Safety through Disruption (Safe-D) National University Transportation Center (UTC)

TTI-06-01 Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking

SAFE-D
SAFETY THROUGH DISRUPTION

Texas A&M Transportation Institute

VIRGINIA TECH TRANSPORTATION INSTITUTE

Estimating Demand & Identifying Truck Parking Guidebook
October 2022

Safe-D National UTC

PURPOSE

To maximize the potential safety benefits of disruptive technologies through targeted research that addresses the most pressing transportation safety questions.

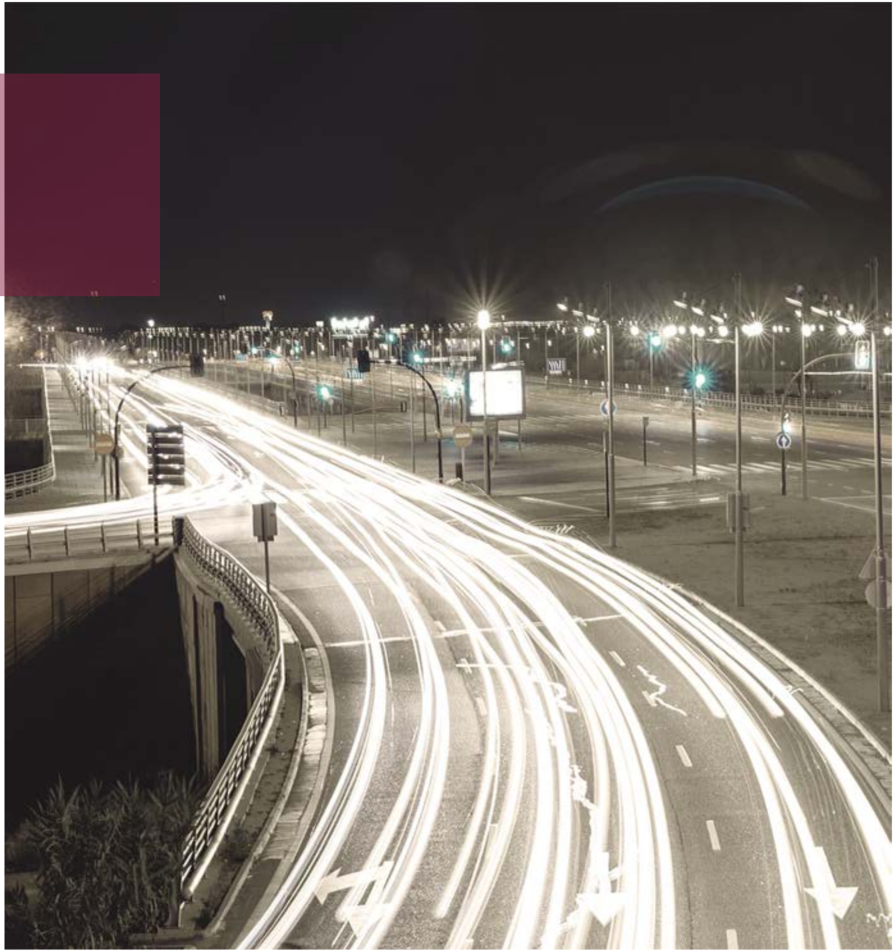
PARTNERSHIP

The largest collection of transportation safety researchers in the nation, encompassing:

- VTTI
- TTI
- SDSU

FOCUS AREA

- Cutting-edge research
- Education and workforce development with programs for all levels
- Fully supported technology transfer



ABOUT THE PROJECT

Safety issues due to commercial truck parking shortages are a national concern. National hours-of-service (HOS) regulations limit drivers' time on the road to increase safety by limiting fatigue. This requires drivers to locate safe, secure, and legal parking wherever they are when or before they hit their limits. If drive time is exhausted with no nearby truck parking, drivers may park in unsafe or unauthorized locations to meet HOS requirements, or they may continue to drive while fatigued.

There are intrinsic safety implications to all highway users due to large trucks parking in unsafe locations or truck drivers driving past their allotted hours. With the projected growth of truck traffic, the demand for adequate truck parking will continue to outpace the supply of public and private parking facilities.

This research was developed to help transportation agencies develop solutions to the parking availability problem by identifying effective methods for using data to estimate truck parking demand and areas of parking opportunity, assessing available data sources for estimating truck parking, and determining the safest solutions for distributing information on parking availability directly to drivers.

This guidebook outlines the steps state Departments ot Transportation (DOTs) can take to apply the lessons learned in this research to estimate truck parking demand, identify opportunities, and to communicate it to the driving community.

Guidebook Purpose

This Guidebook is intended to provide a high-level overview of how State DOT planners and data analysts can estimate truck parking demand and identify truck parking supply in their respective regions. If additional information is needed, please reach out to the research team directly by contacting Nicole Katsikides at n-katsikides@tti.tamu.edu or Brittney Gick at b-gick@tti.tamu.edu.

The purpose of this study that supports this guidebook was to derive insights that will help State DOTs and other transportation agencies mitigate the presumed negative safety impacts of inadequate truck parking. It builds on prior work by the Texas A&M Transportation Institute (TTI) and the Virginia Tech Transportation Institute (VTTI) in mitigating the negative safety impacts of inadequate truck parking. The study involved two main objectives:

- Use big data to understand when and where parking is needed along major corridors and support local and regional planning efforts for better options.
- Push information via technology to truck drivers to enable them to locate available, safe, and legal parking in messaging formats that they will use and heed.

This guidebook has three key sections to support DOTs and truck parking:

ESTIMATING DEMAND

Finding the total number of trucks that want to park in a given location or geographic area

IMPROVING SAFETY

Identifying legal, safe, and secure parking opportunities in that same location or geographic area

COMMUNICATING PARKING INFORMATION

Disseminating information on parking opportunities to drivers when they need it and how they want it

Estimating Demand

This section provides steps to estimate truck parking demand using truck probe data. This work tested three different methods that can be used to estimate demand. These include:

1. Using mathematical algorithms to assess clusters of parking.
2. Geohashing the location of points within the data to identify clusters of parking.
3. Testing the reliability of the data in the parking information it provided.

To apply these techniques, it is recommended to have a sample of truck probe data such as INRIX or ATRI where there are unique identifiers and non-moving, parking trips identified.

The following pages explain the steps for each of these methods.

Truck Parking Demand: Algorithms

Step 1
Filter and Slice Data

Step 2
Apply Artificial Intelligence (AI) Algorithms

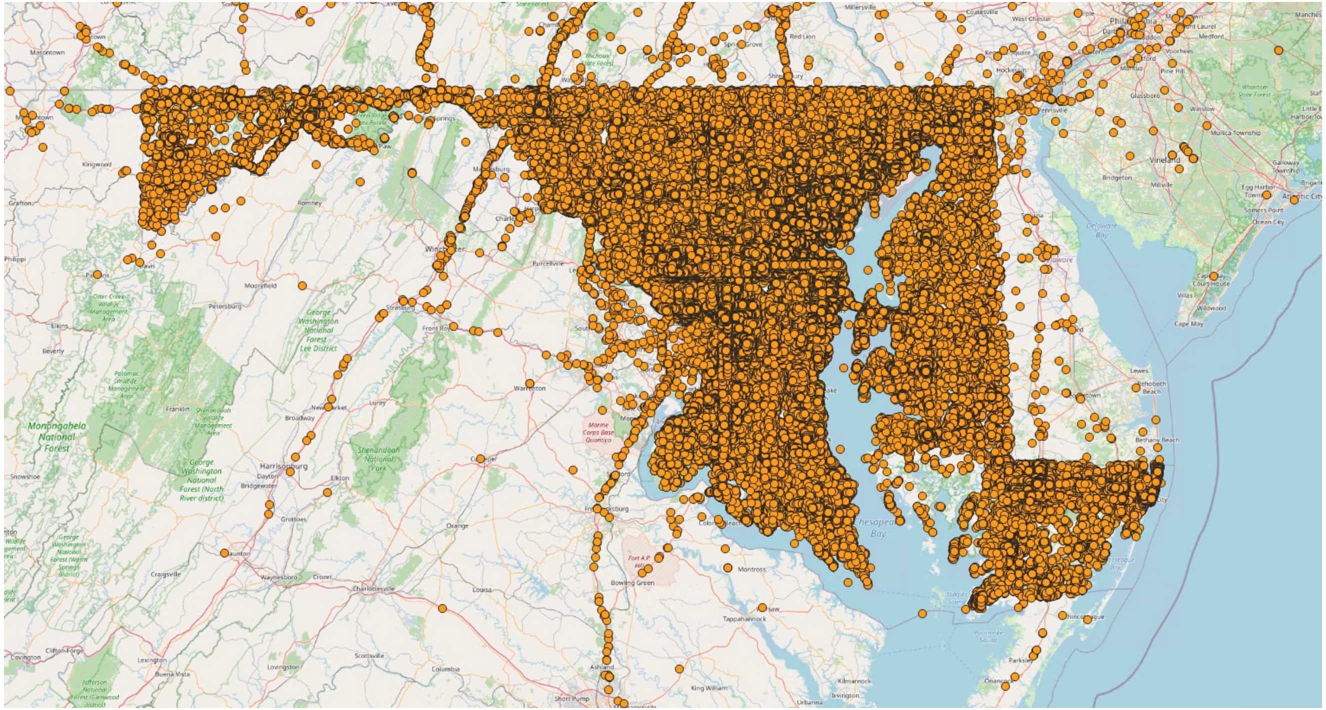
Step 3
Evaluate Results & Repeat Process

STEP 1: FILTER AND SLICE STOPPING TRIPS DATA

Determine areas of truck parking demand

Truck probe data can be assessed to identify demand by using well known mathematical algorithms (DB Scan, Birch, and Optics) .

The most optimal results came when applying each of the algorithms after filtering spatially by county and temporally by day of the week (Monday through Sunday) and time of day (hours from 0 to 23).



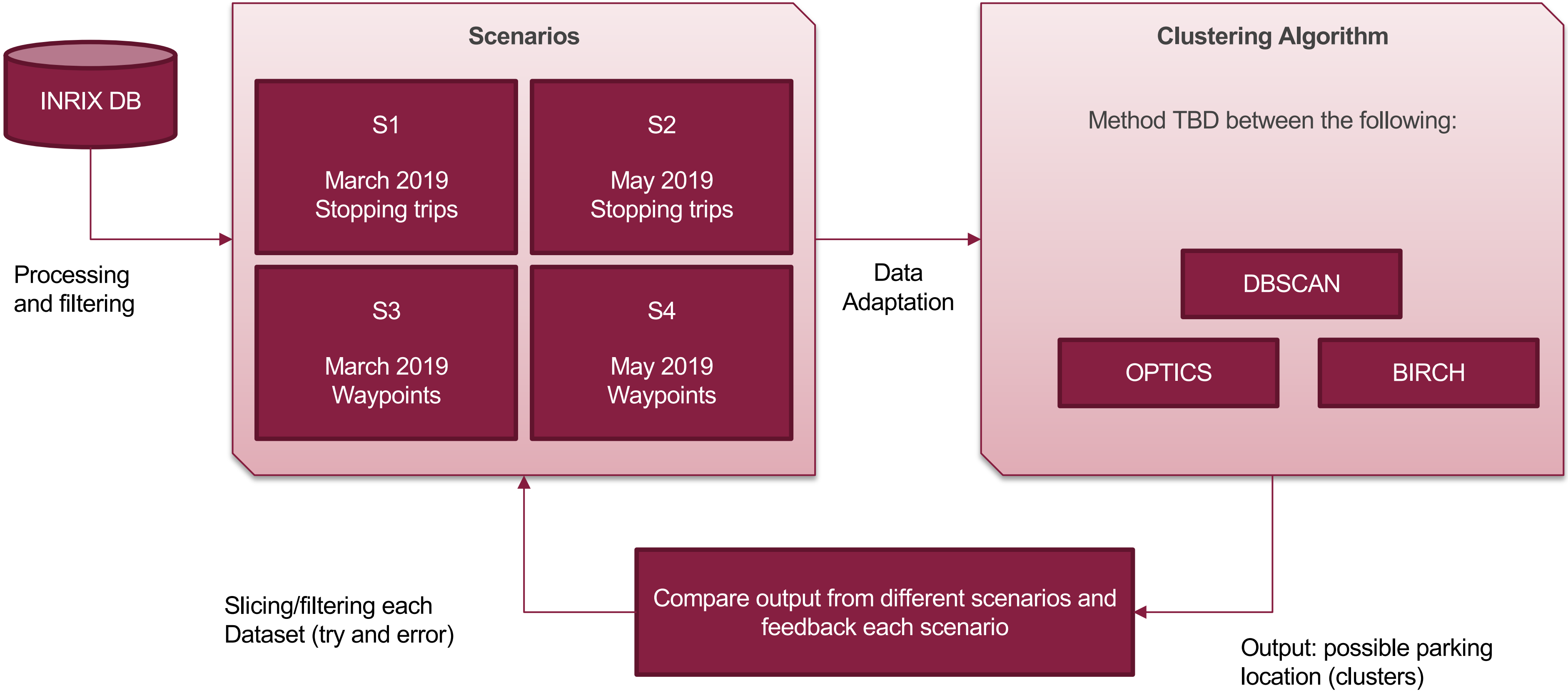
STEP 2: APPLY ARTIFICIAL INTELLIGENCE (AI) ALGORITHMS TO THE FILTERED DATA

The following describe the three different mathematical algorithms.

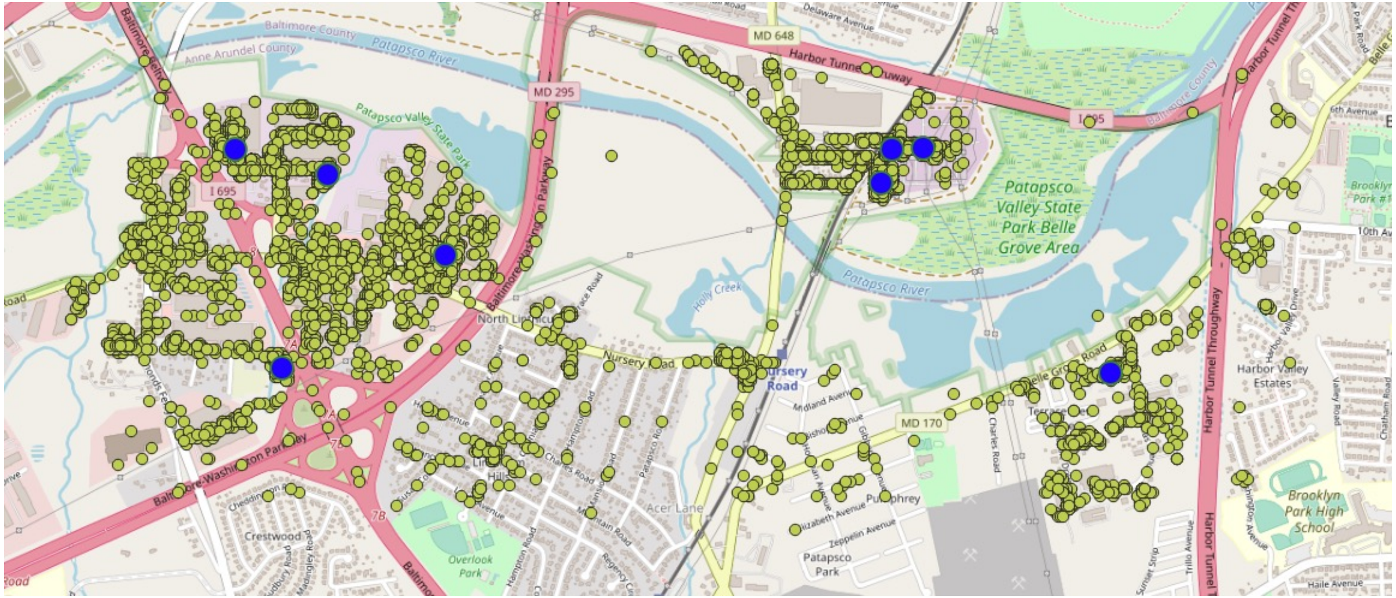
Algorithm Acronym	Algorithm Full Name	Pros	Cons	Parameters
DBSCAN	Density-based spatial clustering of applications with noise	• Produces best fit to parking cluster, regardless of shape • Good treating noise • Easy estimation • Good with large datasets	• Arbitrarily shaped clusters require more time and power to process and have lower accuracy (false positives and negatives) • Overlapping clusters • Possible ‘holed’ and disconnected clusters • Not well accepted wide range of densities	• Minimum number of samples in a cluster • Cluster point radius
OPTICS	Ordering points to identify the clustering structure	• Applicable to a wide range of cluster density • Good treating noise • Great with large datasets • Offers setting cluster boundaries	• Slow • Hard to estimate parameters • Possibly inconsistent parameters across the whole grid • Difficult to determine cluster boundaries	• Minimum number of samples in a cluster • Cluster point radius or range of values • Cluster boundaries
BIRCH	Balanced iterative reducing and clustering using hierarchies	• Local processing (fast is microscopic clustering analysis) • Best with large datasets • Memory efficient • Good with outliers	• Hard to estimate parameters • Possibly inconsistent parameters across the whole grid	• Branching factor (optional) • Tree threshold (optional)

Truck Parking Location Identification Process Map

This process map illustrates how to process the probe data by identifying scenarios and applying the algorithm.



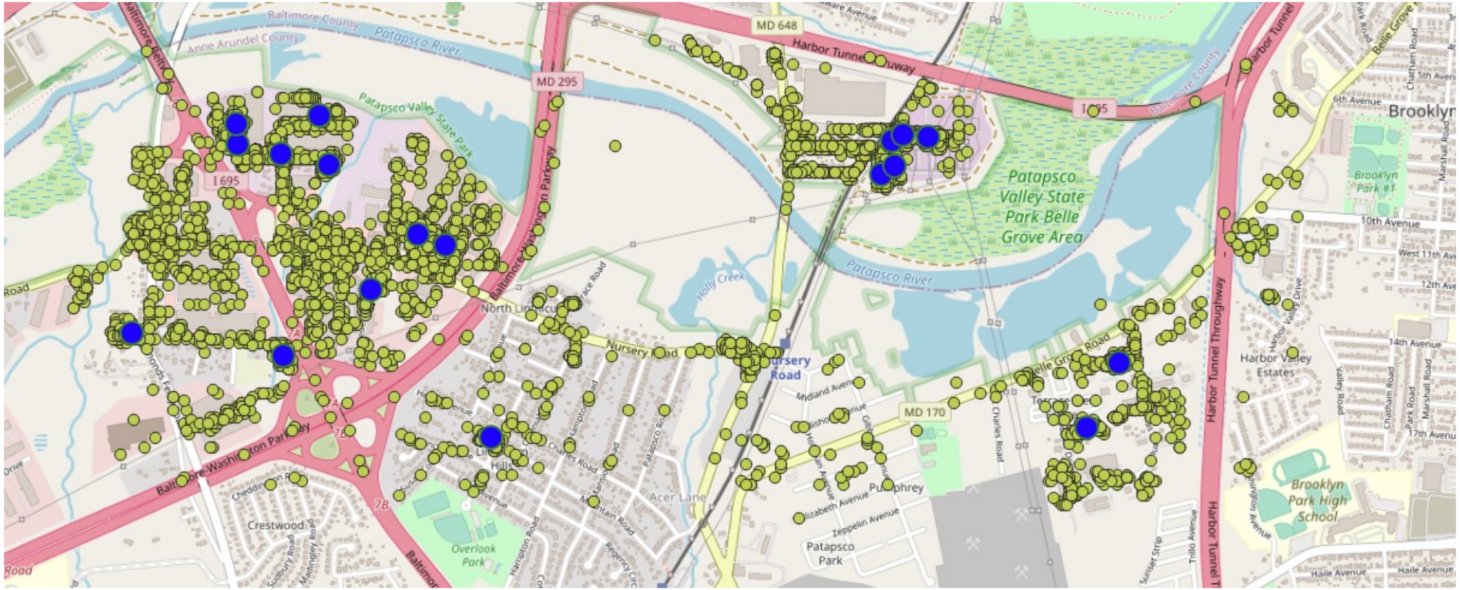
Example DBSCAN Output



Frame processing time: less than a second
Whole processing time: ~7 hours

Min samples: 150
Cluster radius: 3×10^{-3}

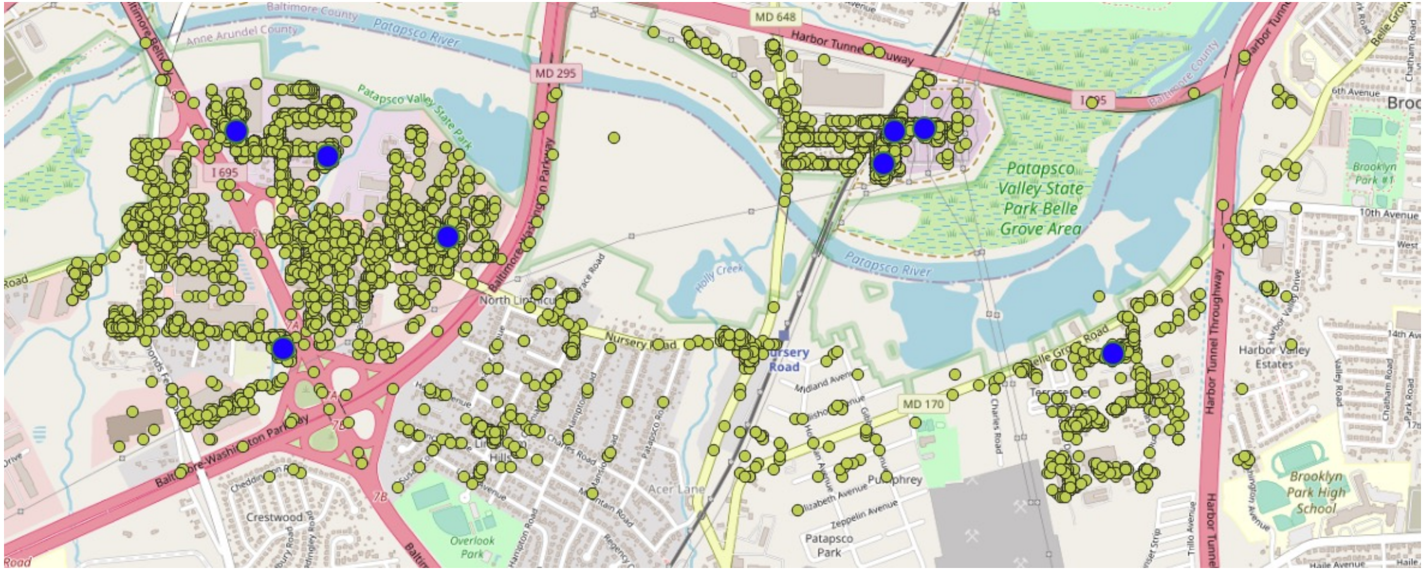
Example OPTICS Output



Frame processing time: less than a second
Whole map processing time: ~12 hours

Min samples: 150
Max Cluster radius: $3x10^{-3}$
No boundaries specified

Example BIRCH Output



Frame processing time: less than a second
Whole map processing time: ~3 hours

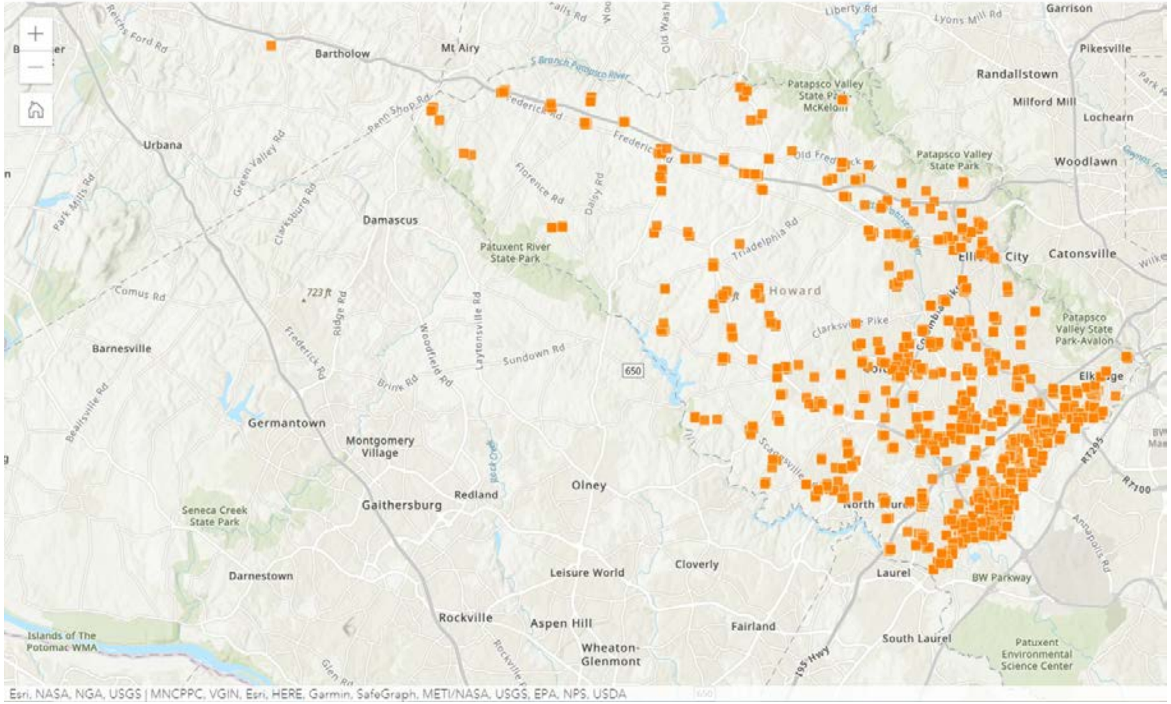
Threshold: 0.65
Branching factor: 50

STEP 3: EVALUATE RESULTS & REPEAT PROCESS

The research found that compiling the results in the OPTICS AI algorithm provided the best results because it provided the most flexibility in terms of the number of results derived from the algorithm. This should be evaluated on a case-by-case basis.

Then, results can be compared with available safety and land use data from MDOT SHA's geospatial catalogue.

SAFE-D Parking Assessment (Demand and Opportunity)



POTENTIAL BIASES / QUALITY ISSUES WITH ANALYSIS

Algorithms

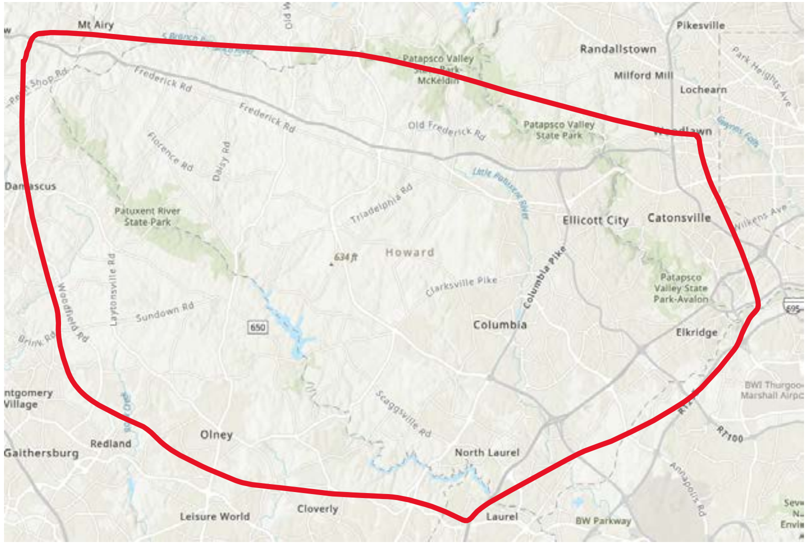
- The algorithm method, while complex, brings great value and reliability to analyzing truck parking.
- Previous work completed without using an algorithm to estimate truck parking demand was comparable (i.e., the locations were in the same general area) but not as precise (i.e., the algorithm can more accurately pinpoint exact locations).
- Evaluating truck parking locations with crash data are not as developed nor accurate, so more research is needed to better understand how truck crash data can be incorporated into the model.
- When evaluating truck parking locations compared to land use data, there is a strong case that there is a lack of adequate truck parking in locations where freight-specific land use is prominent (i.e., many warehouses and distribution centers).

Truck Parking Demand: Geohashing

The following represent the steps for applying geohashing using the truck probe data.

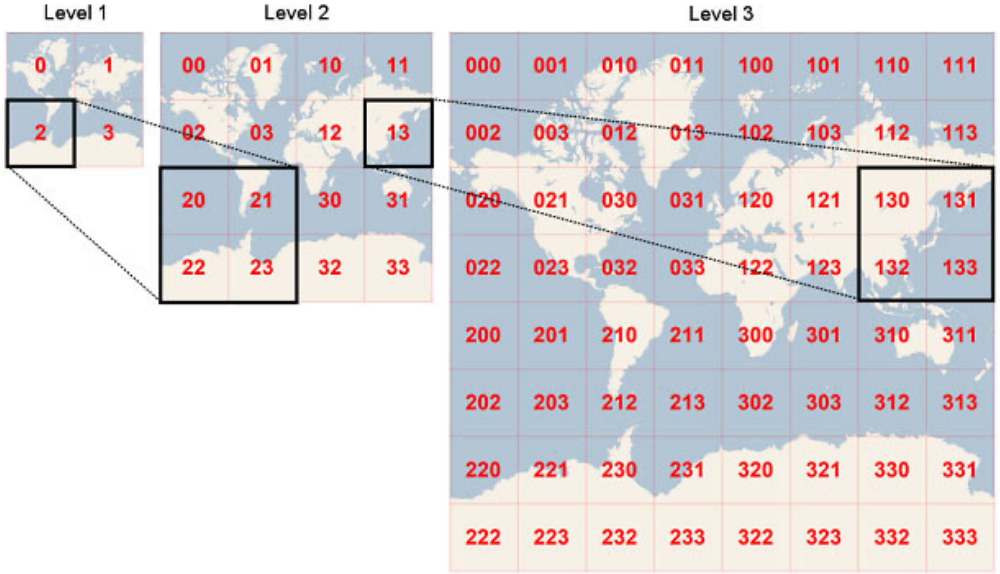
Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Using GIS software (ArcGIS), identify and extract the data points inside the boundary of the area of interest.	Using the "vehicle weight class" information, further filter to extract only heavy-duty vehicles' trips (vehicle weight class = 3 if using INRIX Trips).	Using coordinates of the start point for each stop trip, assign a 7-digit geohash to the stop trip. This information should be stored in a new column. Extract the center point coordinates of all the geohashes with at least one observation assigned to them.	Identify and mark the day-of-week and hour-of-day that each event started in (Monday to Sunday, hours 0 to 23). Store this information in new columns.	Develop a summary table by calculating the total number of stop trips happening in each 7-digit geohash on a specific day-of-week; (e.g., Monday in geohash dqcp1mt).	Import resulting summary table into GIS software and visualize along with geohashed truck crash information and other relevant data.

STEP 1: USING GIS SOFTWARE (ARCGIS), IDENTIFY AND EXTRACT THE DATA POINTS INSIDE THE BOUNDARIES OF THE AREA OF INTEREST



STEP 2: USING THE “VEHICLE WEIGHT CLASS” INFORMATION, FURTHER FILTERED TO EXTRACT ONLY HEAVY-DUTY VEHICLES’ TRIPS (VEHICLE WEIGHT CLASS = 3)

STEP 3: USING COORDINATES OF THE START POINT FOR EACH STOP TRIP, ASSIGN A 7-DIGIT GEOHASH TO THE STOP TRIP. STORE IN A NEW COLUMN. EXTRACT THE CENTER POINT COORDINATES OF ALL THE GEOHASHES WITH AT LEAST ONE OBSERVATION ASSIGNED TO THEM



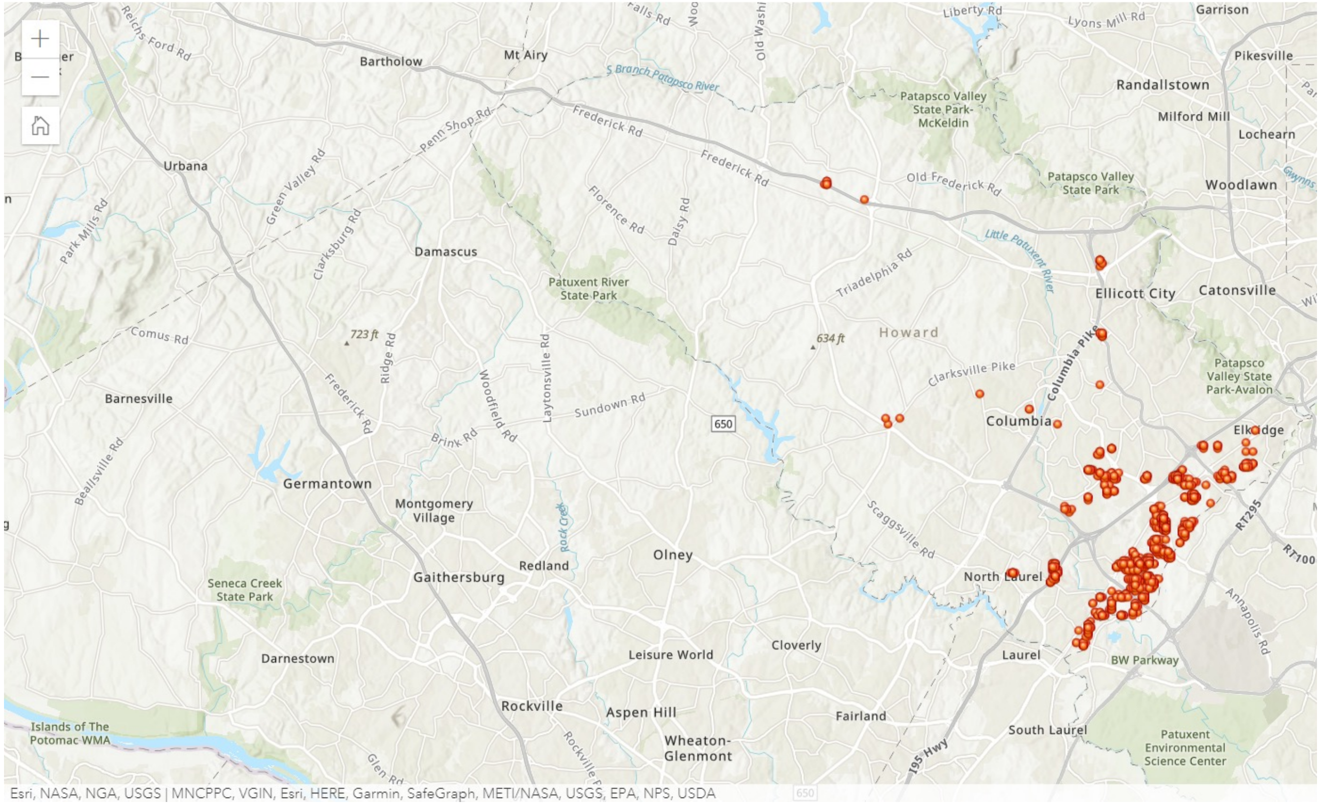
STEP 4: IDENTIFY AND MARK THE DAY-OF-WEEK AND HOUR-OF-DAY THAT EACH EVENT STARTED IN (MONDAY TO SUNDAY, HOURS 0 TO 23). STORE IN NEW COLUMNS

STEP 5: DEVELOP A SUMMARY TABLE BY CALCULATING THE TOTAL NUMBER OF STOP TRIPS HAPPENING IN EACH 7-DIGIT GEOHASH ON A SPECIFIC DAY-OF-WEEK; (E.G., MONDAY IN GEOHASH DQCP1MT)

Vehicle Type	County	geohash7	Latitude	Longitude	Month	Weekday	Number of Stops	Number of Active Days
3. Heavy Duty	Howard	dqcq7xg	39.110641	-76.833572	March	3. Wed	5	4
3. Heavy Duty	Howard	dqcqs49	39.125748	-76.814346	March	3. Wed	5	4
3. Heavy Duty	Howard	dqcqsmf	39.143600	-76.801987	March	3. Wed	5	4
3. Heavy Duty	Howard	dqcqsz0	39.150467	-76.782761	March	3. Wed	5	4
3. Heavy Duty	Howard	dqcqsz8	39.153214	-76.782761	March	3. Wed	5	4
3. Heavy Duty	Howard	dqcqut2	39.184799	-76.793747	March	3. Wed	5	4
3. Heavy Duty	Howard	dqcquvp	39.183426	-76.773148	March	3. Wed	5	4
3. Heavy Duty	Howard	dqcqv5c	39.176559	-76.770401	March	3. Wed	5	4

STEP 6: IMPORT THE DATA FROM THE SUMMARY TABLE INTO GIS SOFTWARE AND VISUALIZED ALONG WITH GEOHASHED TRUCK CRASH INFORMATION AND OTHER RELEVANT DATA

SAFE-D Parking Assessment (Demand and Opportunity)



POTENTIAL BIASES / QUALITY ISSUES WITH ANALYSIS

INRIX Sample Data Limitations

- Not all trucks are included in the database, and regardless of probe data source (INRIX, ATRI, HERE, etc.), there is going to be a range of coverage.
- For this study, the data represent approximately 15 to 20 percent of total truck movement in the region.
- Probe data do not provide vehicle classification (only three vehicle types), and they lack information on the type of operation (long-haul versus local).
- The data lack information on vehicle characteristics that may help to learn more about truck parking behavior (type of cabin, single unit vs. combination/tractor-trailer).
- They have low temporal resolution of waypoint data (every few minutes). There is a constant change in vehicle identification numbers which sometimes provides an error for any stopping/parking event that crosses midnight and reduces the accuracy of the metrics that are needed to describe the parking behavior.
- Often processing large, big data can be cumbersome.

Truck Parking Demand: Reliability

Use this method to determine parking capacity and examine the reliability of the data over time to tell a demand story.

1 → 2 → 3 → 4 → 5 → 6 → 7

Step 1

- Choose study site.

Step 2

- Geofence research area and define official and unofficial parking area.

Step 3

- Extract waypoints of trucks parked at this site during a particular month across 2019, 2020, and 2021.

Step 4

- Compare the number of trucks parked in the official and unofficial areas.

Step 5

- Compare the ratio of trucks parked in the unofficial areas.

Step 6

- Compare the number and percentage of trucks parked in official and unofficial areas based on the parking durations.

Step 7

- Check if these numbers are relatively consistent across years.

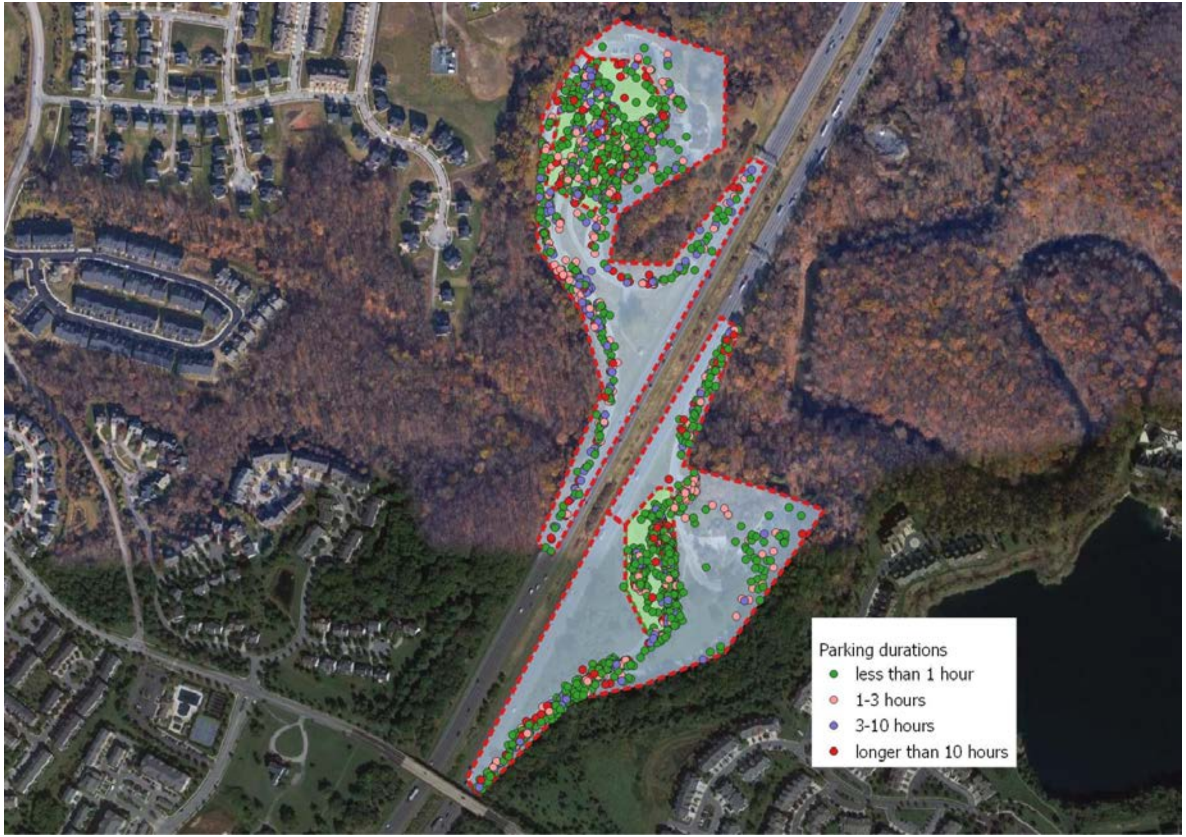
STEP 1: CHOOSE STUDY SITE

Determine area of truck parking reliability testing – Laurel/I-95 Welcome Center

STEP 2: GEOFENCE RESEARCH AREA AND DEFINE OFFICIAL AND UNOFFICIAL PARKING AREA

Direction	Available Space
Southbound	46
Northbound	21

STEP 3: EXTRACT WAYPOINTS OF TRUCKS PARKED AT THIS SITE DURING A PARTICULAR MONTH ACROSS 2019, 2020, AND 2021.



Step 4 — Compare the number of trucks parked in the official and unofficial areas

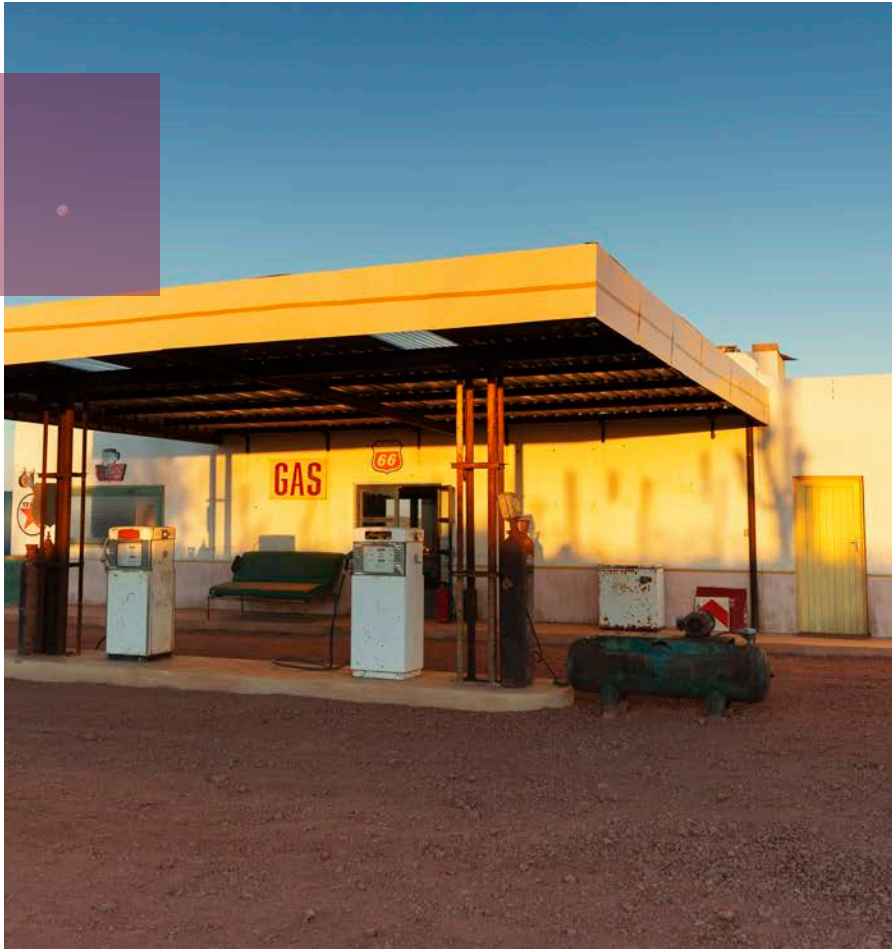
Step 5 — Compare the ratio of trucks parked in the unofficial areas

Step 6 — Compare the number and percentage of trucks parked in official and unofficial areas based on the parking durations

Step 7 — Check if these numbers are relatively consistent across years

Example of summary output from capacity/demand analysis and reliability of information.

Year		2020		2021	
Total Number of Observations		2,119		2,548	
Parking Type		Number of Observations	Percent of Total	Number of Observations	Percent of Total
Parking Location	Authorized	1,344	63%	1,432	56%
	Unauthorized	775	37%	1,116	44%
Parking Duration	Less than 1 Hour	1,349	64%	1,549	61%
	1-3 Hours	431	20%	746	29%
	3-10 Hours	339	16%	253	9.9%



Identify Supply

There are intrinsic safety impacts to all highway users due to large trucks parking in unsafe locations or truck drivers driving past their allotted hours.

With the projected growth of truck traffic, the demand for adequate truck parking will continue to outpace the supply of public and private parking facilities.

This section helps to identify ways to use data to identify opportunities to increase truck parking supply.

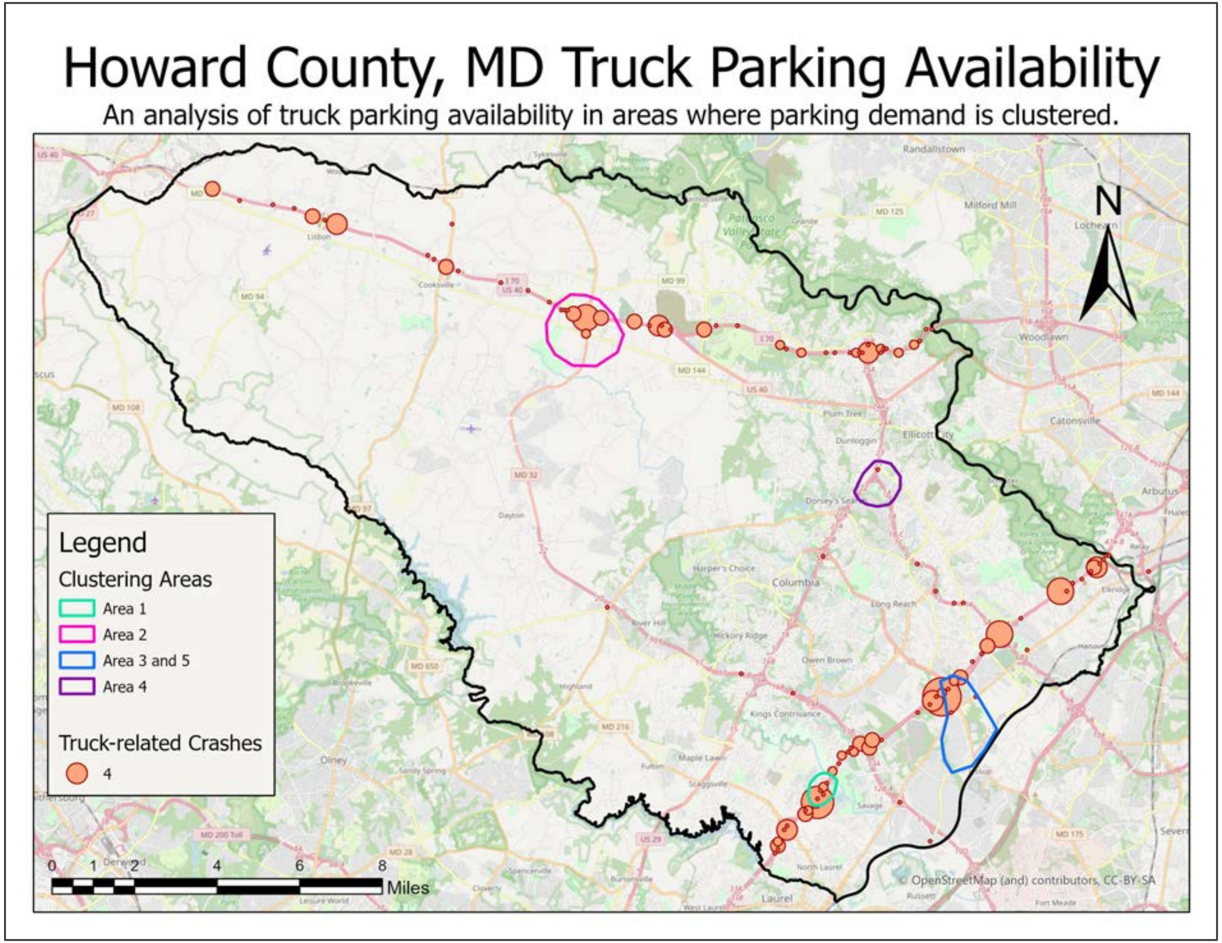
1. **Step 1**
   - Choose areas to analyze for truck parking
2. **Step 2**
   - Find relevant data layers to analyze the chosen areas
3. **Step 3**
   - Suitability Analysis
4. **Step 4**
   - Filter using qualitative data if possible
5. **Step 5**
   - Finalize list of potential parcels

Truck Parking Supply:

Determining usability of land ownership parcels

STEP 1: CHOOSE AREAS TO ANALYZE

Determine areas of truck parking demand



STEP 2: FINDING RELEVANT DATA LAYERS

Searching publicly available databases for relevant layers

- Land Use / Land Cover
- Parcel Boundaries (Land Ownership)
- Elevation (for terrain ruggedness and flood zone info)
- High-Res Land Cover (second source, to confirm Land Use / Land Cover)

Other possible layers to use (not included in this analysis)

- EPA – EJScreen
  - Air pollution, asthma
  - Proximity to traffic
  - Wastewater discharge
  - People of Color
  - Low Income
- Many options from MD's GIS database, depending on necessity

STEP 3: SUITABILITY ANALYSIS

3a - Format any polygon/polyline layers into raster layer

Layers formatted: Land use / Land Cover, Land Ownership

Use elevation to create a Terrain Ruggedness layer

3b – Reclassify raster layers, assign a numerical value to relevant qualitative attributes

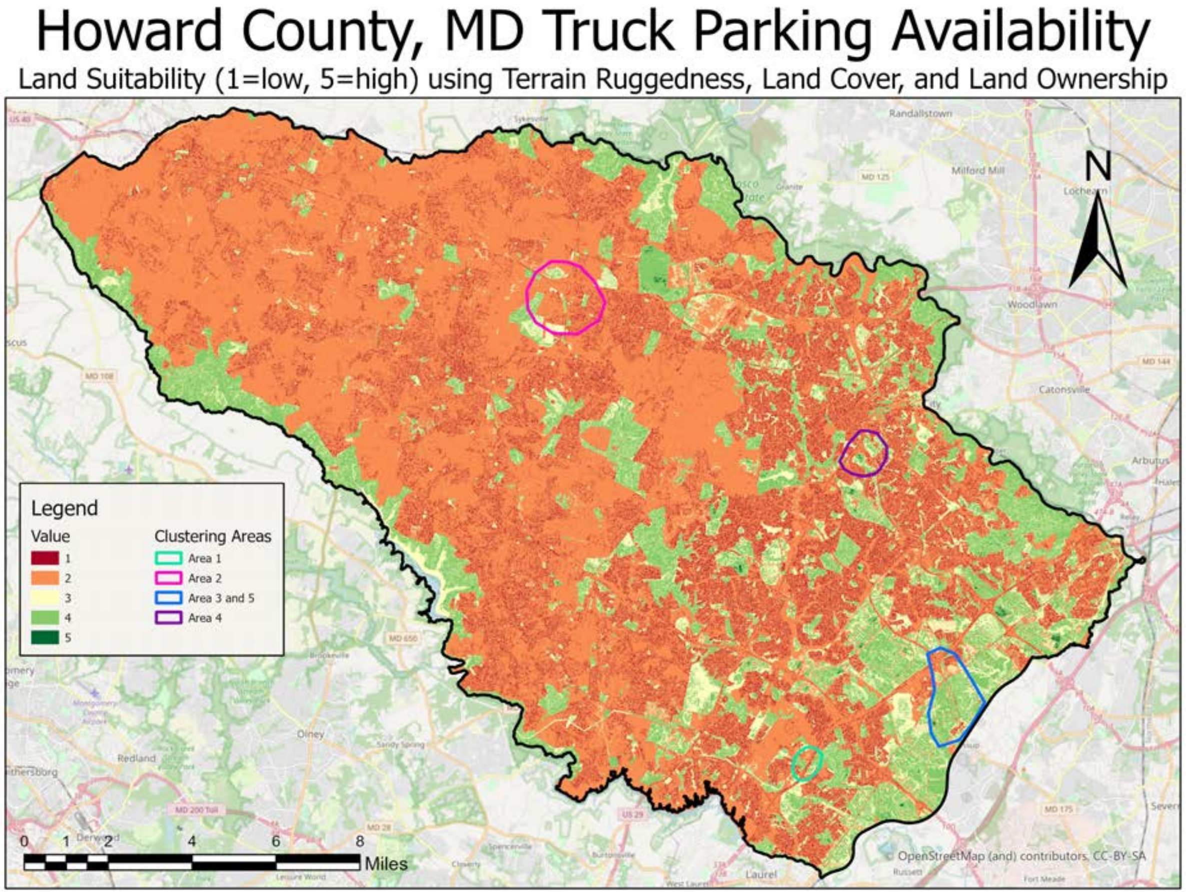
On a scale of 1 to 5, reclass qualitative data to a number apropos to its usability as a truck parking location

3c – Run Suitability Analysis using reclassed layers

Give a percentage weight to each layer used in the analysis

- Land Use / Land Cover – 20%
- Parcel Boundaries – 40%
- Terrain Ruggedness – 20%
- High-Res Land Cover (second source, to confirm Land Use / Land Cover) – 20%

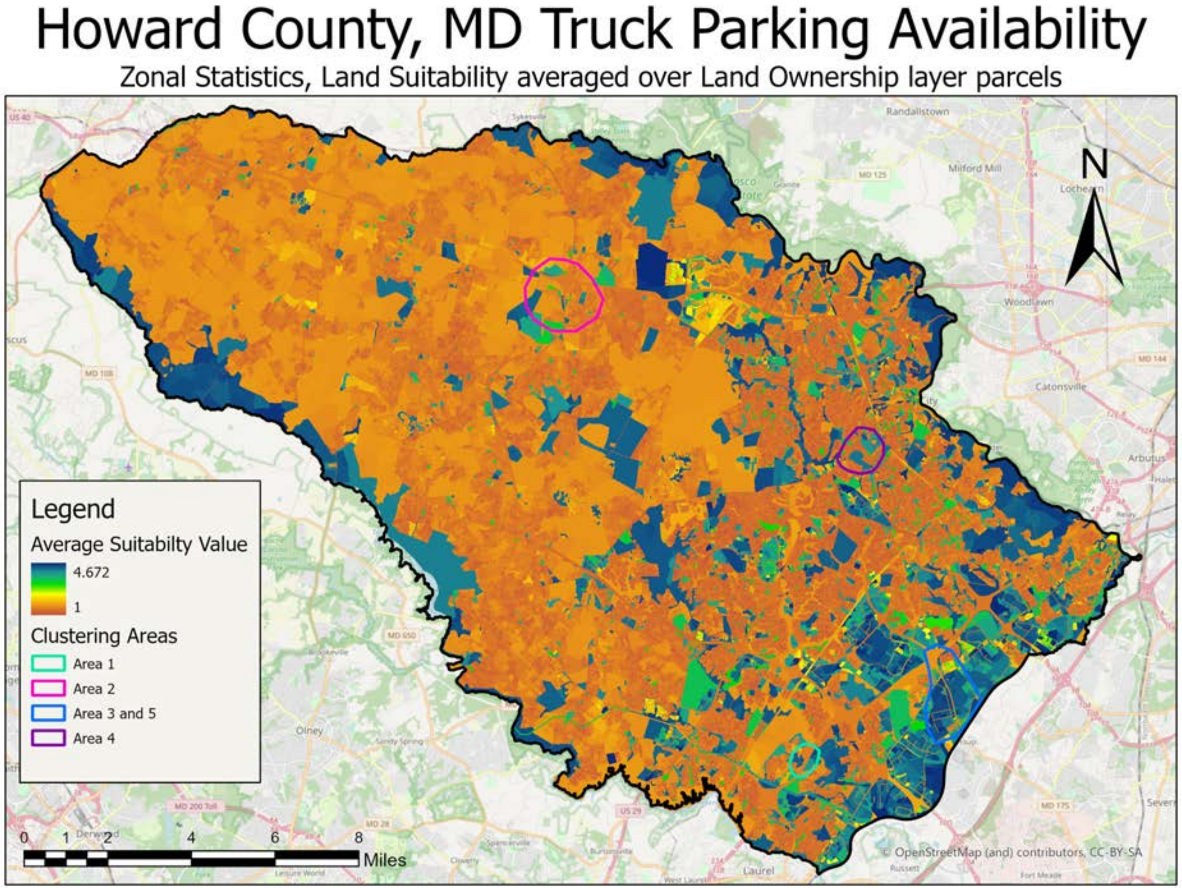
STEP 3: SUITABILITY ANALYSIS



STEP 3: SUITABILITY ANALYSIS

3d – Zonal Statistics

Find average suitability value over the polygons within the Parcel Boundaries layer



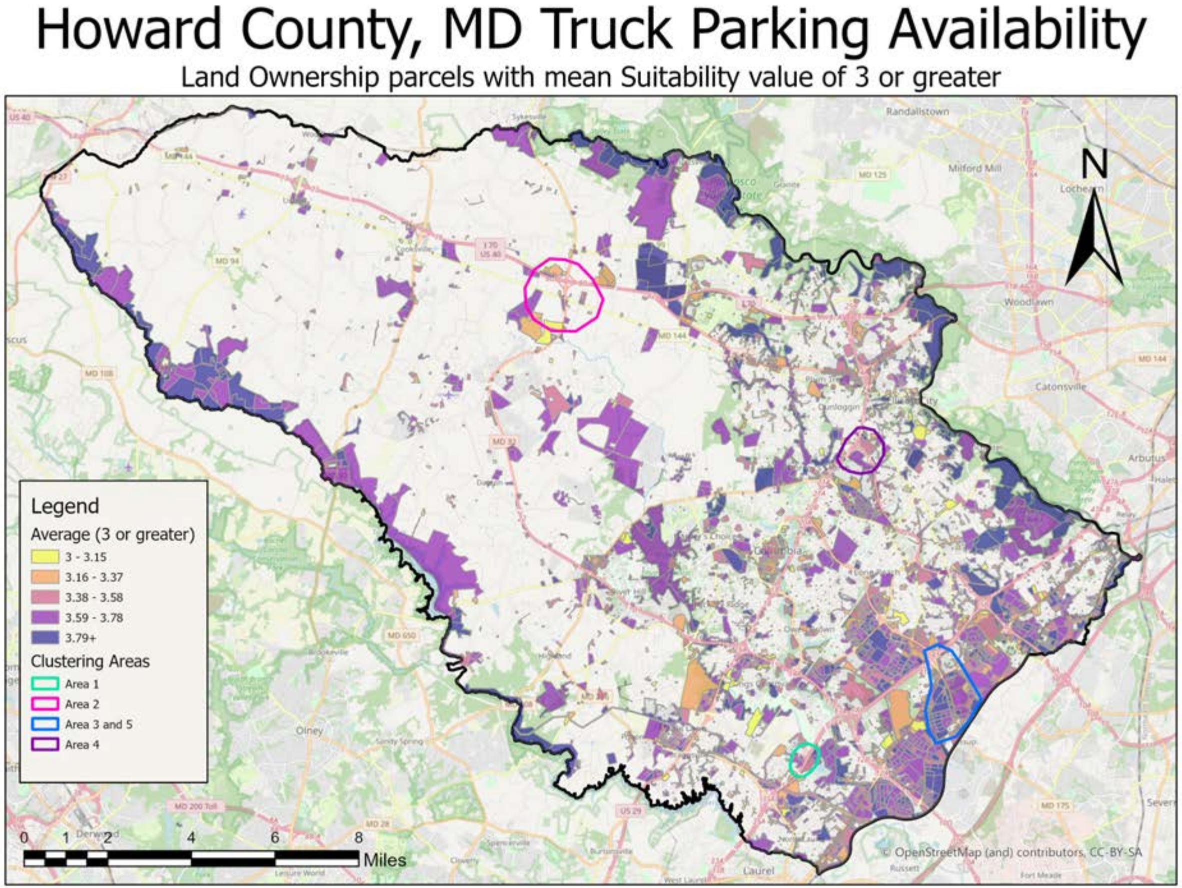
STEP 3: SUITABILITY ANALYSIS

3e – Join suitability values with the Land Ownership Parcels

Find average suitability value over the polygons within the Parcel Boundaries layer

Initial parcels: 97,271

Remaining Parcels (value of 3 or greater): 5,924



STEP 4: QUALITATIVE DATA

Observe any layers that cannot be quantified, utilize these to help narrow parcels

Examples:

- Aerial Photography
- Nearby Human and Environmental Receptors
- If paved, characteristics? (e.g., can the parking lot pavement handle trucks, pavement strength, etc.)
- Access to Facilities, e.g., power, water, trash collection, and security
- Environmental Equity – EJScreen can help quantify

Land Ownership layer - Observe each parcel's data for possibly useful information

Examples:

- If Exempt, does it show an owner of the property? Can use this to contact whoever is in charge.
- If Commercial / Industrial, does this give any owner information?

STEP 5: FINALIZE LIST OF POTENTIAL PARCELS

Select by location – Drive Time Area

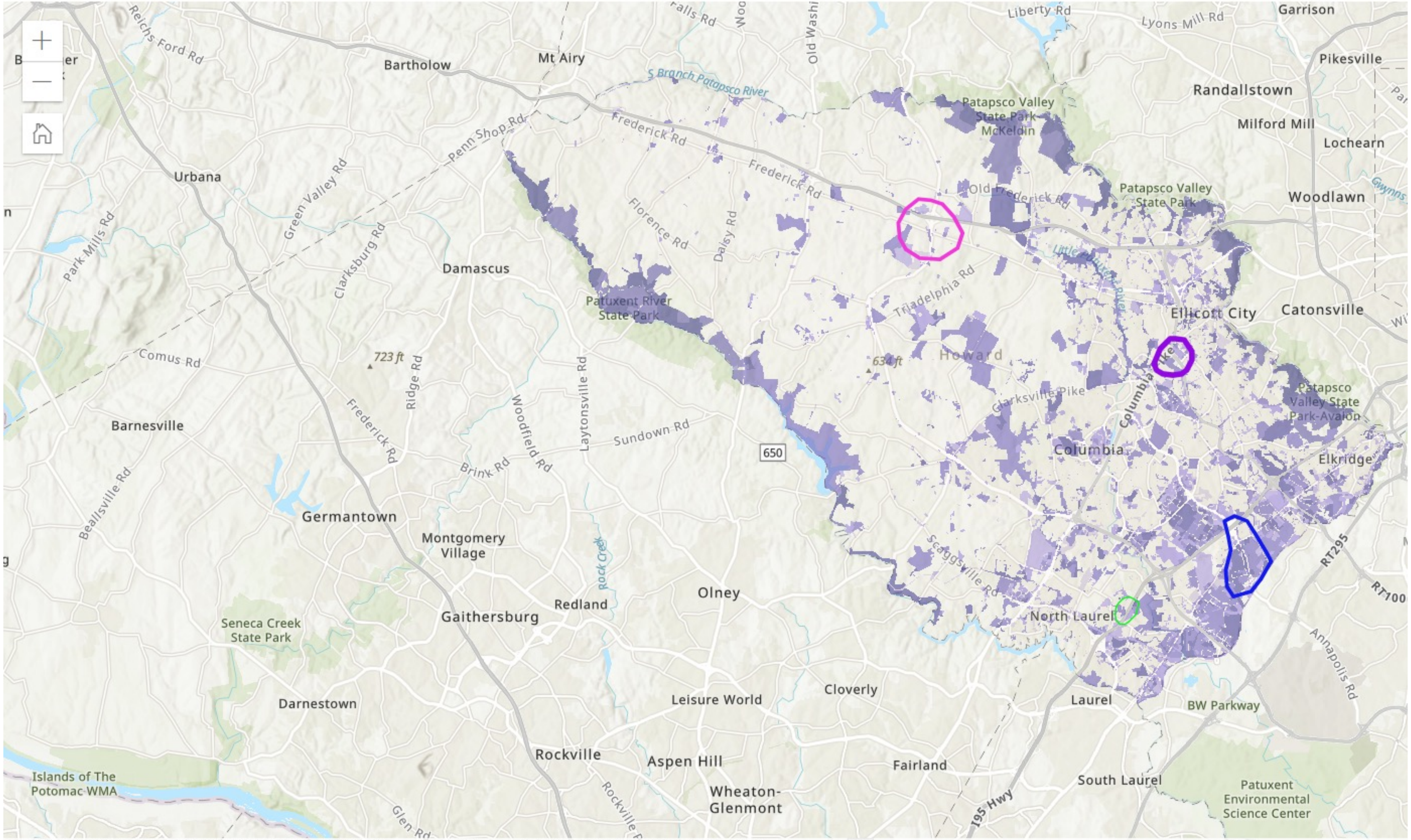
Using the Drive Time Area tool, create areas of a set time it takes to get anywhere from a point.

- Create points along interstates / roads within the clustering areas and run the tool using these points.
- Start with 5 minutes, expand to 10 and 15 minutes if necessary
- Use Select By Location to create a list of potential parcels within these Drive Time Areas for each clustering area

Google Maps – Street View

As a last step, all potential parcels should be checked on Street View, if possible. Then, any that are of interest can be checked by physically going to the location to confirm the usability as a parking area.

SAFE-D Parking Assessment (Demand and Opportunity)



Esri, NASA, NGA, USGS | MNCPPC, VGIN, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, EPA, NPS, USDA

POTENTIAL BIASES / QUALITY ISSUES WITH ANALYSIS

Suitability Analysis

- Weights on each layer were arbitrarily chosen but were based on possibly what a real-life analysis might use.
- More layers could be used for the analysis, however, the more factors/layers used, the muddier the final result may be.

Layers Used

Need to make sure they are the most up-to-date information.

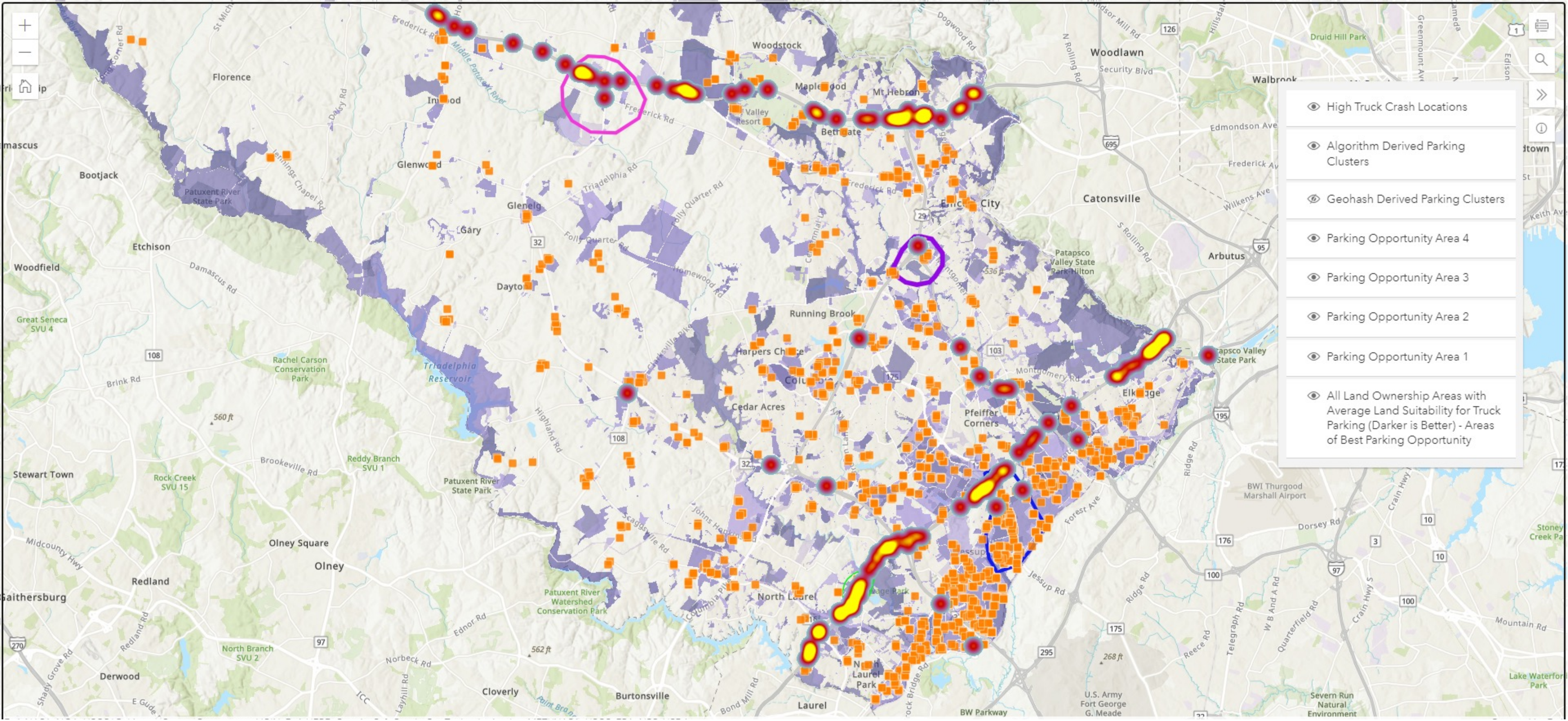
- Private ownership for commercial and industrial parcels?
- Has exempt land exchanged ownership?

Combine Data

The research team decided that it was important to develop an interactive map of the combined data. Therefore, the team created an ArcGIS online map with all the data layers so that readers of this study and future researchers can explore the data in detail and replicate the analysis. The link for this map is: https://arcg.is/0rHnGH and a screenshot is shown on the next slide.

You may want to do the same to help with decision-making. This is easy to do by importing the data as hosted layers in ArcGIS online and then creating a map.

SAFE-D Parking Assessment (Demand and Opportunity)



QUESTIONS?

Nicole Katsikides
Texas A&M Transportation Institute
3135 TAMU
College Station, TX 77843-3135
443-322-6762
N-Katsikides@tti.tamu.edu

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