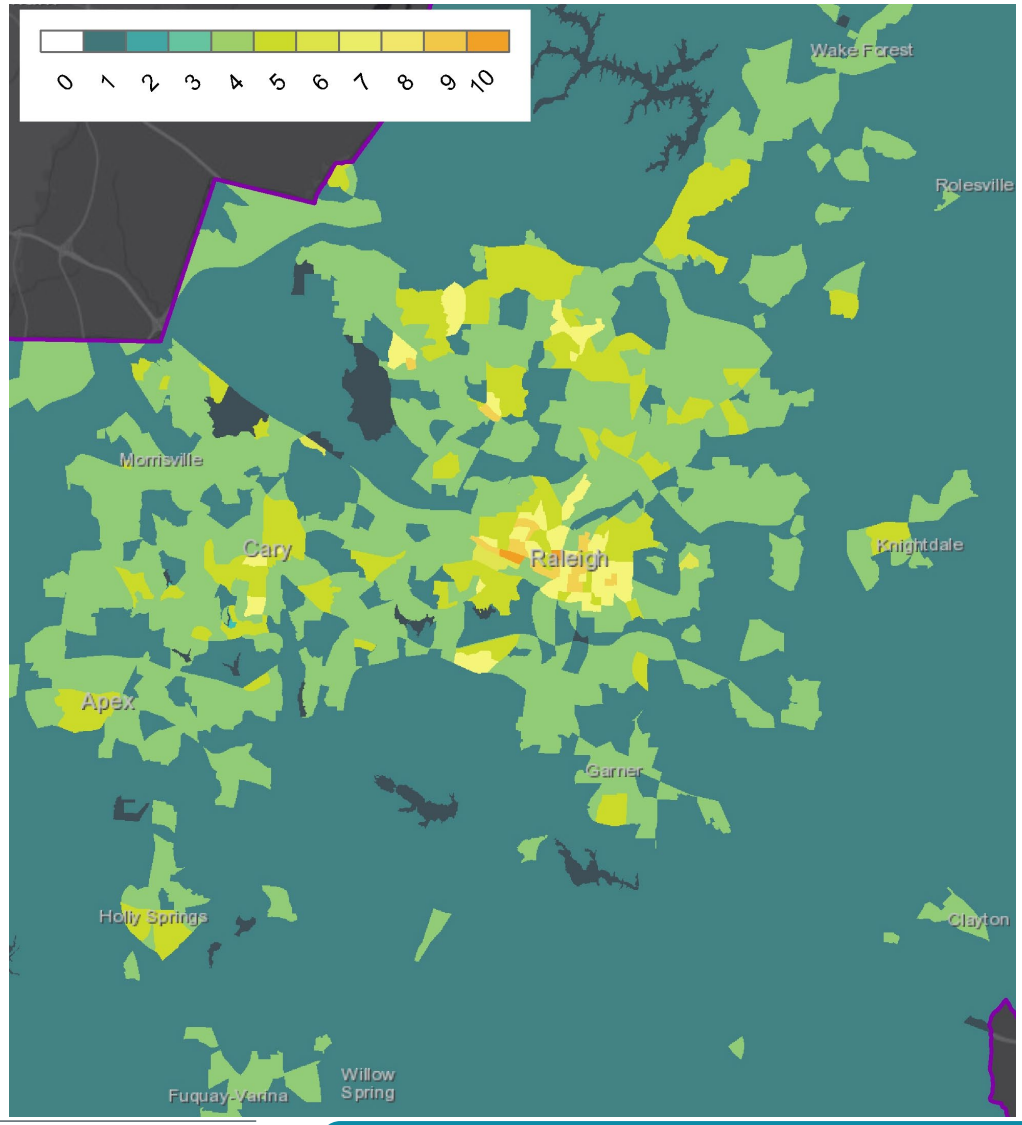


CONTEXT AND DESIGN– SCORING DIMENSIONS

Measure: Context and Design Suitability

- Methods:
  - Overlay the activity density and intersection density scores and take a weighted average
    - Activity unit density: 50%
    - Intersection density: 50%

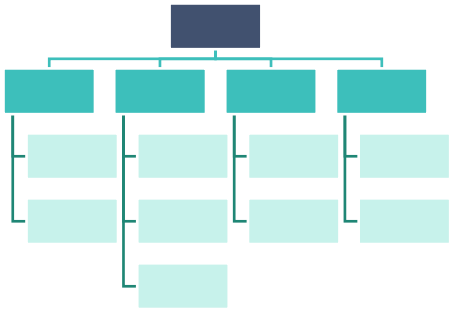


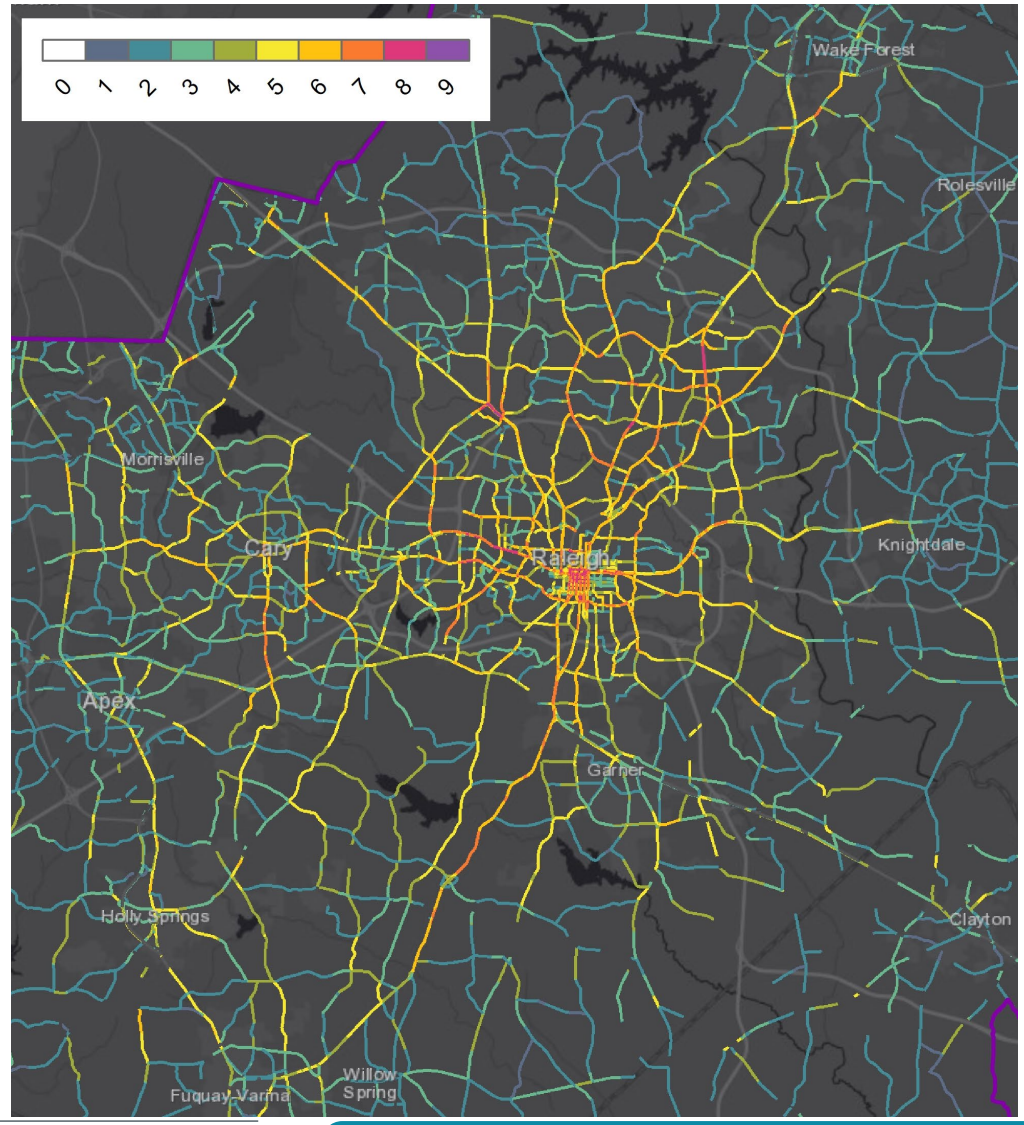


RED LANES SUITABILITY OVERLAY

- Dimensions (weights based on feedback from RED Lanes Core Technical Team and CAMPO Technical Coordinating Committee):
  - Travel Demand (30%)
  - Transit Operations (25%)
  - Highway Operations (30%)
  - Context and Design (15%)

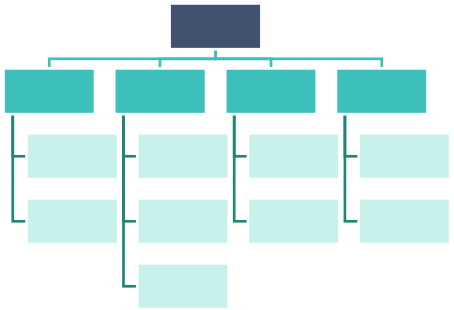
Since highway datasets were included in the suitability scoring, many facilities with no existing or planned transit have a suitability score. We can mask these out by only including segments with existing or planned transit service (see next slide).

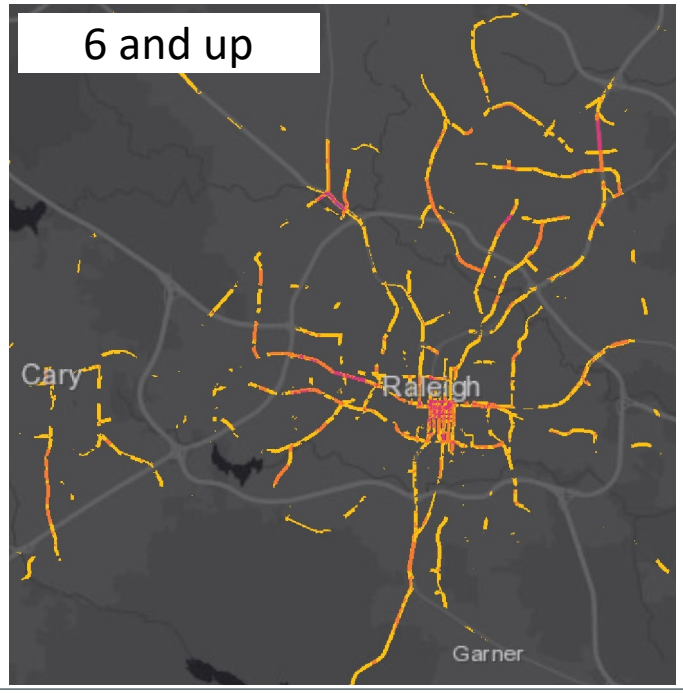


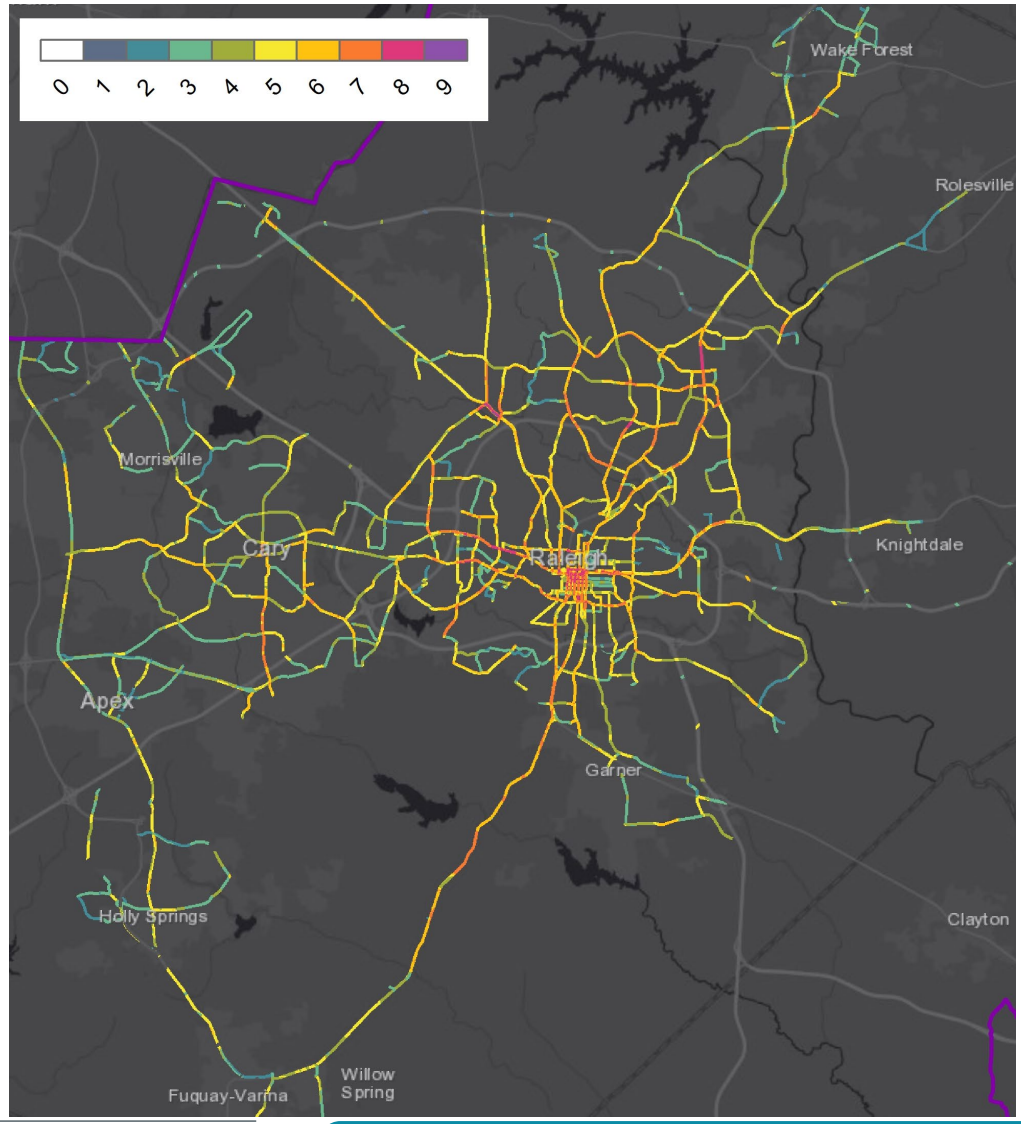


RED LANES SUITABILITY OVERLAY

- Dimensions:
  - Travel Demand (30%)
  - Transit Operations (25%)
  - Highway Operations (30%)
  - Context and Design (15%)



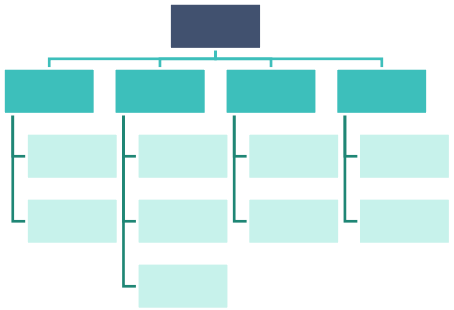


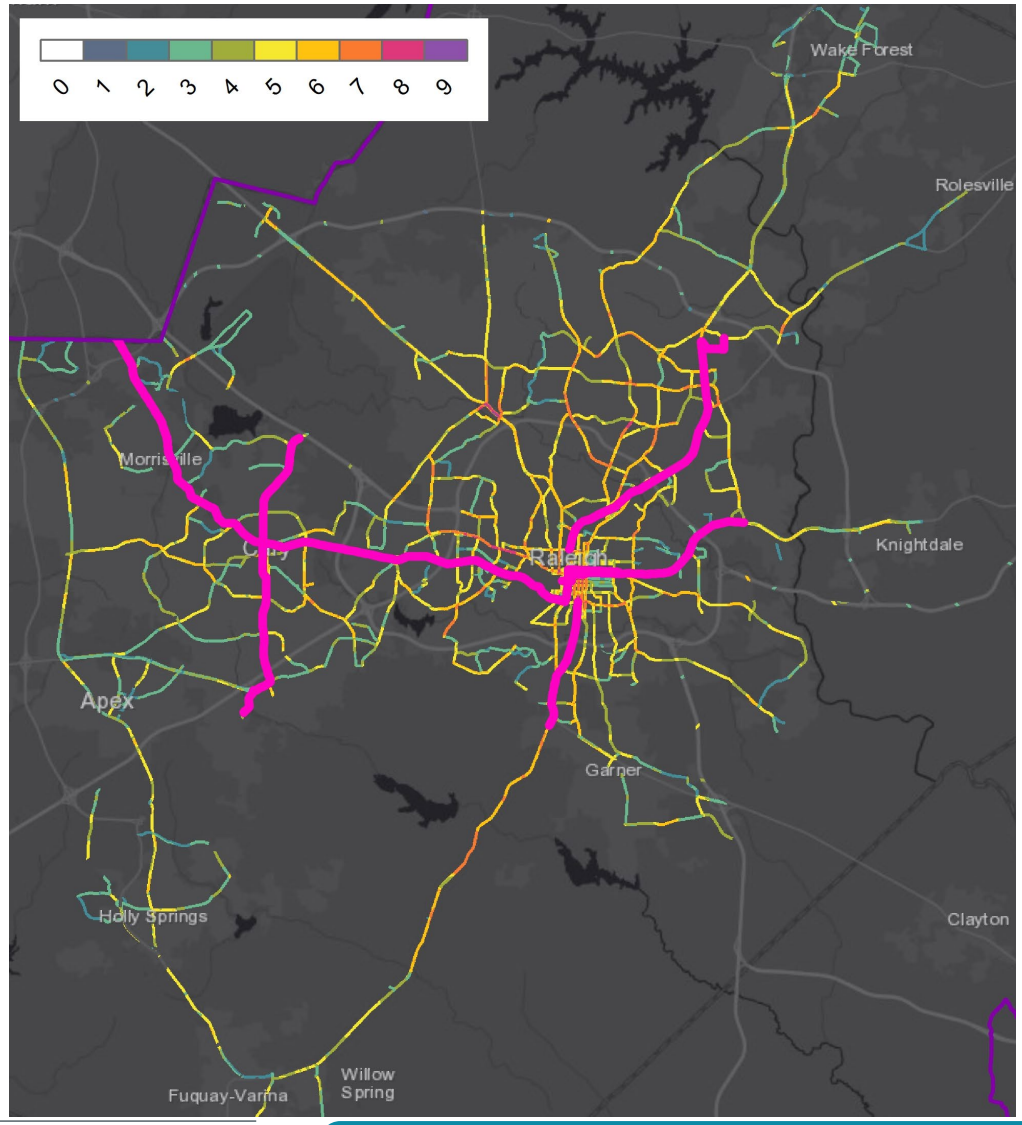


RED LANES SUITABILITY OVERLAY

- Dimensions:
  - Travel Demand (30%)
  - Transit Operations (25%)
  - Highway Operations (30%)
  - Context and Design (15%)

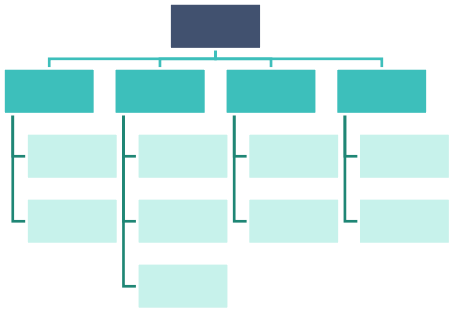
Some segments are already being studied for potential fixed-guideway transit improvements. RED Lanes scores are retained for these segments, but it also helpful to mask these segments out for some maps to show highly-suitable sections of other corridors.

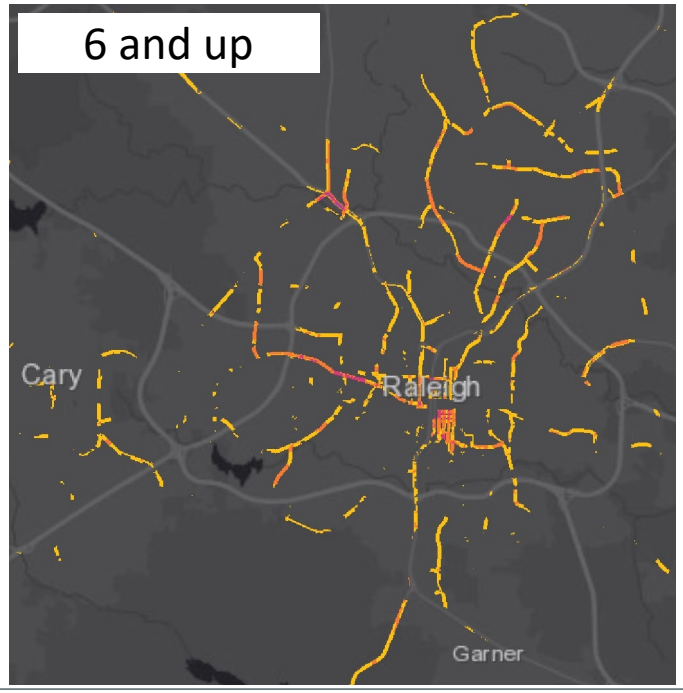


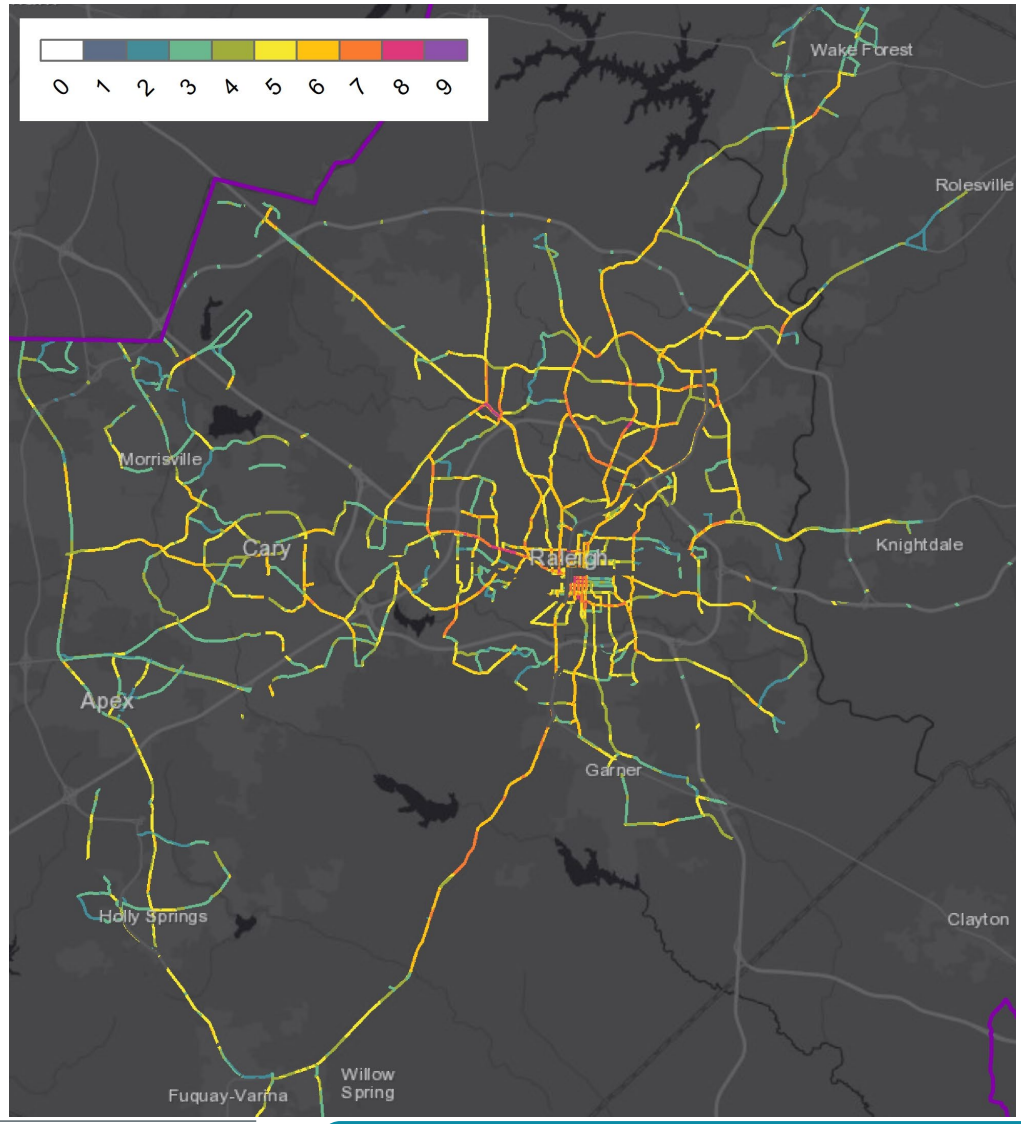


RED LANES SUITABILITY OVERLAY

- Dimensions:
  - Travel Demand (30%)
  - Transit Operations (25%)
  - Highway Operations (30%)
  - Context and Design (15%)



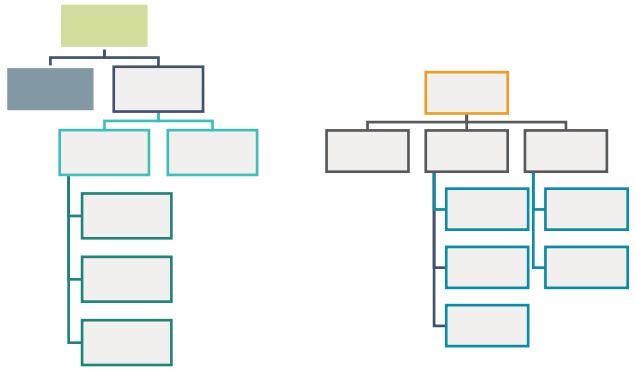




3 WALKTHROUGH OF ENRICHMENT ELEMENTS

WALKTHROUGH OF SUITABILITY ELEMENTS

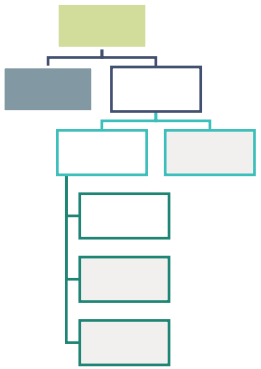
- The following slides provide details of how RED Lanes Enrichment data were developed, including data sources, analysis parameters, scoring rubrics and maps.
- The diagram in the lower left corner indicates which components of the scoring process are depicted in each slide.



FEASIBILITY – RIGHT OF WAY IMPACTS

Measure: Number of buildings impacted per mile with the addition of 11’ RED Lanes in each direction.

- Rationale:
  - RED Lanes utilize right-of-way. In constrained corridors where buildings are near the street, adding RED Lanes in each direction may impact existing buildings, presenting implementation challenges.
- Sources:
  - NC Route Characteristics shape file
  - Microsoft building footprints
- Methods:
  - See ECR report for estimation of buildings-impacted-per-mile due to adding RED Lanes.
  - For a defined floating zone area, take the average number of buildings impacted per mile.
  - Define thresholds to set “feasibility tiers” based on ROW impacts



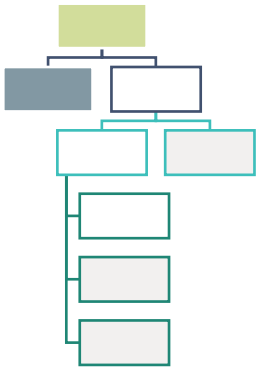
FEASIBILITY – RIGHT OF WAY IMPACTS

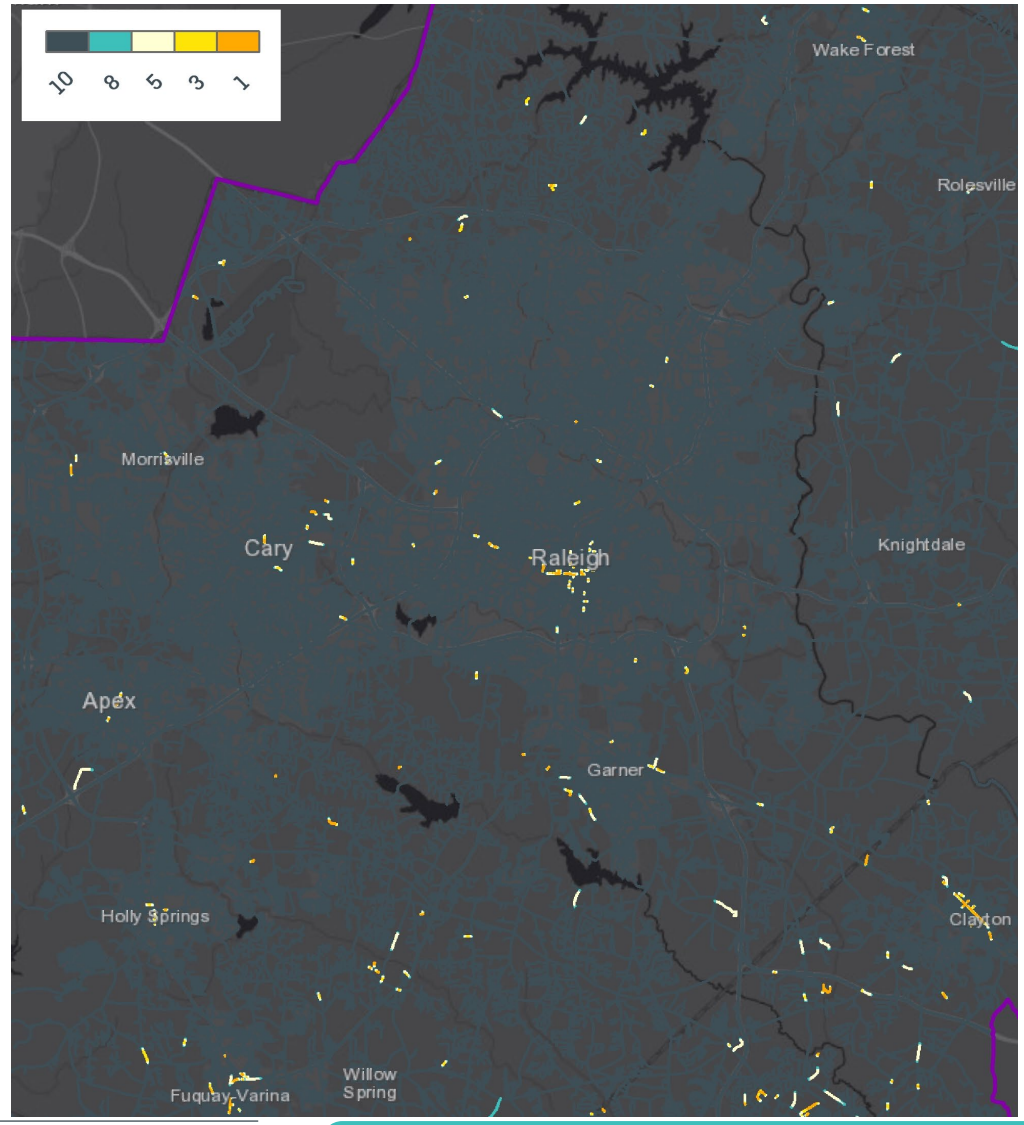
Measure: Potential ROW Impacts (c. 2018)

- Analysis specs:
  - Floating zone: Circle with 200' radius

*Includes all streets in NC route characteristics layer. Highlights **low-feasibility** segments.*

Buildings Impacted per Mile Range	Feasibility Score
0	10
0 – 1	8
1 – 5	5
5 – 9	3
9 +	1

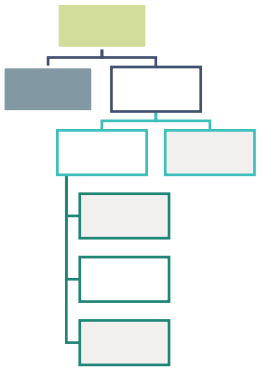




FEASIBILITY – NUMBER OF LANES

Measure: Number of travel lanes in each direction on the existing network

- Rationale:
  - It is not always necessary to add lanes to create RED Lanes. In some cases, taking an existing lane may be feasible. This assessment focuses on existing lane counts to provide a coarse sense of where this approach may be possible.
- Sources:
  - TRM highway network (2013)
- Methods:
  - For a defined floating zone area, take the maximum number of lanes in each travel direction.
  - Define thresholds to set “feasibility tiers” based on number of lanes.



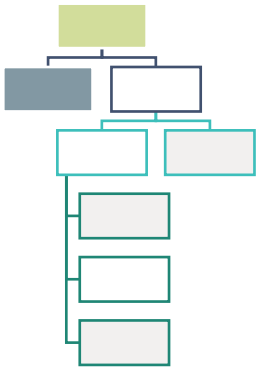
FEASIBILITY – NUMBER OF LANES

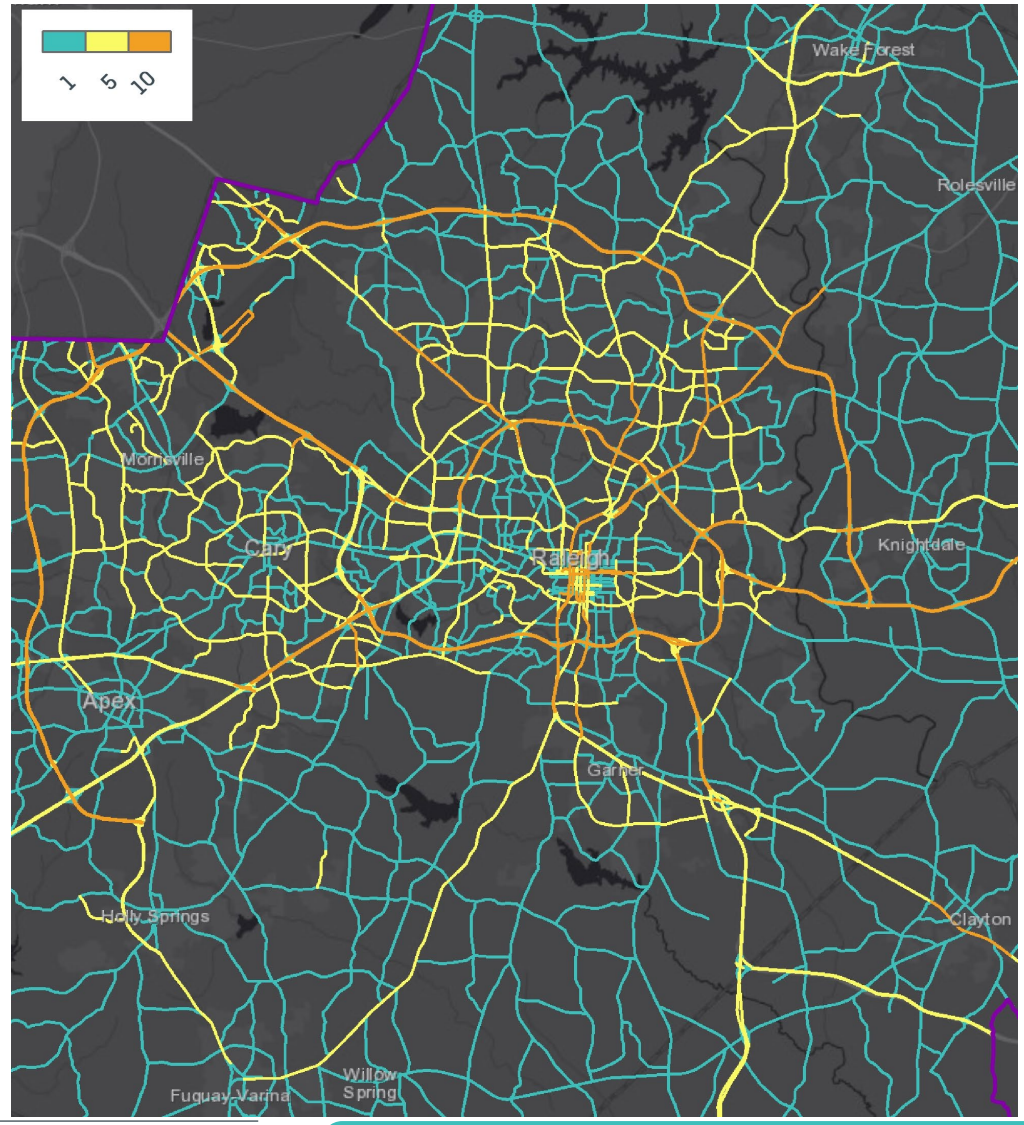
Measure: Number of Lanes (2013)

- Analysis specs:
  - Floating zone: Circle with 200’ radius

*Includes all streets in TRM. Highlights **high-feasibility** segments.*

Number of Lanes Range	Feasibility Score
1/direction	1
2/direction	5
3+/direction	10

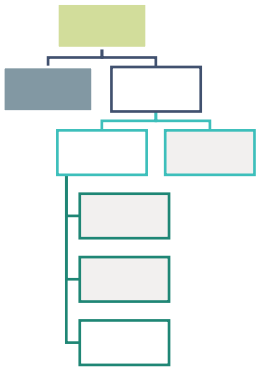




FEASIBILITY – PLANNED WIDENINGS

Measure: Number of travel lanes added in each direction

- Rationale:
  - Whether a facility has constraints or limited number of existing lanes, RED Lanes may be feasible on segments that are already expected to be widened per adopted plans.
- Sources:
  - TRM highway network (2045)
- Methods:
  - For a defined floating zone area, take the maximum number of new lanes added.
  - Define thresholds to set “feasibility tiers” based on number of added lanes.



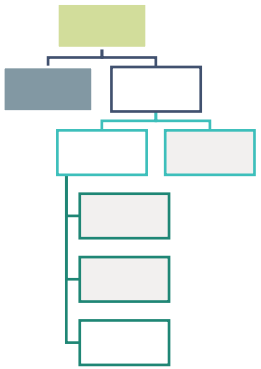
FEASIBILITY – PLANNED WIDENINGS

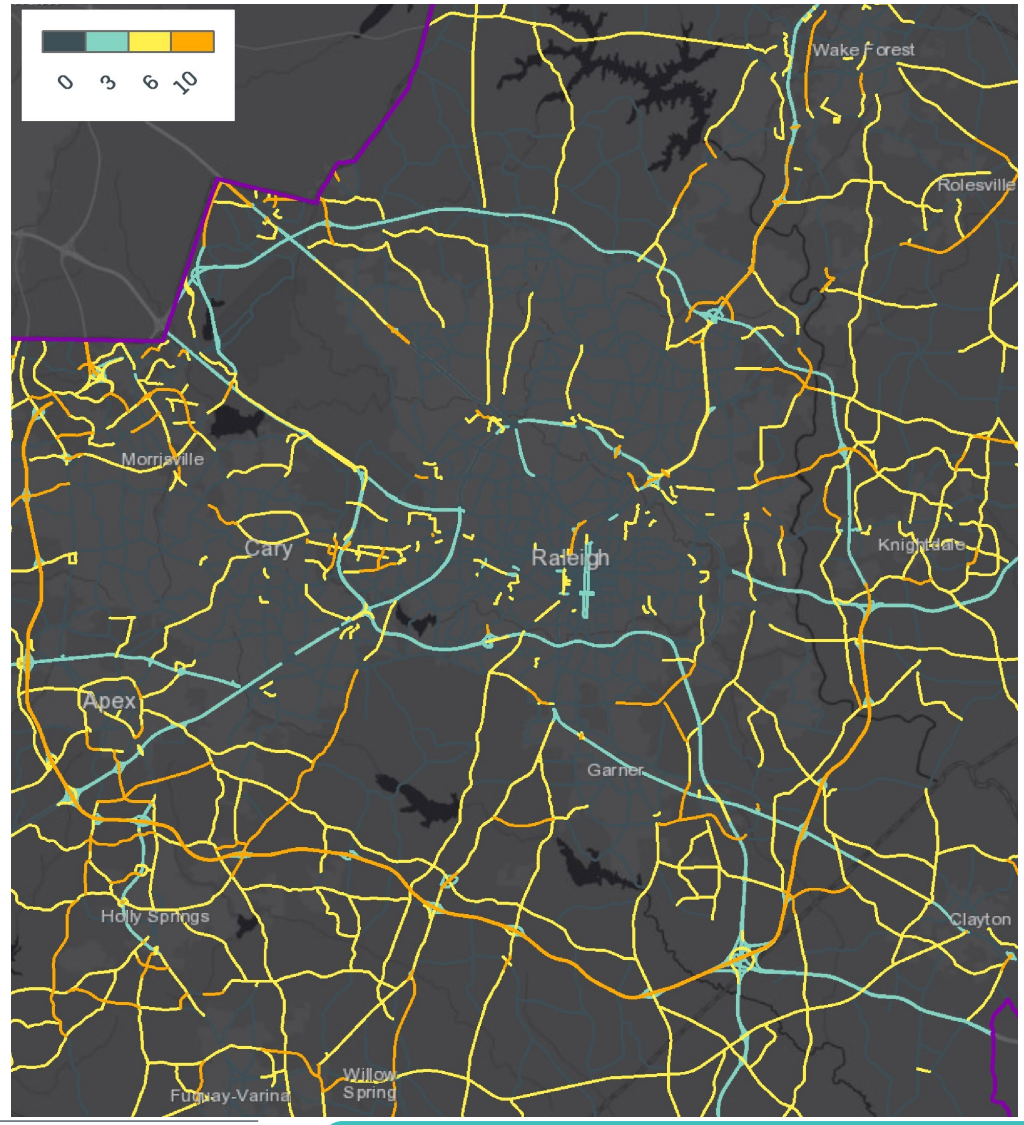
Measure: Planned Widenings (by 2045)

- Analysis specs:
  - Floating zone: Circle with 200’ radius

*Includes all streets in TRM. Highlights **high-feasibility** segments.*

Number of Lanes Added Range	Feasibility Score
0	0
1	3
2	6
3+	10

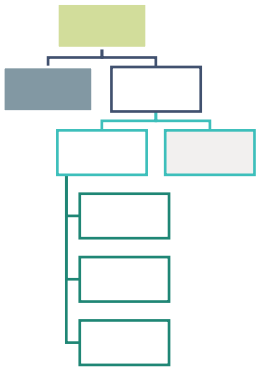


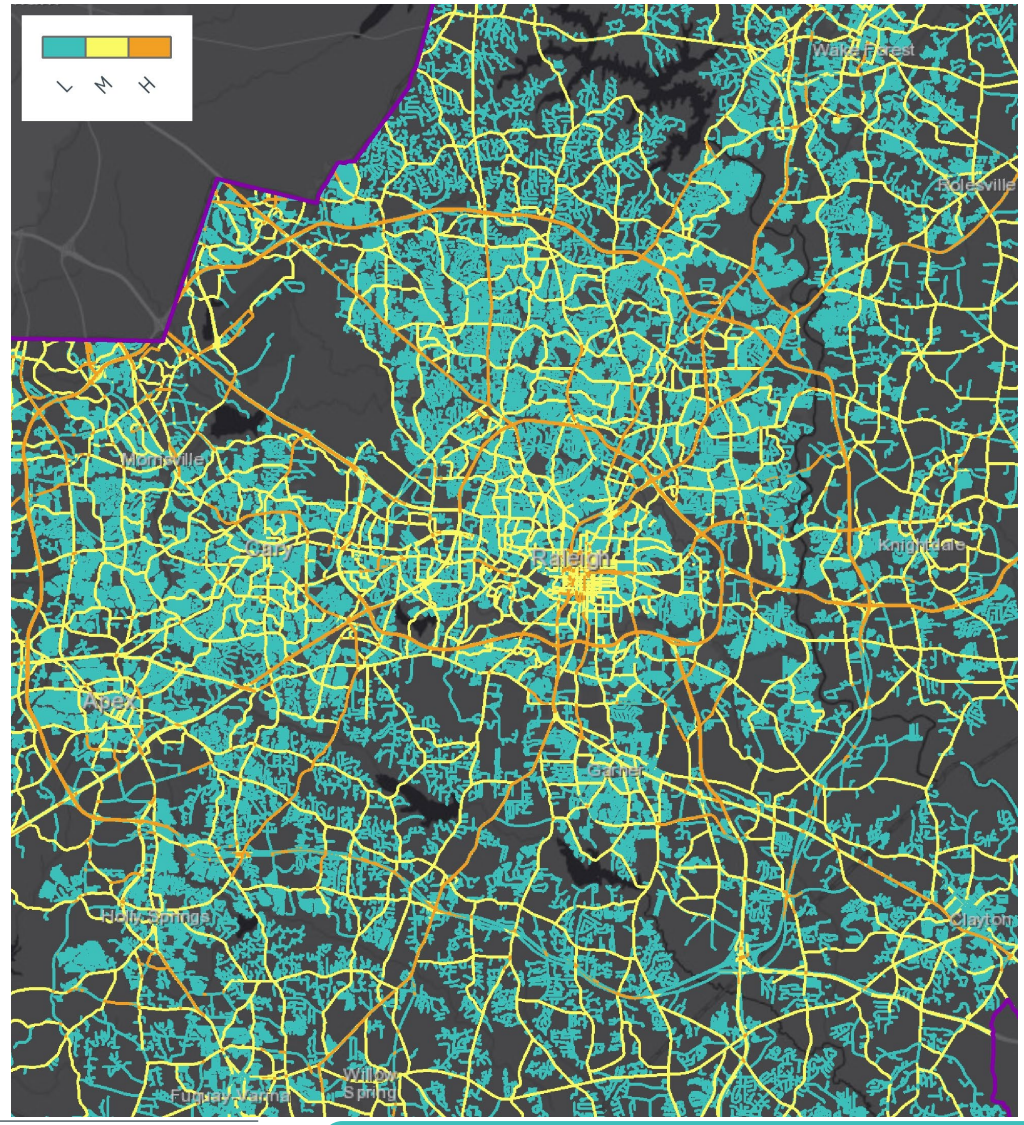


FEASIBILITY OVERLAY

Measure: Feasibility Score Overlay

- Methods:
  - Overlay the ROW impacts estimates, number of existing lanes, and planned widenings and take a weighted average
    - ROW impacts (33%)
    - Number of lanes (33%)
    - Planned widenings (34%)
  - Reclassify overlay results:
    - 3 or less = low feasibility
    - 4 – 6 = medium feasibility
    - 7+ = high feasibility

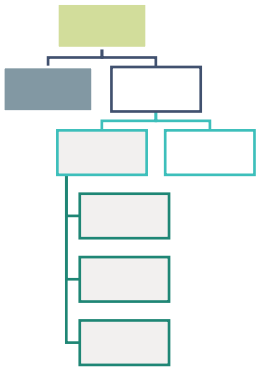




COMMUNITIES OF CONCERN

Measure: Number overlapping communities of concern

- Rationale:
  - RED Lanes that could provide mobility benefits to disadvantaged populations should be differentiated from those that do not. Higher numbers of overlapping groups in the CAMPO Communities of Concern dataset indicate greater prospective benefits to different population segments.
- Sources:
  - CAMPO Communities of Concern polygons
- Methods:
  - Find the number of overlapping communities of concern flagged in the block group(s) adjacent to each segment.
  - Define thresholds to set “equity tiers” based on number of overlapping communities of concern.

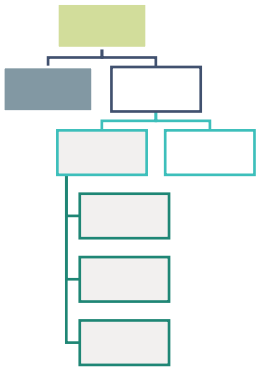


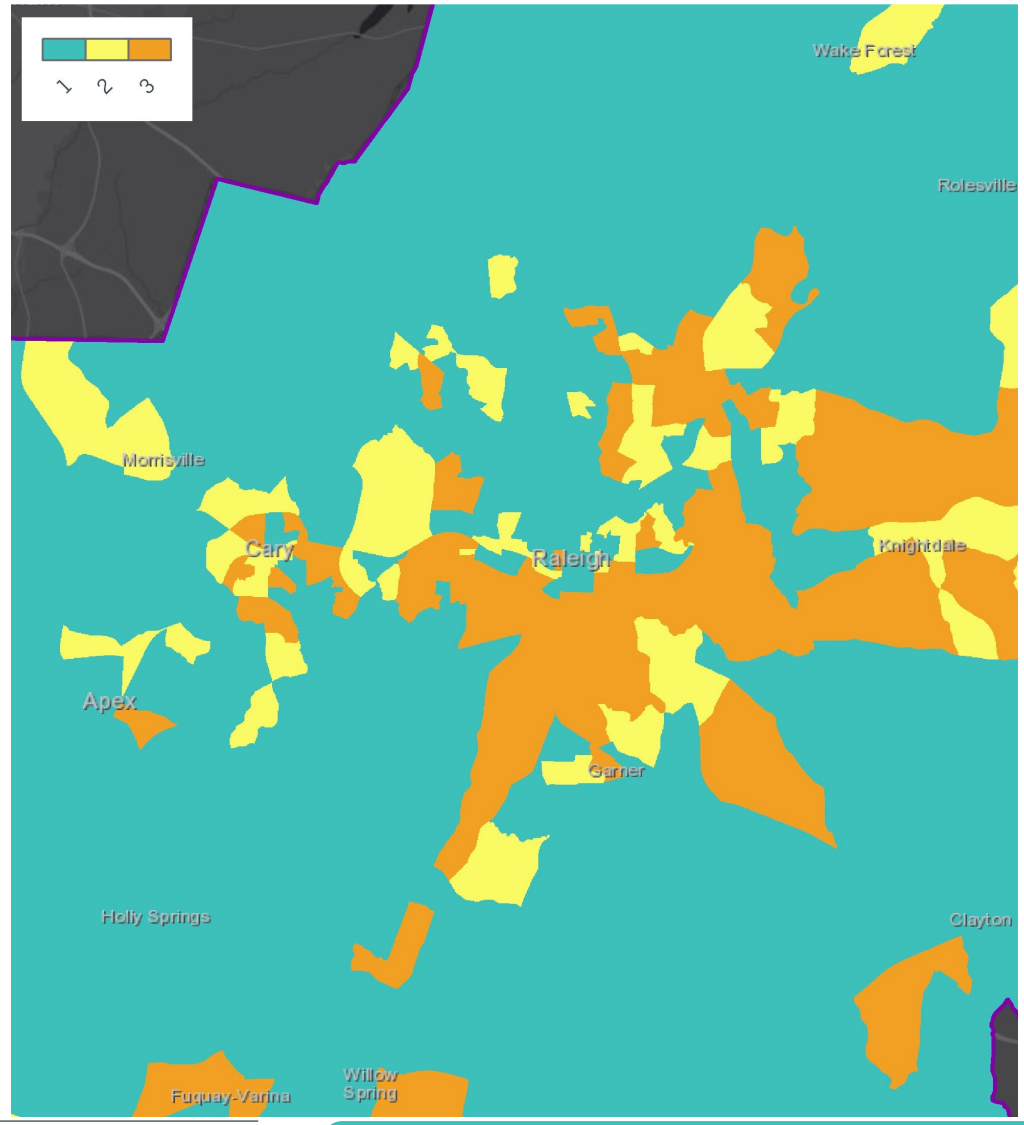
COMMUNITIES OF CONCERN

Measure: Overlapping Communities of Concern (2016)

- Analysis specs:
  - Adjacent block group count of overlapping Communities of Concern

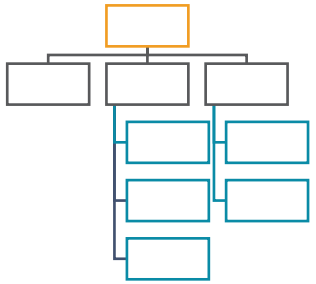
Number of overlapping CofC's Range	Equity Score
0 – 1	1
1 – 2	2
2+	3





IMPLEMENTATION GUIDANCE

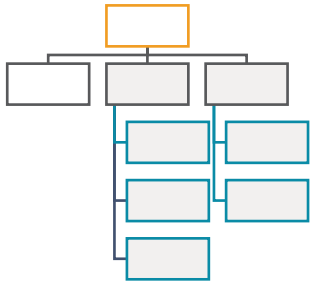
- Measures:
  - **Non-motorized propensity** – uses walk access to jobs as a proxy for the likelihood of non-motorized users in/near a potential RED Lane.
  - **TSP suitability** – a coarse assessment of whether transit-signal priority might be an appropriate operational improvement accompanying RED Lanes in a segment.
  - **Full-time suitability** – evaluates whether a segment should be considered for full-time RED Lanes of if part-time lanes are more appropriate.
    - Peaking of transit ridership (2045)
    - Peaking of traffic volume (2045)



NON-MOTORIZED PROPENSITY

Measure: Walk access to jobs from adjacent blocks

- Rationale:
  - Non-motorized (walking and biking) travel is often correlated with walk access to nearby employment. In RED Lane candidate segments adjacent to blocks with high accessibility, facility design should account for non-motorized users.
- Sources:
  - University of Minnesota Accessibility Observatory Walk Access Scores (2014)
- Methods:
  - Record the number of jobs reachable by walking in census block(s) adjacent to each segment.
  - Define thresholds to set “Non-motorized propensity tiers” based on walk access values.

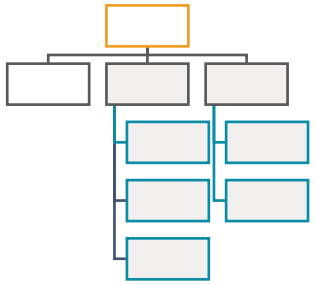


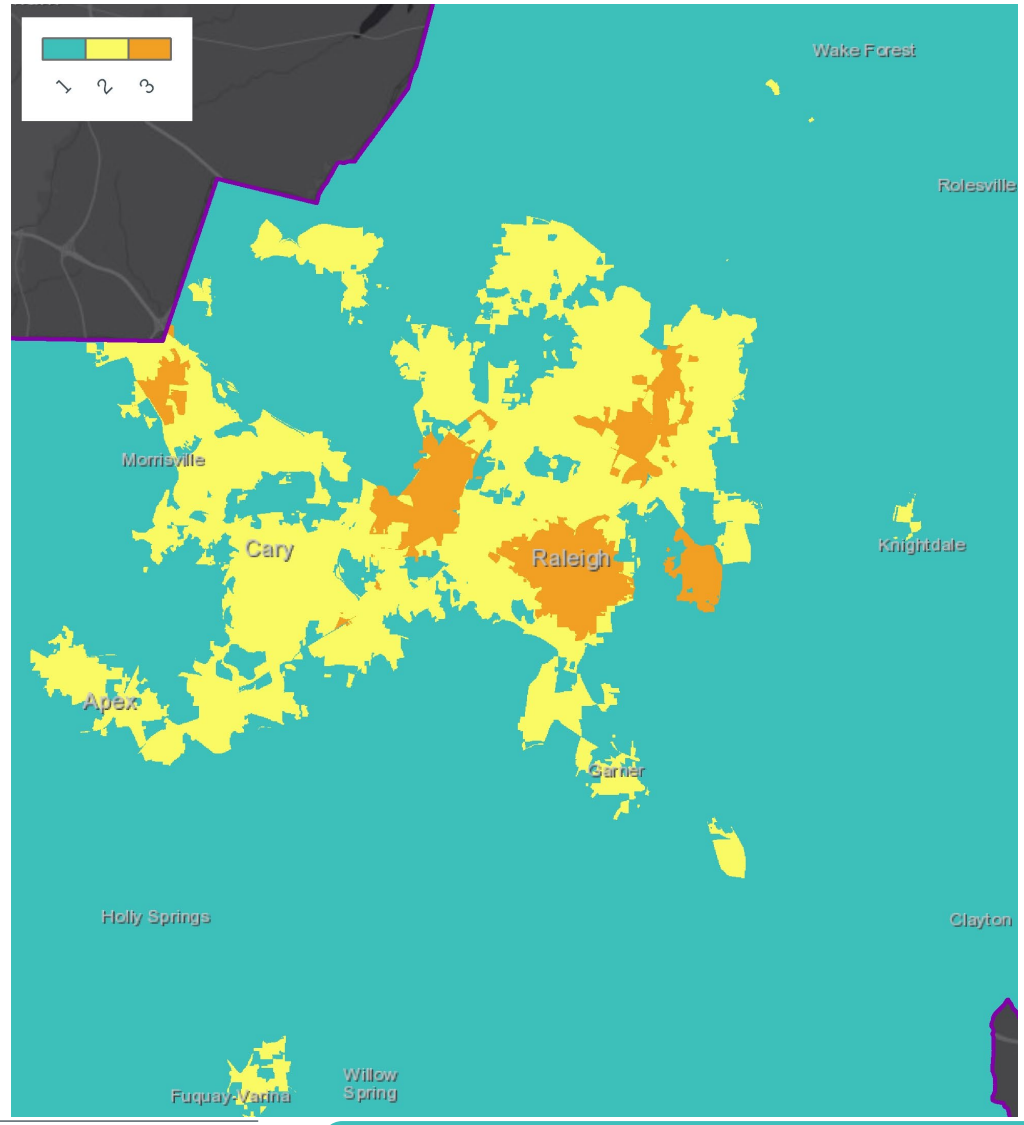
NON-MOTORIZED PROPENSITY

Measure: Walk access to jobs (2014)

- Analysis specs:
  - Adjacent block walk access to jobs score

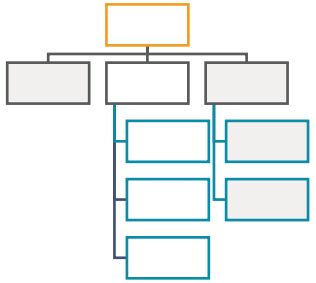
Walk Access Score Range	Non-motorized Propensity Score
-1 – 2,500	1
2,500 – 10,000	2
10,000+	3





TSP SUITABILITY

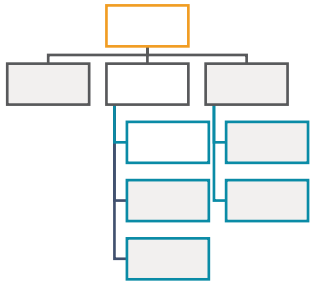
- Measures:
  - Vehicle Delay
  - V/C Ratio
  - Transit On-Time Performance



TSP SUITABILITY – VEHICLE DELAY

Measure: Vehicle Delay

- Rationale:
  - TSP is appropriate in corridors with moderate delay. In segments with minimal delay, transit vehicles general experience limited delay due to signals, while in those with significant delays, transit vehicles often cannot reach the intersection to take advantage of signal priority.
- Sources:
  - TRM loaded highway network (2045)
- Methods:
  - For a defined floating zone area, summarize the minimum congested: free-flow speed ratio in the PM peak period.
  - Define thresholds to set “TSP suitability tiers” based on congested: free-flow speed ratios.

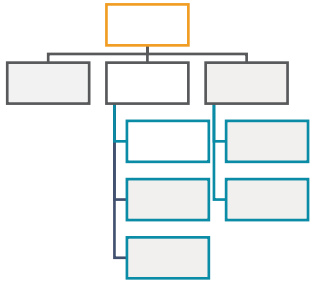


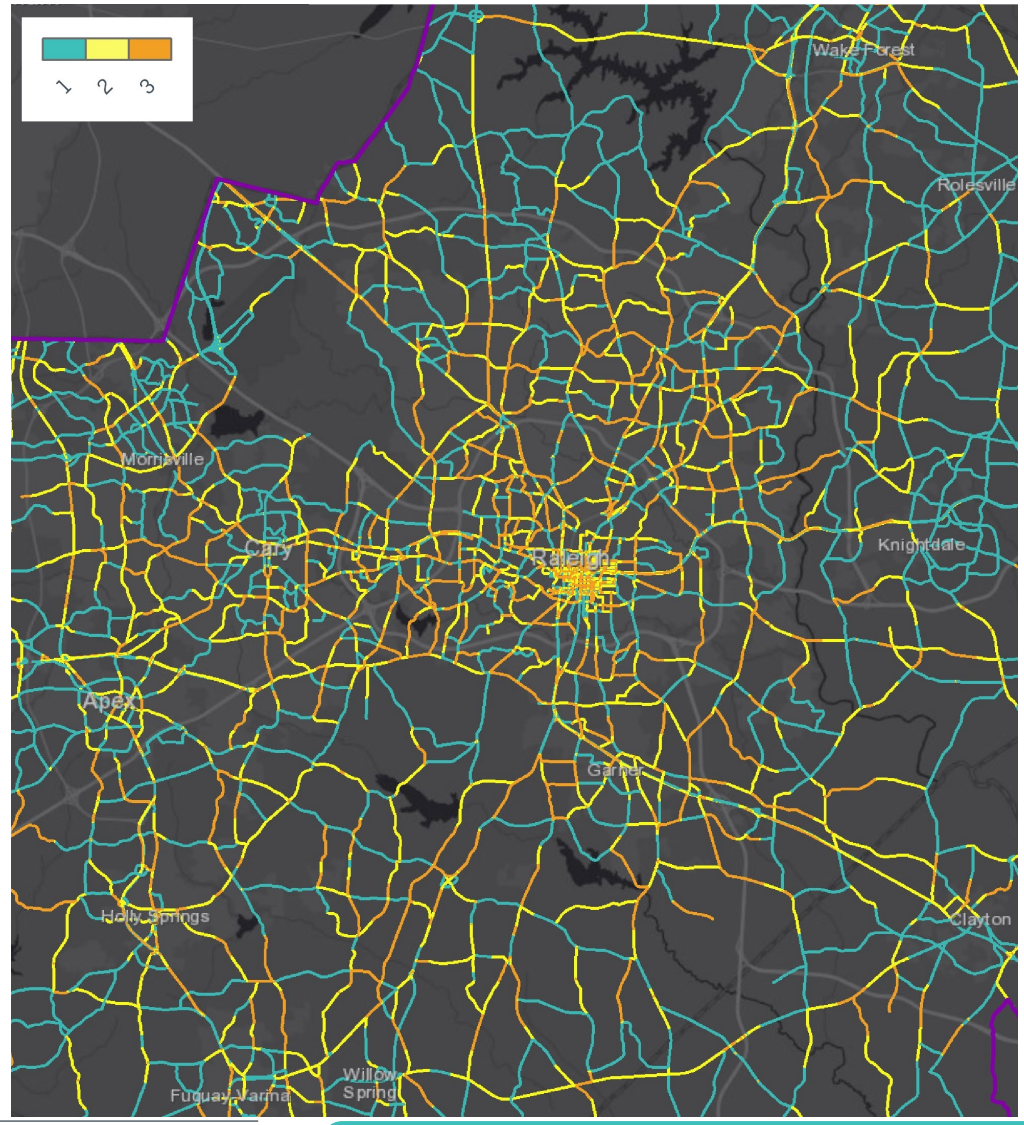
TSP SUITABILITY – VEHICLE DELAY

Measure: Vehicle delay (2045)

- Analysis specs:
  - Floating zone: Circle with 200’ radius

Congested: Free-flow speed ratio	TSP Suitability Score
0.00 – 0.50	1
0.50 – 0.60	2
0.60 – 0.80	3
0.80 – 0.90	2
0.9 – 1	1

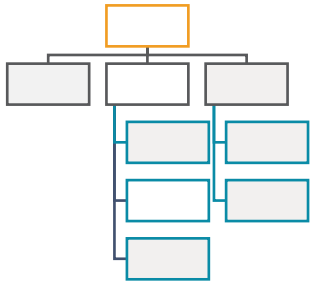




TSP SUITABILITY – V/C RATIO

Measure: V/C Ratio

- Rationale:
  - Similar to delay, TSP is best suited in corridors with moderate V/C ratios.
- Sources:
  - TRM loaded highway network (2045)
- Methods:
  - For a defined floating zone area, summarize the maximum v/c ratio.
  - Define thresholds to set “TSP suitability tiers” based on v/c ratios.

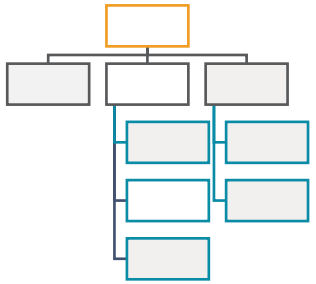


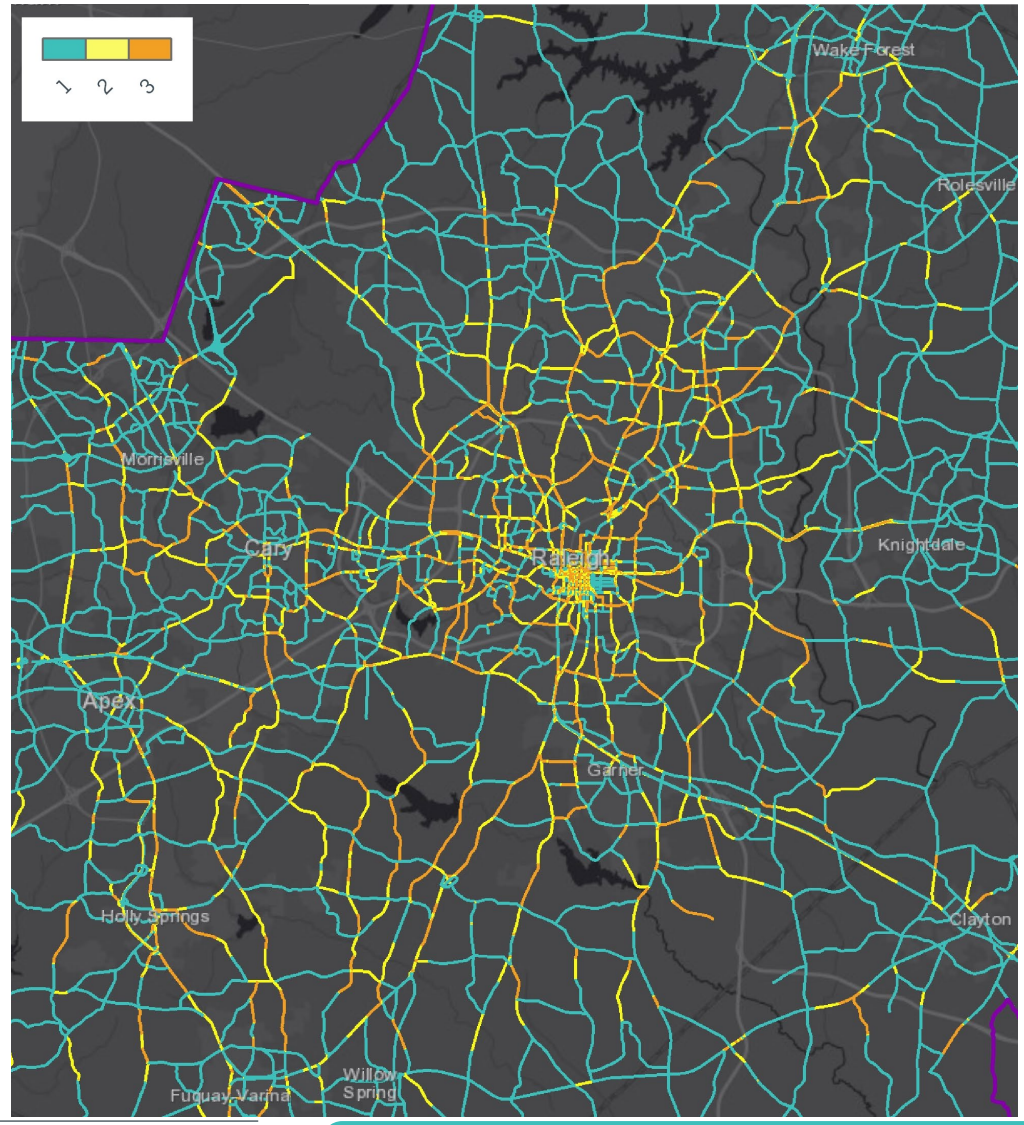
TSP SUITABILITY – V/C RATIO

Measure: V/C Ratio (2045)

- Analysis specs:
  - Floating zone: Circle with 200’ radius

V/C Ratio	TSP Suitability Score
0 – 0.75	1
0.75 – 0.9	2
0.90 – 1.10	3
1.10 – 1.25	2
1.25+	1

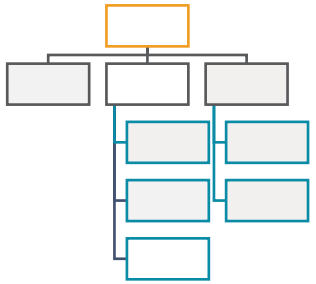




TSP SUITABILITY – TRANSIT ON-TIME PERFORMANCE

Measure: Transit on-time performance

- Rationale:
  - TSP is most appropriate in corridors where delays are contributing to on-time performance problems.
- Sources:
  - Composite on-time performance overlay from RED Lanes Suitability analysis (c. 2019)
- Methods:
  - Use the OTP overlay raster produced in the RED Lanes Suitability analysis
  - Define thresholds to set “TSP suitability tiers” based on transit on-time performance.

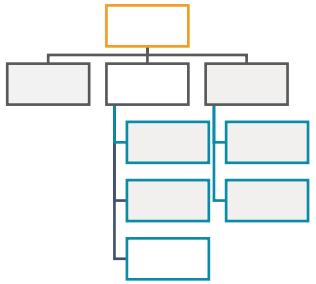


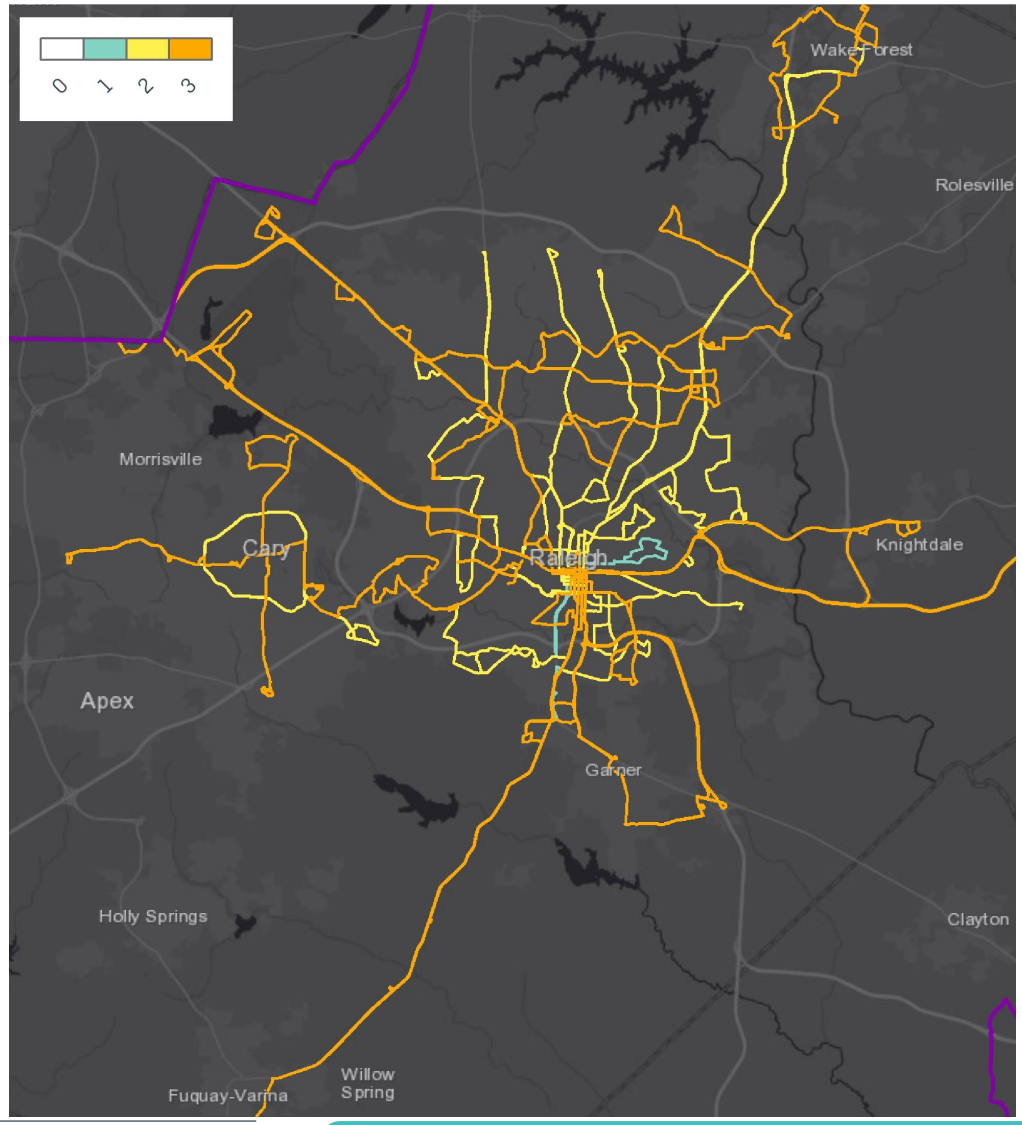
TSP SUITABILITY – TRANSIT ON-TIME PERFORMANCE

Measure: Transit on-time performance score (2019)

- Analysis specs:
  - Floating zone: Circle with 200’ radius

On-time performance score (from RED Lanes suitability analysis)	TSP Suitability Score
0	0
0 – 3	1
3 – 6	2
6 – 10	3

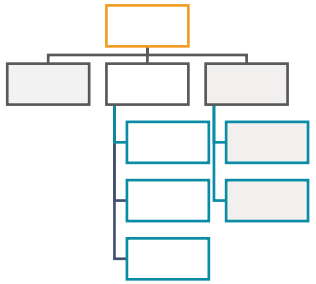


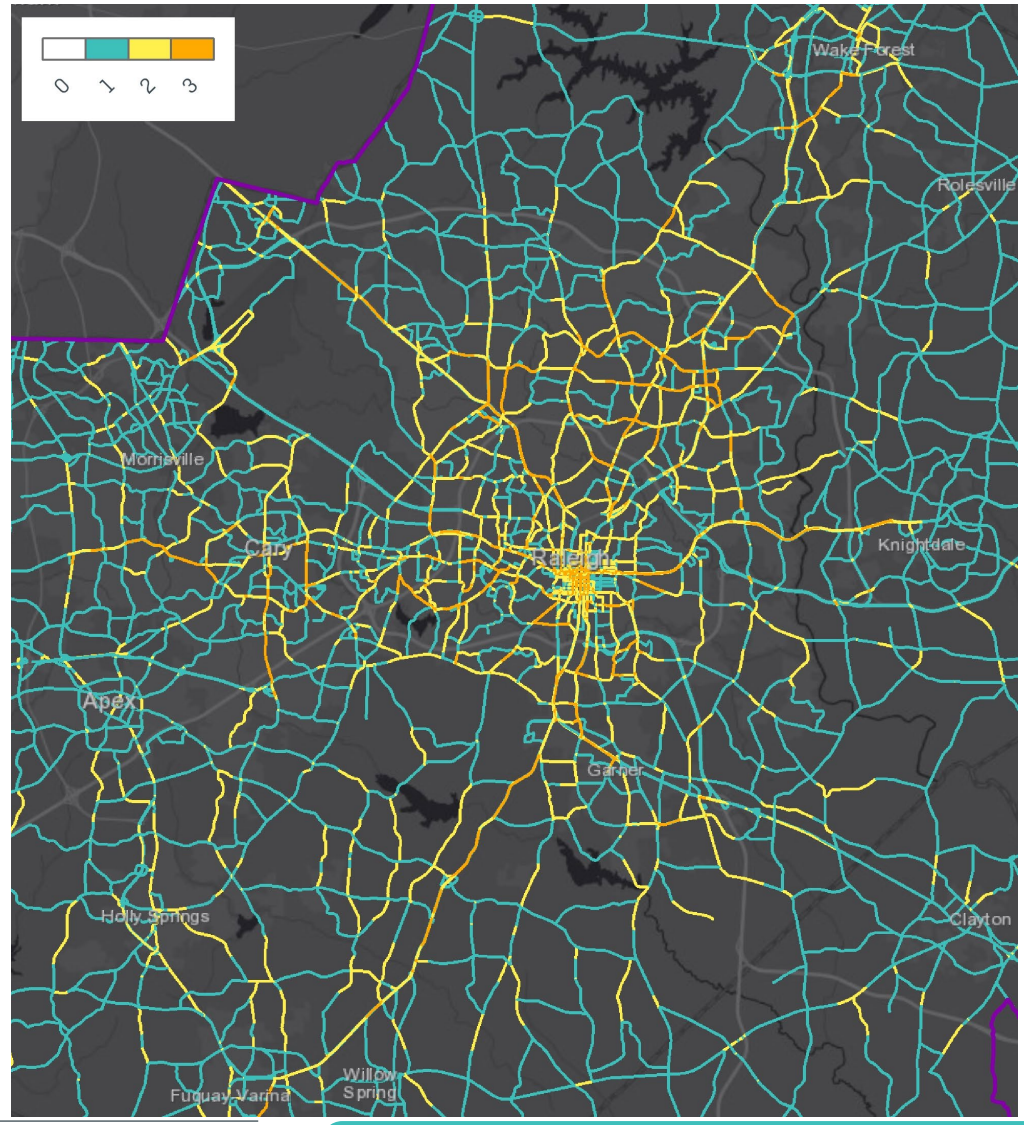


TSP SUITABILITY OVERLAY

Measure: TSP Suitability

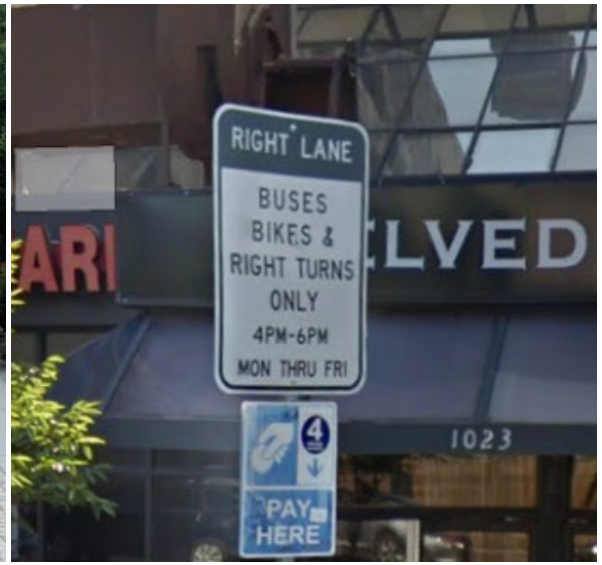
- Methods:
  - Overlay the vehicle delay, v/c ratio, and transit OTP scores and take a weighted average
    - Vehicle delay: 25%
    - V/C ratio: 40%
    - Transit on-time performance: 35%

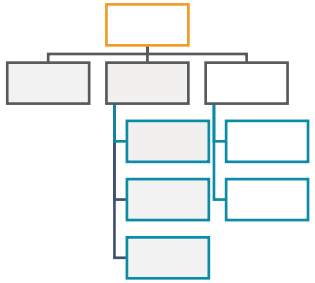




FULL-TIME SUITABILITY

- Measures:
  - Share of transit ridership in peak hours (route level)
  - Share of traffic volume in peak hours (segment level)

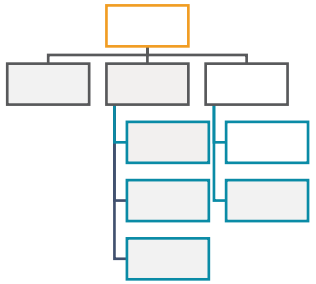




FULL-TIME SUITABILITY – TRANSIT PEAKING

Measure: Share of daily transit ridership during peak periods

- Rationale:
  - If large proportions of transit ridership occur during the peak period, the travel time and reliability benefits of RED Lanes may only be needed during peak hours. Lower proportions suggest consistent demand throughout the day warranting full-time RED Lanes.
- Sources:
  - TRM transit ridership forecasts (2045) – forecasts are available at a route level rather than a segment level.
- Methods:
  - For transit routes in the TRM, calculate the proportion of ridership occurring during the peak period (AM + PM ridership divided by daily ridership).
  - For a defined floating zone area, summarize the average peak ridership proportion
  - Define thresholds to set “Full-time suitability tiers” based on peak ridership rates.

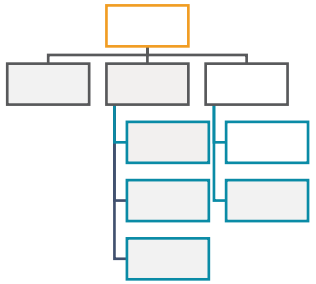


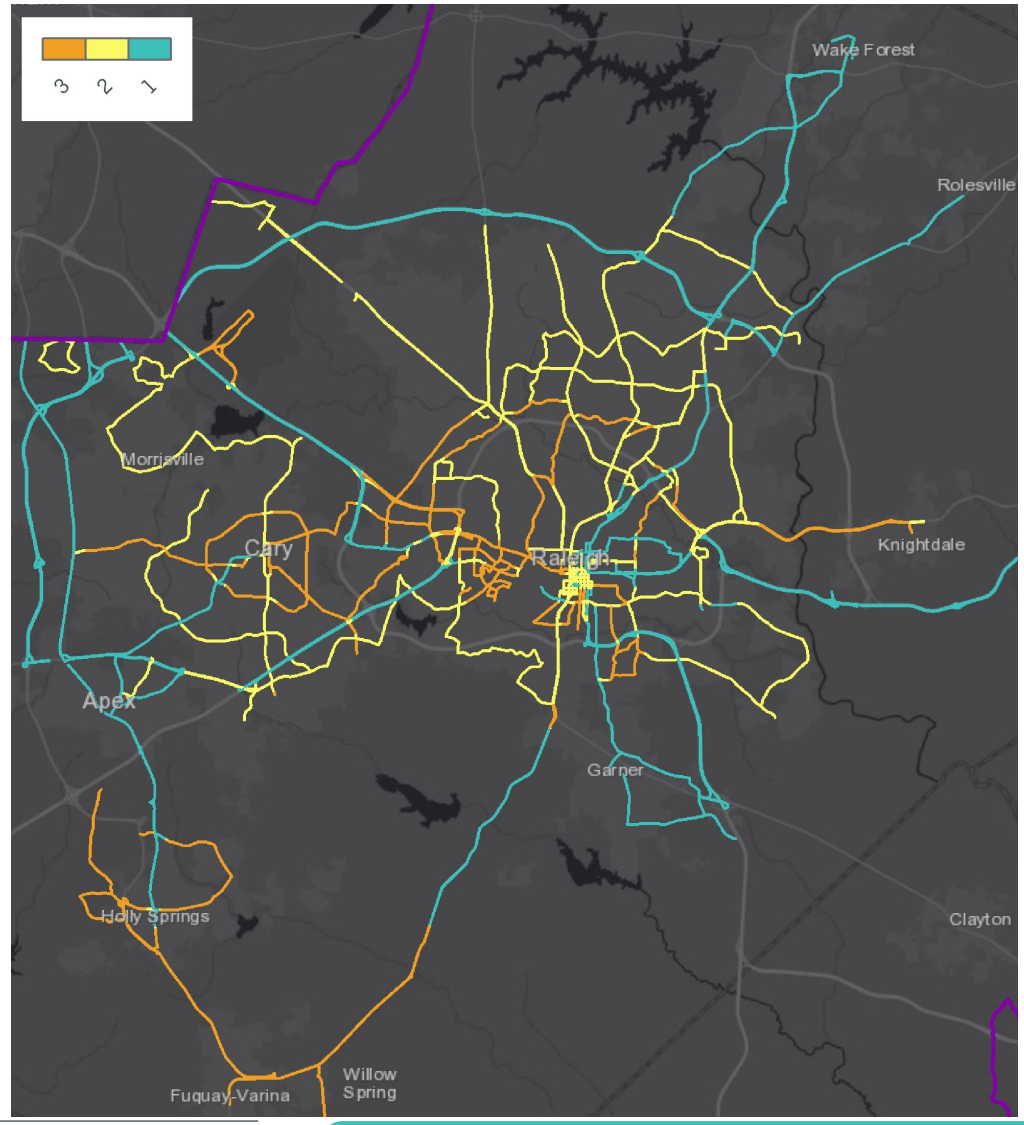
FULL-TIME SUITABILITY – TRANSIT PEAKING

Measure: Peak ridership ratio (2045)

- Analysis specs:
  - Floating zone: Circle with 200’ radius

Peak Ridership Ratio Range	TSP Suitability Score
0 – 0.60	3
0.60 – 0.75	2
0.75 – 1.00	1

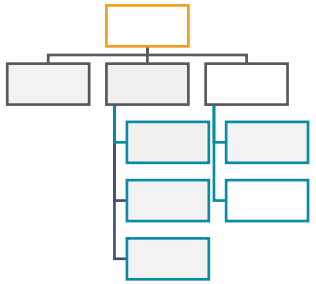




FULL-TIME SUITABILITY – TRAFFIC PEAKING

Measure: Share of daily traffic during peak periods

- Rationale:
  - Similar to transit peaking. Looking at traffic volumes in addition to transit ridership provides insight to overall demand on a segment and how it is utilized by time of day.
- Sources:
  - TRM traffic volume forecasts (2045)
- Methods:
  - For highway links in the TRM, calculate the proportion of ridership occurring during the peak period (AM + PM bi-directional volume divided by daily bidirectional volume).
  - For a defined floating zone area, summarize the average peak volume proportion
  - Define thresholds to set “Full-time suitability tiers” based on peak volume rates.

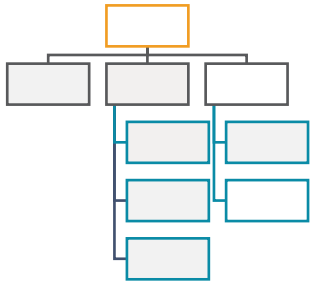


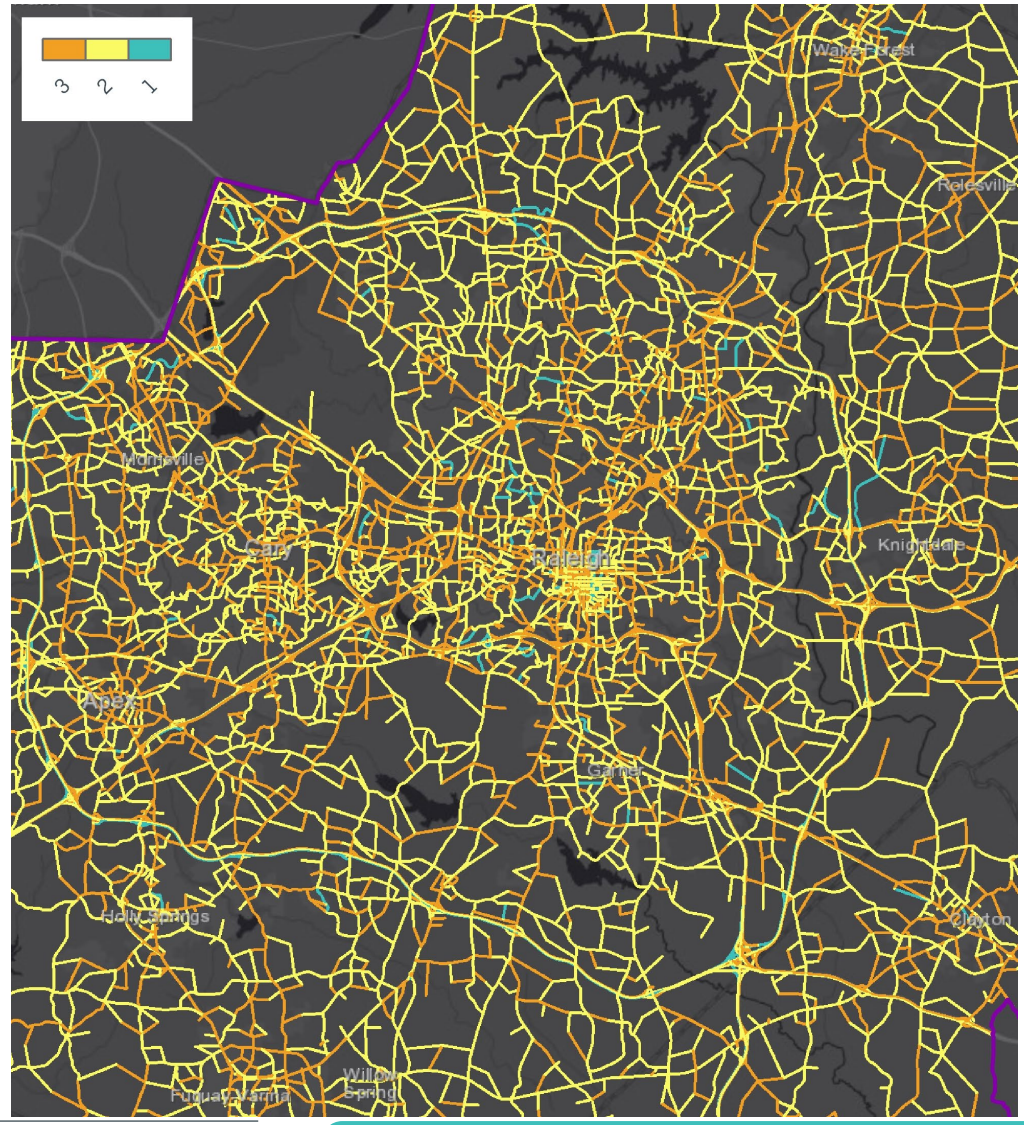
FULL-TIME SUITABILITY – TRAFFIC PEAKING

Measure: Peak volume ratio (2045)

- Analysis specs:
  - Floating zone: Circle with 200’ radius

Peak Volume Ratio Range	TSP Suitability Score
0 – 0.30	3
0.30 – 0.50	2
0.50 – 1.00	1

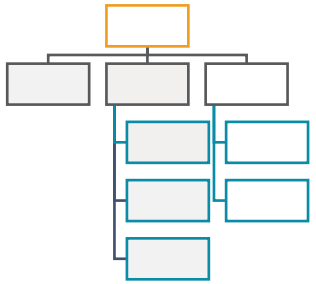


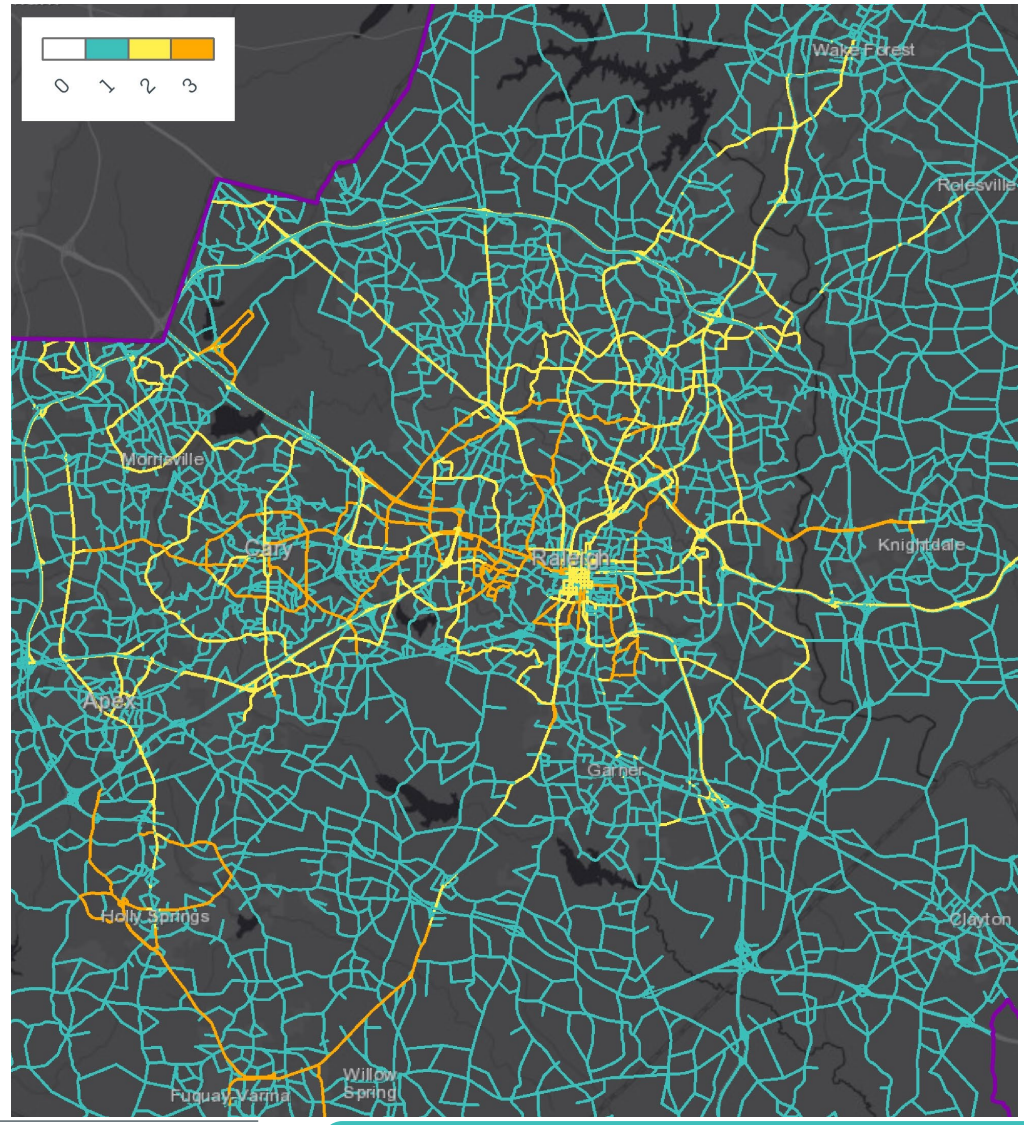


FULL-TIME SUITABILITY OVERLAY

Measure: Full-time suitability

- Methods:
  - Overlay the share of transit ridership and traffic volume in the peak periods (2045) and take a weighted average
    - Peak hour ridership proportion: 70%
    - Peak hour traffic volume proportion: 30%





4 SEGMENTATION AND REPORTING

SEGMENTATION: A 6-STEP PROCESS

1. **INTERSECT** the NCDOT Route Characteristics lines (streets) with the RED Lanes Suitability raster
2. **CLIP** the intersected streets to remove unwanted links
3. **SMOOTH** suitability values along contiguous segments
4. **BUILD INTERSECTIONS** from the NCDOT Route Characteristics streets
5. **SUMMARIZE** smoothed suitability values to intersection-constrained segments
6. **ENRICH** the segments with detailed differentiator and implementation guidance information

STEP 1: INTERSECT

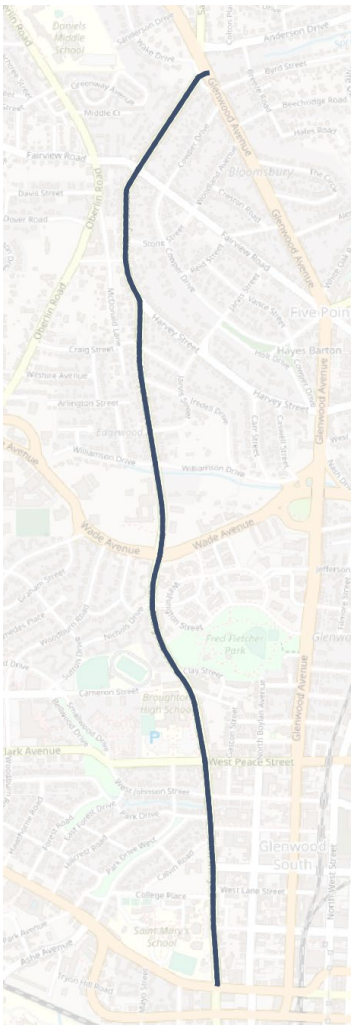
1. Generate polygon features from the suitability raster cells, focusing only on those with non-zero suitability.
2. Spatially intersect the resulting polygons with the NCDOT Route Characteristics lines.
   - This breaks each line into small pieces, each with a suitability value taken from the raster cell through which it crosses

OUTPUT: “Streets links” with unique suitability values

STEP 2: CLIP

1. Remove all street links associated with NCDOT Route IDs appearing fewer than 10 total times in the dataset
   - Segments shorter than ¼-mile total are not long enough to warrant RED Lanes.
   - Because the suitability raster consists of 100-foot cells (~140-foot diagonals), if a Route ID appears fewer than 10 times, no contiguous segments of ¼-mile or longer can exist.
2. For each remaining route ID, collect segments of contiguous links with the same ID. Remove all segments totaling less than ¼-mile.
3. For each remaining segment, if any links involve multiple route IDs, split contiguous links with matching sets of IDs into their own segment(s)
   - This step is necessary to prevent duplicative line features from disrupting downstream components of the analysis

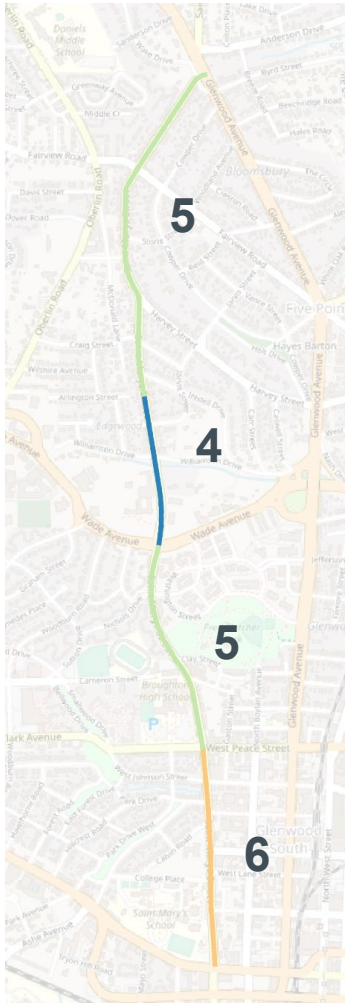
OUTPUT: “Segments” of contiguous street links of at least ¼-mile in length.



STEP 3: SMOOTH

1. For each segment, smooth the suitability values of component links by:
    1. Taking a moving window mode of suitability at each link
    2. Combining sets of contiguous links with matching moving window mode suitability values into “smoothed segments”
    3. Verifying that each smoothed segment totals at least ¼-mile (or the maximum length of the segment)
2. If the minimum length criterion is not met for all smoothed segments, increase the window size and repeat
3. Continue until all smoothed segments meet the minimum length criterion

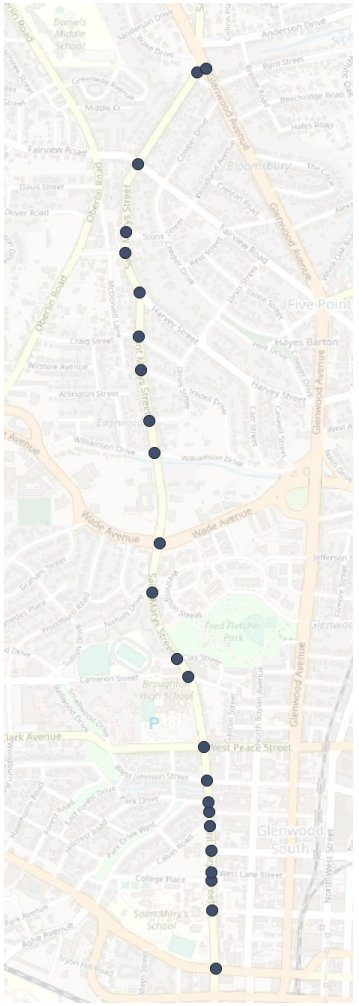
OUTPUT: “Smoothed segments” (nested within contiguous segments) with locally smoothed suitability



STEP 4: BUILD INTERSECTIONS

1. Intersect the NCDOT Route Characteristics lines with themselves. Remove resulting lines and retain only the points
   - After self-intersection, the points will represent the point where two lines meet
2. For each point, identify the two “route collections” – set of Route IDs – for the streets meeting at that point
3. Remove all points for which the two route collections match
   - This eliminates the points where a street continues onto itself, for example after a cross street (where the geometry breaks but the street itself does not)

OUTPUT: “Intersection points” of NCDOT streets in the study area



STEP 5: SUMMARIZE

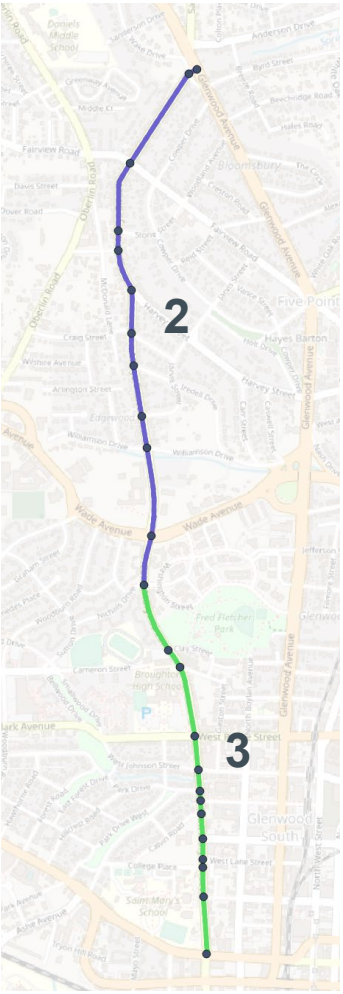
1. For each segment, identify “segment intersections” by extracting intersection points whose primary route collection matches the Route IDs found in the segment ID.
2. Use the intersections and (potentially) segment end points to construct “sections” of links between breakpoints.
3. For the first and last sections, if they do not touch an intersection, check if another segment intersection is within a distance less than the length of the section. If there is, make a note of this “extension point”; if not, remove that section.
4. Create “smoothed sections” by combining sections until a minimum of ¼ mile (or the length of the segment) is achieved. Assign an “intersection smoothed suitability” to the smoothed section by taking the smoothed suitability with the greatest total length amongst component links.
5. Create “final sections” by combining contiguous smoothed sections with the same intersection smoothed suitability.
6. Assign route names, from streets, and to streets to each final section by extracting street names from the segment intersections (or an extension point, if applicable) touched by the end links of the final section.

OUTPUT: Named “intersection smoothed segments”, where suitability is constant between street-intersection derived end points

STEP 6: ENRICH

1. For each of the detailed differentiators and implantation guidance rasters, extract values using the intersection smoothed segments
2. For each intersection smoothed segment, take the detailed differentiator and implementation guidance value as the mode of the extracted values

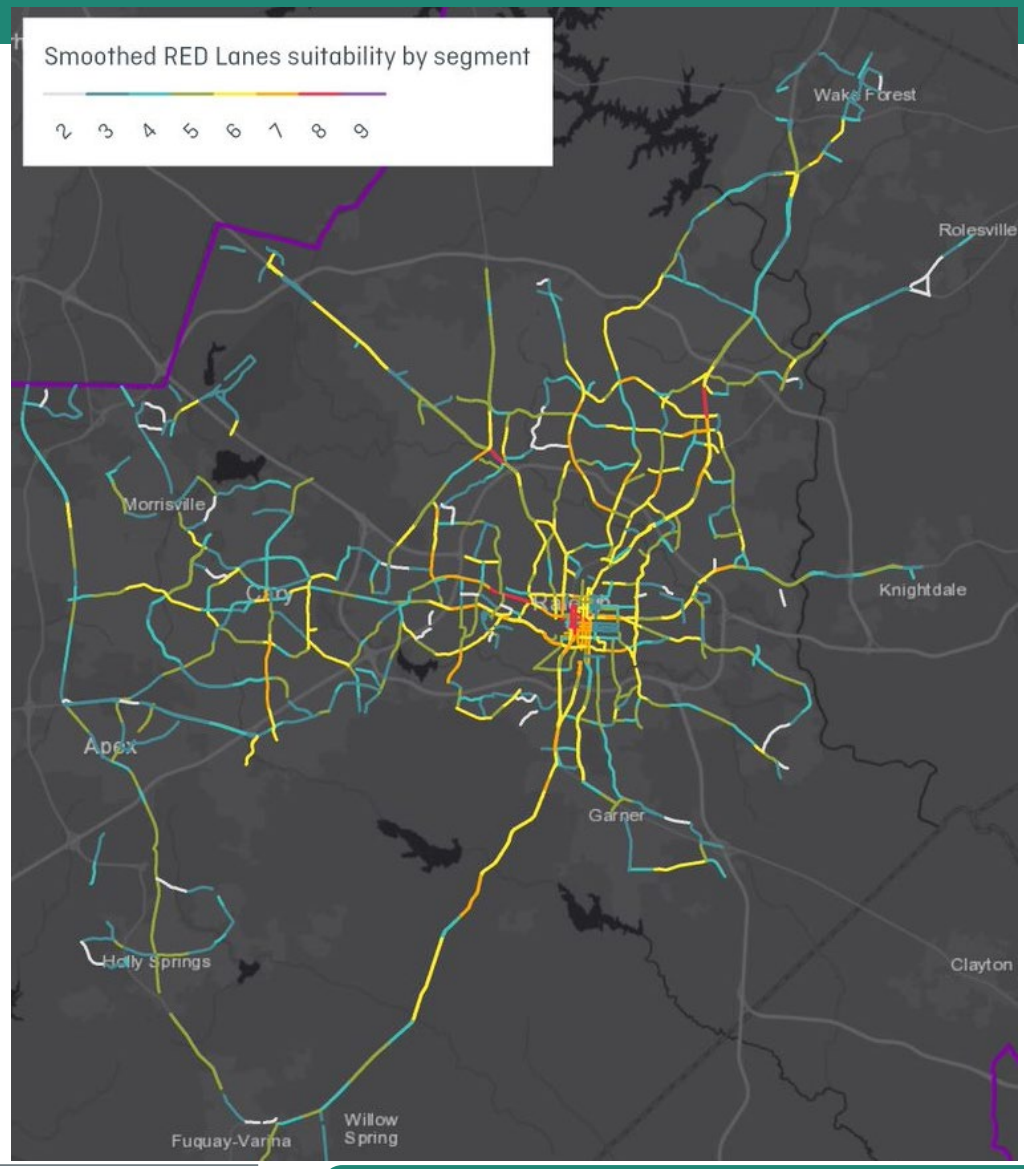
OUTPUT: Final suitability lines, with suitability, detailed differentiator, and implementation guidance values mapped to an interpretable street segment



(For detailed differentiators – communities of concern)

OUTPUT: SMOOTHED, SEGMENTED, AND ENRICHED SCORES

- Cleanly mapped segments with suitability scores, detailed differentiators, and implementation guidance measures.
- Interactive web map available here
- Tabular outputs for advanced sorting and filtering.



OUTPUT: SMOOTHED, SEGMENTED, AND ENRICHED SCORES

Segment Info			RED Lanes	Detailed Differentiators		Implementation Guidance		
Route	From	To	Suitability	Comm. Of Concern	Feasibility	Full Time Suit.	TSP Suit.	Nonmotor. Propensi
Glenwood Ave	Creedmoor Rd / Glenwood Ave	Blue Ridge Rd	9	2	2	3	2	2
Capital Blvd	Sumner Blvd	Spring Forest Rd	8	3	3	2	2	2
Capital Blvd	Spring Forest Rd	Sumner Blvd	8	3	3	2	2	2
S Blount St	E Morgan St	E Davie St	8	1	3	3	2	3
Western Blvd	Clanton St / Whitmore Dr	Varsity Dr	8	3	2	3	2	2
Glenwood Ave	Blue Ridge Rd / Lead Mine Rd	Creedmoor Rd / Glenwood Ave	8	2	2	3	2	2
E Edenton St / W Edenton St	N Person St	W Edenton St / N Mcdowell St	8	1	2	3	2	3
N Salisbury St / S Salisbury St	W Lane St / E Lane St	W Davie St	8	1	2	3	2	3
W Martin St	E Martin St / Fayetteville St	S West St	8	1	2	2	2	3
Founders Dr	Current Dr	Dan Allen Dr	8	1	2	3	3	3
N Dawson St / S Dawson St	W Lane St	W Davie St	8	1	2	3	2	3
S Mcdowell St / N Mcdowell St / Capital Blvd	W Cabarrus St	W Johnson St	8	1	2	3	2	3
Hillsborough St	Henderson St	Gardner St	8	2	1	3	3	2
	Pullen Rd	Gardner St / Hillsborough St	8	2	1	3	3	3
W Morgan St / E Morgan St	Glenwood Ave / W Morgan St	E Morgan St / S Blount St	8	1	1	3	2	3
Louisburg Rd	Capital Blvd	Batts Rd	7	3	3	2	2	2
Capital Blvd	Spring Forest Rd	E Millbrook Rd	7	3	3	3	2	2
Capital Blvd	N New Hope Rd	Spring Forest Rd	7	3	3	3	2	2
S Blount St	E Davie St	Martin Luther King Jr Blvd	7	1	3	2	3	3
Capital Blvd		Wade Ave / Capital Blvd	7	1	3	1	2	2
Capital Blvd	Old Buffaloe Rd	Louisburg Rd / Capital Blvd	7	1	3	2	2	2
Capital Blvd	Capital Blvd	Old Buffaloe Rd	7	1	3	2	2	2
Western Blvd	Crossover	Martin Luther King Jr Blvd / Martin Luther	7	3	2	2	2	3
S Wilmington St	S Wilmington St	I 40 WB	7	3	2	2	3	3
Blue Ridge Rd	Lake Boone Trl	Macon Pond Rd	7	3	2	3	2	3
S Person St / N Person St	Hoke St	E Edenton St	7	3	2	3	2	3
E Millbrook Rd	E Millbrook Rd	Capital Blvd	7	3	2	3	2	2
Poole Rd / E Edenton St	Poole Rd / New Bern Ave	N Person St	7	3	2	2	1	3
New Bern Ave	Seawell Ave	Heath St	7	3	2	2	2	3
Martin Luther King Jr Blvd	S Wilmington St	Ellington St	7	3	2	2	2	3
Martin Luther King Jr Blvd	Holmes St / Chavis Way	Rock Quarry Rd	7	3	2	3	2	3
Shanta Dr / Sunnybrook Rd	Shanta Dr / New Bern Ave	Holston Ln	7	3	2	2	2	3
S Wilmington St	Keeter Center Dr / City Farm Rd	S Wilmington St	7	3	2	2	3	3
Glenwood Ave	Hillsborough St / Glenwood Ave	Glenwood Ave / W Peace St	7	3	2	3	2	3
S Saunders St	S Saunders St / Lake Wheeler Rd	W Lenoir St / S Saunders St	7	3	2	2	2	3
S Salisbury St / S Wilmington St	W Davie St	S Wilmington St	7	3	2	2	1	3
Keeter Center Dr	City Farm Rd / S Wilmington St	MCLENDON ST	7	3	2	2	3	3
Blue Ridge Rd	Blue Ridge Rd / Duraleigh Rd	Forestview Rd	7	3	2	3	2	3