Final Report

Railroad Crossing Wayside Horn Evaluation

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May 11, 2007

For the

North Carolina Department of Transportation
Research and Development Unit
1549 Mail Service Center
Raleigh, NC 27699-1549

Project 2003-11

Technical Report Documentation Page

1. Report No. FHWA/NC/2006-36	2. Government Accession No. …	3. Recipient's Catalog No. … …
4. Title and Subtitle Railroad Crossing Wayside Horn Evaluation		5. Report Date May 11, 2007
		6. Performing Organization Code … …
7. Author(s) Joseph E. Hummer, Ph.D., P.E. and Mohammad Reza Jafari		8. Performing Organization Report No. … …
9. Performing Organization Name and Address North Carolina State University Department of Civil, Construction and Environmental Engineering Campus Box 7908 Raleigh, NC 27695		10. Work Unit No. (TRAIS) … …
		11. Contract or Grant No. … …
12. Sponsoring Agency Name and Address North Carolina Department of Transportation Research and Development Unit 1549 Mail Service Center Raleigh, North Carolina 27699-1549		13. Type of Report and Period Covered Final Report July 2002 to June 2006
		14. Sponsoring Agency Code 2003-11
Supplementary Notes: … …		

16. Abstract

One potential solution for reducing horn noise from a locomotive is a stationary horn mounted at the crossing. This "wayside horn" is sounded in place of the locomotive horn when a train approaches and is positioned to direct the sound precisely down the intersecting roadways rather than along the track. A wayside horn can therefore operate at a lower sound level than a locomotive horn and produce less area sound exposure.

The objective of this project was to evaluate a wayside horn produced by Railroad Controls Limited. We conducted the evaluation through observation of a test installation in Rocky Mount before and after wayside horn installation. Before wayside horn installation, the site had a typical array of safety devices (gates, lights, signs, and marking). The site was a nearly ideal crossing of a road with one through lane in each direction of a single track with low train volumes and speeds in a moderate density suburban area. We examined the reliability of the system and also measured sound in the area, motorist behavior, motorist opinion, area resident opinion, and train engineer opinion.

Based on the results from previous studies and the results from our test, the study team concluded that the wayside horn offers significant sound relief to residents and others in the area around a crossing. The team also concluded that the wayside horn has led to slight, if any, shifts in driver behavior and opinion. Finally, the study team concluded that the wayside horn appears to be reliable and acceptable to train engineers. The team recommends that the NCDOT, other relevant agencies, and railroads continue to allow wayside horns.

17. Key Words Railroad, crossing, at-grade, device, horn, wayside	18. Distribution Statement …		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 49	22. Price … …

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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Acknowledgements

The authors gratefully acknowledge the help of many people in conducting this project and assembling this report. From the NCDOT Rail Division, Jason Field provided tremendous help and guidance throughout the project. Paul Worley, the Chair of our Technical Committee, Patrick Simmons, and Drew Thomas of the Rail Division also provided great support. Kurt Anderson of Railroad Controls, Limited, responded to every request quickly and thoughtfully. Scott Lisenby of Interactive Video Solutions, Anthony Martin at the City of Rocky Mount, and Tim Abbott of the Nash County Railroad Corporation worked diligently to make the site operational. Other members of our Technical Committee who contributed time and thoughts were Kevin Lacy of the NCDOT Traffic Engineering Branch; M. Adam Mastrangelo, Richard Ray, and Bill Barringer of Norfolk Southern Railroad; Danny A. Gilbert of Rail Safety Consultants; John Roberson of the Triangle Transit Authority; Bradley Hibbs of FHWA; and Scott Beaver of the NC Attorney General's Office. From the NC Research and Development Unit, Derry Schmidt got the project off to a good start and Ernest Morrison brought us to a conclusion. Professor Ellis King of UNC Charlotte was the original PI for the project, and we are grateful for his leadership. Johnny Graham of UNC Charlotte advised us in the latter stages. At NC State, Deb Paxton, Tish Attayek, Jeff Cable, and Barbara Rowe were among the people who made the project possible. Finally, we thank the participants in the surveys who gave their time and opinions for nothing more than to help the cause of research on safer and quieter highways and railroads.

Executive Summary

Federal Railroad Administration (FRA) rules require that locomotive horns be sounded at most public highway-rail intersections (grade crossings) in the United States. This is due to the incontrovertible evidence showing that horns are an effective safety device preventing collisions at crossings. However, the rule also provides an opportunity for any community to establish a "quiet zone" in which the locomotive horn would not be sounded at crossings where supplementary safety measures (SSMs) fully compensate for the absence of the warning provided by the locomotive horn. However, the cost of the SSMs the FRA rules require in quiet zones may be prohibitive for some communities. For example, the installation costs for crossing gates could reach $250,000 with yearly maintenance costs of $5,000. In view of these costs it may not be practical to establish or maintain quiet zones in most communities that may desire them.

One proposed solution for the sound issue at crossings allowed by the FRA is a "wayside horn", or stationary horn mounted at the crossing. The wayside horn is sounded in place of the locomotive horn when a train approaches. The wayside horn is positioned to direct the sound precisely down the intersection roadways rather than along the track like the locomotive horn. This directional horn can therefore operate at a lower sound level than a locomotive horn and produce less community area sound exposure. One such Automated Horn System (AHS) has been developed by Railroad Controls Limited. It has equipment costs of around $25,000 per crossing, which are considerably lower than the initial costs of the supplemental safety devices allowed by the FRA in quiet zones.

Prior to this effort, there have been six major efforts to evaluate the effectiveness of wayside horns. Those studies by six different research groups examined ten different wayside horn installations in five different states over about ten years. The previous research studied the same five dimensions studied in this effort (described below), although no previous study looked at all five dimensions as we did. It is easy to summarize the findings from the previous six studies, because they are so uniformly positive. In particular:

1. The AHS-focused sound radiation minimizes community intrusion.
2. Community responses to the AHS and changing sound pattern have been favorable.
3. The AHS is viewed favorably by both motorists and train engineers.
4. There is no evidence that the AHS is less safe than the current practice of using train-mounted horns.

The objective of this research project was to evaluate the AHS produced by Railroad Controls Limited. We conducted the evaluation through observation of a test crossing in Rocky Mount before and after AHS installation. Before AHS installation, the site had a typical array of safety devices (gates, lights, signs, and marking) and employed the locomotive horn in typical fashion. After AHS installation the array of devices remained mostly unchanged, but the wayside horn replaced the locomotive horn. The site was a nearly ideal crossing of a road with one through

lane in each direction of a single track with low train volumes and speeds in a moderate density suburban area.

During the evaluation, we examined the mechanical reliability of the system and also measured:

- Sound level,
- Motorist behavior,
- Motorist opinion,
- Area resident opinion, and
- Train engineer opinion.

Sound measurements were from a large set of data recorded from hand-held meters. Sounds from the wayside horn were measured on the same day as sounds from a working locomotive. Motorist behavior was judged based on images from a camera system. Our main measure of effectiveness was the number of crossings of the stop bar after warning devices had been activated. We recorded and analyzed over 250 events when motorists had to react to a train event at the crossing. Motorist and resident opinion were based on postcard surveys mailed back to the research team and a few interviews. Sample sizes were around 50 responses in the before period and 25 in the after period for both surveys.

Based on the results from previous studies and the results from our test described above, the study team arrived at several conclusions regarding the use of a wayside horn at railroad grade crossings. First, the team concluded that the wayside horn offers significant sound relief to residents and others in the area around a crossing. This conclusion is based on our most robust data. Along the track and throughout the neighborhood the wayside horn reduced sound levels by 10 to 25 decibels compared to the locomotive horn. Along the road, the wayside horn produced about the same sound levels as the locomotive horn at a couple of points, but was generally 5 to 10 decibels quieter. Our resident survey picked up some indication that this lower sound level made some residents happier, particularly those near the crossing and track.

Second, the team concludes that the wayside horn has led to slight, if any, shifts in driver behavior and opinion. Driver opinion is difficult to judge based on our small, changing sample, but seemed to indicate overall that most drivers do not notice a change from locomotive to wayside horn. The driver behavior data we collected are more important and robust than the driver opinions. Those data showed only small shifts in the number of drivers crossing the stop bar after device activation, with some of the small changes better for the wayside horn and some better for the locomotive horn.

Finally, the study team concludes that the wayside horn appears to be reliable and acceptable to train engineers. It is likely that the early research experiences with less reliable wayside horns have been corrected. The fail-safe design of the wayside horn is also comforting in this regard.

Based on the study results and the conclusions provided above, the study team recommends that the FRA, the NCDOT and other state DOTs, local agencies, and railroads continue to allow the use of wayside horns when evaluated as part of an engineering diagnostic. The evidence from this study and the previous literature show that wayside horns provide significant sound relief and do not compromise crossing safety.

The study team recommends a couple of avenues for follow-up future research. First, at the Rocky Mount test site the NCDOT should consider collecting more “after period” data on motorist opinion and behavior. Second, someone at the state or Federal levels should fund a before and after collision study of wayside horn installations after a number of them have been working for a few years. Such a study would be fairly easy to conduct methodologically, since regression to the mean would not be a threat to validity. The success of that study would just hinge on the size of the sample.

Table of Contents

List of Tables

List of Figures

Introduction

Background

Federal Railroad Administration (FRA) rules require that locomotive horns be sounded at most public highway-rail intersections (grade crossings) in the United States. This is due to the incontrovertible evidence showing that horns are an effective safety device preventing collisions at crossings. However, the rule also provides an opportunity for any community to establish a “quiet zone” in which the locomotive horn would not be sounded at crossings where supplementary safety measures (SSMs) fully compensate for the absence of the warning provided by the locomotive horn (1). Numerous communities may seek to implement such quiet zones, including several in North Carolina (2). In fact, New Bern and Rocky Mount in NC have had horn bans in their downtowns for years (2). However, the cost of the SSMs the FRA rules require in quiet zones may be prohibitive for some communities. For example, the installation costs for crossing gates could reach $250,000 with yearly maintenance costs of $5,000. In view of these costs it may not be practical to establish or maintain quiet zones in most communities that may desire them.

The major reason for establishing a quiet zone is to eliminate the disruptive and intrusive affect of the locomotive horns on the community that has developed around the tracks. Federal regulations require that the horn volume be sufficient to reach motorists on roadways perpendicular to the train, far enough in advance for the motorist to be able to stop before reaching the crossing. The horn must reach down intersecting roadways, penetrate the automobile, and compete with other internal and external audio sources in order to alert the motorist of the train’s approach. In order to do this, the horn must be loud and the horn must be used well prior to the train reaching the crossing, allowing the sound to spread into the surrounding community and impacting residents outside their vehicles.

Potential Solution

One proposed solution for the sound problem at crossings allowed by the FRA is a “wayside horn”, a stationary horn mounted at the crossing (1). The wayside horn is sounded in place of the locomotive horn when a train approaches. The wayside horn is positioned to direct the sound precisely down the intersection roadways rather than along the track like the locomotive horn. This directional horn can therefore operate at a lower sound level than a locomotive horn and produce less community area sound exposure. One such Automated Horn System (AHS) has been developed by Railroad Controls Limited. It has an installed equipment cost of around $65,000 per crossing, which are considerably lower than the initial costs of some supplemental safety devices allowed by the FRA in quiet zones. Note that a wayside horn requires a crossing controller to be equipped with constant warning time devices. Thus, some crossing signal systems must be upgraded before the wayside horn can be installed.

Objective

The objective of this research project was to evaluate the AHS produced by Railroad Controls Limited. We conducted the evaluation through observation of a test installation in Rocky Mount before and after AHS installation. Before AHS installation, the site had a typical array of safety devices (gates, lights, signs, and markings) and employed the locomotive horn in typical fashion. After AHS installation the array of devices remained mostly unchanged except for the installation of a median barrier, but the wayside horn replaced the locomotive horn. During the evaluation, we examined the mechanical reliability of the system and also measured:

- Sound level,
- Motorist behavior,
- Motorist opinion,
- Area resident opinion, and
- Train engineer opinion.

The results from the evaluation will show whether the wayside horn should be considered as an alternative to a quiet zone. While not cheap, the AHS is less expensive than some of the supplemental safety devices needed for a quiet zone. If the wayside horn proves reliable, proves to be as safe as a locomotive horn, reduces sound as anticipated, and makes nearby residents happier, it could be an attractive alternative for the NCDOT, other DOTs, and local communities.

After a brief review of the existing literature on wayside horn effectiveness, this report provides a description of the test site and equipment. The bulk of the report describes the five types of evaluation listed above. The report ends with conclusions about the test and recommendations for future uses of the wayside horn.

Literature Review

Prior to this effort, there have been six major efforts to evaluate the effectiveness of wayside horns. Table 1 summarizes the work done in each of those studies. Note that the methodology we followed in this test was more comprehensive than the previous studies, in that we looked at all five dimensions listed. However, everything we analyzed had been examined in at least one of these previous studies.

Table 1. Previous evaluations of wayside horn.

				Did the authors analyze data on…				
Ref. no.	Year of study	City	No. of crossings	Noise	Motorist behavior	Motorist opinion	Resident opinion	Train engineer opinion
3	1995	Gering, NE	1	√	√		√	
4	2000	Gering, NE	1		√			
5	1998	Ames, IA	3	√		√	√	√
6	2001	Richardson, TX	1	√				
7	2002	Mundelein, IL	3	√	√		√	√
8	2003	Roseville, CA	2	√	√		√	√

It is easy to summarize the findings from the previous six studies, because they are so uniformly positive. In particular:

5. The AHS-focused sound radiation minimizes community intrusion.
6. Community responses to the AHS and changing sound pattern have been favorable.
7. The AHS is viewed favorably by both motorists and train engineers.
8. There is no evidence that the AHS is less safe than the current practice of using train-mounted horns.

The four studies that examined motorist behavior did so through observing video recordings of traffic movements at the crossing just before or during train events. Attempts to judge safety effects from collision data, as reference 8 made, for example, fail because of low sample sizes with these few test sites over limited times. Survey methods—phone or mail-back—were used to gather opinions. All six previous evaluations were at crossings with heavy train and motor vehicle volumes (over 30 trains per day in some cases).

A couple of comments on references 3 and 4 may be interesting to readers. First, reference 3 reports on an early version of the wayside horn that, for instance, did not use a digital recording of a horn sound. Nonetheless, the results reported were positive. Second, reference 4 reports a follow-up to reference 3, five years later with a somewhat improved wayside horn. It showed that the motorists are still responding well (as safe if not safer) to the wayside horn.

Reference 5 from the Iowa DOT provided perhaps the clearest look at the sound reductions that the community surrounding the crossing can expect with a wayside horn. Figure 1 shows the sound contour levels measured for a typical locomotive horn at one of their crossings, while Figure 2 shows the same contours at the same crossing with the wayside horn. The difference is striking and extends at least 1000 feet radially from the crossing.

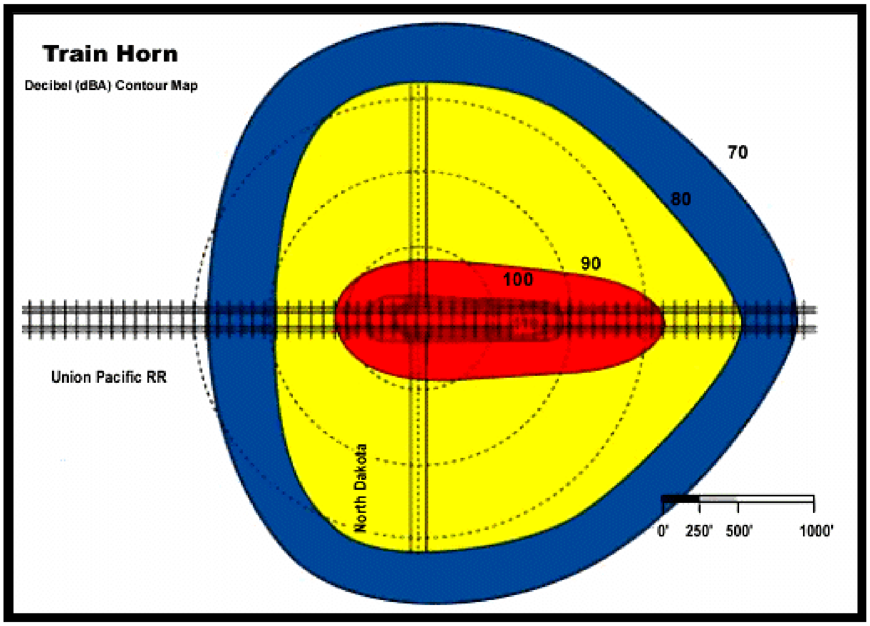

Figure 1. Sound contours at crossing with locomotive horn (5).

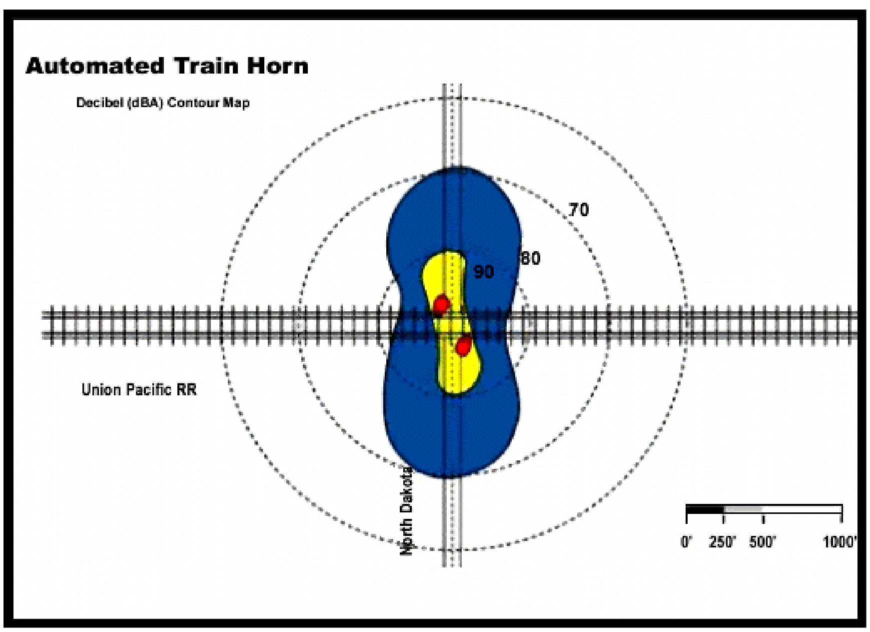

Figure 2. Sound contours at crossing with wayside horn (5).

Several of the references did offer cautions and concerns regarding the use of wayside horns. Reference 3 indicated some reliability concerns with the early equipment. These may have been addressed in later versions. Reference 7 noted that wayside horns may exacerbate the problem of unneeded gate and horn activations at some crossings, particularly near switches. This is when the lights start flashing and the gates come down but no train appears at the crossing. Motor vehicle drivers and passengers experience extra delay, extra chance of rear-end collision, and, perhaps, loss of confidence in the devices that could lead to misjudgments later. A wayside horn blaring in these cases may make these negative effects worse. Finally, reference 7 also noted that the wayside horn may have a startle effect on some drivers approaching a crossing, whereby they suddenly hear a very loud horn sound (usually close to 100 dB near the crossing) instead of first hearing a softer sound from a train still a good distance away. However, readers should not make too much of these cautions and concerns. Reference 4 offered an insightful summary comment along these lines:

> Ancillary questions posed by some concerning factors beyond bottom-line effectiveness, such as Doppler-effect cues or horn directionality and intensity, seem to be holding the AHS to a standard different than that applied to other SSMs and thus appears unwarranted given the performance of the system in Gering.

The bottom line from all of the previous studies is that wayside horns are effective.

Test Site and Equipment

Test Site

Our wayside horn test site was the South Winstead Avenue crossing of the Nash County Railroad in Rocky Mount, NC. Figure 3 shows the area, and Figure 4 provides a closer look. The crossing number is 626 215F and the railroad's milepost is ABA-123.16.

Figure 3. Test site area.

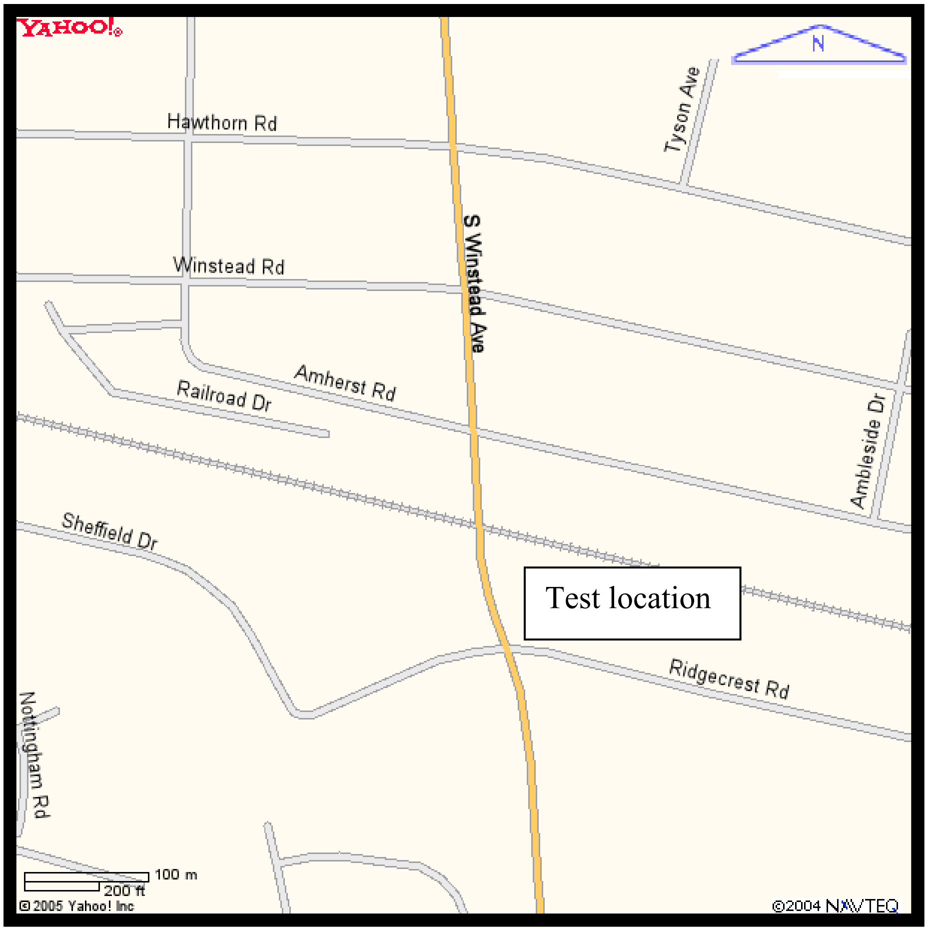

Figure 4. Larger-scale map of test site area.

The crossing is in a stable, moderate-density, single-family residential area several miles west of downtown Rocky Mount. The homes in the area range from small ranches built in the 1960s to larger, newer, two-story dwellings. Most homes are neat and well-kept. There are a few other land uses in the area, including churches, schools, and a fire station.

Winstead Avenue is a minor thoroughfare that runs north and south through the western part of Rocky Mount. South of the major intersection with Sunset Avenue, Winstead Avenue has one through lane in each direction, a continuous two-way left turn lane, curbs, and no sidewalks. Figure 5 shows Winstead looking toward the crossing in March 2006. The grades are virtually nil and the horizontal curvature is gentle. The roadside along Winstead has some trees, but sight distances are adequate at the crossing and in the corridor. NCDOT traffic volume maps from 2003 show that Winstead has an AADT of 11,000 at the crossing. The crossing serves some school buses and trucks, although there is not much industry in the area so the overall heavy vehicle percentage is probably under five percent. Most drivers along Winstead are likely very familiar with the road and the area. There are very few pedestrians or bicycles along this portion of Winstead. The speed limit is 35 mph. The pavement, markings, and signs are in good condition. There is a traffic signal several blocks north of the crossing, but it is too far away to affect traffic operations at the crossing.

Figure 5. Winstead Avenue and the test crossing in March 2006.

The Nash County Railroad is a short line that operates from Rocky Mount to Momeyer. At Winstead Avenue, the railroad is a single track with a train speed of 10 mph. The crossing generally serves two trains per weekday (one in each direction) on a fairly regular schedule. Figure 6 shows the track and the crossing. The crossing is concrete and is in good condition. The crossing has had gates and lights for many years. The crossing meets Winstead Avenue at about a 75-degree angle. It is about 2000 feet in each direction to the next street crossing of the railroad.

Figure 6. Track and crossing at Winstead Avenue in March 2006.

The study team chose to conduct the test at the Winstead Avenue crossing for several reasons, including:

- Proximity to Raleigh, where NC State and NCDOT Rail Division personnel are located,
- Cooperative railroad,
- Cooperative City,
- Nearby City facilities to facilitate transferring video images,
- Virtually ideal roadway and crossing conditions,
- Fairly high traffic volumes allowing for larger sample sizes,
- Moderately-dense residential population,
- Some previous concerns in the neighborhood about horn noise reported to officials,
- No other crossings or traffic signals close enough to confound results, and
- No nearby switching or stopping points for trains.

In sum, the chosen site was quite suitable. The only real negative points about this crossing as a test site were the low train speeds and volumes. The original idea for this project included a second test site in NC with higher train speeds and volumes, but negotiations with railroads never reached fruition. The low train speed probably means that the sound from the locomotive horn is more confined and less irritating to residents than at most crossings. The low train volume meant lower sample sizes and, again, probably less irritation to residents. In this sense, these drawbacks of the test site probably weigh against the wayside horn, in that it will likely have larger impacts at busier and faster crossings.

Video Camera System

An automatic video camera system was an important part of our data collection scheme. With only two trains per weekday, manual collection of motorist behavior was impractical.

Cameras were installed at the test crossing in early 2005. After some adjustment and debugging, the camera system was operational in late-August 2005, which was about eight months before the railroad began to rely on the wayside horn at the crossing. Eventually, four cameras were installed, with views of each road and railroad approach to the test crossing. The two views of the approaching train were not helpful for this study, and for most of the data collection period another camera did not work properly, so we relied on one of the four to carry the load in data collection. Figure 7 shows the view it provided, looking south at the crossing at the backs of southbound vehicles. The camera showed about the last 100 feet of the approach of southbound vehicles.

Figure 7. Southward camera view available throughout the data collection period.

Interactive Video Solutions installed the camera system at the test crossing. Angeltrax EX550NV day/night cameras were used. Figures 8 through 10 show that the cameras were small and unobtrusive, and few drivers were likely aware that they were being recorded. Images were available to the study team over the Internet via a server operated by the City of Rocky Mount. The recorded video is in a “CX3” file format that does not have a time stamp of less than one second. To obtain the precision we desired (in fractions of a second) we converted the images to the “AVI” file format. It takes some time for the conversion but the converted images can be viewed using standard players like Real Player$_{tm}$. Real Player$_{tm}$ shows time to the nearest 0.1-second, which was sufficient for this analysis.

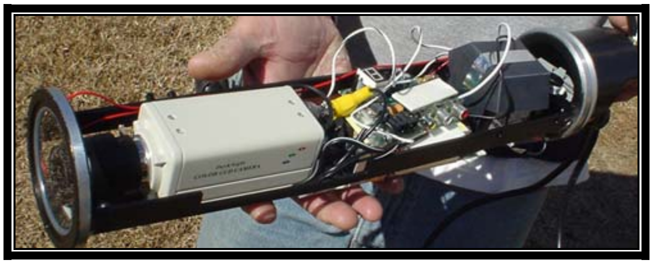

Figure 8. One of the cameras used during the study.

Figure 9. A camera mounted on a pole near the crossing.

Figure 10. A relatively inconspicuous camera near the crossing.

Wayside Horn at Test Crossing

As mentioned above, this study tested an AHS from Railroad Controls, Limited. Figure 11 shows the wayside horn tested in isolation, while Figure 12 shows the horn installed at the test crossing and Figure 13 shows the circuitry inside the cabinet. The signal on top of the unit alerts the crew in an approaching train whether the wayside horn is operating; if the crew does not see the signal they should use the locomotive horn. The horn is cued by the same track circuit that cues the gates and lights. At this crossing, the horn was set to begin blowing when signals and gates start flashing and stop blowing when the train was in the crossing. The horn sound was calibrated by Rail Division engineers to the required 96 dB at a distance of 100 feet from the stop bar on Winstead Avenue. In the opinion of the authors, the horn sound was similar to a locomotive horn but was not an exact match because it was a little higher in pitch.

Important dates in the life of the wayside horn at the test crossing included:

- Installation, 2/25/2006,
- Calibration of wayside horn sound level and sound data collection, 3/10/06,
- Cease operation of locomotive horn, 4/20/2006, and
- Construction of a raised median at the crossing, 6/13/2006.

Between 2/25/06 and 4/20/06, the wayside horn and locomotive horns both blew when a train approached the crossing.

The small raised median constructed on Winstead Avenue extended a short distance from the stop bar. The median probably did not affect motorist operations appreciably.

The study team believes that the wayside horn installed at Winstead Avenue functioned perfectly as designed and intended between installation and the end of our data collection period in mid-July. This is based on input from Rail Division personnel and train engineers from the Nash County Railroad.

Figure 11. AHS from Railroad Controls, Limited.

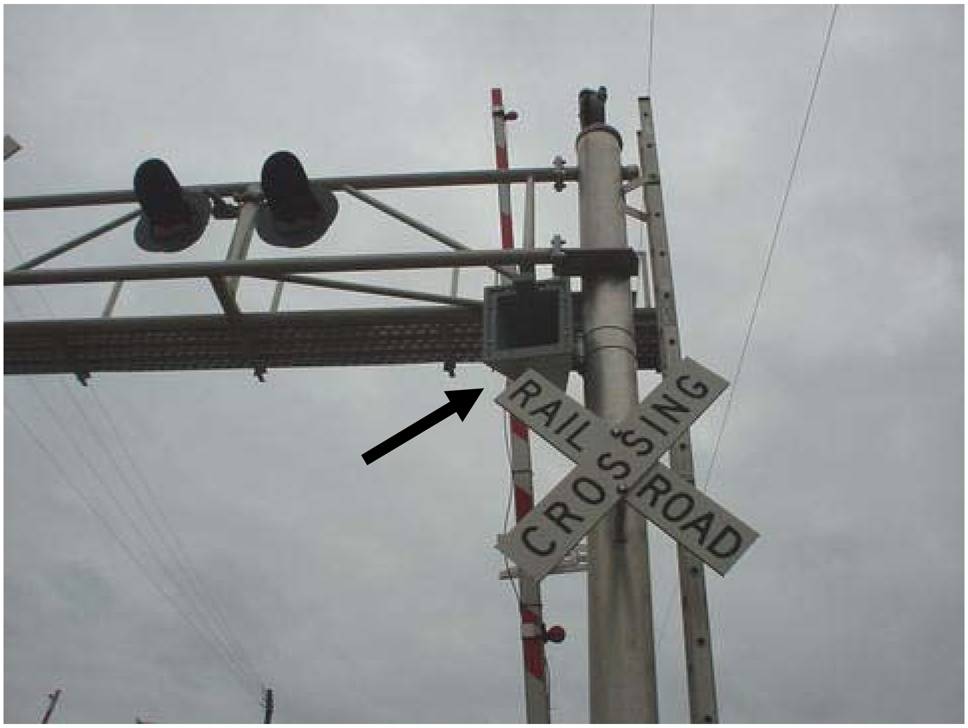

Figure 12. Wayside horn installed at test crossing.

Figure 13. Circuitry inside wayside horn cabinet.

Sound Measurement

Sound measurement was one of the five data collection tasks undertaken during this research. The two NC State researchers were joined by five NCDOT Rail Division engineers and technicians for a large sound data collection effort at the test crossing on March 10, 2006. The collectors worked in fair weather with temperatures of around 60 degrees F, in a light breeze, and while the trees were still without leaves. The Nash County Railroad supplied one of their regular locomotives (shown in Figure 14) and crew for a half-day, and we were also able to measure sound from one train set that moved through the crossing. With the locomotive available and our large crew we were able to collect a complete and thorough set of sound measurements near the crossing and throughout the surrounding neighborhood at points of interest.

The data collectors used the portable sound meters from Radio Shack shown in Figure 15. The collectors recorded sound in dbA. The data collectors found that the meters all provided readings consistent with each other prior to collection. The values recorded were the peak values stored by the meter or seen by the collector on the digital readout during the sound event of interest, such as a blowing of the wayside horn.

Figure 14. Nash County Railroad locomotive used during sound measurement.

Figure 15. Sound meter used during data collection.

Sound Levels in the Neighborhood

Points of interest in the area 2000 ft by 3000 ft around the crossing were numbered 1 to 12 as Figure 16 shows. Points 4 to 9 are close to the track and the rest are farther away. In Figure 16, red (darker) boxes show the sound level of the train horn in dBA. Two different types of trains (locomotive only and larger train set) moved in different directions and the maximum values are presented. The numbers in the white boxes are for the wayside horn. For most of the points, especially farther from the track, the wayside horn was relatively quiet. Background sound was about 50 dbA and the sound of a passing car from an observer on the sidewalk is about 75 dbA, for comparison. Figure 16 shows that there was typically a 10 to 25 dbA difference between the wayside and train horns.

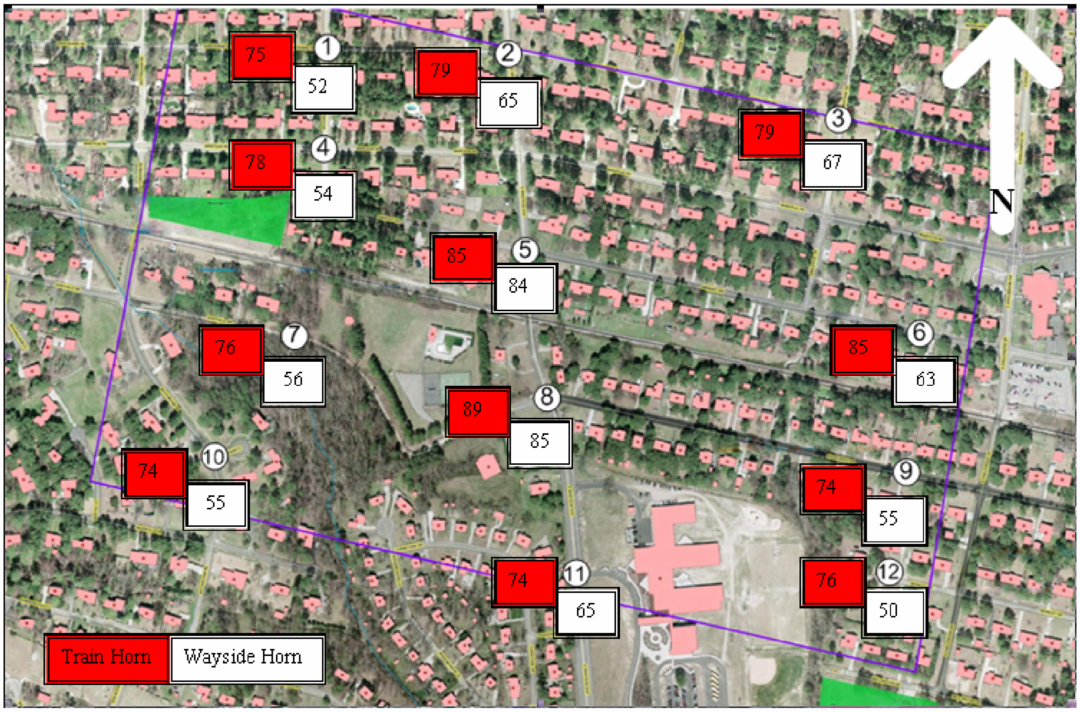

Figure 16. Map of sound levels in the neighborhood.

Figure 17 shows the same data in a different way. Again, notice that the farther from the crossing, higher the difference between the wayside and train horn volumes.

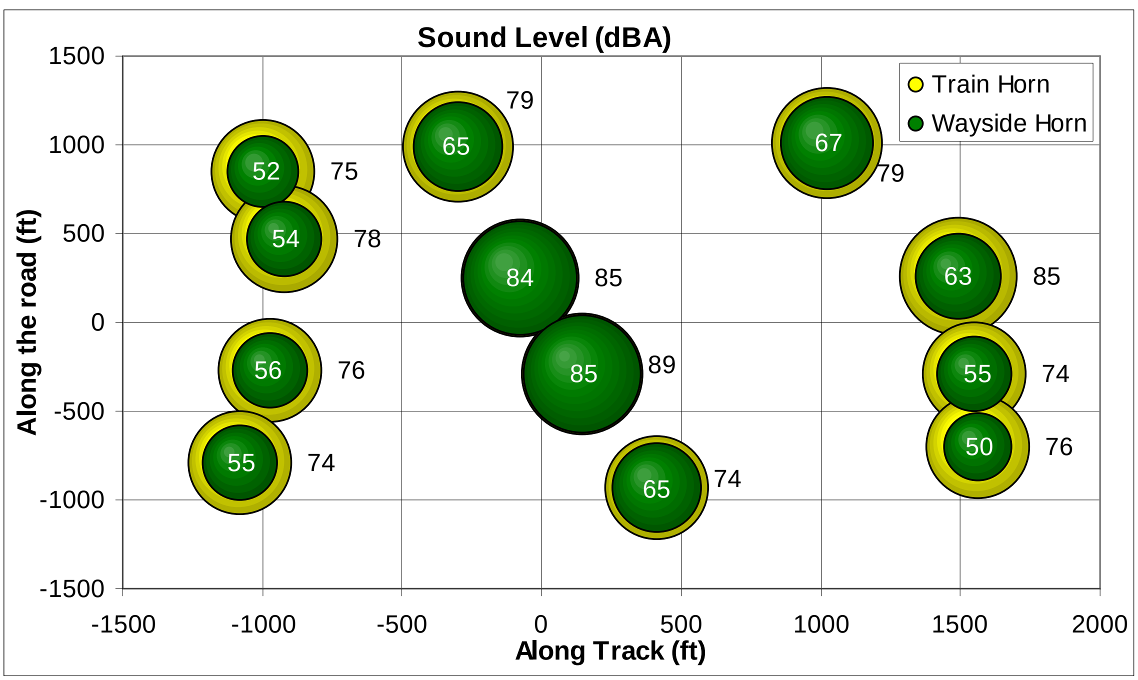

Figure 17. Sound levels in the neighborhood plotted by distance from crossing.

Figure 18 also shows these results. The difference between two horns varies from 0 to 26 dbA. Note that points 5 and 8, where the differences were zero or nearly zero, were close to the crossing along the road.

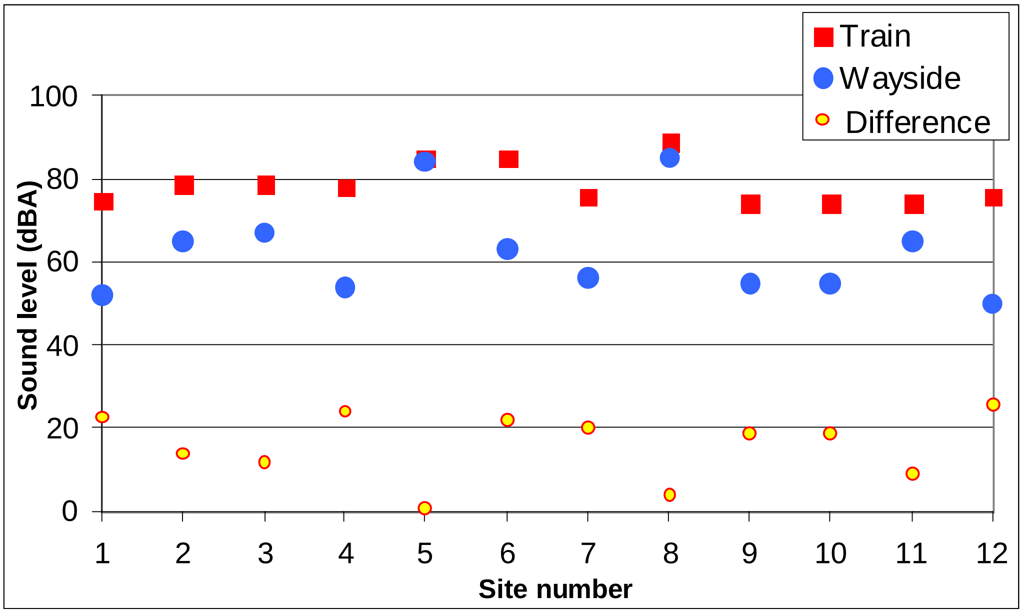

Figure 18. Sound level in neighborhood by site number.

Comparing Our Data with Iowa Research

Important previous research in this area was conducted by a team led by Steve Gent of the Iowa Department of Transportation (5). Mr. Gent confirmed that the site of their research was also in a suburban area, but their site was on a mainline railroad that had a much higher train volume than the Rocky Mount test site. Unfortunately, their sound level data set is no longer available, so to make a reasonable comparison to our data we had to make estimates from the graphs in their report. These graphs were shown previously in Figures 1 and 2.

Figure 19 shows that the sound of the train horn in Iowa was much louder than train horns in Rocky Mount, while the sound produced by the two wayside horns was very similar. Nonetheless, we still obtained a significant improvement in sound level when using the wayside horn at the Rocky Mount site.

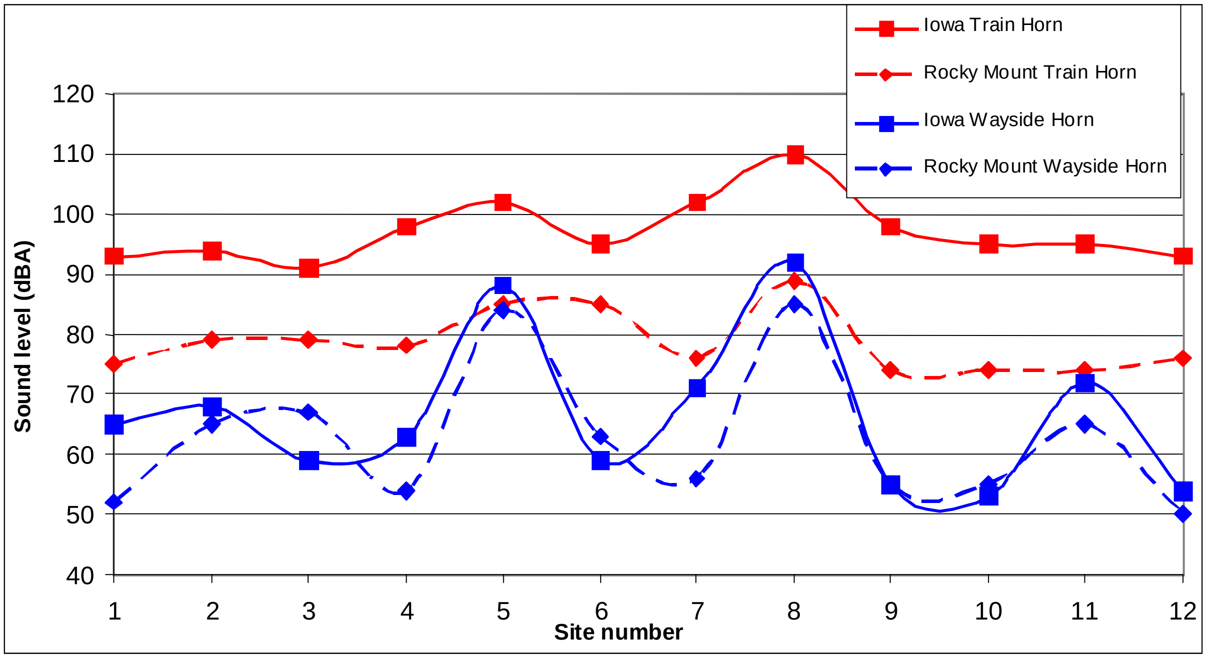

Figure 19. Comparison between Iowa and Rocky Mount sound data.

Sound Level Along the Road

The locomotive horn sound was measured at different places along the road while the locomotive was in different locations approaching the crossing. Table 2 shows the results.

Table 2. Train horn sound level along the road.

		Train distance from crossing (ft)			
		300	**200**	**100**	**50**
Distance from crossing along the road (ft)	**300**	83	89	84	82
	200	87	93	94	96
	100	93	102	106	102
	50	95	97	101	107
	0	104	103	109	115
	50	109	104	101	97
	100	93	96	103	105
	200	89	95	99	96
	300	92	89	90	96

The maximum of these sounds for each spot regardless of the location of train is important and is shown in Figure 20. Figure 20 compares these peak train horn sound levels with the wayside horn sound level along the road.

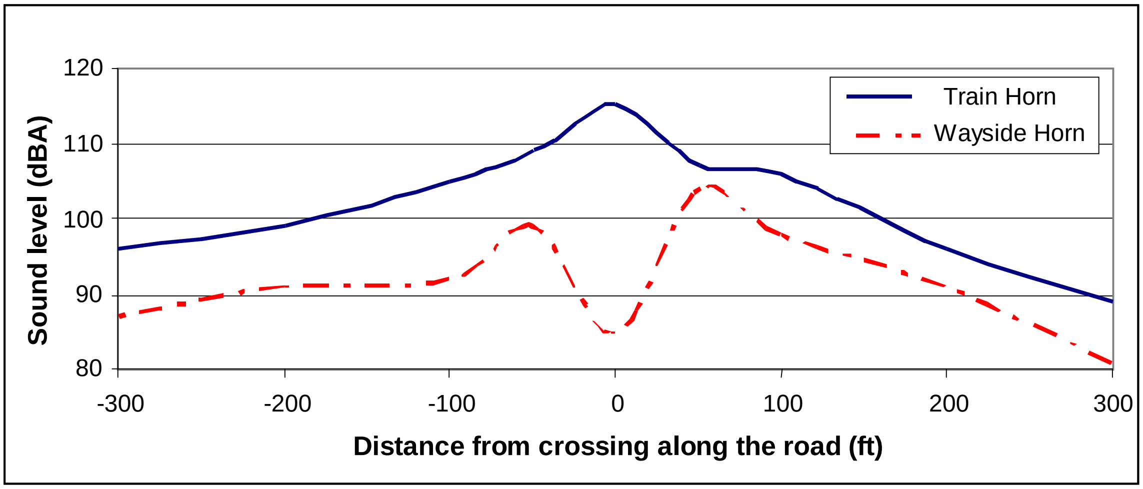

Figure 20. Sound level along the road for wayside and train horns.

One can see that the sound from the wayside horn is significantly lower along the road as well as in the neighborhood. The difference along the road was typically 5 to 10 dbA except at the crossing itself. The reason for the larger difference at the crossing is that wayside horn is mounted on the top of a pole and the sound is aimed toward the approach rather than the stop bar.

Sound Level At and Around the Crossing

With the train located at typical horn points 300 ft and 621 ft from crossing, we measured sound levels along the track and at different spots close to the crossing. Table 3 shows the results; the results when the train was 300 ft from crossing are not in parentheses while result when the train was located 621 ft from crossing are in parentheses. It is clear that the sound when the train was 300 ft away was always higher than when the train was 621 ft away.

Table 3. Sound levels when train horn was near the crossing.

		Distance from crossing along the track (ft)				
		300	**200**	**100**	**50**	**0**
Distance from crossing along the road (ft)	**100**	104 (91)	99 (90)	105 (85)	95 (90)	96
	50	110 (98)	109 (100)	104 (97)	100 (90)	100
	0	117 (106)	109 (101)	105 (96)	103 (93)	99
	50	106 (99)	105 (98)	100 (91)	98 (89)	96
	100	104 (95)	105 (95)	98 (87)	97 (86)	92

Figure 21 compares the result for the 300 ft case from Table 3 to the wayside horn result. As in Figure 17 above, the size of the circle corresponds to the dbA data. It is clear that the wayside horn begins providing significant sound relief within 100 feet or so of the road.

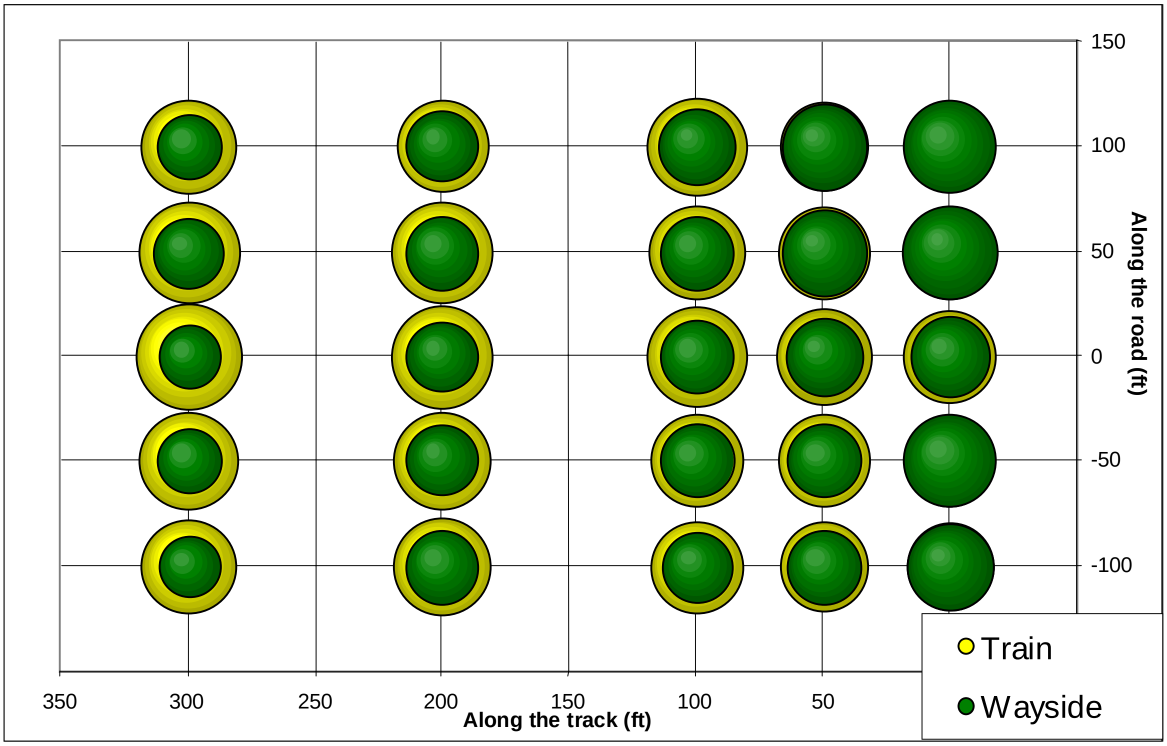

Figure 21. Comparing the wayside and train horns near the crossing.

Resident Opinion

The opinions of the residents living near the test crossing were another of the five types of data we analyzed. We gathered these data before and after installation of the wayside through a postcard-type written survey. Our draft survey form was based on the form used at the previous wayside horn evaluation in Iowa. Based on a draft, we received clearance from the NC State Human Subjects Committee to conduct the surveys in April 2005. We then presented draft survey materials to the research technical committee at the May 11, 2005 meeting, received generally good feedback, made a few revisions, and proceeded with administering the surveys. Figure 22 shows the survey form from the before period, which was printed on heavy poster board. The other side of the form contained postage and our mailing address, so that respondents just had to drop it in the mail. In the after period we added two questions to the form:

3. “Have you noticed a change in the horn system at Winstead Avenue in the past few months?” The responses offered were “yes” and “no”.

4. “If so, which one do you prefer?” The responses offered were “new”, “old”, and “no preference”.

We administered the before period surveys on weekday evenings during the summer 2005 well before the horn was installed and the after period surveys on Saturdays during May and June of 2006 at least one month after the wayside horn had been operating exclusively.

In the before period, we attempted interviews of residents in each house in the first two rows of houses next to the tracks for 1500 feet on either side of the crossing. There are 84 such houses altogether. Many residents had no interest in participating, and in some houses no one answered the door after two attempts at different times on different days. Nonetheless, we were able to complete 41 interviews. Later, we distributed about 95 postcards (hanging them on doorknobs) to houses in the first three rows next to the tracks, including houses in the first two rows that had not responded previously. We received 16 more responses from these, bringing our total to 57 responses in the before period. This response rate of 40-50 percent from the houses in the first three rows next to the tracks was good. Due to fewer available research staff persons during the after period, we relied on postcards hung on 100 household doors in the same area next to the tracks. We received 29 responses from these postcards, providing a lower response rate. A spatial analysis (below) showed that the responses from the before and after periods covered the same areas.

North Carolina Department of Transportation
RAIL DIVISION

Longitudinal Distance: Radial Distance:

Greetings,

We, the Railroad Division of NCDOT and NC State University researchers, are trying to evaluate the effects of the warning devices at the Winstead avenue railroad crossing. Please help us by checking the blank that best answers the questions:

What is the impact of railroad crossing horn in your life?

Very Good | Good | No Effect | Bad | Very Bad

How is the sound of the horn at the crossing?

Too Soft | Soft | No Idea | Loud | Too Loud

Do you have any other feedback about that crossing including the horn and other warning devices?

Please place this postcard in the mail when you are finished. Call Professor Joseph Hummer with questions at (919) 515-7733. We will not identify you or your residence in our analysis and reporting.

Thank you.

Figure 22. Resident opinion survey form before wayside horn installation.

Table 4 summarizes the responses from the resident opinion surveys. The table shows percentages of those responding to each question. At a glance, it is easy to see that there was little change in the distribution of responses from the before to after periods for question 1. A Chi-Square test confirmed that there was no statistically significant difference between the before and after distributions at the 95 percent level. For question 2, it appears as though there was a bit of a shift in opinion. The percentage of people rating the horn "too soft" or "soft" went from 21 to 32, while the percentage rating the horn "loud" or "too loud" went from 44 to 33. A Chi-Square test showed that the shift was not statistically significant at the 95 percent level, but as we stated elsewhere in this report this was due more to low sample sizes than anything else. Question 3 results show that a majority of respondents did not notice the new wayside horn, while question 4 results show that more residents who did notice a change and had a preference preferred the new wayside horn to the old locomotive horn.

Table 4. Summary of resident responses.

Question	Response	Percentage	
		Before	After
1. Impact	Very good	20	21
	Good	23	18
	No effect	50	50
	Bad	4	7
	Very bad	4	4
2. Sound	Too soft	5	0
	Soft	16	32
	No idea	35	36
	Loud	39	29
	Too loud	5	4
3. Noticed	Yes		38
	No		62
4. Prefer	New		21
	No preference		67
	Old		13

Figures 23 through 28 show our spatial analysis of the resident responses. We were able to obtain the location of the respondent while maintaining the respondent anonymity by using longitudinal and radial distances written on each postcard rather than names or addresses.

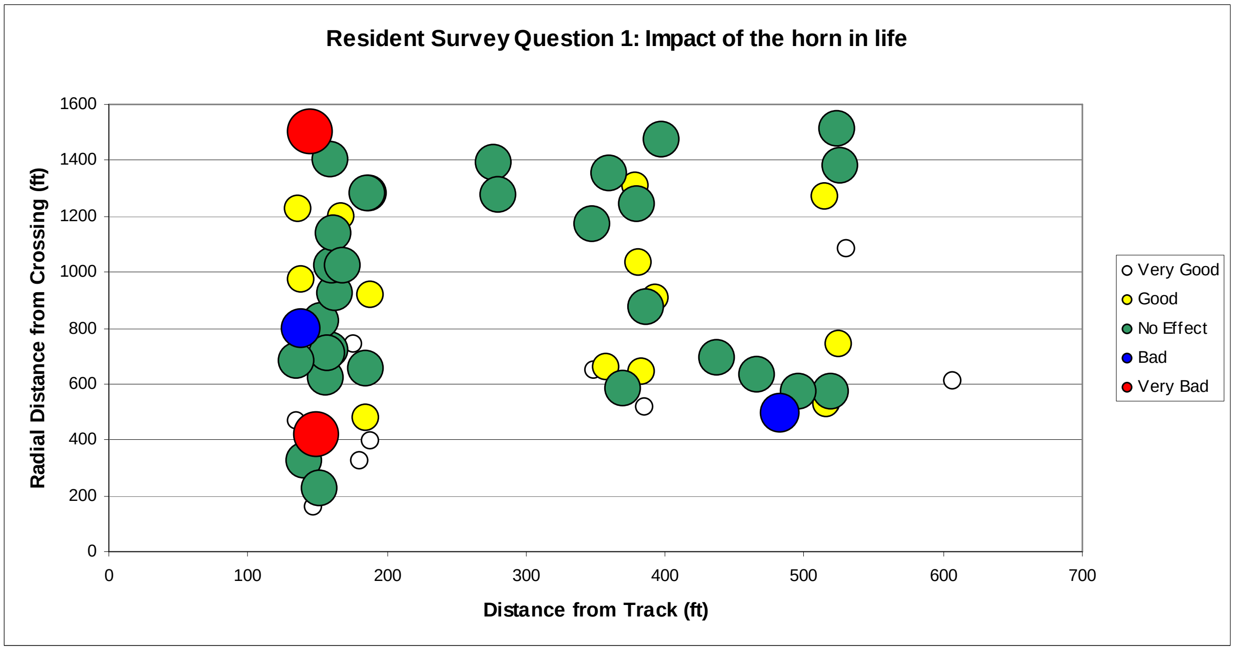

Figure 23. Spatial distribution of responses to question 1 in the before period.

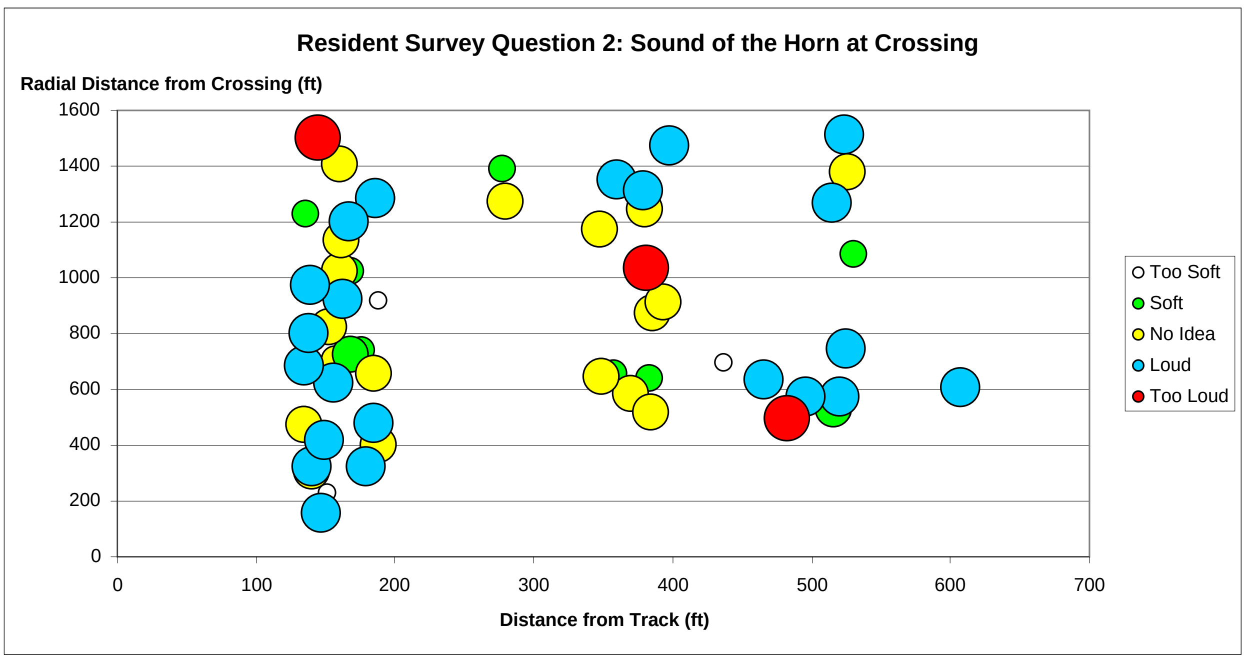

Figure 24. Spatial distribution of responses to question 2 in the before period.

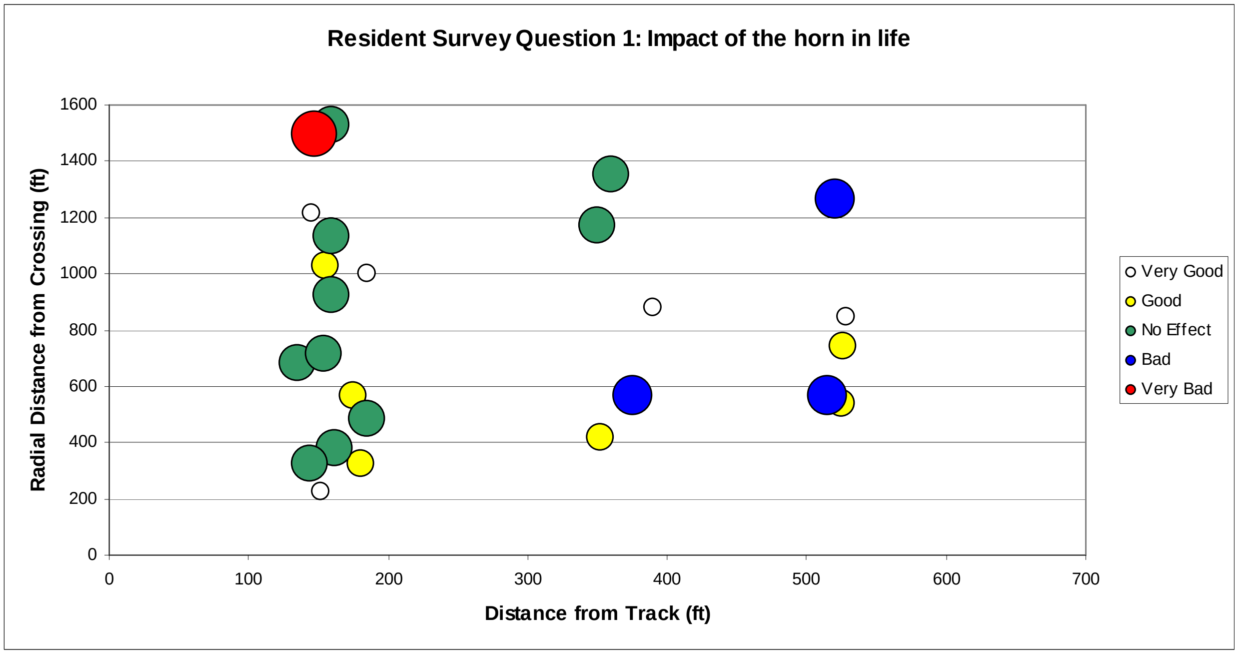

Figure 25. Spatial distribution of responses to question 1 in the after period.

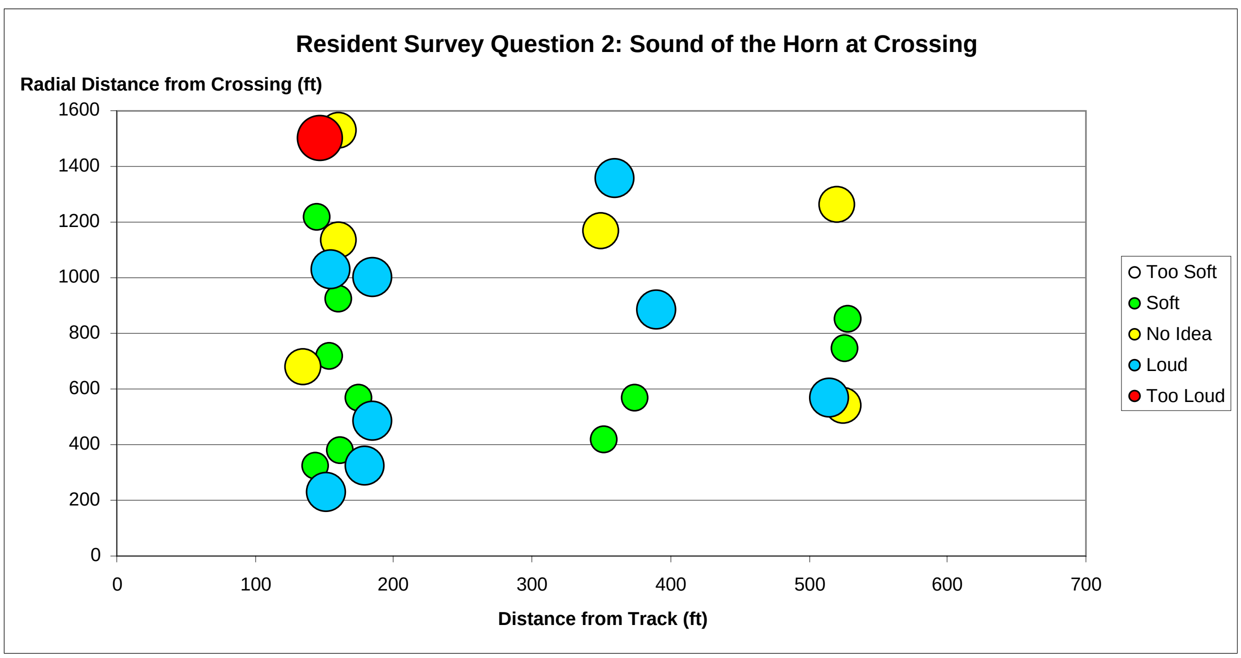

Figure 26. Spatial distribution of responses to question 2 in the after period.

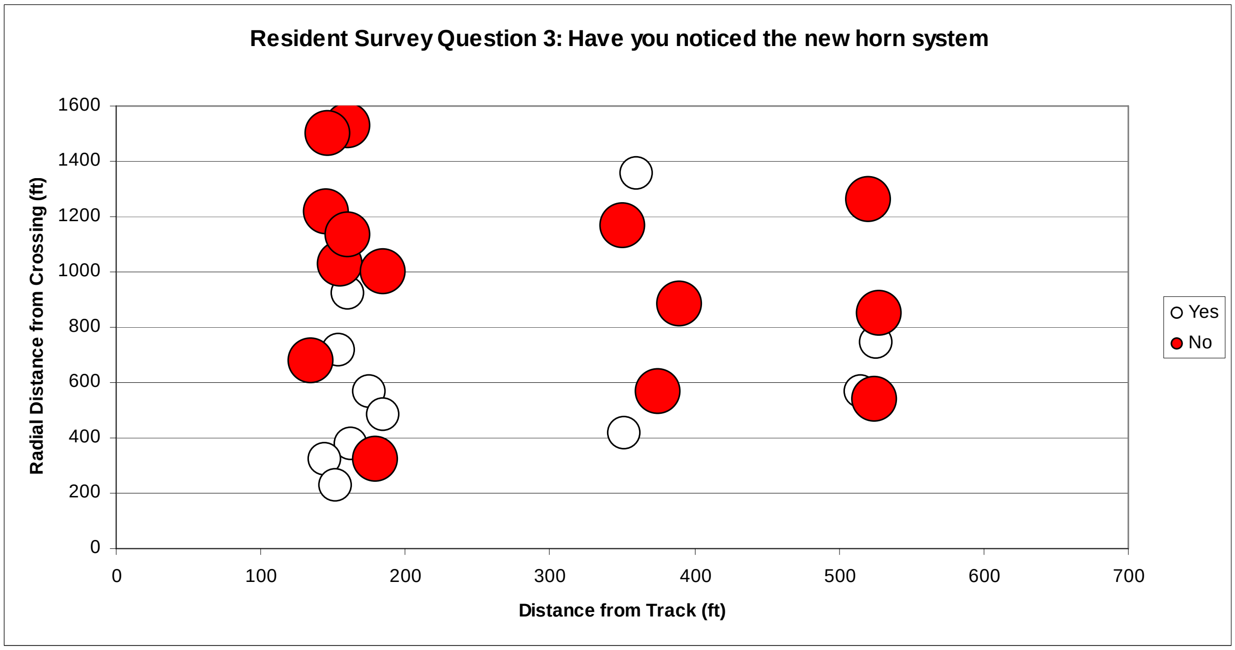

Figure 27. Spatial distribution of responses to question 3 in the after period.

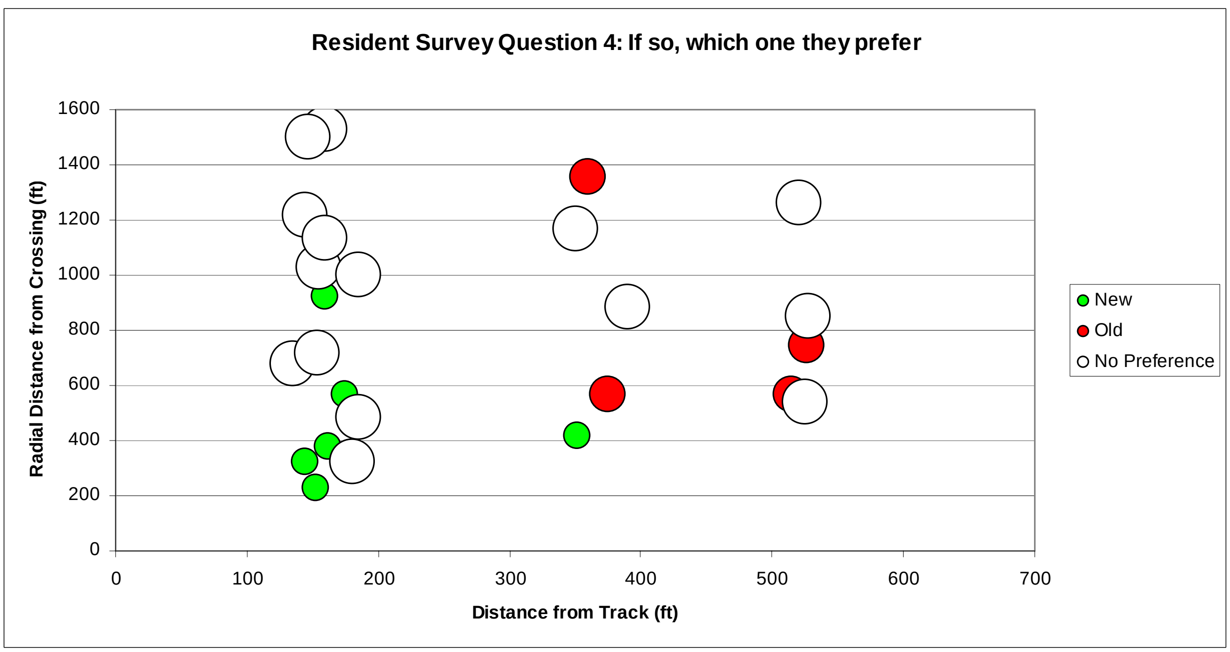

Figure 28. Spatial distribution of responses to question 3 in the after period.

The spatial analysis in Figures 23 through 28 revealed some interesting patterns. First, for question 1 there were only a few "bad" or "very bad" responses, but those few provided tended to shift further from the track in the after period. Second, there were fewer residents reporting "loud" horn sounds away from the tracks in the after period. Third, and most important, the responses to questions 3 and 4 showed that the residents living closest to the crossing tended to both notice and prefer the new wayside horn.

We recorded 23 comments during the before period. Ten of those responses indicated that the current train horn is not a problem. Other interesting comments included:

1. Gates should be constructed in such a manner that makes it impossible for vehicle to go around the gates.
2. I'm thankful for the horn. It could be louder.
3. When driving with the music on, sometimes I can't hear the horn. If they didn't have the things that blocked the tracks when the train is coming, I probably would not realize a train was coming.
4. All I have ever heard are the bells--no horn.
5. I feel the crossing is very safe.
6. The train is so overloaded that the engines sprayed sparks of fire out of the stacks and set two separate fires. The fire dept. came and set the fires out.
7. Thank you for requesting my input. If the train going right through the middle of downtown doesn't have to blow its horn neither should the one going behind my house.
8. I am concerned about the safety of motorists because the crossing rail does not always come down when a train is coming (especially at the Englewood location)

The comments we received in the after period survey included several relevant to the wayside horn:

1. Because the sound from the horn system the sound is hardly noticeable. My office is located 1/2 block 90 degrees from horn direction.
2. The new sound is a little bell. The train does not bother us. We have lived here since 1983 & like the added space the easement adds to our lot.
3. I think you're doing a great job. I love the choo choo train and I'm 82.
4. Leave it alone. I like the train. No change needed.
5. With lights and gates there is no need for a horn. If people don't stop for the lights and gates they will not stop for the horn.
6. Like watching the train come through.
7. I never hear it, but if I did I would appreciate the safety affects.
8. A flashing light is always better – or a gate that lowers.
9. I've lived here so many years that the horn really doesn't bother me.
10. The horn is good. I still like the chopping of the rails fence.
11. Glad to have it. Want engineer to blow horn in plenty of time before crossing in area where marked with "W" not wait until almost here.
12. Drivers are properly notified of a train coming. Very good engineers coming from an X-Engineer.
13. I don't notice the horn at Winstead but do at crossing west of Winstead.

Driver Opinion

Opinions from a sample of drivers using the test crossing were one of the five types of data we analyzed in this research. Early in the project we presented the idea of a survey of drivers waiting at the gate for the train to pass through the crossing. However, preliminary tests in the field showed that this would not be a workable idea for this crossing for several reasons:

- The train only passes through the crossing twice a day,
- The train does not pass through the crossing on a rigorous schedule,
- The sound from the train and its horn makes it difficult to converse with waiting drivers, and
- Because the traffic volume is moderate and the trains are sometimes short, there is rarely a long queue of drivers waiting for the train at this crossing.

The research team therefore modified its plan for the driver survey. With the concurrence of Rail Division engineers, the researchers distributed survey forms in the before period to drivers stopped at a red signal headed toward the crossing at the signalized intersection nearest to the crossing. Since Winstead Avenue serves mostly local traffic, it was our hope that most of the drivers had used the crossing numerous times, had waited for the train at the crossing, and were more qualified to answer the questions we are posing. In the after period, the police asked the researcher to move. The researcher therefore distributed many of his survey forms further upstream of the crossing on Winstead Avenue. In the end, the researchers distributed 100 survey forms before and after the wayside horn installation. This survey was conducted over the same time periods as described earlier for the resident survey. In the before period we received 49 responses for a very respectable response rate, and in the after period we received 23 responses with the decreased response rate likely due to having to move our distribution point.

Figure 29 shows the survey form from the before period. Like the resident opinion form, it was printed on poster board and had the researchers' address and a stamp on the back for easy mailing. The research team tried to limit the number of questions to increase the chances of a response. In the after period, we added two questions:

5. "Have you noticed a change in the horn system at Winstead Avenue in the past few months?" with responses "yes" or "no".

6. "If so, which one do you prefer?" with responses "new", "old", and "no preference".

North Carolina Department of Transportation
RAIL DIVISION

Greetings,

We are from NCDOT and NC State University. Please help us with this short interview about the effect of railroad crossing devices. We will not identify you or your vehicle in our analysis and reporting.

How often do you drive through the crossing at Winstead Avenue?

Every Day | Every 2-Day | Every Week | Every Month | Just Today

What device first alerts you of the train at that crossing?

Horn | Lights | Gate | Other Cars | Don't Know

How is the volume of the train horn at that crossing?

Very Good | Good | Don't know | Bad | Very Bad

Do you usually slow down while crossing the railroad?

Yes | No

Please just place this postcard in the mail when you are finished.
Call Professor Joseph Hummer with questions at (919) 515-7733.

Thank you.

Figure 29. Driver opinion survey form from before period.

Table 5 shows a summary of the results from the driver survey. For question 6 in the after survey, the only respondent who answered “yes” that he or she noticed the wayside horn answered “yes” that he or she preferred the new horn. The results from question 1 in Table 5 show that there was likely some shift in the type of drivers answering the survey from the before to the after periods. A Chi-Square test showed that there was a significant difference at the 95 percent level in response distributions between the before and after periods. Some of this was likely due to the need to distribute many of the surveys in the after period from a different place. At any rate, in the after period sample there were more drivers who used the crossing less frequently, although most used in sometimes.

Table 5. Summary of driver responses.

Question	Response	Percentage	
		Before	After
1. How often?	Day	68	22
	2-day	20	13
	Week	6	22
	Month	0	43
	Just today	6	0
2. Device?	Horn	20	26
	Lights	49	43
	Gate	29	9
	Other cars	0	4
	Don't know	2	17
3. Volume?	Very good	35	22
	Good	45	22
	Don't know	18	48
	Bad	2	4
	Very bad	0	4
4. Slow?	Yes	82	91
	No	18	9
5. Noticed?	Yes		4
	No		96

The results from question 2 in Table 5 show that there was some difference in the type of device that first alerts the respondents of a train. There was some shift from “gate” to “horn” in the after period, which is a good sign for the wayside horn. The difference between the before and after response distributions was not significant at the 95 percent level, probably due mostly to low sample size.

The results from question 3 in Table 5 are difficult to interpret. There was a shift from “good” and “very good” responses regarding the volume of the train horn in the before period to “don’t know” in the after period, and this shift was statistically significant at the 95 percent level.

However, the researchers are not sure if the shift was due to drivers less familiar with the crossing correctly choosing the “don’t know” response or drivers less happy with the sound from the horn choosing responses down the scale from “very good” or “good”. It is clear from the question 3 results that few drivers in the before or after periods were unhappy with the volume of the horn.

For question 4, more of the respondents in the after period said that the slowed at the crossing. The difference was not statistically significant at the 95 percent level.

Finally, question 5 responses in the after period showed that only one driver had noticed a change in horn system (and that driver preferred the new horn). If the idea of the wayside horn is to reduce sound for residents while maintaining adequate sound for motorists, this result seems to confirm that the horn is producing that result. The question 5 results also seem to suggest that the shift in responses to question 3 from the before to after period was due to more unfamiliar drivers than drivers less happy with the new horn sound.

The survey form offered respondents a chance to offer comments. However, none of the few comments we received were particularly relevant to the study objectives.

Driver Behavior

Driver behavior was one of the five types of data we analyzed during the study. The study team judged driver behavior before and after installation of the wayside horn by viewing the video images recorded with the camera system described earlier. Our measure of effectiveness was the number of vehicles that crossed the stop bar at the crossing after the gates and lights (and wayside horn if in place) had been activated. This was the best measure we had available of driver reaction to a train event that was related to safety. The longer this time, the less safe the driver action.

Table 6 shows the data. Between August, 2005 and early July, 2006 we recorded 265 events in which a vehicle had to react to a train event. Most of the time vehicles stopped, but there were 50 cases when the vehicle did not stop. All data from the "after" period were from the time after April 20, 2006 when the train engineers no longer used the train horn. Some of the observations from the "after" period were from the time after the median was installed at the crossing as well, but the study team does not believe that the median was an important confounding factor.

Table 6. Driver behavior data.

	Number of vehicles	
Seconds after gates activated that vehicle crossed stop bar	Before wayside horn	After wayside horn
0.0-0.5	9	4
0.5-1.0	9	1
1.0-1.5	4	3
1.5-2.0	9	1
2.0-2.5	3	1
>2.5	3	3
Total	37	13
Seconds after gates activated that vehicle stopped		
0-2	5	6
2-4	34	14
4-6	23	18
6-8	28	15
8-10	20	8
10-12	13	9
12-14	6	3
14-16	6	2
16-18	1	0
>18	4	0
Total	140	75
Grand total	177	88

Figures 30 and 31 show a couple of the events of interest when a vehicle crossed the stop bar after device activation. Figure 30 is from the time before wayside horn activation, and Figure 31 is from the time after the wayside horn was operational and when the locomotive horn was not used. It took about seven seconds from activation for the gate to become horizontal, so vehicles violating longer than 2.5 seconds after activation were flirting with a collision with the gate, if not the train. We did not record an instance of a severe violation of the crossing devices such as a motorist driving around the gates.

Figure 30. Vehicle crosses stop bar after device activation without wayside horn.

Figure 31. Vehicle crosses stop bar after device activation with wayside horn.

A qualitative look at the motorist behavior data in Table 6 shows that there may have been a slight shift to more vehicles choosing to stop rather than going through the crossing after device activation with the wayside horn in use. There were only 13 such cases in the "after" period as opposed to 37 cases in the "before" period. Otherwise, the distributions of events look quite similar.

Table 7 shows our quantitative analysis of the driver behavior data. The study team computed various proportions of interest and then used the Z-test for proportions to look for statistically significant differences between the before and after periods. The proportions were some form of the number of non-stopping vehicles over some form of the number of stopping vehicles. The Z-test is the appropriate test for this type of data. If the Z-statistic is less than –1.96 or greater than 1.96 the difference between the two proportions is statistically significant at the 95 percent level.

Table 7. Analysis of driver behavior data.

Proportion	Before			After			Z stat.
	Did not stop	Stopped	Proportion	Did not stop	Stopped	Proportion	
Vehs. going through after 2.5 sec over all stopped vehs.	3	140	0.021	3	75	0.038	-0.764
Vehs. going through after 2.0 sec over all stopped vehs.	6	140	0.041	4	75	0.051	-0.331
Vehs. going through after 1.0 sec over all stopped vehs.	19	140	0.119	8	75	0.096	0.542
All vehs. not stopping over all stopped vehs.	37	140	0.209	13	75	0.148	1.201
Vehs. going through after 2.5 sec over vehs. that stopped within 10 secs.	3	110	0.027	3	61	0.047	-0.718
Vehs. going through after 2.0 sec over vehs. that stopped within 10 secs.	6	110	0.052	4	61	0.062	-0.277
Vehs. going through after 1.0 sec over vehs. that stopped within 10 secs.	19	110	0.147	8	61	0.116	0.612
All vehs. not stopping over vehs. that stopped within 10 secs.	37	110	0.252	13	61	0.176	1.275
Vehs. going through after 2.5 sec over vehs. that stopped within 4 secs.	3	39	0.071	3	20	0.130	-0.786
Vehs. going through after 2.0 sec over vehs. that stopped within 4 secs.	6	39	0.133	4	20	0.167	-0.375
Vehs. going through after 1.0 sec over vehs. that stopped within 4 secs.	19	39	0.328	8	20	0.286	0.392
All vehs. not stopping over vehs. that stopped within 4 secs.	37	39	0.487	13	20	0.394	0.894

Table 7 shows that there were no statistically significant differences between the before and after proportions for anything tested. However, one should not read too much into this pattern. The finding is more a commentary on the small sample sizes available than anything else. In the before period there was a slightly smaller proportion of vehicles going through after 2.0 or 2.5 seconds (the most severe crossings) than in the after period. This was based on very small samples. In the after period there was a somewhat smaller proportion of vehicles going through after 1.0 seconds or at any time. Overall, the quantitative analysis confirms the suspicion that there were very small, if any, changes in key motorist behavior at the onset of device activation due to the wayside horn.

Train Crew Opinion

The fifth and final method of evaluating the test crossing in this research was the opinion of the crews who operated the train through the crossing. The study team collected these opinions at two stages. First, the team asked the engineers who helped us with the sound data collection on March 10, 2006. The wayside horn had been installed and functional for about three weeks at this point, and the engineers were using the locomotive horn in conjunction with the wayside horn. The crew members said that they liked the idea of the wayside horn and thought it would work well alone. They felt as though the signal was visible enough.

The second stage at which the study team collected train crew opinion was in June, about two months after the wayside horn had been operating without the locomotive horn. The study team provided a short written questionnaire to the Nash County Railroad, and two of the crew members who regularly operate trains through the test crossing responded. The first question was, “How is the crossing after installation of the wayside horn?” One crew member responded that it was “safer”, one responded that was “the same” and neither responded that it was “less safe”. The second question was, “Have you had to blow the train horn at lease once when approaching Winstead Avenue since the wayside horn has been operating?” Both crew members responded “no”. The form asked for additional comments on the wayside horn, but neither responding crew member offered any.

In sum, the response of the train crews using the crossing was generally positive. They appreciated the purpose of the horn, thought that, at least, it did not make the crossing less safe, and had no problem responding properly to the signal.

Conclusions and Recommendations

Conclusions

Based on the results from previous studies and the results from our test described above, the study team arrived at several conclusions regarding the use of a wayside horn at railroad grade crossings. First, the team concludes that the wayside horn offers significant sound relief to residents and others in the area around a crossing. This conclusion is based on our most robust data. Along the track and throughout the neighborhood the wayside horn reduced sound levels by 10 to 25 decibels compared to the locomotive horn. Along the road, the wayside horn produced about the same sound levels as the locomotive horn at a couple of points, but was generally 5 to 10 decibels quieter. Our resident survey picked up some indication that this lower sound level made some residents happier, particularly those near the crossing and track. This finding has been noted in other studies as well.

Second, the team concludes that the wayside horn has led to slight, if any, shifts in driver behavior and opinion. Driver opinion is difficult to judge based on our small, changing sample, but seemed to indicate overall that most drivers do not notice a change from locomotive to wayside horn. The driver behavior data we collected are more important and robust than the driver opinions. Those data showed only small shifts in the number of drivers crossing the stop bar after device activation, with some of the small changes better for the wayside horn and some better for the locomotive horn. Overall, this research team agrees with conclusions of previous wayside horn researchers that the wayside horn is likely to provide crossings that are as safe as crossings with locomotive horns. However, there does not appear to be any significant increase in the level of safety over locomotive horns.

Finally, the study team concludes that the wayside horn appears to be reliable and acceptable to train crews. It is likely that the early research experiences with less reliable wayside horns have been corrected. The fail-safe design of the wayside horn is also comforting in this regard.

Recommendations

Based on the study results and the conclusions provided above, the study team recommends that the FRA, the NCDOT and other state DOTs, local agencies, and railroads continue to allow the use of wayside horns when evaluated as part of an engineering diagnostic. The evidence from this study and the previous literature show that wayside horns provide significant sound relief and do not compromise crossing safety.

The study team recommends a couple of avenues for follow-up future research. First, at the Rocky Mount test site the NCDOT should consider collecting more “after period” data on motorist opinion and behavior. Second, someone at the state or Federal levels should fund a before and after collision study of wayside horn installations after a number of them have been working for a few years. Such a study would be fairly easy to conduct methodologically, since regression to the mean would not be a threat to validity. The success of that study would just hinge on the size of the sample.

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