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Trespass Risk in Quiet Zones

DOT/FRA/ORD-20/37

Final Report | September 2020

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14. ABSTRACT
The U.S. Department of Transportation (DOT) John A. Volpe National Transportation Systems Center, under the direction of the DOT's Federal Railroad Administration (FRA), Office of Research, Development and Technology, studied the effects of the implementation of quiet zones on trespass accidents along the national rail network. This study focused on 333 quiet zones established between 6/1/2012 and 5/31/2018. Trespass casualties that occurred within the 333 quiet zones were compared before and after the establishment of the quiet zones. Trespass casualties in quiet zones with 2 and 3 years of observable accident data increased from 28 before to 40 after and from 39 before to 47 after the establishment of the quiet zones, respectively. However, trespass casualties in quiet zones with 1 year of observable accident data decreased from 19 before to 17 after the establishment. There was no statistically significant difference in trespass casualties before and after the establishment of the quiet zones for all three observable periods.

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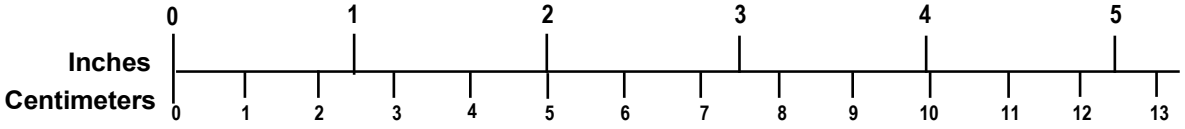

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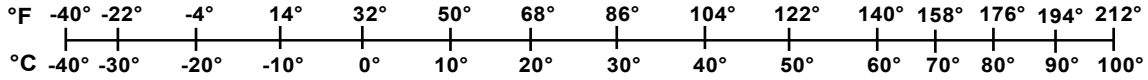

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Executive Summary

The John A. Volpe National Transportation Systems Center (Volpe) was tasked by the Federal Railroad Administration (FRA) Office of Research, Development and Technology to analyze rail trespass accident data to determine the effects of implementing quiet zones (QZs) on trespass accidents. A *quiet zone* is an area at least one-half mile in length that contains one or more consecutive public grade crossings at which railroads do not routinely sound locomotive horns when approaching those crossings. Localities seeking to establish a quiet zone are first required to mitigate the increased risk caused by the absence of a horn. This is typically done through supplemental safety measures (SSMs) such as gates with channelization or medians, four-quadrant gates, one-way streets, and crossing closures. SSMs are designed for the motoring public and not necessarily for other crossing users such as pedestrians and cyclists. Additionally, SSMs target grade crossing safety and generally do not address potential nearby trespass issues on the right-of-way (ROW).

Researchers analyzed 333 quiet zones established between June 2012 and May 2018 to determine their effects on trespass accidents. Trespass casualties from June 2011 to May 2019 were spatially analyzed in relation to the 333 quiet zones. Trespass casualties that occurred within the 333 quiet zone were then classified into casualties that occurred before, and those that occurred after the establishment of the quiet zone. A total of 190 trespass casualties were observed within the 333 quiet zones; 86 were observed before and 104 were observed after the establishment of the quiet zones.

Results indicated that trespass casualties in quiet zones with 1 year of observable accident data decreased from 19 before to 17 after the establishment of the quiet zones. However, trespass casualties in quiet zones with 2 and 3 years of observable accident data increased from 28 before to 40 after and from 39 before to 47 after the establishment of the quiet zones, respectively. There was no statistically significant difference in trespass casualties before and after the establishment of the quiet zones for all three observable periods.

Additionally, results showed that trespass casualties along the railroad ROW decreased by 11.1 percent – from 63 before to 56 after the establishment of the quiet zones. However, trespass casualties at grade crossings increased by 108.7 percent from 23 before to 48 after the establishment of the quiet zones. In comparison, overall grade crossing incidents increased by 7.4 percent from 2,064 in 2011 to 2,217 in 2019.

The analysis was also performed based on quiet zone type and on basis section (the regulatory provision that provides the basis for establishing the quiet zone). The analysis by quiet zone type revealed that neither quiet zone types designated as *New* nor *Wayside Horns* showed a significant difference in trespass casualties following the establishment of the quiet zones. The analysis based on basis section also revealed that there was no statistically significant difference in number of trespass casualties following the establishment of the quiet zones for all basis sections included in this study.

Volpe recommends that FRA advise communities establishing a quiet zone to consider the effects of the absence of train horns on railroad trespassing, including at crossings, and encourage those communities to develop appropriate trespass mitigation strategies. Furthermore,

FRA should consider adding similar trespass-specific requirements to the Train Horn Rule (49 CFR Part 222).

Volpe also recommends conducting a more in-depth analysis in 2 to 3 years, when there will be a much bigger dataset of trespass accidents with location information and a trespass risk methodology that FRA is currently working on becomes available so that factors such as population density and train frequency can be incorporated into the analysis.

1. Introduction

The John A. Volpe National Transportation Systems Center (Volpe) provides technical support to the Federal Railroad Administration (FRA) on grade crossing safety and trespass prevention research. This support includes key research associated with highway-rail grade crossing safety and rail right-of-way (ROW) trespass prevention. One major effort is to develop a more precise understanding of the risks presented by trespassing on ROWs and then determine how best to mitigate the risks. This report presents the findings of a study of the effects of the implementation of quiet zones (QZs) on trespass accidents along the national rail network.

1.1 Background

Trespassing along railroad ROWs is the leading cause of rail-related deaths in America. Generally, most trespassers are pedestrians who use railroad tracks as a shortcut. More than 500 trespass fatalities and nearly as many injuries occur in the U.S. every year, with the vast majority of these events being preventable.

Figure 1 shows a heat map of U.S. rail ROW trespass casualties from June 2011, when latitude/longitude information was first required to be submitted to FRA, to September 2019.

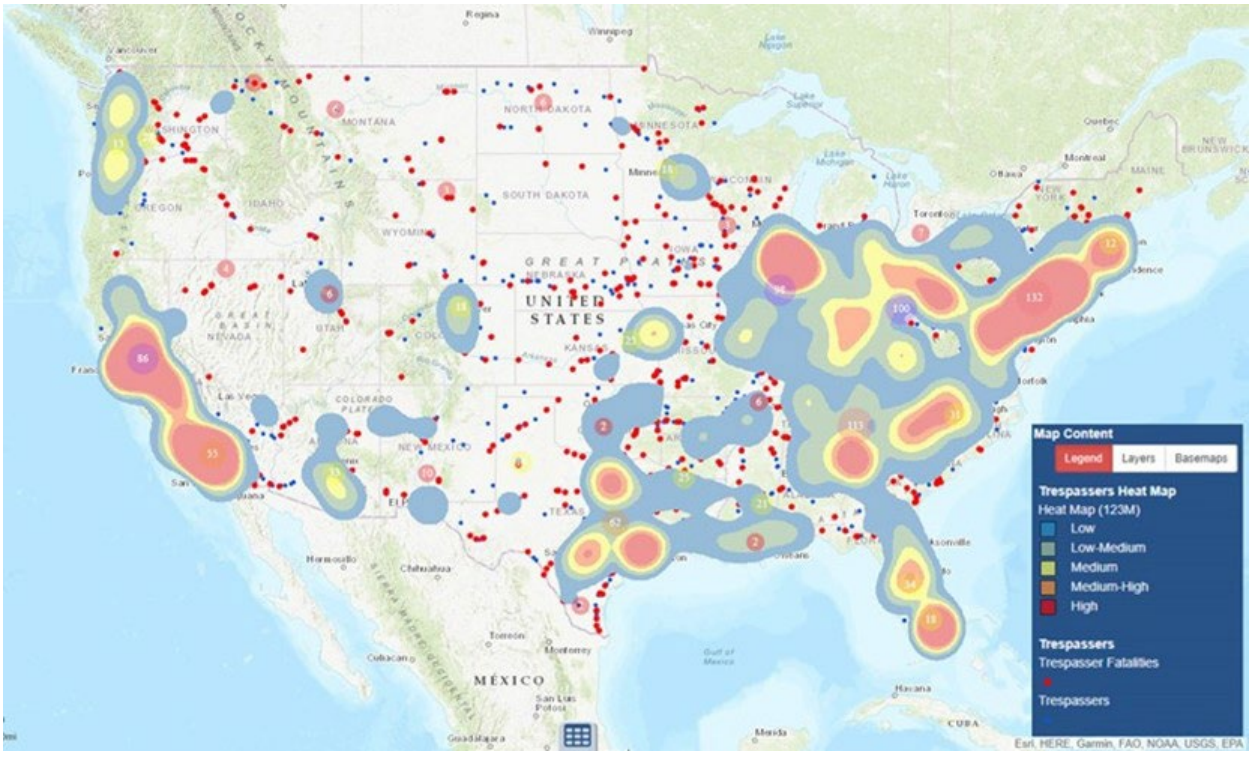

Figure 1. FRA Trespass Casualty Map, 6/2011–9/2019

Analysis of the ROW trespass data revealed that trespass casualties have been increasing. In 2018 alone, there were 1,016 trespassing casualties on the nation's rail network, excluding

trespass accidents at grade crossings and known suicides. A total of 532 of these casualties were fatalities.[1]

FRA's Train Horn Rule (49 CFR Part 222), enacted in 2005, mandates that locomotive engineers must begin sounding horns 15–20 seconds before entering public grade crossings, no more than one-quarter mile in advance.[2] The rule also provides an opportunity for localities nationwide to mitigate the effects of train horn noise by establishing "quiet zones." A quiet zone (QZ) is an area at least one-half mile in length that contains one or more consecutive public grade crossings at which railroads do not routinely sound locomotive horns when approaching those public grade crossings. In a QZ, railroads have been directed to cease the routine sounding their horns when approaching public highway-rail grade crossings. However, locomotive engineers can still sound their horns in an emergency situation, such as the presence of trespassers or vehicles violating the grade crossing warning devices, or to comply with other railroad or FRA rules. There were a total of 906 QZs as of February 14, 2020.[3]

Localities wanting to establish a QZ are first required to mitigate the increased risk caused by the absence of a horn. This is typically done through additional safety improvements such as gates with channelization or medians, four-quadrant gates, one-way streets, and crossing closures. These supplemental safety measures (SSMs) are designed to compensate for the absence of a locomotive horn. SSMs are designed for the motoring public and not necessarily for other crossings users such as pedestrians and cyclists. Additionally, SSMs target grade crossing safety and generally do not address potential nearby trespass issues on the ROW.

The majority of trespass casualties occur near grade crossings. A recent FRA analysis revealed that, although trespassing casualties can occur anywhere along the ROW, about 74 percent occur within 1,000 feet (less than one-quarter mile) of a grade crossing.[4] At least half occur within a much closer distance to a crossing – within 400 feet. Table 1 shows the results of the analysis, which excludes suicides.

Not sounding the train horn on approach to grade crossings within QZ may have an effect on trespassing accidents near those crossings, since trespassers may not have the benefit of the sounding of the horn of an oncoming train. Again though, locomotive engineers can still sound their horns in certain situations including observing the presence of trespassers in their path.

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[1] Obtained from the FRA Office of Safety Analysis web site, available at https://safetydata.fra.dot.gov/OfficeofSafety/default.aspx, last accessed on February 18, 2020.
[2] Use of Locomotive Horns at Highway-Rail Grade Crossings; Final Rule, 71 FR 47614 (to be codified at 49 CFR Parts 222 and 229), available at https://railroads.dot.gov/elibrary/final-rule-use-locomotive-horns-highway-rail-grade-crossings-2006.
[3] "Quiet Zone Locations by City and State," Federal Railroad Administration, February 2020, available at https://cms8.fra.dot.gov/elibrary/quiet-zone-locations-city-and-state-1.
[4] "Report to Congress: National Strategy to Prevent Trespassing on Railroad Property," Federal Railroad Administration, October 2018, available at https://cms8.fra.dot.gov/elibrary/national-strategy-prevent-trespassing-railroad-property.

Table 1. Locations of Pedestrian Trespasser Casualties* November 2013 to October 2017

Distance from a Highway-Rail Grade Crossing (feet)	Number	Percentage of Total	Cumulative	
			Number	Percentage
At a grade crossing	516	12.2%	516	12.0%
Within 50'	337	7.9%	853	20.0%
50' to 100'	263	6.2%	1,116	26.0%
100' to 200'	492	11.6%	1,608	38.0%
200' to 300'	365	8.6%	1,973	46.0%
300' to 400'	259	6.1%	2,232	53.0%
400' to 500'	230	5.4%	2,462	58.0%
500' to 600'	196	4.6%	2,658	63.0%
600' to 700'	140	3.3%	2,798	66.0%
700' to 800'	147	3.5%	2,945	69.0%
800' to 900'	104	2.5%	3,049	72.0%
900’ to 1,000'	93	2.2%	3,142	74.0%
1,000' to 1,250'	186	4.4%	3,328	78.0%
1,250' to 1,500'	149	3.5%	3,477	82.0%
1,500' to 2,000'	234	5.5%	3,711	87.0%
2,000' to 3,000'	239	5.6%	3,950	93.0%
3,000' to 5,000'	157	3.7%	4,107	97.0%
5,000' to 10,000'	79	1.9%	4,186	99.0%
More than 10,000'	56	1.3%	4,242	100.0%
Total Casualties	**4,242**	**100.0%**		

* Deaths and injuries, excluding suicides.

1.1.1 Past Research

In 2013, FRA conducted an internal study on the effectiveness of quiet zones. The study included an analysis of 997 crossings in 203 QZs to “determine whether or not silencing train horns has had a negative effect on crossing safety and whether or not the FRA has accurately assessed that the installation of SSMs and Alternative Safety Measures (ASMs) mitigate the negative impact that the lack of a train horn has on safety at highway-rail grade crossings.” The number of accidents before and after the establishment of a quiet zone was recorded for each crossing in the QZ and then aggregated across crossings within the QZ. The results indicated that there was no statistically significant difference in the number of accidents before and after the establishment of QZs, meaning that the safety risk remained the same. That analysis, however, did not assess safety impacts on the trespass problem.

In a provision of the Fixing America's Surface Transportation (FAST) Act, the U.S. Government Accountability Office (GAO) was directed to examine quiet zone regulations. GAO conducted

an analysis and issued a report to Congress on its findings in 2017.[5] The agency recommended that FRA should revise the methodology for the analysis to take into account relevant changes over time, including changes in train and automotive traffic (e.g., volume and speed) or in the physical characteristics of the grade crossing. FRA concurred with the recommendations to explore alternative methods, and conduct the analysis using those methods if deemed suitable for the data. This analysis, again, did not look at the potential impact on trespassing.

1.2 Objectives

Volpe sought to study the effects of implementation of quiet zones on trespass accidents along the national rail network.

1.3 Overall Approach

The research team analyzed the rail trespass accident data to determine the effects of implementing QZs on trespass accidents. Localities wanting to establish a QZ are first required to mitigate the increased risk at grade crossings caused by the absence of a horn. This is typically done through additional safety improvements such as gates with channelization or medians, four-quadrant gates, one-way streets, and crossing closures. However, no trespass mitigation requirements are included in this study. It is uncertain how well these improvements work in place of the train horn for trespassing at crossings and on the rail ROW.

1.4 Scope

This study investigated the frequency of trespass accidents on the U.S. rail network, specifically along sections designated as quiet zones. The analysis included trespass accidents at grade crossings. However, the analysis does not include reported suicides.

1.5 Organization of the Report

This report is organized as follows:

- Section 2 describes the data collection.
- Section 3 describes the analysis method.
- Section 4 presents the findings.
- Section 5 presents the conclusions of the study.
- Section 6 presents the potential limitations of the study.

[5] "Quiet Zone Analyses and Inspections Could Be Improved," Government Accountability Office, October 2017, available at https://www.gao.gov/assets/690/688079.pdf.

2. Data Collection

The primary source of data for this study is the FRA data file on quiet zones and the FRA Office of Railroad Safety Data Analysis website. The researcher received a list of all quiet zones established as of March 28, 2019 from FRA. Each QZ is identified by a unique train horn number and contains a lists of highway-rail grade crossings at which locomotive horns are not routinely sounded when approaching the crossing. The list also includes information such as QZ type, start date, basis section (the regulatory provision that provides the basis for establishing the QZ), and SSMs (describes pre-approved risk reduction engineering treatments).

FRA developed the Grade Crossing Inventory System (GCIS) database in 1970, managed by its Office of Railroad Safety. It contains all U.S. public and private highway-rail grade crossings, with detailed information on individual crossings. This database was used to identify the locations and characteristics of the individual crossings within a given QZ.

FRA developed the Railroad Accident Incident Reporting System (RAIRS) database in 1975, also managed by the Office of Railroad Safety. It contains all the accidents involving a highway user, railroad equipment, and railroad-related casualties. This database was used to obtain trespass casualties for an 8-year period from June 1, 2011 to May 31, 2019.

2.1 Quiet Zone Data

FRA started requiring railroads to submit trespass casualties location data starting in June 2011; therefore, trespass casualty data from June 1, 2011 to May 31, 2019 was used for this study.

To use a before-and-after study design, the analysis required equal numbers of observable periods before and after the establishment of a QZ, with a minimum of 1 year of observable data. This data selection process resulted in selecting QZs established between June 1, 2012 and May 31, 2018. During this 6-year period, a total of 333 QZs containing 1,318 highway-rail grade crossings were established. Out of the total of 333 QZs, 111 were QZs with only 1 grade crossing and 222 were QZs with 2 or more grade crossings (the number of grade crossing in this group ranged from 2 to 47).

Table 2 lists a breakdown of the 333 QZs by the observable period length. QZs in Group 1 had an observable period of 12 months before and 12 months after their establishment, those in Group 2 had an observable period of 24 months before and 24 months after their establishment, and those in Group 3 had an observable period of 36 months before and 36 months after their establishment.

Table 2. Breakdown of QZs by Number of Observable Months

Group	Observable period before and after QZ Establishment (months)	Established Between		Number of QZs	Number of Crossings
1	12	6/1/2012	5/31/2013	47	254
2	24	6/1/2013	5/31/2014	50	207
3	36	6/1/2014	5/31/2015	51	177
3	36	6/1/2015	5/31/2016	60	194
2	24	6/1/2016	5/31/2017	63	243
1	12	6/1/2017	5/31/2018	62	243
Total				333	1,318

Four QZs types were selected: *New, New Partial, Pre-Rule,* and *Wayside Horns*. There was one QZ with a missing QZ type. Table 3 shows the breakdown of the QZs and grade crossings by QZ type. Most QZs (92.5 percent) and the grade crossings (93.1 percent) are New Quiet Zone type. The definition of each QZ type is provided below.[6]

- *New Quiet Zone* means a segment of a rail line within which is situated one or a number of consecutive public highway-rail grade crossings at which routine sounding of locomotive horns is restricted pursuant to this part and which does not qualify as either a Pre-Rule Quiet Zone or Intermediate Quiet Zone.
- *New Partial Quiet Zone* means a segment of a rail line within which is situated one or a number of consecutive public highway-rail crossings at which locomotive horns are not routinely sounded between the hours of 10 p.m. and 7 a.m., but are routinely sounded during the remaining portion of the day, and which does not qualify as a Pre-Rule Partial Quiet Zone or an Intermediate Partial Quiet Zone.
- *Pre-Rule Quiet Zone* means a segment of a rail line within which is situated one or a number of consecutive public highway-rail crossings at which State statutes or local ordinances restricted the routine sounding of locomotive horns, or at which locomotive horns did not sound due to formal or informal agreements between the community and the railroad or railroads, and at which such statutes, ordinances, or agreements were in place and enforced or observed as of October 9, 1996 and December 18, 2003.
- *Wayside Horn* means a stationary horn located at a highway rail grade crossing, designed to provide, upon the approach of a locomotive or train, audible warning to oncoming motorists of the approach of a train.

[6] 49 CFR §222.9 Definitions, available at https://www.ecfr.gov/cgi-bin/text-idx?SID=5b54e66e049741371a77e43730b92b35&mc=true&node=pt49.4.222&rgn=div5#sp49.4.222.b

Table 3. Breakdown of QZs by QZ Type

QZ Type	Number of QZs	Number of Crossings within QZ Types
New	308	1,227
New Partial	2	6
Pre-Rule	7	49
Wayside Horns	15	35
(Blank)	1	1
Total	333	1,318

Localities wanting to establish a QZ are required to meet one of the following conditions:

- The Quiet Zone Risk Index (QZRI) is less than or equal to the Nationwide Significant Risk Threshold (NSRT) with or without additional safety improvements.
- The QZRI is less than or equal to the Risk Index With Horns (RIWH).
- SSMs are installed at every public grade crossing.

As noted in the FRA Guide to the Quiet Zone Establishment Process[7]:

> *The QZRI is the average risk for all public highway-rail crossings in the quiet zone, including the additional risk for absence of train horns and any reduction in risk due to the risk mitigation measures. The NSRT is the level of risk calculated annually by averaging the risk at all of the Nation's public highway-rail grade crossings equipped with flashing lights and gates where train horns are routinely sounded. The RIWH is the average risk for all public highway-rail crossings in the proposed quiet zone when locomotive horns are routinely sounded.*

Table 4 shows the breakdown of the QZs and associated grade crossings by basis section. Basis section is a specific reference in the train horn regulation that provides the basis for QZ establishment. Of the total of 333 QZs, 162 (over 48 percent) were established by installing SSMs at every public grade crossing, which falls under Basis Section 222.39(a)(1). However, only 384 of the grade crossings (29.1 percent) in these QZs were upgraded using this method. The QZs established on the basis of this method averaged the least number of grade crossings per QZ at 2.37 (384/162) and ranged from 1 to 12 grade crossing per QZ. The QZs established on the basis of 222.39(a)(3) made up 19.5 percent of the overall QZs but encompassed 38.3 percent of the grade crossings. The number of grade crossings within the QZ established per this basis ranged from 1 to 47 grade crossings and averaged 7.8 grade crossings per QZ.

[7] Federal Railroad Administration, "Guide to the Quiet Zone Establishment Process," September 2013, available at https://railroads.dot.gov/sites/fra.dot.gov/files/fra_net/3403/QuietZoneBrochure.pdf.

Table 4. Breakdown of QZs by Basis Section

Basis Section	Description	Number of QZs	Number of Crossings within QZs
222.39(a)(1)	QZ established by implementing SSMs at every public grade crossings.	162	384
222.39(a)(2)(i)	QZ may be established if QZRI is at or below NSRT without SSMs.	19	51
222.39(a)(2)(ii)	QZ established by implementing SSMs which reduce the QZRI to a level at or below NSRT.	15	86
222.39(a)(3)	QZ established by implementing SSMs which reduce the QZRI to a level at or below RIWH.	65	505
222.39(b)(4)(i)(A)	QZ approved by FRA Associate Administrator where QZRI is at or below RIWH.	53	225
222.41(a)(1)(ii)	Pre-Rule QZ established where QZRI is at or below the NSRT.	2	20
222.41(a)(1)(iv)	Pre-Rule QZ established where QZRI is at or below the RIWH.	1	11
222.59	QZ established by installing wayside horns.	16	36
Total		333	1,318

2.2 Trespass Casualty Data

FRA developed the RAIRS Casualty database in 1975. It contains reported cases of railroad related injuries, illnesses, and fatalities. Casualties resulting from trespassing on railroad ROWs can be found by using "TYPPERS" data field for Type of Person=E, trespasser. Railroads are responsible for reporting accidents on their ROWs to the FRA using form 6180.55A.

This database was used to obtain the trespass casualty data on railroad ROWs. This dataset includes trespass accidents at grade crossing but does not include reported cases of suicide. FRA started requiring railroads to submit the geographical location (latitude/longitude coordinates) of trespass casualties starting in June 2011. Therefore, trespass casualty data from June 1, 2011 to May 31, 2019, covering an 8-year period, was used for the analysis. A total of 10,376 trespass casualties resulted in 4,882 fatalities over this period on the entire rail network. Figure 2 shows trespass casualties, injury, and fatality trends from June 1, 2011 to May 31, 2019. As can be seen from the chart, there was almost a linear increase in the number of trespass casualties, injuries, and fatalities over the study period. Trespass casualties, injuries, and fatalities increased by 35.8 percent, 19.2 percent, and 56.5 percent, respectively, over the study period.

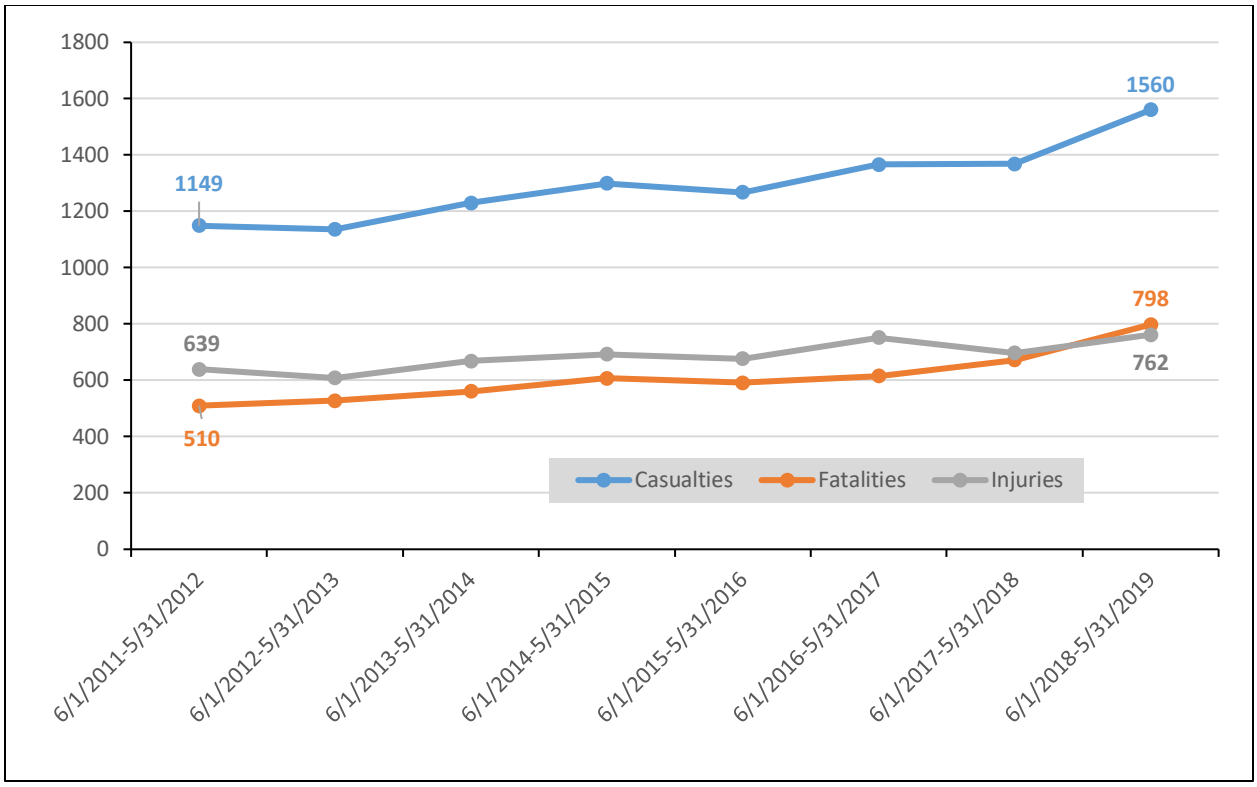

Figure 2. Trespass Casualty Statistics, 6/1/2011–5/31/2019

3. Data Analysis Method

To understand the effects of implementing QZs on trespass accidents, trespass casualties that occurred within a QZ were classified into casualties that occurred before and those that occurred after the establishment of the QZ. There is no simple way—such as using a filter for a data field—to query for trespass casualties that occurred within a QZ. Trespass casualties were spatially analyzed using ArcGIS to determine whether they occurred within a QZ.

As discussed in Section 2.1, QZs established between June 1, 2012 and May 31, 2018 were selected for this study. During this 6-year period, a total of 333 QZs covering 1,318 highway-rail grade crossings were established. For the 1,318 grade crossings, location information (latitude/longitude coordinates) was obtained from the FRA GCIS database and plotted in ArcGIS. It is worth noting that railroads and states can change the data in the inventory at any time to keep the information up-to-date. Since location information for some grade crossings can be inaccurate for a variety of reasons including human error during data entry, each grade crossing location was manually verified and corrected as needed. Researchers cross-referenced the street name of the grade crossing and the primary operating railroad from the FRA crossing inventory database with the map to obtain accurate locations for all crossings. An example of a manual validation and correction is the West Hidden Valley Boulevard grade crossing in Boca Raton, Florida (crossing ID 272499F). The latitude and longitude coordinates obtained from the FRA GCIS database for this crossing placed the crossing in the Atlantic Ocean. Based on crossing street name and primary operating railroad (Florida East Coast Railway), the crossing was correctly placed in its location.

While the example described above is a unique case, the level of inaccuracy of the grade crossing data in the GCIS is below 6 percent. The inaccuracies are no more than 20 meters (60 feet) between the recorded location and the actual location.

For the 222 QZs with more than one grade crossing, grade crossings within each QZ were joined to form a section of a rail line that represented that QZ. The remaining 111 QZs with one grade crossing were represented by points on a map. As mentioned earlier, Federal regulation requires locomotive engineers begin sounding the horn 15–20 seconds before entering a grade crossing, no more than one-quarter mile in advance. Therefore, a buffer of one-quarter mile was created around each QZ.

The 10,376 trespass casualties that occurred between June 1, 2011 and May 31, 2019 were then plotted on the map along with the QZs layer, and spatial analysis was performed to determine if a trespass casualty had occurred within a QZ buffer. If a trespass casualty fell within multiple QZ buffers or if there were multiple rail lines within a single QZ buffer, a manual validation was conducted to make sure that a trespass casualty was tagged to the correct QZ and was counted only once. Figure 3 shows an example of a review for trespass incident number 000119051. This trespass accident fell within two QZ buffers. Based on the trespass accident narrative, the trespasser on an all-terrain vehicle was struck by a CSX freight train when it became stuck on the tracks. The CSX railroad operates on the northern tracks and Norfolk Southern railroad operates on the southern track. Therefore, the trespass accident was assigned to the QZ located on the CSX tracks (Quiet Zone Case ID Number THR_Request_000000170001).

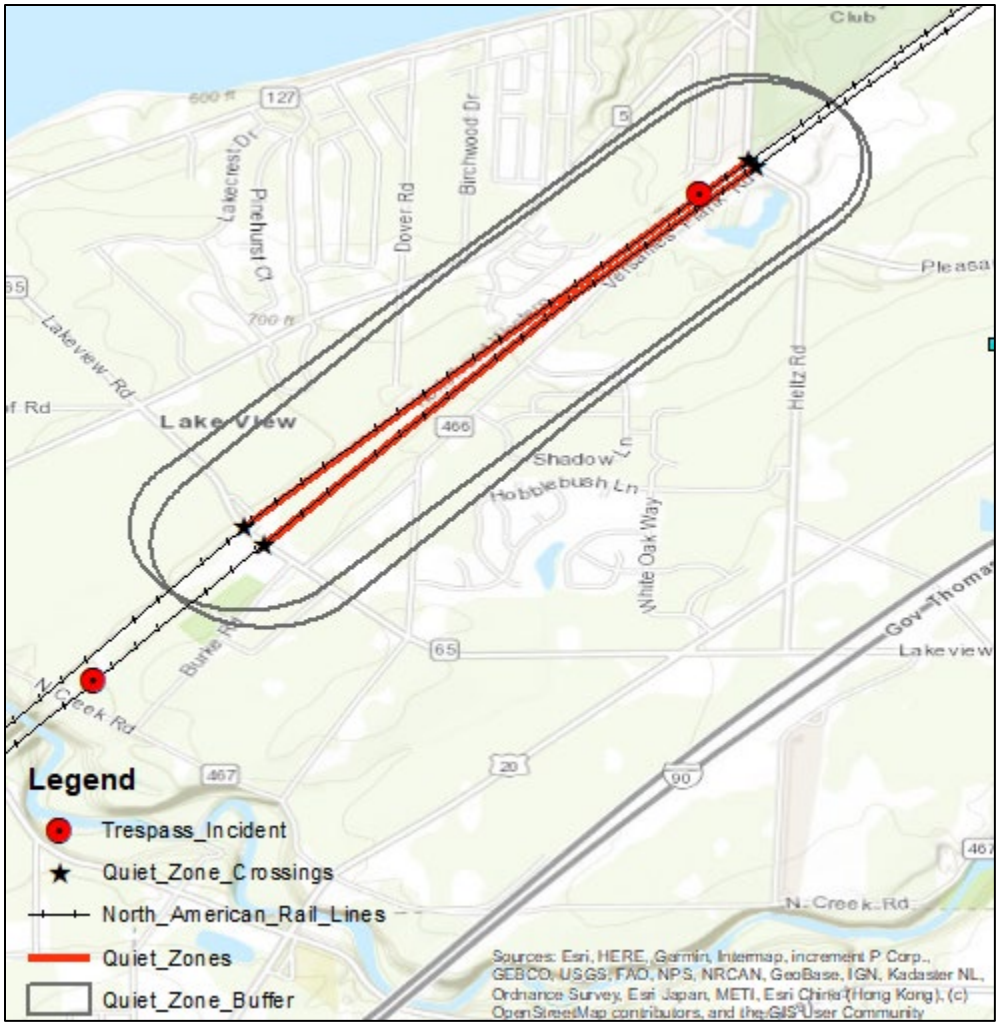

Figure 3. An Example of a Trespass Casualty within Multiple QZ Buffers

Figure 4 shows an example of a review for trespass incident number 0714HO010. This trespass accident falls within the QZ buffer, but it occurred on different tracks that is not part of the QZ. Therefore, this trespass accident was not included in the dataset.

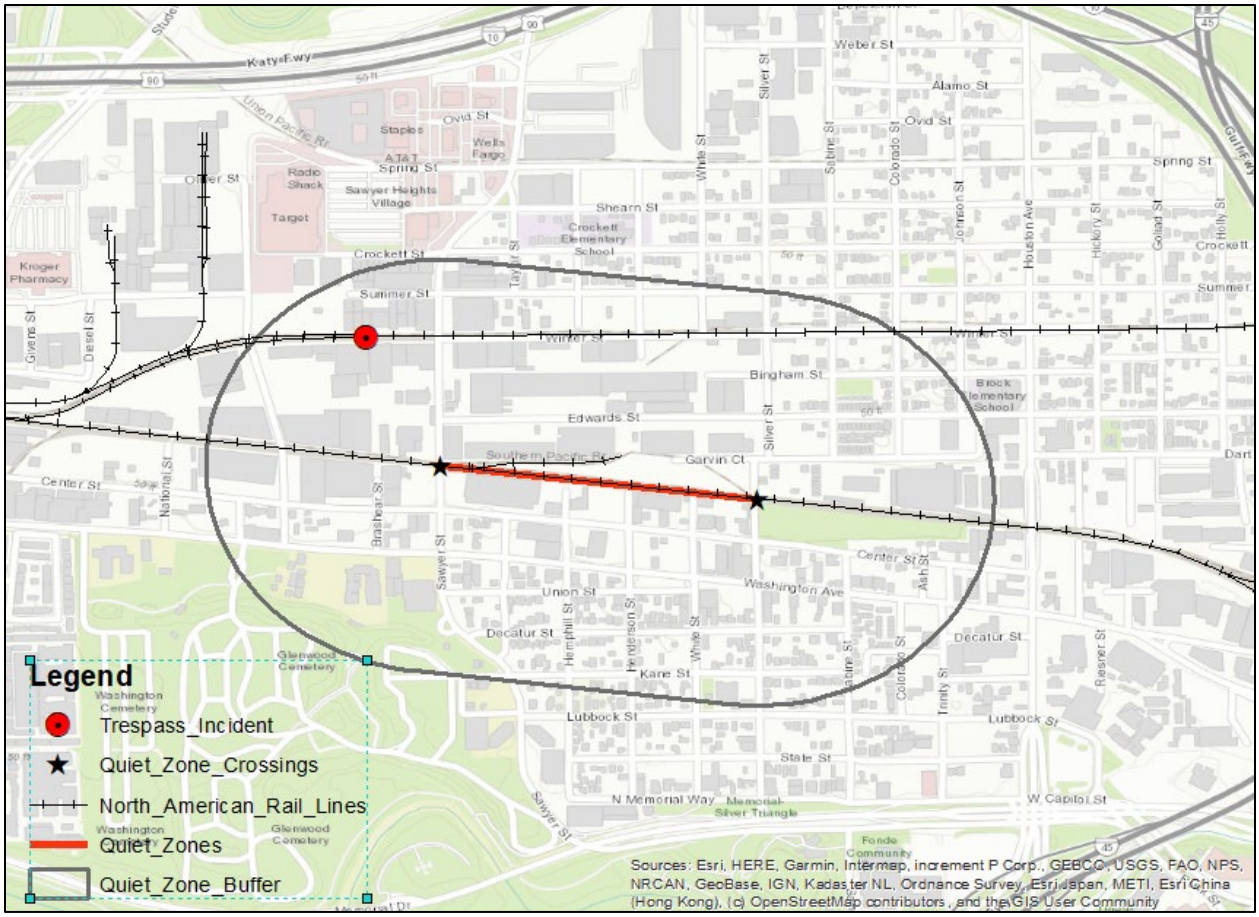

Figure 4. An Example of a Trespass Casualty within a QZ Buffer with Multiple Rail Lines

The trespass accidents that occurred within QZ buffers were then grouped into accidents that occurred before and those that occurred after the establishment of the QZ. To use a before-and-after study design, the experiment required an equal number of observable periods with a minimum of one year of observable data. The notice of establishment (NOE) date and availability of trespass accident data with location information (June 1, 2011 to May 31, 2019) was used to determine how many years of data was available before and after the QZ was established. For example, if a QZ was established on July 19, 2013, 2 years of accident data prior to (July 19, 2011 to July 18, 2013) and following (July 20, 2013 to July 19, 2015) the establishment of the QZ was used.

4. Results

Over the 8-year period from June 1, 2011 to May 31, 2019, a total 337 trespass casualties were observed within the 333 QZs. Based on the requirement of equal observation periods before and after the establishment of the QZs and a 1-year minimum observable period, 190 trespass casualties were selected for this study. A total of 86 trespass casualties (46 fatalities and 40 injuries) were observed prior to the establishment of the QZs, and 104 trespass casualties (47 fatalities and 57 injuries) were observed after the establishment of the QZs.

Out of 190 trespass casualties selected for this study, 71 occurred at grade crossings and 119 occurred along railroad ROWs. Trespasser casualties at grade crossing increased by 108.7 percent (from 23 before to 48) after the establishment of the QZs, and trespasser casualties along the railroad ROW decreased by 11.1 percent (from 63 before to 56) after the establishment of the QZs. In comparison, overall grade crossing incidents increased by 7.4 percent (from 2,064 in 2011 to 2,217 in 2019). This dataset does not include reported cases of suicide. Appendix A lists the 190 trespass casualties that occurred within the QZs.

4.1 Observable Period

The main indicator for this study was changes in number of trespass casualties before and after the establishment of the QZs. Table 5 shows the distribution of the QZs by number of years of available accident data, along with the number of QZs and trespass casualties before and after the establishment of each group. As shown in Table 5, trespass casualties over all three groups increased from 86 trespass casualties before to 104 trespass casualties after the establishment of the QZs.

Group 1 corresponds to QZs with 1 year of available accident data before and after the establishment of the QZs. The QZs in this group were established between June 1, 2012 and May 31, 2013, and between June 1, 2017 and May 31, 2018. The number of trespass casualties in this group decreased by 10.5 percent, from 19 trespass casualties before to 17 trespass casualties after the establishment of the QZs. A paired t-test revealed that this decrease in trespass casualties was not statistically significant ($t(108)=0.425$, $p=0.672$). Appendix B provides the results of paired t-test.

Group 2 corresponds to QZs with 2 years of available accident data before and after the establishment of the QZs. The QZs in this group were established between June 1, 2013, and May 31, 2014, and June 1, 2016, and May 31, 2017. The number of trespass casualties in this group increased by 42.9 percent, from 28 trespass casualties before to 40 trespass casualties after the establishment of the QZs. However, a paired t-test revealed that this increase was not statistically significant ($t(112)=-1.615$, $p=0.109$).

Group 3 corresponds to QZs with 3 years of available accident data before and after the establishment of the QZs. The QZs in this group were established between June 1, 2014, and May 31, 2016. The number of trespass casualties in this group increased by 20.5 percent, from 39 trespass casualties before to 47 trespass casualties after the establishment of the QZs. However, a paired t-test revealed that this increase was not statistically significant ($t(110)=-0.695$, $p=0.489$).

Table 5. QZ Grouping Based on Years of Available Data

Group	Number of Observable Years before and after NOE	# of QZs in group	Casualties before NOE	Casualties after NOE	Percent Change
1	1	109 (32.7%)	19 (22.1%)	17 (16.3%)	-10.5%
2	2	113 (33.9%)	28 (32.6%)	40 (38.5%)	42.9%
3	3	111 (33.3%)	39 (45.3%)	47 (45.2%)	20.5%
	Total	333	86	104	

4.2 Quiet Zone Type

Table 6 shows the distribution of the QZs by QZ type, along with the number of QZs and trespass casualties before and after the establishment of each QZ type. *New Partial* and *Pre-Rule* QZ types were not included in this QZ type analysis because of their small sample size. (QZ type with at least 15 QZs were included.) Based on a paired t-test, neither *New* QZ nor *Wayside Horns* QZ types showed a significant difference in trespass casualties following the establishment of the QZs [*New*: (t(307)=-0.926, p=0.355) and *Wayside Horns*: (t(14)=-1.0, p=0.334)]. However, note that the number of trespass casualties in QZs designated as *Wayside Horns* doubled from three before to six after the establishment of the QZs. Appendix C provides the results of the paired t-test for QZ type.

Table 6. QZ Grouping based on QZ Type

QZ Type	Number of QZs	Casualties before NOE	Casualties after NOE	Percent Change
New	308 (92.8%)	82 (95.3%)	95 (91.3%)	15.9%
Wayside Horns	15 (4.5%)	3 (3.5%)	6 (5.8%)	100.0%
Pre-Rule	7 (2.1%)	1 (1.2%)	3 (2.9%)	200.0%
New Partial	2 (0.6%)	0	0	
Blank	1	0	0	
Total	333	86	104	20.9%

4.3 Basis Section

As previously noted, there are different ways localities can mitigate the effects of train horn noise in order to establish a QZ. The basis section codes identify the methods used to establish each QZ. Table 7 shows the distribution of the QZs by QZ basis section, along with the number of QZs and trespass casualties before and after establishment of each QZ. Similar to the analysis performed for QZ type, only basis sections with at least 15 or more QZs were analyzed. Based on a paired t-test, there was no statistically significant difference in trespass casualties before and after the establishment of the QZs for all basis section types. However, note that the number of trespass casualties in the QZs established based on Basis Sections 222.39(a)(2)(ii) and 222.59 increased by 125 percent (from four before to nine after) and by 100 percent (from three before

to six after), respectively. Basis Section 222.59 refers to QZs established by installing wayside horns. One QZ with the blank QZ type was established based on Basis Section 222.59. Appendix D provides the results of the paired t-test for QZs grouping based on basis section. Basis Section 222.41(a)(1)(ii) and 222.41(a)(1)(iv) are not included in the analysis.

Table 7. QZ Grouping based on Basis Section

Basis Section	# of QZs in Group	Casualties before NOE	Casualties after NOE	Percent Change
222.39(a)(1)	162	24	26	8.3%
222.39(a)(2)(i)	19	0	2	
222.39(a)(2)(ii)	15	4	9	125.0%
222.39(a)(3)	65	36	50	38.9%
222.39(b)(4)(i)(A)	53	19	11	-42.1%
222.41(a)(1)(ii)	2	0	0	
222.41(a)(1)(iv)	1	0	0	
222.59	16	3	6	100.0%
Total	333	86	104	20.9%

5. Conclusion

This study focused on 333 QZs that were established between June 1, 2012 to May 31, 2018. To understand the effects of implementing QZs on trespass accidents, trespass casualties that occurred within the 333 QZs were classified into casualties that occurred before, and those that occurred after the establishment of the QZs. A total of 190 trespass casualties were observed within the 333 QZs, 86 trespass casualties (46 fatalities and 40 injuries) were observed before and 104 trespass casualties (47 fatalities and 57 injuries) were observed after the establishment of the QZs. Trespass casualties along the railroad ROW decreased by 11.1 percent from 63 before to 56 after the establishment of the QZs, but trespass casualties at grade crossing increased by 108.7 percent from 23 before to 48 after the establishment of the QZs. In comparison, overall grade crossing incidents increased by 7.4 percent, from 2,064 in 2011 to 2,217 in 2019.

Trespass casualties in QZs with 1 year of observable accident data decreased from 19 before to 17 after the establishment of the QZs. However, trespass casualties in QZs with 2 and 3 years of observable accident data increased from 28 before to 40 after and from 39 before to 47 after the establishment of the QZs, respectively. There was no statistically significant difference in trespass casualties before and after the establishment of the QZs for all three observable periods. Note that there was a linear increase in the overall number of trespass casualties on the nation's rail network from June 2011 to May 2019. The number of trespass casualties increased by 35.8 percent, from 1,149 to 1,560.

The analysis by QZ type revealed that neither QZ types designated as *New* nor *Wayside Horns* showed a significant difference in trespass casualties following the establishment of the QZs [*New*: (t(307)=-0.926, p=0.355) and *Wayside Horns*: (t(14)=-1.0, p=0.334)]. The number of trespass casualties increased from 82 before to 95 after the establishment of QZs designated as *New* and from 3 before to 6 after the establishment of QZs designated as *Wayside Horns*.

The analysis based on basis section also revealed that there was no statistically-significant difference in the number of trespass casualties following the establishment of the QZs for all basis sections included in this study. The number of trespass casualties increased after the establishment of the QZs for all basis sections except for the QZs established based on Basis Section 222.39(b)(4)(i)(A) (QZ approved by FRA Associate Administrator where QZRI is at or below RIWH). The number of trespass casualties in this group decreased by 42.1 percent, from 19 before to 11 after the establishment of the QZs.

Volpe recommends that the FRA advise communities establishing a QZ to consider the effects of the absence of train horn on railroad trespassing, including at grade crossings, and encourage those communities to develop appropriate trespass mitigation strategies. Furthermore, FRA should consider adding similar trespass-specific requirements to the Train Horn Rule.

Finally, Volpe recommends conducting a more in-depth analysis in 2 to 3 years, when there will be a much bigger dataset of trespass accidents with location information, and a trespass risk methodology, currently under development by the FRA, becomes available, so that factors such as population density and train frequency can be incorporated into the analysis.

6. Potential Limitations

The major limiting factor for this study was the availability of trespass casualty records with location information. As discussed earlier, FRA started requiring railroads to submit trespass casualty location information starting on June 1, 2011. Therefore, trespass casualties over an 8-year period from June 1, 2011, to May 31, 2019, were used for this study. A before-and-after study design used in this study required an equal period of observable data before and after the establishment of the QZs. This resulted in an observable period that ranged from 1 to 3 years for each QZ. This observable period length, especially the 1 year before and after period used for almost one-third of the QZs in this analysis, might not be a sufficient amount of time to assess the effect of a QZ on trespass casualties.

This same limiting factor also resulted in selecting QZs that were established between June 1, 2012, and May 31, 2018, for this study. There were 333 QZs established during this 6-year period. This number represented a little over one-third of the overall number of QZs in the national rail network.

Note that the analysis used in this study assumes that changes in trespass accidents is primarily due to the effects of implementation of the QZs. It does not take into account other changes—such as changes in rail traffic, train speed, population density, or changes to the surrounding roads or infrastructure—that might contribute to trespass accidents.

Lastly, the QZ grade crossing and trespass casualty location information was obtained from the FRA GCIS and RAIRS databases. These data are manually entered into the database, and as such contained some errors. The location of the QZ grade crossings were manually verified and corrected as needed by cross-referencing the street name of the grade crossing and the primary operating railroad from the FRA GCIS database with the map. However, there may have been some errors in crossing locations that were not identified.

Similar to grade crossings location, trespass casualty location also included some error. To account for errors in trespass casualty location, researchers created a quarter-mile buffer on both sides of each QZ to capture trespass casualties that occurred within these zones. However, there may be trespass casualties that may have been affected by the absence of the locomotive horn but fell outside of the quarter-mile buffer and were therefore excluded from the analysis.

7. References

Federal Railroad Administration. Office of Safety Analysis web site.

Federal Railroad Administration. (2006). Use of Locomotive Horns at Highway-Rail Grade Crossings; Final Rule.

Federal Railroad Administration. (2013). Guide to the Quiet Zone Establishment Process.

Federal Railroad Administration. (2018). National Strategy to Prevent Trespassing on Railroad Property.

Federal Railroad Administration. (2020). Quiet Zone Locations by City and State.

Electronic Code of Federal Regulations (2020). PART 222 – USE OF LOCOMOTIVE HORNS AT PUBLIC HIGHWAY-RAIL GRADE CROSSINGS.

Government Accountability Office. (2017). Quiet Zone Analyses and Inspection Could Be Improved.

Appendix A.
Quiet Zone with Trespass Accidents

QZ Case ID	State	City	Basis Section	QZ Type	CCM QZID	QZ NOE Date	# of Years	Period	Trespass Accident Date	Trespass INCDTNO	RR
THR_Request_000000110069	TX	Austin	222.39(b)(4)(i)(A)	New	THR-000852	11/12/2014	3	After	2/18/2015	0215SA020	UP
THR_Request_000000110069	TX	Austin	222.39(b)(4)(i)(A)	New	THR-000852	11/12/2014	3	After	5/19/2015	137495	ATK
THR_Request_000000110069	TX	Austin	222.39(b)(4)(i)(A)	New	THR-000852	11/12/2014	3	After	6/7/2016	0616SA009	UP
THR_Request_000000110069	TX	Austin	222.39(b)(4)(i)(A)	New	THR-000852	11/12/2014	3	After	1/30/2017	0117SA019	UP
THR_Request_000000110445	WI	Waukesha	222.39(a)(3)	Pre-Rule	THR-000128	6/13/2013	2	After	7/23/2013	786454	WC
THR_Request_000000110445	WI	Waukesha	222.39(a)(3)	Pre-Rule	THR-000128	6/13/2013	2	After	6/15/2014	816708	WC
THR_Request_000000110858	TX	San Marcos	222.39(a)(3)	New	THR-000589	5/21/2015	3	Before	8/2/2014	0814SA001	UP
THR_Request_000000110858	TX	San Marcos	222.39(a)(3)	New	THR-000589	5/21/2015	3	Before	4/17/2015	0415SA013	UP
THR_Request_000000110858	TX	San Marcos	222.39(a)(3)	New	THR-000589	5/21/2015	3	After	3/29/2016	0316SA020	UP
THR_Request_000000110858	TX	San Marcos	222.39(a)(3)	New	THR-000589	5/21/2015	3	After	8/26/2016	0816SA021	UP
THR_Request_000000110859	TX	San Marcos	222.39(a)(3)	New	THR-000590	5/21/2015	3	After	7/31/2017	0717SA027	UP
THR_Request_000000110859	TX	San Marcos	222.39(a)(3)	New	THR-000590	5/21/2015	3	After	11/12/2017	1117SA006	UP
THR_Request_000000110859	TX	San Marcos	222.39(a)(3)	New	THR-000590	5/21/2015	3	After	3/20/2018	0318SA008	UP
THR_Request_000000110859	TX	San Marcos	222.39(a)(3)	New	THR-000590	5/21/2015	3	After	3/29/2018	0318SA021	UP
THR_Request_000000110892	WI	Wauwatosa	222.39(b)(4)(i)(A)	Pre-Rule	THR-000052	10/20/2013	2	Before	2/27/2012	230548	SOO
THR_Request_000000110892	WI	Wauwatosa	222.39(b)(4)(i)(A)	Pre-Rule	THR-000052	10/20/2013	2	After	10/29/2014	1000138849	CP
THR_Request_000000111047	OH	Hilliard	222.39(a)(1)	New	THR-000782	11/1/2013	2	After	3/24/2015	000143574	CSX
THR_Request_000000111073	TX	San Antonio	222.39(b)(4)(i)(A)	New	THR-000808	6/13/2015	3	Before	11/6/2012	1112SA028	UP
THR_Request_000000111073	TX	San Antonio	222.39(b)(4)(i)(A)	New	THR-000808	6/13/2015	3	Before	9/29/2012	0912SA015	UP
THR_Request_000000111073	TX	San Antonio	222.39(b)(4)(i)(A)	New	THR-000808	6/13/2015	3	Before	10/14/2013	1013SA013	UP
THR_Request_000000111073	TX	San Antonio	222.39(b)(4)(i)(A)	New	THR-000808	6/13/2015	3	Before	11/7/2014	1114SA008	UP
THR_Request_000000111082	CA	Riverside	222.39(a)(1)	New	THR-000818	11/17/2016	2	Before	10/3/2015	CA1015101	BNSF
THR_Request_000000111082	CA	Riverside	222.39(a)(1)	New	THR-000818	11/17/2016	2	Before	12/11/2015	CA1215108	BNSF
THR_Request_000000111082	CA	Riverside	222.39(a)(1)	New	THR-000818	11/17/2016	2	Before	4/22/2016	042216	SCAX
THR_Request_000000111082	CA	Riverside	222.39(a)(1)	New	THR-000818	11/17/2016	2	Before	10/31/2016	CA1016205	BNSF
THR_Request_000000111082	CA	Riverside	222.39(a)(1)	New	THR-000818	11/17/2016	2	After	2/28/2017	022817	SCAX

QZ Case ID	State	City	Basis Section	QZ Type	CCM QZID	QZ NOE Date	# of Years	Period	Trespass Accident Date	Trespass INCDTNO	RR
THR_Request_000000111082	CA	Riverside	222.39(a)(1)	New	THR-000818	11/17/2016	2	After	1/18/2017	145958	ATK
THR_Request_000000111082	CA	Riverside	222.39(a)(1)	New	THR-000818	11/17/2016	2	After	7/5/2017	CA0717101	BNSF
THR_Request_000000111082	CA	Riverside	222.39(a)(1)	New	THR-000818	11/17/2016	2	After	6/28/2017	CA0617116	BNSF
THR_Request_000000111082	CA	Riverside	222.39(a)(1)	New	THR-000818	11/17/2016	2	After	10/6/2017	CA1017200	BNSF
THR_Request_000000111082	CA	Riverside	222.39(a)(1)	New	THR-000818	11/17/2016	2	After	10/17/2018	CA1018110	BNSF
THR_Request_000000111101	TX	Houston	222.39(b)(4)(i)(A)	New	THR-000841	1/25/2016	3	Before	9/8/2013	GC0913107	BNSF
THR_Request_000000111101	TX	Houston	222.39(b)(4)(i)(A)	New	THR-000841	1/25/2016	3	Before	6/14/2015	GC0615108	BNSF
THR_Request_000000111101	TX	Houston	222.39(b)(4)(i)(A)	New	THR-000841	1/25/2016	3	Before	8/22/2015	GC0815118	BNSF
THR_Request_000000111101	TX	Houston	222.39(b)(4)(i)(A)	New	THR-000841	1/25/2016	3	After	10/20/2018	RD1018206	BNSF
THR_Request_000000111116	NE	Scottsbluff	222.39(a)(1)	New	THR-000858	4/25/2014	2	Before	6/8/2012	PR0612100	BNSF
THR_Request_000000111123	MN	Anoka	222.39(a)(1)	New	THR-000865	11/16/2013	2	After	9/7/2014	TC0914100	BNSF
THR_Request_000000111128	IL	Tinley Park	222.39(b)(4)(i)(A)	New	THR-000874	12/4/2012	1	Before	12/19/2011	RIE157	NIRC
THR_Request_000000111134	ND	Minot	222.39(b)(4)(i)(A)	New	THR-000880	10/11/2014	3	After	1/11/2017	MT0117114	BNSF
THR_Request_000000111138	CA	Sacramento	222.39(b)(4)(i)(A)	New	THR-000885	1/9/2016	3	After	1/25/2017	146049	ATK
THR_Request_000000111141	AZ	Maricopa	222.39(a)(3)	New	THR-000888	5/29/2013	1	Before	2/27/2013	0213ST010	UP
THR_Request_000000111165	TX	San Antonio	222.39(a)(3)	New	THR-000913	4/21/2015	3	Before	3/18/2013	0313SA014	UP
THR_Request_000000111165	TX	San Antonio	222.39(a)(3)	New	THR-000913	4/21/2015	3	Before	4/30/2013	0413SA020	UP
THR_Request_000000111165	TX	San Antonio	222.39(a)(3)	New	THR-000913	4/21/2015	3	Before	6/27/2014	0614SA025	UP
THR_Request_000000111165	TX	San Antonio	222.39(a)(3)	New	THR-000913	4/21/2015	3	Before	2/14/2015	0215SA018	UP
THR_Request_000000111165	TX	San Antonio	222.39(a)(3)	New	THR-000913	4/21/2015	3	After	9/13/2015	GC0915201	BNSF
THR_Request_000000111165	TX	San Antonio	222.39(a)(3)	New	THR-000913	4/21/2015	3	After	9/13/2015	GC0915201	BNSF
THR_Request_000000111165	TX	San Antonio	222.39(a)(3)	New	THR-000913	4/21/2015	3	After	7/18/2016	0716SA015	UP
THR_Request_000000111165	TX	San Antonio	222.39(a)(3)	New	THR-000913	4/21/2015	3	After	3/9/2016	0316SA009	UP
THR_Request_000000111165	TX	San Antonio	222.39(a)(3)	New	THR-000913	4/21/2015	3	After	1/30/2016	0116SA015	UP
THR_Request_000000111165	TX	San Antonio	222.39(a)(3)	New	THR-000913	4/21/2015	3	After	4/28/2017	147220	ATK
THR_Request_000000111165	TX	San Antonio	222.39(a)(3)	New	THR-000913	4/21/2015	3	After	3/2/2017	0317SA001	UP
THR_Request_000000111165	TX	San Antonio	222.39(a)(3)	New	THR-000913	4/21/2015	3	After	11/19/2017	1117SA016	UP
THR_Request_000000111178	TX	San Antonio	222.39(a)(3)	New	THR-000928	7/20/2013	2	After	12/16/2013	1213SA006	UP

QZ Case ID	State	City	Basis Section	QZ Type	CCM QZID	QZ NOE Date	# of Years	Period	Trespass Accident Date	Trespass INCDTNO	RR
THR_Request_000000111189	WY	Newcastle	222.39(a)(1)	New	THR-000939	11/9/2013	2	Before	9/15/2012	PR0912105	BNSF
THR_Request_000000111193	CA	Sacramento	222.39(a)(3)	New	THR-000943	9/7/2013	2	Before	12/8/2012	1212RS004	UP
THR_Request_000000111193	CA	Sacramento	222.39(a)(3)	New	THR-000943	9/7/2013	2	Before	4/12/2013	0413RS009	UP
THR_Request_000000111193	CA	Sacramento	222.39(a)(3)	New	THR-000943	9/7/2013	2	Before	3/3/2013	127397	ATK
THR_Request_000000111193	CA	Sacramento	222.39(a)(3)	New	THR-000943	9/7/2013	2	After	7/25/2014	0714RS024	UP
THR_Request_000000111193	CA	Sacramento	222.39(a)(3)	New	THR-000943	9/7/2013	2	After	4/10/2014	0414RS006	UP
THR_Request_000000111193	CA	Sacramento	222.39(a)(3)	New	THR-000943	9/7/2013	2	After	1/11/2015	0115RS010	UP
THR_Request_000000111212	OR	Portland	222.39(b)(4)(i)(A)	New	THR-000962	3/2/2015	3	Before	8/12/2013	129422	ATK
THR_Request_000000111212	OR	Portland	222.39(b)(4)(i)(A)	New	THR-000962	3/2/2015	3	After	6/20/2017	148011	ATK
THR_Request_000000111213	TX	San Antonio	222.39(a)(3)	New	THR-000963	4/14/2015	3	Before	4/1/2014	0414SA003	UP
THR_Request_000000111217	UT	Provo	222.39(a)(3)	New	THR-000967	11/29/2012	1	Before	8/30/2012	0812UT017	UP
THR_Request_000000111217	UT	Provo	222.39(a)(3)	New	THR-000967	11/29/2012	1	After	2/19/2013	02192013	UTAX
THR_Request_000000111217	UT	Provo	222.39(a)(3)	New	THR-000967	11/29/2012	1	After	9/27/2013	0927132	UFRC
THR_Request_000000111229	CA	Rocklin	222.39(a)(3)	New	THR-000979	8/13/2013	2	Before	7/22/2013	0713RS011	UP
THR_Request_000000111243	OR	Salem	222.39(a)(1)	New	THR-000993	7/24/2013	2	Before	12/14/2011	122132	ATK
THR_Request_000000111243	OR	Salem	222.39(a)(1)	New	THR-000993	7/24/2013	2	Before	1/30/2012	0112PD010	UP
THR_Request_000000111262	CA	Galt	222.39(a)(3)	New	THR-001012	3/21/2016	3	Before	3/7/2014	0314RS008	UP
THR_Request_000000111270	FL	Ocala	222.39(a)(3)	New	THR-001020	9/13/2014	3	Before	6/3/2014	000130472	CSX
THR_Request_000000111270	FL	Ocala	222.39(a)(3)	New	THR-001020	9/13/2014	3	After	2/20/2016	000157276	CSX
THR_Request_000000111270	FL	Ocala	222.39(a)(3)	New	THR-001020	9/13/2014	3	After	12/15/2016	000165224	CSX
THR_Request_000000111270	FL	Ocala	222.39(a)(3)	New	THR-001020	9/13/2014	3	After	12/15/2016	000165224	CSX
THR_Request_000000111270	FL	Ocala	222.39(a)(3)	New	THR-001020	9/13/2014	3	After	12/15/2016	000165224	CSX
THR_Request_000000111270	FL	Ocala	222.39(a)(3)	New	THR-001020	9/13/2014	3	After	12/6/2016	000164904	CSX
THR_Request_000000111290	IL	Bensenville	222.39(b)(4)(i)(A)	New	THR-001040	7/4/2015	3	Before	3/14/2013	MRG020	NIRC
THR_Request_000000111296	TX	New Braunfels	222.39(b)(4)(i)(A)	New	THR-001046	4/22/2016	3	After	2/23/2018	0218SA022	UP
THR_Request_000000111307	FL	Lakeland	222.39(a)(1)	New	THR-001057	11/5/2013	2	After	3/9/2015	000142711	CSX
THR_Request_000000111309	IL	Joliet	222.39(a)(3)	New	THR-001059	11/3/2013	2	After	2/7/2015	840134	WC
THR_Request_000000111310	TX	Caldwell	222.39(a)(3)	New	THR-001060	8/9/2014	3	Before	10/26/2012	GC1012115	BNSF

QZ Case ID	State	City	Basis Section	QZ Type	CCM QZID	QZ NOE Date	# of Years	Period	Trespass Accident Date	Trespass INCDTNO	RR
THR_Request_000000111311	CO	Castle Rock/ Douglas County	222.39(a)(1)	New	THR-001061	11/26/2014	3	After	7/26/2016	PR0716113	BNSF
THR_Request_000000111317	WY	Torrington	222.59	wayside horns	THR-001067	12/24/2013	2	After	8/26/2015	PR0815111	BNSF
THR_Request_000000111317	WY	Torrington	222.59	wayside horns	THR-001067	12/24/2013	2	After	8/26/2015	PR0815111	BNSF
THR_Request_000000111325	AZ	Kingman	222.39(a)(1)	New	THR-001075	8/9/2014	3	Before	6/2/2013	SW0613008	BNSF
THR_Request_000000111332	MN	Elk River	222.39(a)(1)	New	THR-001082	10/31/2016	2	After	11/8/2016	TC1116200	BNSF
THR_Request_000000111332	MN	Elk River	222.39(a)(1)	New	THR-001082	10/31/2016	2	After	11/8/2016	TC1116200	BNSF
THR_Request_000000111332	MN	Elk River	222.39(a)(1)	New	THR-001082	10/31/2016	2	After	11/8/2016	TC1116200	BNSF
THR_Request_000000111345	TX	Canyon	222.39(a)(1)	New	THR-001095	10/2/2015	3	After	2/26/2016	KS0216202	BNSF
THR_Request_000000111349	AZ	Willcox	222.39(a)(3)	New	THR-001099	4/14/2015	3	Before	4/7/2015	0415ST008	UP
THR_Request_000000111349	AZ	Willcox	222.39(a)(3)	New	THR-001099	4/14/2015	3	After	7/23/2016	0716ST016	UP
THR_Request_000000111350	IL	Itasca	222.39(a)(3)	New	THR-001100	12/23/2015	3	Before	1/13/2015	MRI001	NIRC
THR_Request_000000111353	WI	Pepin	222.39(a)(3)	New	THR-001103	9/24/2015	3	After	1/23/2017	CH0117200	BNSF
THR_Request_000000111356	TX	Mesquite	222.39(b)(4)(i)(A)	New	THR-001106	8/2/2015	3	Before	6/9/2013	0613FW009	UP
THR_Request_000000111356	TX	Mesquite	222.39(b)(4)(i)(A)	New	THR-001106	8/2/2015	3	Before	11/18/2014	135266	ATK
THR_Request_000000111356	TX	Mesquite	222.39(b)(4)(i)(A)	New	THR-001106	8/2/2015	3	Before	7/20/2015	0715FW026	UP
THR_Request_000000111358	TN	Nashville	222.39(a)(2)(ii)	New	THR-001108	9/9/2014	3	Before	10/28/2011	000097153	CSX
THR_Request_000000111358	TN	Nashville	222.39(a)(2)(ii)	New	THR-001108	9/9/2014	3	After	8/9/2015	000150370	CSX
THR_Request_000000111362	TX	Mansfield	222.39(a)(2)(ii)	New	THR-001112	10/16/2015	3	After	9/30/2017	0917FW023	UP
THR_Request_000000111377	WI	Hartland	222.39(a)(1)	New	THR-001127	10/24/2015	3	Before	2/16/2015	1000174766	CP
THR_Request_000000111382	TX	Orange	222.39(a)(3)	New	THR-001133	5/23/2016	3	Before	3/30/2014	GC0314006	BNSF
THR_Request_000000111382	TX	Orange	222.39(a)(3)	New	THR-001133	5/23/2016	3	After	3/25/2017	146840	ATK
THR_Request_000000111393	OK	Oklahoma City	222.39(b)(4)(i)(A)	New	THR-001145	2/28/2017	2	Before	5/13/2015	TX0515102	BNSF
THR_Request_000000111393	OK	Oklahoma City	222.39(b)(4)(i)(A)	New	THR-001145	2/28/2017	2	Before	8/1/2015	0815WH002	UP
THR_Request_000000111393	OK	Oklahoma City	222.39(b)(4)(i)(A)	New	THR-001145	2/28/2017	2	Before	11/19/2016	RD1116111	BNSF
THR_Request_000000111393	OK	Oklahoma City	222.39(b)(4)(i)(A)	New	THR-001145	2/28/2017	2	After	9/9/2018	RD0918131	BNSF
THR_Request_000000111398	NM	Isleta	222.39(a)(1)	New	THR-001150	6/13/2015	3	After	6/4/2016	04062016	NMRX

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THR_Request_000000111401	FL	Orlando	222.39(a)(1)	New	THR-001154	7/22/2015	3	After	8/24/2017	17236	CFRC
THR_Request_000000111402	IN	Muncie	222.39(a)(2)(ii)	New	THR-001155	1/9/2016	3	After	7/17/2016	000167109	CSX
THR_Request_000000111402	IN	Muncie	222.39(a)(2)(ii)	New	THR-001155	1/9/2016	3	After	7/8/2016	000161187	CSX
THR_Request_000000111402	IN	Muncie	222.39(a)(2)(ii)	New	THR-001155	1/9/2016	3	After	6/2/2018	000176813	CSX
THR_Request_000000111404	IN	Muncie	222.39(a)(2)(ii)	New	THR-001157	1/9/2016	3	Before	9/11/2013	106337	NS
THR_Request_000000111404	IN	Muncie	222.39(a)(2)(ii)	New	THR-001157	1/9/2016	3	Before	2/17/2014	109181	NS
THR_Request_000000111404	IN	Muncie	222.39(a)(2)(ii)	New	THR-001157	1/9/2016	3	After	7/17/2016	122104	NS
THR_Request_000000111409	OK	Woodward	222.39(a)(1)	New	THR-001162	10/1/2017	1	Before	3/20/2017	KS0317200	BNSF
THR_Request_000000111497	IL	Rochelle	222.39(a)(3)	New	THR-000353	9/30/2016	2	Before	11/20/2015	1115PR010	UP
THR_Request_000000111497	IL	Rochelle	222.39(a)(3)	New	THR-000353	9/30/2016	2	After	11/19/2016	1116PR009	UP
THR_Request_000000111653	OH	Olmsted Falls	222.39(a)(3)	New	THR-000557	11/22/2012	1	Before	2/22/2012	000100987	CSX
THR_Request_000000111653	OH	Olmsted Falls	222.39(a)(3)	New	THR-000557	11/22/2012	1	After	10/20/2013	000121949	CSX
THR_Request_000000111798	NE	Lincoln	222.39(a)(1)	New	THR-000719	8/4/2012	1	After	7/20/2013	NE0713106	BNSF
THR_Request_000000111826	CA	San Juan Capistr	222.39(a)(3)	New	THR-000749	3/19/2013	1	Before	12/24/2012	126535	ATK
THR_Request_000000111832	OR	Milwaukie	222.39(b)(4)(i)(A)	New	THR-000755	5/2/2015	3	Before	8/30/2013	PNW427313T	PNWR
THR_Request_000000111846	IL	Mokena	222.39(a)(3)	New	THR-000769	1/15/2013	1	Before	6/13/2012	RIF047	NIRC
THR_Request_000000120001	TX	Pearland	222.39(a)(1)	New		3/16/2016	3	After	3/17/2017	0317HO072	UP
THR_Request_000000210001	TX	Kilgore	222.39(a)(3)	New		5/14/2018	1	After	7/1/2018	0718HO003	UP
THR_Request_000000260002	MI	Battle Creek	222.39(a)(3)	New		12/28/2016	2	Before	12/21/2016	909348	GTW
THR_Request_000000260002	MI	Battle Creek	222.39(a)(3)	New		12/28/2016	2	Before	8/18/2016	898213	GTW
THR_Request_000000260002	MI	Battle Creek	222.39(a)(3)	New		12/28/2016	2	After	4/22/2017	920020	GTW
THR_Request_000000260002	MI	Battle Creek	222.39(a)(3)	New		12/28/2016	2	After	5/31/2017	924333	GTW
THR_Request_000000260002	MI	Battle Creek	222.39(a)(3)	New		12/28/2016	2	After	1/1/2018	945794	GTW
THR_Request_000000260002	MI	Battle Creek	222.39(a)(3)	New		12/28/2016	2	After	7/12/2018	965836	GTW
THR_Request_000000320001	OK	Norman	222.39(a)(3)	New		2/17/2017	2	Before	4/17/2015	TX0415103	BNSF
THR_Request_000000320001	OK	Norman	222.39(a)(3)	New		2/17/2017	2	Before	1/5/2016	TX0116200	BNSF
THR_Request_000000320001	OK	Norman	222.39(a)(3)	New		2/17/2017	2	Before	10/7/2016	RD1016200	BNSF
THR_Request_000000320001	OK	Norman	222.39(a)(3)	New		2/17/2017	2	After	8/16/2017	RD0817203	BNSF

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THR_Request_000000320001	OK	Norman	222.39(a)(3)	New		2/17/2017	2	After	11/17/2018	156336	ATK
THR_Request_000000320001	OK	Norman	222.39(a)(3)	New		2/17/2017	2	After	11/17/2018	RD1118208	BNSF
THR_Request_000000320001	OK	Norman	222.39(a)(3)	New		2/17/2017	2	After	9/29/2018	RD0918149	BNSF
THR_Request_000000360001	MN	Big Lake	222.39(a)(1)	New		1/5/2015	3	After	9/28/2016	TC0916201	BNSF
THR_Request_000000410003	MN	Little Canada	222.39(a)(2)(ii)	New		6/15/2016	2	After	4/23/2018	1000742381	CP
THR_Request_000000430002	CA	San Clemente	222.59	wayside horns		6/24/2016	2	Before	7/18/2015	138323	ATK
THR_Request_000000430002	CA	San Clemente	222.59	wayside horns		6/24/2016	2	After	11/11/2016	145090	ATK
THR_Request_000000520003	CT	Wallingford	222.59	wayside horns		10/20/2015	3	Before	12/15/2014	CSO668214T	CSO
THR_Request_000000530001	OR	Salem	222.39(a)(1)	New		5/1/2017	2	Before	8/6/2015	138653	ATK
THR_Request_000000550004	GA	Lithonia	222.39(a)(2)(i)	New		10/20/2016	2	After	11/19/2017	000172984	CSX
THR_Request_000000720006	TX	Fort Worth	222.39(a)(1)	New		4/23/2018	1	After	11/7/2018	156181	ATK
THR_Request_000000720006	TX	Fort Worth	222.39(a)(1)	New		4/23/2018	1	After	11/7/2018	156181	ATK
THR_Request_000000770004	WY	Glendo	222.39(a)(1)	New		1/30/2018	1	After	6/15/2018	PR0618201	BNSF
THR_Request_000000790002	NC	Kannapolis	222.39(a)(1)	New		8/14/2017	1	Before	8/31/2016	121974	NS
THR_Request_000000790002	NC	Kannapolis	222.39(a)(1)	New		8/14/2017	1	Before	1/4/2017	123478	NS
THR_Request_000000950001	MN	Elk River	222.39(a)(3)	New		2/16/2018	1	After	2/25/2018	NS2018001	NSCR
THR_Request_000001060002	FL	Deerfield Beach	222.39(a)(3)	New		2/15/2018	1	Before	4/28/2017	042817	SFRV
THR_Request_000001060002	FL	Deerfield Beach	222.39(a)(3)	New		2/15/2018	1	After	9/4/2018	90418	SFRV
THR_Request_000001150001	FL	Lake Worth	222.39(a)(3)	New		5/22/2018	1	Before	12/2/2017	T27120217	FEC
THR_Request_000001150001	FL	Lake Worth	222.39(a)(3)	New		5/22/2018	1	Before	6/8/2017	T09060817	FEC
THR_Request_000001150001	FL	Lake Worth	222.39(a)(3)	New		5/22/2018	1	After	9/17/2018	20180265	BLF
THR_Request_000001150001	FL	Lake Worth	222.39(a)(3)	New		5/22/2018	1	After	12/1/2018	X35120118	FEC
THR_Request_000001150001	FL	Lake Worth	222.39(a)(3)	New		5/22/2018	1	After	6/23/2018	X16062318	FEC
THR_Request_000001150001	FL	Lake Worth	222.39(a)(3)	New		5/22/2018	1	Before	2/2/2018	T04020218	FEC
THR_Request_000001150001	FL	Lake Worth	222.39(a)(3)	New		5/22/2018	1	Before	1/7/2018	T02010718	FEC
THR_Request_000001150001	FL	Lake Worth	222.39(a)(3)	New		5/22/2018	1	After	1/29/2019	X05012919	FEC
THR_Request_000001160001	FL	Boca Raton	222.39(a)(3)	New		5/30/2018	1	Before	7/3/2017	T14070317	FEC

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THR_Request_000001160001	FL	Boca Raton	222.39(a)(3)	New		5/30/2018	1	Before	7/24/2017	201707001	BLF
THR_Request_000001160001	FL	Boca Raton	222.39(a)(3)	New		5/30/2018	1	Before	2/14/2018	20180039	BLF
THR_Request_000001160001	FL	Boca Raton	222.39(a)(3)	New		5/30/2018	1	After	1/17/2019	20190014	BLF
THR_Request_000001160001	FL	Boca Raton	222.39(a)(3)	New		5/30/2018	1	After	4/23/2019	T13042319	FEC
THR_Request_000000111238	GA	College Park	222.39(a)(2)(ii)	New	THR-000988	6/13/2014	3	Before	7/5/2013	000118097	CSX
THR_Request_000000111238	GA	College Park	222.39(a)(2)(ii)	New	THR-000988	6/13/2014	3	After	2/5/2015	000140994	CSX
THR_Request_000000111238	GA	College Park	222.39(a)(2)(ii)	New	THR-000988	6/13/2014	3	After	5/22/2017	000169114	CSX
THR_Request_000000111292	GA	Acworth	222.39(a)(1)	New	THR-001042	9/12/2016	2	After	9/21/2016	000163024	CSX
THR_Request_000000240001	NY	Camillus	222.39(a)(2)(i)	New		6/14/2016	2	After	1/12/2017	1122017	FGLK
THR_Request_000000111348	AZ	Gila Bend	222.39(a)(1)	New	THR-001098	10/22/2014	3	Before	6/24/2012	0612ST021	UP
THR_Request_000000111228	CA	Del Mar	222.59	wayside horns	THR-000978	9/14/2012	1	Before	8/16/2012	I680212	PSRR
THR_Request_000000590001	CA	Richmond	222.59	wayside horns		8/1/2016	2	After	8/4/2016	0816RS002	UP
THR_Request_000000300001	CA	Atherton	222.39(a)(1)	New		6/13/2016	2	Before	7/10/2014	20140710B	PCMZ
THR_Request_000000300001	CA	Atherton	222.39(a)(1)	New		6/13/2016	2	Before	5/17/2015	20150517B	PCMZ
THR_Request_000000111195	IL	Park Forest	222.39(b)(4)(i)(A)	New	THR-000945	10/8/2013	2	Before	3/1/2013	772262	WC
THR_Request_000000970002	KS	Merriam	222.59	wayside horns		12/6/2017	1	After	9/4/2018	HL0918118	BNSF
THR_Request_000000111408	MD	Riverdale Park	222.39(a)(1)	New	THR-001161	9/11/2015	3	Before	9/23/2013	2013092318	MACZ
THR_Request_000000111408	MD	Riverdale Park	222.39(a)(1)	New	THR-001161	9/11/2015	3	Before	4/10/2015	1504101830	MACZ
THR_Request_000000111408	MD	Riverdale Park	222.39(a)(1)	New	THR-001161	9/11/2015	3	After	6/18/2016	000160660	CSX
THR_Request_000000750001	NC	Charlotte	222.39(a)(1)	New		3/1/2017	2	After	9/22/2017	149614	ATK
THR_Request_000000111067	OH	Brook Park	222.39(a)(1)	New	THR-000802	4/15/2015	3	After	8/27/2015	000151514	CSX
THR_Request_000000111225	TX	San Marcos	222.39(a)(1)	New	THR-000975	5/21/2015	3	Before	4/8/2015	0415SA005	UP
THR_Request_000000111300	TX	Arlington	222.39(a)(1)	New	THR-001050	12/7/2013	2	Before	2/22/2012	0212FW016	UP
THR_Request_000000700001	TX	Sugar Land	222.59	wayside horns		2/6/2017	2	After	9/12/2017	0917HO006	UP
THR_Request_000000930001	TX	Brenham	222.39(a)(1)	New		1/15/2018	1	Before	3/1/2017	RD0317201	BNSF
THR_Request_000000111337	VA	Prince William	222.39(a)(1)	New	THR-001087	8/20/2014	3	Before	4/29/2012	123644	ATK

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THR_Request_ 000000111337	VA	Prince William	222.39(a)(1)	New	THR-001087	8/20/2014	3	Before	4/29/2012	000103194	CSX

Appendix B.
Paired T-test Results – By Year

Violation Rate Descriptive Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	1 Year-Before	.17	109	.575	.055
	1 Year-After	.16	109	.547	.052
Pair 2	2 Year-Before	.25	113	.714	.067
	2 Year-After	.35	113	.925	.087
Pair 3	3 Year-Before	.35	111	.794	.075
	3 Year-After	.42	111	1.116	.106

Violation Rate Paired Sample T-Tests									
		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	1 Year-Before 1 Year-After	.018	.451	.043	-.067	.104	.425	108	.672
Pair 2	2 Year-Before 2 Year-After	-.106	.699	.066	-.236	.024	-1.615	112	.109
Pair 3	3 Year-Before 3 Year-After	-.072	1.093	.104	-.278	.134	-.695	110	.489

Appendix C.
Paired T-test Results – By QZ Type

Violation Rate Descriptive Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	New -Before	.27	308	.722	.041
	New -After	.31	308	.920	.052
Pair 2	Wayside Horns-Before	.20	15	.414	.107
	Wayside Horns-After	.40	15	.632	.163

Violation Rate Paired Sample T-Tests									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	New -Before New -After	-.042	.800	.046	-.132	.047	-.926	307	.355
Pair 2	Wayside Horns-Before Wayside Horns-After	-.200	.775	.200	-.629	.229	-1.000	14	.334

Appendix D.
Paired T-test Results – By Basis Section

Violation Rate Descriptive Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	222.39(a)(3)-Before	.55	65	.985	.122
	222.39(a)(3)-After	.77	65	1.529	.190
Pair 2	222.39(a)(2)(i)-Before	.00	19	.000	.000
	222.39(a)(2)(i)-After	.11	19	.315	.072
Pair 3	222.39(a)(1) -Before	.15	162	.513	.040
	222.39(a)(1) -After	.16	162	.610	.048
Pair 4	222.39(b)(4)(i)(A)-Before	.36	53	.901	.124
	222.39(b)(4)(i)(A)-After	.21	53	.631	.087
Pair 5	222.59-Before	.19	16	.403	.101
	222.59-After	.38	16	.619	.155
Pair 6	222.39(a)(2)(ii)-Before	.27	15	.594	.153
	222.39(a)(2)(ii)-After	.60	15	.910	.235

Violation Rate Paired Sample T-Tests									
		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	222.39(a)(3)-Before 222.39(a)(3)-After	-.215	1.038	.129	-.473	.042	-1.673	64	.099
Pair 2	222.39(a)(2)(i)-Before 222.39(a)(2)(i)-After	-.105	.315	.072	-.257	.047	-1.455	18	.163
Pair 3	222.39(a)(1) -Before 222.39(a)(1) -After	-.012	.600	.047	-.105	.081	-.262	161	.794
Pair 4	222.39(b)(4)(i)(A)-Before 222.39(b)(4)(i)(A)-After	.151	1.026	.141	-.132	.434	1.071	52	.289
Pair 5	222.59-Before 222.59-After	-.187	.750	.188	-.587	.212	-1.000	15	.333
Pair 6	222.39(a)(2)(ii)-Before 222.39(a)(2)(ii)-After	-.333	.900	.232	-.832	.165	-1.435	14	.173

Abbreviations and Acronyms

ASMs	Alternative Safety Measures
CFR	Code of Federal Regulations
FAST	Fixing America's Surface Transportation
FRA	Federal Railroad Administration
GAO	Government Accountability Office
GCIS	Grade Crossing Inventory System
NOE	Notice of Establishment
NSRT	Nationwide Significant Risk Threshold
QZ	Quiet Zone
QZRI	Quiet Zone Risk Index
RAIRS	Railroad Accident Incident Reporting System
RD&T	Railroad Development and Technology
RIWH	Risk Index With Horns
ROW	Right-of-Way
SSMs	Supplemental Safety Measures
U.S. DOT	U.S. Department of Transportation
Volpe	John A. Volpe National Transportation Systems