RESEARCH & DEVELOPMENT

Reduction in Railroad Right-of-Way Trespassing Incidents

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Abstract:
This research analyzed Federal Railroad Administration (FRA)-reported trespassing events along the North Carolina Railroad (NCRR) between Raleigh and Charlotte, NC using rate calculation, train crew surveys, and geospatial methods to identify communities with the highest risk of railroad right-of-way trespass. Since the FRA started geolocating trespass data in July 2011 through June 2016, this corridor had 65 reported trespasser strikes, or an average of one strike for every 677 trains. Based on an analysis of historic trespass strike data, associated environmental features, and survey data provided by train crews who travel along the portion of the NCRR under study, the communities with the highest trespass risk are Durham, Mebane, Elon/Burlington, and Greensboro. The rate of strikes from the 5 year study period indicates that these communities have the highest risk corridors. The close proximity of pedestrian generators to the railroad in these areas shows some correlation to the high number of strikes.

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1. Introduction

According to the Federal Railroad Administration (FRA), railroad right-of-way trespassing is the leading cause of death along railroads, with over 400 fatalities occurring each year (*1*). While trespassing is costly in terms of lives lost, transportation delays, infrastructure damage and operator stress, the scale of the rail network often makes it economically infeasible for railroads to 'prevent' these activities. Trespassing countermeasures include: fencing, policing, video monitoring, alternative pedestrian facilities, and education programs, all of which are only effective if utilized in trespasser areas. Field observation and historic data are currently used to inform the placement of these countermeasures. However, limited data exists, meaning many miles of railroad are without any measure of trespasser activity.

The FRA and various state governments have developed investigative index models to address safety issues at railroad at-grade crossings. These models use railroad crossing data and historic crash information to estimate absolute and relative ranking systems for high risk at-grade crossings. This method allows for objective comparison of the crossings, which in turn, is used to allot safety improvement funding. The objective of this study was to analyze historic trespasser strike information in relation to railroad and geospatial data to evaluate trespass risk for sections of a rail corridor in North Carolina from Raleigh to Charlotte. The proposed planning-level methods are intended to provide decision makers with an objective tool for evaluating trespass risk along a rail corridor.

2. Background

Railroad fatalities are classified in three general categories: fatalities occurring at or near at-grade highway/railroad crossings, fatalities to railroad employees or passengers, and fatalities due to trespassing or suicide (*1*). Data collected by the FRA is categorized and stored into these groups, and the causes and countermeasures for each are independent (*1*). At-grade fatalities (-4.6% annually) and employee/passenger fatalities (-7.2% annually) have been on the decline since the 1970's because a majority of safety improvements are focused on preventing these types of fatalities (*2*). Trespass and suicide fatalities, on the other hand, have remained nearly constant (-0.8% annually), indicating a need for additional attention (*2*). Traditionally, addressing the trespassing issue has been avoided, as the countermeasures are expensive to implement along the many miles of railroad right-of-way with little way to measure their effectiveness. Concerns about partial treatments which could result in Tort liability lawsuits also discourage addressing trespassing. Additionally the 'blame' for these fatalities is attributed to the individual, as they made a choice to trespass and in turn suffered the consequences of that action. The impact of trespasser fatalities is not just the cost of the life lost, but also includes significant railroad delay, extensive maintenance issues, and extreme work-related stress for locomotive engineers (*3*).

Trespassing and suicide fatalities are often grouped together when considering countermeasures, but in many cases, negative relationships exist between these (*4*). For example, educational campaigns that stress the extreme risk and deadly nature of trespassing could lead to idealization of a means of suicide for a distressed individual (*5*). Therefore it is necessary to consider the causes of fatalities separately and to carefully examine the interaction between countermeasures.

Trespassing in terms of railroad right-of-way is defined as crossing railway lines that are not marked for crossing, walking along railroad tracks, or loitering in the right-of-way (*4*). Vandalism is another form of trespassing, which must be addressed through enforcement as vandals are likely to navigate around countermeasures (*4*). Trespassing is illegal on railroads, and results in more than 400 annual fatalities in the United States (*1*). Trespass reduction also requires a multifaceted approach, with engineered countermeasures to reduce access, educational campaigns / signage to inform potential trespassers of the risk and legality of their actions, enforcement to respond to hot spot locations, and safe, convenient alternative access (*6*).

Characteristics of the Average Trespasser Fatality

Information regarding the exact circumstances of each trespass-related fatality is difficult to determine due to limitations in the data collection process. Nonetheless, general demographic information is collected, and this information can help to create the profile of a typical trespasser fatality. Demographic profiles of typical trespassers can help to target countermeasures and possible trespass locations. Three demographic studies were identified in the literature that were conducted in Finland, Canada and the United States, respectively. While the rail systems and land use in these countries varies significantly, the studies indicate the typical trespasser fatality is a 20 to 40 year old male, who is intoxicated during the weekend or nighttime.

A 2012 study by Silla and Luoma in Finland examined 311 trespasser and suicide fatality records to find relationships between demographic factors and event information. It should be noted that suicide accounts for a much larger percentage of right-of-way fatalities in Finland than in other countries. The average Finish trespasser is a younger male, intoxicated on the weekend. These events most commonly take place in areas with high population density and high train frequency, and suicide victims are generally waiting on the tracks (*3*).

Research at the Université du Québec à Montréal began as a metro suicide intervention project (*7*). However, it expanded to include all trespasser fatalities and now focuses on the impact of trespasser strikes on train crews. 1134 trespasser incidents were reported from 1999-2008 by the Transportation Safety Board, Canadian National Railroad, and Canadian Pacific Railroad – 40.6% were accidental and 37.7% were accidental or determined to be suicide, respectively, while the remainder are undetermined or missing information. Several common demographics were identified for suicide and accident victims. *Suicide victims* were 70% men, with 46% under the influence of substances prior to the strike. Twenty two percent were under psychiatric care with 35% of the events taking place within two miles of a psychiatric facility. Victims were typically struck by passenger trains. These incidents happened away from stations on the tracks. *Accidental victims* were 70% men, with 73% having used substances prior to the strike. Most strikes happened at crossings and in rural settings involving freight trains. A majority also happened during the night. In general, most accidental victims are either children, older persons under the influence of drugs or alcohol, or on the tracks during the night.

The FRA contracted North American Management Company to analyze 2,749 trespass fatality reports from the United States between 2005 and 2010 (*8*). Additional information was gathered from coroners and chief medical examiners responsible for filling out FRA forms through a separate follow up survey. Based on these results, the average age of a victim is 38 years, with two thirds of fatalities occurring between ages 20 and 49. Eighty-one percent were white, and generally had lower income and educational levels. Eighty-two percent of the fatalities were male, with half involving drugs or alcohol. Demographic data was collected based on the listed address of the deceased using consumer psychographic data. Incidents were classified into 12 categories of what the trespasser was doing at the time of the incident including walking across the track, on a bridge, using ATV vehicle, hitching a ride on a train, sleeping, suicide, and walking along the track. Based on the marketing data, trespassers are most likely to be renters in large cities with lower incomes and education levels (*8*). Another common group is rural homeowners with lower income that are married with no children or empty nesters.

3. Trespassing Models

The Long Island Railroad created a prioritization algorithm to assign relative risk for four-mile-long sections of 95 miles of track (*9*). This algorithm weighs historical information on fatalities, both accidental (10 points) and suicide (5 points), debris strikes (2 points) and trespass reports (1 point) to determine the risk of trespass in a given segment. The segments were then grouped into four priority categories, with three of the sections ranking as highest priority. These locations are in close proximity to schools, parks, homeless camps, graffiti, or trails.

A geospatial model has been developed in the United Kingdom to predict suicide events at passenger rail stations and grade crossings (*10*). The model examines a portion of the UK rail network and evaluates the relative risk of fatalities along 30 meter sections of rail corridor based on local factors. Ultimately the model focus is on grade crossings and stations, where a majority of pedestrian/train interactions take place. The model evaluates the risk for crossings based on various railroad characteristics: number of trains, local land use, crossing protection, and train interval. Station risk is determined by the number of entrances and exits, percent of non-stopping trains, station type, percentage of tracks with adjacent platforms and percentage of season ticket holders. A generalized linear model was developed using these statistically significant variables.

The Volpe Center completed an analysis of trespasser risk along the railroad right-of-way in West Palm Beach, Florida using hazard identification and a prioritization algorithm (*11*, *12*). The study focused on the interaction of collision risk and countermeasure effectiveness for various trespass behaviors. The study right-of-way was divided into 34 segments with grade crossings as segment end points, and the track between grade crossings as segments. Field observation and stakeholder feedback were used to identify hazardous geographical attributes for each segment. Risk was examined as a function of frequency and severity, and various data sources were used to identify the frequency of trespasser events. FRA incident data, law enforcement records, train crew observations (along with locomotive video review), and field observations made up the frequency dataset. The prioritization algorithm scores the risk by evaluating the severity of each trespassing incident by categorizing the incident into four types: fatal, fatal suicide and attempted suicides, debris strikes, and trespasser reports. Trespasser reports are broken into two categories, walking along the track and crossing the track, with the higher risk score assigned to crossings. Each of these events has a weight, as outlined in the Long Island Rail Road method and a total score is calculated based on the sum of all events. Four classes of risk were developed, from high risk to negligible risk, to group the segments and in turn to determine which locations need priority attention.

A presentation by the Volpe National Transportation Systems Center at the 2012 Trespass Prevention Workshop outlined current research to develop a GIS mapping tool to track incidents, identify causes, and evaluate the effectiveness of countermeasures (*14*). Using geospatial data allows information to be stored graphically, visually providing locations of high risk. Data used in the tool includes: demographics of the 'average' trespasser, intentional versus unintentional, hospitals, schools, parks and playgrounds, grade crossings, quiet zones, date of incident, time of day, and location. Several data issues are identified, including that FRA data before June 2011 is only specified to the county level and that the data is generally inconsistent due to reporting methods. Involvement of stakeholders, additional data sources, and tool design are the future steps for the research.

4. Methodology

The FRA began recording geolocated trespass data in 2011. These historic trespass events are a clear indicator of high risk trespassing areas since they represent injuries or fatalities resulting from train strikes. The information recorded in the FRA database can be decoded using the FRA's Guide for Preparing Accident/Incident Reports (*13).* Using this guide, the trespass data was decoded and compared to the typical trespasser demographic found in the literature. Fields of interest include: age, month, time of day, railroad, county, physical action, fatality, and type of event. Additional records were provided by NCDOT and were integrated into the dataset. This analysis allows for overarching characteristics to surface and also provides insight into potential countermeasures.

The Raleigh to Charlotte corridor was divided into one mile segments based on milepost. Mileposting is the linear reference system used along railroads, increasing from the beginning of a corridor. Mile posts are typically one mile apart, but due to changes in alignment, some variation is common. The resolution of the analysis is defined by the number of segments per window, and several resolutions were analyzed. Depending on the environment around the railroad, coarse or fine resolution may be desired. In urban areas with high environmental diversity, a finer resolution of one milepost per segment or smaller would provide a more precise description of trespassing compared to rural areas. A continuous system was considered but ruled out due to the clustering of the trespass incident data. The finest resolution of data was defined as 1 mile segments roughly based on the milepost. From this starting point, 3, 5, and 10 mile windows were used to aggregate the segment data into community or regional groups. Figure 1 shows how the segments were aggregated into windows.

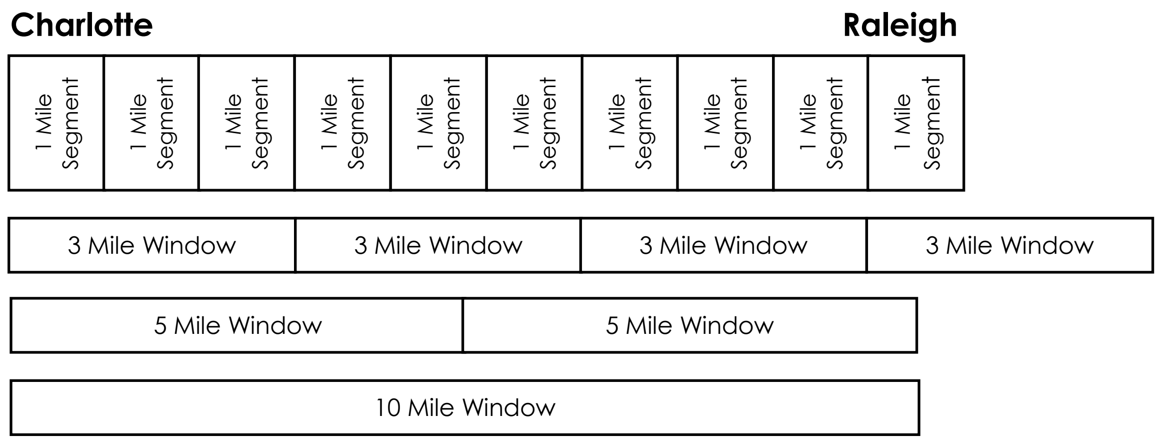

FIGURE 1 Diagram of segments and windows used for the analysis.

Two methods were used to analyze this data: (1) strike per causal variable rates, and (2) geospatial analysis using strike locations from FRA data and trespass locations from train crew survey data. The strike per causal variable rates divide the number of segment strikes by each potentially causal variable for information such as number strikes per population density. This is intended to show how the risk of each site compared. For example the highest number of strikes per population density would indicate a higher proportion of strikes per capita. A geospatial analysis in relation to strike locations and train crew observations of trespassing activity additionally corroborates or supplements locations that have been identified as high risk for railroad right-of-way trespassing through the correlation and strike rate analyses.

Train crew surveys were developed to gather observational data along the corridor. Train crews travel the corridor frequently and have a firsthand look at the conditions of the track. A graph was provided in the survey that shows milepost of the track along the x axis and a relative scale of trespass activity from 0-5 along the y axis, with 0 representing no observed activity and 5 representing extremely frequent trespass activity. The survey also asks crews to identify known hot spot locations and typical characteristics of the trespassers they observe. This data provides critical contextual support for pinpointing high risk areas for railroad right-of-way trespassing. Six Amtrak crews were surveyed in total. The survey responses were compared to the historic FRA incident data and analyzed in relation to key features along the railroad corridor including fencing breakpoints, at-grade crossings, rail bridges, and local attractors to identify high trespass locations for further study. Specific locations were identified such as goat paths and general problematic areas were highlighted by milepost in GIS. Each time a crew identified a milepost as a high trespass area, the highlighted section increased in line weight. For example, a section identified twice is twice as thick as one identified only once. This created a heat map of where the most commonly observed problematic areas are located.

Peak searching was employed when deriving the strike per causal variable rates. Peak searching is a technique that starts with small segments of a dataset, and aggregates the data into larger and larger groups until the data meets desired thresholds. In this case the finest resolution of data is 1 mile segments roughly based on the milepost. From this starting point, 3, 5, and 10 mile windows were used to aggregate the segment data into community or regional groups. For example, if a 5 mile window had one strike in each segment, the 5 mile rate would be much higher than an isolated two strike segment. To account for variations in the exposure along the corridor, the strike rate is used instead of just the number of strikes. The strike rate is the number of strikes per 1000 trains, derived from the number of trains that travel each segment over the course of the study period. The number of trains per day can be found using the FRA crossing database. Once the highest risk areas are identified, an in depth geospatial analysis of potential causal variables allows for more detailed understanding of the most problematic areas.

The number of strikes per 1000 people along the corridor is calculated using the following equation:

$$\frac{Strikes}{1000\ People} = \frac{Strikes}{Segment} * \frac{Segment}{Miles\ Long * Miles\ Wide} * \frac{Square\ Mile}{Population} * 1000$$

The first term describes the number of strikes per segment, the second term describes the length and width of the study corridor, and the third term is the inverse of population density.

Several datasets were attributed to the segments to identify common features in areas associated with high trespass risk. Table 1 shows the datasets used, how the data was categorized, and the expected influence of the data on trespass risk. The data were gathered from various sources, including a review of corridor video provided by NCDOT. The data were organized and analyzed by the windows composed of aggregated segment data.

TABLE 1 GIS Data Sources, Data Types, and Estimated Influence

DATA SET	DATA SOURCE	TYPE	EVIDENCE / PREDICTIVE	INFLUENCE
STRIKES	FRA & NCDOT Records	Count	Evidence	(++) Most objective measure of problem areas
TRAIN CREW SURVEYS	Amtrak Crews	Scalar	Evidence	(+) First-hand account of problematic areas
CORRIDOR VIDEO REVIEW	NCDOT Video	Binary	Evidence	(+) Visual evidence of paths, graffiti or camps
GRADE CROSSINGS	FRA Grade Crossing Data	Count	Predictive	(+) Crossings provide access to the right-of-way
TRAIN VOLUME	FRA Grade Crossing Data	Scalar	Predictive	(+) Train volume determines the exposure on the tracks
TRAIN SPEED	FRA Grade Crossing Data	Scalar	Predictive	(+) Faster trains reduces the time to detect and avoid the train
FENCING	Video Review	Binary	Predictive	(-) Fencing should reduce access

PASSENGER STATIONS	NCDOT Rail Facilities Shapefile	Binary	Predictive	(+) Stations inherently cause people to be near the tracks
POPULATION DENSITY	2010 US Census Tract Data (Summary File 1)	Scalar	Predictive	(+) More people are near the tracks
MEDIAN HOUSEHOLD INCOME	2013 US Census Tract Data (2009-2013 5-Year ACS Estimates)	Scalar	Predictive	(-) People typically drive more with increased wealth
PUBLIC SCHOOLS	County GIS Data/Google Maps	Count	Predictive	(+) Young people are risk averse, and likely to take short cuts
COLLEGES/ UNIVERSITIES	Google Maps	Count	Predictive	(+) Young people are risk averse, and likely to take short cuts
COMMERCIAL SERVICES	County Tax Parcels	Count	Predictive	(+) Food & drink service generates pedestrian traffic

Video evidence is a binary variable that indicates that visual evidence of paths, graffiti, or camps exist in the segment from the NCDOT corridor video. The number of grade crossings per window was counted from the FRA grade crossing inventory. The train volume and speed values are averages of the values shown in the FRA grade crossing inventory for each window. Fencing is a binary variable that indicates that access to the right of way is restricted either by grade, landscaping, or fencing based on the NCDOT video review. The count of passenger stations was extracted from a GIS layer provided by NCDOT that contains rail facility point features. The population density and median household income are values taken from census data based on the nearest census tract (within 0.25 miles of the NCRR track). For windows encompassing multiple census tracts, an average was calculated. The count of public schools, colleges, and universities within one half mile of the window are based on county GIS data or Google Maps data. The count of commercial services within one quarter of a mile of the window are based on county tax parcels or Google Maps data and includes bars, restaurants, convenience stores, gas stations and strip malls. Other potential variables that were considered but not analyzed include: parks (not evident in literature), transit facilities (unable to locate GIS data), car ownership (household income provides surrogate measure), land cover (data not available at the desired scale), and number of railroad tracks (not in literature).

5. Results

5.1. Trespasser Demographics

The characteristics of the 65 trespasser strikes were analyzed based on the FRA recorded data from July 2011 through June 2016 (5 years). All of the strikes within 150 feet of the NCRR corridor between Raleigh and Charlotte were included in the analysis in order to account for geolocation error.

Of the 65 strikes, 47 were fatal (72%), which is lower than the typical rate of 90% found in the literature. Amtrak trains struck 37 of the 65 trespassers, or 57%, which indicates a higher rate of strikes for passenger trains as there are on average 8 passenger trains per day compared to the 28 strikes by freight trains which average 20 trains per day. This is likely due to the higher speed of passenger trains, as trespassers would have less time to notice and avoid these trains. The geographical distribution of the strikes is shown in Table 2 as the number of strikes for each county along the study corridor. This will be discussed in more depth in the geospatial analysis section.

TABLE 2 Number of Strikes per County

County	MECKLENBURG	CABARRUS	ROWAN	DAVIDSON	GUILFORD	ALAMANCE	ORANGE	DURHAM	WAKE
Number of Strikes	2	5	7	5	17	14	3	10	2
	WEST	→	→	→	→	→	→	→	EAST

Table 3 provides the characteristics of the trespassing incidents by month of year that they occurred. With the exception of January, the yearly distribution follows the trends found in the literature, with more strikes during the summer months. The time of day shows that most strikes happen during the midday travel hours. A large number of strikes also occurred during the PM peak and the evening travel hours. The AM peak had the fewest strikes. Alcohol and drug use data were not available, but it is suspected that the nighttime strikes would correlate with alcohol and drug use.

The average trespasser age is 35 years old, which is in line with the US average trespasser age of 38 years old. The largest number of trespassing incidents involved 18 to 25 year olds, and most trespassers were 20 to 40 years old. This general age distribution mirrors the trends described in the literature. No gender information is provided in the FRA data, so an additional analysis of age and gender relationships is not included.

TABLE 3 Characteristics of Trespassing Incidents by Month of Year

	Month of Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
Age	Unknown			1		1					1			3
	<18			1			1		1					3
	18-25	5		1	3	3	1			3	1			17
	26-35	2	1		1	1	1	1	3	1			1	12
	36-45	2			1	1	1	2	1	1		1		10
	46-55	1	2			1		3	1			1		9
	56-65	1					1	2			2	1	1	8
	>65	1				1							1	3
TOTAL		**12**	**3**	**3**	**5**	**8**	**5**	**8**	**6**	**5**	**4**	**3**	**3**	**65**
Physical Action	Climbing Over/On					1			1	1				3
	Driving						1					1	2	4
	Laying	1			1	1	1	2			1			7
	Riding	2	1											3
	Sitting				1			2	1	1				5
	Standing		1	1	1	1	1		3		1			9
	Walking	9	1	2	1	5	2	4	1	3	2	2	1	33
	Jumping From				1									1
TOTAL		**12**	**3**	**3**	**5**	**8**	**5**	**8**	**6**	**5**	**4**	**3**	**3**	**65**
Event Type	Highway-rail collision/impact	2	1				1	1			1	2	1	9
	Slipped, fell, stumbled, other				2				1	1				4
	Struck by on-track equipment	10	2	3	3	7	4	7	5	4	3	1	2	51
	Other					1								1
TOTAL		**12**	**3**	**3**	**5**	**8**	**5**	**8**	**6**	**5**	**4**	**3**	**3**	**65**
Time of Day	Nighttime (0000-0600)	2			1	1		2	3		1			10
	AM Peak (0601-1000)				2	2	1	1					1	7
	Midday (1001-1500)	4		1	2	3	1	2	1	2	1	2	1	20
	PM Peak (1501-1900)	5	1	1		1	2	1	1	1	1			14
	Evening (1901-2400)	1	2	1		1	1	2	1	2	1	1	1	14
TOTAL		**12**	**3**	**3**	**5**	**8**	**5**	**8**	**6**	**5**	**4**	**3**	**3**	**65**

The physical action at the time of the strike and the type of event are provided in Table 3 by month of year and in Table 4 as a crosstab. The most common actions are walking along the tracks (51%), standing (14%), or laying (11%). The West Palm Beach study (*12*) divides the walking category into crossing the tracks, or walking along the tracks, but this distinction is not possible with the current data set. If this could be retrieved from the accident reports, some consideration for the types of countermeasures could be derived. For example, if a location has strikes related to crossing the tracks, alternative pedestrian facilities may be most appropriate.

TABLE 4 Distribution of Physical Action and Event Type at Time of Strike

PHYSICAL ACTION/TYPE OF EVENTS	Highway-rail collision/impact	Slipped, fell, stumbled, other	Struck by on-track equipment	Other	TOTAL
Climbing Over/On		2		1	**3**
Driving	3		1		**4**
Laying			7		**7**
Riding	3				**3**
Sitting			5		**5**
Standing			9		**9**
Walking	3	1	29		**33**
Jumping From			1		**1**
TOTAL	**9**	**3**	**52**	**1**	**65**

5.2. Strike Rate Analysis

The rail corridor was divided into 1 mile equal length segments resulting in 174 total segments. The segments are numbered from 1 to 174, with 1 originating at the Raleigh Amtrak station and 174 originating at the Charlotte Amtrak station. This segment length was selected as a compromise between resolution and coverage, and the choice facilitates entering railroad information which is in milepost. To focus the scope of the study, historical evidence of trespassing (FRA reported strikes) was used to identify communities or segments with frequent trespassing. Peak searching was used to identify the highest strike rate based on FRA train volumes. In 5 years, an estimated 44,000 trains ran on the corridor, resulting 65 strikes, or 1 strike per 677 trains. Four different window sizes were used (1 mile, 3 mile, 5 mile and 10 mile) which were described previously in Figure 1. Fractional windows containing the remaining segments are located at the Raleigh end of the corridor.

Using the 1 mile window, one site had four strikes (#26 west of Durham) and seven sites had 3 strikes (#27 west of Durham, #50 Mebane, #60 Elon College/Burlington, #62 Elon College/Burlington, #79 Greensboro, #80 Greensboro, and #103 Mebane), with a higher rate in Durham due to lower train volumes. Of the 174 total segments, only 43 (25%) had recorded strikes, resulting in 131 sites with no strikes. As long as trains are running on the tracks there will always be a nonzero level of risk for trespass strikes. However, the sporadic nature of these events makes it difficult to draw conclusions about trespass risk for most of the corridor at this resolution since no strike information is available.

The data were aggregated in 3, 5, and 10 mile windows to identify target regions. The tradeoff between precision of analysis and aggregated data enables a wider perspective of trespass risk at the community or regional level. As more data becomes available about the corridor, the resolution could be increased. Table 5 provides information about the number of segments, the number of nonzero strike segments, average number of strikes, average strike rate per 1000 trains, and the standard deviation for the four window sizes. Table 5 also provides the information for the communities and their associated rail segments with the highest strike rates based on the analysis windows.

TABLE 5 Data Summary by 1, 3, 5, and 10 Mile Windows

Window Size (Miles)	**1**	**3**	**5**	**10**
Number of Segments	174	58	35	18
Nonzero Segments	43 (25%)	33 (57%)	26 (74%)	16 (89%)
Average Number of Strikes	0.37	1.12	1.86	3.61
Standard Deviation	0.78	1.57	2.06	3.26
Average Strike Rate (Per 1000 Trains)	0.013	0.029	0.047	0.091
Standard Deviation	0.022	0.047	0.061	0.094
Highest Strike Rate (*Segment Number(s), Community, Rate*)	#26 Durham (0.14)	#26-28 Durham (0.27)	#26-30 Durham (0.31)	#22-31 Durham (0.34)
2nd Highest Strike Rate (*Segment Number(s), Community, Rate*)	#27 Durham, #50 Mebane, #62 Elon/Burlington (0.10)	#60-62 Elon/Burlington (0.18)	#59-63 Elon/Burlington (0.26)	#57-66 Elon/Burlington (0.30)
3rd Highest Strike Rate (*Segment Number(s), Community, Rate*)	#79 Greensboro (0.08)	#48-50 Mebane (0.17)	#46-50 Mebane (0.21)	#43-52 Mebane, #77-86 Greensboro (0.21)

As expected, aggregating the data increases the percentage of nonzero segments allowing for a better comparison between segments. The 3 mile window provides the largest increase in nonzero segments, while the 5 mile segment divides the corridor into segments with roughly one strike a piece. The frequency and rate of strikes tend to increase by the same factor as the window size increase. The standard deviation does not change to a great extent based on the size of the window. Based on the number of FRA recorded trespassing-rated strikes for the study period, the community (3, 5, and 10 mile windows) with the highest strike rate per 1000 trains is Durham, and the one mile segment with the highest strike rate is located in West Durham.

5.3. Geospatial Analysis

Table 6 provides a summary of the GIS, corridor video review, and FRA data used in the analysis. The segments and windows are selected based on the strikes rates. The individual segments show the characteristics of the worst sites, while the windows show the characteristics of the surrounding communities. Regression to the mean indicates that the worst case locations are likely to see a reduction in rate towards the mean in the future. Therefore if only these worst case sites are addressed, adjacent locations that have similar characteristics could be overlooked. These adjacent sites are statistically more likely to see events in the future. Looking at the wider windows allows for the communities' characteristics to be evaluated instead of simply the worst one mile segment. The top ten sites with the highest strike rates are included in the 10 mile window groups, though several of the sites are grouped together at this level.

TABLE 6 GIS, FRA, and Corridor Video Review Data

Community/Segment Number		FRA STRIKES	VIDEO EVIDENCE	GRADE CROSSINGS	TRAIN VOLUME	TRAIN SPEED (MPH)	FENCING	PASSENGER STATIONS	AVERAGE POPULATION DENSITY PER SQ MI (2010)	AVERAGE MEDIAN HOUSEHOLD INCOME (2013)	PUBLIC SCHOOLS	COLLEGES/UNIVERSITIES	COMMERCIAL SERVICES
Durham	#26	4	1	2	16	60	1	1	3,630	$29,384	2	0	6
	#26-28	8	1	8	16	60	1	1	4,704	$27,381	7	2	24
	#26-30	9	1	10	16	60	1	1	3,929	$35,350	7	2	41
	#22-31	10	1	16	16	60	1	1	3,456	$37,402	8	2	50
Burlington	#62	3	0	2	16	60	1	1	1,786	$38,408	1	1	7
	#60-62	5	0	5	18	60	1	1	2,320	$33,669	1	1	21
	#59-63	9	0	9	19	55	1	1	2,309	$40,527	1	2	24
	#57-66	10	0	16	18	57	1	1	1,880	$43,487	5	2	36
Mebane	#50	3	0	3	16	60	0	0	713	$49,554	2	0	6
	#48-50	4	0	4	16	60	0	0	713	$49,554	2	0	11
	#46-50	5	0	6	16	60	0	0	713	$49,554	2	0	11
	#43-52	6	0	10	16	62	0	0	605	$50,054	3	0	11
Greensboro	#79	2	1	3	20	59	1	0	2,802	$26,935	2	2	8
	#77-86	10	1	13	26	67	1	1	3,460	$29,934	13	4	94

Table 7 takes the various count variables in Table 6 and divides them by the length of each window to develop a rate per mile comparison of the windows. The data is sorted by community and strikes per mile per segment (FRA Strikes). The highest strike rate segments are located in Durham (#26), Burlington (#60), and Mebane (#50). The Durham and Burlington locations have passenger stations. Mebane (#50) and Greensboro (#79) have the highest number of grade crossing per mile, while Durham (#26-28) has the highest number of public schools within one half mile. Greensboro (#79) has the highest number of college and universities within one half mile and the highest number of commercial services within one quarter mile (#77-86). In general, the highest strike rate locates relate to areas with high numbers of pedestrian generators, either passenger stations, schools, colleges, or commercial services.

TABLE 7 Count Variables per Mile for Each Dataset

Community/Segment Number		SEGMENTS	FRA STRIKES	GRADE CROSSINGS	PASSENGER STATIONS	PUBLIC SCHOOLS	COLLEGES/UNIVERSITIES	COMMERCIAL SERVICES
Durham	**#26**	1	4.0	2.0	1.0	2.0	0.0	6.0
	#26-28	3	2.7	2.7	0.3	2.3	0.7	8.0
	#26-30	5	1.8	2.0	0.2	1.4	0.4	8.2
	#22-31	10	1.0	1.6	0.1	0.8	0.2	5.0
Burlington	**#62**	1	3.0	2.0	1.0	1.0	1.0	7.0
	#60-62	3	1.7	1.7	0.3	0.3	0.3	7.0
	#59-63	5	1.8	1.8	0.2	0.2	0.4	4.8
	#57-66	10	1.0	1.6	0.1	0.5	0.2	3.6
Mebane	**#50**	1	3.0	3.0	0.0	2.0	0.0	6.0
	#48-50	3	1.3	1.3	0.0	0.7	0.0	3.7
	#46-50	5	1.0	1.2	0.0	0.4	0.0	2.2
	#43-52	10	0.6	1.0	0.0	0.3	0.0	1.1
Greensboro	**#79**	1	2.0	3.0	0.0	2.0	2.0	8.0
	#77-86	10	1.0	1.3	0.1	1.3	0.4	9.4

The population density per square mile from census tract data was used to calculate the number of strikes per 1000 people living within one quarter mile of the rail. The number of strikes per 1000 people living within one quarter mile of the rail is shown in Table 8. A one mile rail segment in Mebane (#50) has the highest number of strikes per 1000 population at 8.42. The location with the next highest number of strikes per 1000 population is also in Mebane (#48-50) at 3.74.

TABLE 8 Strikes per 1000 People Living Within 0.25 Miles of the Rail

Community/Segment Number		STRIKES PER 1000 PEOPLE
Durham	#26	2.20
	#26-28	1.13
	#26-30	0.92
	#22-31	0.58
Burlington	#62	3.36
	#60-62	1.44
	#59-63	1.56
	#57-66	1.06
Mebane	#50	8.42
	#48-50	3.74
	#46-50	2.81
	#43-52	1.98
Greensboro	#79	1.43
	#77-86	0.58

An additional geospatial analysis of various features along the railroad corridor was preformed using web-based mapping. This analysis combined historic FRA incidents and train crew surveys to identify high trespass locations for further study. Using the FRA incident locations, several derivative measures were gathered for each location including distance to parallel roads, fencing breakpoints, at-grade crossings, rail bridges, and local attractors.

Greensboro had the highest number of train crew survey responses as a problematic area, with one crew saying this area is the 'worst place I've ever seen.' Trespassers are observed every trip by the crews, along with eight historic strikes. While this high level study cannot provide a treatise on why trespassing is such an issue within Greensboro, it can identify locations where further efforts of education, enforcement or engineering could be fruitful.

Just east of the Greensboro train station, a well-established goat path connects two secondary roadways. This path is parallel to a multilane freeway facility with grade separated intersections and steep embankments. A resource center for those experiencing homelessness is located nearby and accessible via the goat path. While the connection between the two secondary roadways using the designated at-grade crossing is less than a half mile long, the shortcut along the goat path is a quarter of the distance at around 500 feet long.

6. Conclusions and Recommendations

Several methods for examining high risk trespass areas are discussed, each providing insight into potential causal factors that may contribute to trespassing. High risk communities are identified along the NCRR between Charlotte and Raleigh based on historic FRA & NCDOT trespass strike data. A peak search of the strike rate is developed at a 1 mile resolution and aggregated to 3, 5, and 10 mile windows. Geospatial data was analyzed in the highest risk communities to identify potential locations for installing a detection countermeasure as a future phase of this project. Evidence gathered from the detection system can then be used to verify the observations from the data.

Trespasser demographics follow the trends established in the literature review concerning age, time of day, time of year, and action at the time of the event. The average trespasser strike victim on the NCRR is 35 years old, during the PM peak or evening travel period, during the month of January or summer, and walking along the track. Information regarding gender, education levels, drug and alcohol use were not available in the data. Over the 5 year (July 2011–June 2016) study period, an estimated 44,000 trains traveled the corridor resulting in 65 strikes, or 1 strike every 677 trains.

The corridor was divided into 174 one mile segments with aggregate analysis windows of 3, 5, and 10 miles. The individual segments help to identify the highest risk spots, while the larger windows draw attention to the highest risk communities. The 1 mile segment provides high resolution and help pinpoint the highest trespass risk locations, while the 3 and 5 mile windows help capture the communities with the highest trespass risk.

The highest strike rate segment is #26 located in West Durham, and the highest strike rate 3, 5, and 10 mile windows are also located in Durham (#26-28, #26-30 and #24-33, respectively). Mebane, Burlington, and Greensboro also have high strike rates. The population density per square mile from census tract data was used to calculate the number of strikes per 1000 people living within one quarter mile of the rail. The segment with the highest number of strikes per 1000 people is in Mebane (#50) with 8.42. The next highest segment is also in Mebane (#48-50) at 3.74.

Geospatial data was gathered for the high strike rate locations from US census, county parcel, and FRA datasets, as well as a corridor video review. Count variables like grade crossings, passenger stations, public schools, colleges/universities, and commercial services were divided by the window length to get rates or counts per mile. Durham, where the highest strike rate segment (#26) is located, has a passenger station and high numbers of grade crossings, public schools, and colleges/universities. Burlington, where second highest strike rate segment (#62) is located, has a passenger station and a high amount of commercial services. Greensboro, where the third highest strike rate segment (#79) is located, has the most commercial services within one quarter mile, and the second most grade crossings and public schools within one half mile. Based on the analysis of historic trespass strike data, associated environmental features, and survey data provided by train crews who travel along the NCRR between Raleigh and Charlotte, NC, the communities with the highest trespass risk are Durham, Mebane, Elon/Burlington, and Greensboro. The rate of strikes from July 2011-June 2016 indicates that these communities have the highest risk segments along with high risk windows. The close proximity of pedestrian generators to the railroad in these areas tends to relate to the high number of strikes. These communities should be analyzed for installation of countermeasures. The exact location of such countermeasures should depend on the type of technology and the intended target trespasser.

Future research efforts should evaluate characteristics along the whole corridor to avoid selection bias and to gain a more comprehensive understanding of the factors that influence trespass. With more rigorous statistical evaluation, a general model could be developed to estimate the trespass risk in a community based on causal factors, similar to the investigative indexes used for grade crossing safety. However, the methods discussed and developed here provide insight on how to use historic and geospatial data to identify high risk locations. These methods should be replicated on other corridors to continue to refine their predictive nature. As more data is collected, either from strike information, or train crew surveys, these methods could be reapplied to the corridor to update to the current state of trespassing on the corridor.

7. Acknowledgements

This research was funded by the North Carolina Department of Transportation (NCDOT). The authors would like to specifically thank Richard Mullinax for his guidance throughout this project.

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Appendix A: GIS Sources

DATA SET	Mebane / Greensboro	High Point	Burlington	Durham
FRA Strikes	FRA Trespasser strikes from 2011-2016.	FRA Trespasser strikes from 2011-2016.	FRA Trespasser strikes from 2011-2016. Added additional point to dataset on #60 for 03/2015 from NCDOT Rail data.	FRA Trespasser strikes from 2011-2016.
Grade Crossings	At-grade crossings from FRA Grade Crossing Data.	At-grade crossings from FRA Grade Crossing Data.	At-grade crossings from FRA Grade Crossing Data.	At-grade crossings from FRA Grade Crossing Data.
Train Volume	Average trains per day from FRA Grade Crossing Data.	Average trains per day from FRA Grade Crossing Data.	Average trains per day from FRA Grade Crossing Data.	Average trains per day from FRA Grade Crossing Data.
Train Speed	Timetable speed in mph from FRA Grade Crossing Data.	Timetable speed in mph from FRA Grade Crossing Data.	Timetable speed in mph from FRA Grade Crossing Data.	Timetable speed in mph from FRA Grade Crossing Data.
Passenger Stations	Passenger stations from 2014 NC Rail Facilities shapefile from NCDOT Rail Division.	Passenger stations from 2014 NC Rail Facilities shapefile from NCDOT Rail Division.	Passenger stations from 2014 NC Rail Facilities shapefile from NCDOT Rail Division.	Passenger stations from 2014 NC Rail Facilities shapefile from NCDOT Rail Division.
Population Density (2010)	Average Population Density per square mile from 2010 US Census parcel data (U.S. Census Bureau, 2010 Census Summary File 1).	Average Population Density per square mile from 2010 US Census parcel data (U.S. Census Bureau, 2010 Census Summary File 1).	Average Population Density per square mile from 2010 US Census parcel data (U.S. Census Bureau, 2010 Census Summary File 1).	Average Population Density per square mile from 2010 US Census parcel data (U.S. Census Bureau, 2010 Census Summary File 1).
Population Density (2013)	Average Population Density per square mile from 2013 US Census parcel data (U.S. Census Bureau, 2009-2013 5-Year American Community Survey Estimates).	Average Population Density per square mile from 2013 US Census parcel data (U.S. Census Bureau, 2009-2013 5-Year American Community Survey Estimates).	Average Population Density per square mile from 2013 US Census parcel data (U.S. Census Bureau, 2009-2013 5-Year American Community Survey Estimates).	Average Population Density per square mile from 2013 US Census parcel data (U.S. Census Bureau, 2009-2013 5-Year American Community Survey Estimates).
Household Income (2013)	Average Median Household Income from 2013 Census parcel data (U.S. Census Bureau, 2009-2013 5-Year American Community Survey Estimates).	Average Median Household Income from 2013 Census parcel data (U.S. Census Bureau, 2009-2013 5-Year American Community Survey Estimates).	Average Median Household Income from 2013 Census parcel data (U.S. Census Bureau, 2009-2013 5-Year American Community Survey Estimates).	Average Median Household Income from 2013 Census parcel data (U.S. Census Bureau, 2009-2013 5-Year American Community Survey Estimates).

Public Schools	2013 Alamance County Schools shapefile provided by Alamance County GIS. No shapefile found for Orange County Schools, but Google Maps was used. E.M. Yoder Elementary and Efland-Cheeks School are within 0.5 mile of the rail line for #46-50. 2013 Guilford County Parcels shapefile provided by Guilford County GIS used to find public school locations in Greensboro area. Washington Montessori, Random Woods School. Weaver Academy, Otis L Hairston Middle, WM Hampton Elementary, Hunter Elementary, Bessemer Elementary, and Pilot Elementary are within 0.5 mile of the rail line for #77-81.	Google Maps used to find public school locations for #101-103 in the absence of schools polygon or point shapefiles for Davidson County. 2013 Guilford County Parcels shapefile used to find public school locations for #94-103.	2013 Alamance County Schools shapefile provided by Alamance County GIS. Broadview Middle School, Hillcrest Elementary, and Elon College Elementary are within 0.5 mile of the rail line.	2013 Durham County Schools shapefile provided by Durham County GIS. Burton Elementary, E.K. Powell Elementary, George Watts Elementary, Durham School of the Arts, and W. G. Pearson Middle are within 0.5 mile of the rail line.
College / Universities	No colleges or universities are located within 0.5 mile of the rail line for #46-50. UNC-G, NC A&T, and Guilford Technical Community College are located within 0.5 mile of the rail line for #77-81.	Davidson County Community College is located within 0.5 mile of the rail line #101-103.	Elon University and the Burlington School are located within 0.5 mile of the rail line.	Duke University and Durham Technical Community College are located within 0.5 mile of the rail line.

Bars / Restaurants / Convenience Stores / Gas Stations / Strip Malls	2013 Alamance County Parcels shapfile used to find locations within 0.25 mile of the rail line for #50. Google Maps used to find locations within 0.25 mile of the rail line for #46-49. 2013 Guilford County Parcels shapefile used to find locations within 0.25 mile of the rail line for #77-81.	2013 Guilford County Parcels shapefile used to find locations within 0.25 mile of the rail line for #94-99. Google Maps used to find locations within 0.25 mile of the rail line for #100-103.	2013 Alamance County Parcels shapefile provided by Alamance County GIS. Location within 0.25 mile of the rail line.	2013 Durham County Parcels shapefile provided by Durham County Office of Tax Administration. Location within 0.25 mile of the rail line.

Appendix B: Train Crew Survey

Railroad Trespass Activity Survey: Charlotte to Raleigh

Please Return Completed Surveys to: Chris Cunningham
Mail: ITRE at North Carolina State University
Centennial Campus, Box 8601
Raleigh, North Carolina 27695-8601
Fax: 919-515-8898
Email: cmcunnin@ncsu.edu

Return By: March 6th, 2015

Researchers at North Carolina State University are working with the NCDOT Rail Division to develop a model to predict high risk trespass areas along railroad right-of-ways with the possibility of addressing this issue with future safety programs. Trespassers are defined as someone on railroad property without permission crossing or walking along the tracks. The goal is to better understand where trespass issues are, and what type of trespass is occurring (hunting, fishing, short cut). This model will use various information about the railroad and the land use around the track to estimate the relative risk of trespassing for each community along a corridor. The intent is to use this information to target areas for improvement projects like fencing or pedestrian facilities, and educational or law enforcement campaigns.

This survey will help to better understand trespass issues along the North Carolina Railroad corridor between Raleigh and Charlotte North Carolina. According to FRA data, this busy freight and passenger rail corridor has had **36 trespasser strikes since 2011**. While this number is high, we are well aware that near miss and general trespass activity has not been actively recorded. Train crews travel this corridor daily and know the locations that have ongoing issues. Given that, we need your help to identify the hot spots for trespass activity to assist us with developing a model that will be effective.

On the following pages, we provide you with an opportunity to share your knowledge of trespass issues along this corridor using a graphical format. The graphs show the control points and milepost the H-Line along the horizontal (x) axis. A relative scale of trespass activity is located on the vertical (y) axis, with **5 being the most problematic areas, and 0 being areas with no issues.** For reference, locations of FRA recorded strikes from the past three years are shown with a ranking of 5. Table 1 (page 2) provides some guidance for where certain types or frequency of activity might rank. An example of how to fill out the graphs is also shown on page 2.

1. Examine the blank graph; note that each graph contains approximately 20-25 miles of track.
2. Mark a line to indicate the range for which you have noticed trespasser activity at certain intensity.
3. Information about the whole corridor is critical to developing an accurate model, so identification of problem areas and areas without issues are both very helpful.
4. Please identify known hot spots and provide additional information that will help improve our understanding of trespassing in the space provided after each graph.

If you have any questions or additional comments, please call Dylan Horne at 980.234.0564.

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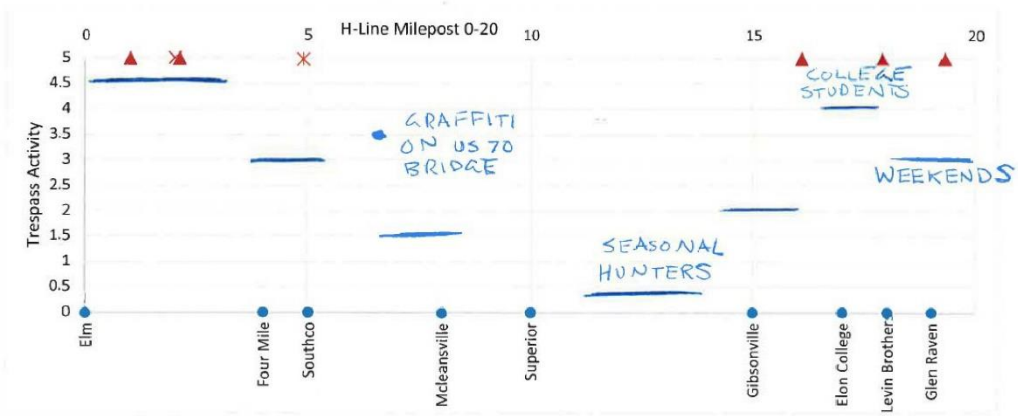
Railroad Trespass Activity Survey: Charlotte to Raleigh

Table 1: Intensity of Trespass Activity Scores

Trespass Activity Score	Types of Activity	Trespasser Observed
5	Trespasser Strike	Every trip
4.5		
4	Near-Miss	Daily
3.5		
3	Paths Across or Along the Track	Weekly
2.5		
2	Evidence: Debris or Graffiti	Monthly
1.5		
1	Fishing or Hunting	Seasonally
0.5		
0	None	Never

EXAMPLE



Additional Information: H-Line MP 0-20:

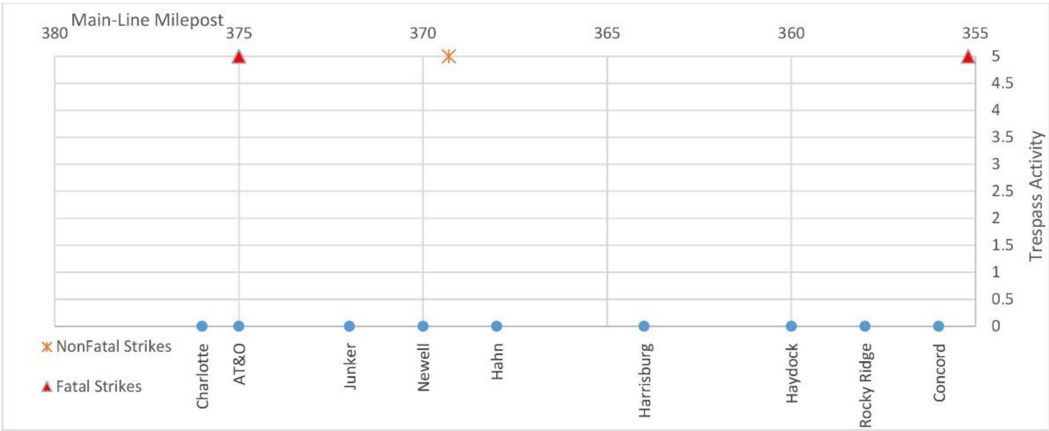
TRESPASSERS EVERY DAY IN GREENSBORO WALKING ALONG TRACKS

FOOT PATH AT MILEPOST H4.5

COMMON TO SEE PEOPLE CROSSING TRACKS TO GET G'BORO AMTRAK STATION

If you have any questions or additional comments, please call Dylan Horne at 980.234.0564.

Railroad Trespass Activity Survey: Charlotte to Raleigh



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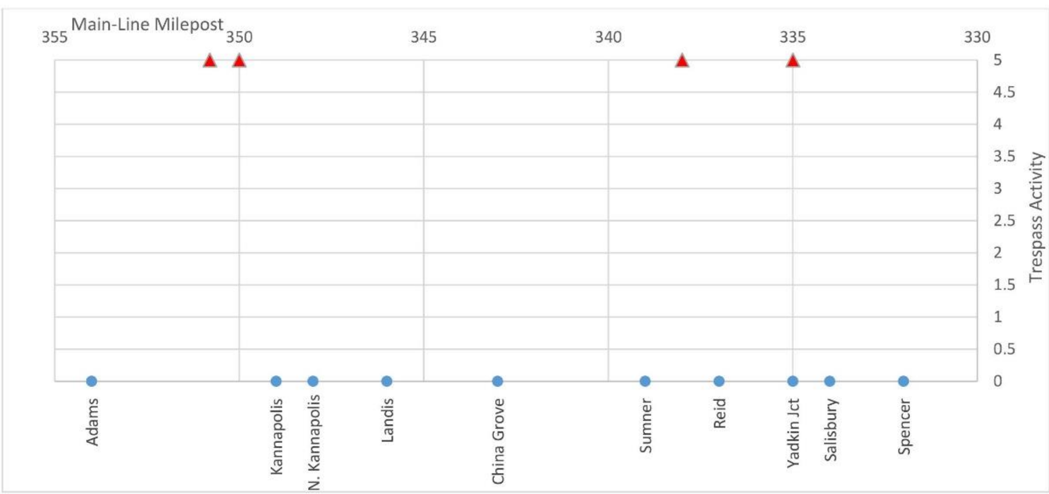

Additional Information: Main-Line MP 355-330:____

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If you have any questions or additional comments, please call Dylan Horne at 980.234.0564.

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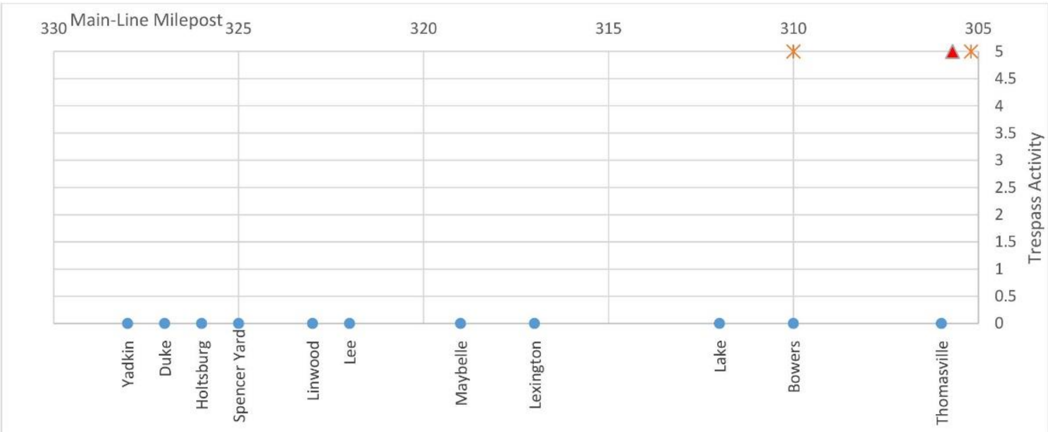
Railroad Trespass Activity Survey: Charlotte to Raleigh



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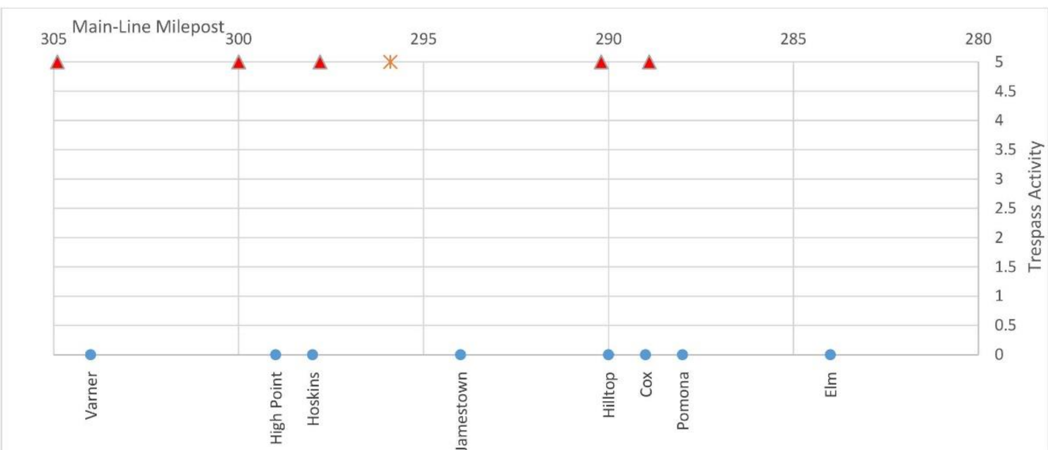

Additional Information: Main-Line MP 305-280:____

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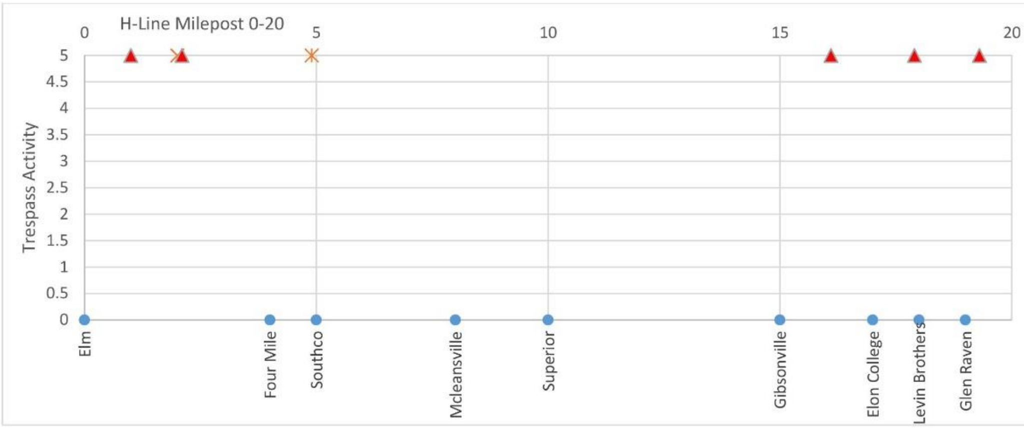
If you have any questions or additional comments, please call Dylan Horne at 980.234.0564.

Railroad Trespass Activity Survey: Charlotte to Raleigh



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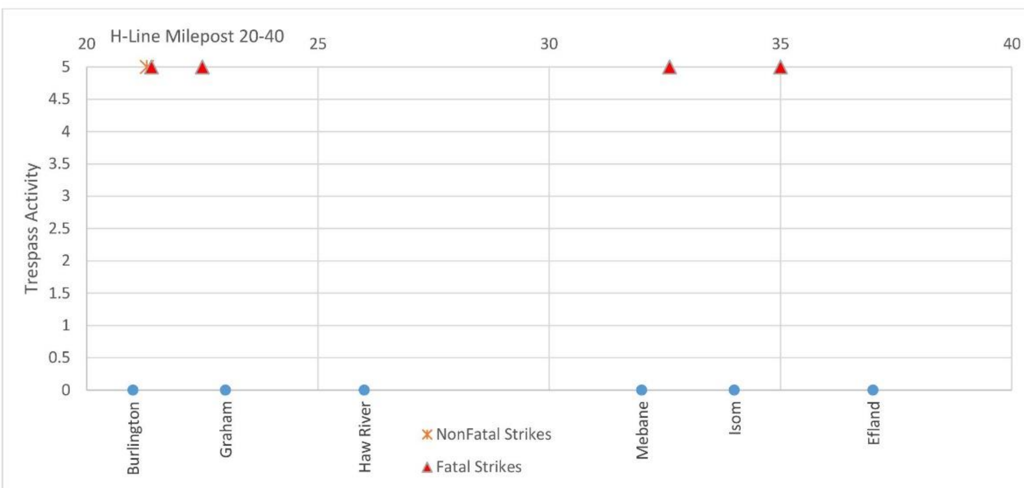
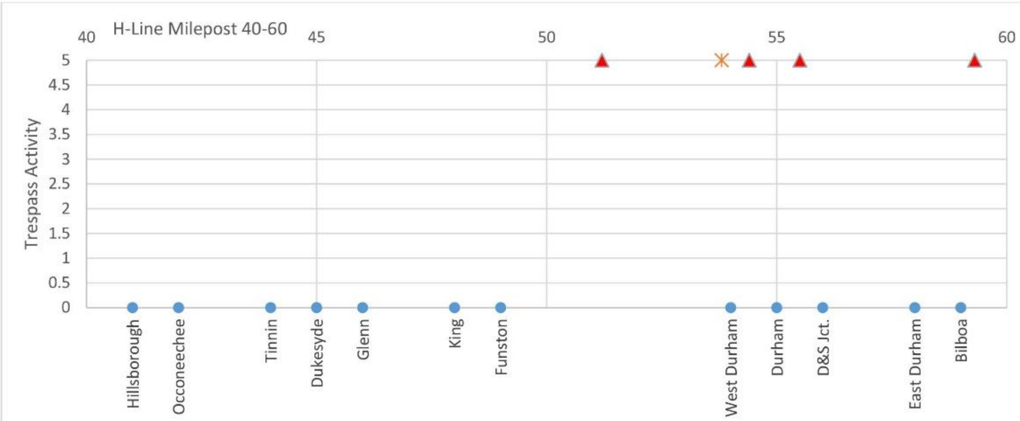


Additional Information: H-Line MP 20-40:______________________________

If you have any questions or additional comments, please call Dylan Horne at 980.234.0564.

Railroad Trespass Activity Survey: Charlotte to Raleigh



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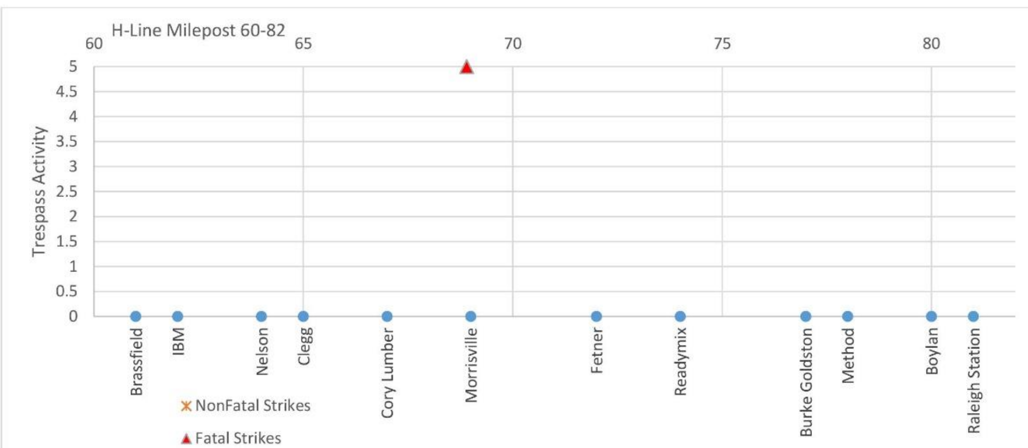

Additional Information: H-Line MP 60-82:____

If you have any questions or additional comments, please call Dylan Horne at 980.234.0564.

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Appendix C: Samples of Fencing Classification

High Point: Classified as fenced, as the step grades restrict access.

Elon / Burlington: Fenced, fencing and ditches restrict access.

Mebane: Not fenced, with parallel roads trespassing is likely and unhindered

Durham: Fenced, the fence and dense vegetation restrict access.

Durham: Not Fenced, no restrictions to access in a downtown area.

Appendix D: Additional Geospatial Analyses

Methodology

A geospatial analysis of various features along the railroad corridor was preformed Using Google My Maps. This analysis combined historic FRA incidents and train crew surveys to identify high trespass locations for further study. Using the FRA incident locations, several derivative measures were gathered for each location including: distance to parallel roads, fencing breakpoints, at-grade crossings, rail bridges and local attractors.
The NCRR corridor is divided into 174 one mile segments which roughly correspond to mileposts between the Amtrak stations in Raleigh and Charlotte. Throughout the corridor east represents the direction towards Charlotte, while west represents towards Raleigh. Likewise north represents the side of the track with Charlotte on the left hand side and Raleigh on the right hand side. The inverse is true for south. This convention was adopted to simplify data collection, as the corridor primarily runs north south between Charlotte and Greensboro, then east west between Greensboro and Raleigh.

Geospatial Data

FRA Incidents

Trespasser strikes, including fatalities, recorded in the FRA's database for the NCRR are the bases of the historic data. This dataset included 54 strikes from July 2011 to May 2015. The strikes are geospatial located in the FRA's database, and were imported into My Maps.

Parallel Roads

At the location of each strike, the distance to the nearest parallel road north and south of the track was measured perpendicular to the track. Throughout the state, this historic railroad route is a defining feature in a community's transportation network. In many communities such as Landis, Thomasville, Elon, and Durham the corridor divides the downtown business district at grade. Especially where parallel roads are in close proximity on both sides of the tracks, people are likely to cut across the tracks instead of walking to at-grade crossings. Trespass activity is expected to be higher where parallel roads are close to the tracks, especially in at-grade crossings are spread further apart.

Fencing Breakpoints

Using Google Maps and Streetview, fencing was identified for each strike location. The distance along the track to the nearest break in fencing was recorded for both directions. This distance indicates the extent of the fencing. Additional a quadrant binary variable indicates where the fencing is located. For example if the fencing was east of the incident and north of the track, but not in other quadrants it would be coded as NE 1, NW 0, SE 0, SW 0. If no fencing was observed all variables would be recorded as 0. In addition to traditional fencing, extremely dense vegetation or significant slopes were included in the fencing data. Fencing is expected to reduce trespass activity across the tracks, but could also capture a trespasser within the corridor if located on both sides of the track. Thirty seven of the 54 strike locations had no evidence of fencing.

At-Grade Crossings

The distance to at-grade crossings was measured along the track in both directions for each strike location. Both active at-grade crossings and closed crossings were included, as closing a crossing to motor vehicles does not typically address pedestrian movements. In some cases the strike happened at an at-grade crossing, so the measured distance is zero. Close proximity to an at-grade crossing could indicate a potential entry point onto the corridor, while long distances to a crossing could indicate a convenient cut through.

Rail Bridges

Rail bridges includes railroad bridges over water features, pedestrian tunnels or roadways and also includes highway or freeway bridges over the railroad. The rail over features typically provide a crossing point over nonnegotiable terrain and act as a funneling point for people walking along the track. The rail under features offer a shorter path cross multilane highway facilities. The distance to this feature is measured in both directions along the track. Two of the strikes happened on rail bridges measured as zero. Rail bridges are particularly dangerous to trespassers as they may have very little room to avoid an incoming train with the alternative of jumping off the bridge.

Attractors

Locations that are likely to attract pedestrian activity like convenience stores, bars, gas stations, liquor stores, fast food joints, universities and shopping centers were identified using Google Maps. The distance to the nearest attractor on both sides (east and west) of each incident were measured along a direct path. The objective of this measure is not to estimate where the trespasser was walking to or from, but instead to provide a surrogate measure for proximity to businesses that are likely to attract pedestrian activity. This combined with census data like population density and commercial zoning could be used to identify high pedestrian demand path ways which could be in turn used to improve the safe connectivity of communities.

Goat Paths

Goat paths, or unofficial footpaths, are a great indicator of pedestrian activity as they form from repetitive use. At some locations along the corridor, these paths are so well established that they are visible from aerial imaging. Other locations were identified from several months of bi-weekly Amtrak trips between Raleigh and Salisbury. Locations of known goat paths are highlighted in My Maps. These locations would be a great place to target education or enforcement campaigns. Additionally encampments along the corridor have been noted in this section with a pin.

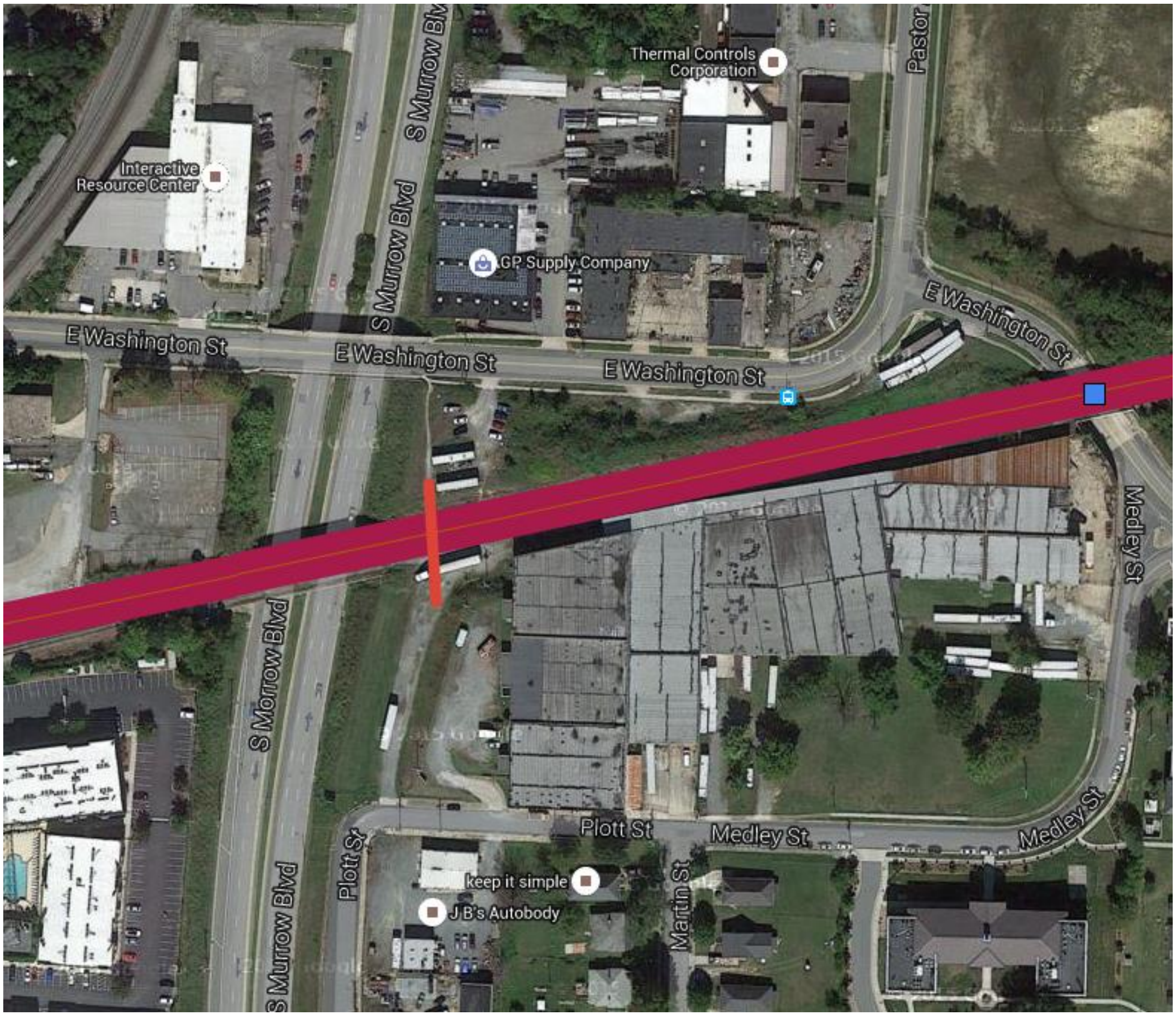
Train Crew Surveys

A survey was developed which asked Amtrak train crews to identify trespasser prone areas. As these crews travel the corridor daily, they have firsthand knowledge of where trespass activity occurs. The horizontal axis has the milepost of the track along with control points. The vertical axis has a relative scale of trespass activity, from 0, no observed activity, to 5 extremely frequent or strike location. A total of 6 train crews completed the surveys, and the responses were integrated into the graphical analysis. Specific locations were identified as goat paths, and general problematic areas are highlighted by milepost. Each time a crew identified a milepost, the highlighted section increased in line weight. For example, a section identified twice is twice as thick as one identified only once. This created a heat map of where the most commonly observed problematic areas are located.

Suggested Locations for Further Study

Greensboro had the highest number of train crew survey responses as a problematic area, with one crew saying this area is the 'worst place I've ever seen.' Trespassers are observed every trip by the crews, along with eight historic strikes. While this high level study cannot provide a treatise on why trespassing is such an issue within Greensboro, it can identify locations where further efforts of education, enforcement or engineering could be fruitful.

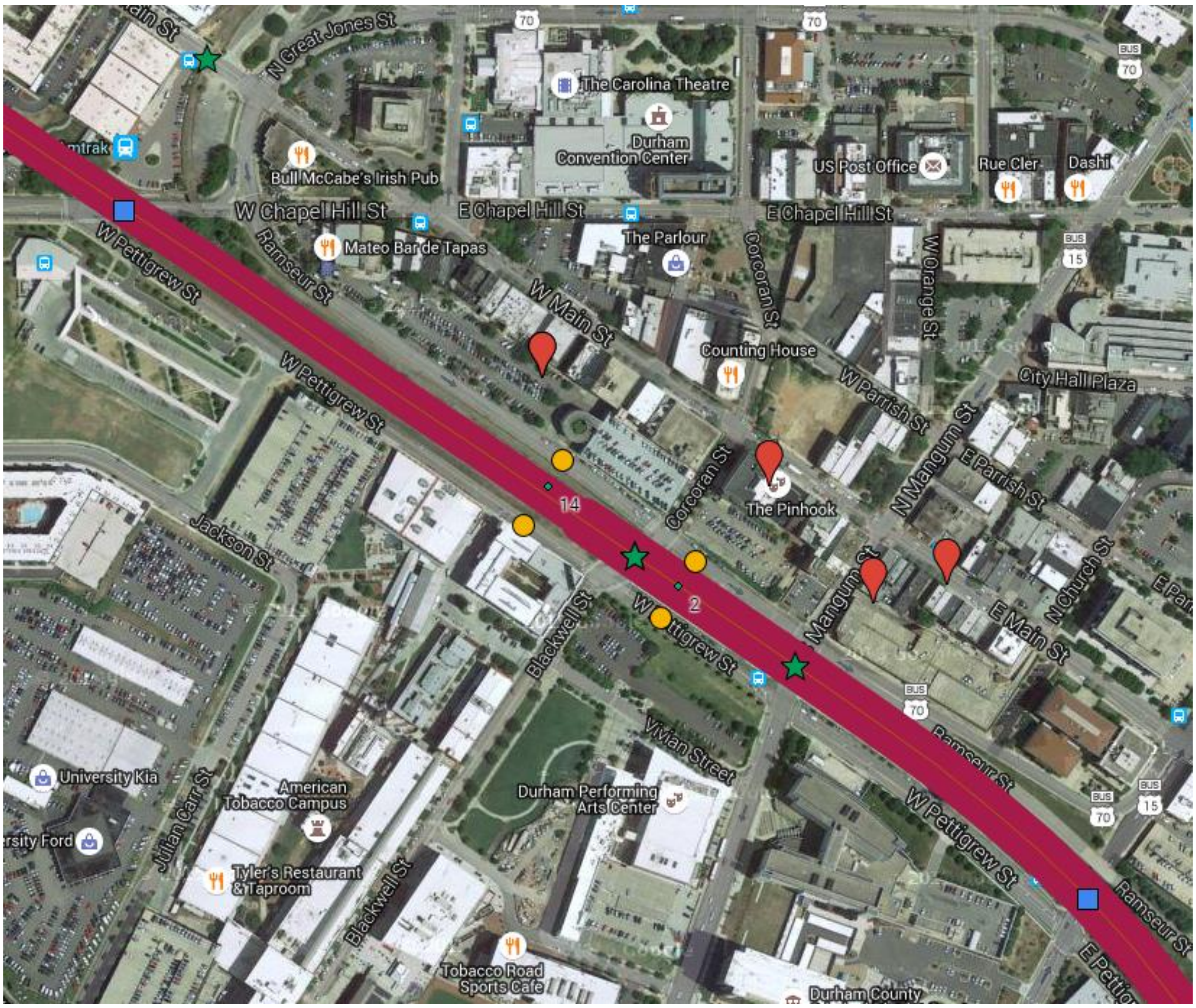
Just east of the Greensboro train station, a very well established goat path connects East Washington Street to Plott Street. This path is parallel to Murrow Boulevard, a multilane freeway facility with grade separated intersections and steep embankments. The Interactive Resource Center, a refuge for those experiencing homelessness, is located on Washington Street. While the route along Plott, Medley and Washington Streets is less than a half mile, this shortcut is a quarter of the distance, around 500 feet.



Aerial Image Identifying a Major Goat Path in Greensboro (Google My Maps)

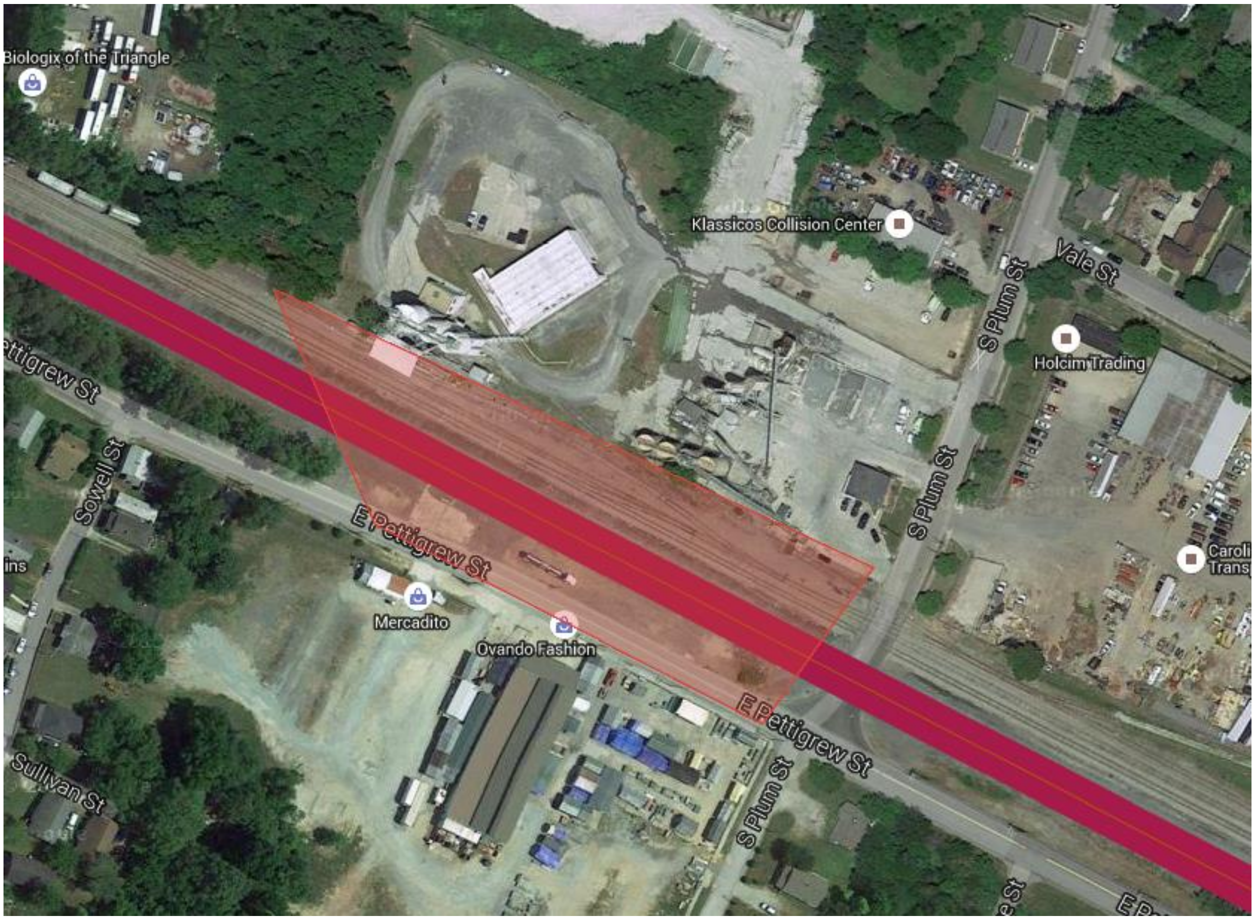
Image from Google Street View showing Pedestrian Crossing Track

Downtown Durham is divided by the NCRR, and while it has several at-grade and grade separated railroad crossings numerous pedestrians can be observed crossings the tracks. Four historic strikes have happened in this two miles area. The close proximity to the Durham Transit Station, the Amtrak Station, and numerous bars and restaurants make the location a prime area for pedestrians. The long sight distance at this section could provide a great location for trespasser counting.



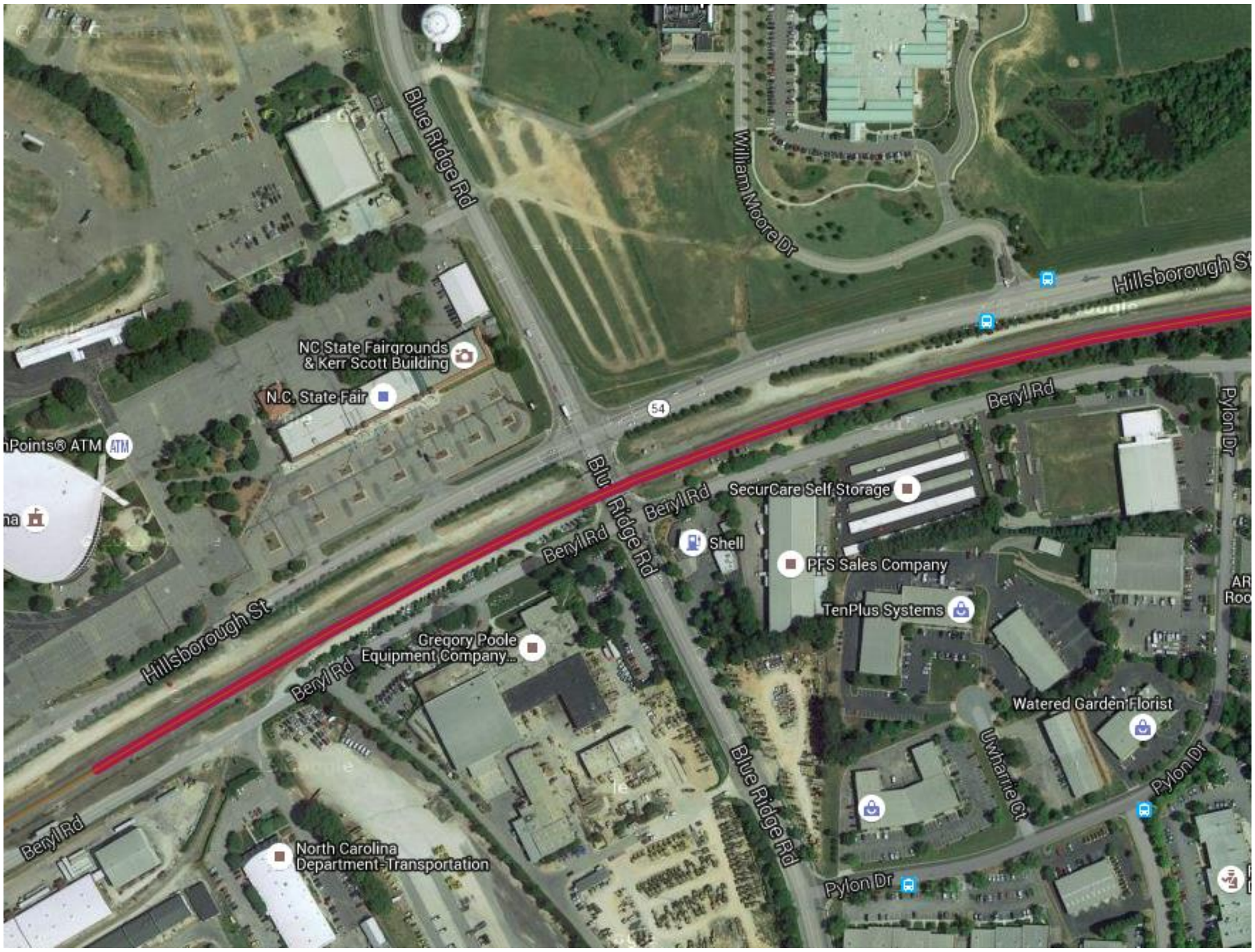
Downtown Durham (Google My Maps)

The Durham Green Flea Market on East Pettigrew Street was cited a problematic area in several of the train crew surveys, especially on Saturday. Five parallel tracks make for long exposure while trespassers cross, along with multiple train issues (Notice the first, but second train coming).



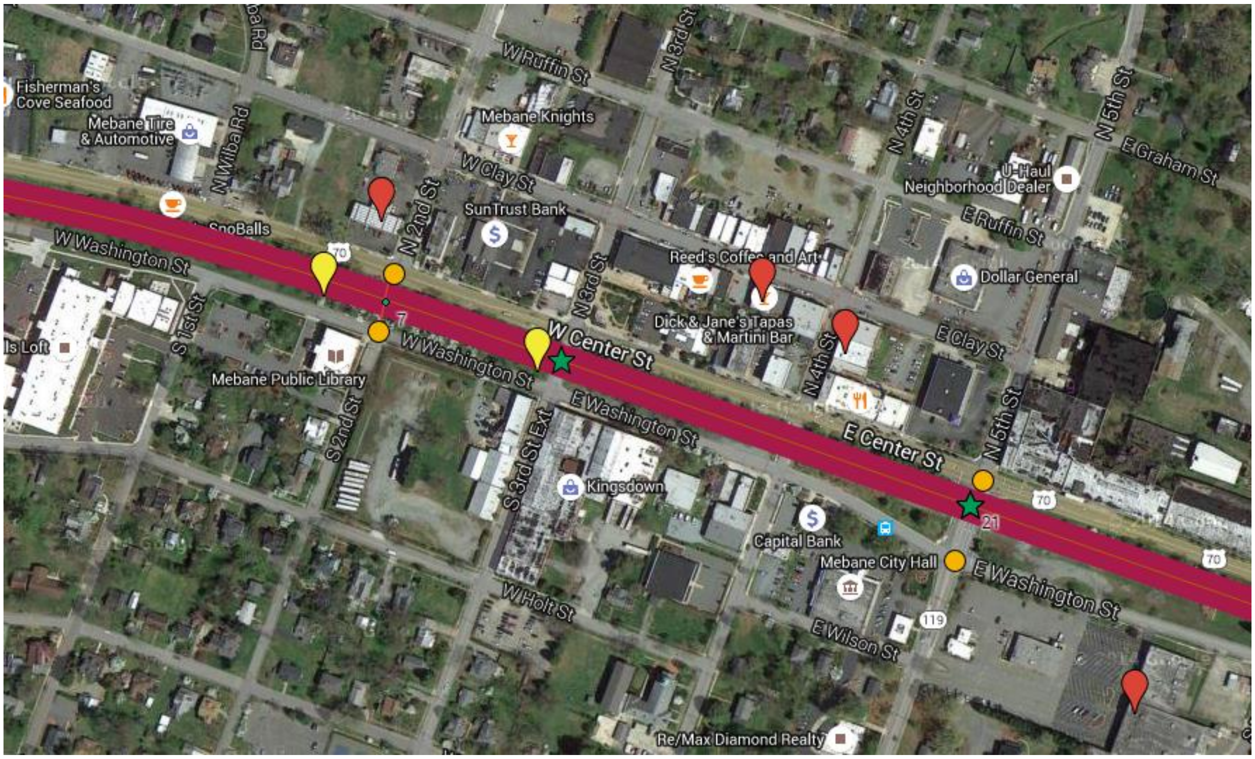
Durham Green Flea Market (Google My Maps)

The North Carolina State Fair Grounds and NC State Athletic Facilities in Raleigh generate huge pedestrian volumes during special events. Trains are under speed restrictions during the State Fair, but train crews still noted the area as problematic. Beryl Road is a popular parking location, and large groups of pedestrian funnel along the right of way.



Beryl Road at Blue Ridge Road (Google My Maps)

Downtown Mebane is divided by the NCRR, with two reported strikes and train crew comments. While some ornamental fencing exists, the corridor is flat and narrow, encouraging trespassing. A goat path is evident between 2nd Street. Tree coverage would make video observation difficult in this location.



Downtown Mebane (Google My Maps)