RESEARCH & DEVELOPMENT

Rail Network Trespass Statewide Severity Assessment and Predictive Modeling

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16. Abstract

The Institute for Transportation Research and Education (ITRE) at NC State University in collaboration with the North Carolina Department of Transportation (NCDOT) has conducted research to develop a more complete understanding of the extent of pedestrian trespassing along the rail network in North Carolina. This research seeks to better quantify and describe the universe of trespassing activities including those events that do not result in injury or death through the development and testing of static (fixed base) thermal camera systems. Thermal camera systems were deployed at a sample of trespassing hot spots along railroad corridors in North Carolina to determine a count of trespassing events for the data collection time periods and an estimate of the trespassing frequency at the hot spots. Using these trespassing event data, models for estimating and predicting trespassing across the rail network were developed. The data were also used to develop profiles of trespassing activity by season of year, month of year, day of week, and hour of day for each hot spot location that can inform local-level intervention strategies.

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1. BACKGROUND AND RESEARCH NEED

Trespassing is the leading cause of rail-related deaths in the United States. Nearly half of all railroad fatalities were trespassers and over a quarter of all railroad fatalities were suicides for the five-year period from 2012-2017.[1] Between 2012 and 2017, the annual number of trespassing-related pedestrian fatalities increased 18%, from 725 in 2012 to 858 in 2017.[2] In North Carolina, trespassers represent the largest share of rail-related deaths, and the frequency of trespasser incidents has not experienced the same level of overall decline since 1975 as other types of rail-related incidents in the state. Addressing trespassing along railroad rights-of-way (ROW) is a leading priority for the Federal Railroad Administration (FRA). In 2017, the Federal Rail Administration (FRA) held a Grade Crossing Research Needs Workshop that established five research needs focus areas.[3] The top recommended action for the Community Outreach and Education focus area is trespasser identification, motivation, and messaging.[4] The goal of this action is to provide communities with tools for deterring trespassing, including better targeting of messaging based on demographics, geography, and reasons for trespassing. Achievement of this goal requires identifying types of and reasons for trespassing along with developing modes and methods to test messaging aimed at trespassers. On February 19, 2019, the FRA issued to Congress the first National Strategy to Prevent Trespassing on Railroad Property.[5] The report acknowledges that more people are struck and killed by trains each year while trespassing than in motor vehicle collisions with trains at highway-rail crossings, and further emphasizes that the number of trespassing events each year exceeds the number of fatalities and injuries. This report recognizes that previous FRA trespassing prevention programs have not been national in scope or proactive to address the root causes of trespassing. The national strategy includes four focus areas: data gathering and analysis, community site visits, funding, and partnerships with stakeholders. Data gathering and analysis involves review of trespass incidents and close calls to enable the FRA to target its resources to trespassing "hot spots." The collection and analysis of quantitative event-based data is an important element for achieving this goal.

The Institute for Transportation Research and Education (ITRE) at NC State University in collaboration with the North Carolina Department of Transportation (NCDOT) has conducted research to develop a more complete understanding of the extent of pedestrian trespassing along the rail network in North Carolina. This research seeks to better quantify and describe the universe of trespassing activities including those events that do not result in injury or death through the development and testing of static (fixed base) thermal camera systems. Thermal camera systems were deployed at a sample of trespassing hot spots along railroad corridors in North Carolina to determine a count of trespassing events for the data collection time periods and an estimate of the trespassing frequency at the hot spots. Using these trespassing event data, models for estimating and predicting trespassing across the rail network were developed. The data were also used to develop profiles of trespassing activity by season of year, month of year, day of week, and hour of day for each hot spot location that can inform local-level intervention strategies.

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[1] Topel, K. (2019). **Scope and Trend of U.S. Rail Trespassing and Suicide Fatalities.** In *Toward Railroad Trespassing Solutions* – TR News, Number 322, July-August 2019. Retrieved from http://onlinepubs.trb.org/onlinepubs/trnews/trnews322.pdf.

[2] DaSilva, M., Grizkewitsch, M., and Jacobini, F. (2019). **Development, Implementation, and Evaluation of a Community-Based Trespass Prevention Model.** In *Toward Railroad Trespassing Solutions* – TR News, Number 322, July-August 2019. Retrieved from http://onlinepubs.trb.org/onlinepubs/trnews/trnews322.pdf.

[3] Alibrahim, Sam. (2017). **FRA Grade Crossing Safety Research.** Retrieved from https://www.fra.dot.gov/conference/2017/rnw/pdf/Presentations/Other%20Sessions/FRA%20Accomplishments.pdf.

[4] Federal Rail Administration. (2017). **Working Group Summary of Top Recommended Actions.** Retrieved from https://www.fra.dot.gov/conference/2017/rnw/pdf/Presentations/Other%20Sessions/Working%20group%20Summaries.pdf.

[5] Federal Railroad Administration. (2019). **FRA Issues National Trespass Prevention Strategy.** Retrieved from https://cms7.fra.dot.gov/newsroom/fra-issues-national-trespass-prevention-strategy.

The overall research goal is to generate estimates of overall trespassing events for the entire North Carolina rail network. To achieve this objective, this project builds on previous research, including the methods and data generated from NCDOT Research Project (RP) 2017-15. Under this previous effort, ITRE collected data samples of trespassing activity at hot spot locations along the 170-mile Piedmont corridor from Raleigh to Charlotte using two static thermal video cameras. The hot spot locations included Durham, Greensboro, Mebane, Elon, Charlotte, and Salisbury and were informed by the most recent five years of FRA rail trespasser incident data and Piedmont Amtrak train crew surveys administered in May 2015.

Data samples of trespassing events at additional locations on the rail network were collected under the scope of NCDOT RP 2019-08 using three static thermal video cameras to achieve a robust dataset of trespassing activity for use in the development of models to estimate and forecast trespassing events by location for the rail network in North Carolina. A secondary objective was the development of a prototype tool for presenting the trespassing data in a user-friendly visualization environment.

2. LITERATURE REVIEW

The FRA is the primary source for data related to the injury or death of trespassers on the railroad right-of-way in the United States. Under Title 49 Code of Federal Regulations (CFR) Part 225, railroad carriers are required to provide the FRA with accurate information concerning the hazards and risks that exist on railroads in the United States so that the FRA can effectively carry out its regulatory and enforcement responsibilities under the Federal railroad safety statutes.[6] Railroads are required to complete reports and records of accidents/incidents in accordance with the current FRA Guide for Preparing Accident/Incident Reports.[7] According to the FRA guide, the following definitions are used in reference to trespassing:

- Trespass: Any vehicle or pedestrian is deemed by the FRA to be trespassing if they are on the part of railroad property used in railroad operation and whose presence is prohibited, forbidden, or unlawful, including if
    - They are in the railroad right-of-way not at a designated crossing
    - They are in the railroad right-of-way at a designated crossing when the gates are down
- Trespass incident: A trespasser is killed or injured on railroad property, resulting in a form being submitted to the FRA

The FRA released a report in 2013[8] as an update to a 2008 study[9] that provided demographic profiles of deceased trespassers based on surveys sent to coroners/CMEs associated with the trespass fatalities. Further, the FRA released a report in July 2018 that presents a baseline measure of FRA trespassing and suicide incident data from 2012-2014 with information on populations and locations deemed at most risk for trespass and suicide.[10] These datasets do not include data for individuals who trespass but were not struck and killed or injured by a train, thus it provides only a partial view of the universe of trespassing activity. Further, since the studies sought national representativeness with demographics provided by FRA Region as the smallest geography, their aggregated results may not reflect local realities and thus may have limited utility for informing local countermeasures.

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[6] Federal Railroad Administration. (2011). **FRA Guide for Preparing Accident/Incident Reports.** DOT/FRA/RRS-22.

[7] Ibid.

[8] North American Management. (2013). **Rail Trespasser Fatalities: Demographic and Behavioral Profiles.** Report for the Federal Railroad Administration. North American Management (NAM), Alexandria, Virginia.

[9] George, B.F. (2008). **Rail Trespasser Fatalities: Developing Demographic Profiles.**
Report for the Federal Railroad Administration. Cadle Creek Consulting, Edgewater, Maryland.

[10] Volpe National Transportation Systems Center. (2018). **Characteristics of Trespassing Incidents in the United States (2012-2014).** Federal Railroad Administration, USDOT. Retrieved from https://rosap.ntl.bts.gov/view/dot/36451/dot_36451_DS1.pdf.

While FRA incident reporting potentially provides a near-census of trespasser casualties on railroad right-of-ways in the United States, the dataset does not capture the universe of trespassing activities including those events that do not result in injury or death. ITRE's research in North Carolina attempts to address this gap by developing a scientific data collection strategy and analysis approach to better understand pedestrian trespassing along railroad right-of-ways in the state.

In recent years, researchers have studied and documented railroad trespassing events in various parts of the United States.[11,12,13] Data collected in these studies used fixed-base standard video camera systems to capture pedestrian activity along rail corridors or involved review and analysis of locomotive video data. Thermal or infrared systems can also be used for pedestrian detection including in trespassing scenarios. Thermal or infrared camera systems allow greater detection capability in low light, nighttime, rainy, or hazy conditions since heat signatures are more readily detectable than the visible spectrum in these settings.[14] Thermal video detection of rail trespassing has been used in combination with alarm or alert systems to warn and deter trespassers.[15] However, few comprehensive studies have been conducted to generate representative data on trespassing activity, including using thermal video detection.

3. METHODOLOGY

Exhibit 1 summarizes the overall study methodology. Site selection was informed by a review of the most recent five years of FRA incident data, train crew surveys, input from NCDOT Rail Division staff, analysis of U.S. Census Bureau population data, and evaluation of desire lines and attractors near the railroad track using GIS. After sites were selected, a sampling plan was created to collect at least one complete week of 24/7 thermal video data at each site in each season for one year. Primary data collection was conducted using AXIS thermal video camera systems with motion detection, remote data access, and local data storage. Two camera systems were deployed for data collection at five sites in 2017-2018 and three camera systems were deployed across six sites in 2019-2020. The camera installation locations were chosen based on consultation with community contacts. The thermal video data were reviewed and reduced into trespassing events and their associated characteristics. Descriptive statistics were produced for the first round of data collection that occurred in 2017-2018, and preliminary predictive modeling was performed using the data collected across all 11 sites.

[11] Savage, I. (2007). **Trespassing on the Railroad.** Research in Transportation Economics: Railroad Economics. Volume 20(1), pages 199-224. Amsterdam: Elsevier Science.

[12] DaSilva, M.; Baron, W.; and Carroll, A. (2004). **Highway Rail-Grade Crossing Safety Research: Railroad Infrastructure Trespassing Detection Systems Research in Pittsford, New York.** Federal Railroad Administration, USDOT. Retrieved from https://trid.trb.org/view.aspx?id=795856.

[13] DaSilva, M. and Ngandung, T. (2014). **Trespass Prevention Research Study – West Palm Beach, FL.** Federal Railroad Administration, USDOT. Retrieved from https://dotcms.fra.dot.gov/elibrary/trespass-prevention-research-study-west-palm-beach-fl.

[14] Torresan, H.; Turgeon, B.; Ibarra-Castanedo, C.; Hebert, P.; and Maldague, X. (2004). **Advanced Surveillance Systems: Combining Video and Thermal Imagery for Pedestrian Detection.** Proceedings Volume 5405, Thermosense XXVI; (/conference-proceedings-of-spie/5405.toc); doi:10.1117/12.548359.

[15] FLIR. (2019). **Application Note – Rail: FLIR Cameras Spot Trespassers on Belgium's Busiest Rail Connection.** Retrieved from https://www.flir.eu/globalassets/its/flir_rail_infrabel_application_story.pdf

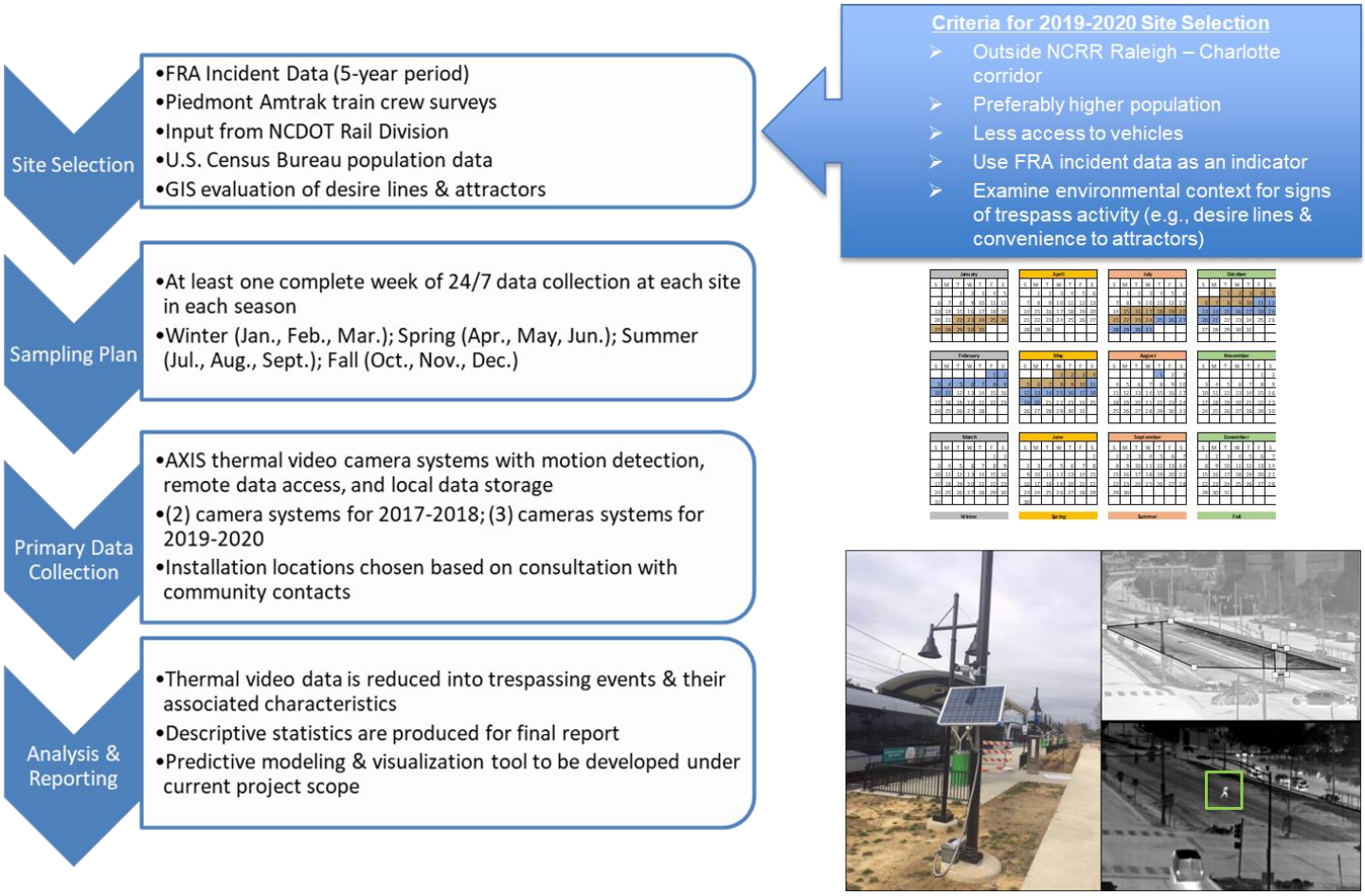


Exhibit 1. Study Methodology

3.1. Data Collection

3.1.1. Site Selection

This section summarizes the methodology and results for identifying and selecting additional hot spot locations for static thermal video detection outside of the 170-mile Piedmont corridor from Raleigh to Charlotte to be used in conjunction with those identified in NCDOT RP 2017-15. Site selection was informed by examining several secondary data sources, including FRA trespasser incident data for the most recent five-year period for the entire North Carolina rail network, U.S. Census Bureau population-level characteristics at the census tract level, and environmental characteristics using aerial imagery in a GIS. This section summarizes the video data collection plan based on the site selection results. The data collection plan was designed to be cost-effective and time-efficient relative to the rotation of the camera equipment between several locations during the period of study.

3.1.1.1. Evaluation of Secondary Data Sources

Several data sources were used to identify hot spot locations for trespassing along the railroad right-of-way for the entire North Carolina rail network. Federal Railroad Administration (FRA) trespasser incident data for the five-year period from 2013-2017 were downloaded from the FRA's online database.[16] A

[16] Federal Railroad Administration Office of Safety Analysis. **Accident Data as Reported by Railroads, 2013-2017.** https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/on_the_fly_download.aspx. Accessed September 1, 2018.

trespasser incident describes when a trespasser is killed or injured on railroad property, resulting in an incident report being submitted to the FRA. Any vehicle or pedestrian is deemed by the FRA to be trespassing if: 1) they are in the right-of-way not at a designated crossing or 2) if they are in the right-of-way at a designated crossing when the gates are down. Trespasser incidents were extracted from the total incident dataset and sorted into two groups: crossing incidents and non-crossing incidents. The data were displayed in a GIS to examine geospatial clustering of the incidents (Exhibit 2). A total of 205 trespasser incidents (casualties) were recorded by the FRA for the five-year period from 2013-2017 in NC.

Decennial Census and American Community Survey (ACS) data were also examined in a GIS in relation to the geospatial distribution of the trespasser incidents. As expected, population density as people per square mile (U.S. Census Tract level)[17] was found to be strongly correlated with the frequency of trespasser incidents (Exhibit 3).

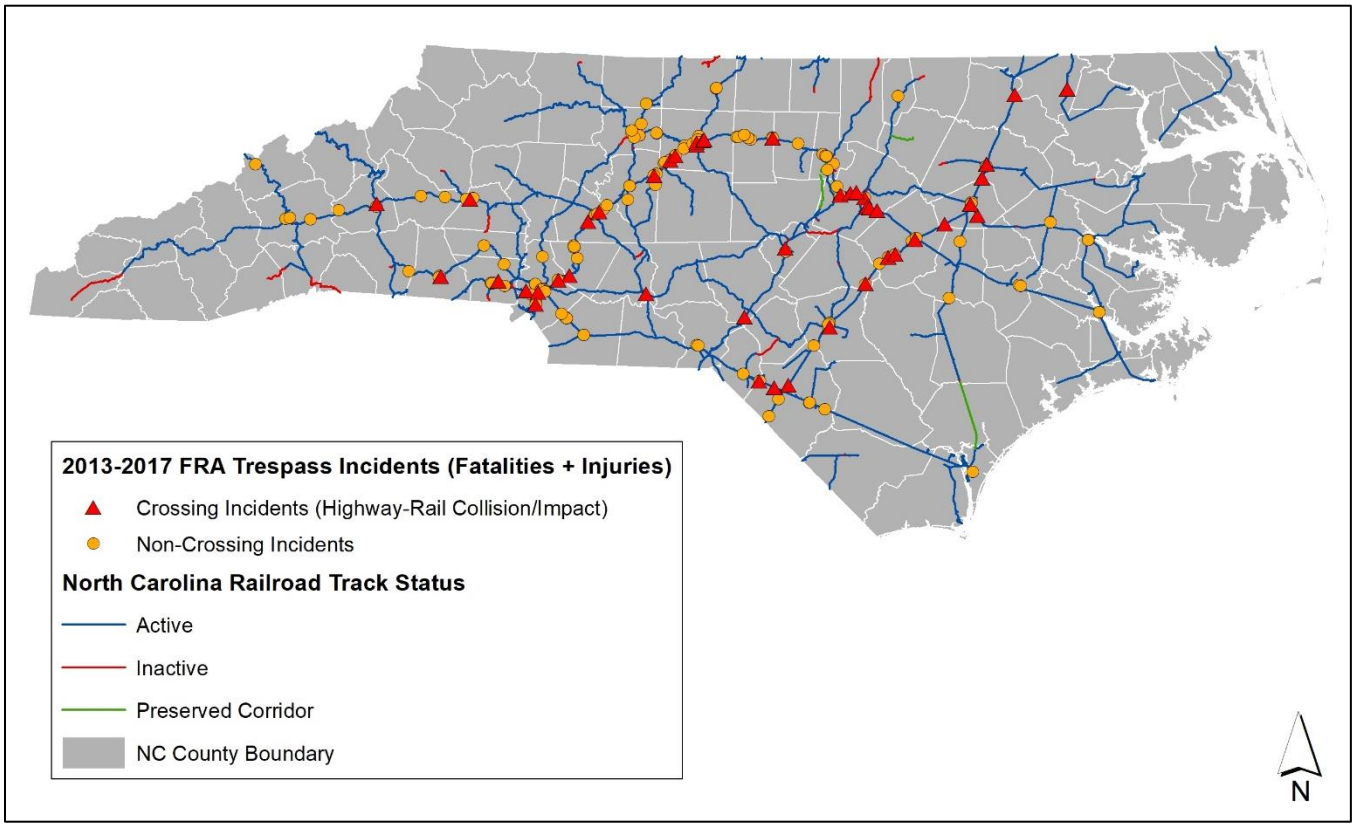


Exhibit 2. FRA Trespasser Incidents (2013-2017) – Crossing and Non-Crossing Overlaid with NC Rail Network

[17] U.S. Census Bureau, Census 2010, Summary File 1, Total Population.

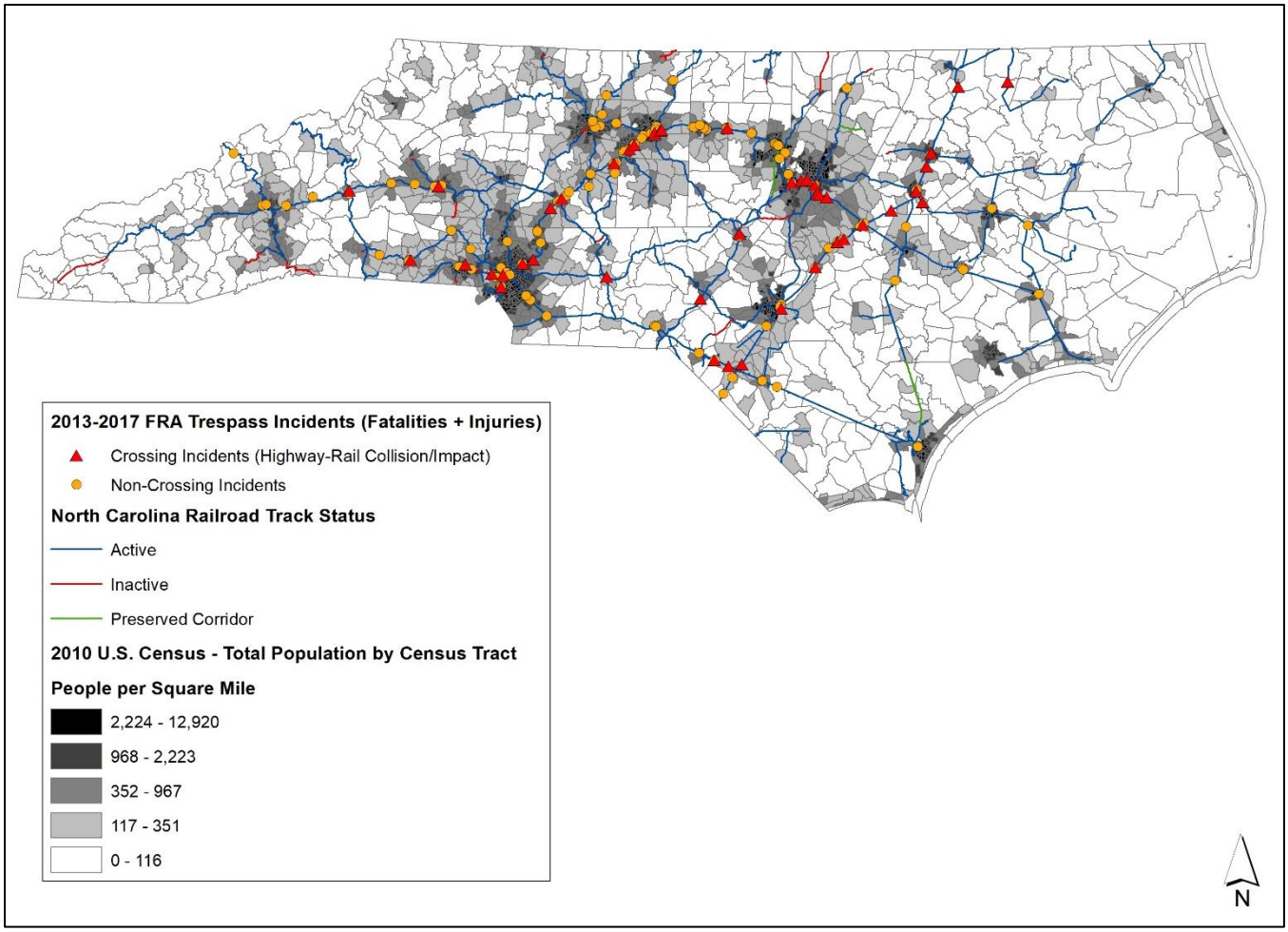


Exhibit 3. FRA Trespasser Incidents (2013-2017) with Population Density as People per Square Mile by U.S. Census Tract

Aerial imagery was also used to investigate environmental evidence of trespassing activity at locations where the FRA trespass incidents were clustered. Evidence included desire lines such as informal footpaths along and/or across the railroad right-of-way, particularly where attractors (e.g., housing, businesses, social/recreational areas) are separated by rail corridors.

Based on an evaluation of the secondary data sources, the following criteria were used as a guide for selecting the new data collection sites:

- Outside NCRR Raleigh – Charlotte corridor
- Preferably higher population
- Less access to vehicles
- Use FRA trespasser incident data as an indicator
- Examine environmental context for signs of trespassing activity (e.g., desire lines, convenience to attractors)

3.1.1.2. Description of Selected Sites

ITRE identified five locations outside of the NCRR corridor from Raleigh to Charlotte as potential data collection sites (Rockingham, Shelby, Fayetteville, Rocky Mount and Lumberton). ITRE also identified one location in Charlotte and one location in Raleigh for potential inclusion to provide additional data

samples on the NCRR corridor beyond those collected under NCDOT RP 2017-15. These locations were shared with the NCDOT Rail Division and their expert feedback was used to inform the preliminary list of candidate sites (Gastonia, Shelby, Charlotte, Rocky Mount, Fayetteville, and Lumberton). Upon receiving feedback from NCDOT Rail Division and compiling the short list of candidate data collection sites, the ITRE research team visited each of the six locations to further evaluate their feasibility, including examining environmental conditions and determining camera installation points. NCDOT Rail Division staff coordinated with stakeholders in each community to share information about the research project and to secure permissions to install the thermal camera systems. ITRE created an information packet for each community that included a form letter with the camera install dates and images of the camera equipment provided in Appendix A. Gastonia, Shelby, and Charlotte were visited on 11/16/2018; Rocky Mount, Fayetteville, and Lumberton were visited on 11/29/2018.

One of the six locations selected for data collection was identified as problematic after the first set of camera system installations were completed in January 2019. The Fayetteville site experienced too much vehicular traffic triggering the motion detection and too little trespassing activity to reasonably include the location in the study. The research team evaluated alternate sites to replace the location in Fayetteville, including a site in Raleigh and in Rockingham. Based on feedback from the NCDOT Rail Division, the research team visited a potential replacement site near Pullen Park in Raleigh on 4/3/2019. There are several well-defined desire lines between the Pullen Park Aquatic Center and municipal softball fields created by families traveling from parking areas to the athletic fields. The research team was also informed that a homeless population resides along the right-of-way and frequently crosses the tracks to access bathrooms and park benches at the city-owned facilities. The research team investigated a potential camera installation location on the east side of the Pullen Road bridge over the railroad tracks. The location has an ideal view to the east down the railroad corridor that captures several sets of desire lines across the right-of-way. The research team obtained permission from the City of Raleigh to install the camera system in May 2019.

To summarize, five locations on the Piedmont corridor from Raleigh to Charlotte, NC were observed in 2017-2018. These locations were from east to west: Durham, Mebane, Elon, Greensboro, and Salisbury. Six locations outside of the Piedmont corridor were observed in 2019-2020 as the study was expanded to the wider North Carolina rail network. These locations were from west to east: Shelby, Gastonia, Charlotte, Raleigh, Lumberton, and Rocky Mount. The eleven locations are geographically dispersed across the state and represent small, medium, and larger-sized urban and rural communities with populations ranging from less than 10,000 to over half a million people.

3.1.1.3. Site Visits and Camera Installation Locations

The ITRE research team initially inspected each location in a GIS to determine feasible camera installation locations. The team then visited each of the six locations to further evaluate their viability, including examining environmental conditions and finalizing camera installation points. NCDOT Rail Division staff coordinated with stakeholders in each community to share information about the research project and to secure permissions to install the thermal camera systems.

A map of the study locations included in the 2017-2018 and 2019-2020 thermal video data collection is provided in Exhibit 4.

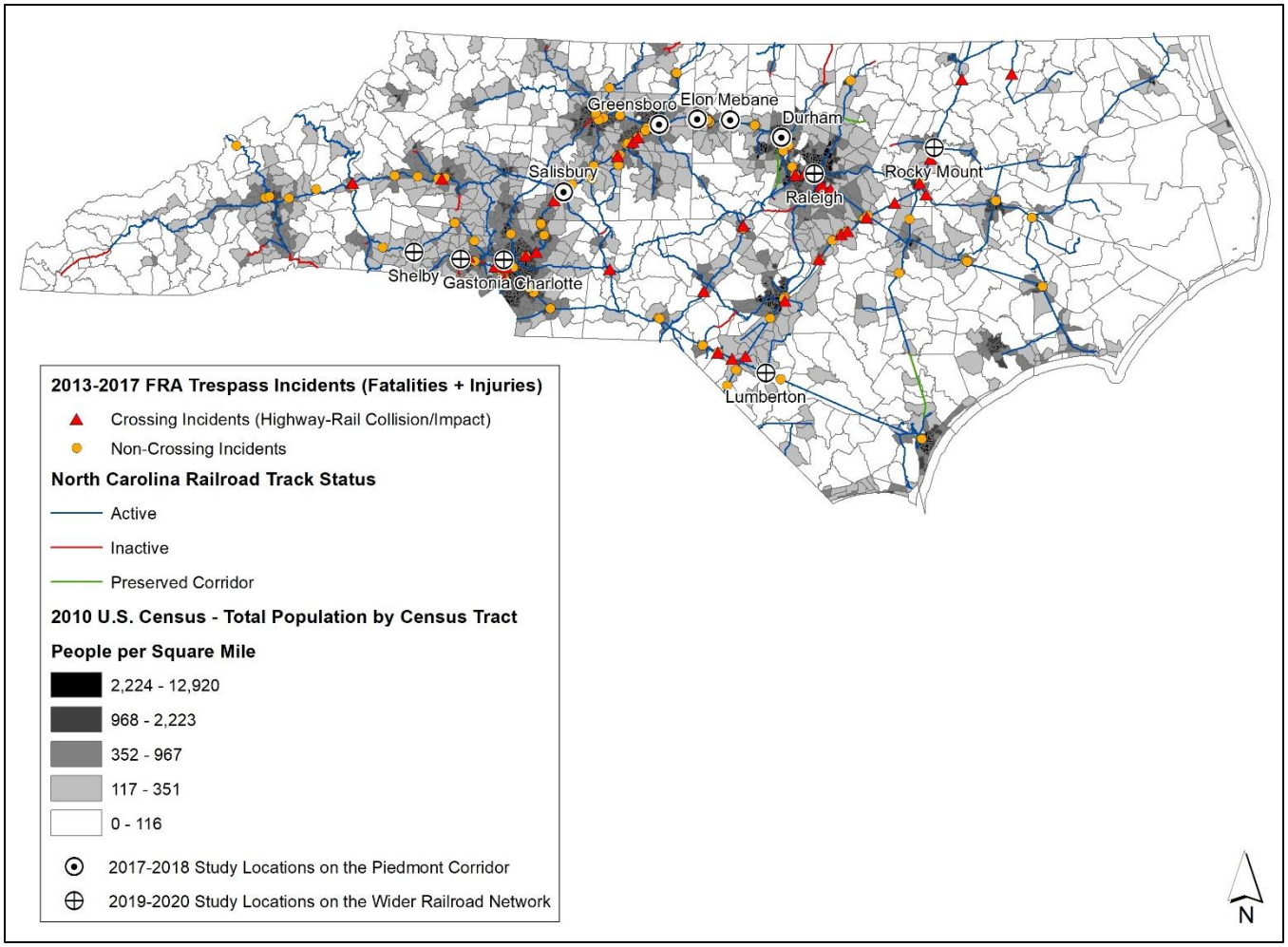


Exhibit 4. Study Locations on the Piedmont Corridor and the Wider Rail Network

2017-2018 Observation Sites

- Durham (35.99461, -78.9019)
  - Four historic strikes within 0.25 mi of this location from 2012, 2014, and 2015; marked as a corridor of concern on Amtrak Piedmont train crew surveys. Unfenced along entire stretch that bisects downtown Durham. Possibly a short cut to destinations on either side of tracks.
  - Camera installed on railing along the south side of the Corcoran Street parking garage roof. Camera detected activity south across the corridor between Ramseur Street and Vivian Street.
- Greensboro (36.06946, -79.78339)
  - Marked as a corridor of concern on Amtrak Piedmont train crew surveys. Short cut to social services and downtown area from neighborhood to the south. Obvious desire line that crosses through the railroad right-of-way.
  - Camera installed on lamp post on the eastern side of the secondary Amtrak platform and detected activity down the corridor towards the informal path between East Washington Street and Plott Street.
- Elon (36.10044, -79.50804)

    - Frequent trespassing activity according to Amtrak Piedmont train crew surveys. Low number of strikes according to FRA incident data. University housing, businesses, and academic buildings are attractors on both sides of the railroad right-of-way.
    - Camera installed on rail radar detection pole at the intersection of West Lebanon Avenue and North Williamson Avenue. Camera detected activity west down the corridor towards Church Street.
- Mebane (36.0970, -79.27110)
    - Four historic strikes within 0.25 mi of this location from 2011, 2014, 2015, and 2016. Marked as a corridor of concern on Amtrak Piedmont train crew surveys. Short cut from housing to the south to Tommy's MiniMart and downtown Mebane to the north.
    - Camera installed on the rail radar detection pole at the intersection of South Third Street and East Washington Street. Camera detected activity west down the corridor towards South 1st Street.
- Salisbury (35.66734, -80.46552)
    - Frequent trespassing activity according to Amtrak Piedmont train crew surveys. Three historic strikes within one mile of this location from 2014 and 2015.
    - Camera installed on the south side of the Amtrak platform. Camera detected activity south across the corridor towards East Liberty Street.

2019-2020 Observation Sites

- Charlotte (35.26484, -80.88366)
    - Multiple desire lines identified leading to the railroad right-of-way near Rozzelles Ferry Road.
    - Camera installed on a utility pole in the Hoskins Avenue Baptist Church parking lot between the church and the railroad right-of-way. Camera detected activity south towards North Linewood Avenue.
- Gastonia (35.26476, -81.19401)
    - Path visible between the end of Highland Street and the parking lot of the social services building on Airline Avenue. These tracks are along the NS mainline, but outside of the NCRR corridor.
    - Camera initially installed on a utility pole on the eastern edge of the Crisis Assistance Ministry parking lot that is on City of Gastonia-owned property, but later moved to a privately-owned warehouse to the southeast. Camera detected activity at the path that crosses to the south over the tracks.
- Lumberton (34.61783, -79.01216)
    - Path across the railroad right-of-way and over the tracks where the Riverwalk Trail meets Martin Luther King Junior Drive. Obvious desire line used as a shortcut on the Riverwalk Trail.
    - Camera installed on utility guy pole adjacent west to the Riverwalk that is owned by the Town of Lumberton. Camera detected activity at the path running south from the Riverwalk Trail over the tracks to the riverbank towards a residential neighborhood.
- Raleigh (35.78313, -78.66521)
    - This location replaced the Fayetteville location due to low trespassing and high motor vehicle interference. There are several well-defined desire lines between the Pullen Park Aquatic Center and municipal softball fields created by families traveling from parking areas to the athletic fields. A homeless population also resides along the railroad right-

of-way and frequently crosses the tracks to access bathrooms and park benches at the city-owned facilities.
    - Camera installed on the Pullen Road rail bridge owned by the City of Raleigh to capture activity to the east down the corridor.
- Rocky Mount (35.92995, -77.80037)
    - Path between Henry Street and Dunn Street that passes through Thelonious S. Monk Park and across a railroad storage yard.
    - Camera installed on a utility pole located adjacent to the basketball court in Thelonious S. Monk Park. The camera detected activity at the path that crosses from Dunn Street through the park and across the tracks to the vicinity of Henry Street.
- Shelby (35.29779, -81.52864)
    - Path runs between a neighborhood and the nearby Eastside Kwik Stop. It crosses from Lincoln Street over the tracks to Airline Extension.
    - Camera installed in a privately-owned warehouse to the east of the path over the tracks. The camera detected activity at the path and to the west down the rail corridor.

3.1.2. Sampling Plan and Data Collection Schedule

The final video data collection dates are provided below in Exhibit 5. This table also provides the final video data collection dates for the study locations included in NCDOT RP 2017-15 whose events will be included in analyses for the NC rail network.

Based on the site selection results, the ITRE research team created a video data collection plan. The data collection plan was designed to be cost-effective and time-efficient relative to the testing of the camera equipment and the rotation of the equipment between several locations during the period of study. Two camera systems were deployed to collect data for at least one week of 24/7 data collection at each site in each season (Winter, Spring, Summer, Fall). Adequate time was budgeted between seasonal installs to allow time to evaluate the data and to troubleshoot the camera systems, if needed.

The total number of dates collected, coded, and used in the analyses across the 11 total study locations are provided in Exhibit 6. Data collected at a site in Charlotte in 2017 and 2018 were excluded from the analyses due to the impact of light rail track construction and associated fencing along the corridor which limited access to the railroad right-of-way. Data were also collected during an initial testing period in summer 2017 in Durham and Greensboro that utilized different camera placements and angles than the primary placements and angles used for the official data collection period. These data are not included in the analyses. Data from preliminary camera placements and fields of view at Elon and Gastonia were also removed from the analyses.

Latitude	Longitude	City	Season	Year	Data Collection Dates
35.26484	-80.88366	Charlotte	Winter	2019	Jan. 23 - Feb. 4
35.26484	-80.88366	Charlotte	Spring	2019	May 28 - Jun. 6; Jun. 24 - Jun. 30
35.26484	-80.88366	Charlotte	Summer	2019	Jul. 1 - Jul. 25
35.26484	-80.88366	Charlotte	Fall	2019	Oct. 1 - Oct. 11
35.99461	-78.90190	Durham	Fall	2017	Nov. 3 - Nov. 8; Nov. 30 - Dec. 8; Dec. 10
35.99461	-78.90190	Durham	Spring	2018	Apr. 2 - Apr. 11
35.99461	-78.90190	Durham	Spring	2019	Apr. 18 - Apr. 29
35.99461	-78.90190	Durham	Summer	2017	Aug. 10; Aug. 11; Aug. 21 - Aug. 28
35.99461	-78.90190	Durham	Summer	2018	Jul. 31 - Aug. 10
35.99461	-78.90190	Durham	Winter	2018	Jan. 6 - Jan. 15
36.10044	-79.50804	Elon	Fall	2017	Nov. 10 - Nov. 21
36.10044	-79.50804	Elon	Spring	2018	May 22 - May 31; Jun. 1 - Jun. 30
36.10044	-79.50804	Elon	Spring	2019	Apr. 1 - Apr. 8
36.10044	-79.50804	Elon	Summer	2018	Jul. 1 - Jul. 11; Aug. 20; Aug. 21; Aug. 27 - Sept. 4
36.10044	-79.50804	Elon	Winter	2018	Jan. 19 - Jan. 27; Jan. 30; Jan. 31; Feb. 1 - Feb. 6; Mar. 1 - Mar. 30
36.10044	-79.50804	Elon	Winter	2019	Mar. 22 - Mar. 31
35.26476	-81.19401	Gastonia	Winter	2019	Jan. 22 - Feb. 4; Feb. 26 - Mar. 11
35.26476	-81.19401	Gastonia	Spring	2019	May 29 - Jun. 6; Jun. 24 - Jun. 30
35.26476	-81.19401	Gastonia	Summer	2019	Jul. 1 - Jul. 25
35.26476	-81.19401	Gastonia	Fall	2019	Oct. 1 - Oct. 11
36.06946	-79.78339	Greensboro	Fall	2017	Nov. 2 - Nov. 8; Nov. 10; Nov. 30 - Dec. 8; Dec. 10
36.06946	-79.78339	Greensboro	Spring	2018	Jun. 11 - Jun. 30
36.06946	-79.78339	Greensboro	Summer	2017	Sept. 12 - Sept. 21
36.06946	-79.78339	Greensboro	Summer	2018	Jul. 1 - Jul. 11
36.06946	-79.78339	Greensboro	Winter	2018	Jan. 7 - Jan. 16
34.61783	-79.01216	Lumberton	Winter	2019	Feb. 5 - Feb. 14
34.61783	-79.01216	Lumberton	Spring	2019	May 14 - May 23
34.61783	-79.01216	Lumberton	Summer	2019	Jul. 29 - Aug. 16
34.61783	-79.01216	Lumberton	Fall	2019	Oct. 14 - Oct. 23
36.09700	-79.27110	Mebane	Fall	2017	Oct. 12 - Oct. 22; Nov. 11 - Nov. 21
36.09700	-79.27110	Mebane	Spring	2018	May 3 - May 11
36.09700	-79.27110	Mebane	Summer	2018	Jul. 11 - Jul. 20
36.09700	-79.27110	Mebane	Winter	2018	Jan. 16; Jan. 18 - Jan. 31; Feb. 1 - Feb. 7

Exhibit 5. Final Video Data Collection Results by Season with Dates

Latitude	Longitude	City	Season	Year	Data Collection Dates
35.78313	-78.66521	Raleigh	Winter	2020	Feb. 14 - Feb. 28
35.78313	-78.66521	Raleigh	Spring	2019	May 13 - May 23
35.78313	-78.66521	Raleigh	Summer	2019	Jul. 30 - Aug. 16
35.78313	-78.66521	Raleigh	Fall	2019	Oct. 14 - Oct. 23
35.92995	-77.80037	Rocky Mount	Winter	2019	Feb. 5 - Feb. 14
35.92995	-77.80037	Rocky Mount	Spring	2019	May 14 - May 23
35.92995	-77.80037	Rocky Mount	Summer	2019	Jul. 29 - Aug. 16
35.92995	-77.80037	Rocky Mount	Fall	2019	Oct. 14 - Oct. 23
35.66734	-80.46552	Salisbury	Fall	2017	Oct. 24 - Nov. 1
35.66734	-80.46552	Salisbury	Spring	2018	May 11 - May 22
35.66734	-80.46552	Salisbury	Summer	2018	Aug. 10 - Aug. 20
35.66734	-80.46552	Salisbury	Winter	2018	Feb. 9 - Feb 16
35.29779	-81.52864	Shelby	Winter	2019	Jan. 22 - Feb. 4
35.29779	-81.52864	Shelby	Spring	2019	May 28 - May 30; Jun. 24 - Jun. 30
35.29779	-81.52864	Shelby	Summer	2019	Jul. 1 - Jul. 24
35.29779	-81.52864	Shelby	Fall	2019	Oct. 1 - Oct. 11
Sites Not Included in Analyses					
35.25822	-80.77337	Charlotte	Fall	2017	Oct. 23 - Nov. 1; Dec. 11 - Dec. 20
35.25822	-80.77337	Charlotte	Winter	2018	Feb. 8 - Feb. 14
35.05320	-78.88600	Fayetteville	Winter	2019	Feb. 5 - Feb. 14
35.05320	-78.88600	Fayetteville	Spring	2019	This location was replaced by the Raleigh site due to low trespassing and high motor vehicle traffic interference at the Fayetteville site.
35.05320	-78.88600	Fayetteville	Summer	2019	
35.05320	-78.88600	Fayetteville	Fall	2019	

Exhibit 5. Final Video Data Collection Results by Season with Dates (Continued)

Site	Camera Position	Number of Dates Collected & Coded	Used in Analysis?
Charlotte	Camera Angle 1 - CATS Station	27	N
Charlotte	Camera Angle 1 - Church Parking Lot	66	Y
Durham	Camera Angle 1 - DPAC	57	Y
Durham	Camera Angle 2 - Parking Deck	9	N
Elon	Camera Angle 1 - Tree Between Tangent and Subway	12	N
Elon	Camera Angle 2 - Island Radar Pole	110	Y
Fayetteville	Camera Angle 1 - Light Pole	10	N
Gastonia	Camera Angle 1 - Crisis Center	14	N
Gastonia	Camera Angle 2 - Warehouse	14	Y
Gastonia	Camera Angle 3 - Mast Arm	52	Y
Greensboro	Camera Angle 1 - Plott Street Footpath	8	N
Greensboro	Camera Angle 2 - AWOL Fitness and Rail Station	69	Y
Lumberton	Camera Angle 1 - Power Pole	49	Y
Mebane	Camera Angle 1 - Island Radar Pole	61	Y
Raleigh	Camera Angle 1 - Pullen Bridge	54	Y
Rocky Mount	Camera Angle 1 - Light Pole	49	Y
Salisbury	Camera Angle 1 - Station Platform	40	Y
Shelby	Camera Angle 1 - Esther Warehouse	59	Y
	Grand Total	**760**	**680**

Exhibit 6. Number of Dates Collected and Coded by Site and Camera Position

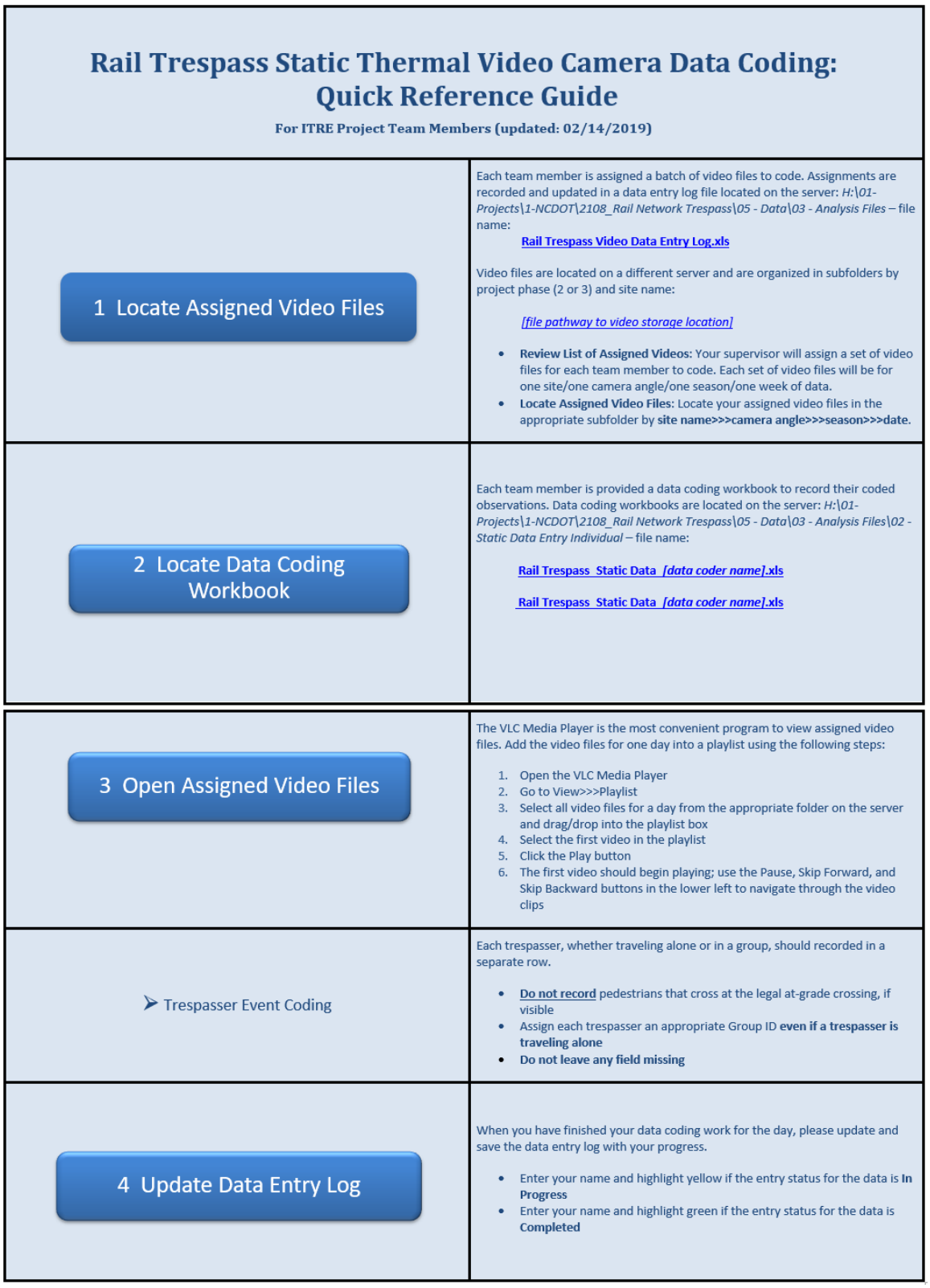
3.1.3. Data Reduction

3.1.3.1. Data Processing

Videos were downloaded from the static thermal detection systems by connecting the systems to a local computer with a hard wire and using AXIS Companion software at the end of each seasonal data collection period. The video clips were organized in folders on secure servers by date, season, and location. The video clips were also cataloged in an inventory file which documents and tracks the recording and data status.

3.1.3.2. Data Coding

Once the video clips were downloaded, organized, and cataloged, trained data coders manually reduced the videos into individual trespassing events and their associated characteristics in a data coding workbook using the protocols in Exhibit 7. For this research and data coding, a trespasser and qualifying trespassing event is defined as a human walking under their own will or assisted by another human entered the railroad right-of-way and moved along the ballast or crossed the tracks.



Rail Trespass Static Thermal Video Camera Data Coding: Quick Reference Guide

For ITRE Project Team Members (updated: 02/14/2019)

1 Locate Assigned Video Files

Each team member is assigned a batch of video files to code. Assignments are recorded and updated in a data entry log file located on the server: *H:\01-Projects\1-NCDOT\2108_Rail Network Trespass\05 - Data\03 - Analysis Files* – file name:

Rail Trespass Video Data Entry Log.xls

Video files are located on a different server and are organized in subfolders by project phase (2 or 3) and site name:

[file pathway to video storage location]

- **Review List of Assigned Videos**: Your supervisor will assign a set of video files for each team member to code. Each set of video files will be for one site/one camera angle/one season/one week of data.
- **Locate Assigned Video Files**: Locate your assigned video files in the appropriate subfolder by **site name>>>camera angle>>>season>>>date**.

2 Locate Data Coding Workbook

Each team member is provided a data coding workbook to record their coded observations. Data coding workbooks are located on the server: *H:\01-Projects\1-NCDOT\2108_Rail Network Trespass\05 - Data\03 - Analysis Files\02 - Static Data Entry Individual* – file name:

Rail Trespass_Static Data_*[data coder name]*.xls

Rail Trespass_Static Data_*[data coder name]*.xls

3 Open Assigned Video Files

The VLC Media Player is the most convenient program to view assigned video files. Add the video files for one day into a playlist using the following steps:

1. Open the VLC Media Player
2. Go to View>>>Playlist
3. Select all video files for a day from the appropriate folder on the server and drag/drop into the playlist box
4. Select the first video in the playlist
5. Click the Play button
6. The first video should begin playing; use the Pause, Skip Forward, and Skip Backward buttons in the lower left to navigate through the video clips

➢ Trespasser Event Coding

Each trespasser, whether traveling alone or in a group, should recorded in a separate row.

- **Do not record** pedestrians that cross at the legal at-grade crossing, if visible
- Assign each trespasser an appropriate Group ID **even if a trespasser is traveling alone**
- **Do not leave any field missing**

4 Update Data Entry Log

When you have finished your data coding work for the day, please update and save the data entry log with your progress.

- Enter your name and highlight yellow if the entry status for the data is **In Progress**
- Enter your name and highlight green if the entry status for the data is **Completed**

Exhibit 7. Data Coding Protocols for Rail Trespassing Events

Descriptions for the fields captured from the video clips are provided in Exhibit 8.

➢ Data Coding Field Descriptions

The data coding workbook contains the following fields to be captured from the video files:

Field Name	Field Description	Data Type
Site	Location name (Gastonia, Shelby, Charlotte, Raleigh, Rocky Mount, or Lumberton)	String
Camera Angle	1 or 2	Numeric
Date	Date of video (mm/dd/yyyy)	Date
Group (Y/N)	Is trespasser in a group? (Y/N)	String
Group ID	Numeric group ID beginning at 1 and continuous within site; every trespasser including single trespassers is assigned a group ID	Numeric
Enter ROW	Time that trespasser enters the railroad right-of-way (military time; hh:mm:ss)	Time
Enter Tracks	Time that trespasser enters the railroad tracks with boundary defined by the top of the rock bed (military time; hh:mm:ss)	Time
Exit Tracks	Time that trespasser exits the railroad tracks with boundary defined by the top of the rock bed (military time; hh:mm:ss)	Time
Train Arrival (If Applicable)	Time that train arrives (military time; hh:mm:ss); code NA if not applicable	Time
Exit ROW	Time that trespasser exits the railroad right-of-way (military time; hh:mm:ss)	Time
Activity	Trespasser activity coded as 1 (yes) or 0 (no); one or more may be applicable	Numeric
Direction Traveled	Direction that trespasser traveled coded as N (north), S (south), E (east), or W (west)	String
Crossed Tracks?	Did the trespasser cross the railroad tracks? (Y/N)	String
Travel Along Tracks?	Did the trespasser travel along the tracks? (Y/N)	
Notes	Record any additional information about the trespasser that may be useful for characterizing their activity	String

Exhibit 8. Data Coding Field Descriptions

3.2. Data Analysis

The analysis dataset was composed of the pedestrian trespassing events for the dates summarized previously in Exhibit 5. This dataset contained 15,570 records, with each record representing a single person who was recorded as being in the railroad right-of-way along or on the tracks within view of the thermal video camera system. The total number of events by site including the average number of events per date is provided in Exhibit 9. All sites except for Elon and Salisbury showed 90% or more observed dates with daily pedestrian trespassing events. For Elon, dates with no events correlated with Elon University's academic schedule. The dates included the Thanksgiving holiday, summer break, and spring break periods. For Salisbury, the site is near a passenger rail station which may dissuade overt trespassing within the area observed within view of the thermal camera system.

Latitude	Longitude	Site	Number of Events	Number of Dates with Events	Number of Dates with No Events	Total Dates	% of Dates with Events	Average Number of Events per Date
35.26484	-80.88366	Charlotte	525	65	1	66	98%	***8***
35.99461	-78.90190	Durham	1,104	67	2	69	97%	***16***
36.10044	-79.50804	Elon	4,638	111	28	139	80%	***42***
35.26476	-81.19401	Gastonia	396	62	4	66	94%	***6***
36.06946	-79.78339	Greensboro	2,912	69	0	69	100%	***42***
34.61783	-79.01216	Lumberton	875	45	4	49	92%	***18***
36.09700	-79.27110	Mebane	1,978	61	0	61	100%	***32***
35.78313	-78.66521	Raleigh	496	52	2	54	96%	***10***
35.92995	-77.80037	Rocky Mount	978	48	1	49	98%	***20***
35.66734	-80.46552	Salisbury	28	14	26	40	35%	***2***
35.29779	-81.52864	Shelby	1,640	58	1	59	98%	***28***
		Grand Total	**15,570**			**Average Number of Events per Day: 24**		

Exhibit 9. Total Number of Trespassing Events and Dates Observed by Site

3.2.1. Descriptive Summary

Most events across all sites (95%) involved crossing the tracks. Only 5% of events involved activity in the right-of-way without crossing the tracks, and 2% of events involved riding or carrying a bicycle. Over one third (35%) of people observed in the railroad right-of-way were traveling in a group with at least one other person. One percent of events across all sites included the presence of a train. The median amount of time on the tracks was 3 seconds. Most events involved walking along or through the railroad right-of-way. Very few events (<1%) involved sitting or lying on the tracks or elsewhere in the railroad right-of-way. Additional results by site are shown in Exhibits 10 and 11. Summaries by month of year, day of week, and hour of day are provided in Appendix B.

Site	In Group (Two or More) (n)	Alone (n)	In Group (%)	Cross Tracks Only (n)	Along Tracks Only (n)	Both (n)	Cross Tracks Only (%)	Along Tracks Only (%)	Both (%)	Ride or Carry Bike (n)	All Others (n)	Ride or Carry Bike (%)
Charlotte	130	395	25%	434	67	10	85%	13%	2%	0	525	0%
Durham	373	731	34%	889	149	23	84%	14%	2%	4	1,100	<1%
Elon	2,675	1,963	58%	4,564	18	33	99%	<1%	1%	5	4,633	<1%
Gastonia	74	322	19%	307	39	39	80%	10%	10%	1	395	<1%
Greensboro	590	2,322	20%	2,813	25	28	98%	1%	1%	152	2,760	5%
Lumberton	221	654	25%	537	233	99	62%	27%	11%	91	784	10%
Mebane	446	1,532	23%	1,916	5	25	98%	<1%	1%	26	1,952	1%
Raleigh	250	246	50%	262	154	23	60%	35%	5%	18	478	4%
Rocky Mount	194	784	20%	923	13	12	97%	1%	1%	56	922	6%
Salisbury	21	7	75%	11	16	0	41%	59%	0%	0	28	0%
Shelby	531	1,109	32%	1,572	35	27	96%	2%	2%	21	1,619	1%
		Overall	**35%**			**Overall**	**93%**	**5%**	**2%**		**Overall**	**2%**

Exhibit 10. Summary of Trespassing Activity by Site

Site	Median Time on Tracks (Seconds)	Maximum Time on Tracks (Seconds)	Minimum Time on Tracks (Seconds)	Number of Events with Arriving Train	% of Events with Arriving Train	Distance (Feet)* and Description** to Authorized Crossing
Charlotte	6	46	1	24	5%	241' to S. Hoskins Rd. at-grade crossing
Durham	2	270	1	6	1%	165' to Blackwell St. at-grade crossing
Elon	2	604	1	28	1%	390' to S. Williamson Ave. at-grade crossing
Gastonia	8	222	2	9	2%	343' to N. Trenton St. at-grade crossing
Greensboro	8	1,641	1	40	1%	703' to Washington St. at-grade crossing
Lumberton	6	731	1	11	1%	808' to MLK Jr. Dr. at-grade crossing
Mebane	2	474	1	11	1%	398' to N. Third St. at-grade crossing
Raleigh	12	1,296	2	22	4%	726' linear, 854' reasonable walking path through the perimeter of Pullen Park to Pullen Rd. separated crossing**
Rocky Mount	2	333	1	9	1%	1504' linear, 1700' reasonable walking path via Washington St. to Bennett St. at-grade crossing**
Salisbury	30	165	3	0	0%	420' north to E. Kerr St. at-grade crossing or 420' south to E. Council St. at-grade crossing
Shelby	3	602	1	4	<1%	176' to E. Lineberger St. at-grade crossing
Overall	**3**	**1,641**	**1**	**164**	**1%**	

*Distances measured with Google Maps distance tool from the camera location to the edge of pavement on the nearest at-grade crossing.
**Rocky Mount and Raleigh measurements include a linear distance from the known trespass path to the nearest authorized crossing and a distance for a reasonable safe walking route to the nearest authorized crossing.

Exhibit 11. Summary of Trespassing Event Duration by Site with Distance to Nearest Authorized Railroad Crossing

The research team hypothesized that most trespassing events captured at the observation locations are the result of people trying to reach their destinations through the shortest, most direct route. The thermal video camera systems captured people traveling alone, in pairs, and in groups, adults and children, people carrying bags and bikes, walking dogs, and pushing strollers. Most people moved quickly through the right-of-way, some lingered, very few stood around or sat on or near the tracks.

From our preliminary analyses completed for NCDOT RP 2017-15, the Elon site was recognized as the most different from the other sites included in the sample on the Piedmont corridor. This site is also an outlier amongst the total sample of sites that includes the wider rail network in North Carolina. The Elon site is located near Elon University, a mid-sized private university with an undergraduate enrollment of around 6,000 students in a town of less than 10,000 people. This site experiences the most extreme variation between months and the highest average number of trespassing events per day which typically ramp up on the weekend during months when the university is in session. There is a clear decrease in activity during the summer months when the university is not in session. The sharp increase in events in February (an average of 145 trespassing events per day in 2018) can be correlated with university athletic schedules during basketball season when large gatherings occur before and after games. Most events happened late at night into the early morning hours, and people regularly climbed the fencing on the north side of the tracks to cross, just a few hundred feet from a designated crossing. People continued to climb the fencing in the months after it was converted from 3' to 6' foot fencing in the summer of 2018, with over 50% of the 118 trespassing events captured on 8/31/2018 (the Friday after

classes began) involving fence climbing. However, thermal video captured in the spring of 2019 showed a sharp decline in trespassing events at the location indicating that the enhanced fencing was working as a deterrent. This Elon site is also unique because student housing and a student community center are located directly adjacent to the tracks and restaurants and shops are nearby. The grassy right-of-way appears to be used as a gathering place.

In further analyses and exploratory modeling, the Elon site is treated as an outlier. Analyses are conducted with all eleven sites and with the subset of sites that excludes Elon to account for the extreme differences in daily and seasonal volumes at the location compared to all other sites.

3.2.2. Exploratory Modeling

Additional analyses were conducted to explore the variability in pedestrian trespassing frequency between and across observation sites. For each record, a set of variables were attributed to the trespassing event records for use in the analysis as provided in Appendix C. These variables were derived from the following data sources:

1. Railroad crossing inventory data: Railroad crossing locations and their attributes were obtained from the NCDOT State Authoritative Rail and Highway (SARAH) database including the USDOT Crossing Inventory Number, train movement volumes and speeds at the crossing, and type(s) of train service at the crossing. These data were attributed based on the at-grade or separated crossing closest to an observation site. The distance from the edge of pavement on the nearest at-grade or separated crossing to the observation site was calculated using the distance tool in Google Maps. The data were provided by the NCDOT Rail Division in September 2019.
2. Historic climate data: Daily precipitation, minimum daily temperature, and maximum daily temperature were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) Global Historical Climatology Network (GHCN). This database is a composite of climate records from numerous sources that were merged and quality assured. Data were collected from the nearest GHCN stations with complete data for the observation periods.
3. Business location data: Business point locations in North Carolina were obtained through the Environmental Systems Research Institute's (ESRI) Business Analyst software and were queried by North American Industry Classification System (NAICS) code to obtain a near census of locations for certain place types that were hypothesized to correlate with trespassing activity. These data were used to calculate density measures based on the number of businesses by type located in U.S. Census tracts within one mile of an observation site. The density measures are population-based and were calculated by dividing the number of locations by the U.S. Census tract population within one mile of an observation site and multiplying by 1,000 to generate the density of places by type per 1,000 residents. A breakdown of how businesses were classified into groupings for the analyses based on NAICS codes is provided in Appendix D.
4. Population data: Population data were obtained from the 2018 American Community Survey (ACS) 5-Year Estimates. These data are at the U.S. Census tract level and include total population, race, Hispanic or Latino origin, means of transportation to work, median household income, and educational attainment.

3.2.2.1. Variability in Trespassing Events – All Sites and Subset of Sites

Data analyses were performed to determine the variability in pedestrian trespassing frequency across the observation sites. Variability in the total trespassing events per date for all sites were analyzed using analysis of variance (ANOVA) to identify which variables could potentially be used to forecast pedestrian trespassing on the North Carolina rail network. This preliminary testing aids in showing the feasibility of

forecasting pedestrian trespassing given the random variation in the data. Each daily total for each site was treated as a single observation with no adjustments made to the dataset.

The ANOVA results show that when a site was defined as the location where pedestrian trespassing events were observed, the Site variable explained a portion (18.1%) of all variation in the total daily events. The Site variable was established as a block in the ANOVA so that the influence of other variables could be detected while controlling for the variation across sites. With the Site variable as a block and including the Month and Year variables as main effects along with the interaction effect of the Month variable crossed with the Year variable, the model explained 21.9% of all variation in the total daily events, while adding Day as a main effect increased the explained variation to 22.7%.

When the Site variable was removed as an independent variable, a similar amount of variation in the total daily events could be explained compared to when the Site variable was included. Exhibit 12 shows that population and business density variables could explain some variation in the total daily events where the Site variable was excluded from the model. A model that only includes the Site and temporal variables explains a comparable amount of the variation in the total daily events. This finding indicates that there is considerable amount of variation in the total daily events between the sites that is not accounted for in the ANOVA.

Variables	% Variation Explained	Discussion
Site	18.1%	Some of the variation in total daily events can be explained by the Site variable and temporal variables. Population and business density variables can partially replace the Site variable.
Site, Month	18.5%	
Site, Month, Year, Month*Year	21.9%	
Site, Month, Year, Month*Year, Day	22.7%	
Month, Year, Month*Year, Race – Percent Black Only, Race – Percent White Only, Ethnicity – Percent Hispanic or Latino Origin, Educational Attainment – Percent High School or Higher, Means of Transport to Work – Percent No Vehicle / Walk to Work	19.5%	
Month, Year, Month*Year, Business Density – Low-Income Housing, Business Density – Restaurants and Other Eating Places, Business Density – Retail Food Products and Grocers / Convenience Stores, Business Density – Schools, Business Density – Universities, Colleges, and Professional Schools, Business Density – Social Services	16.6%	
Month, Year, Month*Year, Race – Percent Black Only, Race – Percent White Only, Ethnicity – Percent Hispanic or Latino Origin, Educational Attainment – Percent High School or Higher, Means of Transport to Work – Percent No Vehicle / Walk to Work, Business Density – Low-Income Housing, Business Density – Restaurants and Other Eating Places, Business Density – Retail Food Products and Grocers / Convenience Stores, Business Density – Schools, Business Density – Universities, Colleges, and Professional Schools, Business Density – Social Services	21.9%	

Exhibit 12: Variation in Total Daily Events According to ANOVA Results for All Sites

The effect of month and year were statistically significant at $p<0.05$ in relation to variation in the total daily events when controlling only for the Site variable. Exhibit 13 provides the average number of events per day and their 95% confidence intervals by month. Exhibit 15 provides the average number of events per month and their 95% confidence intervals by day of week (1 = Sunday). It is important to note the extreme variability in number of events per day within March, February, September,

November, and December and for Friday and Saturday as reflected in the wide 95% confidence intervals for these months and days of week.

To determine the impact of the Elon site on the overall distribution and variation in total daily events across all sites, the data were subset into Elon events and events at all other sites (10 total comprised of 10,932 records). The research team hypothesized that the activity at the Elon site associated with nearby Elon University was not representative of typical trespassing activity as captured at the other sites in the sample. Exhibit 14 shows the average number of events per day and their 95% confidence intervals by month comparing Elon to all other sites, while Exhibit 16 shows the average number of events per day and their 95% confidence intervals by day of week comparing Elon to all other sites (1 = Sunday). The charts indicate that the extreme variability in number of events per day within March, February, September, November, and December and for Friday and Saturday shown across all sites in Exhibits 13 and 15 can be accounted for by Elon, and that for the other ten sites in the sample most trespassing activity occurred during daylight hours and volumes were generally consistent across the days of the week and month to month. Considering all data collection dates, 52% of trespassing events at the Elon site occur from 9pm to 2am (compared to 14% at the Greensboro site, 9% at the Mebane site, 17% at the Durham site, and 25% at the Salisbury site). Exhibit 17 shows the average proportion of trespassing events by hour of day and their 95% confidence intervals for all sites and all dates. Exhibit 18 shows the average proportion of trespassing events by hour of day and their 95% confidence intervals comparing Elon to all other sites to highlight its concentration of trespassing activity in the late night and early morning hours.

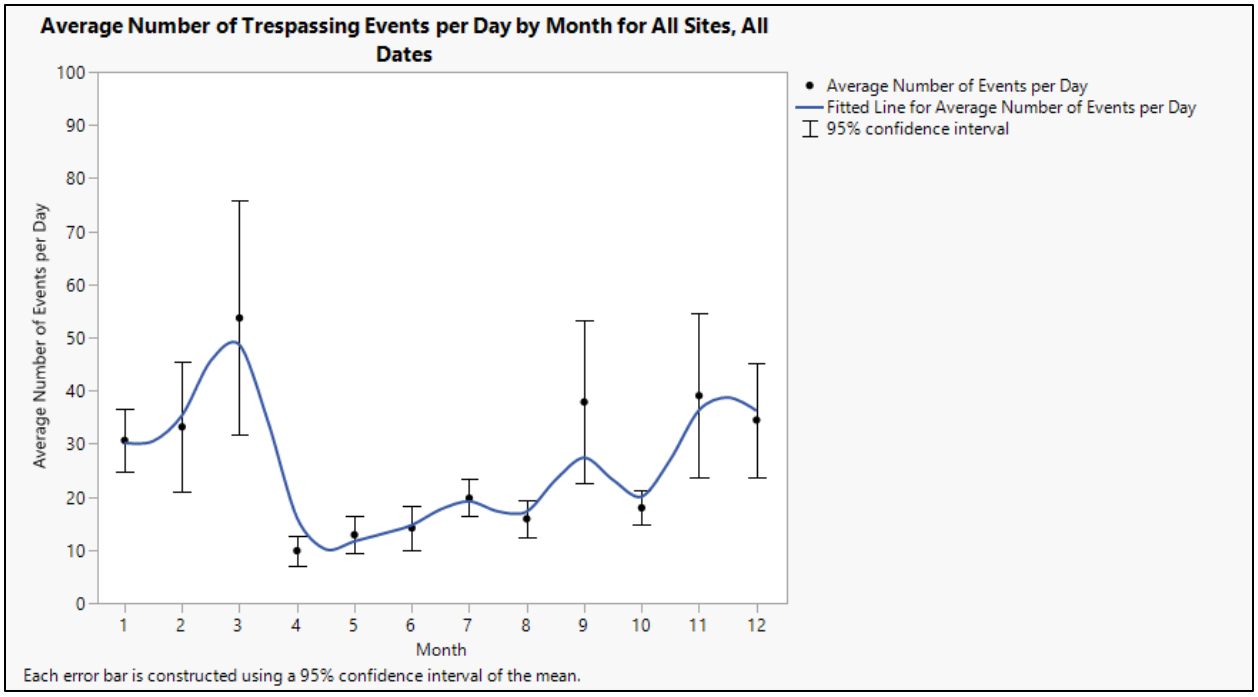


Exhibit 13: Average Number of Trespassing Events per Day by Month for All Sites, All Dates

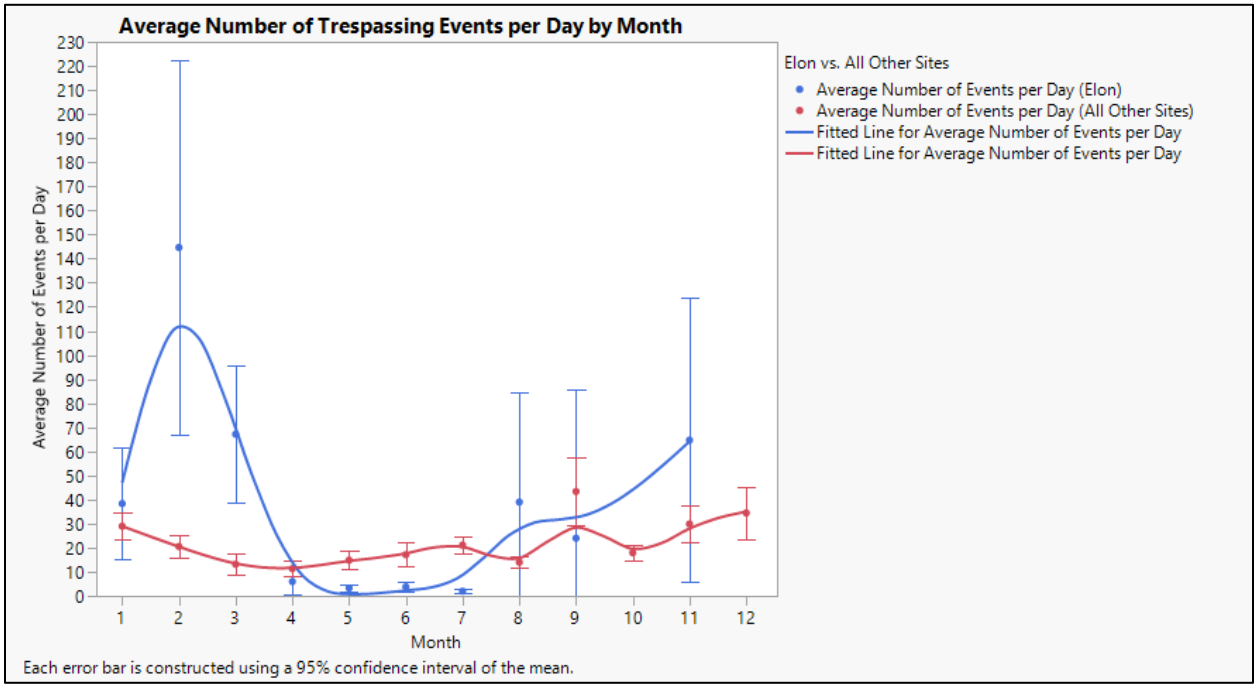


Exhibit 14: Average Number of Trespassing Events per Day by Month, Elon vs. All Other Sites

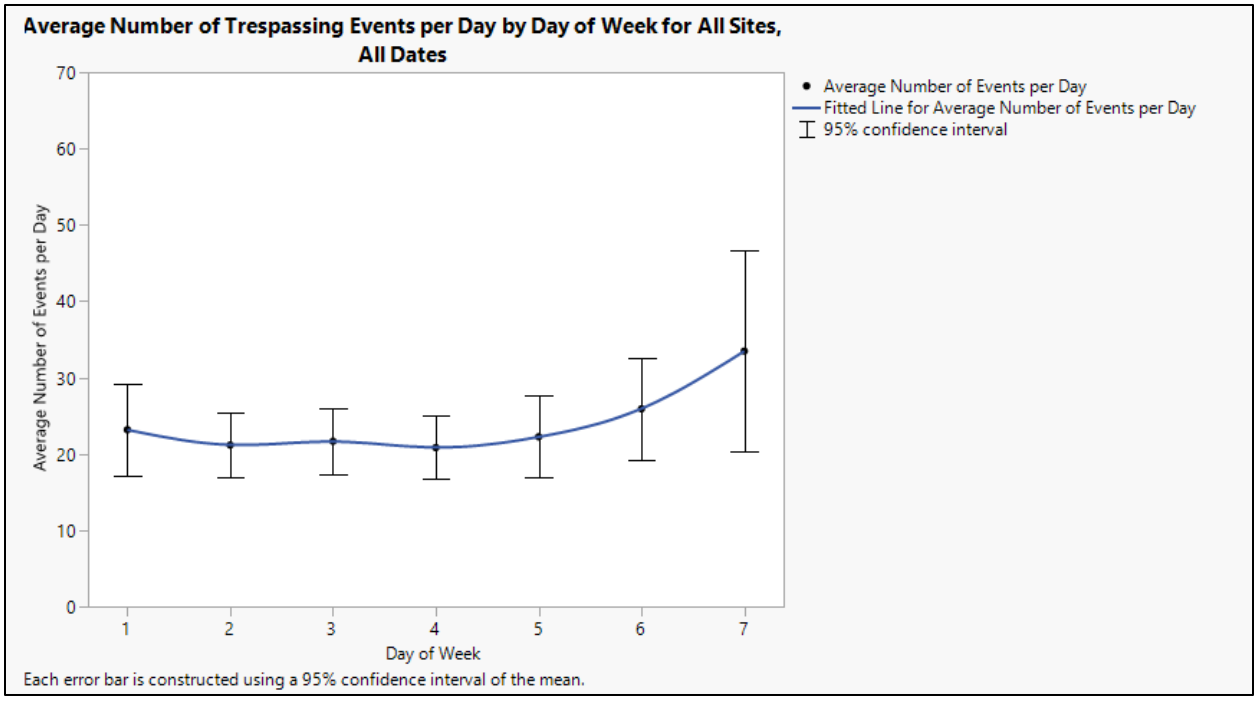


Exhibit 15: Average Number of Trespassing Events per Day by Day of Week for All Sites, All Dates

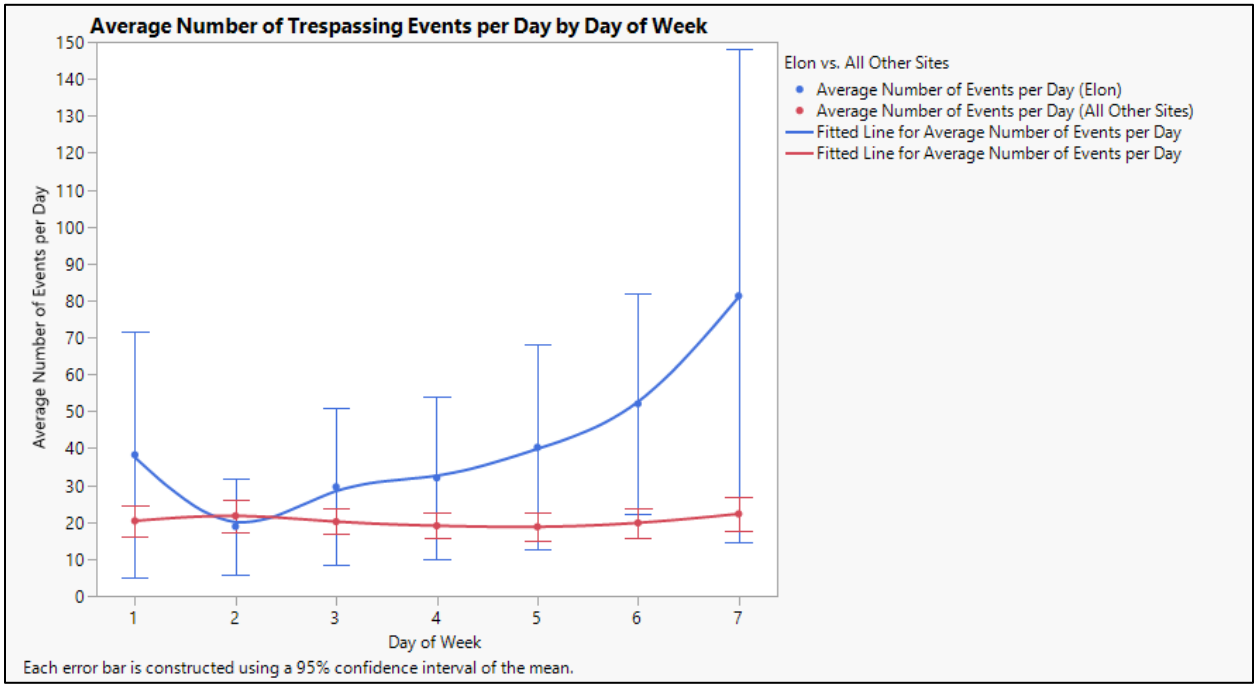


Exhibit 16: Average Number of Trespassing Events per Day by Day of Week, Elon vs. All Other Sites

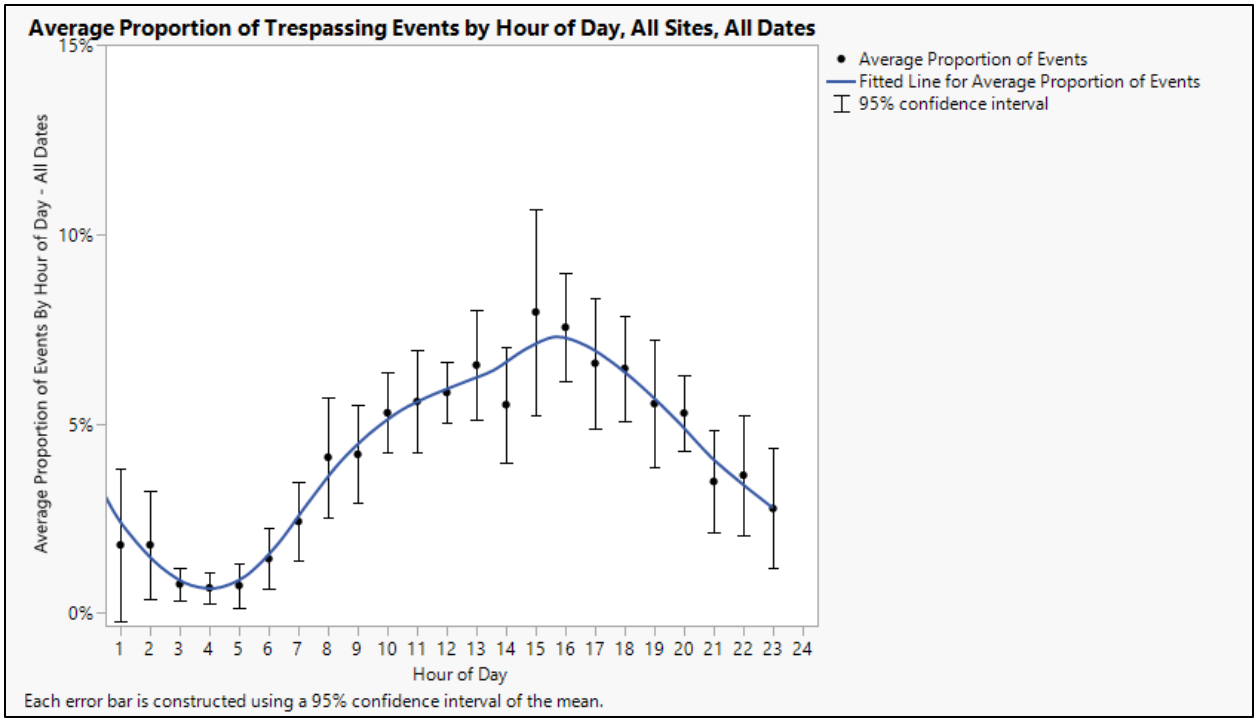


Exhibit 17: Average Proportion of Trespassing Events by Hour of Day for All Sites, All Dates

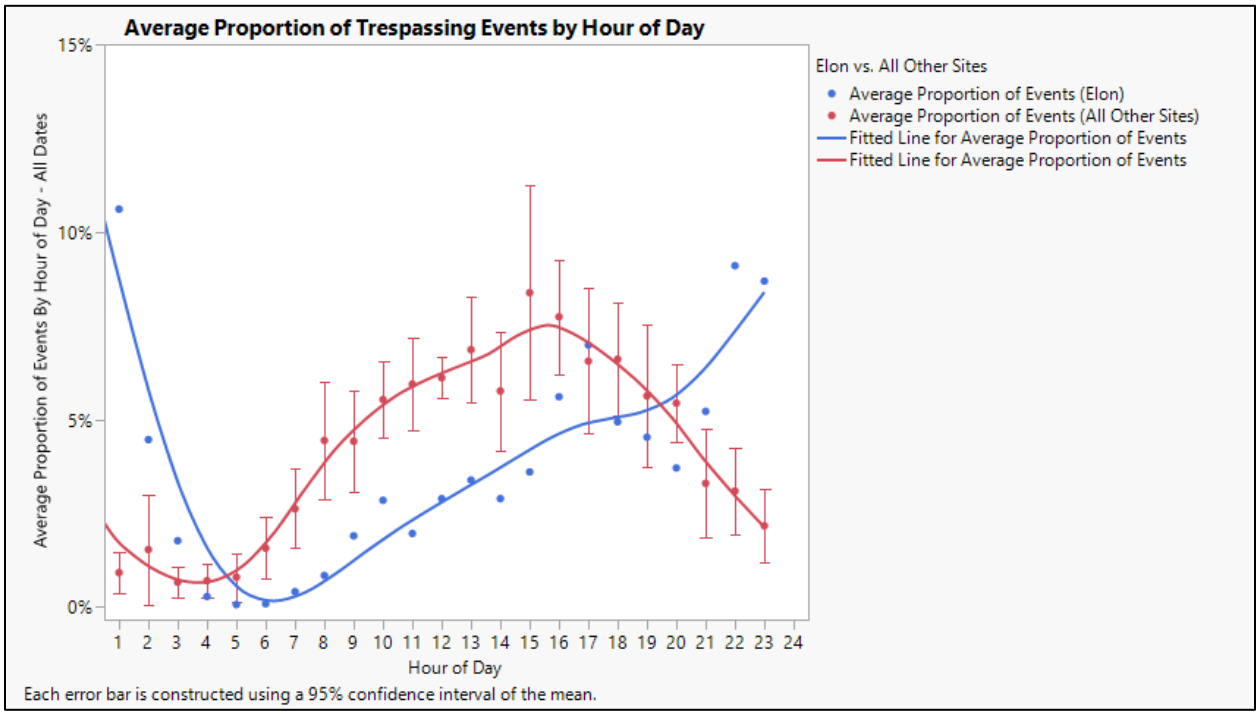


Exhibit 18: Average Proportion of Trespassing Events by Hour of Day, Elon vs. All Other Sites

From an evaluation of the 2018 American Community Survey (ACS) 5-Year Estimates at the U.S. Census tract level including total population, race, Hispanic or Latino origin, means of transportation to work, median household income, and educational attainment, Elon differs from the other sites in the sample due to its lower percentage of Black and Hispanic or Latino residents, higher percentage of White residents, higher percentage of residents with no access to a vehicle who walk to work, and higher average median household income for U.S. Census tracts within one mile of the observation location (Exhibit 19).

Site	U.S. Census Tracts Within One Mile of the Site									
	Population per Square Mile	Percent Black Only	Percent White Only	Percent Hispanic or Latino Origin	Percent No Vehicle	Percent Walk to Work	Percent No Vehicle / Walk to Work	Average Median Household Income	Percent High School Only	Percent High School or Higher
Charlotte	2,181	71%	17%	8%	6%	1%	13%	$35,989	28%	77%
Durham	3,583	43%	46%	17%	9%	4%	3%	$41,457	19%	79%
Elon	**1,094**	**9%**	**86%**	**7%**	**1%**	**3%**	**58%**	**$65,453**	**19%**	**92%**
Gastonia	1,588	38%	56%	10%	4%	2%	8%	$34,639	32%	79%
Greensboro	3,975	65%	28%	5%	7%	5%	11%	$32,801	27%	84%
Lumberton	673	41%	37%	8%	6%	1%	6%	$30,373	34%	76%
Mebane	1,024	22%	71%	8%	1%	2%	35%	$50,288	23%	91%
Raleigh	4,790	16%	72%	4%	6%	6%	13%	$45,992	11%	93%
Rocky Mount	901	76%	21%	1%	3%	1%	0%	$33,521	38%	78%
Salisbury	1,072	43%	52%	8%	5%	2%	22%	$40,515	29%	86%
Shelby	538	38%	60%	2%	7%	2%	25%	$32,895	32%	82%

Exhibit 19: 2018 ACS 5-Year Estimates for U.S. Census Tracts within One Mile of Each Site

A summary of the correlation results for the 10-site subset in relation to all sites is provided in Exhibit 20.

Explanatory Variables	All Sites (11 total – 15,570 events, 652 daily totals)	Subset of Sites (10 total – 10,932 events, 541 daily totals)
	Daily Totals – Trespassing Events	
Month	-0.0873**	0.0197
Year	-0.2900***	-0.4044***
Day	0.0874**	-0.0009
Population Density	-0.0701*	0.0092
Race – Percent Black Only	-0.1262**	0.0770*
Race – Percent White Only	0.1570***	-0.0185
Ethnicity – Percent Hispanic or Latino Origin	-0.1223**	-0.2193***
Average Median Household Income	0.2116***	-0.0403
Educational Attainment – Percent High School or Higher	0.2266***	0.2057***
Means of Transport to Work – Percent No Vehicle / Walk to Work	0.2811***	0.2544***
Business Density – Drinking Places	-0.1081**	-0.0486
Business Density – Off-Premises Alcohol Outlets	-0.1328***	-0.0603
Business Density – Low-Income Housing	0.0028	0.2330***
Business Density – Restaurants and Other Eating Places	0.0288	0.2343***
Business Density – Retail Food Products and Grocers / Convenience Stores	-0.2582***	-0.2310***
Business Density – Schools	-0.0318	0.2632***
Business Density – Universities, Colleges, and Professional Schools	-0.0016	0.1035**
Business Density – Social Services	-0.0651*	0.1725***

**Significance level: p<0.10; **Significance level: p<0.05; ***Significance level: p<0.001*

Exhibit 20: Pairwise Pearson's Correlation Coefficient Results for All Sites and Subset of Sites

The same variables were considered in relation to variation in the total daily events for the site subset as with the complete analysis dataset. The results are provided in Exhibit 21. The ANOVA results show that when a site was defined as the location where pedestrian trespassing events were observed, the Site variable explained much (48.9%) of the variation in the total daily events. With the Site variable as a block and including the Month and Year variables as main effects along with the interaction effect of the Month variable crossed with the Year variable, the model explained slightly more variation in the total daily events (50.1%), while adding Day as a main effect did not increase the explained variation.

When the Site variable was removed as an independent variable, a similar amount of variation in the total daily events could be explained compared to when the Site variable was included. However, population and business density variables explain a greater portion of variation in the total daily events for the subset of sites compared to when the Elon site is included in the analysis. Exhibit 21 shows that the population and business density variables could explain half (50.1%) of the variation in the total daily events where the Site variable was excluded from the model. A model that only includes the Site and temporal variables explains the same amount of the variation in the total daily events. This finding indicates that a considerable amount of variation in the total daily events for the 10 sites included in the analysis can be explained by the variables included in the ANOVA.

The results of the two sets of ANOVA tests indicate that the single best predictor of the total daily pedestrian trespassing events was the Site variable. This variable accounted for most of the variation in the total daily events for the subset of sites where Elon was removed as an outlier. The results also suggest that other variables may explain the variation in the total daily events to a lesser extent, and that it may be possible to develop a measure that incorporates population and business density data to use as a predictor for pedestrian trespassing activity along railroad right-of-ways in North Carolina.

Variables	% Variation Explained	Discussion
Site	48.9%	Most of the variation in total daily events can be explained by the Site variable and temporal variables. Population and business density variables can partially replace the Site variable.
Site, Month	49.0%	
Site, Month, Year, Month*Year	50.1%	
Site, Month, Year, Month*Year, Day	50.1%	
Month, Year, Month*Year, Race – Percent Black Only, Race – Percent White Only, Ethnicity – Percent Hispanic or Latino Origin, Educational Attainment – Percent High School or Higher, Means of Transport to Work – Percent No Vehicle / Walk to Work	36.0%	
Month, Year, Month*Year, Business Density – Low-Income Housing, Business Density – Restaurants and Other Eating Places, Business Density – Retail Food Products and Grocers / Convenience Stores, Business Density – Schools, Business Density – Universities, Colleges, and Professional Schools, Business Density – Social Services	39.4%	
Month, Year, Month*Year, Race – Percent Black Only, Race – Percent White Only, Ethnicity – Percent Hispanic or Latino Origin, Educational Attainment – Percent High School or Higher, Means of Transport to Work – Percent No Vehicle / Walk to Work, Business Density – Low-Income Housing, Business Density – Restaurants and Other Eating Places, Business Density – Retail Food Products and Grocers / Convenience Stores, Business Density – Schools, Business Density – Universities, Colleges, and Professional Schools, Business Density – Social Services	50.1%	

Exhibit 21: Variation in Total Daily Events According to ANOVA Results for 10 Site Subset

3.2.2.2. Development of Exploratory Models to Forecast Daily Trespassing Events

The data for all sites except Elon were used for exploratory modeling. The explanatory variables that were considered in the model development are summarized in Exhibit 22 and were derived from the data sources described in Appendix C and chosen based on the correlation and ANOVA analyses results.

Variable	Definition
Race – Percent Black Only	Percent Black only for U.S. Census tracts within one mile of the observation location (2018 American Community Survey (ACS) 5-Year Estimates, Table B02001: Race)
Ethnicity – Percent Hispanic or Latino Origin	Percent Hispanic or Latino origin for U.S. Census tracts within one mile of the observation location (2018 American Community Survey (ACS) 5-Year Estimates, Table B03003: Hispanic or Latino Origin)
Educational Attainment – Percent High School or Higher	Percent High School or higher for U.S. Census tracts within one mile of the observation location (2018 American Community Survey (ACS) 5-Year Estimates, Table S1501: Educational Attainment)
Means of Transport to Work – Percent No Vehicle / Walk to Work	Percent no vehicle and walk to work as means of transportation to work for U.S. Census tracts within one mile of the observation location (2018 American Community Survey (ACS) 5-Year Estimates, Table B08141: Means of Transportation to Work by Vehicles Available)
Business Density – Low-Income Housing	Number of low-income housing per 1,000 people for U.S. Census tracts within one mile of the observation location (2019 US Business Locations [ESRI product licensed from Infogroup])
Business Density – Restaurants and Other Eating Places	Number of restaurants and other eating places per 1,000 people for U.S. Census tracts within one mile of the observation location (2019 US Business Locations [ESRI product licensed from Infogroup])
Business Density – Retail Food Products and Grocers / Convenience Stores	Number of grocers and convenience stores per 1,000 people for U.S. Census tracts within one mile of the observation location (2019 US Business Locations [ESRI product licensed from Infogroup])
Business Density – Schools	Number of schools per 1,000 people for U.S. Census tracts within one mile of the observation location (2019 US Business Locations [ESRI product licensed from Infogroup])
Business Density – Universities, Colleges, and Professional Schools	Number of universities, colleges, and professional schools per 1,000 people for U.S. Census tracts within one mile of the observation location (2019 US Business Locations [ESRI product licensed from Infogroup])
Business Density – Social Services	Number of social services per 1,000 people for U.S. Census tracts within one mile of the observation location (2019 US Business Locations [ESRI product licensed from Infogroup])

Exhibit 22. Variables Included in Exploratory Model Development

Using the data from the subset of ten sites (Charlotte, Durham, Gastonia, Greensboro, Lumberton, Mebane, Raleigh, Rocky Mount, Salisbury, and Shelby), a linear regression model was developed to model total daily pedestrian trespassing events as a function of the variables described in Exhibit 22. Pairwise Pearson's Correlation Coefficient results were evaluated for the explanatory variables to assess multicollinearity. Variables that were statistically significantly correlated at $p<0.05$ with a correlation coefficient of 0.50 or greater were not included together in the same model.

Model building began by entering all variables into the linear regression model. Then variables that were not statistically significant were removed one at a time until only variables that were statistically significant at p<0.05 remained.

Model 1 is provided in the following equation:

$$\begin{aligned} &Estimated\ Total\ Daily\ Events \\ &= 61.25(Percent\ Black\ Only) + 38.32(Business\ Density{:}\ Low\ Income\ Housing) \\ &+ 11.15(Business\ Density{:}\ Restaurants\ and\ Other\ Eating\ Places) \\ &- 10.14(Business\ Density{:}\ Retail\ Food\ Products\ \&\ Grocers\ and\ Convenience\ Stores) - 32.80 \end{aligned}$$

Where,

Percent Black Only = percent Black only for U.S. Census tracts within one mile of the observation location

Business Density: Low-Income Housing = number of low-income housing per 1,000 people for U.S. Census tracts within one mile of the observation location

Business Density: Restaurants and Other Eating Places = number of restaurants and other eating places per 1,000 people for U.S. Census tracts within one mile of the observation location

Business Density: Retail Food Products & Grocers and Convenience Stores = number of grocers and convenience stores per 1,000 people for U.S. Census tracts within one mile of the observation location

All terms represent variables that were statistically significant at p<0.001. 31% of the variation was explained (adjusted R-square value was 0.3062).

Model 2 is provided in the following equation:

$$\begin{aligned} &Estimated\ Total\ Daily\ Events \\ &= -58.17(Percent\ Hispanic\ or\ Latino\ Origin) + 39.17(Percent\ No\ Vehicle\ and\ Walk\ to\ Work) \\ &+ 73.48(Business\ Density{:}\ Low\ Income\ Housing) \\ &- 20.00(Business\ Density{:}\ Retail\ Food\ Products\ \&\ Grocers\ and\ Convenience\ Stores) + 30.75 \end{aligned}$$

Where,

Percent Hispanic or Latino Origin = percent Hispanic or Latino origin for U.S. Census tracts within one mile of the observation location

Percent No Vehicle and Walk to Work = percent no vehicle and walk to work as means of transportation to work for U.S. Census tracts within one mile of the observation location

Business Density: Low-Income Housing = number of low-income housing per 1,000 people for U.S. Census tracts within one mile of the observation location

Business Density: Retail Food Products & Grocers and Convenience Stores = number of grocers and convenience stores per 1,000 people for U.S. Census tracts within one mile of the observation location

All terms represent variables that were statistically significant at p<0.001. 24% of the variation was explained (adjusted R-square value was 0.2442).

Model 3 is provided in the following equation:

$$\begin{aligned} &Estimated\ Total\ Daily\ Events \\ &= 55.84(Percent\ No\ Vehicle\ and\ Walk\ to\ Work) \\ &+ 63.03(Business\ Density{:}\ Low\ Income\ Housing) \\ &- 26.69(Business\ Density{:}\ Retail\ Food\ Products\ \&\ Grocers\ and\ Convenience\ Stores) \\ &+ 7.05(Business\ Density{:} Social\ Services) + 20.98 \end{aligned}$$

Where,

Percent No Vehicle and Walk to Work = percent no vehicle and walk to work as means of transportation to work for U.S. Census tracts within one mile of the observation location

Business Density: Low-Income Housing = number of low-income housing per 1,000 people for U.S. Census tracts within one mile of the observation location

Business Density: Retail Food Products & Grocers and Convenience Stores = number of grocers and convenience stores per 1,000 people for U.S. Census tracts within one mile of the observation location

Business Density: Social Services = Number of social services per 1,000 people for U.S. Census tracts within one mile of the observation location

All terms represent variables that were statistically significant at $p<0.001$. 30% of the variation was explained (adjusted R-square value was 0.3011).

As previously discussed, the ANOVA for all sites and the subset of sites indicated that the site variable was the strongest predictor of the total daily pedestrian trespassing events. Models 1 through 3 indicate that population and business density variables can account for some but not most of the variation in the total daily events between the sites.

Exhibit 23 shows the overall modeling results that compare the observed average total daily events alongside the predicted average total daily events for Models 1-3. Based on an evaluation of the model residuals (the difference between the observed and the predicted values), Model 3 more closely estimates the average total daily events across all sites compared to the other two models. Appendix F provides a summary of the residual results by site and overall. It should be noted that the models were specified based on excluding Elon and its observations, but they were applied to the data from Elon to determine how well they predicted the average total daily events at the site.

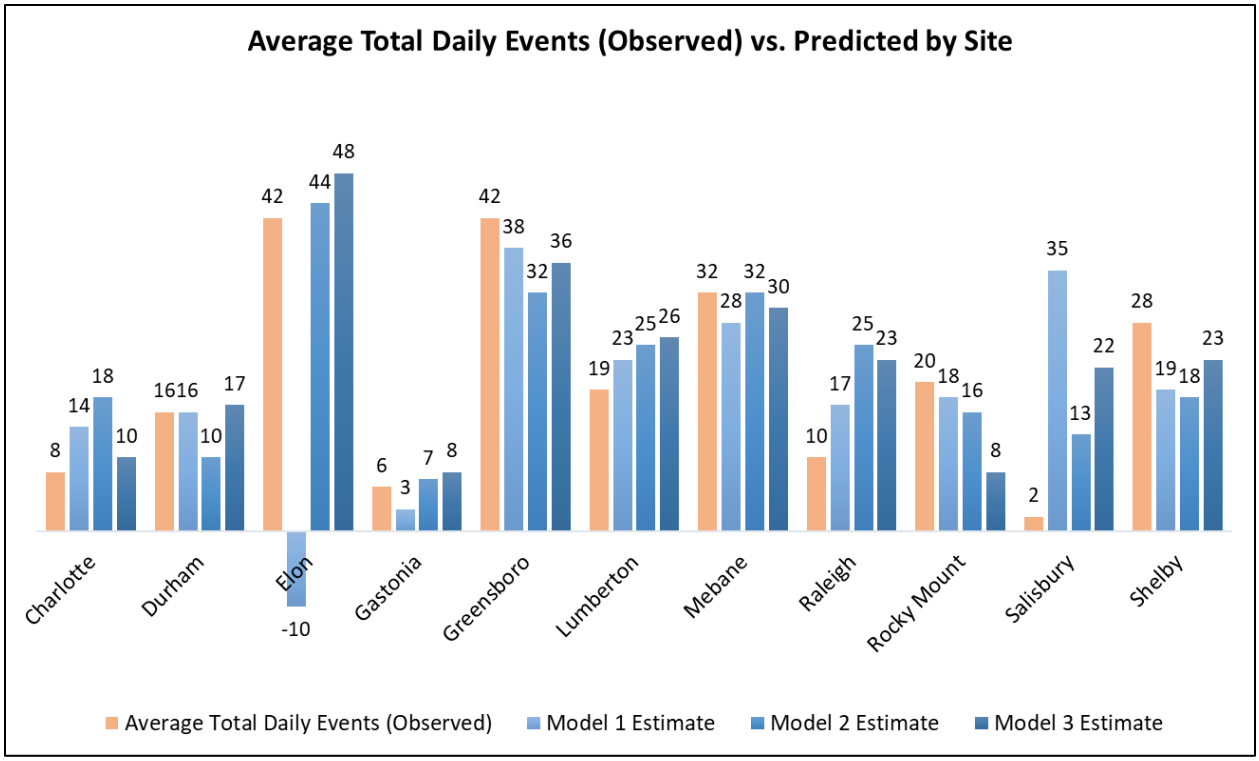


Exhibit 23. Average Total Daily Events (Observed) vs. Predicted by Site

4. DISCUSSION AND CONCLUSIONS

This study at six pedestrian trespassing hot spots on the wider rail network in North Carolina further supports key preliminary findings from NCDOT RP 2017-15 that were based on observations from five locations along the Piedmont corridor from Raleigh to Charlotte. These findings include:

- The magnitude of trespassing at hot spots along the corridor and the wider rail network is much greater than indicated by FRA incident reporting and Amtrak train crew surveys.
- Most trespassing events are short in duration and involve crossing the tracks rather than movement along the right-of-way.
- Variability in time-of-day/day-of-week/month-of-year patterns appear to be influenced by local environmental and population factors, such as the case of the Elon site where university academic and athletic schedules appear correlated with trespassing activity.
    - For all sites in the sample except for Elon, most trespassing activity occurred during daylight hours and volumes were generally consistent across the days of the week and month to month.
- The profile of the average trespasser represented in the event-based data may not be consistent with the profile as defined with FRA incident data, particularly when analyzed at the local level rather than as a regional or state level aggregate.
    - Based on a national study of the characteristics of those killed in railroad trespasser incidents conducted for the FRA in 2013, the average age at death was 38 with two thirds of decedents between the ages of 20 and 49. Those killed were more likely to be male and white. Drugs and/or alcohol were associated with approximately half of all the railroad fatalities included in the analysis.

Several factors were identified as associated with higher frequencies of daily trespassing events:

- Greater densities of pedestrian attractors such as schools, universities and colleges, social services, and restaurants and other eating places in proximity to the railroad right-of-way and in combination with less access to vehicles as means of transportation to work, greater density of racial minorities, and greater density of low-income housing.

The site was the single greatest predictor of total daily pedestrian trespassing events and the variation in total daily events could be partially explained by the population and business density variables when the site was excluded from modeling.

The research team hypothesized that most trespassing events captured at the observation locations are the result of people trying to reach their destinations through the shortest, most direct route. Across the eleven study locations, 95% of trespassing events involved crossing the tracks compared to 5% of events that involved movement along the tracks within the view of the camera. The median time on the tracks for those crossing is 3 seconds. 35% of people were traveling in groups of two or more. One percent of events across all sites included the presence of a train. Most events involved walking along or through the railroad right-of-way. Very few events (<1%) involved sitting or lying on the tracks or elsewhere in the railroad right-of-way. The thermal video camera systems captured people traveling alone, in pairs, and in groups, adults and children, people carrying bags and bikes, walking dogs, and pushing strollers. Most people moved on their way, some lingered, very few stood around or sat on or near the tracks.

A key gap in this research is data that helps describe the reasons and motivations for trespassing. Limited research exists that focuses on interviewing or surveying railroad trespassers about their motivations and perceptions to learn more about their reasons for trespassing – i.e., the “why?” of their behavior. This contextual data is needed at the case study level to be used by the FRA, local communities, and the NCDOT to construct a better picture of trespassing activities that do not result in injury or loss of life. These data can also contribute to models for estimating pedestrian trespassing activity along railroad right-of-ways in the state. Future scientific data collection should focus on interviewing those engaged in trespassing activity to achieve a representative sample of trespasser responses that can be associated with event-based data collected at the hot spot locations, including the thermal video data and corresponding database of trespassing events.

Appendix A – Form Letter and Site Descriptions

North Carolina Department of Transportation (NCDOT) – Rail Division
1553 Main Service Center
Raleigh, NC 27699-1553
(919) 707-4700

[Enter Current Date]

To Whom It May Concern,

Trespassing on railroad tracks and right-of-way is the leading cause of rail-related deaths in the United States, with 553 trespass-related fatalities reported in 2017 alone compared to 271 highway-rail fatalities for the same period.[18] This represents a 10-year high and an 18.6% increase from the previous year. North Carolina is one of the top ten states for injuries and deaths related to railroad trespassing. With the goal of saving future lives, the NCDOT Rail Division and the Institute for Transportation Research and Education (ITRE) at NC State University are involved in a railroad trespassing research program to study this epidemic.

ITRE is collaborating with the NCDOT Rail Division to gather thermal video data of pedestrian trespassing events at locations with significant trespassing activity along the railroad right-of-way in North Carolina. At least one week of 24/7 thermal video data is collected in each seasonal quarter at each location. The locations are selected based on Federal Railroad Administration (FRA) incident data and GIS analyses. The video data are reduced by coding attributes for each trespassing event, including time of day, duration, direction of travel, whether the trespasser is alone or in a group, group size, whether the trespasser crossed the tracks or traveled along the tracks, and basic information about the trespasser's activity (walking, standing, sitting, laying). A notes field captures additional information not covered by the standardized fields, such as whether the trespasser was a child, riding or pushing a bicycle, walking a dog, carrying something, etc. Fundamentally, the final dataset provides a count of trespassing events for the data collection time periods and provides an estimate of the trespassing frequency at the locations. The data will be used by local communities and NCDOT to construct a better picture of trespassing activities that do not result in injury or loss of life. This information is crucial to more precisely identify high-risk groups and inform practical safety initiatives and countermeasures to reduce overall trespassing.

We have identified a location in your community with significant trespassing activity for inclusion in our study. This letter is to inform you that we will be installing a static thermal camera near [Street or Cross Street Location] (GPS Coordinates) along the railroad right-of-way to capture trespassing events. The camera will passively record trespassing activity. The research equipment will consist of a small solar panel, batteries in a plastic container, the thermal camera and mounting device, cables, and wires (see enclosure). The system will be labeled with NC State University and ITRE credentials including contact information for the key researchers.

The thermal camera looks similar to a surveillance camera and the battery container is simply a small plastic box. Please share with only essential personnel that ITRE researchers plan to install the thermal camera on [Install Date/Time]. The camera will be in place for approximately one week and then will be removed. Additional research will take place in the coming months and the thermal camera and

[18] Federal Railroad Administration Office of Safety Analysis. **Trespasser Causalities.** Trespasser fatality data for 2016/2017 retrieved from https://safetydata.fra.dot.gov/officeofsafety/publicsite/query/castally4.aspx.

supporting equipment will return to these or nearby locations. Additional notifications will occur before reinstallation. If you have any questions or clarification please feel free to call **Chris Cunningham** at **(919) 515-8562**, **Chris Vaughan**, at **(919) 515-8036** or **Sarah Searcy** at **(919) 513-3482**.

We look forward to partnering with your community on this useful and timely research project.

Sincerely,

[Contact Name and Information]

Enclosure: Image of Thermal Camera System Installation

ITRE Institute for Transportation Research and Education

NCDOT and ITRE: Rail Trespass Research Project

Thermal Video Data Collection in Charlotte, NC

Trespassing identified as an issue along Rozzelles Ferry Road (35.26484, -80.88366). Multiple desire lines across railroad right-of-way from Linwood Avenue north to Hoskins Road.

A static thermal camera will be installed at the identified location along the railroad right-of-way to capture trespassing events. The research equipment will consist of a small solar panel, batteries in a plastic container similar to an ammo box, the thermal camera and mounting device, cables, and wires. The system will be labeled with NC State University and ITRE credentials including contact information for the key researchers.

Expected data collection periods in 2019 include:

1/22 - 1/31** **7/15 - 7/24
5/1 - 5/10** **10/1 - 10/10

For more information, please contact:

Sarah Searcy | ITRE @ NC State University | (919) 513-3482 | sesearcy@ncsu.edu
Chris Cunningham | ITRE @ NC State University | (919) 515-8562 | cmcunnin@ncsu.edu
Chris Vaughan | ITRE @ NC State University | (919) 515-8036 | clvaugha@ncsu.edu

ITRE Institute for Transportation Research and Education

NCDOT and ITRE: Rail Trespass Research Project

Thermal Video Data Collection in Gastonia, NC

Trespassing identified as an issue between the end of Highland Street and the parking lot of the social services building on Airline Avenue (35.264758, -81.194011). A desire line runs across the railroad right-of-way. These tracks are along the NS mainline, but outside of the NCRR corridor.

A static thermal camera will be installed at the identified location along the railroad right-of-way to capture trespassing events. The research equipment will consist of a small solar panel, batteries in a plastic container similar to an ammo box, the thermal camera and mounting device, cables, and wires. The system will be labeled with NC State University and ITRE credentials including contact information for the key researchers.

Expected data collection periods in 2019 include:

1/22 - 1/31** **7/15 - 7/24
5/1 - 5/10** **10/1 - 10/10

For more information, please contact:
Sarah Searcy | ITRE @ NC State University | (919) 513-3482 | sesearcy@ncsu.edu
Chris Cunningham | ITRE @ NC State University | (919) 515-8562 | cmcunnin@ncsu.edu
Chris Vaughan | ITRE @ NC State University | (919) 515-8036 | clvaugha@ncsu.edu

ITRE Institute for Transportation Research and Education

NCDOT and ITRE: Rail Trespass Research Project

Thermal Video Data Collection in Shelby, NC

Trespassing identified as an issue along the railroad right-of-way near Airline Avenue and Black Street (35.297785, -81.528638). A desire line runs between a neighborhood and the nearby Eastside Kwik Stop and crosses the tracks along Airline Avenue. These tracks are along the CSX SF-line.

A static thermal camera will be installed at the identified location along the railroad right-of-way to capture trespassing events. The research equipment will consist of a small solar panel, batteries in a plastic container similar to an ammo box, the thermal camera and mounting device, cables, and wires. The system will be labeled with NC State University and ITRE credentials including contact information for the key researchers.

Expected data collection periods in 2019 include:

1/22 - 1/31** **7/15 - 7/24
5/1 - 5/10** **10/1 - 10/10

For more information, please contact:
Sarah Searcy | ITRE @ NC State University | (919) 513-3482 | sesearcy@ncsu.edu
Chris Cunningham | ITRE @ NC State University | (919) 515-8562 | cmcunnin@ncsu.edu
Chris Vaughan | ITRE @ NC State University | (919) 515-8036 | clvaugha@ncsu.edu

NCDOT and ITRE: Rail Trespass Research Project

Thermal Video Data Collection in Lumberton, NC

Trespassing identified as an issue across the railroad right-of-way as a short cut to the Riverwalk Trail (34.617833, -79.012160). A desire line connects the trail from the NC Hwy 72 crossing and across the railroad right-of-way.

A static thermal camera will be installed at the identified location along the railroad right-of-way to capture trespassing events. The research equipment will consist of a small solar panel, batteries in a plastic container similar to an ammo box, the thermal camera and mounting device, cables, and wires. The system will be labeled with NC State University and ITRE credentials including contact information for the key researchers.

Expected data collection periods in 2019 include:

2/1 - 2/11** **7/25 - 7/31
5/11 - 5/20** **10/11 - 10/21

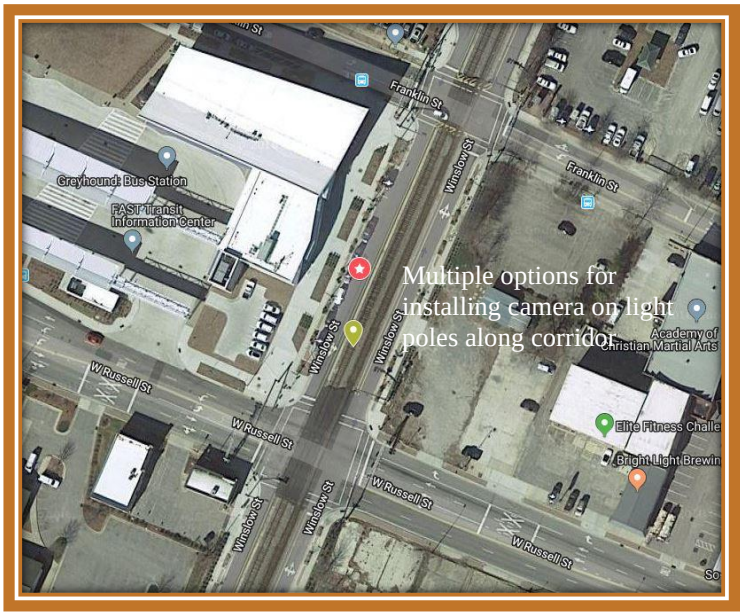
For more information, please contact:
Sarah Searcy | ITRE @ NC State University | (919) 513-3482 | sesearcy@ncsu.edu
Chris Cunningham | ITRE @ NC State University | (919) 515-8562 | cmcunnin@ncsu.edu
Chris Vaughan | ITRE @ NC State University | (919) 515-8036 | clvaugha@ncsu.edu

ITRE Institute for Transportation Research and Education

NCDOT and ITRE: Rail Trespass Research Project

Thermal Video Data Collection in Fayetteville, NC

Trespassing identified as an issue between the brewery and the bus station along Winslow Street (35.0532, -78.886).



A static thermal camera will be installed at the identified location along the railroad right-of-way to capture trespassing events. The research equipment will consist of a small solar panel, batteries in a plastic container similar to an ammo box, the thermal camera and mounting device, cables, and wires. The system will be labeled with NC State University and ITRE credentials including contact information for the key researchers.

Expected data collection periods in 2019 include:

2/1 - 2/11** **7/25 - 7/31
5/11 - 5/20** **10/11 - 10/21

For more information, please contact:
Sarah Searcy | ITRE @ NC State University | (919) 513-3482 | sesearcy@ncsu.edu
Chris Cunningham | ITRE @ NC State University | (919) 515-8562 | cmcunnin@ncsu.edu
Chris Vaughan | ITRE @ NC State University | (919) 515-8036 | clvaugha@ncsu.edu

ITRE Institute for Transportation Research and Education

NCDOT and ITRE: Rail Trespass Research Project

Thermal Video Data Collection in Rocky Mount, NC

Trespassing identified as an issue along the railroad right-of-way near Thelonious S. Monk Park (35.929945, -77.800370). A desire line runs between Henry Street and Dunn Street, passing through Thelonious S. Monk Park.

A static thermal camera will be installed at the identified location along the railroad right-of-way to capture trespassing events. The research equipment will consist of a small solar panel, batteries in a plastic container similar to an ammo box, the thermal camera and mounting device, cables, and wires. The system will be labeled with NC State University and ITRE credentials including contact information for the key researchers.

Expected data collection periods in 2019 include:

2/1 - 2/11** **7/25 - 7/31
5/11 - 5/20** **10/11 - 10/21

For more information, please contact:
Sarah Searcy | ITRE @ NC State University | (919) 513-3482 | sesearcy@ncsu.edu
Chris Cunningham | ITRE @ NC State University | (919) 515-8562 | cmcunnin@ncsu.edu
Chris Vaughan | ITRE @ NC State University | (919) 515-8036 | clvaugha@ncsu.edu

Appendix B – Trespassing Activity Summaries (All Sites)

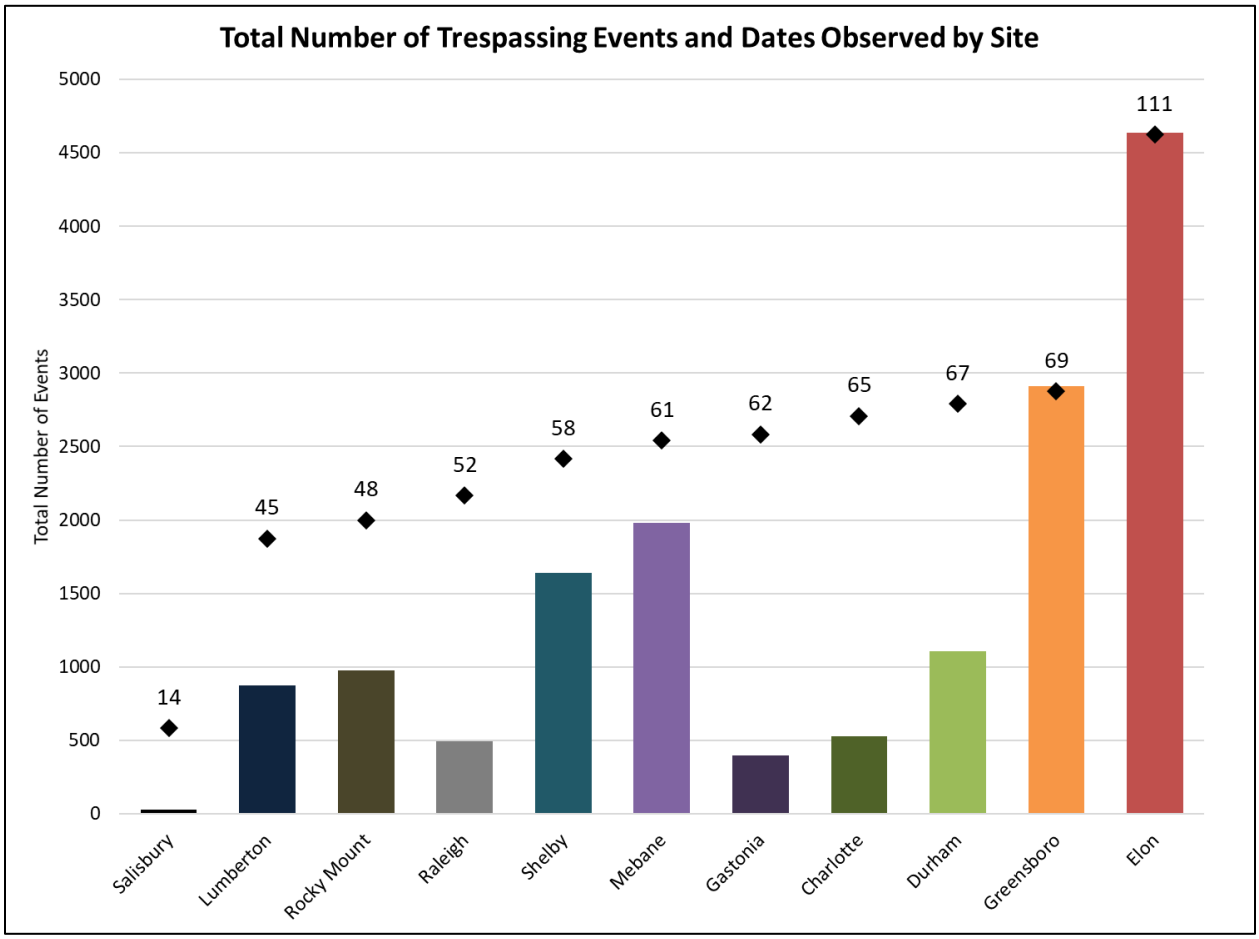


Exhibit 24. Total Number of Trespassing Events and Dates Observed by Site

Site	Proportion of Trespassing Events by Hour of Day - All Dates																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Charlotte	2%	1%	1%	1%	1%	0%	1%	1%	7%	4%	7%	6%	5%	8%	7%	6%	6%	8%	9%	9%	7%	1%	1%	2%
Durham	2%	2%	1%	0%	1%	0%	2%	1%	3%	5%	5%	6%	6%	8%	7%	9%	9%	7%	5%	5%	5%	6%	4%	3%
Elon	13%	11%	4%	2%	0%	0%	0%	0%	1%	2%	3%	2%	3%	3%	3%	4%	6%	7%	5%	5%	4%	5%	9%	9%
Gastonia	1%	1%	1%	1%	2%	1%	4%	3%	7%	5%	6%	6%	7%	7%	6%	9%	6%	6%	7%	3%	3%	2%	5%	4%
Greensboro	2%	2%	1%	2%	2%	3%	3%	6%	6%	6%	5%	5%	6%	6%	7%	5%	6%	6%	4%	5%	5%	4%	3%	2%
Lumberton	1%	1%	1%	1%	1%	1%	1%	4%	6%	7%	9%	10%	7%	9%	4%	5%	7%	6%	3%	3%	4%	3%	2%	2%
Mebane	0%	0%	0%	0%	0%	1%	2%	3%	4%	4%	5%	6%	6%	6%	7%	9%	9%	10%	6%	6%	6%	4%	4%	1%
Raleigh	1%	0%	0%	0%	0%	1%	1%	1%	4%	4%	6%	6%	6%	10%	7%	11%	11%	10%	6%	3%	5%	3%	3%	1%
Rocky Mount	3%	2%	1%	1%	1%	0%	1%	3%	3%	6%	4%	6%	5%	6%	7%	6%	7%	7%	9%	4%	5%	3%	4%	3%
Salisbury	18%	0%	7%	0%	0%	0%	0%	4%	0%	0%	4%	4%	7%	4%	0%	18%	11%	0%	7%	11%	7%	0%	0%	0%
Shelby	2%	1%	1%	1%	1%	1%	1%	2%	5%	4%	6%	4%	6%	5%	5%	6%	6%	8%	9%	7%	7%	7%	4%	4%

Exhibit 25. Proportion of Trespassing Events by Hour of Day

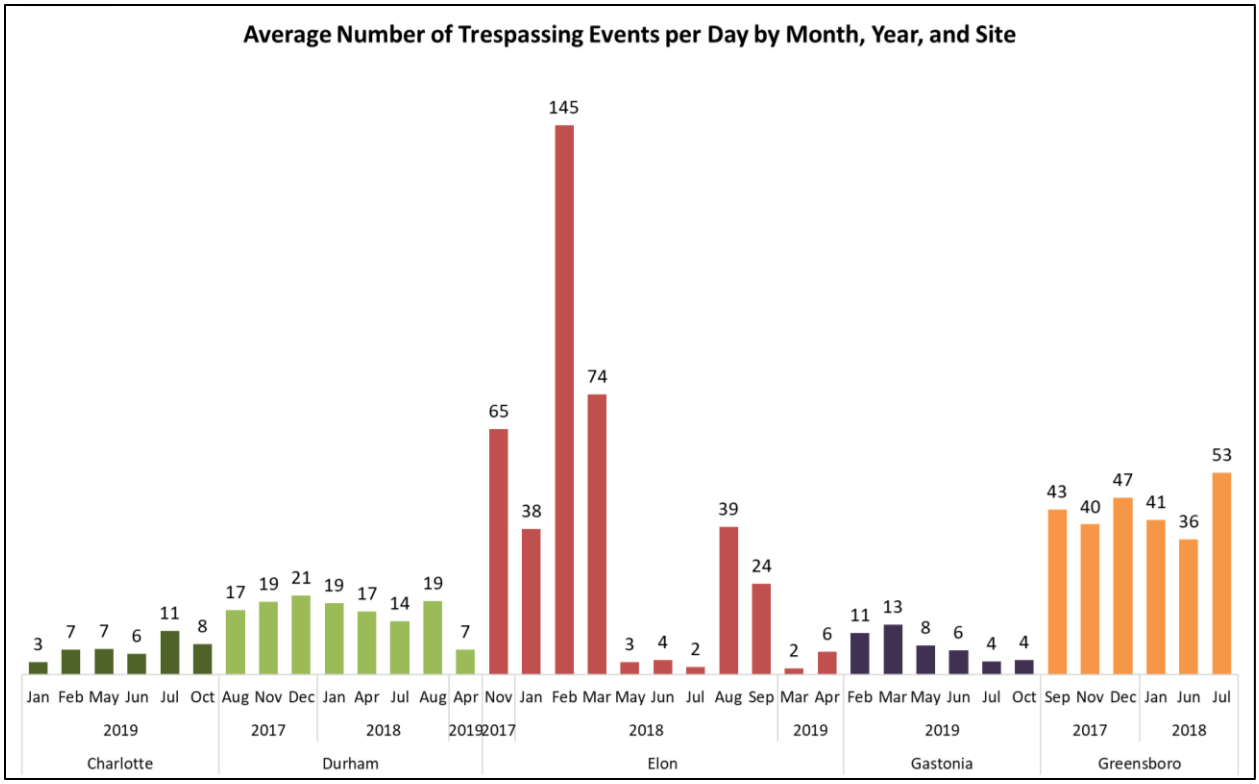


Exhibit 26. Average Number of Trespassing Events per Day by Month, Year, and Site

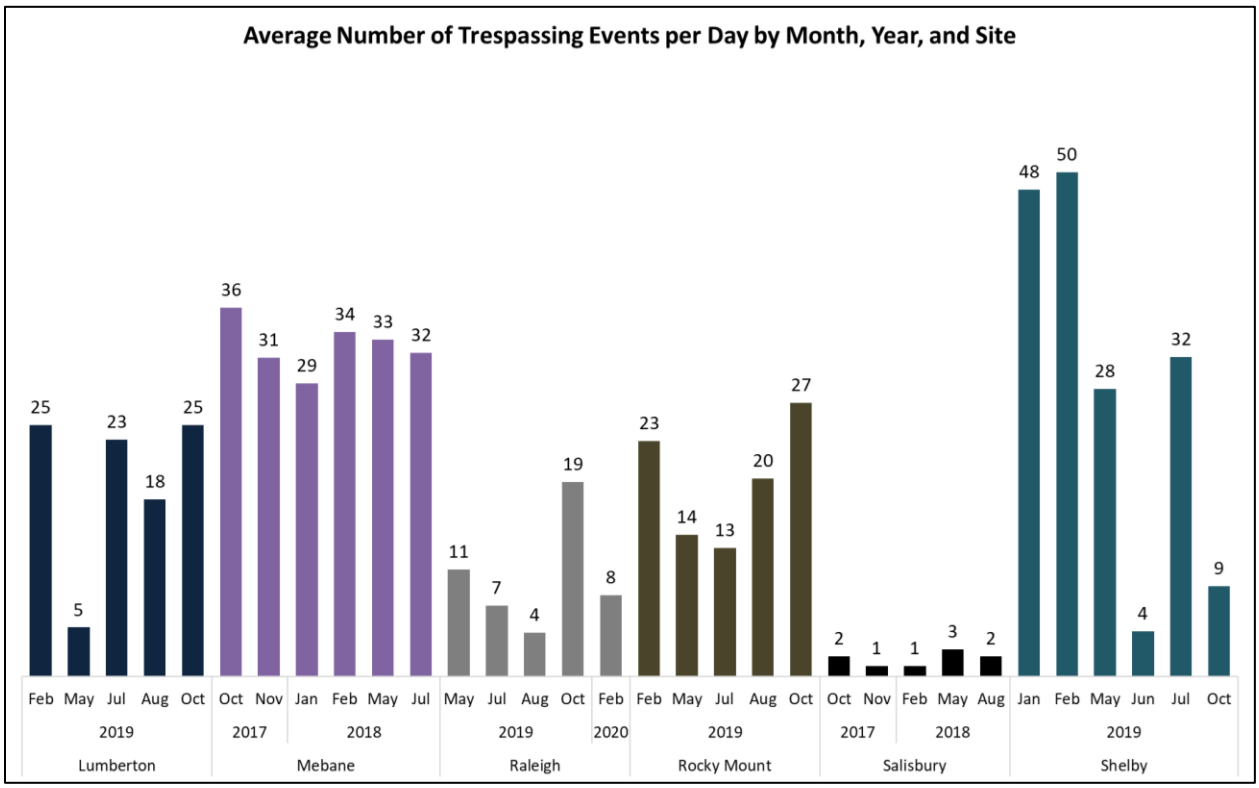


Exhibit 27. Average Number of Trespassing Events per Day by Month, Year, and Site

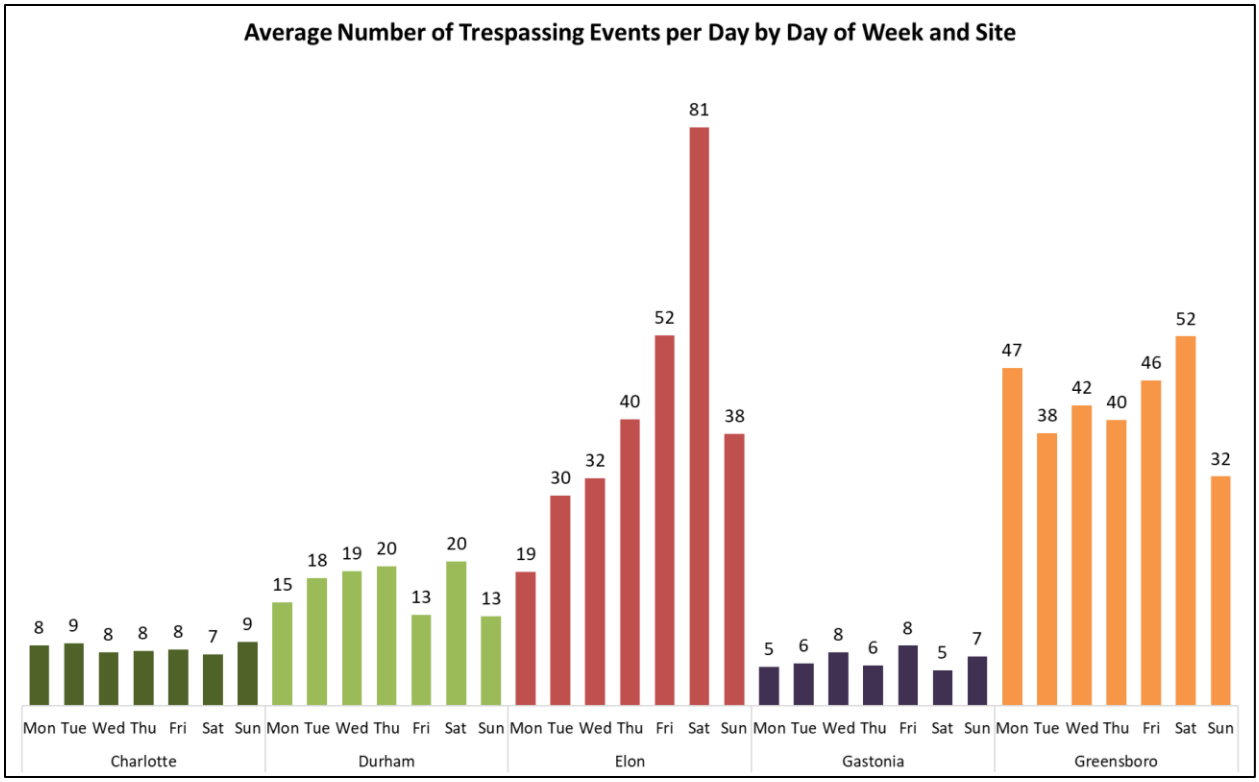


Exhibit 28. Average Number of Trespassing Events per Day by Day of Week and Site

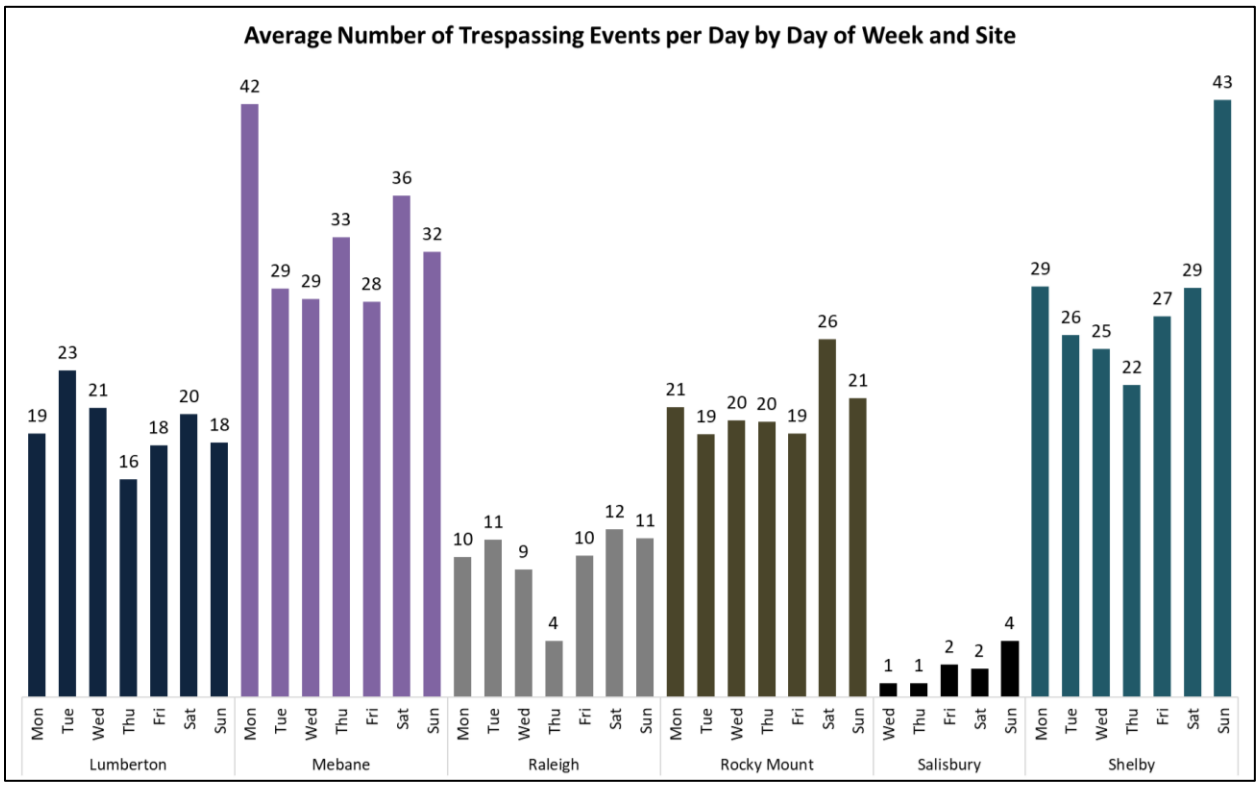


Exhibit 29. Average Number of Trespassing Events per Day by Day of Week and Site

Appendix C – Definitions of Variables Used in Analyses

Variable	Definition	Source
Event ID	Unique identifier for each trespassing event	Thermal video collected at the observation location by ITRE
Location ID	Unique identifier for each observation location	Thermal video collected at the observation location by ITRE
Latitude	Latitude for the observation location	Thermal video collected at the observation location by ITRE
Longitude	Longitude for the observation location	Thermal video collected at the observation location by ITRE
Site	Observation location descriptor as nearest city or town	Thermal video collected at the observation location by ITRE
Camera Angle	Unique identifier for the position of the thermal video camera system	Thermal video collected at the observation location by ITRE
Camera Angle Description	Description of the thermal video camera system position	Thermal video collected at the observation location by ITRE
Date	The date on which an event was captured by the thermal video camera system, formatted mm/dd/yyyy	Thermal video collected at the observation location by ITRE
Season	Season of the year defined by a monthly quarter (Winter: Jan, Feb, Mar; Spring: Apr. May, Jun; Summer: Jul, Aug, Sept; Fall: Oct, Nov, Dec)	Thermal video collected at the observation location by ITRE
Day	Day of week during which event data were observed	Thermal video collected at the observation location by ITRE
Month	Calendar month during which event data were observed	Thermal video collected at the observation location by ITRE
Year	Calendar year (2017 through 2020) for which event data were observed or historic climate data, business location data, or population data were obtained	Thermal video collected at the observation location by ITRE
Group	Whether the observed pedestrian captured in the event is alone or in a group	Thermal video collected at the observation location by ITRE
Group ID	Unique identifier for the group	Thermal video collected at the observation location by ITRE
Enter ROW	Time that the pedestrian captured in the event entered the railroad right of way	Thermal video collected at the observation location by ITRE
Enter Tracks	Time that the pedestrian captured in the event entered the railroad track	Thermal video collected at the observation location by ITRE
Exit Tracks	Time that the pedestrian captured in the event exited the railroad track	Thermal video collected at the observation location by ITRE
Time Until Train (If Applicable)	Time that train arrived during the event (if applicable)	Thermal video collected at the observation location by ITRE
Exit ROW	Time that the pedestrian captured in the event exited the railroad right of way	Thermal video collected at the observation location by ITRE

Variable	Definition	Source
Duration on Tracks (Top of Rock Bed)	Total duration that the pedestrian captured in the event was on the railroad tracks in seconds	Thermal video collected at the observation location by ITRE
Duration in ROW	Total duration that the pedestrian captured in the event was in the railroad right of way in seconds	Thermal video collected at the observation location by ITRE
Hour Enter ROW	The hour of the day that the pedestrian captured in the event entered the railroad right of way	Thermal video collected at the observation location by ITRE
Hour of Day	Hour of the day	Thermal video collected at the observation location by ITRE
Activity - Walking	Indicates if the pedestrian was walking when captured in the event	Thermal video collected at the observation location by ITRE
Activity - Standing	Indicates if the pedestrian was standing when captured in the event	Thermal video collected at the observation location by ITRE
Activity - Sitting	Indicates if the pedestrian was siting when captured in the event	Thermal video collected at the observation location by ITRE
Activity - Laying	Indicates if the pedestrian was laying when captured in the event	Thermal video collected at the observation location by ITRE
Activity - Carrying Bike	Indicates if the pedestrian was carrying a bicycle when captured in the event	Thermal video collected at the observation location by ITRE
Activity - Riding Bike	Indicates if the pedestrian was riding a bicycle when captured in the event	Thermal video collected at the observation location by ITRE
Direction Traveled	Indicates the primary direction that the pedestrian was traveling when captured in the event	Thermal video collected at the observation location by ITRE
Crossed Tracks?	Indicates if the pedestrian crossed the railroad tracks	Thermal video collected at the observation location by ITRE
Travel Along Tracks?	Indicates of the pedestrian traveled along the railroad tracks	Thermal video collected at the observation location by ITRE
Complete Event (Y/N)	Indicates if the event is complete, i.e., an event is defined as incomplete if the video capture begins when a pedestrian is already in the railroad right of way or on the tracks, and it does not show the pedestrian entering and/or exiting the tracks and/or the railroad right of way	Thermal video collected at the observation location by ITRE
Bike	Indicates if the pedestrian has a bicycle (either riding or carrying)	Thermal video collected at the observation location by ITRE
Riding Bike	Indicates if the pedestrian is riding a bicycle	Thermal video collected at the observation location by ITRE
Carrying Bike	Indicates if the pedestrian is carrying a bicycle	Thermal video collected at the observation location by ITRE
Nearest Crossing ID	USDOT Crossing Inventory Number for the crossing nearest to the observation location	September 2019 NCDOT State Authoritative Rail and Highway (SARAH) Database

Variable	Definition	Source
Railroad	Valid railroad code (up to 4 letters) for the primary operating railroad company, i.e., the railroad that operates train movements over the crossing; the primary operating railroad will normally be the reporting railroad, but may or may not own and maintain the roadbed, tracks, and signal system controlling the crossing	September 2019 NCDOT State Authoritative Rail and Highway (SARAH) Database
Purpose and Position	Combines the purpose of the crossing with the position of the railroad relative to the crossing; all crossings included in the analysis dataset are highway (highway use) at grade (railroad intersects the roadway)	September 2019 NCDOT State Authoritative Rail and Highway (SARAH) Database
Street	Name of the highway or street at the crossing	September 2019 NCDOT State Authoritative Rail and Highway (SARAH) Database
Distance from Observation Location in Feet	Distance of the crossing from the observation location in feet	September 2019 NCDOT State Authoritative Rail and Highway (SARAH) Database
Day Thru Trains	Total through train movements across the crossing during the day	September 2019 NCDOT State Authoritative Rail and Highway (SARAH) Database
Night Thru Trains	Total through train movements across the crossing during the night	September 2019 NCDOT State Authoritative Rail and Highway (SARAH) Database
Total Switching Trains	Total switching train movements across the crossing	September 2019 NCDOT State Authoritative Rail and Highway (SARAH) Database
Typical Min Speed	Typical minimum train movement speed across the crossing	September 2019 NCDOT State Authoritative Rail and Highway (SARAH) Database
Typical Max Speed	Typical maximum train movement speed across the crossing	September 2019 NCDOT State Authoritative Rail and Highway (SARAH) Database
Type(s) of Train Service	Type(s) of train service at the crossing	September 2019 NCDOT State Authoritative Rail and Highway (SARAH) Database
Station Identifier	Station identification code	National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCDC) Global Historical Climatology Network (GHCN)
Station Identifier & Date	Station identification code and date (4 digit year of record followed by 2 digit month and 2 digit day)	National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCDC) Global Historical Climatology Network (GHCN)
Precipitation (Inches)	Precipitation in inches	National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCDC) Global Historical Climatology Network (GHCN)
Max Temperature	Minimum temperature in Fahrenheit	National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCDC) Global Historical Climatology Network (GHCN)
Min Temperature	Maximum temperature in Fahrenheit	National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCDC) Global Historical Climatology Network (GHCN)

Variable	Definition	Source
# Businesses per 1,000 People - Drinking Places	Number of drinking places per 1,000 people for U.S. Census tracts within one mile of the observation location	2019 US Business Locations (ESRI product licensed from Infogroup)
# Businesses per 1,000 People - Off-Premises Alcohol Outlets	Number of off-premises alcohol outlets per 1,000 people for U.S. Census tracts within one mile of the observation location	2019 US Business Locations (ESRI product licensed from Infogroup)
# Businesses per 1,000 People - Low Income Housing	Number of low-income housing per 1,000 people for U.S. Census tracts within one mile of the observation location	2019 US Business Locations (ESRI product licensed from Infogroup)
# Businesses per 1,000 People - Restaurants and Other Eating Places	Number of restaurants and other eating places per 1,000 people for U.S. Census tracts within one mile of the observation location	2019 US Business Locations (ESRI product licensed from Infogroup)
# Businesses per 1,000 People - Retail Food Products & Grocers / Convenience Stores	Number of grocers and convenience stores per 1,000 people for U.S. Census tracts within one mile of the observation location	2019 US Business Locations (ESRI product licensed from Infogroup)
# Businesses per 1,000 People - Schools	Number of schools per 1,000 people for U.S. Census tracts within one mile of the observation location	2019 US Business Locations (ESRI product licensed from Infogroup)
# Businesses per 1,000 People - Universities & Colleges & Professional Schools	Number of universities, colleges, and professional schools per 1,000 people for U.S. Census tracts within one mile of the observation location	2019 US Business Locations (ESRI product licensed from Infogroup)
# Businesses per 1,000 People - Student Housing	Number of student housing per 1,000 people for U.S. Census tracts within one mile of the observation location	2019 US Business Locations (ESRI product licensed from Infogroup)

Variable	Definition	Source
# Businesses per 1,000 People - Social Services	Number of social services per 1,000 people for U.S. Census tracts within one mile of the observation location	2019 US Business Locations (ESRI product licensed from Infogroup)
Population per Sq Mi - Census Tracts within 1 Mi - ACS 2018 5YR	Population per square mile for U.S. Census tracts within one mile of the observation location	2018 American Community Survey (ACS) 5-Year Estimates, Table B01003: Total Population
Percent Black Only - Census Tracts within 1 Mi - ACS 2018 5YR	Percent Black only for U.S. Census tracts within one mile of the observation location	2018 American Community Survey (ACS) 5-Year Estimates, Table B02001: Race
Percent White Only - Census Tracts within 1 Mi - ACS 2018 5YR	Percent White only for U.S. Census tracts within one mile of the observation location	2018 American Community Survey (ACS) 5-Year Estimates, Table B02001: Race
Percent Hispanic or Latino Origin - Census Tracts within 1 Mi - ACS 2018 5YR	Percent Hispanic or Latino origin for U.S. Census tracts within one mile of the observation location	2018 American Community Survey (ACS) 5-Year Estimates, Table B03003: Hispanic or Latino Origin
Percent No Vehicle - Means of Transport to Work - Census Tracts within 1 Mi - ACS 2018 5YR	Percent no vehicle as means of transportation to work for U.S. Census tracts within one mile of the observation location	2018 American Community Survey (ACS) 5-Year Estimates, Table B08141: Means of Transportation to Work by Vehicles Available
Percent Walk to Work - Means of Transport to Work - Census Tracts within 1 Mi - ACS 2018 5YR	Percent walk to work as means of transportation to work for U.S. Census tracts within one mile of the observation location	2018 American Community Survey (ACS) 5-Year Estimates, Table B08141: Means of Transportation to Work by Vehicles Available

Variable	Definition	Source
Percent No Vehicle / Walk to Work - Means of Transport to Work - Census Tracts within 1 Mi - ACS 2018 5YR	Percent no vehicle and walk to work as means of transportation to work for U.S. Census tracts within one mile of the observation location	2018 American Community Survey (ACS) 5-Year Estimates, Table B08141: Means of Transportation to Work by Vehicles Available
Average Median Household Income - Census Tracts within 1 Mi - ACS 2018 5YR	Average median household income for U.S. Census tracts within one mile of the observation location	2018 American Community Survey (ACS) 5-Year Estimates, Table B19013: Median Household Income in the Past 12 Months (in 2018 Inflation-Adjusted Dollars)
Percent High School Only - Educational Attainment - Census Tracts within 1 Mi - ACS 2018 5YR	Percent High School only for U.S. Census tracts within one mile of the observation location	2018 American Community Survey (ACS) 5-Year Estimates, Table S1501: Educational Attainment
Percent High School or Higher - Educational Attainment - Census Tracts within 1 Mi - ACS 2018 5YR	Percent High School or higher for U.S. Census tracts within one mile of the observation location	2018 American Community Survey (ACS) 5-Year Estimates, Table S1501: Educational Attainment

Appendix D – NAICS Code Groups Used in the Analyses

NAICS	NAICS 8-Digit Description	NAICS 5-Digit Description	NAICS Analysis Group
44511002	Food Products-Retail	Supermarkets and Other Grocery (except Convenience) Stores	Retail Food Products & Grocers; Convenience Stores
44511003	Grocers-Retail	Supermarkets and Other Grocery (except Convenience) Stores	Retail Food Products & Grocers; Convenience Stores
44512001	Convenience Stores	Convenience Stores	Retail Food Products & Grocers; Convenience Stores
44531001	Beer & Ale-Retail	Beer, Wine, and Liquor Stores	Off-Premises Alcohol Outlets
44531002	Cocktail Mixes	Beer, Wine, and Liquor Stores	Off-Premises Alcohol Outlets
44531004	Liquors-Retail	Beer, Wine, and Liquor Stores	Off-Premises Alcohol Outlets
44531005	Wines-Retail	Beer, Wine, and Liquor Stores	Off-Premises Alcohol Outlets
53119004	Mobile Homes-Parks & Communities	Lessors of Other Real Estate Property	Low Income Housing
53131106	Housing Authorities	Real Estate Property Managers	Low Income Housing
53131108	Housing-Low Income	Real Estate Property Managers	Low Income Housing
61111007	Schools	Elementary and Secondary Schools	Schools
61121001	Business Colleges	Junior Colleges	Universities & Colleges & Professional Schools
61121002	Junior-Community College-Tech Institutes	Junior Colleges	Universities & Colleges & Professional Schools
61131009	Schools-Universities & Colleges Academic	Colleges, Universities, and Professional Schools	Universities & Colleges & Professional Schools
61131013	University-College Dept/Facility/Office	Colleges, Universities, and Professional Schools	Universities & Colleges & Professional Schools
61141004	School-Business & Vocational	Business and Secretarial Schools	Universities & Colleges & Professional Schools
62149202	Dialysis	Outpatient Mental Health and Substance Abuse Centers	Social Services
62149204	Kidney Dialysis Centers	Outpatient Mental Health and Substance Abuse Centers	Social Services
62149301	Clinics	Outpatient Mental Health and Substance Abuse Centers	Social Services
62199921	Health Services	All Other Ambulatory Health Care Services	Social Services
62211002	Hospitals	General Medical and Surgical Hospitals	Social Services
62221001	Mental Health Services	Psychiatric and Substance Abuse Hospitals	Social Services
62411003	Government-Individual/Family Social Svcs	Child and Youth Services	Social Services
62411004	Counseling Services	Child and Youth Services	Social Services
62411005	Crisis Intervention Service	Child and Youth Services	Social Services
62411006	Youth Organizations & Centers	Child and Youth Services	Social Services
62411011	Community Centers	Child and Youth Services	Social Services
62412003	Senior Citizens Service	Services for the Elderly and Persons with Disabilities	Social Services

NAICS	NAICS 8-Digit Description	NAICS 5-Digit Description	NAICS Analysis Group
62419009	Counselors-Licensed Professional	Other Individual and Family Services	Social Services
62419012	Social Service & Welfare Organizations	Other Individual and Family Services	Social Services
62419014	Community Services	Other Individual and Family Services	Social Services
62419016	Support Groups	Other Individual and Family Services	Social Services
62419031	Substance Abuse Centers	Other Individual and Family Services	Social Services
62419036	Counselors	Other Individual and Family Services	Social Services
62421001	Food Banks	Community Food Services	Social Services
62422901	Housing Assistance	Community Housing Services	Social Services
62431009	Rehabilitation Services	Vocational Rehabilitation Services	Social Services
72131009	Student Housing	Rooming and Boarding Houses	Student Housing
72241001	Bars	Drinking Places (Alcoholic Beverages)	Drinking Places (Alcoholic Beverages)
72241003	Cocktail Lounges	Drinking Places (Alcoholic Beverages)	Drinking Places (Alcoholic Beverages)
72241004	Comedy Clubs	Drinking Places (Alcoholic Beverages)	Drinking Places (Alcoholic Beverages)
72241006	Night Clubs	Drinking Places (Alcoholic Beverages)	Drinking Places (Alcoholic Beverages)
72241008	Pubs	Drinking Places (Alcoholic Beverages)	Drinking Places (Alcoholic Beverages)
72251117	Restaurants	Restaurants and Other Eating Places	Restaurants and Other Eating Places
72251	Restaurants and Other Eating Places	Restaurants and Other Eating Places	Restaurants and Other Eating Places

Appendix E – Number of Businesses in U.S. Census Tracts within 1 Mile by Site – NAICS Code Groups Used in the Analyses

Site	NAICS Analysis Group	Total Number of Businesses – U.S. Census Tracts within 1 Mi	Number of Businesses Per 1,000 People
Charlotte	Drinking Places (Alcoholic Beverages)	3	0.100
Charlotte	Low Income Housing	2	0.067
Charlotte	Restaurants and Other Eating Places	27	0.903
Charlotte	Retail Food Products & Grocers; Convenience Stores	27	0.903
Charlotte	Schools	11	0.368
Charlotte	Social Services	4	0.134
Durham	Drinking Places (Alcoholic Beverages)	11	0.283
Durham	Low Income Housing	3	0.077
Durham	Off-Premises Alcohol Outlets	6	0.154
Durham	Restaurants and Other Eating Places	100	2.573
Durham	Retail Food Products & Grocers; Convenience Stores	34	0.875
Durham	Schools	36	0.926
Durham	Social Services	73	1.878
Durham	Universities & Colleges & Professional Schools	9	0.232
Elon	Drinking Places (Alcoholic Beverages)	1	0.042
Elon	Off-Premises Alcohol Outlets	1	0.042
Elon	Restaurants and Other Eating Places	43	1.795
Elon	Retail Food Products & Grocers; Convenience Stores	7	0.292
Elon	Schools	7	0.292
Elon	Social Services	7	0.292
Elon	Student Housing	1	0.042
Elon	Universities & Colleges & Professional Schools	2	0.083
Gastonia	Drinking Places (Alcoholic Beverages)	7	0.259
Gastonia	Low Income Housing	1	0.037
Gastonia	Off-Premises Alcohol Outlets	5	0.185
Gastonia	Restaurants and Other Eating Places	57	2.112
Gastonia	Retail Food Products & Grocers; Convenience Stores	31	1.148
Gastonia	Schools	16	0.593
Gastonia	Social Services	43	1.593
Gastonia	Universities & Colleges & Professional Schools	1	0.037
Greensboro	Drinking Places (Alcoholic Beverages)	16	0.385
Greensboro	Low Income Housing	6	0.145
Greensboro	Off-Premises Alcohol Outlets	4	0.096
Greensboro	Restaurants and Other Eating Places	114	2.746
Greensboro	Retail Food Products & Grocers; Convenience Stores	22	0.530
Greensboro	Schools	31	0.747
Greensboro	Social Services	80	1.927
Greensboro	Student Housing	2	0.048
Greensboro	Universities & Colleges & Professional Schools	28	0.674

Site	NAICS Analysis Group	Total Number of Businesses – U.S. Census Tracts within 1 Mi	Number of Businesses Per 1,000 People
Lumberton	Low Income Housing	5	0.339
Lumberton	Off-Premises Alcohol Outlets	1	0.068
Lumberton	Restaurants and Other Eating Places	43	2.916
Lumberton	Retail Food Products & Grocers; Convenience Stores	21	1.424
Lumberton	Schools	16	1.085
Lumberton	Social Services	39	2.645
Lumberton	Universities & Colleges & Professional Schools	2	0.136
Mebane	Low Income Housing	2	0.135
Mebane	Off-Premises Alcohol Outlets	3	0.202
Mebane	Restaurants and Other Eating Places	68	4.573
Mebane	Retail Food Products & Grocers; Convenience Stores	13	0.874
Mebane	Schools	10	0.673
Mebane	Social Services	9	0.605
Raleigh	Drinking Places (Alcoholic Beverages)	19	0.486
Raleigh	Low Income Housing	1	0.026
Raleigh	Off-Premises Alcohol Outlets	11	0.282
Raleigh	Restaurants and Other Eating Places	155	3.968
Raleigh	Retail Food Products & Grocers; Convenience Stores	20	0.512
Raleigh	Schools	16	0.410
Raleigh	Social Services	39	0.998
Raleigh	Student Housing	7	0.179
Raleigh	Universities & Colleges & Professional Schools	43	1.101
Rocky Mount	Drinking Places (Alcoholic Beverages)	1	0.041
Rocky Mount	Low Income Housing	2	0.082
Rocky Mount	Off-Premises Alcohol Outlets	2	0.082
Rocky Mount	Restaurants and Other Eating Places	26	1.060
Rocky Mount	Retail Food Products & Grocers; Convenience Stores	25	1.019
Rocky Mount	Schools	9	0.367
Rocky Mount	Social Services	31	1.264
Rocky Mount	Universities & Colleges & Professional Schools	2	0.082
Salisbury	Drinking Places (Alcoholic Beverages)	4	0.161
Salisbury	Off-Premises Alcohol Outlets	3	0.121
Salisbury	Restaurants and Other Eating Places	116	4.662
Salisbury	Retail Food Products & Grocers; Convenience Stores	27	1.085
Salisbury	Schools	13	0.522
Salisbury	Social Services	62	2.492
Salisbury	Universities & Colleges & Professional Schools	3	0.121
Shelby	Drinking Places (Alcoholic Beverages)	1	0.049
Shelby	Off-Premises Alcohol Outlets	2	0.097
Shelby	Restaurants and Other Eating Places	73	3.549
Shelby	Retail Food Products & Grocers; Convenience Stores	22	1.070
Shelby	Schools	15	0.729
Shelby	Social Services	47	2.285
Shelby	Universities & Colleges & Professional Schools	2	0.097

Appendix F – Modeling Results (Observed Compared to Predicted Average Total Daily Events)

Site	Average Total Daily Events (Observed)	Model 1 Estimate	Observed Minus Predicted (Absolute Value)	Model 2 Estimate	Observed Minus Predicted (Absolute Value)	Model 3 Estimate	Observed Minus Predicted (Absolute Value)
Charlotte	8	14	6	18	10	10	2
Durham	16	16	0	10	6	17	1
Elon	42	-10	52	44	2	48	6
Gastonia	6	3	3	7	1	8	2
Greensboro	42	38	4	32	10	36	6
Lumberton	19	23	4	25	6	26	7
Mebane	32	28	4	32	0	30	2
Raleigh	10	17	7	25	15	23	13
Rocky Mount	20	18	2	16	4	8	12
Salisbury	2	35	33	13	11	22	20
Shelby	28	19	9	18	10	23	5
Total Observed Minus Predicted (Overall with Elon)			**124**		**75**		**76**
Total Observed Minus Predicted (Overall without Elon)			**72**		**73**		**70**