8-2013

Driver Behavior at Railway-Highway Grade Crossings with Passive Traffic Control: A Driving Simulator Study

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To the Graduate Council:

I am submitting herewith a thesis written by Bryan Andre Bartnik entitled "Driver Behavior at Railway-Highway Grade Crossings with Passive Traffic Control: A Driving Simulator Study." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.

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Driver Behavior at Railway-Highway Grade Crossings with Passive Traffic Control: A Driving Simulator Study

A Thesis Presented for the
Master of Science Degree
The University of Tennessee, Knoxville

Bryan Andre Bartnik
August 2013

ACKNOWLEDGMENTS

Dr. Richards, Dr. Han, and Dr. Cherry thank you for all of the help and guidance you have provided for me during my time as a student at the University of Tennessee. Dr. Mee, without your help, this may have taken another semester, so thank you. Very special thanks to the CTR for their support during my time at the University. I am very thankful for the funding provided by the Southeastern Transportation Center, the Region 4 University Transportation Center administered by the Research and Innovative Technology Administration as a part of the USDOT. Stephanie Hargrove, Ryan Overton, Casey Langford, Jun Liu, Jianjiang Yang and all the rest of you get a very special thank you for helping me when times were tough and not so tough. And finally, maybe most importantly, a big thank you to my parents for always being there when I need them. I could not have done any of this without all of you.

ABSTRACT

Research to evaluate driver behavior at railway-highway grade crossings with passive traffic control attempts to find an answer to a much debated subject. This study examines the difference in driver behavior and safety at several different types of passive traffic control at grade crossings utilizing a driving simulator. This project utilized the University of Tennessee's high fidelity driving simulator to perform a study on passive highway-railway grade crossings. Although the crash rates at grade crossings have decreased in recent years, there is still more work to be done. Safety improvements can be made to both passive and active grade crossings. However, with increasingly tight budgets for transportation infrastructure, there is not enough money to upgrade and improve every grade crossing. Upgrading a passive grade crossing with flashing lights or gates is very expensive and can cost upwards of $400,000 in some parts of the country. This paper further investigates the use of STOP and YIELD signs as viable alternatives to upgrading a passive grade crossing to an active grade crossing. By utilizing a driving simulator, several variables were tested on sixty-four drivers in a safe environment. The driving simulator allowed tests to be run on grade crossings that range from safe to fairly unsafe. By varying the visibility at the crossing, which sign the driver saw at the crossing, the presence of a train, and the presence of other traffic, reasonable conclusions about the safety of various types of passive grade crossings are made.

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CHAPTER I. INTRODUCTION

Background

In 2009, according to the Federal Railroad Administration (FRA) the United States (US) had 136,041 public, as opposed to those located on private property, highway-railroad at-grade crossings (grade crossings). Of these grade crossings, approximately 42,301 have gates, 22,039 have flashing lights, and 1,196 have highway traffic signals, wigwags, and bells. This leaves 70,505 grade crossings that are passively controlled. In the state of Tennessee, there are 2,764 total grade crossings with 1332 of them being passively controlled [1, 2].

There are two types of railway-highway grade crossings: active and passive. Active grade crossings have flashing lights, gates, bells, or whistles that activate to warn the driver of the approach and the presence of a train. Passive grade crossings are only protected by conventional signage and pavement markings. Active grade crossings are considered much safer than passive grade crossings because of the added ability to obtain the attention of a driver. According to Cooper, the cost to upgrade a passive grade crossing to an active grade crossing can be between $200,000 and $400,000 depending on the part of the nation you are in [3]. With prices this high and a large number of passive grade crossings on low-traffic, rural roadways, it is simply not feasible to spend such a large sum of money for marginal improvements to driver safety.

Most passive grade crossings only have a CROSSBUCK sign (R15-1). Adding either a YIELD sign (R1-2) or a STOP sign (R1-1) is suggested on the more troublesome grade crossings. If a passive grade crossing gets two or more trains per day and visibility is restricted to a point that in order for a driver to safely navigate the grade crossing the driver must reduce speed to 10 miles per hour (mph) or below, a STOP sign is recommended. If the grade crossing has restricted visibility but only enough to reduce the driver's speed to 15 mph, then a YIELD sign is recommended. If either of these measures are not enough to significantly increase the safety of the grade crossing, then active warning devices should be considered [4]. The cost differential between a STOP sign and flashing lights or gates is large enough that it is worthwhile to continue to explore the options available to transportation engineers regarding passive grade crossings.

Objective

The objective of this research is to determine how different primary types of passive traffic control impact driver behavior which, in turn, may affect driver safety at these grade crossings. By measuring driver response and behavior through several variables provided by the DS-607c driving simulator, a safe, cost-effective alternative to upgrading a passive grade crossing to an active grade crossing can be discovered. Various situations will be tested. Variances will be made in the driver's visibility when approaching the grade crossing, the type of signage at the grade crossing, the effect that trains may have on drivers as they approach the grade crossing, and the effect that other drivers may have on a driver as they are approaching a grade crossing.

CHAPTER II. LITERATURE REVIEW

Drivers are expected to understand the meaning on various signs on the roadway. The railroad advance warning sign systems are generally recognized by drivers; however, they are much less often understood. Drivers do not understand the action required or the location at the grade crossing. Typically, active warning devices allow for a greater understanding than passive warning devices although not all drivers comply with either category of warning devices [5]. In Chapter 8 of the MUTCD, guidance on what traffic control devices (TCDs) should be used and where they should be placed is given. The TCDs should mark the location of the railroad tracks at the point they cross the road. In most States, the CROSSBUCK sign requires road users to yield the right-of-way to traffic at a grade crossing [6].

In the US, passive grade crossings account for roughly 52% of all grade crossings. In 2009, there were 1,934 incidents at grade crossings leading to 249 fatalities. 1,645 of the 1,934 incidents occurred at a passive grade crossing and of those 1,645, 65 fatalities and 242 injuries occurred at passive grade crossings. These grade crossings accounted for 29% (65 of 227) of deaths at grade crossings in the US. In the state of Tennessee, there were 56 incidents leading to 2 fatalities. 52 of the 56 incidents occurred at a public grade crossing and of those 56, 1 fatality and 9 injuries occurred at passive grade crossings [2]. Over the last 30 years, there has been a significant decrease in the amount of grade crossing crashes. This is typically attributed to the improvements made on active grade crossings. There have been no clear improvements at passive grade crossings [7].

Richards and Heathington surveyed 211 Tennessee drivers to assess drivers' comprehension and knowledge of grade crossing traffic control devices and safety issues. 35% of the drivers had received no training on grade crossing safety in their driver's education course while 11% said they had never received any instruction or information on grade crossing safety from any source. It was also discovered that although the CROSSBUCK sign is easily recognized, its true meaning is not widely understood [16]. According to the American Driver and Traffic Safety Education Association (ADTSEA), 31 states require drivers to take a driver's education course before getting a license. Tennessee is not one of those 31 states and so it is possible that drivers can be completely unfamiliar with passive grade crossings [15].

Section 11-701 of the Uniform Vehicle Code (UVC) defines drivers' duties when approaching an active grade crossing; however it makes no specific mention of passive grade crossings. A driver's responsibility at a passive crossing is much greater than at an active crossing. Using the UVC as a guideline for active crossings will allow for drivers duties to be surmised for passive crossings. Although adoption of the UVC is done on a state by state basis, most states have incorporated its provisions relative to grade crossing traffic control into their state traffic regulations. The following is from Section 11-701 of the UVC and can apply to passive grade crossings in addition to active grade crossings [17].

> a. Whenever any person driving a vehicle approaches a railroad grade crossing under any of the circumstances stated in this section, the driver of such vehicle shall stop within 50 feet but not less than 15 feet from the nearest rail of such

railroad and shall not proceed until he can do so safely. The foregoing requirements shall apply when:

3. A railroad train approaching within approximately 1500 feet of the highway crossing emits a signal audible from such distance and such railroad train, by reason of its speed or nearness to such crossing in an immediate hazard.

4. An approaching railroad train is plainly visible and is in hazardous proximity to such crossing.

Driving Simulator Validity

This section of the report examines several studies that have been performed validating the use of driving simulators. The acceptance of these studies of various performance variables proves that driving simulators are a valid research tool.

In 2010, Bédard, et al conducted a study examining the validity and reproducibility of simulator-based driving evaluations. Bédard expanded the evidence that support the validity of using simulators as clinical tools. The relationship between simulator data, neuropsychological, and on road data was replicated in regards to previous studies. Utilizing independent driving evaluators, each simulation was evaluated by two separate evaluators. Bédard found that a moderate to strong relationship exists between the performance assessed in the simulator and neuropsychological tests that are known to predict safe driving and crashes. Further, the evaluation of a simulated driving session can be very closely reproduced by the same evaluator or a different one using a recording of the simulation [8].

In 2001, Godley, et al conducted a study to determine behavioral validation of an advanced driving simulator for its use in speed research. Three forms of validity were studied: absolute validity (numerical correspondence), relative validity (or correspondence), and interactive (or dynamic) validity. Subjects drove a real vehicle for between forty and fifty minutes. The routes driven consisted of three approaches with rumble strips. These approaches were recreated in a driving simulator. The results show that while subjects typically have a higher driving speed in the simulator, their behavior correlates to that of driving a real vehicle. Due to the higher driving speed in the simulator, absolute validity could not be established. Since the driving behavior correlates between the simulator and a real vehicle, relative validity was established [9].

In 2011, Tey, et al conducted a study measuring driver response at railway grade crossings. Tey tested drivers as they approached three separate grade crossings. The grade crossings tested contained three different types of warning systems. The first grade crossing consisted of a stop sign. The second grade crossing consisted of a flashing red light and bell. The third grade crossing consisted of flashing red lights, a bell, and a half boom barrier. The results from the driving simulator were consistent with the field results which will be discussed in a further section [10].

The Use of STOP Signs at Passive Grade Crossings

This section of the report will examine the ongoing debate regarding the use of STOP signs at passive grade crossings.

Chapter 8 of the Manual on Uniform Traffic Control Devices (MUTCD) provides guidance on what TCDs should be used at public passive grade crossings. Section 8B.03.03 states that at a minimum, one CROSSBUCK sign shall be used on each highway approach to a grade crossing, alone or in combination with other TCDs. Section 8A.02.01 states that Because of the large number of significant variables to be considered, no single standard system of traffic control devices is universally applicable for all highway-rail grade crossings. As such, both YIELD and STOP signs may be placed with a CROSSBUCK sign. Section 8B.04 standardizes the placement of CROSSBUCK assemblies with STOP or YIELD signs. A YIELD sign shall be the default TCD for CROSSBUCK assemblies on all highway approaches to passive grade crossings unless an engineering study performed by the regulatory agency or highway authority determines that a STOP sign is appropriate. [6].

The 1961 MUTCD guidelines put forth seven conditions that could warrant a STOP sign. The sixth warrant stated that STOP signs may be placed at "railroad crossings where a stop is required by law or by order of the appropriate public authority." In the next 10 years there was much debate on the topic. In the next edition of the MUTCD released in 1971 that warrant was removed. There was one remaining warrant that could be applied to grade crossings. However, it was never made clear if the warrant applied to grade crossings or not. The State of Florida asked for an "interpretation" from FHWA whom responded that the STOP sign could be used after an engineering study was performed which shows a specific need but only as an interim measure. Several states and counties were putting stop signs at every grade crossing while others avoided placing stop signs at grade crossings completely. In 1991, the US

Congress passed a law under the Intermodal Surface Transportation Efficiency Act authorizing the use of STOP and YIELD signs at grade crossings with two more trains per day [11].

Millegan, et al performed a study on the effectiveness of STOP sign treatments at grade crossings. 26 years of vehicle-train crash history in the US from 1980 through 2005 was examined. In particular, 7,394 public grade crossings were examined. These grade crossings had a STOP sign added to the CROSSBUCK sign. It was found that the annual incident rates during the study period when the grade crossings were controlled by just a CROSSBUCK sign were consistently higher than when that same grade crossing was controlled by just a STOP sign. The study found that STOP sign treatment should be an effective and inexpensive method to improve safety at public grade crossings [12, 13].

Lindsay examined the costs associated with the use of STOP signs at passive grade crossings and compared those costs to upgrading the passive crossing to an active crossing. Lindsay found that although the initial installation of a STOP sign is very cheap, over time the increased travel delay, increased fuel consumption, and increased pollution would outweigh the costs of an active grade crossing. This research further supports the belief that STOP signs should only be used at locations where engineering studies and analysis have been done to justify their use [18].

Burnham evaluated the effectiveness of STOP signs placed at 7 passive grade crossings. Burnham found that, although individual sites had different rates, overall only 18% of motorists actually stopped at the grade crossings. As such, the STOP sign was shown to not be an effective means of traffic control at grade crossings. Burnham investigated further and came up with several guidelines that should be used when placing STOP signs. First, the crossing should be evaluated as a highway. Lower volume roads will not receive the enforcement necessary unless special coordination is used. Secondly, the train traffic must be factored. More details than the total train traffic should be considered including train speed, track curvature, grade crossing smoothness, crossing illumination, and switching maneuvers. Third, the drivers' line of sight must be considered. Railroads must clear the proper amount of right-of-way so that drivers have an adequate view down the tracks while approaching the crossing. Fourth, the position of the STOP bar should be considered. Determine the proper distance so that the driver does not stop in the hazard area around the track nor with a blocked view of the tracks due to rail equipment. Finally, the type of roadway traffic that will cross the grade crossing must be taken into consideration. Is it in an area with regular users or will the majority of travelers be unfamiliar with this grade crossing? Are school buses, hazardous materials, or pedestrians of significant concern? While Burnham found that STOP signs were ineffective, he proposed ways to improve their use [19].

CHAPTER III. STUDY METHODOLOGY

In order to determine the effectiveness of the various types of passive highway-railway grade crossings, a simulation was created using the DriveSafety DS-607c model driving simulator. The simulator consists of 5 aspheric mirror technology projectors wrapping 300° around a Ford Focus cab. The resolution on the projected screens is 1024 x 768 pixels each. Real-time data collection occurs at a rate of 10 Hz meaning that every second; ten data points will be found. The interior of the vehicle is an exact replica of a Ford Focus featuring a windshield, driver and passenger seat (no rear seats), center console, a fully functional instrument panel, and a radio/CD player. Additionally, there are 3 LCD screens that act as mirrors, one rear view and two side views. This simulation was used to obtain various driver parameters including approach speed, position, and whether or not the driver collided with the train. Further, the driver's looking behavior was observed as the train was approached. Drivers also answered a survey giving information on their background with passive highway-railway grade crossings and driving in general. Figure 1 shows the DS-607c driving simulator cab and projection equipment used in this study.

Figure 1. DriveSafety DS-607c driving simulator cab and projection.

Test Participants

Due to the limited resources and funding constraints, participation in this study was completely voluntary. Unfortunately, these constraints somewhat limited the scope of the project as subjects could not be brought in from around the region. Subjects were randomly recruited with the only requirements being a valid driver’s license holder and a minimum age of 18. 69% (44 of 64) subjects were male. The average age was 28.7 years with a standard deviation of 10.4 years. 29 subjects made up the 18-24 age group, while 27 subjects made up the 25-44 age group, and 8 subjects made up the 45+ (max age 59) age group. As the age groups show, this study had a large number of subjects from the nearby campus community rather than the region as a whole.

Experiment Design

Before any design work was completed in the simulator, the experiment was designed. The first grade crossing was designed to be a control. The grade crossing has clear sight distance, no train, no opposing traffic, and a simple CROSSBUCK sign. The second grade crossing varies by sight distance (clear or poor), the presence of a train, and by the type of sign at the grade crossing (CROSSBUCK or STOP sign and CROSSBUCK). The third grade crossing varies by the presence of opposing traffic, the presence of a train, and by the type of sign at the grade crossing (CROSSBUCK or YIELD sign and CROSSBUCK). As this experiment tested three passive grade crossings, two of which have three variables each, a design of experiment was conducted. The three variables lead to sixty-four possible combinations with thirty two of the combinations being unique. Using statistical software, a simple two-level factorial design was created and randomized. The design randomizes the thirty-two variations and allows for greater statistical significance. Each of these scenarios was tested by two different drivers. In total, thirty-two scenarios were driven by sixty-four different drivers. Table 1 shows the various scenarios and the combination of their variables.

Table 1. Experiment Design

Scenario Number	Crossing 1	Crossing 2			Crossing 3		
	Train?	Sight Distance?	Train?	Sign	Sign	Train?	Opposite Driver Action
1	No	Poor	No	Stop	Cross	Yes	Cross
2	No	Poor	No	Stop	Yield	Yes	Stop
3	No	Clear	Yes	Stop	Yield	Yes	Stop
4	No	Clear	Yes	Cross	Yield	No	Stop
5	No	Poor	No	Cross	Cross	Yes	Stop
6	No	Clear	Yes	Cross	Cross	Yes	Stop
7	No	Poor	No	Cross	Yield	Yes	Cross
8	No	Poor	Yes	Cross	Cross	Yes	Cross
9	No	Clear	Yes	Stop	Cross	No	Stop
10	No	Clear	No	Stop	Cross	Yes	Stop
11	No	Poor	No	Stop	Cross	No	Stop
12	No	Poor	Yes	Cross	Yield	Yes	Stop
13	No	Clear	No	Cross	Yield	Yes	Stop
14	No	Poor	Yes	Stop	Cross	Yes	Stop
15	No	Poor	Yes	Cross	Yield	No	Cross
16	No	Clear	Yes	Cross	Cross	No	Cross
17	No	Poor	Yes	Stop	Cross	No	Cross
18	No	Clear	Yes	Stop	Cross	Yes	Cross
19	No	Clear	No	Stop	Cross	No	Cross
20	No	Poor	Yes	Cross	Cross	No	Stop
21	No	Clear	No	Stop	Yield	No	Stop
22	No	Poor	Yes	Stop	Yield	No	Stop
23	No	Clear	No	Cross	Cross	No	Stop
24	No	Clear	No	Cross	Cross	Yes	Cross
25	No	Clear	No	Stop	Yield	Yes	Cross
26	No	Clear	Yes	Cross	Yield	Yes	Cross
27	No	Poor	No	Stop	Yield	No	Cross
28	No	Poor	No	Cross	Cross	No	Cross
29	No	Clear	Yes	Stop	Yield	No	Cross
30	No	Clear	No	Cross	Yield	No	Cross
31	No	Poor	No	Cross	Yield	No	Stop
32	No	Poor	Yes	Stop	Yield	Yes	Cross

Scenario Creation

With the configuration of the various scenarios, the next step was to create the scenario in the driving simulator. First, a warm-up session was designed. This warm-up session was created to allow drivers to familiarize themselves with the driving simulator before any data was collected from them. The warm-up session was designed to take subjects approximately eight to ten minutes to complete. Scenario creation utilizing the DriveSafety DS-607c driving simulator is done through the Hyperdrive program.

Following the creation of the warm-up scenario, the first of the scenarios was created. This program allows users to place tiles that contain roadways with various features. These basic tiles contain rural, suburban, urban, and industrial roadways. Various tiles have different features; some are a straight road while some contain intersections. Additional items can be added to the scenarios. These items range from pedestrians and vehicles to buildings and trees. Various pieces of signage can also be added. Various weather effects can be added. For this study, the weather was programmed to be daytime driving with clear skies.

The most important aspect of the design was the grade crossing. Participants were not told before the study began that the focus was on passive grade crossings. So as not to bias their results, testers were led to believe the study was on driver reaction to various pieces of signage at various distances from intersections. It was especially important that subjects had no prior indications that their performance at grade crossings was being studied. The scenario was intended to flow seamlessly from one grade crossing to another with enough intersections, traffic, and other roadside features to disguise the true purpose. One tile containing a passive grade crossing was exclusively used for this experiment. The rural grade crossing is located at one end of the tile which leads into a large hill with a curve. This grade crossing is repeated three times in the scenario. In order to disguise this grade crossing and not give a feeling of deja vu to the subjects, the first grade crossing occurs after the large hill, while the second and third grade crossings lead into the large hill. After passing the third grade crossing and continuing on, the subject may realize the general purpose of the study; however, it would be too late for subjects to alter their driving patterns in response.

Subjects drive on a two lane rural road for the duration of the test. The rural setting was chosen as it is the most common setting for passive grade crossings. A conscious decision was made to not include an audible warning from any trains. This study focused on driver’s responses to varying visual elements at crossings. Including an audible warning for trains may have skewed the results with regards to the effectiveness of the passive traffic control devices. Subjects will see continuously flowing oncoming traffic except for when they are approaching and crossing the first and second grade crossings. At the third grade crossing, there will be one opposing vehicle that may stop at the crossing or drive through it without stopping. There will never be a vehicle that is travelling in the same lane as the subject as that vehicle could impede on the subject’s desired speed.

The scenario is finished by adding various extra pieces. First, additions are made to the grade crossings based upon the variables. Different signs are placed at the grade crossings as necessary. Additionally, to simulate poor sight distance, a large grouping of trees was added to run along the railway. Any trains that were included in the scenario were added as well. Trains were added so that subjects would have 20 to 30 seconds, depending on their speed, to decide whether to stop and wait for the train or accelerate and beat the train through the grade crossing. This time was chosen as it is a critical amount of time that allows for safety in whatever decision the driver makes. This time frame allows drivers to either safely stop at the grade crossing or to accelerate and beat the train through the grade crossing. With the first scenario completed, the additional scenarios were created by making slight changes at each of the grade crossings based upon that specific scenario. All additional signage and pavement markings follow the proper guidelines as shown in the MUTCD [6]. Figure 2 shows an overview of the map with the three grade crossings highlighted. The speed limit on the roadway was 45 miles per hour (mph). Trains moved at 35 mph. At the second grade crossing, with clear sight distance, a train could be seen from a distance of approximately 525 feet. Conversely, with poor sight distance, a train could be seen from a distance of approximately 100 feet. At the third grade crossing, a train can first be seen from a distance of approximately 1500 feet. The train is easier to notice from a distance of approximately 475 feet. Depending on the driver’s speed, for the grade crossings with clear sight distance, the subject has 20 to 30 seconds from the moment they can see the train to react and make a decision. At the third grade crossing, that time may be doubled or tripled depending on how far back the subject notices the oncoming train. Figure 3 shows the scenario from the point of view of a driver as they approach the second crossing with a stop sign and poor sight distance. The image reads from left to right and top to bottom. The image shows the driver's view from the STOP AHEAD sign, the grade crossing warning, straight ahead 100 feet from the crossing, looking to the right approximately 75 feet from the crossing, straight ahead at approximately 50 feet, and looking to the right while stopped at the crossing. Appendix A contains photographic comparisons of the physical variations that occur at the crossings.

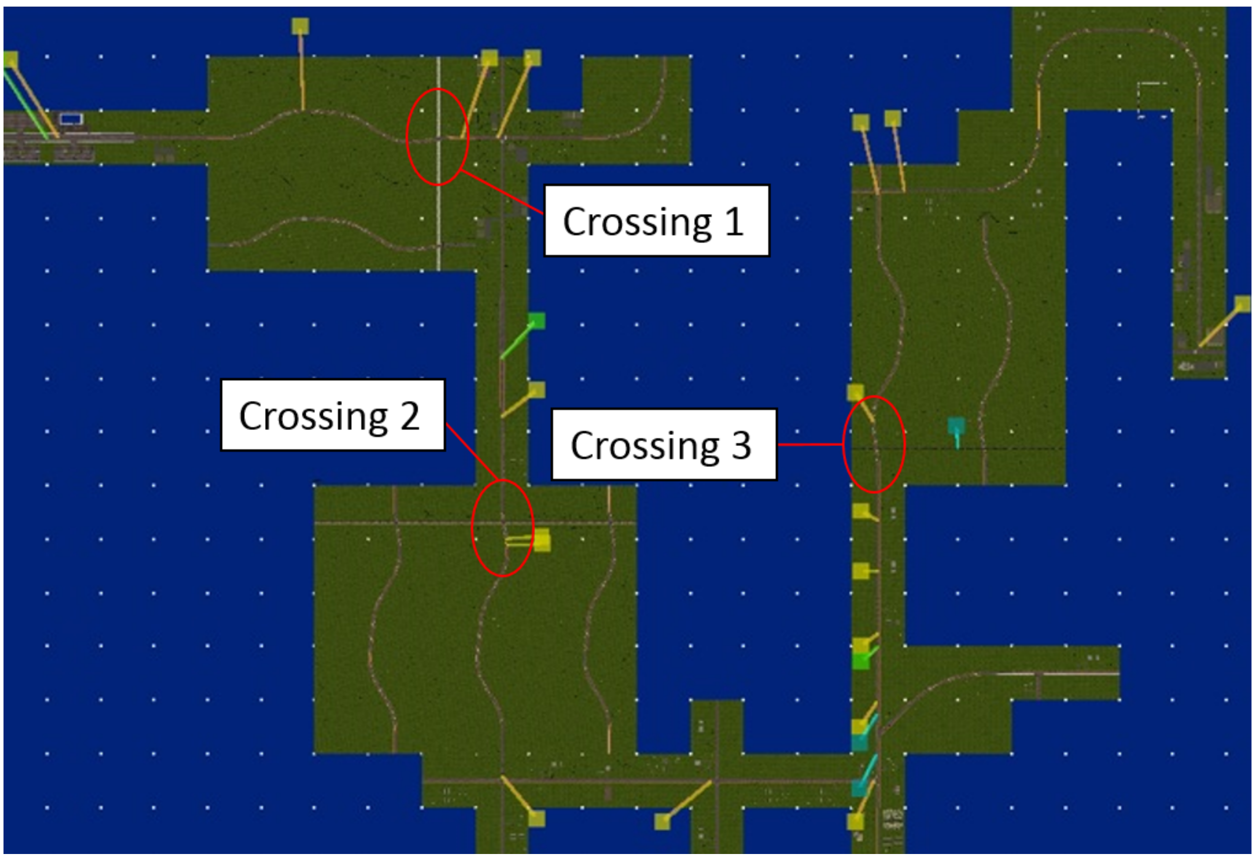


Figure 2. Scenario map with grade crossings shown.

Figure 3: Driver's view while approaching Crossing 2.

The tester did not want the subject to know that the study was focusing on their responses at grade crossings.

Survey Creation

In order to have an increased ability to classify and examine the data, a survey was created. This survey asks the subject basic background questions in order to determine their age, gender, and driving experience. Additional questions are asked to determine the subject's personal experience with regards to passive highway-railway grade crossings. The survey can be found in Appendix B.

Testing Procedure

When subjects arrive at the University of Tennessee Driving Simulator Laboratory (UTDSL), subjects were greeted and given a review of the testing procedure. Subjects were told that the study was completely voluntary and that they could stop at any time and their results would be discarded. The tester presents an informed consent form to the subject and gives a few minutes for the subject to read and understand it. The informed consent form was approved by the Institutional Review Board (IRB) at the University of Tennessee. The subject information and the data collected are to remain confidential according to the Human Research Institutional Review Board guidelines at the University of Tennessee. The tester explains the risks associated with the driving simulator, chiefly, motion sickness. The tester also explains to the subject that they will have complete anonymity with regards to this project.

After the form is signed, the subject is allowed into the simulator. The tester ensures the subject's comfort before turning out the lights and beginning the simulation. Before the subject begins driving, the subject is informed of several directions. Subjects are told that the first session is only a practice session which is designed to help them learn how the vehicle handles. The session should help subjects with starting, stopping, turning, and general control of the vehicle. Subjects are told to drive as they would normally drive, more specifically, subjects are told that if they typically drive above the speed limit in the real world, to try and do so in the simulator. The subjects are also told that when approaching an intersection, both a verbal and visual instruction will be given to inform the subject of the proper direction to follow. For instance, when approaching a traffic signal, the words “Turn RIGHT at this intersection” will appear on the screen while the words “turn right” will be played from the speakers. Perhaps most importantly, subjects are told that if there is a feeling of simulation sickness, especially a strong one, they can stop the vehicle at any time and take a break from testing. Subjects are told that there is no penalty for needing to stop the vehicle and take a break. Finally, before the subject is allowed to go, they are asked if they have any questions before beginning.

The subject then drives the practice session. It takes approximately eight to ten minutes. During this time, any questions the subject has are answered by the tester. The tester will also try to gauge their feelings of simulator sickness should any occur. After finishing the first session, the subject is asked if they would like a break before continuing onto the studied session. Subjects were offered refreshments at this time as well. After the break, if any, subject reenters the vehicle and the studied scenario begins. Before allowing the subject to drive, the tester explains several pieces of information. First, the tester explains that the speed limit for the majority of the roadway is 45 mph while near the end, the speed limit increases to 55 mph before dropping back down as the subject enters a town. The tester continues by reminding the subject to drive as close to normal as possible. The subject is told that if they prefer to drive 5 mile per hours above or below the speed limit, and so on, to do so in the simulation. The subject is informed that, similar to the practice session, when approaching an intersection the simulator will tell the subject which way to go. Most importantly, the subject is told that if they need to take a break for any reason, they can at any time.

The tester asks the subject if there are any questions. When all questions are answered, the subject is allowed to begin. After the subject is finished with this scenario, each subject was again offered refreshments. The tester then explained the purpose of the experiment to the subjects and introduced the survey before asking the subject to answer it. After each subject finished the survey, the tester thanked them for their participation in the study.

Independent and Dependent Variables

The only variable output from the driving simulator to be analyzed for all subjects is the subject's velocity (reported in m/s). From velocity, subject's stop times were found. A subject was considered to be stopped when their velocity was 0 to ensure a complete stop. Independent variables such as age, gender, etc. were coded for statistical testing, but were not utilized in this study. Each subject's looking behavior was observed by the tester utilizing both an in-cab camera and his own vision. Additionally, if a subject collided with an object, the name of the object, speed of the driver, and angle of the vehicle were collected.

Statistical Analysis

Three variables were analyzed to evaluate driver behavior: looking behavior, stopping behavior, and approach speed. The statistical testing of the collected data for this study was completed using JMP statistical software. Looking and stopping behavior were both tested using the same methods. Either a Pearson's chi-squared test or a likelihood ratio test (for counts that are sufficiently small, i.e. less than 5) was performed on two-by-two contingency tables [14]. Both values will be shown with the utilized value being highlighted. These tests were selected as they are a fairly simple and straightforward way to compare various yes/no variables. For looking behavior, data was divided and examined in two overarching categories: those that looked for a train at the first grade crossing and those that did not. The speed data was analyzed using a basic regression with significance determined by a t-test. Before the speed data could be analyzed, however, the data had to be transformed due to its unequal variance. A square root transformation was performed.

CHAPTER IV. RESULTS AND DISCUSSIONS

Prior to presenting the statistical results, several observations will be noted. 2 of the 64 (3%) subjects were struck by a train. Subject numbers 24 and 58 were both hit by a train at the third grade crossing. Subject 24 saw two grade crossings with a CROSSBUCK sign and no previous trains. The third grade crossing had a CROSSBUCK sign. On the two previous grade crossings, the subject did not look for a train. The subject was within 5 mph of the speed limit at each grade crossing, driving 42.7 mph when struck by the train. The subject was a 33 years old male; however, he only had 2 years of driving experience. Subject 58 saw two grade crossings with a CROSSBUCK sign and no previous trains. At the second grade crossing, with clear sight distance, there was a train that the driver beat through the grade crossing and did not see. The third grade crossing had a YIELD sign. The subject was travelling at 39.3 mph when struck by the train. Subject 58 was a 23 year old female with 7 years of driving experience. Neither subject looked for a train as they approached the grade crossings. 2 collisions out of 64 tests suggest that something should be done to improve driver safety, and possibly education, with regards to passive grade crossings.

3 (5%) subjects reported having no familiarity with passive grade crossings, including subject 58. An additional 4 (6%) subjects did not know that a stop sign could be placed at a grade crossing and reported being confused by the signage. Interestingly, 22 (34%) subjects reported having no formal driver training, including a high school driver's education class. Subject 24 had no driver training while subject 58 had taken a high school driver's education class. 6 (9%) drivers beat trains through

grade crossings without realizing there was a train. The questions on the survey regarding the driver's experience with passive grade crossings were discarded as several subjects answered them based upon their simulated experience rather than real life experience.

Looking Behavior

38% (24 of 64) of subjects did not look for a train while approaching a grade crossing one or multiple times. On 22% (43 of 192) of all approaches, the subject did not look for a train. Looking behavior at the first grade crossing was used to further separate the analysis at the second and third grade crossings. 70% (45 of 64) of drivers looked for a train while approaching the first grade crossing. This leaves 30% (19 of 64) that did not look for a train while approaching the first grade crossing.

Crossing 2

Of the 45 subjects that looked for a train while approaching the first grade crossing, 42 (93%) looked again. 3 (7%) of these subjects did not look at this second grade crossing. With the group that had looked at the first grade crossing, clear or poor sight distance, STOP sign or CROSSBUCK sign, and the presence of a train was not found to be statistically significant. As such, it can be deduced that if the subject was safe at the control grade crossing, they would have safe behaviors at the following grade crossings. The Likelihood Ratio was used for each of these variables.

Of the 19 subjects that did not look for a train while approaching the first grade crossing, 9 (47%) of these changed their behavior and looked while 10 (53%) followed with the same behavior as at the first grade crossing. Clear or poor sight distance and the presence of a train were not found to be statistically significant. The type of sign, STOP or CROSSBUCK, was found to be significant. As such the addition of a STOP sign at a passive grade crossing will increase a driver's safety, as they will be much more likely to look for an approaching train. It is understandable that the subject's ability to see down the rail road tracks upon approaching would not affect their looking behavior as they would already have decided whether or not to look when they see the warning sign regardless of how much they could actually see. The same holds true for the presence of a train. Their decision to look or not look is made whether or not there is a train. The Likelihood Ratio was used for each of these variables. A summary of the results is shown in Table 2. Additional data can be found in Appendix D.

Table 2. Crossing 2: Looking Behavior Summary of Results

Did not look at Crossing 1		
Variable	Chi Squared	p
Train	0.426	0.5142
Sight Distance	0.091	0.7633
STOP sign	19.785	<0.0001
Looked at Crossing 1		
Variable	Chi Squared	p
Train	3.697	0.0545
Sight Distance	0.643	0.4226
STOP sign	0.318	0.5731

Crossing 3

Of the 45 subjects that looked for a train while approaching the first grade crossing, 41 (91%) looked again. 4 (9%) of these subjects did not look at this third grade crossing. Within this group that looked at the first grade crossing, it was found that the actions of a vehicle in opposing traffic, the presence of a train, and the type of sign, YIELD or CROSSBUCK, were not statistically significant. The Likelihood Ratio was used for each of these variables. As with the second grade crossing, it can be seen that if a subject is safe at the control crossing, they would have safe behavior at the following grade crossings.

Of the 19 subjects that did not look for a train while approaching the first grade crossing, 12 (63%) of these changed their behavior and looked while 7 (37%) continued with the same behavior as at the first grade crossing. It was found that the actions of a vehicle in opposing traffic, the presence of a train, and the type of sign, YIELD or CROSSBUCK, were not statistically significant. In addition, 8 of 11 (73%) subjects that had a YIELD sign looked for a train. These results are understandable as, like with the second grade crossing, the presence of a train will not have an effect on a decision that is already made. The actions of an opposing vehicle do not have a significant effect on the subjects because they were preoccupied with driving in their own way and did not rely on other traffic to determine their actions. The case of the YIELD sign is interesting. It is trending towards significance. More subjects may be able to cause significance. As it is, however, it is acting remarkably like a CROSSBUCK sign. As such, this study shows that a grade crossing is no safer with a YIELD sign than it is with just a CROSSBUCK sign. The Likelihood Ratio was used for each of these variables. A summary of these results is shown in Table 3. Additional data can be found in Appendix D.

Table 3. Crossing 3: Looking Behavior Summary of Results

Did not look at Crossing 1		
Variable	Chi Squared	p
Train	0.426	0.5142
Opposing Vehicle	1.027	0.3109
YIELD sign	1.027	0.3109
Looked at Crossing 1		
Variable	Chi Squared	p
Train	1.244	0.2647
Opposing Vehicle	0.02	0.8888
YIELD sign	0.318	0.5731

Stopping Behavior

Unlike the analysis on looking behavior, the first grade crossing was not used as a control crossing to separate the subjects into sub groups. The first grade crossing had 3 (5%) subjects stop. As there was no reason for a subject to stop at this grade crossing; after the test was over the subjects were asked why they had stopped and each had a similar response. A lack of familiarity with the concept of passive grade crossings caused the drivers to be overly cautious in the simulator.

Crossing 2

31 (48%) subjects stopped at this grade crossing while 33 (52%) subjects did not stop at the grade crossing. It was found that adding a STOP sign to the grade crossing had a statistically significant effect on stopping behavior as 27 (84%) subjects that saw the sign made a complete stop. The remaining 5 subjects that saw the STOP sign at this grade crossing did not make a complete stop and instead rolled past the STOP sign at a moderate to low speed. The presence of a train was not statistically significant at this grade crossing though it is trending in that direction and with a larger sample size, could very well become significant. The STOP sign was analyzed using the Likelihood Ratio chi-square, while the presence of a train was analyzed using Pearson's chi-square. A summary of these results is shown in Table 4. Additional data can be found in Appendix E.

Table 4. Crossing 2: Stopping Behavior Summary of Results

Variable	Chi Squared	p
Train	3.065	0.08
Sign	36.81	<.0001*

Crossing 3

23 (36%) subjects stopped at this grade crossing while 41 (64%) did not stop at the crossing. It was found that the presence of a train had a statistically significant effect on stopping behavior as 21 (66%) of subjects that saw a train stopped. As the

train could be seen from over 1000 feet prior to the grade crossing, this result is expected. Additionally, the YIELD sign acted as a CROSSBUCK sign. The YIELD sign did not have a significant effect on stopping behavior as only 13 (41%) of subjects that saw the YIELD sign came to a full stop. The presence of a train was analyzed using the Likelihood Ration chi-square and the YIELD sign was analyzed using Pearson's chi-square. A summary of these results is shown in Table 5. Additional data can be found in Appendix E.

Table 5. Crossing 3: Stopping Behavior Summary of Results

Variable	Chi Squared	p
Train	27.445	<0.0001
Sign	0.612	0.434

Approach Speed

Approach speeds were analyzed for grade crossings 2 and 3. These grade crossings featured the variables being studied. Approach speeds were taken at various distances. Larger differences in significant variables can be seen nearer to the grade crossing. Speeds were analyzed at points 50 feet, 100 feet, 150 feet, 200 feet, 250 feet, and at 311 feet (at the warning sign). Due to the carefully planned number of cases and equality in subjects between them, when finding mean speed, the least square mean will be equal to the actual mean of the data. It is interesting to note that there is generally a small variance when the data collection begins but as the subjects near the grade crossings, the variance increases based upon the differing scenarios.

Crossing 2

At a point 50 feet from the grade crossing, both the sight distance and the type of sign proved to be significant. A subject that is approaching a STOP sign will decrease speeds by 18.8 mph as compared to a subject that is approaching a CROSSBUCK sign. This is a significant change in driver speed. The quality of the sight distance down the railroad tracks also has a significant effect on approach speed at 50 feet. Subjects approaching a grade crossing with poor sight distance drove 6.6 mph slower than those approaching a grade crossing with clear sight distance. Both of these results are to be expected as one of the main purposes of a STOP sign is to slow drivers down so that they can be safer as they approach an intersection. When approaching said intersection, a driver will drive slower if they cannot see the cross traffic due to some obstructions.

At points 100, 150, 200, and 250 feet from the grade crossing, only the presence of the STOP sign was found to be significant. At the warning sign, 311 feet, from the grade crossing, both the type of sign and the quality of the sight distance down the tracks had a significant effect on subjects' approach speeds. The STOP sign caused subjects to travel 5.7 mph slower than drivers approaching a CROSSBUCK sign. Slightly surprising, subjects with poor sight distance down the rail road tracks drove 4.8 mph slower than those with clear sight distance. This may be due to an immediate reaction from passing the warning sign. Seeing the warning sign causes drivers to look for a grade crossing and when their view is mostly obstructed, they instinctively slow down. The presence of a train was not significant in affecting approach speeds at this grade crossing.

Figure 4 shows the approach speeds for one case involving a STOP sign. The figure shows that 7 of the 8 drivers came to a complete stop while the remaining drivers slowed to a speed less than 5 mph. Figures showing the approach speeds can be found in Appendix F. It is of interest to note that the figures depicting the approach speed of a STOP sign look deceiving. Although the plots do not show that approach speed reached zero as in Figure 4, they did. The plots do not show a specific zero point because each driver stopped at different locations. This means that as they approached the grade crossing, one subject may have stopped 55 feet from the crossing. The next subject may have stopped 5 feet from the crossing. A third subject may have stopped 25 feet from the crossing. Each plot shows one specific case of how that grade crossing could have been configured. As a result, each graph represents 8 drivers and uses quartiles to show their upper and lower bound. The top bar is the 75% speed, the solid line is the 50% speed, and the bottom bar is the 25% speed. The data points are being plotted at approximately every 30 feet for the larger graphs and every 15 feet for the more focused graphs. Unfortunately, when trying to find a constant scale between all of the variations of crossing 2, 15 feet was the shortest distance that was feasible due to the subjects that did not stop at the grade crossing. Their higher speeds meant that if the points were to be separated by 5 feet, they would not always have data at a specific point.

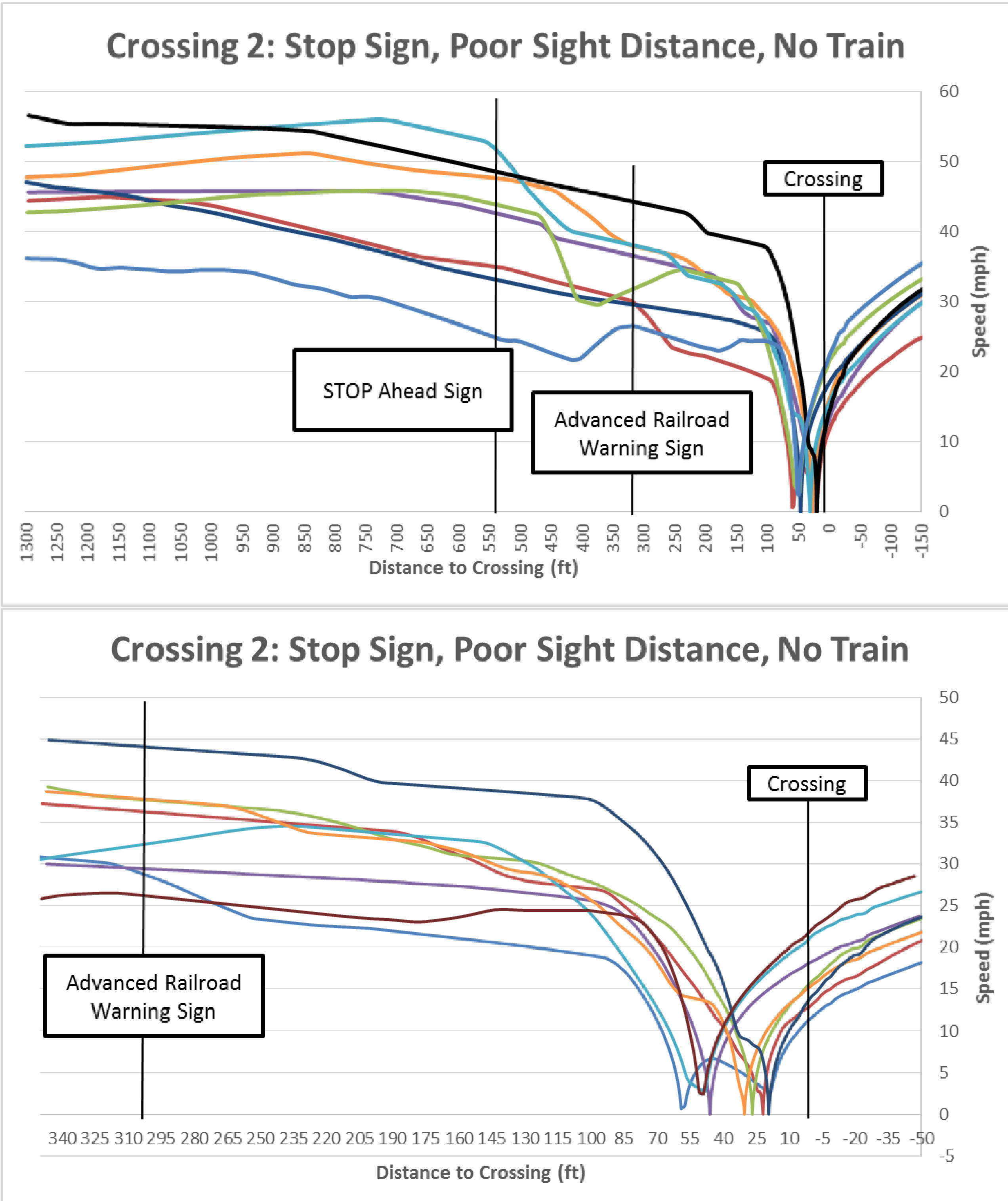


Figure 4. Crossing 2: Approach Speeds for STOP sign, Poor Sight Distance, No Train

Crossing 3

50, 100, 150, 200 and 311 feet from the grade crossing, there was only one variable that had a significant effect on approach speeds. Since the oncoming train could be seen for over 1000 feet before it reached the grade crossing, it is understandable that the presence of a train had a significant effect on subjects' approach speeds. Subjects with an oncoming train drove 6.3 mph slower than subjects without an oncoming train at 311 feet from the grade crossing. 50 feet from the grade crossing, the difference in speeds between subjects with and without a train was 17.3 mph. At 250 feet, the probability that a train would affect approach speeds lied just out of the desired range. With a few more subjects, it should join the rest of the points in showing significance.

The YIELD sign performed very similarly to a CROSSBUCK sign. Although no statistical significance could be found between a YIELD sign and a CROSSBUCK sign, the speed data shows a decrease of 5.3 mph when the subjects are 50 feet from the grade crossing. Between 150 and 100 feet from the crossing, the subjects were able to make out the YIELD sign as speeds dropped by 0.91 mph and 3.7 mph respectively. These slight drops in speed show that while the YIELD sign is acting similarly to a CROSSBUCK sign, it is also slowing drivers even if just by a small amount. Figures showing approach speeds can be found in Appendix F. As with the approach to the stop signs, the graphs look misleading. Subjects stopped near the third grade crossing, but due to the large variance in where the subjects stopped to wait for the train the graphs do not show that the subjects stopped.

CHAPTER V. CONCLUSIONS AND RECOMMENDATIONS

Following expectations, drivers that behave safely at a basic grade crossing will continue to do so at grade crossings with various levels of complexity. However, the safety of the delinquent drivers must be addressed. Utilizing a driving simulator allowed for various solutions to be tested in a safe environment. As 2 of 64 subjects were struck by a train in this study, improvements clearly need to be made. Improvements may come from improved education of drivers, improved enforcement at dangerous grade crossings, or infrastructure improvements. A solution was found that increased the likelihood of a driver to look for an oncoming train while approaching a passive grade crossing. Increasing the looking behavior of drivers at passive grade crossings will have positive effects on transportation safety. STOP signs force a driver to stop and typically, when stopped, a driver will look for any crossing traffic before accelerating again.

Conversely, 3 drivers had no familiarity with passive grade crossings and believed that if a grade crossing did not have flashing lights or gates that there was no possibility of a train being on that rail. 4 drivers expressed confusion at having a STOP sign at a grade crossing. In this study, 27 of the 32 drivers that saw a STOP sign at a grade crossing came to a complete stop while the remaining 5 drivers performed a rolling stop at the grade crossing. Over time, the number of drivers that make a complete stop may decrease if there is not enough rail activity and the driver begins to believe that trains do not use that rail.

The YIELD sign at the grade crossing affected drivers differently than one at an intersection typically would. Drivers did not slow as much as was expected. The YIELD sign acted very similarly to CROSSBUCK signs. As the CROSSBUCK sign does not have a specific meaning in the MUTCD other than to show drivers the exact location of a grade crossing, many drivers assume that they must yield at the grade crossing. While there was no significant proof that the YIELD sign would improve driver safety compared to the CROSSBUCK, the data is trending towards it being an improvement. With a larger sample size, it is very likely to be proven as such.

With the high cost of upgrading a passive grade crossing to an active grade crossing, a feasible alternative should be found. This study shows that the addition of a STOP sign greatly improves driver safety. Over time, however, drivers may begin to lose respect for the STOP sign and either fully or partially disregard it. This is a problem that can be solved by proper enforcement. With proper enforcement, drivers will respect the signage at the grade crossings. Additionally, a television or radio ad campaign would aid in informing drivers of their responsibilities at passive grade crossings.

The results show that adding a STOP sign significantly decreases the approach speed of drivers at grade crossings. 50 feet from the grade crossing, drivers with a STOP sign drove 18.8 mph slower than drivers that only had a CROSSBUCK sign. The driver's ability to see down the tracks was also a significant factor in speed reduction as poor sight distance conditions caused drivers to drive 6.6 mph slower than those with clear sight conditions.

Continuing Research

This study collected data on subject's age, gender, driver training, as well as driver steering, braking, and acceleration behavior. A more in-depth look into the data would allow for various additional conclusions to be made. Determining whether a specific type of driver, shown through their age, gender, braking behavior, and acceleration behavior, are more willing to beat a train through a grade crossing or stop and wait for it could lead to further innovations and increased safety.

The data from this study was fairly limited in scope, utilizing only 64 test subjects from the surrounding area. Replicating this study and expanding with more subjects will help to complete trends that were seen to be developing. With this expansion, there should also come a test of regional differences. Drivers from one area of the nation act differently than drivers from other areas. There are many reasons for these differences including what kind of driver's education classes are offered or required in that area. With several drivers having no familiarity with passive grade crossings, it would be interesting to see if those results could be replicated in a region with mandatory driver's education classes for high school students.

In this study, the testing was all done in a driving simulator. As such, subjects only saw a specific type of grade crossing once. Expanding the scope into comparable real world passive grade crossings would be beneficial. Field testing would be able to validate the findings of this study. Field testing would also be able to show how effective STOP and YIELD signs may be over a longer period. When driver passes a STOP sign at a grade crossing without seeing a train very often, there is a large possibility they may begin to disregard the STOP sign. With some driver's completely ignoring or rolling through a STOP sign, better enforcement may become the answer. The feasibility of enforcing every passive grade crossing in the nation is daunting to say the least, but a system can be devised to optimize the enforcement policies.

LIST OF REFERENCES

1. http://safety.fhwa.dot.gov/xings/xing_facts.cfm "Facts and Statistics," Accessed March 2013.
2. Federal Railroad Administration (2009). *Railroad Safety Statistics*. *2009 Annual Report*. Washington, D.C.: U.S. Department of Transportation.
3. Cooper, Douglas L. & David R. Ragland (2009). "Driver Behavior at Rail Crossings: Cost Effective Improvements to Increase Driver Safety at Public At-Grade Rail-Highway Crossings in California." Institute of Transportation Studies, University of California, Berkeley.
4. Federal Highway Administration (2007). *Railroad-Highway Grade Crossing Handbook*. Washington, D.C.: U.S. Department of Transportation.
5. Yeh, Michelle, Jordan Multer. "Driver Behavior at Highway-Railroad Grade Crossings: A Literature Review from 1990-2006"
6. Federal Highway Aministration (2009). *Manual on Uniform Traffic Control Devices.* Washington, D.C.: U.S. Department of Transportation.
7. Lerner, N. D., R. E. Llaneras, H. W. McGee, and D.E. Stephens. NCHRP Report 470: Traffic-Control Devices for Passive Railroad-Highway
8. Bédard, M., Parkkari, M., Weaver, B. Riendeau, J. & Dahlquist, M. (2010). Brief Report—Assessment of driving performance using a simulator protocol: Validity and reproducibility. American Journal of Occupational Therapy, 34, 336-340.
9. Godley, Stuart T, Thomas J. Triggs, Brian N. Fildes, 2002. Driving simulator validation for speed research. Accident Analysis and Prevention 34 pg. 589-600.
10. Tey, Li-Sian, Luis Ferreira, Angela Wallace, 2011. Measuring driver responses at railway level crossings. Accident Analysis and Prevention 43 (1), 2134-2141.

11. Russell, E.R., Burnham, A. “Guidelines and Practice for the Proper use of Stop signs at Rail-Highway Grade Crossings,” ITE Journal, 1999.
12. Xuedong Yan, Lee D. Han, Stephen Richards & Hal Millegan (2010): Train–Vehicle Crash Risk Comparison Between Before and After Stop Signs Installed at Highway–Rail Grade Crossings, Traffic Injury Prevention, 11:5, 535-542
13. Millegan, Hal, Xuedong Yan, Stephen Richards, Lee Han (2009). Evaluation of Effectiveness of Stop Sign Treatments at Highway-Railroad Grade Crossings, Transportation Research Record: Journal of the Transportation Research Board, 2122, 78-85.
14. “Chi-Square Test – Analysis of Contingency Tables” [Supplemental material]. (2010). Howell, D. From *Statistical Methods for Psychology*. 7th ed. <http://www.uvm.edu/~dhowell/methods7/Supplements/ChiSquareTests.pdf>
15. American Driver and Traffic Safety Education Association, (2008). *National Overview of Driver Education*.
16. Richards, Stephen H., *An Evaluation of Undesirable Driver Actions at Railroad-Highway Grade Crossings with Active Traffic Control*, Doctoral Dissertation, The University of Tennessee, December 1982.
17. *Uniform Vehicle Code and Model Traffic Ordinance: Revised 1968*, National Committee on Uniform Traffic Laws and Ordinances, Washington D.C., 1968.
18. Lindsay, David N., K.W. Heathington, West, B., Stop Signs at Railroad-Highway Grade Crossings: An Evaluation of Some of the Associated Costs, Fourth International Symposium on Railroad-Highway Grade Crossing Research and Safety, Proceedings. October 1996, Tennessee, USA.

19. Burnham, Archie, Stop Sign Effectiveness at Railroad Grade Crossings (Abuse without Excuse), Third International Symposium on Railroad-Highway Grade Crossing Research and Safety, Proceedings. October 1994, Tennessee, USA.

APPENDIX

Appendix A: Photographic Comparisons of Grade Crossings

Figure 5. Crossing 1

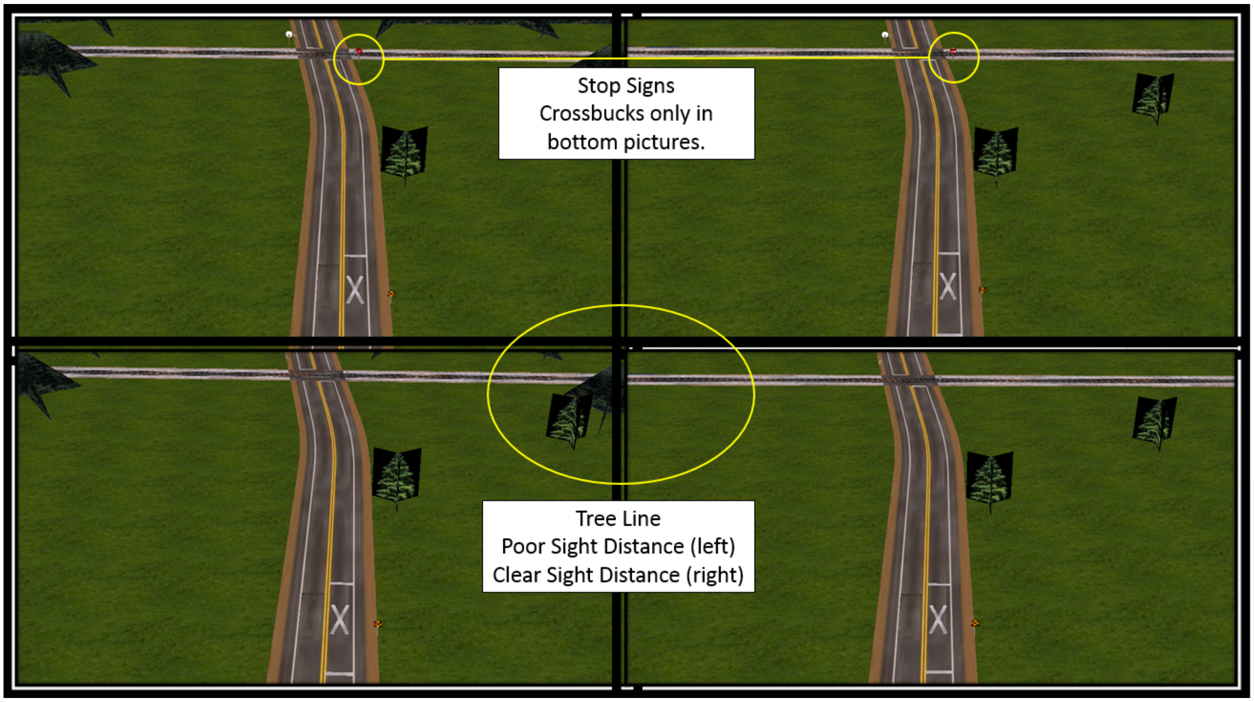


Figure 6. Crossing 2 variations.

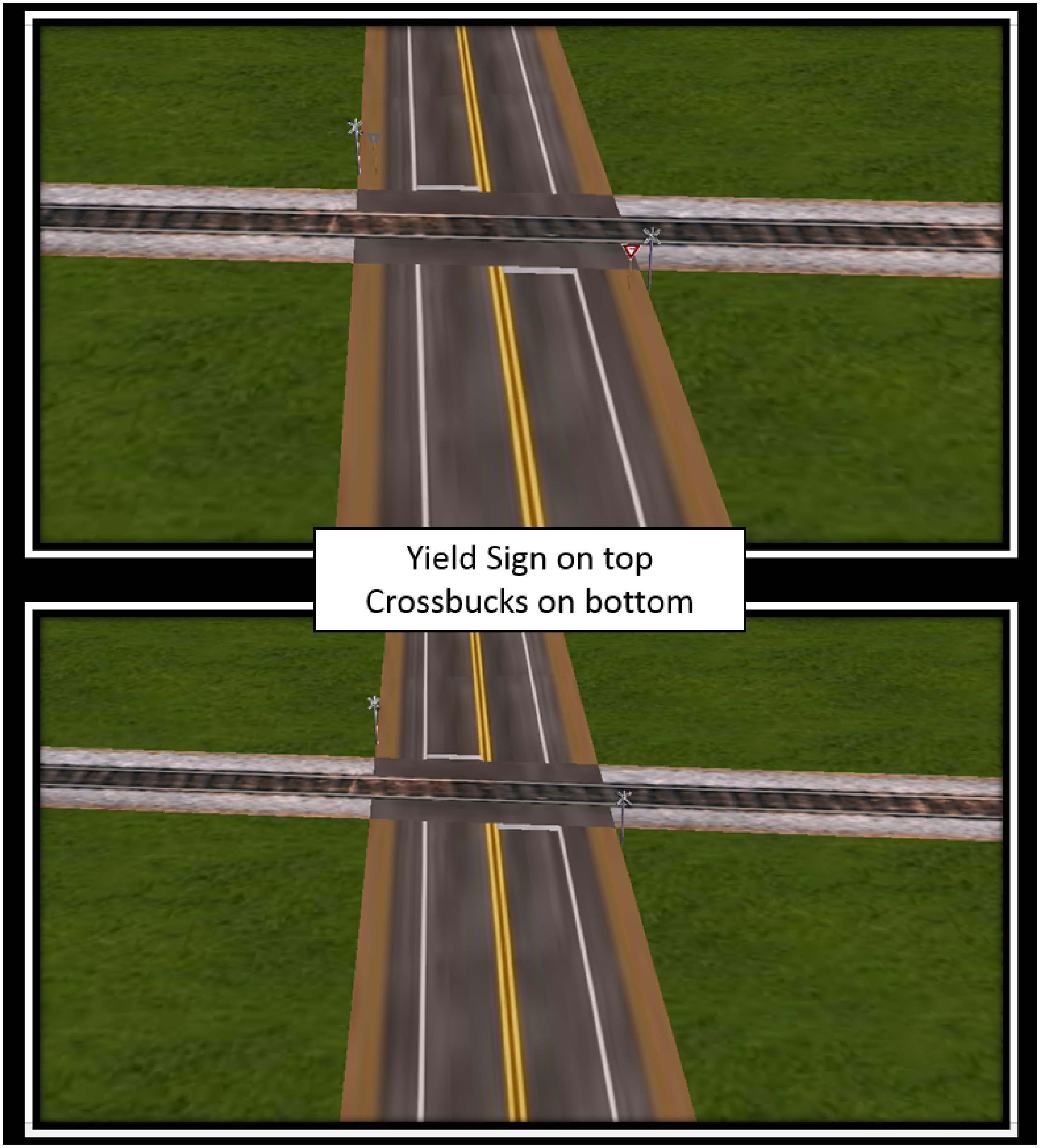


Figure 7. Crossing 3 variations (Opposing vehicle not shown).

Appendix B: Survey

DRIVER SURVEY

Please complete this survey based upon your own driving patterns and experience. It is important that you answer every question, and that you report your true actions and opinions. Your responses will be confidential and you do not need to give your name.

This survey is being given to help understand your familiarity and experience with railroad crossings. There are some railroad crossings that have flashing lights and gates that activate as a train approaches; those **<u>are not</u>** the focus for this study. This study is focused on the railroad crossings that **<u>do not</u>** have any flashing lights or gates. These are called **<u>passive crossings</u>**. Answer these questions based upon this category of crossings, i.e. the crossings that **<u>do not</u>** have any flashing lights or gates. Please answer these questions from the perspective of **<u>a driver</u>**.

1) Approximately how many years have you been driving? ___________

2) How many **<u>passive</u>** railway-highway grade crossings do you encounter in a **<u>typical week</u>**? Please choose the answer that **<u>best describes</u>** your experience.

______ None
______ 1-2 crossings per week
______ 3-5 crossings per week
______ 5 or more crossings per week

3) How often in a **<u>typical week</u>** of driving do you see a train at these crossings? Please choose the answer that **<u>best describes</u>** your experience.

______ Never or almost never
______ 1 time per week on average
______ 2 or 3 times per week on average
______ More than 3 times per week on average

4) Several sign types are shown below. How many crossings that you pass in a **<u>typical week</u>** have each sign at them?

______ Seen at **<u>none</u>** of the crossings you encounter weekly
______ Seen at **<u>some</u>** of the crossings you encounter weekly
______ Seen at **<u>all</u>** of the crossings you encounter weekly
______ Not applicable (you do not drive at a crossing in a typical week)

______ Seen at **<u>none</u>** of the crossings you encounter weekly
______ Seen at **<u>some</u>** of the crossings you encounter weekly
______ Seen at **<u>all</u>** of the crossings you encounter weekly
______ Not applicable (you do not drive at a crossing in a typical week)

______ Seen at **none** of the crossings you encounter weekly
______ Seen at **some** of the crossings you encounter weekly
______ Seen at **all** of the crossings you encounter weekly
______ Not applicable (you do not drive at a crossing in a typical week)

5) How often do you **fail to obey** the signs you see at those crossings (without gates or flashing red lights) in your **typical weekly driving**?

1 2 3 4 5 6 7 8 9 10 N/A
Never Half the time Always

If you answered anything other than never, why do you fail to obey the signs at those crossings? ____

6) How often do you **observe others failing to obey** the signs you see at those crossings (without gates or flashing red lights) in your **typical weekly driving**?

1 2 3 4 5 6 7 8 9 10 N/A
Never Half the time Always

If you answered anything other than never, why do you **believe others fail to obey** the signs at those crossings? ____

7) What types of **formal driver training** have you had? Please check all that apply.

______ None (self-taught, taught by family, etc.)
______ High school driver's ed course
______ Professional driver's training course
______ Other (please specify) _________________________

8) Your age? _______ 9) Sex: _____ Male _____ Female

10) Circle the highest education level completed.

Grade School College
1 2 3 4 5 6 7 8 9 10 11 12 (GED) 1 2 3 4 4+

11) What type of vehicle do you **regularly drive**? Please check all that apply and circle the answer that is most common for you.

______ Car
______ Pick-up or van
______ Motorcycle
______ Truck
______ Bus

Appendix C: Institutional Review Board Research Consent Form

INFORMED CONSENT STATEMENT

You are invited to participate in a research study. The purpose of this research is to utilize the DriveSafety DS-607c model driving simulator located in Perkins Hall room 72 to conduct tests of participants' driving performance. You will be tested to analyze the effects of different factors on your driving performance. The objective of this study is to explore how drivers react to various configurations of roadway features.

INFORMATION ABOUT PARTICIPANTS' INVOLVEMENT IN THE STUDY

You will be asked to read and sign this consent form. You will then be asked your age and relevant driving experience for proper data collection. After information is collected, you will be asked to open the door of the car cab and sit down in the seat of the simulator cab. Next, you will be asked to drive an 8-10 minute practice session in order to familiarize yourself with the simulated driving environment. Then, you will be asked to complete a course totaling 8-12 minutes in the University's driving simulator. Each session will be comprised of a virtual driving course developed by the researchers. The total amount of time required of you as a participant is approximately half an hour. Breaks in the testing will be permitted at your discretion.

RISKS

The only potential risk to you during testing could be motion sickness due to the conflicting body queues of visual movement without actual body movement. You can quit the test anytime during the test without penalty if you feel uncomfortable or simply do not wish to continue.

BENEFITS

In transportation research, the use of driving simulators to conduct research is growing rapidly due to the declining costs of high quality technology. The results of the study will provide useful guidance in regards to roadway design standards.

CONFIDENTIALITY

All information in the study records will be kept confidential. Data will be stored securely and will be made available only to persons conducting the study. No reference will be made in oral or written reports which could link participants to the study.

CONTACT INFORMATION

If you have questions at any time about the study or the procedures, (or you experience adverse effects as a result of participating in this study,) you may contact the researcher, Bryan Bartnik, at 11 Estabrook Hall and (815) 685-3913. If you have questions about your rights as a participant, contact the Office of Research Compliance Officer at (865) 974-3466.

PARTICIPATION
Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be destroyed.

CONSENT
I have read the above information. I have received a copy of this form. I agree to participate in this study.

Investigator's signature ____ Date .

Participant's signature ____ Date .

Appendix D: Looking Behavior Contingency Tables and Chi-Squared

Table 6. Crossing 2: Sight distance, subject did not look at first crossing.

<table>
<tr><td colspan="4">Sight Distance by Look? (Y/N)</td></tr>
<tr><td>Count
Total %
Col %
Row %</td><td>Yes</td><td>No</td><td></td></tr>
<tr><td rowspan="4">Poor</td><td>3</td><td>4</td><td rowspan="2">7</td></tr>
<tr><td>15.79</td><td>21.05</td></tr>
<tr><td>33.33</td><td>40</td><td rowspan="2">36.84</td></tr>
<tr><td>42.86</td><td>57.14</td></tr>
<tr><td rowspan="4">Clear</td><td>6</td><td>6</td><td rowspan="2">12</td></tr>
<tr><td>31.58</td><td>31.58</td></tr>
<tr><td>66.67</td><td>60</td><td rowspan="2">63.16</td></tr>
<tr><td>50</td><td>50</td></tr>
<tr><td rowspan="2"></td><td>9</td><td>10</td><td rowspan="2">19</td></tr>
<tr><td>47.37</td><td>52.63</td></tr>
</table>

Test	**ChiSquare**	**Prob>ChiSq**
Likelihood Ratio	0.091	0.7633
Pearson	0.09	0.7636

Table 7. Crossing 2: Sign, subjects did not look at first crossing.

Sign by Look? (Y/N)			
Count / Total % / Col % / Row %	Yes	No	
Crossbuck	0	9	9
	0	47.37	
	0	90	47.37
	0	100	
Stop	9	1	10
	47.37	5.26	
	100	10	52.63
	90	10	
	9	10	19
	47.37	52.63	

Test	**ChiSquare**	**Prob>ChiSq**
Likelihood Ratio	19.785	<.0001*
Pearson	15.39	<.0001*

Table 8. Crossing 2: Train, subjects did not look at first crossing.

Train? (Y/N) by Look? (Y/N)			
Count	Yes	No	
Total %			
Col %			
Row %	Yes	No	
No	5	7	12
	26.32	36.84	
	55.56	70	63.16
	41.67	58.33	
Yes	4	3	7
	21.05	15.79	
	44.44	30	36.84
	57.14	42.86	
	9	10	19
	47.37	52.63	

Test	**ChiSquare**	**Prob>ChiSq**
Likelihood Ratio	0.426	0.5142
Pearson	0.425	0.5146

Table 9. Crossing 2: Sight distance, subjects looked at first crossing.

Sight Distance by Look? (Y/N)			
Count Total % Col % Row %	Yes	No	
Poor	24	1	25
	53.33	2.22	
	57.14	33.33	55.56
	96	4	
Clear	18	2	20
	40	4.44	
	42.86	66.67	44.44
	90	10	
	42	3	45
	93.33	6.67	

Test	**ChiSquare**	**Prob>ChiSq**
Likelihood Ratio	0.643	0.4226
Pearson	0.643	0.4227

Table 10. Crossing 2: Train, subjects looked at first crossing.

Train? (Y/N) by Look? (Y/N)			
Count Total % Col % Row %	Yes	No	
No	20 44.44 47.62 100	0 0 0 0	20 44.44
Yes	22 48.89 52.38 88	3 6.67 100 12	25 55.56
	42 93.33	3 6.67	45

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	3.697	0.0545
Pearson	2.571	0.1088

Table 11. Crossing 2: Sign, subjects looked at first crossing.

Sign by Look? (Y/N)			
Count Total % Col % Row %	Yes	No	
Crossbuck	21	2	23
	46.67	4.44	
	50	66.67	51.11
	91.3	8.7	
Stop	21	1	22
	46.67	2.22	
	50	33.33	48.89
	95.45	4.55	
	42	3	45
	93.33	6.67	

Test	**ChiSquare**	**Prob>ChiSq**
Likelihood Ratio	0.318	0.5731
Pearson	0.311	0.5769

Table 12. Crossing 3: Opposing vehicle, subjects did not look at first crossing.

Opposing Vehicle Crossing by Look? (Y/N)			
Count Total % Col % Row %	Yes	No	
Cross	4	4	8
	21.05	21.05	
	33.33	57.14	42.11
	50	50	
Stop	8	3	11
	42.11	15.79	
	66.67	42.86	57.89
	72.73	27.27	
	12	7	19
	63.16	36.84	

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	1.027	0.3109
Pearson	1.028	0.3106

Table 13. Crossing 3: Train, subjects did not look at first crossing

Train? (Y/N) by Look? (Y/N)			
Count Total % Col % Row %	Yes	No	
No	7	3	10
	36.84	15.79	
	58.33	42.86	52.63
	70	30	
Yes	5	4	9
	26.32	21.05	
	41.67	57.14	47.37
	55.56	44.44	
	12	7	19
	63.16	36.84	

Test	**ChiSquare**	**Prob>ChiSq**
Likelihood Ratio	0.426	0.5142
Pearson	0.425	0.5146

Table 14. Crossing 3: Sign, subjects did not look at first crossing.

Sign by Look? (Y/N)			
Count Total % Col % Row %	Yes	No	
Crossbuck	4	4	8
	21.05	21.05	
	33.33	57.14	42.11
	50	50	
Yield	8	3	11
	42.11	15.79	
	66.67	42.86	57.89
	72.73	27.27	
	12	7	19
	63.16	36.84	

Test	**ChiSquare**	**Prob>ChiSq**
Likelihood Ratio	1.027	0.3109
Pearson	1.028	0.3106

Table 15. Crossing 3: Opposing vehicle, subjects looked at the first crossing.

Opposing Vehicle Crossing by Look? (Y/N)			
Count / Total % / Col % / Row %	Yes	No	
Cross	22	2	24
	48.89	4.44	
	53.66	50	53.33
	91.67	8.33	
Stop	19	2	21
	42.22	4.44	
	46.34	50	46.67
	90.48	9.52	
	41	4	45
	91.11	8.89	

Test	**ChiSquare**	**Prob>ChiSq**
Likelihood Ratio	0.02	0.8888
Pearson	0.02	0.8887

Table 16. Crossing 3: Train, subjects looked at the first crossing.

Train? (Y/N) by Look? (Y/N)			
Count Total % Col % Row %	Yes	No	
No	19 42.22 46.34 86.36	3 6.67 75 13.64	22 48.89
Yes	22 48.89 53.66 95.65	1 2.22 25 4.35	23 51.11
	41 91.11	4 8.89	45

Test	**ChiSquare**	**Prob>ChiSq**
Likelihood Ratio	1.244	0.2647
Pearson	1.198	0.2737

Table 17. Crossing 3: Sign, subjects looked at first crossing.

Sign by Look? (Y/N)			
Count Total % Col % Row %	Yes	No	
Crossbuck	21	3	24
	46.67	6.67	
	51.22	75	53.33
	87.5	12.5	
Yield	20	1	21
	44.44	2.22	
	48.78	25	46.67
	95.24	4.76	
	41	4	45
	91.11	8.89	

Test	**ChiSquare**	**Prob>ChiSq**
Likelihood Ratio	0.318	0.5731
Pearson	0.311	0.5769

Appendix E: Stopping Behavior Contingency Tables and Chi-Squared

Table 18. Crossing 2: Train by stop.

<table>
<tr><td colspan="4">Train? (Y/N) by Stop? (Y/N)</td></tr>
<tr><td>Count
Total %
Col %
Row %</td><td>Yes</td><td>No</td><td></td></tr>
<tr><td rowspan="4">No</td><td>12</td><td>20</td><td rowspan="2">32</td></tr>
<tr><td>18.75</td><td>31.25</td></tr>
<tr><td>38.71</td><td>60.61</td><td rowspan="2">50</td></tr>
<tr><td>37.5</td><td>62.5</td></tr>
<tr><td rowspan="4">Yes</td><td>19</td><td>13</td><td rowspan="2">32</td></tr>
<tr><td>29.69</td><td>20.31</td></tr>
<tr><td>61.29</td><td>39.39</td><td rowspan="2">50</td></tr>
<tr><td>59.38</td><td>40.63</td></tr>
<tr><td rowspan="2"></td><td>31</td><td>33</td><td rowspan="2">64</td></tr>
<tr><td>48.44</td><td>51.56</td></tr>
<tr><td>Test</td><td>ChiSquare</td><td>Prob>ChiSq</td><td></td></tr>
<tr><td>Likelihood Ratio</td><td>3.091</td><td>0.0787</td><td></td></tr>
<tr><td>Pearson</td><td>3.065</td><td>0.08</td><td></td></tr>
</table>

Table 19. Crossing 2: Sign by stop.

Sign by Stop? (Y/N)			
Count Total % Col % Row %	Yes	No	
Crossbuck	4	28	32
	6.25	43.75	
	12.9	84.85	50
	12.5	87.5	
Stop	27	5	32
	42.19	7.81	
	87.1	15.15	50
	84.38	15.63	
	31	33	64
	48.44	51.56	

Test	**ChiSquare**	**Prob>ChiSq**
Likelihood Ratio	36.81	<.0001*
Pearson	33.095	<.0001*

Table 20. Crossing 3: Train by stop.

<table>
<tr><td colspan="4">Train? (Y/N) by Stop? (Y/N)</td></tr>
<tr><td>Count
Total %
Col %
Row %</td><td>Yes</td><td>No</td><td></td></tr>
<tr><td rowspan="4">No</td><td>2</td><td>30</td><td rowspan="2">32</td></tr>
<tr><td>3.13</td><td>46.88</td></tr>
<tr><td>8.7</td><td>73.17</td><td rowspan="2">50</td></tr>
<tr><td>6.25</td><td>93.75</td></tr>
<tr><td rowspan="4">Yes</td><td>21</td><td>11</td><td rowspan="2">32</td></tr>
<tr><td>32.81</td><td>17.19</td></tr>
<tr><td>91.3</td><td>26.83</td><td rowspan="2">50</td></tr>
<tr><td>65.63</td><td>34.38</td></tr>
<tr><td rowspan="2"></td><td>23</td><td>41</td><td rowspan="2">64</td></tr>
<tr><td>35.94</td><td>64.06</td></tr>
</table>

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	27.445	<.0001*
Pearson	24.501	<.0001*

Table 21. Crossing 3: Sign by stop.

Sign by Stop? (Y/N)			
Count Total % Col % Row %	Yes	No	
Crossbuck	10	22	32
	15.63	34.38	
	43.48	53.66	50
	31.25	68.75	
Yield	13	19	32
	20.31	29.69	
	56.52	46.34	50
	40.63	59.38	
	23	41	64
	35.94	64.06	

Test	**ChiSquare**	**Prob>ChiSq**
Likelihood Ratio	0.612	0.4340
Pearson	0.611	0.434

Appendix F: Approach Speed Plots and Regression

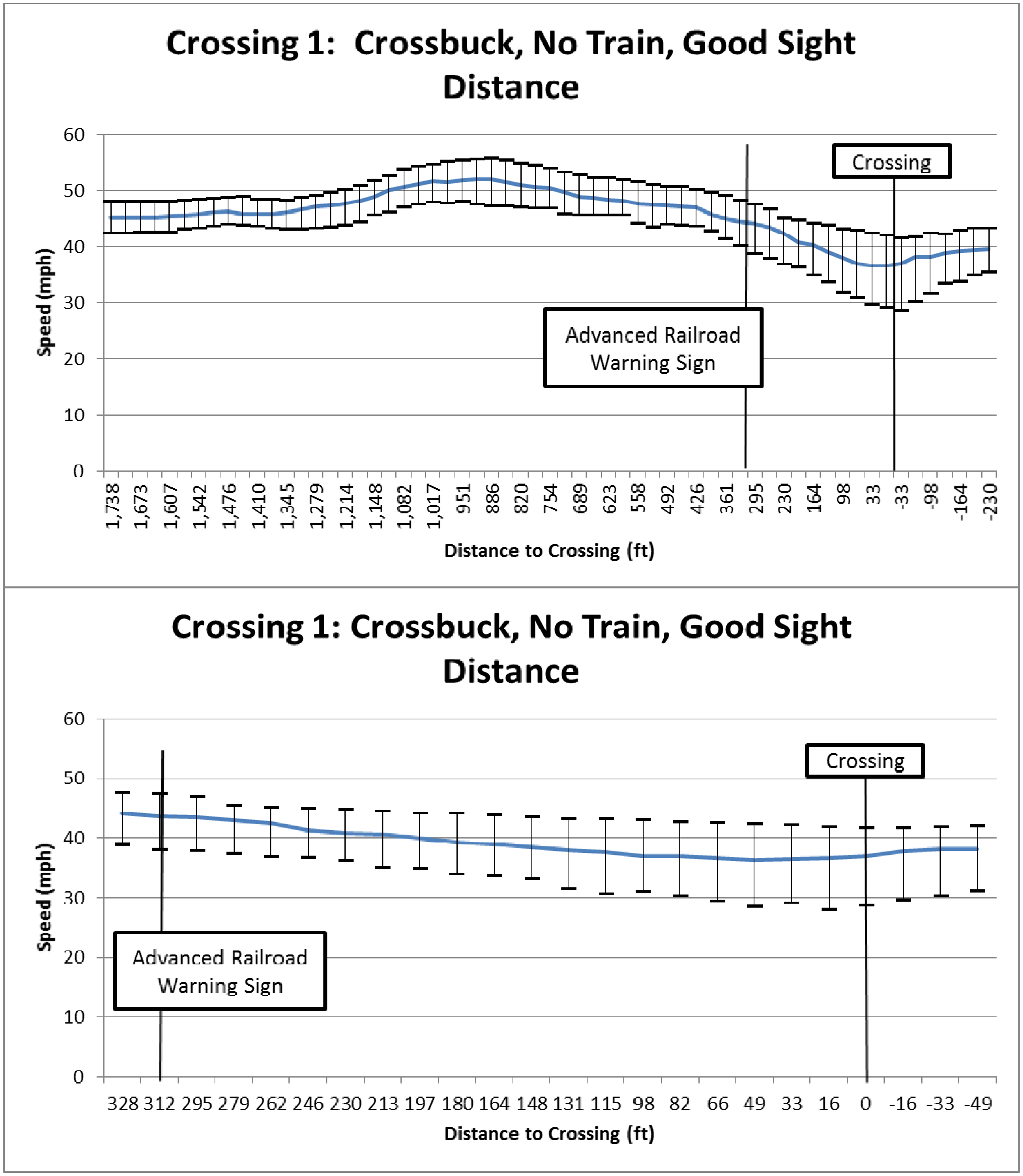
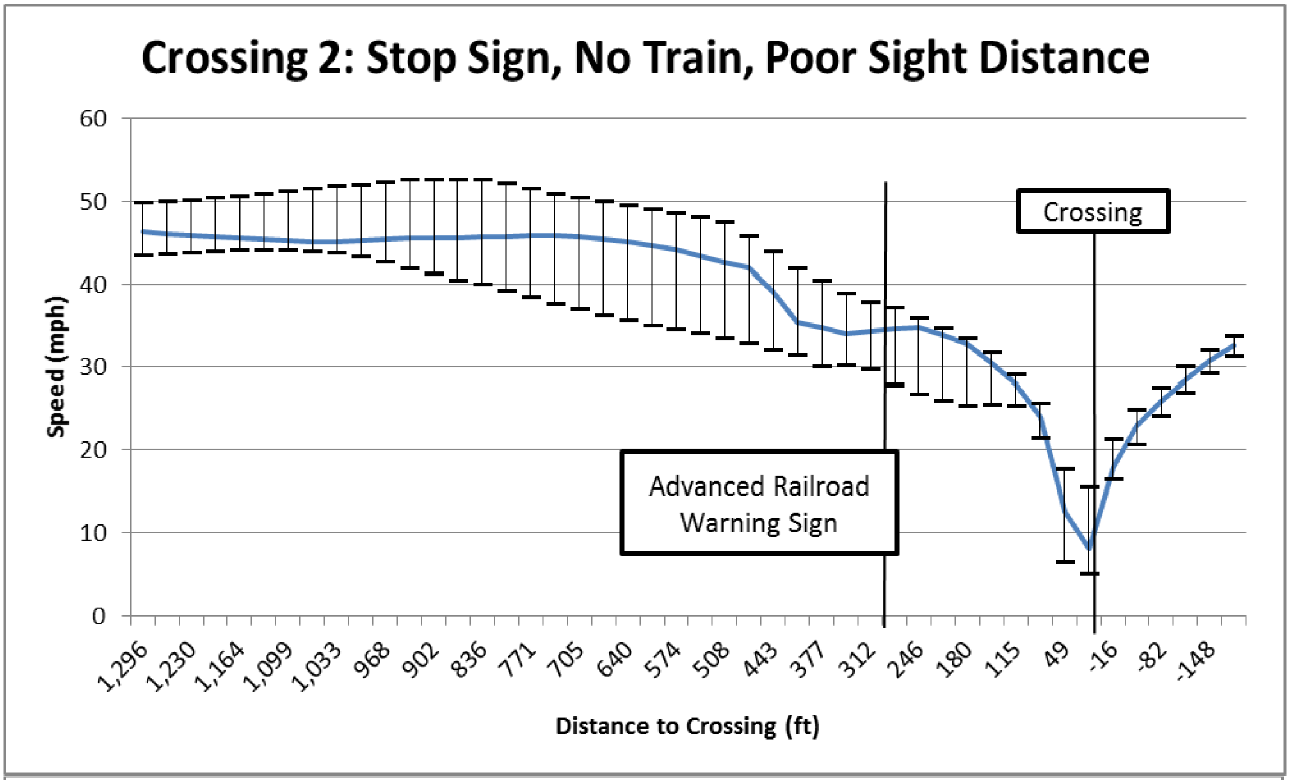


Figure 8. Crossing 1: Approach speed.



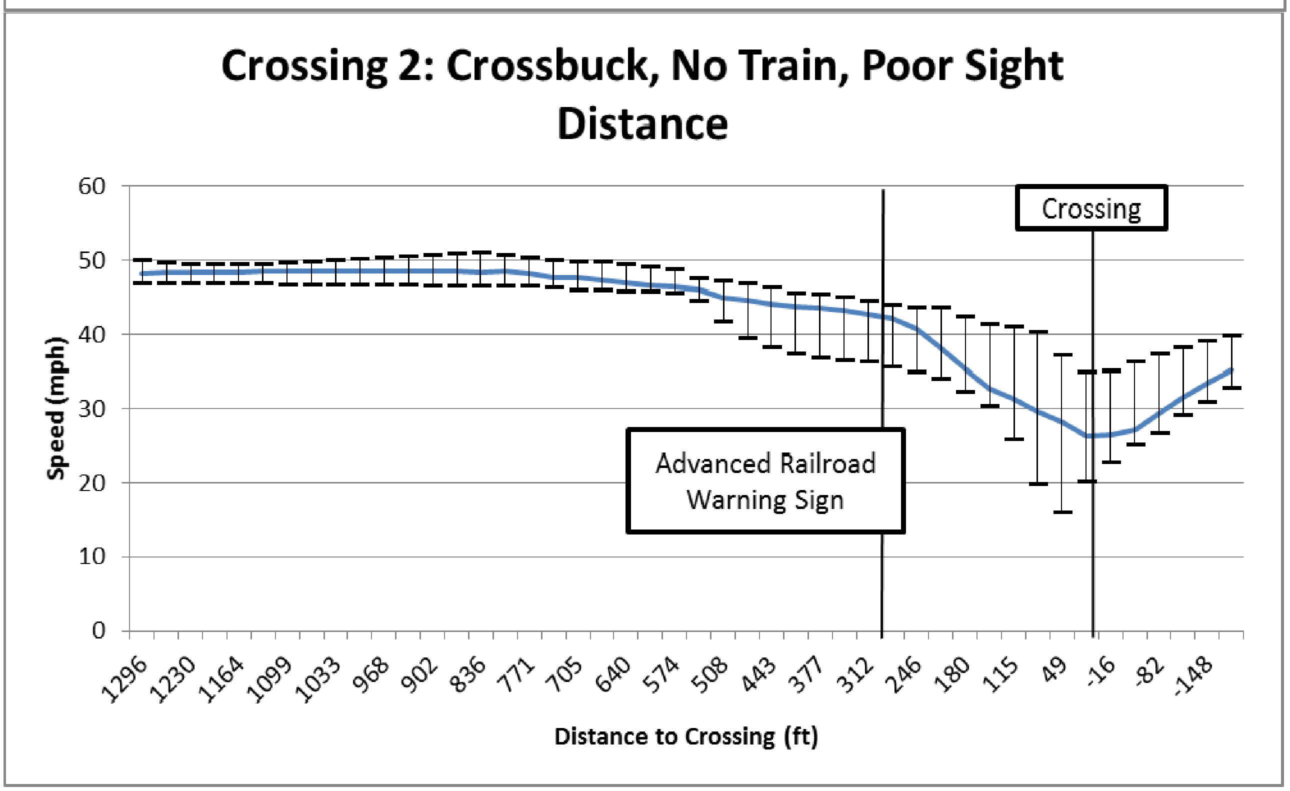
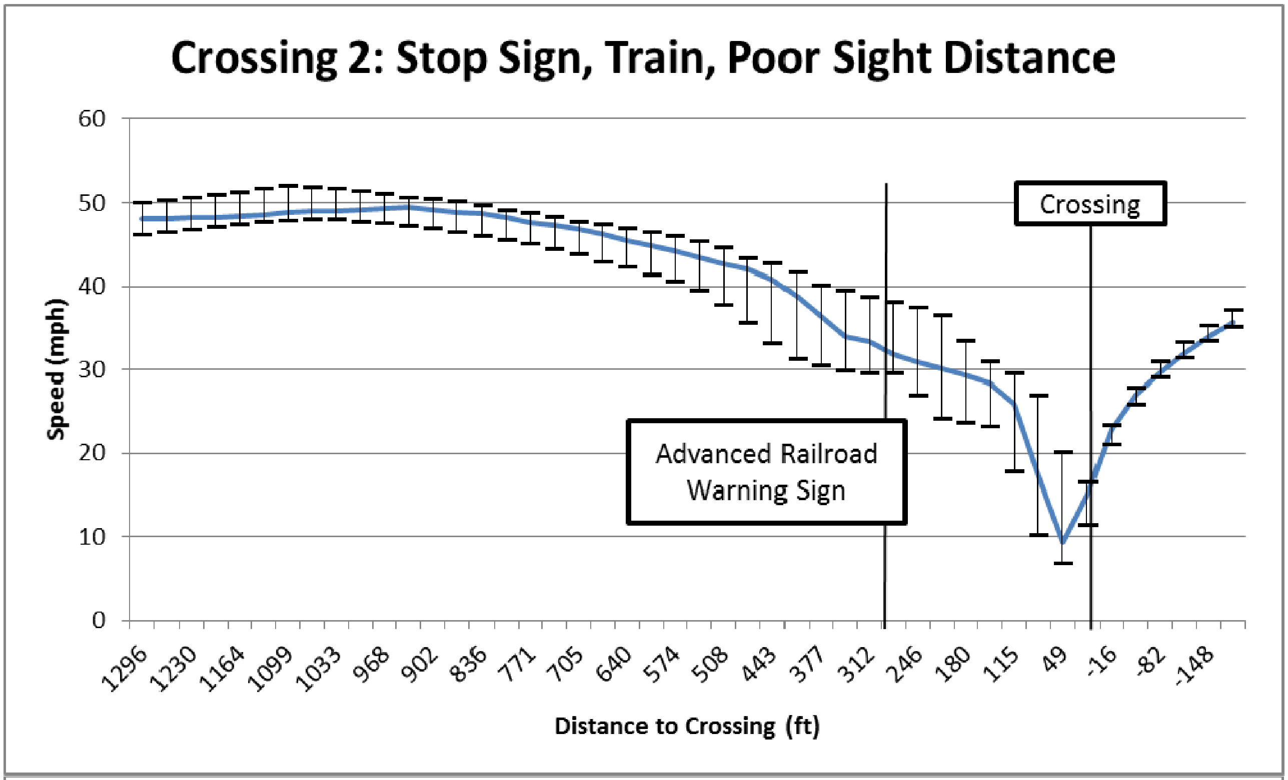


Figure 9. Crossing 2: Approach speeds for no train and poor sight distance.



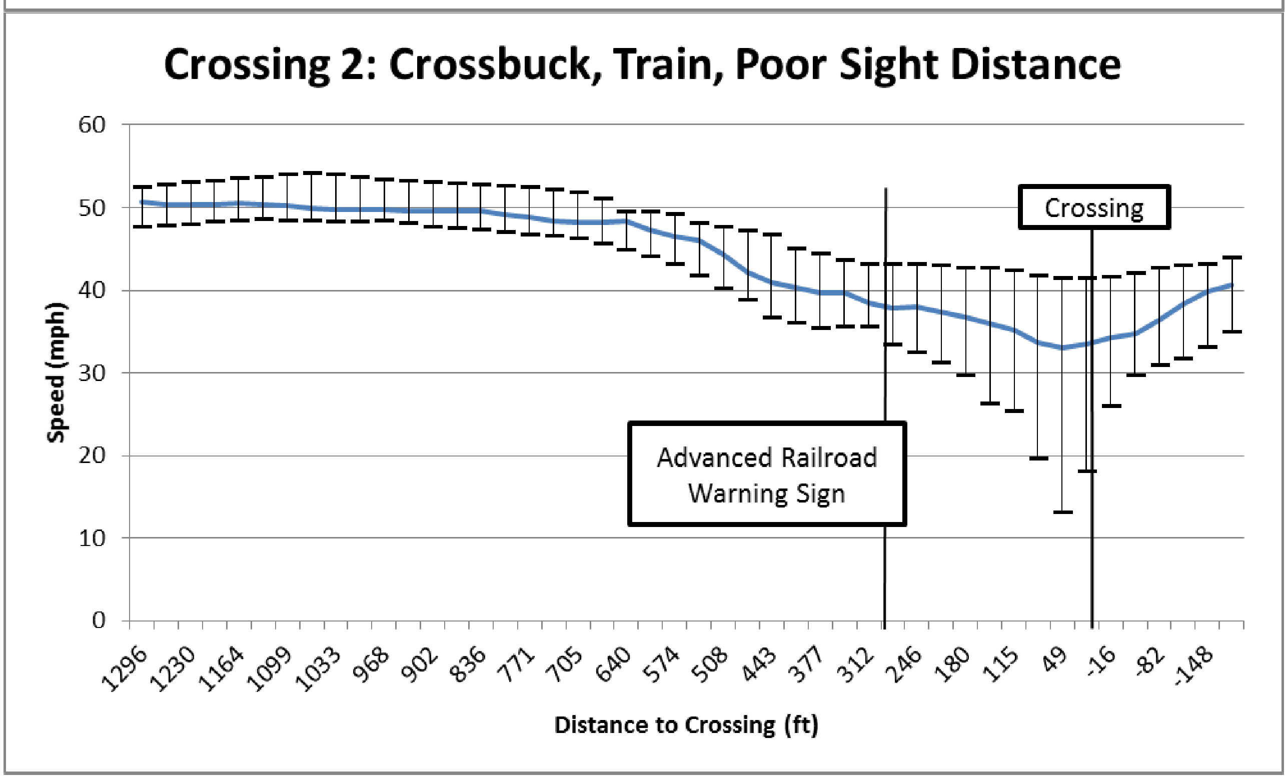
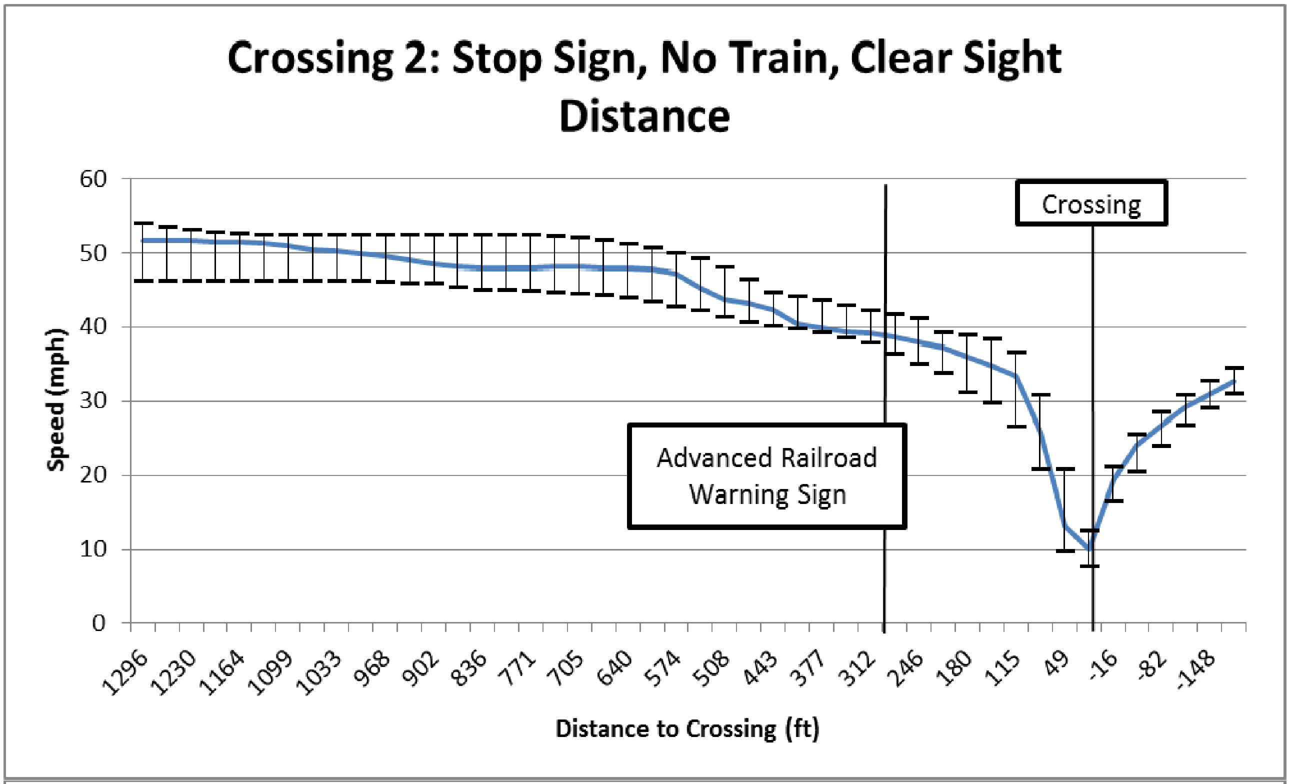


Figure 10. Crossing 2: Approach speeds for train and poor sight distance.



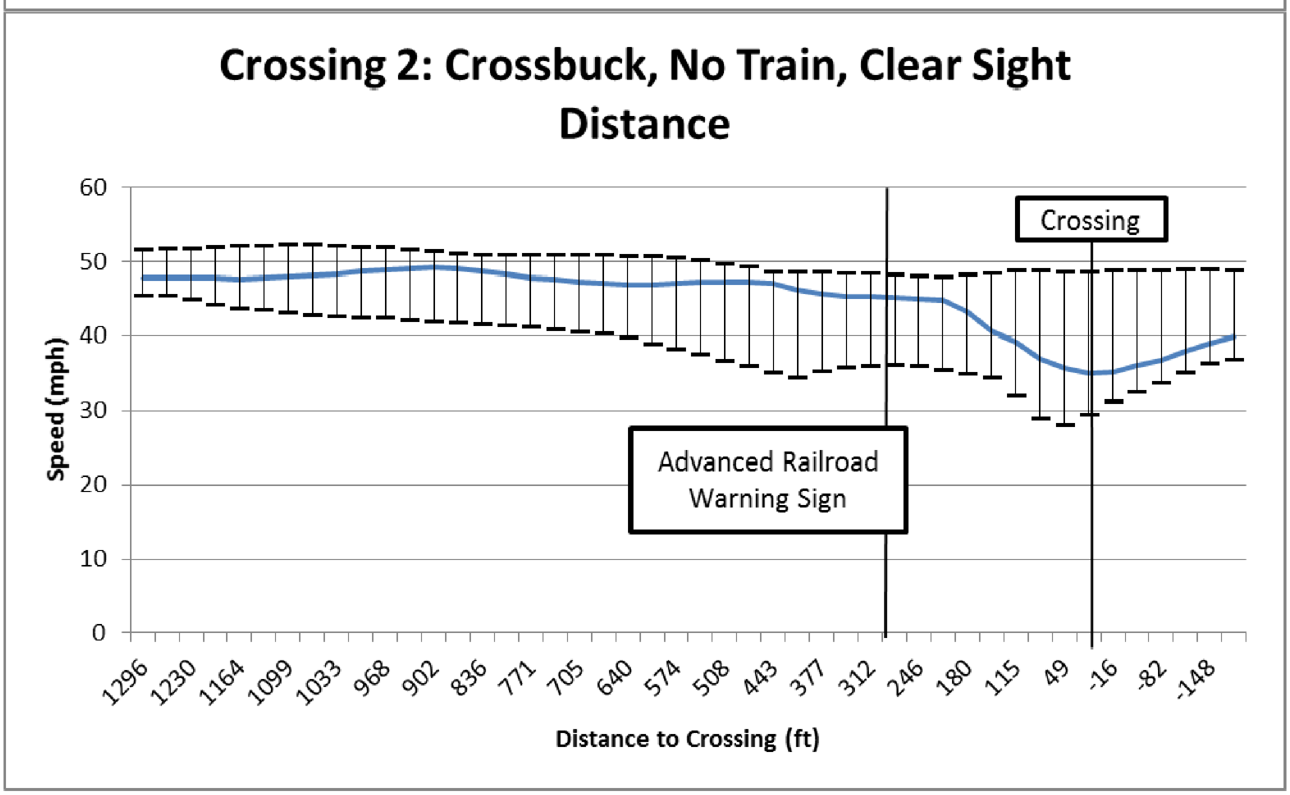


Figure 11. Crossing 2: Approach speeds for no train and clear sight distance.

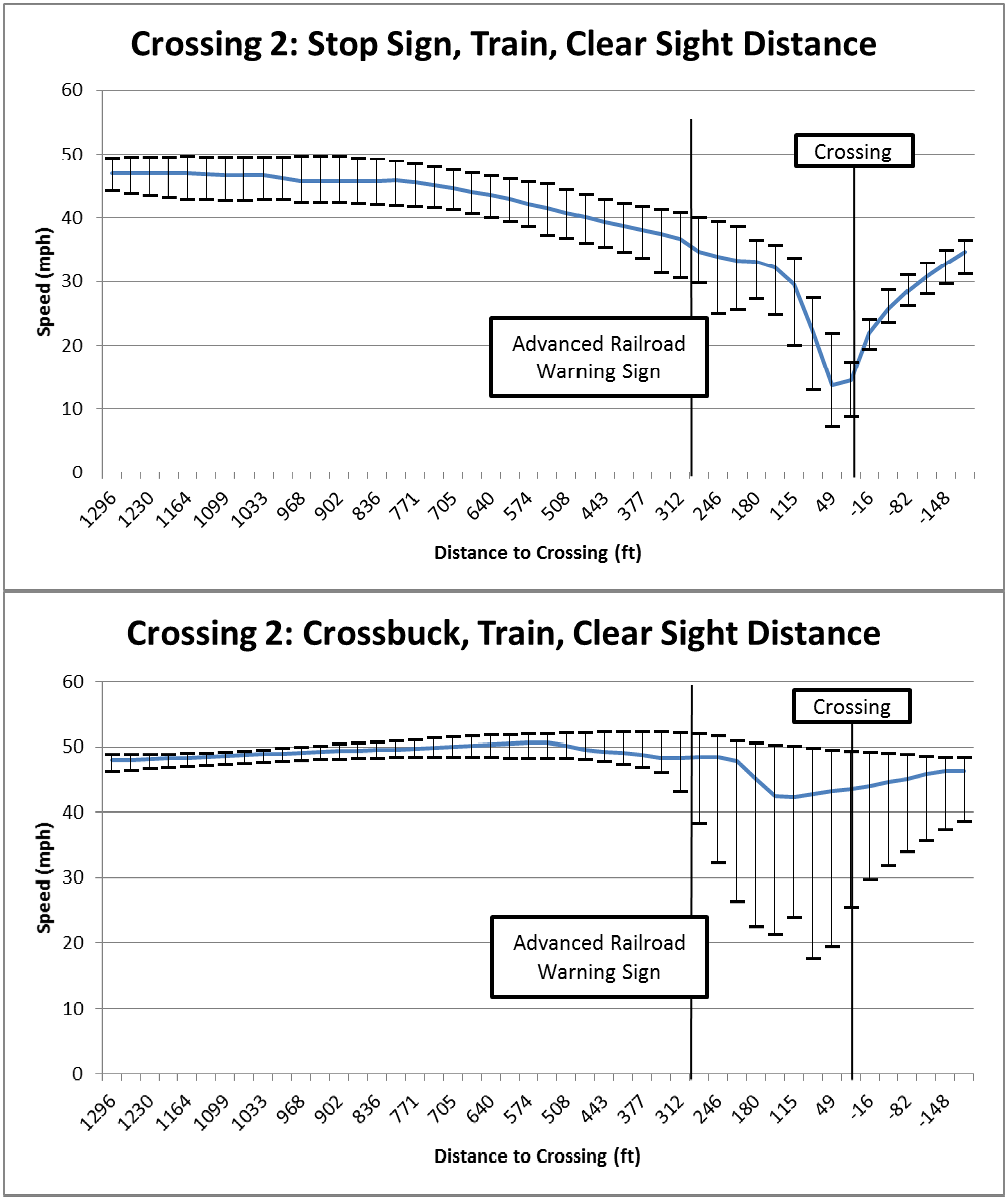
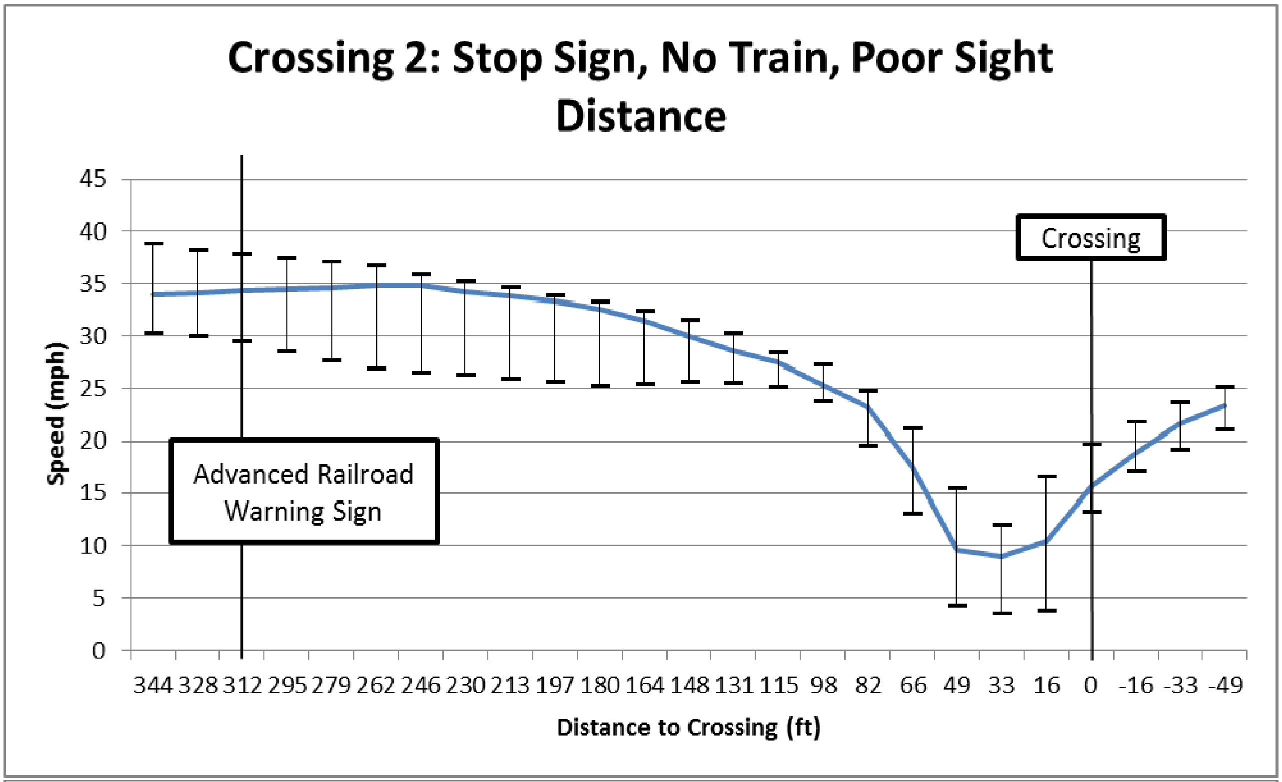


Figure 12. Crossing 2: Approach speeds for train and clear sight distance.



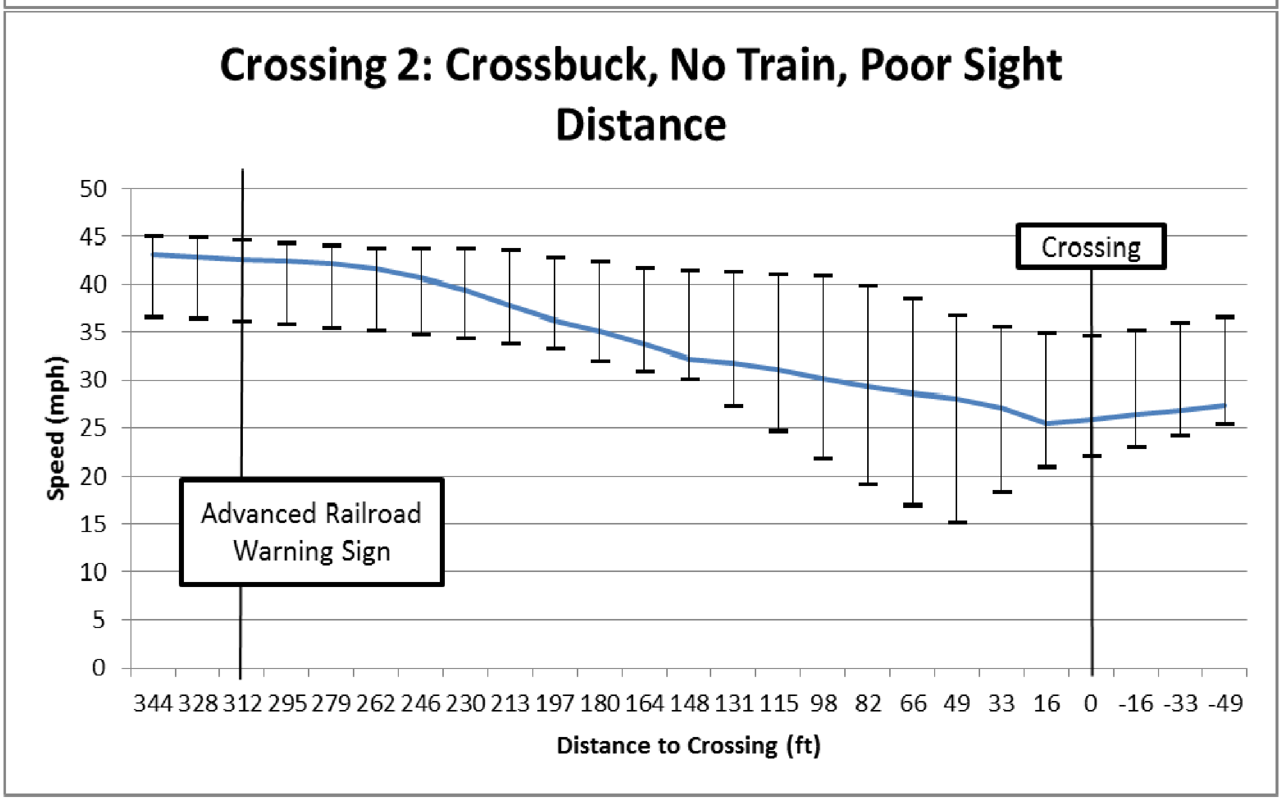
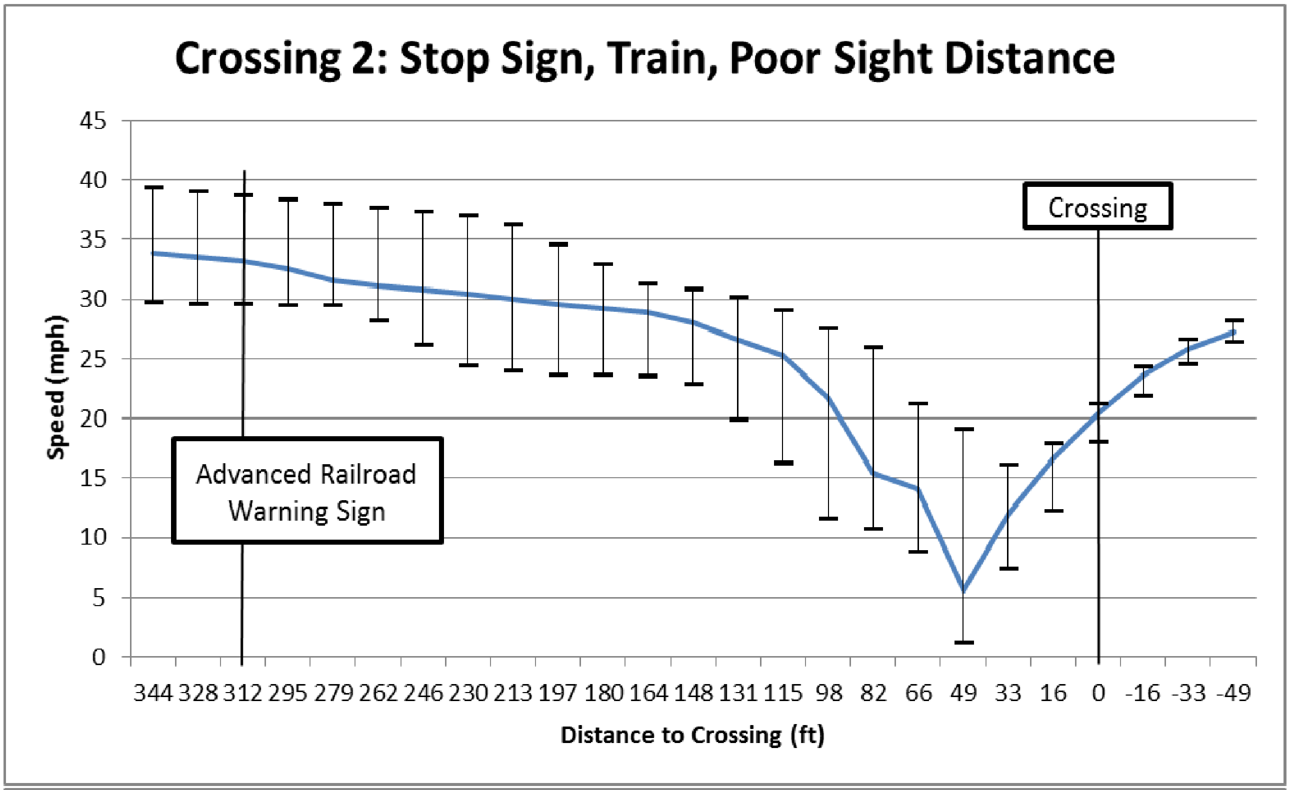


Figure 13. Crossing 2: Focused approach speed with no train and poor sight distance.



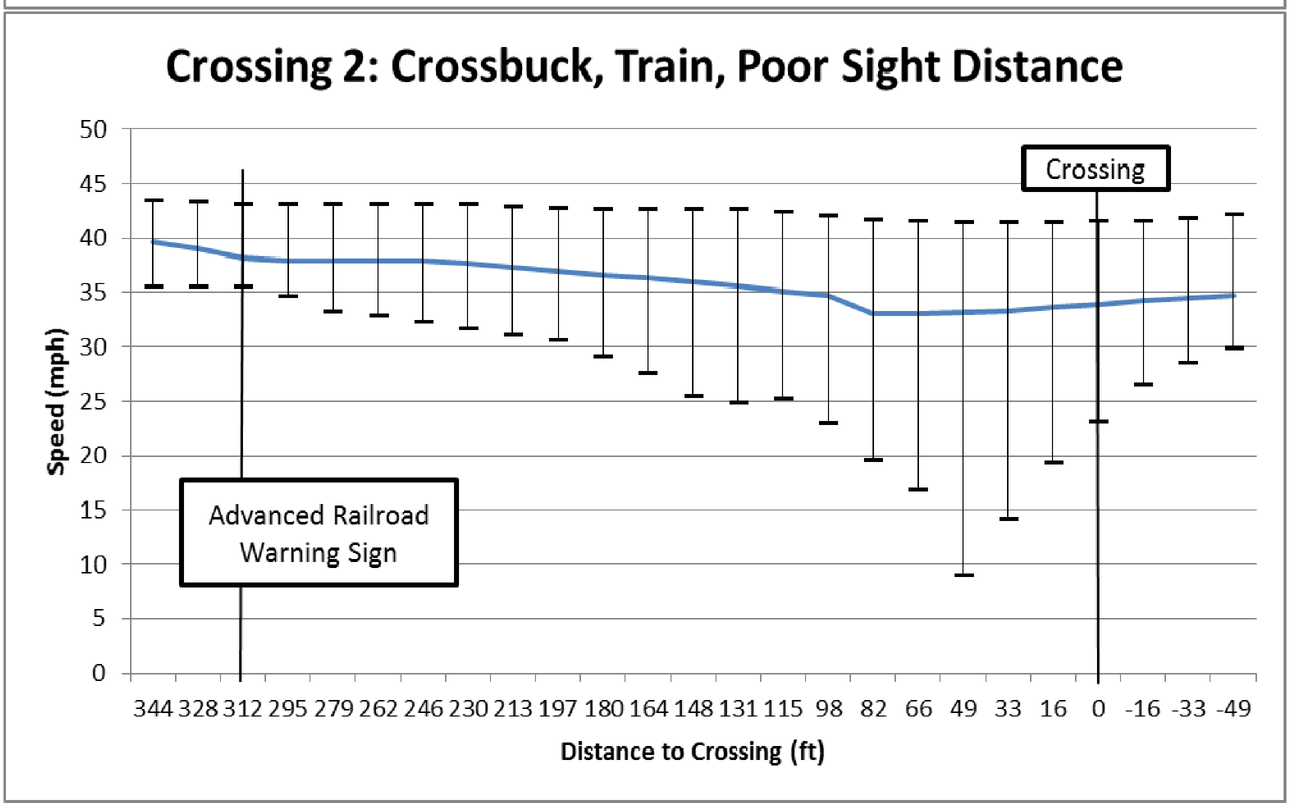


Figure 14. Crossing 2: Focused approach speeds with a train and poor sight distance.

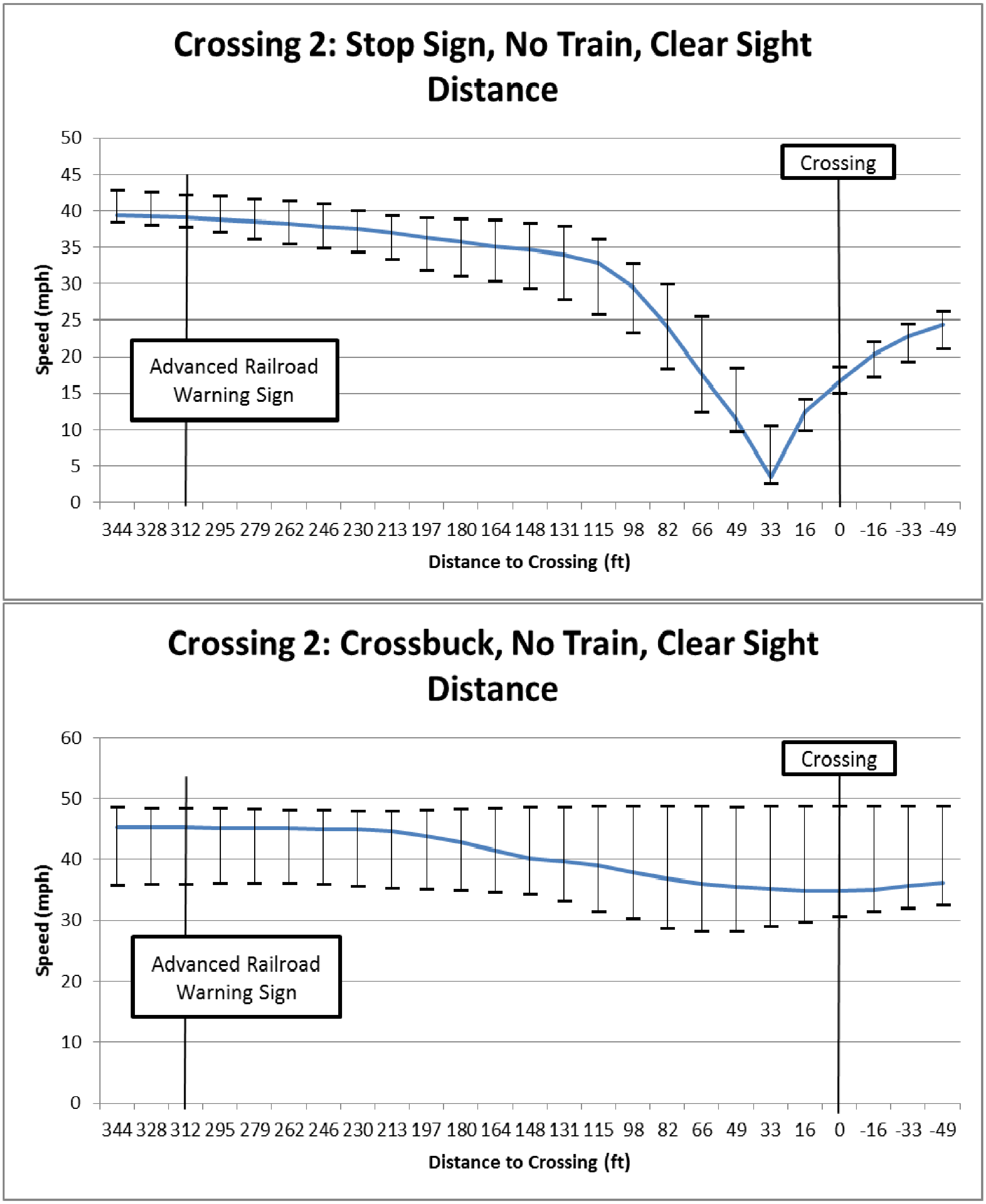
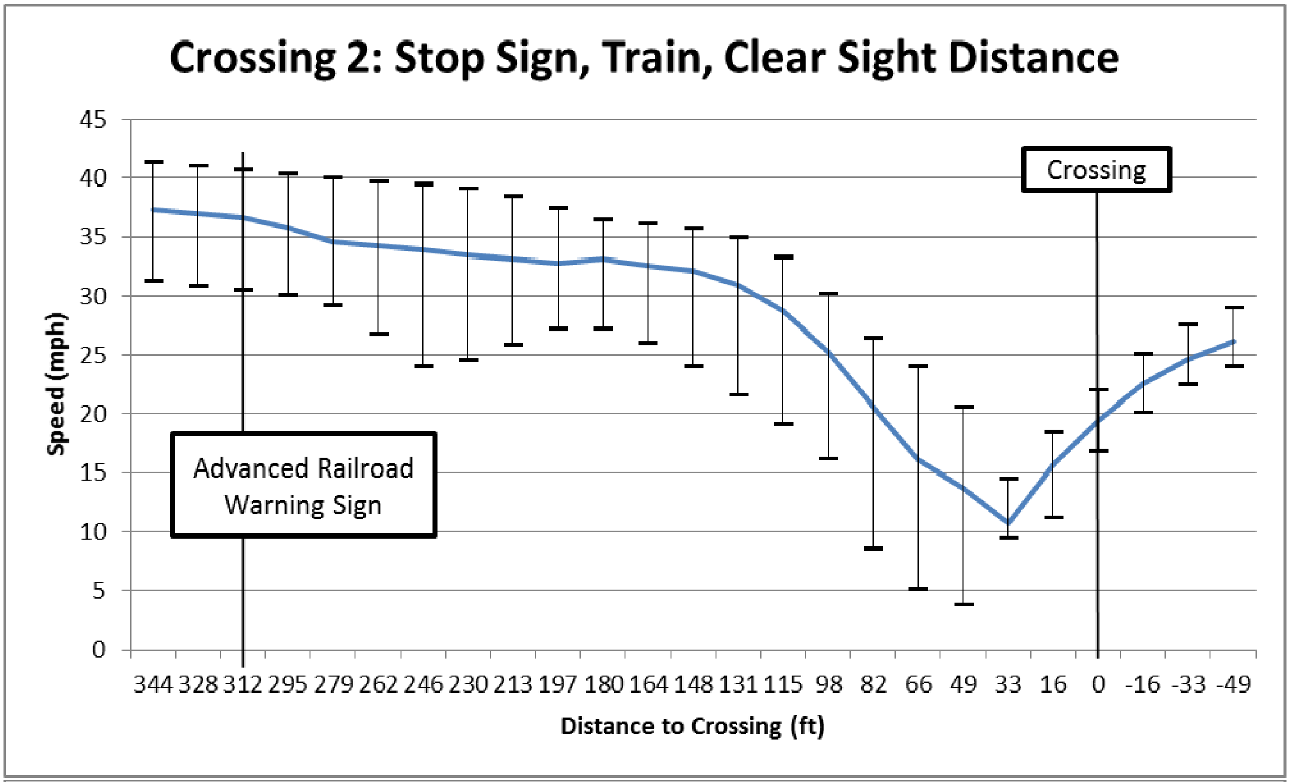


Figure 15. Crossing 2: Focused approach speeds with no train and clear sight distance.



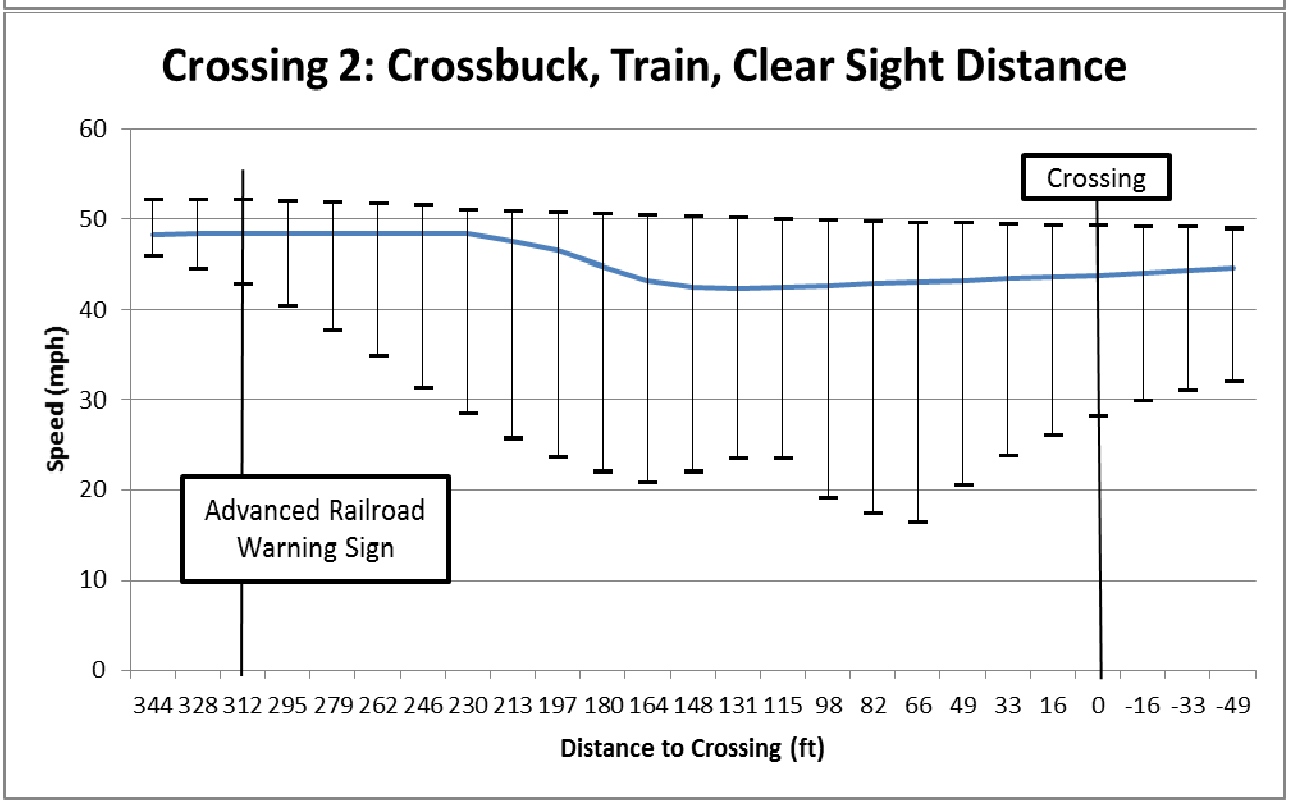
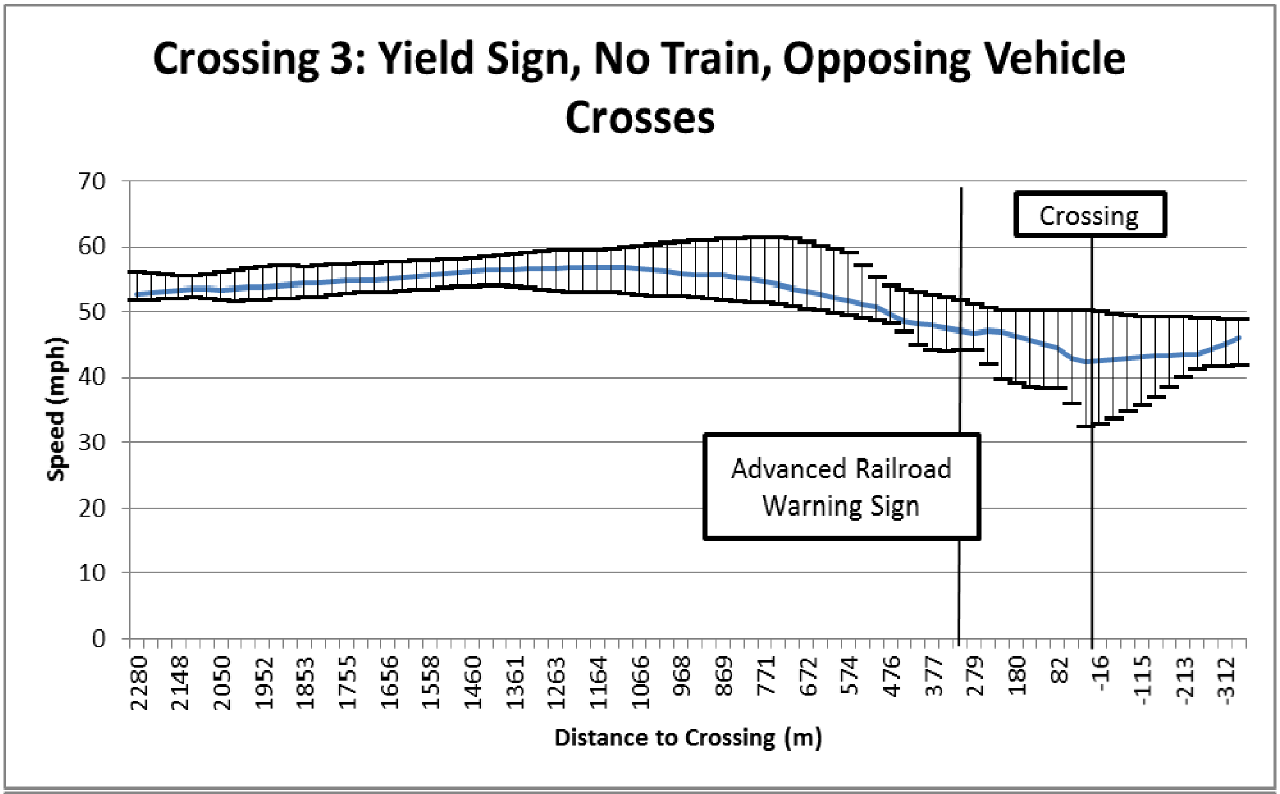


Figure 16. Crossing 2: Focused approach speed with a train and clear sight distance.



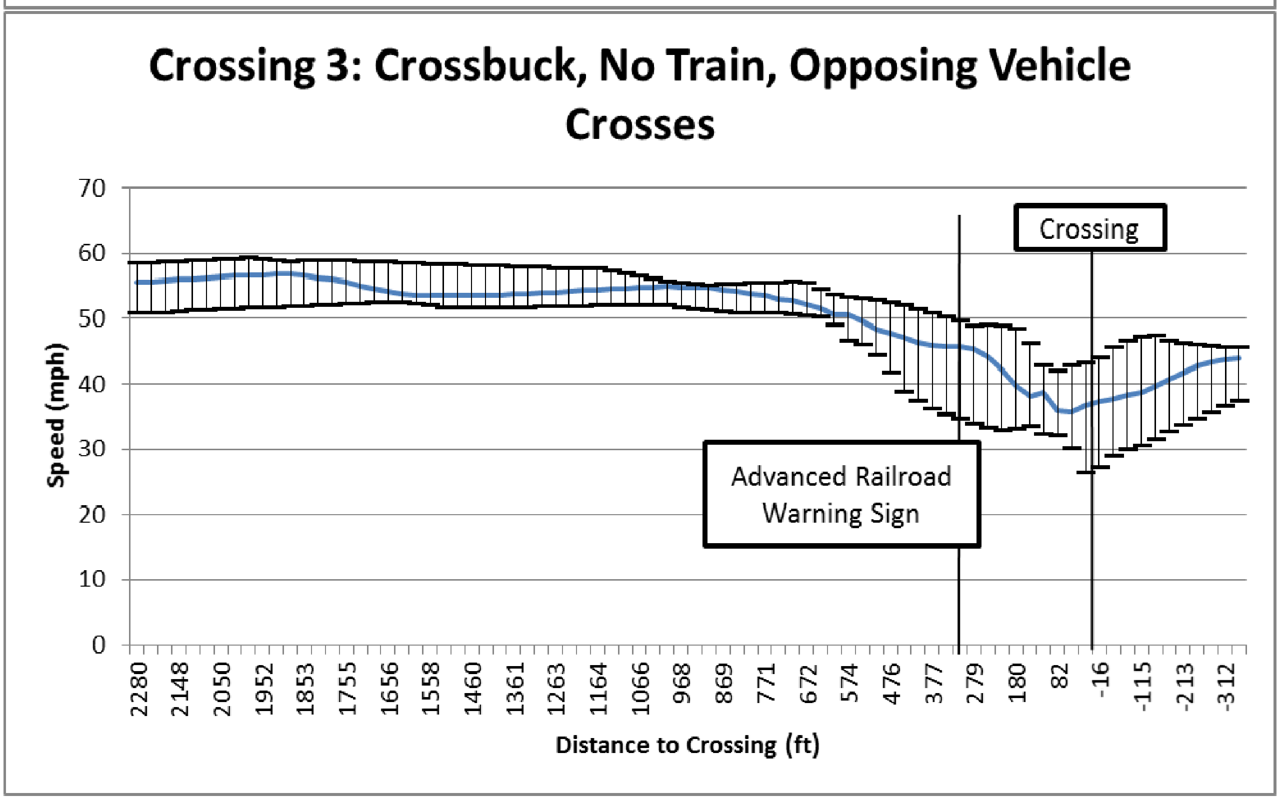


Figure 17. Crossing 3: Approach speeds with no train and opposing vehicle crossing.

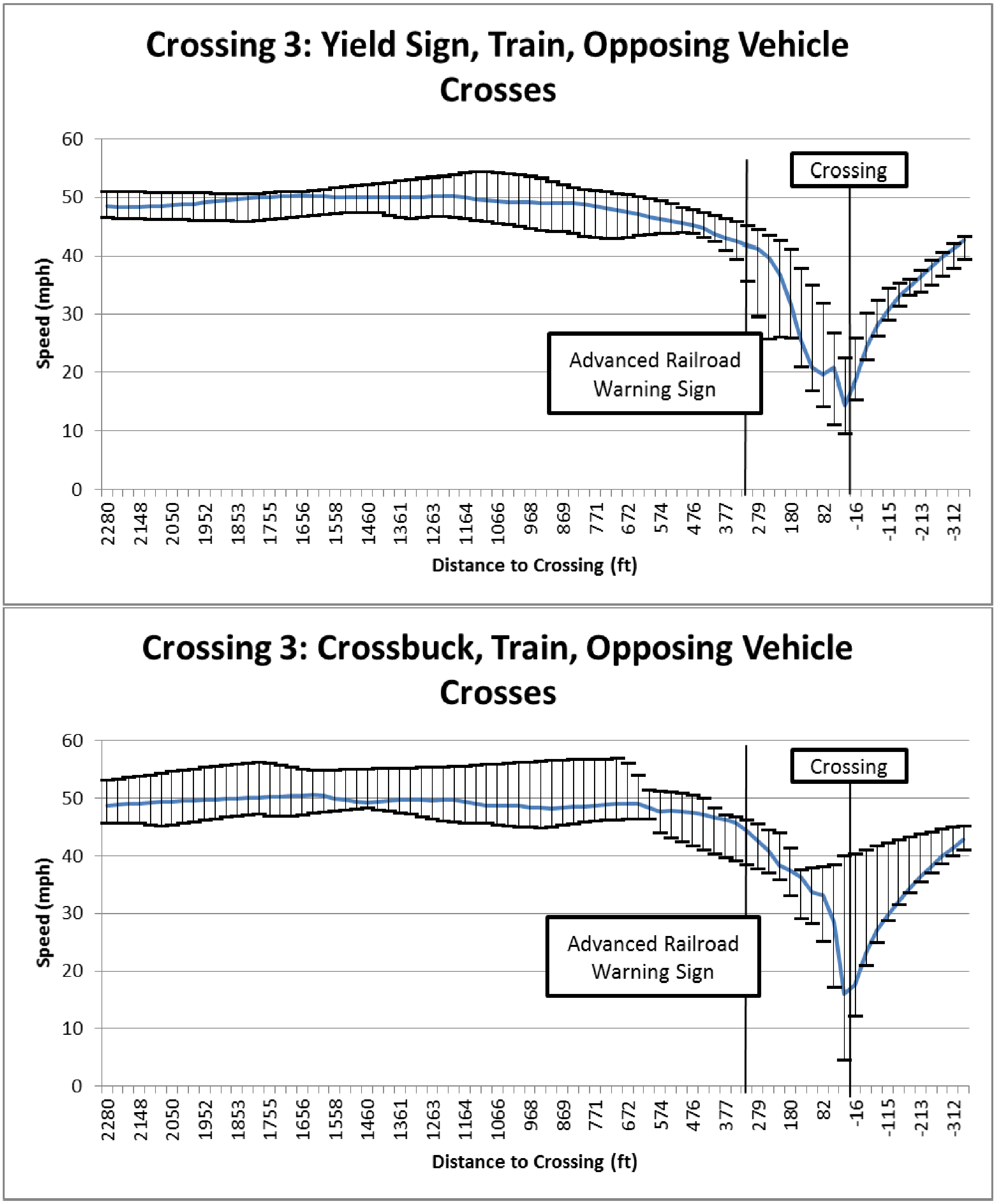
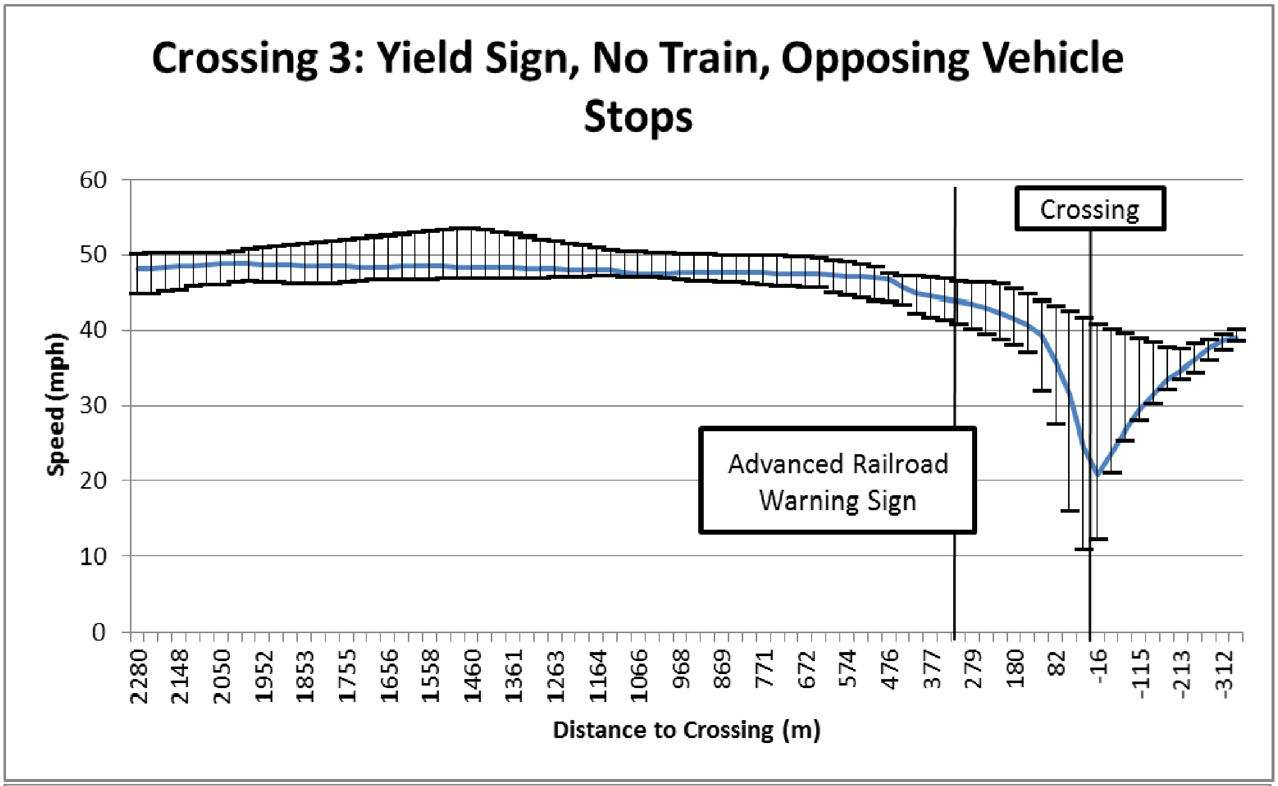


Figure 18. Crossing 3: Approach speeds with a train and opposing vehicle crossing.



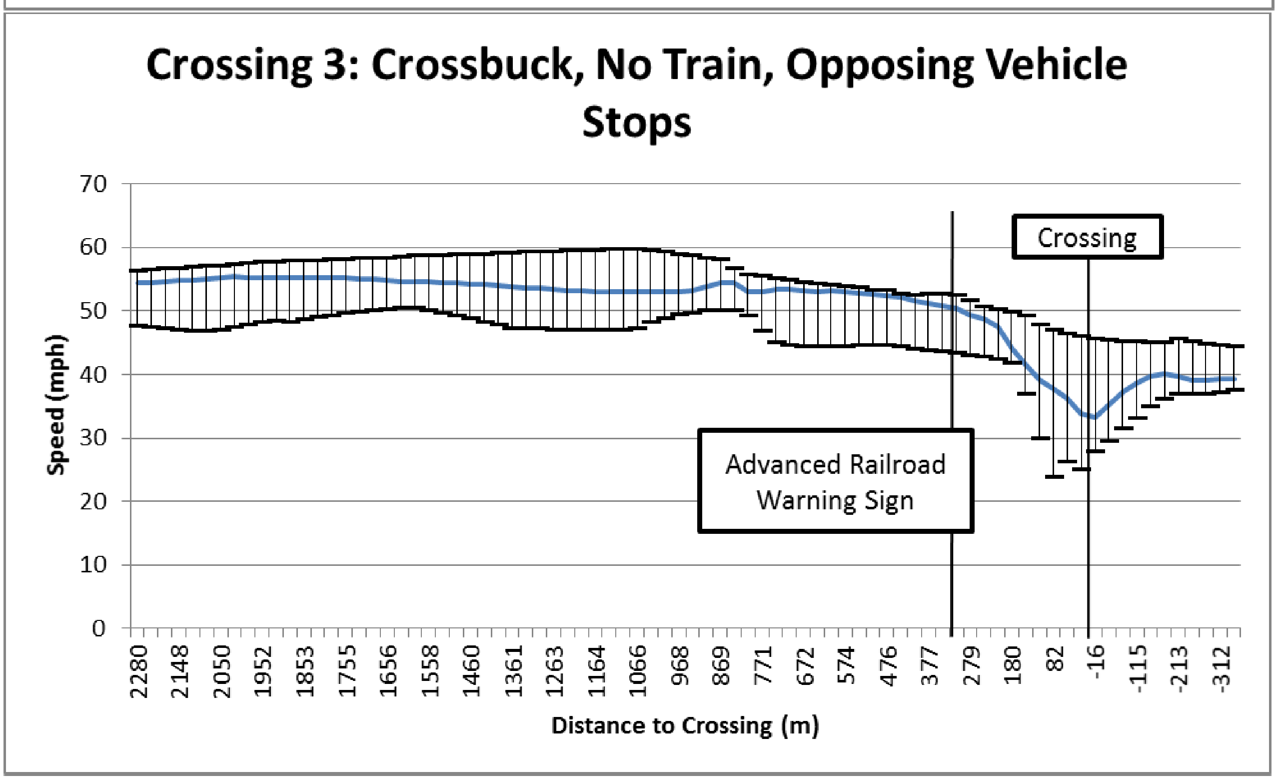


Figure 19. Crossing 3: Approach speeds with no train and opposing vehicle stopping.

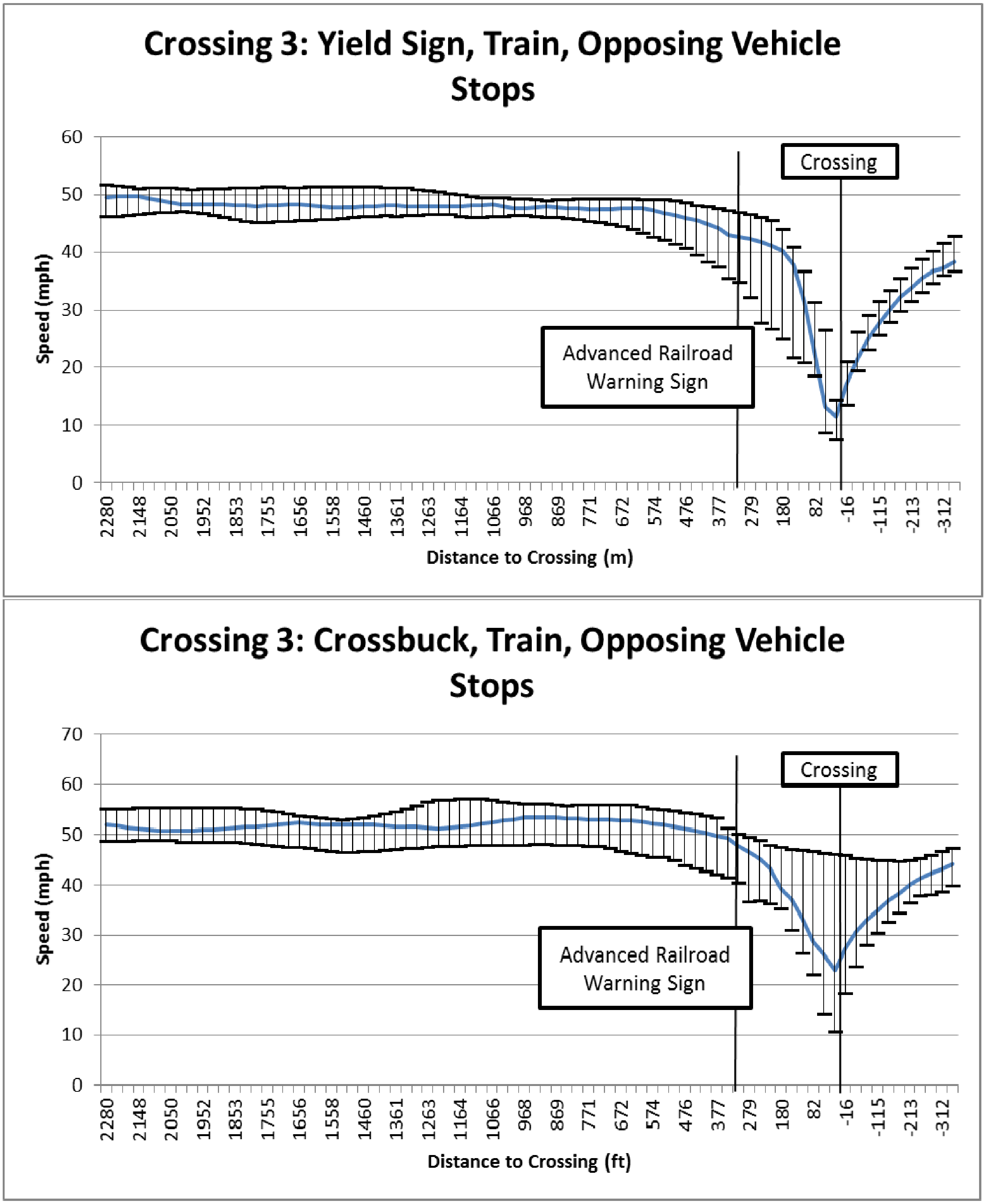
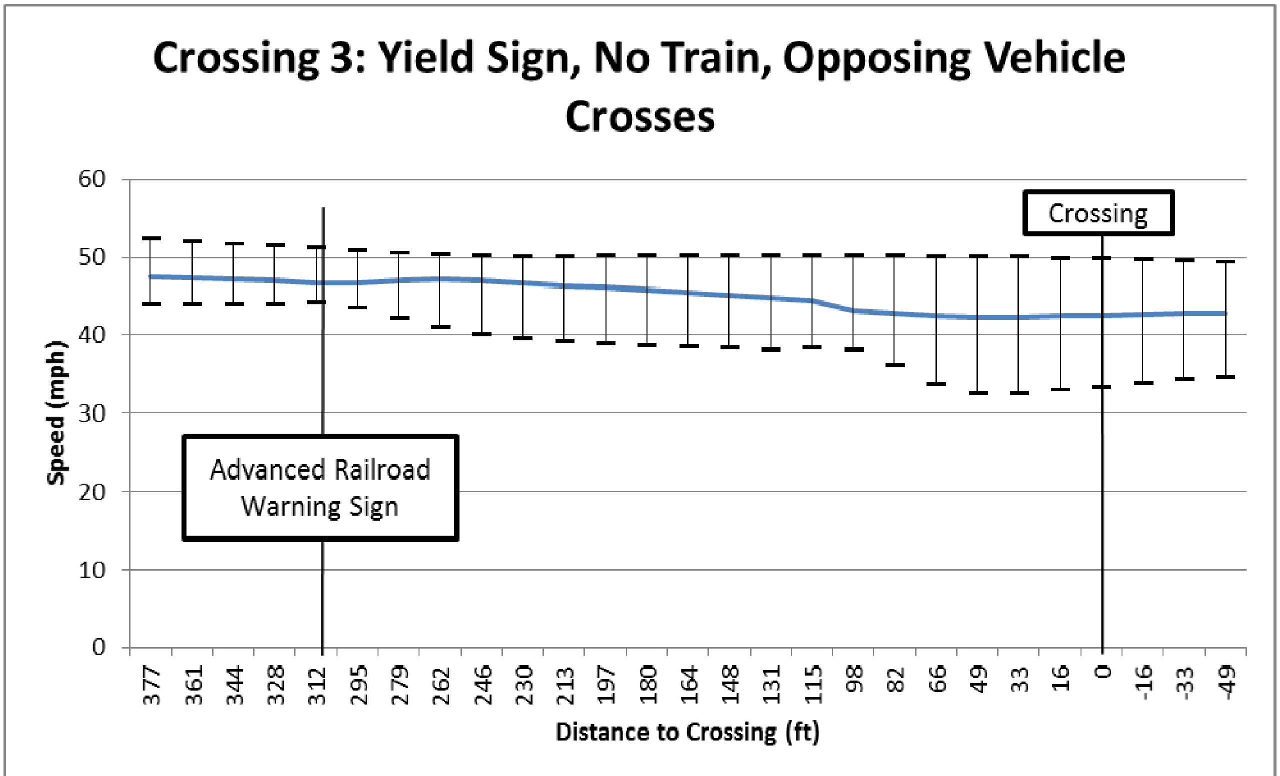


Figure 20. Crossing 3: Approach speeds with train and opposing vehicle stopping.



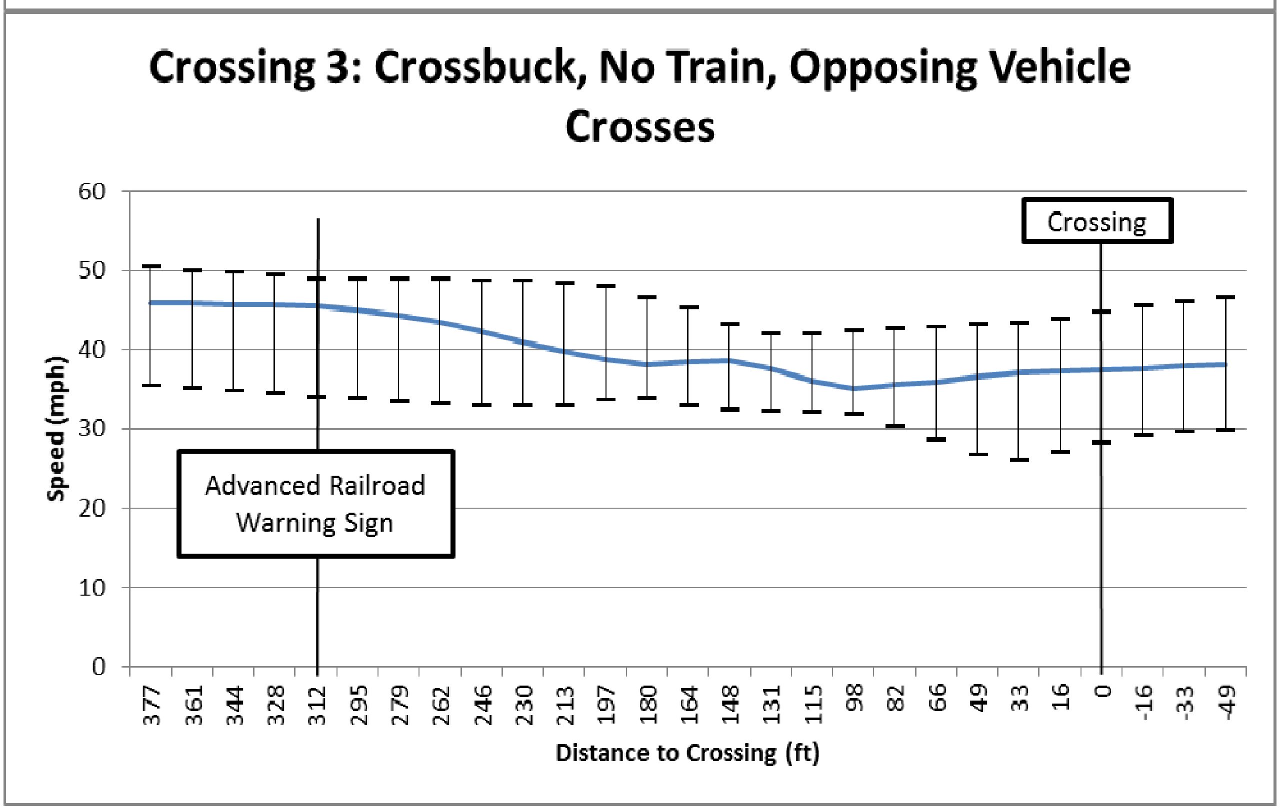
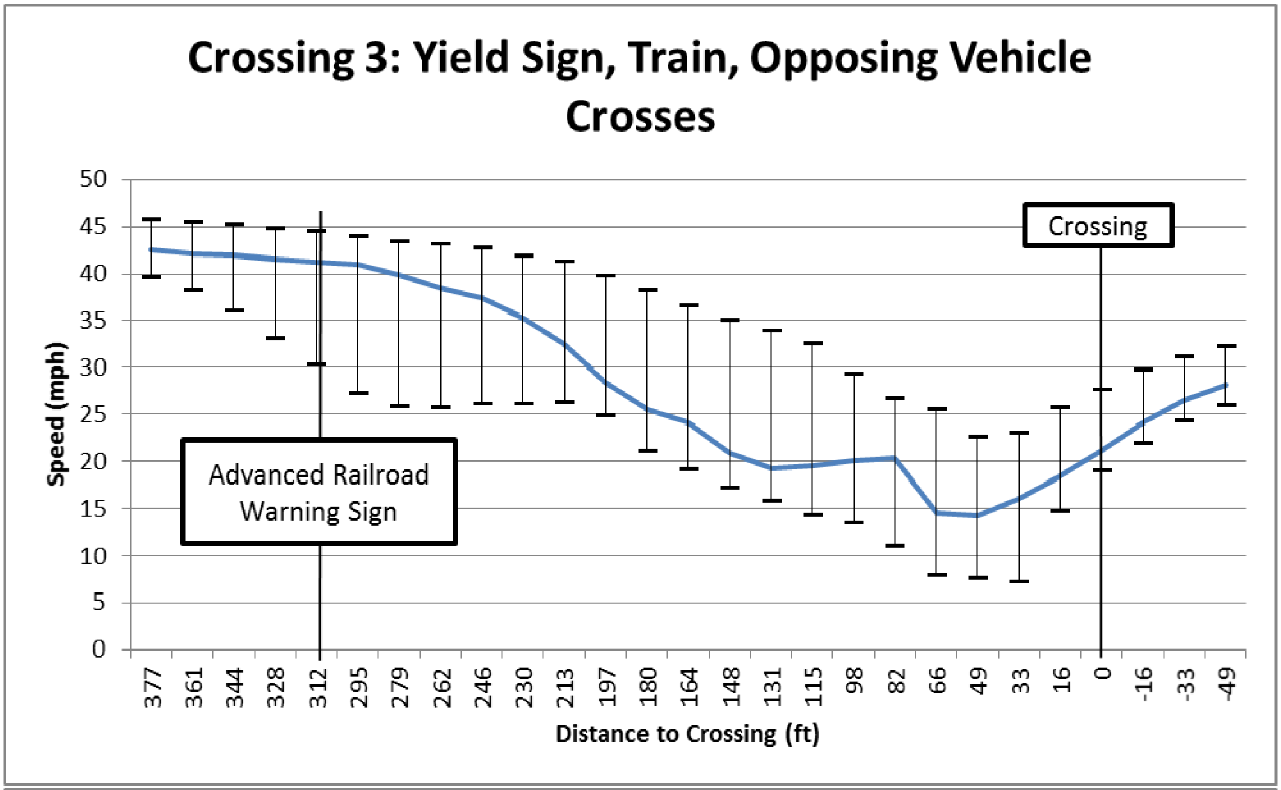


Figure 21. Crossing 3: Focused approach speeds with no train and opposing vehicle crosses.



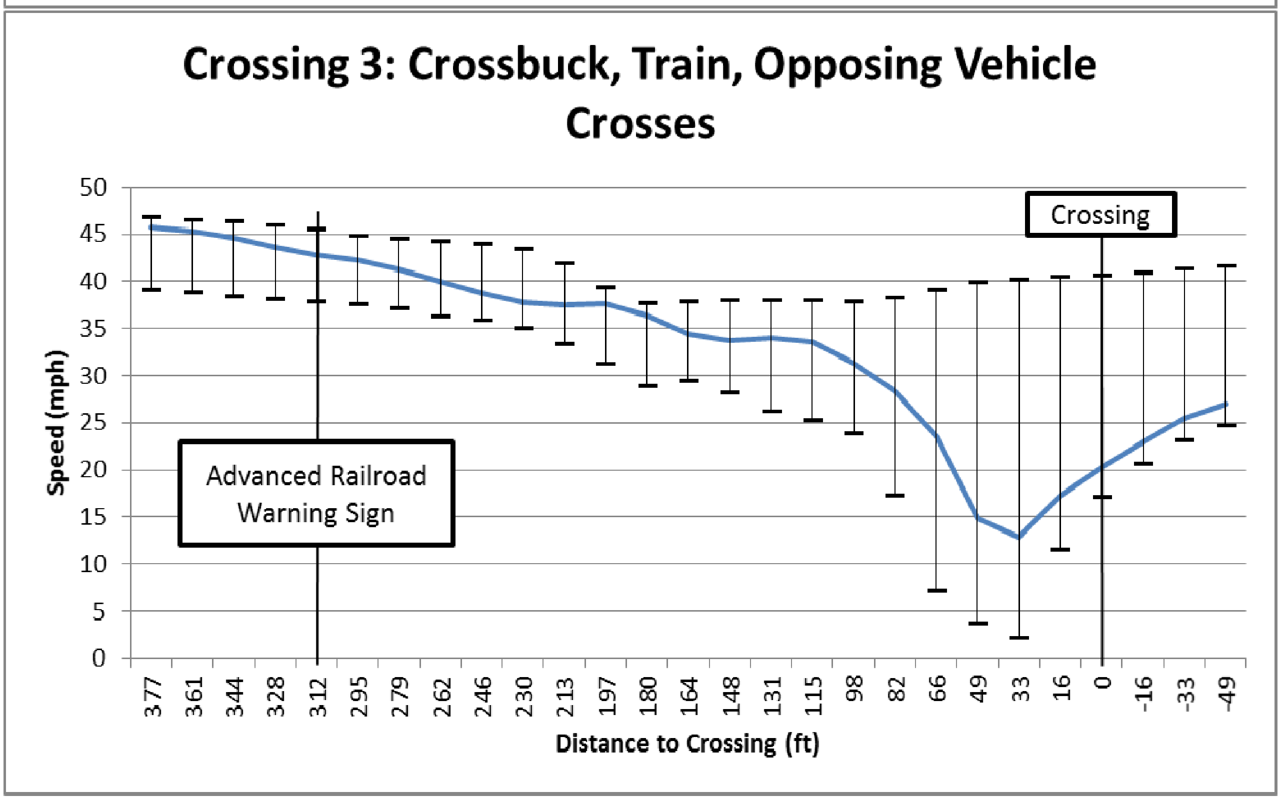
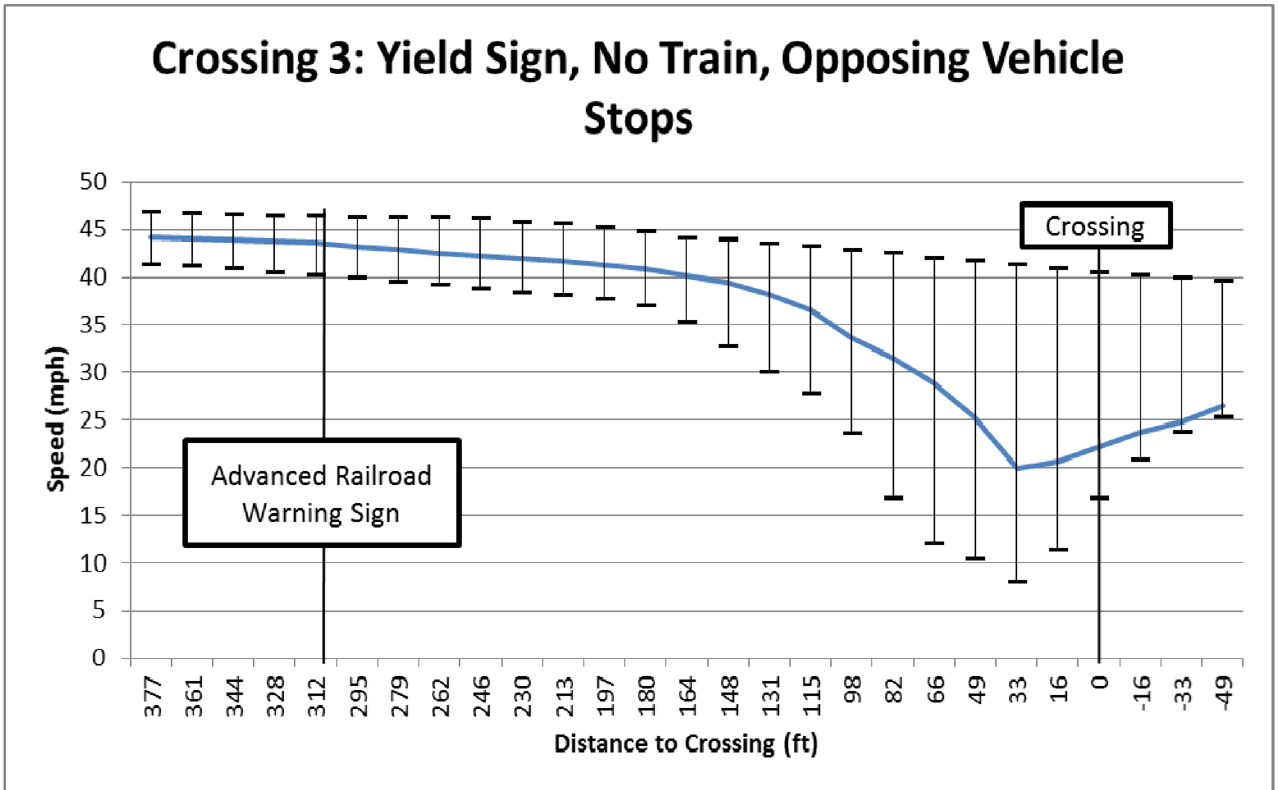


Figure 22. Crossing 3: Focused approach speeds with a train and opposing vehicle crossing.



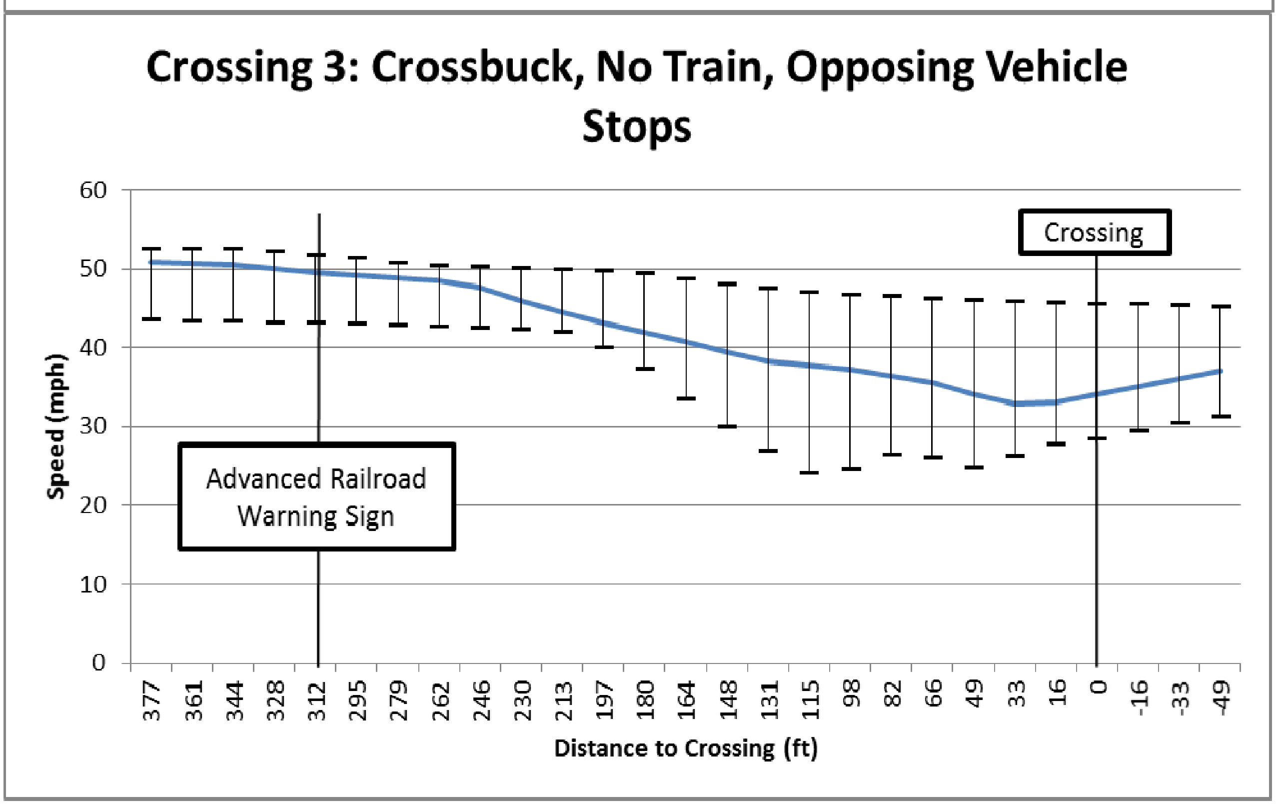
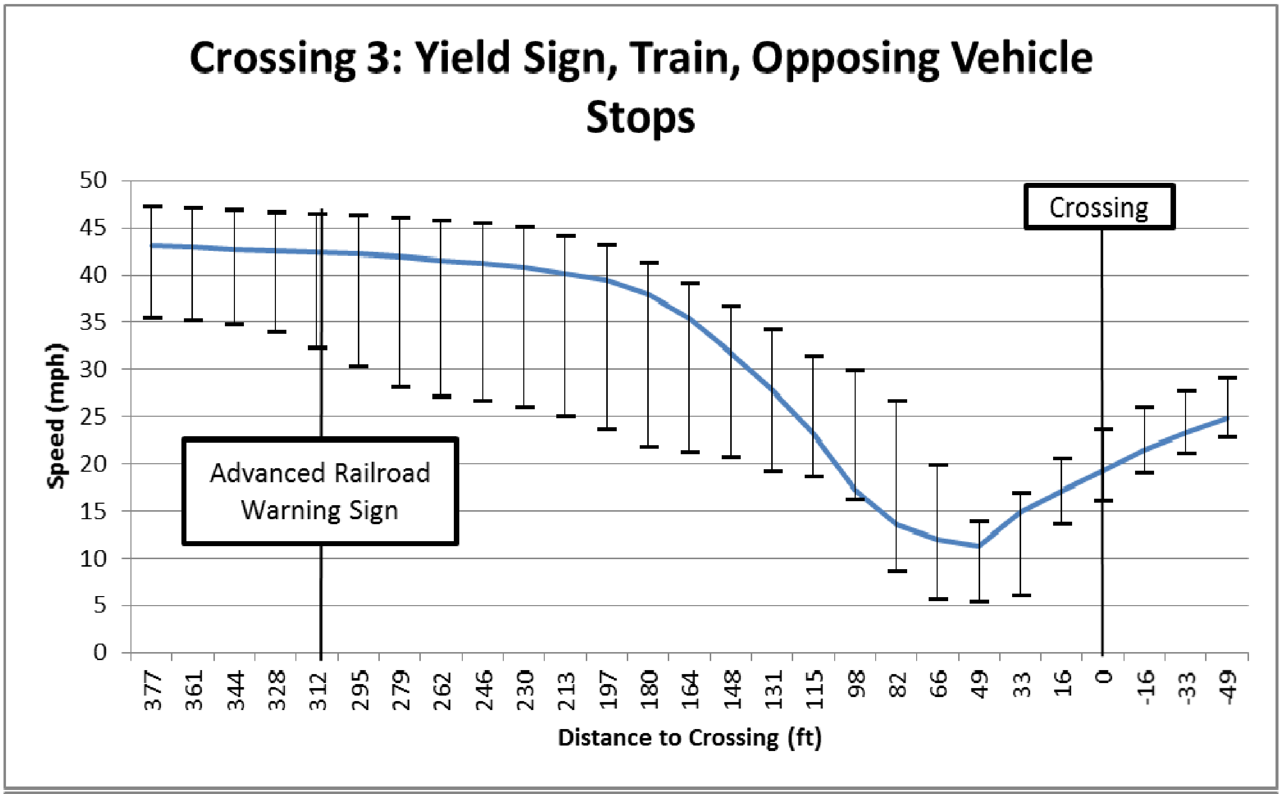


Figure 23. Crossing 3: Focused approach speeds with no train and opposing vehicle stopping.



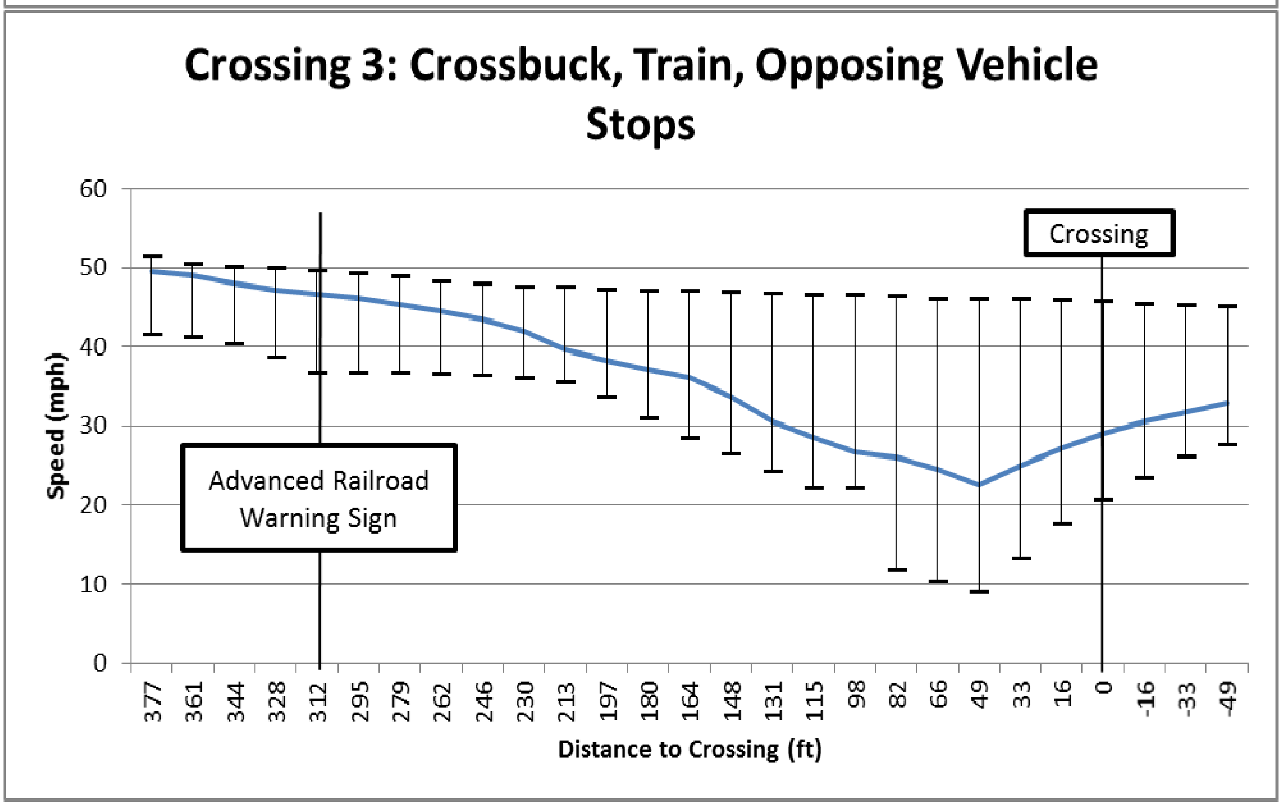


Figure 24. Crossing 3: Focused approach speeds with a train and opposing vehicle stopping.

Table 22. T-test on approach speeds for Crossing 2.

Approach Speed - Crossing 2				
Term	Estimate	Std Error	t Ratio	Prob > |t|
50 feet from Crossing				
Intercept	4.2995514	0.184585	23.29	<0.0001
Sight Distance [Poor]	-0.384507	0.184585	-2.08	0.0415
Train? (Y/N) [No}	0.1205461	0.184585	0.65	0.5162
Sign [Crossbuck]	1.0921398	0.184585	5.92	<0.0001
100 feet from Crossing				
Intercept	5.2643582	0.148398	35.47	<0.0001
Sight Distance [Poor]	-0.247318	0.148398	-1.67	0.1008
Train? (Y/N) [No}	0.2349346	0.148398	1.58	0.1186
Sign [Crossbuck]	0.4127077	0.148398	2.78	0.0072
150 feet from Crossing				
Intercept	5.6967006	0.101365	56.2	<0.0001
Sight Distance [Poor]	-0.16776	0.101365	-1.66	0.1031
Train? (Y/N) [No}	0.126177	0.101365	1.24	0.2181
Sign [Crossbuck]	0.2575951	0.101365	2.54	0.0136
200 feet from Crossing				
Intercept	5.8349674	0.108164	53.95	<0.0001
Sight Distance [Poor]	-0.110672	0.108164	-1.02	0.3103
Train? (Y/N) [No}	0.1492135	0.108164	1.38	0.1729
Sign [Crossbuck]	0.2391068	0.108164	2.21	0.0309
250 feet from Crossing				
Intercept	6.0045843	0.088833	67.59	>0.0001
Sight Distance [Poor]	-0.130596	0.088833	-1.47	0.1468
Train? (Y/N) [No}	0.1052119	0.088833	1.18	0.2409
Sign [Crossbuck]	0.2701552	0.088833	3.04	0.0035
311 feet from Crossing (Warning Sign)				
Intercept	6.1807736	0.070916	78.08	<0.001
Sight Distance [Poor]	-0.195433	0.070916	-2.47	0.0164
Train? (Y/N) [No}	0.0075394	0.070916	0.1	0.9244
Sign [Crossbuck]	0.2297444	0.070916	2.9	0.0052

Table 23. Mean approach speeds for Crossing 2.

Average Speeds for Crossing 2		
50 feet from Crossing		
	Speed (mph)	Difference in Speeds (mph)
Poor Sight Distance	15.3276	6.6128
Clear Sight Distance	21.9404	
No Train Present	19.5373	2.0732
Train Present	17.4641	
CROSSBUCK sign	29.0703	18.7828
STOP sign	10.2875	
100 feet from Crossing		
	Speed (mph)	Difference in Speeds (mph)
Poor Sight Distance	25.1707	5.2079
Clear Sight Distance	30.3786	
No Train Present	30.2422	4.9471
Train Present	25.2951	
CROSSBUCK sign	32.2291	8.6906
STOP sign	23.5385	
150 feet from Crossing		
	Speed (mph)	Difference in Speeds (mph)
Poor Sight Distance	30.5692	3.8227
Clear Sight Distance	34.3919	
No Train Present	33.9059	2.8752
Train Present	31.0307	
CROSSBUCK sign	35.4536	5.8697
STOP sign	29.5839	
200 feet from Crossing		
	Speed (mph)	Difference in Speeds (mph)
Poor Sight Distance	32.7676	2.583
Clear Sight Distance	35.3506	
No Train Present	35.8104	3.4826
Train Present	32.3278	
CROSSBUCK sign	36.8944	5.5807
STOP sign	31.3137	

Table 23. Continued.

250 feet from Crossing		
	Speed (mph)	Difference in Speeds (mph)
Poor Sight Distance	34.5037	3.1367
Clear Sight Distance	37.6404	
No Train Present	37.3296	2.527
Train Present	34.8026	
CROSSBUCK sign	39.3724	6.4887
STOP sign	32.8837	
311 feet from Crossing		
	Speed (mph)	Difference in Speeds (mph)
Poor Sight Distance	35.8243	4.8317
Clear Sight Distance	40.656	
No Train Present	38.2952	0.1864
Train Present	38.1088	
CROSSBUCK sign	41.0947	5.68
STOP sign	35.4147	

Significance was found through the T-test shown previously.

Table 24. T-test on approach speeds for Crossing 3.

Approach Speed - Crossing 3				
Term	Estimate	Std Error	t Ratio	Prob > |t|
50 feet from Crossing				
Intercept	4.8092827	0.231004	22.58	<0.0001
Opposing Vehicle [Cross]	0.1597215	0.231004	0.75	0.4563
Train? (Y/N) [No}	0.8971368	0.231004	4.21	<0.0001
Sign [Crossbuck]	0.2776086	0.231004	1.3	0.1975
100 feet from Crossing				
Intercept	5.4684886	0.153149	35.71	<0.0001
Opposing Vehicle [Cross]	0.1254736	0.153149	0.82	0.4159
Train? (Y/N) [No}	0.5274142	0.153149	3.44	0.0011
Sign [Crossbuck]	0.1703823	0.153149	1.11	0.2704
150 feet from Crossing				
Intercept	5.8452406	0.120247	48.61	<0.0001
Opposing Vehicle [Cross]	-0.037835	0.120247	-0.31	0.7541
Train? (Y/N) [No}	0.395683	0.120247	3.29	0.0017
Sign [Crossbuck]	0.0389064	0.120247	0.32	0.7474
200 feet from Crossing				
Intercept	6.148048	0.105219	58.43	<0.0001
Opposing Vehicle [Cross]	-0.023046	0.105219	-0.22	0.8274
Train? (Y/N) [No}	0.304851	0.105219	2.9	0.0052
Sign [Crossbuck]	0.0202025	0.105219	0.19	0.8484
250 feet from Crossing				
Intercept	6.2831003	0.11467	54.79	>0.0001
Opposing Vehicle [Cross]	-0.005161	0.11467	-0.05	0.9643
Train? (Y/N) [No}	0.2255787	0.11467	1.97	0.0538
Sign [Crossbuck]	0.0146837	0.11467	0.13	0.8985
311 feet from Crossing (Warning Sign)				
Intercept	6.4135076	0.118116	54.3	<0.001
Opposing Vehicle [Cross]	-0.081791	0.118116	-0.69	0.4913
Train? (Y/N) [No}	0.2471281	0.118116	2.09	0.0407
Sign [Crossbuck]	0.0364532	0.118116	0.31	0.7587

Table 25. Mean approach speeds for Crossing 3.

Average Approach Speeds - Crossing 3		
50 feet from Crossing		
	Speed (mph)	Difference in Speeds (mph)
Opposing Vehicle Crosses	24.691	3.0726
Opposing Vehicle Stops	21.6184	
No Train Present	32.5632	17.2583
Train Present	15.3049	
CROSSBUCK Sign	25.8765	5.3404
YIELD Sign	20.5361	
100 feet from Crossing		
	Speed (mph)	Difference in Speeds (mph)
Opposing Vehicle Crosses	31.2924	2.7446
Opposing Vehicle Stops	28.5478	
No Train Present	35.9509	11.5367
Train Present	24.4142	
CROSSBUCK Sign	31.7969	3.727
YIELD Sign	28.0699	
150 feet from Crossing		
	Speed (mph)	Difference in Speeds (mph)
Opposing Vehicle Crosses	33.726	0.8846
Opposing Vehicle Stops	34.6106	
No Train Present	38.9491	9.2514
Train Present	29.6977	
CROSSBUCK Sign	34.6232	0.9097
YIELD Sign	33.7135	
200 feet from Crossing		
	Speed (mph)	Difference in Speeds (mph)
Opposing Vehicle Crosses	37.5157	0.5667
Opposing Vehicle Stops	38.0824	
No Train Present	41.6399	7.4969
Train Present	34.143	
CROSSBUCK Sign	38.0473	0.4968
YIELD Sign	37.5505	
YIELD Sign	40.6668	

Table 25. Continued.

Average Approach Speeds – Crossing 3		
250 feet from Crossing		
	Speed (mph)	Difference in Speeds (mph)
Opposing Vehicle Crosses	39.4125	0.1297
Opposing Vehicle Stops	39.5422	
No Train Present	42.3629	5.6693
Train Present	36.6936	
CROSSBUCK Sign	39.6621	0.3691
YIELD Sign	39.293	
311 feet from Crossing (Warning Sign)		
	Speed (mph)	Difference in Speeds (mph)
Opposing Vehicle Crosses	40.0906	2.0983
Opposing Vehicle Stops	42.1889	
No Train Present	44.3641	6.3399
Train Present	38.0242	
CROSSBUCK Sign	41.602	0.9352
YIELD Sign	40.6668	

Significance was found through the T-test shown previously.

VITA

Bryan Bartnik was born on January 30, 1989. He grew up in Channahon, IL. He graduated from Southern Illinois University Edwardsville in 2011 with a B.S. in Civil Engineering. Following his graduation, Bryan enrolled at the University of Tennessee where he studied Civil and Environmental Engineering with a concentration in Transportation Engineering. After graduating with his Master's degree, Bryan took a job at the Tennessee Department of Transportation in Strawberry Plains, TN.