STUDY OF DRIVERS' BEHAVIOR AT PASSIVE RAILROAD-HIGHWAY GRADE CROSSINGS

Prepared for

MACK BLACKWELL RURAL TRANSPORTATION CENTER
Project No. MBTC-2079
Contract No. SA0612184
Award No. BG0170

By

EUGENE R. RUSSELL
Professor Emeritus
Department of Civil Engineering

HARSHIT D. SHAH
Graduate Student,
Department of Industrial and Manufacturing Systems Engineering

MARGARET J. RYS
Associate Professor
Department of Industrial and Manufacturing Systems Engineering

Kansas State University
Manhattan, KS 66506

With cooperation by
KANSAS DEPARTMENT OF TRANSPORTATION

AUGUST 2007

ACKNOWLEDGEMENTS

The authors wish to acknowledge the $25,000+ in-kind contribution of the Kansas Department of Transportation (KDOT) for the equipment and many hours that KDOT personnel spent in finding suitable sites, installing and removing equipment and changing videotapes at all locations. In particular, the efforts of Mr. Al Cathcart, Coordinating Engineer, Bureau of Design, KDOT, for his many hours organizing and coordinating the efforts of his office and staff, making suggestions and reading drafts. Also, acknowledged is the cooperation and assistance by Union Pacific Railway forces in supplying power at most sites. In particular, the cooperation of Mr. Mike Benjamin is recognized.

DISCLAIMER

The contents of the report and conclusions are strictly the views of the authors and do not necessarily reflect any agreement by KDOT, Union Pacific Railway or any of the many other persons that provided assistance with this project.

ABSTRACT

Railway Highway grade crossing safety has always been a concern in the United States. This report presents an overview of drivers' behavior at different active and passive warning sign systems present at railroad-highway grade crossings. The report summarizes past studies on controversies over use of STOP sign at grade crossings, a history of guidelines over the years in the Manual on Uniform Traffic Control Devices (MUTCD) and problems associated with passive signs, including the STOP sign and YIELD sign at grade crossings. A field study is conducted on nine grade crossings with selected warning devices to determine driver stopping behavior with various warning devices at passive grade crossings during day and night. Statistical analysis and comparisons are done for stopping of school buses, heavy trucks and other vehicles, poor sight distance vs good sight distance approaches at grade crossings, and grade crossings with parallel highway vs grade crossings without parallel highway. After conducting the field study it was found that the majority of drivers did not stop at the STOP signs at the grade crossings. Results from the comparison between stopping behavior of school bus, heavy truck and other vehicles showed that heavy trucks had a poorer compliance percentage than all other vehicles (not including school buses). The number of school buses was too small to make any statistically reliable conclusion. Results from comparison between poor sight distance vs good sight distance approaches showed that a higher percentage of drivers actually stopped at poor sight distance approaches than good sight distance approaches. Comparison between grade crossings with parallel highway vs grade crossings without parallel highway showed that a higher percentage of drivers stopped at the grade crossings with no parallel highway than the grade crossings with

parallel highway. Based on this limited study and review of previous studies the authors recommended that a STOP sign should not be used at grade crossings without a valid engineering study.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 PROBLEM IDENTIFICATION

Highway Railroad grade crossing collisions are a source of concern to US railway authorities and public road agencies. Approximately every 90 minutes one crash takes place on highway-railroad crossings at grade (grade crossings) in the US. The Association of American Railroads (AAR) has estimated that vehicle-train collision cost the railroad industry nearly one billion dollars a year [1]. In 2005, according to Federal Railroad Administration (FRA) there were 145,608 public grade crossings (as opposed to those on private property) in the US out of which 55.7% (81,052) were passive grade crossings, i.e. no train activated signals or gates. About 44% of the fatalities from public grade crossing accidents in 2005 (143 of 325) occurred at passive crossings [2]. The Federal Highway Administration (FHWA) reported that fatal and nonfatal injury rates have declined over the years. Although the crash rate has been decreasing at grade crossings, both daily vehicle trip miles and train traffic are growing, increasing the potential for crashes at grade crossings [3].

1.2 ACTIVE AND PASSIVE GRADE CROSSINGS

An active grade crossing is the one that has automatic, train-activated warning devices like flashing lights, gates, bells, etc. A passive grade crossing is the one which does not have any train-activated devices but it has only passive signs e.g., CROSSBUCK sign, STOP sign, YIELD sign, etc [4]. Approximately 38% of total public crossings are equipped with flashing lights and gates and the remainder have passive signs or no signs or markings at all [5].

It is generally accepted that active grade crossings with flashing lights and gates are safer then passive grade crossings but they don't stop vehicle-train crashes. No doubt, active warning devices help in recognizing the approach and presence of trains at grade crossing. It is not economically feasible to convert all passive grade crossings to active grade crossings because of the cost. To convert a passive grade crossing to an active grade crossing can cost around $200,000 to $400,000 per intersection [6]. Overall about 67% of grade crossings are on low volume roads where upgrading them to active warning system is not cost-effective [4].

1.3 FACTORS WHICH CAN CONTRIBUTE TO CRASHES

When approaching a passive grade crossing it is the sole responsibility of the driver to determine if it is safe to proceed across or if some action such as stopping is necessary. To be able to make a good decision, a driver needs to be able to see and understand that there is a grade crossing ahead and while still within safe stopping distance, should be aware that there are no train-activated lights and gates, i.e. it is a passive crossing, and understand that it is the driver's responsibility to determine if a train is at the grade crossing or approaching at a speed and distance requiring a stop and then carry out the stop if necessary. The most effective signage to aid drivers in understanding and complying with the necessary safe action has been the subject of debate for several decades.

There are many factors which contribute to grade crossing crashes and some of them are: sight distance, horizontal alignment, vertical profile, train visibility, bad weather, trees, track geometry, quadrant sight distance, headlight illuminance, etc [7]. These are the factors beyond the control of drivers. Poor horizontal alignment and vertical profile on approaches can cause sight distance problems which are dangerous especially during nighttime. In these cases an engineering study needs to determine adequate warning device to an approaching driver.

There are other factors for which drivers are completely responsible. Some of the factors are risk taking, not looking, distraction, speeding to beat a train, alcohol consumption, etc. Individual differences like age, gender, exposure are also some of the variables in train-vehicle collisions. Sometimes drivers get so acquainted with the grade crossings that they do not bother to stop and look for trains which are usually infrequent. They may become conditioned not to expect a train. Infrequent traffic on some sets of tracks may lead driver to assume that the tracks are never used which can lead to a fatal mistake [5, 9].

Showing less respect for passive signs is always a concern when it comes to fatalities. Not stopping at STOP signs or not slowing down at CROSSBUCK or not yielding at a YIELD sign can cause fatalities. It is important to know how people react to grade crossings and different passive signs.

1.4 RESEARCH OBJECTIVE

The objective of this research is to study drivers' reaction to a select number of passive signing systems at a grade crossing on a sample of passive and active grade crossings. The systems include CROSSBUCK only, CROSSBUCK with STOP sign, CROSSBUCK with YIELD sign and two special cases where a STOP sign is used with active warning devices that are close to a parallel, high-speed state highway where there is limited space between the tracks and the highway. At two STOP sign locations, the YIELD sign location and the two CROSSBUCK only locations, there was also a parallel state highway with limited space between the grade crossing and highway. Thus it should be noted that the grade crossings selected were not typical grade crossings nor were they selected at random.

1.5 ORGANIZATION OF THE REPORT

Chapter 2 summarizes the results of a literature review conducted to find out about past grade crossing studies. It includes studies carried out at different States, studies carried out at Kansas State University, controversies over the STOP sign, and changes in MUTCD guidelines over the years.

Chapter 3 discusses the current field study. With the help of KDOT, nine grade crossings with different warning devices were selected and the field study was conducted. Chapter 3 gives details of all the grade crossings, the various phases involved and the methodology of the field study.

Chapter 4 shows the results of the field study. It takes an in depth look at the statistical data obtained through the field study. As far as possible various statistical comparisons are represented in this chapter to determine the significant and non significant factors involved and the results are discussed.

Chapter 5 presents the conclusions and some recommendations on conducting future research on passive grade crossings and driver's reaction to different passive signs.

CHAPTER 2

LITERATURE REVIEW

Railroad advance warning sign systems should be considered to be a well understood indication of a grade crossing ahead. However, there are some who believe that beyond clear and good recognition, traffic control devices at grade crossings may not be well understood or do not result in safe driver action. Since 1970 there have been numerous studies carried out to understand the driver's behavior towards different warning sign systems [10].

In Kansas there are approximately 6,300 public highway railroad at grade crossings, out of which around 5,000 grade crossings are passive railroad grade crossings and out of those grade crossings around 4,521 are on rural roads. In the United States (US) about 67% of grade crossings are on low volume roads where upgrading it to active grade crossing is not cost effective but still they account for 50% of the 400 annual deaths in US. A high percentage of these accidents occur at night when the major problem is visibility [5, 11].

Russell in 1991 carried out a study in which headlight illuminance was measured [10]. He found that if the right hand side cross buck were lowered by 0.61 meters (2.00 feet) from its current recommended height the headlight illuminance on cross buck from 76.2 meters (250 feet) distance would increase by 69%. Secondly the amount of light striking the right Crossbuck post at 1.07 meters (3.51 feet) from ground is 417% greater than light striking at 2.75 meters (9.02 feet). The typical US headlight illumination values are low in the upper right toward a right shoulder sign location. This causes concerns about illuminance and visibility on right shoulder signs. Generally, from a distance of around 60.96 meters (200 feet), the illuminance from the headlight is maximum near the base or roadway elevation and decreases rapidly with height above the base.

In another demonstration study conducted by Russell, 1993, six rural passive grade crossings having following sign systems were studied [10]:

1. Having a “Conrail-Shield”, a crossing sign which is attached to the Crossbuck post at a height of 1.07 meters (3.51 feet).
2. “Delineators systems” consisting high intensity retro-reflective tape on both sides of both Crossbuck posts and roadside reflective delineators on the right side of each approach spaced at 15 meters (49.21 feet) from the advanced warning sign to the Crossbuck post and extended an equal distance beyond the Crossbuck post.
3. Yield sign at the crossing and Yield ahead sign on approach.
4. Combination of 1 & 2.
5. Combination of 1, 2 & 3.
6. Same as 2.

Before and after studies were done and it was concluded that the most effective sign system was the “delineators system”.

In a study conducted by Russell and Rys, 1996, different patterns and spacing of delineators were evaluated. In one of the two patterns delineators were kept only on right hand side and in second pattern they were kept on both sides. Three types of spacing were used: 15.24 meters (50 feet), 30.48 meters (100 feet) and 60.96 meters (200 feet). At the end of the study it was concluded that reduced spacing increases visual impact of delineators and a two-sided pattern has more visual impact [12].

School bus grade crossing accidents are infrequent occurrences but the results can be shattering when they do occur. Particularly, passive grade crossings are dangerous for school buses because there are no active warning devices to signal that a train is approaching and school buses often carry large numbers of children. Exposing them to the risk of collision at a grade crossing poses severe danger. In cooperation with the National Association of State Directors of Pupil Transportation Services, The National

Transportation Safety Board (NTSB) developed and implemented a program of initiatives for passive grade crossings and school buses. The program recommended following actions [7],

- Installation of stop signs at passive crossings that are traversed by school buses except where an engineering study shows their installation would create a greater hazard.
- Use of information about whether school buses routinely cross passive grade crossings as a factor in selecting crossings to upgrade with active warning devices.
- A requirement that all newly purchased and in-service school buses be equipped with noise-reducing switches.
- Enhanced school bus driver training and evaluation, including periodic reviews of on-board videotapes where available, especially with regard to driver performance at grade crossing.
- Incorporation of questions on passive grade crossings in the commercial driver's license manual and examination.

A study by Russell, et al at Kansas State University (KSU) recommended the actions below:

- Double sided cross buck with high performance, retro-reflective sheeting should be used.
- There should be a unique sign at crossing starting with advanced warning sign.
- Brushes at grade crossings having sight distance problems should be cut.
- In rural areas the Crossbuck should be no further than two meters (6.56 feet) from the edge of the traveled way to avoid brush problem and to increase visibility at night.

- Grade crossings where poor approach geometry and/or inadequate sight distance cannot be improved to acceptable crossings should be upgraded to active crossings or should be closed [7].

One of the studies carried out in Texas supported active warning signs over passive signs. Researchers in Texas selected four sites having the YIELD TO TRAIN sign, two sites with LOOK FOR TRAIN AT CROSSING with flashing strobe lights and three sites with the LOOK FOR TRAIN AT CROSSING enhanced sign system with flashing beacons. The results of the study showed that at the two sites with the sign LOOK FOR TRAIN AT CROSSING with flashing strobe lights, 82% people noticed the light and 73% people noticed the sign placed below. Thus it was concluded that flashing lights were effective in gaining the driving population's attention [3].

In an Indiana study, Butcher noticed that the driver's reaction to the approach of grade crossings depended on roughness of the road approaching the grade crossings. According to Butcher if the road approaching the grade crossing is rough the driver had to slow down his vehicle and in that case he also looked for incoming trains. However, it was generally not true in cases where the road approaching the grade crossing is smooth [14].

The state of Idaho conducted one study of 27 grade crossings with or without a Conrail-shield and they found that compliance increased from 51.7% to 73.7% and looking behavior increased from 64.5% to 88.9% in the case of grade crossings with a Conrail-shield. The Conrail shield is a retro-reflective device that is attached to the CROSSBUCK post about 1 meter (3.28 feet) above the ground [7].

In a research study in 1971, rumble strips and STOP signs were installed at 30 grade crossings in McCracken County, Kentucky. It was found that only one accident took place in two years after installation where previously several accidents had occurred. In 1972 the same research team installed rumble strips at two grade crossings in Louisiana. They had a "cross with care" sign (134.11 meters (440 feet) before the track), "rumble strip ahead" sign (60.96 meters (200 feet) before the track) and "danger-railroad

crossing" sign (at the crossing) with a CROSSBUCK and rumble strips. With this sign system they found that driver's attention was increased and this sign system was effective in reducing the number of accidents [15].

Alabama conducted one study to compare the effectiveness of STOP signs vs. a CROSSBUCK sign for three years (1974-1976). They found that there were four accidents at 12 CROSSBUCK locations and three at 17 STOP sign locations. Also there were two rear-end collisions at the STOP sign locations compared to none at the CROSSBUCK locations. They concluded that the CROSSBUCK sign was more effective than the STOP sign [15].

Researchers at Vienna, VA conducted a project on recommended traffic control devices for railroad-highway grade crossings. The objective of their study was to determine whether any innovative or non-standard traffic control devices could be recommended as an improvement to safety at passive rail-highway grade crossings. The main focus was on low-cost treatments that could be widely implemented. The project evaluated the shortcomings of general practice and the potential benefits of alternative devices through a variety of activities. These included a critical review of research on grade crossings traffic control signs and alternatives; a detailed driver task analysis in order to describe appropriate and in-appropriate motorists behavior and associated information requirements when approaching and traversing an at-grade crossing [16].

The Vienna researchers concluded that despite the long use of the standard, required signs, W10-1 advance warning signs and R-15-1 CROSSBUCK sign, it seems they only conveyed the general idea of "railroad crossings", but not more specific meaning. Also these signs were not designed with a systematic attempt to match the information requirements to support appropriate drivers' behavior. According to the authors, the CROSSBUCK doesn't have particularly good conspicuity, and; attention getting value should be enhanced. They also concluded the STOP sign should not be the typical treatment at passive crossings, and a "yield" condition is preferred unless warrants for the

use of STOP sign were met. The standard W10-1 and R15-1 signs can be made more effective with the use of supplementary signs [16].

In an article in Institute of Transportation Engineers (ITE) Journal, Richard Raub examined differences between the classes of warning devices at grade crossings in seven Midwestern States using collision and inventory data from Federal Railroad Administration (FRA) office of Safety Website and the category "Highway-Rail Accidents" from a Statistical Analysis System (SAS) table covering 1994-2003. Richard Raub examined four specific warning device classes: CROSSBUCK only, STOP sign, Flashing lights and Gates in seven Midwestern States covering collision data over 10 years. Collision rates used in the analysis had three bases: millions of crossing vehicles (MCV), which is the sum of ADT at the crossings provided by 1 million, Average Daily Trains (ADT) and an exposure factor which is derived from the product of ADT and crossing trains [25].

In the seven Midwestern States, the above four classes of public crossings had a total of 8,856 collisions for 1994-2003 with total vehicle damage of $37 millions without including cost resulting from injuries and deaths or any cost to the railroad, employees, or passenger. Injuries and fatalities occurred in 3,503 of the collisions [25].

Using 10 years of collision data in the seven Midwestern States, Richard Raub concluded that collisions at highway-rail grade crossings where STOP sign was installed were more likely to occur than with any other form of warning system. Even when STOP sign was installed at crossings that previously had CROSSBUCK, collision rates were increased. Gates generally had the lowest collision rate [25].

In 2007, Richard Raub examined crash rates for seven Midwestern States. Crash data came from the FRA office of Safety Web site. The data was available from 1988 to the present. In this paper Richard Raub concentrated on the two most frequently used active warning devices, i.e., a system triggered by the presence of the train, gates and flashing

lights and the two most frequently used passive systems, CROSSBUCK only and CROSSBUCKS with a STOP sign [26].

According to Richard Raub, from 1996 to 2005, 34,166 grade crossing crashes were reported to the FRA. In 1996, there were 4,268 reported public crossings crashes which were reduced by 28% i.e., 3,043 in 2005. Fatal crashes at public crossings were decreased by 25% from 410 in 1996 to 304 in 2005 [26].

Richard Raub concluded that the class of warning device present at a highway-rail grade crossing plays a critical role in the likelihood of a vehicle-train collision. Gates or flashing lights present at the crossings generated very low rates. The passive devices which include CROSSBUCK only or those augmented by STOP sign or YIELD sign, at a minimum resulted in more than double rates. Only CROSSBUCK resulted in 2.5 times more than likely. The most surprising was crash rates were very high when STOP sign or YIELD sign were used in addition. Especially, STOP sign locations had more number of crashes [26].

2.1 GUIDELINES FROM MUTCD AND OTHER PUBLICATIONS

This section of the report takes an in-depth look at how the changes were made in Manual on Uniform Traffic Control Devices (MUTCD) guidelines over the years regarding the use of the STOP sign at grade crossings. The MUTCD is recognized as a standard and is used by traffic engineers and road managers nationwide to install and maintain traffic control devices on all streets and highways.

In 1961 MUTCD guidelines, seven conditions were set forth warranting STOP sign. Condition no. 6 stated, “Railroad crossings where a stop is required by law or by order of the appropriate public authority”. During the period of 1961 to 1971 there was lot of controversy and debate on this warrant. Subsequently, when the 1971 edition of the MUTCD was written the “railroad warrant” was removed. The only warrant that could be

applied was (MUTCD, 1971): “Other intersections where a combination of high speed, restricted view, and serious accident record indicates a need for control by the stop sign”. It was never made clear whether this warrant could be applied to rail-highway grade crossings or not. State of Florida asked for an “interpretation” through the normal manual interpretation process and in reply FHWA replied that the STOP sign could be used after an engineering study which shows a specific need but only as an interim measure [17].
Until 1975, the Uniform Vehicle Code and Model Traffic Ordinance (UVCMTO) authorized the use of STOP sign at particularly dangerous railroad-highway grade crossings. However in 1975 this permission was deleted. The removal of permission for the use of STOP sign essentially ended the “stop look and listen” era. Some states used STOP sign extensively and some states had requirements for all motor vehicles to stop at all grade crossings. This situation was precisely the reason for the change in the UVCMTO [17].

In 1972, the National Joint Committee on Uniform Traffic Control Devices (NJCUTCD) which had published the MUTCD guidelines continuously since 1935 became the National Advisory Committee on Uniform Traffic Control Devices (NACUTCD). In 1978 a new edition of manual came out which incorporated all revisions which had been approved through official rulings approved by the FHWA since the prior 1971 printing. The interpretation for the State of Florida on the use Stop signs at railroad grade crossings was incorporated into section 2B-5 “Warrants for Stop sign,” i.e., Stop signs could be used after an engineering study showed a specific need but only as an interim measure (MUTCD, 1978). An engineering study that considered approach speeds, sight distance restrictions, traffic volumes, accidents records and other necessary factors was fixed. Since the MUTCD was taken as a whole, further details for grade crossing approach were presented under the title; “Traffic Control Systems for Railroad-Highway Grade Crossings”, a new section in the 1978 manual [17].

In 1976 the railroad grade crossing subcommittee of the NACUTCD formed a committee to review a 1978 FHWA study (reviewed in a section below) and in a report it was concluded that the STOP sign could be effective under certain conditions. A task force

was formed to: 1) determine if new language should be proposed for the MUTCD and 2) draft appropriate new language. Language suggested by the subcommittee subsequently became a part of 1988 MUTCD guidelines. The language is as follows [17]:

8B-7 STOP SIGN AT GRADE CROSSING (R1-1, W3-1). The use of Stop signs at railroad highway grade crossings shall be limited to those grade crossings selected by a detailed traffic engineering study and should also meet the following four elements:

1) Highways should be secondary in character with low traffic counts.
2) Train traffic should be substantial.
3) Line of sight to an approaching train is restricted by physical features; such that approaching traffic is required to reduce to speed to 10 mph or less in order to stop safely.
4) At the stop bar, there must be sufficient sight distance down the track to afford ample time for a vehicle to cross the tracks before the arrival of a train.

The US congress passed a law under the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) authorizing the use of STOP sign and YIELD sign at highway-rail grade crossings with two or more trains per day. In effect, indiscriminate use was made legal in section 1077, Revision of Manual [17].

FHWA issued Final Rule 92-11 which was published in the federal Register on November 6, 1992 (57FR 53029). An FHWA interpretation defined “two or more trains per day” as meaning two or more per day for one full year prior to sign installation, i.e., 365 * 2 = 730 trains. MUTCD section VIII-32 (C) was then revised [17].

FHWA issued a memorandum on March 17, 2006 regarding the guidance for use of YIELD or STOP signs with the CROSSBUCK sign at passive Highway-rail grade crossings, paraphrased as follows, The 2003 MUTCD requires the CROSSBUCK (R15-1) sign for all highway approaches to railroad grade crossings. It also allows the optional use of YIELD or STOP signs at passive crossings. While the CROSSBUCK sign is in

fact a regulatory sign that requires vehicles to yield to trains and stop if necessary. According to research studies of FHWA insufficient road user understand and comply with regulatory requirement when just the CROSSBUCK sign is present at passive crossings. Therefore, the FHWA encourages consideration of the use of YIELD or STOP signs in conjunction with the CROSSBUCK sign at all passive crossings except where train crews always provide flagging to roadway users [22].

FHWA recommended that YIELD signs be considered the default choice for traffic control at a passive crossing unless an engineering study or judgment determines that a STOP sign is appropriate. A STOP sign establishes a legal requirement for each and every vehicle to come to a full stop. Indiscriminate use of the STOP sign at all or many passive grade crossings can cause poor compliance, increasing the risk of collisions associated with a high non-compliance rate. Therefore, the use of STOP signs at passive crossings should be limited to unusual conditions where requiring all vehicles to make a full stop is deemed essential by the engineering study or judgment. The engineering study or engineering judgment should consider the following factors [22]:

- The line of sight from an approaching highway vehicle to an approaching train;
- Characteristics of the highway, such as the functional classification, geometric conditions, and traffic volumes and speed;
- Characteristics of the railroad including, but not limited to, frequency, type and speed of trains, and number of tracks;
- Crossing crash history; and
- Need for active control devices.

Certain commercial motor vehicles and school buses are required to stop at all highway-rail grade crossings, in accordance with 49 CFR 392.10, even if a YIELD sign or just a CROSSBUCK sign are posted [22].

In June, 2004 National Committee on Uniform Traffic Control Devices (NCUTCD) recommended some proposed changes in MUTCD regarding Crossbuck with Yield sign or Stop sign. The changes are presented as below [24],

Section 8B:03
The CROSSBUCK (R15-1) sign assigns right of way to rail traffic at a highway-rail grade crossings.

Section 8B:04
At all public highway-rail grade crossings not equipped with active traffic control systems a Crossbuck assembly shall be installed on the right hand side of the highway on each approach to the highway-rail grade crossing. Where there is restricted sight distance, unfavorable highway geometry or one way multiple approach is present, an additional Crossbuck assembly shall be installed on left side of the highway.

The meaning of a Crossbuck assembly which includes a YIELD sign is that the road user approaching the highway-rail grade crossing shall be prepared to slow, and when necessary, yield the right-of-way to any rail traffic that may be occupying the crossing, or approaching and in proximity to the crossing, such that it would be unsafe for the road user to cross. The meaning of a Crossbuck assembly which includes a STOP sign is that the road user approaching the highway-rail grade crossing shall come to a full stop not less than 15 feet short of the near rail, and remain stopped while the road user determines if there is rail traffic occupying the crossing, or approaching and in proximity to the crossing, such that the road user must yield the right of way to rail traffic. The road user may then proceed when it is safe to cross [24].

The YIELD (R1-2) sign or STOP (R1-1) sign may be omitted from the Crossbuck assembly on passive crossings where either of the following conditions exists [24]:

- All rail traffic movements are 10 mph or less; and all rail traffic movements over the crossing are stopped near the roadway edge by the train crew prior to

entering the crossing or all rail traffic movements directed by a flagger prior to occupying the crossings. OR

- When an EXEMPT highway-rail grade crossing (R15-3, W10-1a) sign is installed in accordance with Section 8B:07.

The entire Crossbuck assembly may be omitted on one or both sides of passive grade crossings where all of the following conditions exist [24]:

- There is no reasonable location to install them; and
- All rail traffic movements are 10 mph or less; and
- All rail traffic movements over the crossing are stopped near the roadway edge by the train crew prior to entering the crossing or all rail traffic movements are directed by a flagger prior to occupying the crossing.

Section 8B:05

Upon a determination by the responsible regulatory agency or highway authority, Crossbuck assemblies which include STOP (R1-1) sign shall be used at highway-rail grade crossing where the need has been established by an engineering study, except that Crossbuck assemblies which include STOP signs shall not be installed at any grade crossing with active traffic control devices. Crossbuck assemblies which include STOP signs should not be installed at crossings having more than 2000 Annual Average Daily Traffic (AADT) except as an interim measure pending the installation of active devices [24].

When it comes to use of STOP signs at grade crossings there has been a lot of controversy. The next section discusses controversy over use of STOP signs at grade crossings.

2.2 CONTROVERSIES OVER USE OF STOP SIGN AT GRADE CROSSINGS

When it comes to use of STOP sign at the grade crossings, mixed reactions and different concerns were observed over the years. In the sixties the concern was whether the STOP sign was effective or not, in the seventies it was indiscriminate overuse, in the eighties it was determining appropriate use and in the nineties the controversy was with the passage of Federal legislation, which some believed to be "politics" vs. traffic engineering judgment. Russell and Burnham believe that the STOP sign at grade crossings can be effective when used where certain specified conditions exist. These conditions were very well specified in the 1988 edition of MUTCD guidelines. Indiscriminate use of the STOP sign at grade crossings would lead to disrespect for both the sign and also grade crossings which can be more dangerous [16].

The "classic" Bezkorovainy-Holsinger study (1966) found that 84% of Lincoln, NE drivers violated the rules and did not stop at STOP signs at grade crossings. During that time too many STOP signs were in use on Lincoln's local streets and that may have contributed to the lack of respect for the STOP sign. In an extensive study by the Michigan Public Service Commission, they found that one in ten motorists actually stopped at STOP signs at grade crossings, 25 to 30 % slowed down but did not stop, while the remaining motorists (60 to 65%) made no effort to stop or slow down. Many studies evaluating advantages and disadvantages of STOP signs were conducted and it was concluded that the STOP sign was effective at grade crossings which fulfilled certain requirements. Most of the traffic engineers were against its use but most railroad officials and public attorneys were in favor of using the STOP sign at grade crossings [14].

Burnham & Associates (1994) selected seven study sites in Alabama and Georgia that used the stop sign for traffic control. The data was collected in daylight hours in the summer of 1993. Video camera was used to collect the data. The crossings were measured to determine the available sight distance when motorists were 30.48 meters (100 feet) in advance of the rail in the direction of the critical approach where past accidents had occurred. The results showed that 18 % people came to a full stop, 50 %

made a slow roll over and remaining 32 % did not stop at all. The results were close to the 1966 Bezkorovainy study, which means nothing had changed in the intervening 30 years. An interesting observation was made when stopping habits of motorists approaching the STOP sign site locations was compared to the sight distance available for determination of train presence. Almost no stops were recorded at sites 1, 3 and 4 although site 1 had less than 15.24 meters (50 feet) of available sight distance and site 3 was less than 30.48 meters (100 feet) [17].

Georgia reevaluated the use of STOP sign control at over 600 grade crossings on the state route system. This evaluation lead to a decision to remove STOP signs at nearly 500 of the grade crossings studied.

In 1976, Russell conducted a survey of state, city and railroad engineers. The results of this survey showed that about 50% believed that the Bezkorovainy study results were valid and they believed that the STOP sign was ineffective at grade crossings. However, according to the survey, the actual interpretation of the Bezcorovainy results was broken down into “thirds”. One third of respondents were strongly opposed to the use of the STOP sign at grade crossings, one third were mildly opposed but would use STOP sign in certain limited conditions while the last third were in total favor of use of STOP sign at grade crossings [17].

One of the studies from the American Railway Engineering Association (AREA) showed that 74% of auto drivers did comply with the STOP sign and if 5 mph or less is accepted as a safe action the figure went up to 96.8% [14]. The authors of this study believe that this is the only study in the available literature that has reported a majority of drivers complying with the STOP sign at grade crossings.

FHWA 1978 [14] conducted an extensive study to determine advantages and disadvantages of the selective use of highway STOP sign as safety improvements at rail-highway grade crossings and to develop guidelines for their use. In this study they compared the STOP sign with the CROSSBUCK sign. They conducted a field study of

17 crossings with STOP sign and 8 with only a CROSSBUCK sign and they found that 60% of all drivers exhibited “acceptable” stopping and 82.5% looked for trains at STOP sign locations, while only 42% looked for trains at CROSSBUCK sign sites The final report concluded that the STOP sign could be more effective when applied selectively at hazardous passive grade crossings, and if guidelines for their use is provided. The guidelines from this study are presented below,

1. The installation must be believable. The driver must be able to perceive a reason for the stop sign which satisfies his requirements for validity. These requirements include low visibility to train detection, high train expectancy and enforcement.
2. The vehicle-train exposure value should exceed 100. Translated into trains per day and AADT value, this means that the train volume must be higher than average and AADT’s lower than average. At less than three trains per day, the stop sign should not be used without a compelling reason. Rough guidelines are that stop signs are acceptable for an AADT under 2,000, temporarily acceptable while awaiting active protection up to 4,000 AADT, and impractical above 4,000. The vehicle delay imposed by the stop sign and the potential for vehicle-vehicle conflicts should be acceptable at these levels.
3. The driver should be unable to adequately detect trains unless he nearly stops. It is also necessary that the driver be able to perceive that a stop may be required.
4. The level of enforcement must at least equal that applied to intersection stop signs. The courts must also agree that the offense of failure to stop is equal for grade crossings and intersections.
5. The stop sign must be selectively used so that expectancy is reinforced. If a driver is exposed to improperly used grade crossing stop signs, his respect for those which are properly used will be reduced. (The driver does not confuse intersection applications with grade crossing applications).
6. A high level of traffic engineering is required so that hazardous traffic conflicts are not created at nearby locations by the grade crossing stop sign.

7. The stop sign installation must be treated as a system, including proper deployment and maintenance of advance warning for both the grade crossing and the stop sign.
8. The crossing must be periodically reviewed to insure that the original conditions which prompted the stop sign use still exist.

According to Russell and Burnham several general provisions in the MUTCD were in conflict with politically, allowable, indiscriminate use of the stop sign at any and all locations. Practitioners were urged to the use of the 1993 FHWA guidelines, paraphrased from a 1993 joint FHWA/FRA memorandum as follows [17, 23]:

It is recommended that the following indications should be considered before a stop sign is installed:

Positive Indications:

1) Local and/or State police and judicial officials will commit to a program of enforcement no less vigorous than would apply at a highway intersection equipped with Stop signs.
2) Installation of a Stop sign would not occasion a more dangerous situation (taking into consideration both the likelihood and severity of highway-rail collisions and other highway traffic risks) than would exist with a Yield sign.
3) Maximum train speeds equal or exceed 30 mph (a factor highly correlated with highway-rail accident severity).
4) Highway traffic mix includes buses, hazardous materials carriers and/or large (trash or earth moving) equipment.
5) Trains movements are 10 or more per day, 5 or more days per week.
6) The rail line is used by passenger trains.
7) The rail line is regularly used to transport a significant quantity of hazardous materials.

8) The highway crosses two or more tracks, particularly where both tracks are main tracks or one track is passing siding that is frequently used.
9) The angle of approach to the crossing is skewed.
10) The line of sight from an approaching highway vehicle to an approaching train is restricted such that approaching traffic is required to substantially reduce speed.

Counter Indications:

1) The highway is other than secondary in character. Recommended maximum of 400 ADT in rural areas, and 1,500 ADT in urban areas.
2) The roadway is a steep ascending grade to or through the crossing, sight distance in both directions is unrestricted in relation to maximum closing speed, and the crossing is used by heavy vehicles.

A National Transportation Safety Board (NTSB) safety study investigated 60 grade crossing accidents. In May 1997 the safety board recommended that STOP sign should be installed at all the passive grade crossings unless a traffic engineering analysis determines that installation of a STOP sign would reduce the level of safety at a grade crossing. The study concluded that STOP signs are an interim measure to improve the safety at passive grade crossings; the long-term solution for eliminating passive crossings and reducing collisions between highway and rail vehicles will be through the use of intelligent transportation systems (ITS) that will alert the motorist to the presence of a train [19].

2.3 TEXAS STUDIES

Different studies proposed new and innovative ideas for sign systems at grade crossings. Some of them actually implemented the sign systems and reported the results; others just proposed ideas but never implemented anything. The results of a Texas study are presented below in this section.

Texas A & M University evaluated enhanced sign systems to increase driver awareness of passive highway-railroad grade crossings, with the premise that increased awareness would result in more cautious behavior when drivers approached grade crossings. The first experimental enhanced sign system was consisting of a 36-inch YIELD sign (Manual on Uniform Traffic Control Devices [MUTCD] R1-2) with a supplemental message plate (36 inches by 24 inches) containing the phrase "TO TRAINS". The second experimental enhanced sign system had a vehicle-activated strobe or flashing yellow beacon mounted above a standard railroad advance warning sign (MUTCD W10-1) in combination with a new yellow warning sign that reads "LOOK FOR TRAIN AT CROSSING" [13].

Researchers selected nine project sites from TxDOT's list of passive crossings that were scheduled to be upgraded to active grade crossings. TxDOT and the Texas Transportation Institute (TTI) developed criteria to rank the potential sites, and researchers made field visits to determine the roadway alignment and to verify that each site satisfied the defined criteria. Researchers selected four sites for the YIELD TO TRAINS enhanced sign systems, two sites for the LOOK FOR TRAIN AT CROSSING enhanced sign systems with flashing strobe lights, and three sites for the LOOK FOR TRAIN AT CROSSING enhanced sign system with flashing beacons (see figure 1) [13].

Figure 1: Flashing Beacon assembly (Ref. # 13)

The analysis of the before and after speed studies did not find any across-the-board decreases in speeds at any of the locations using the three enhanced sign systems. On-site surveys indicated that the vehicle-activated systems were effective in gaining drivers' attention and that the devices did not alarm the drivers (See Figure 2).

Figure 2: Enhanced sign system (Ref. # 13)

For the LOOK FOR TRAIN AT CROSSING enhanced sign systems, 82% of survey respondents at the four sites surveyed, noticed the flashing lights at the approaches to the railroad-highway grade crossings, and 73% noticed the sign placed below the flashing light or beacon. Additionally, 20% of the survey respondents remembered that the sign said to look or watch for trains, and another 36% noted that the signs said something about a railroad crossing. Thirty eight percent of the survey participants stated that they believed the LOOK FOR TRAIN AT CROSSING enhanced sign system was a good idea. Also, 69% to 91% of the survey respondents at the four project sites where surveys were conducted were from the same county, verifying the researchers' belief that most drivers were familiar with the area [13].

A lot of work has been done in the past in the area of grade crossings and different passive and active sign systems at grade crossings but there are still studies needed to determine driver's reaction at different grade crossings with specific warning sign systems. Chapter 3 concentrates more on the field study of nine grade crossings which were selected for this project.

CHAPTER 3

INTRODUCTION

3.1 SELECTING GRADE CROSSINGS FOR FIELD STUDY

A field study was conducted to determine how drivers react to a select group of warning devices. With input from the Kansas Department of Transportation (KDOT) nine grade crossings with different warning devices were selected. The original plan was to include two crossings with CROSSBUCK signs only, two with CROSSBUCK and STOP signs, two with CROSSBUCK and YIELD signs, two with STOP signs at the grade crossings and YIELD sign at a nearby parallel highway and two where STOP signs were placed at an active grade crossings. Only one site with CROSSBUCK and YIELD signs could be located, thus nine grade crossings were included. Out of the nine, seven grade crossings were passive grade crossings and two were active grade crossings which also had a STOP sign. The two sites with a STOP sign used at active grade crossings are special cases explained in a following section. KDOT wanted to know what drivers' compliance was in these cases. KDOT supplied the details of the grade crossings required for the study. It should be noted that resources were not available to determine vehicle speeds, except subjectively, or driver's "looking behavior". There was no way to determine if a driver coming to a full stop or a rolling stop looked for a train.

3.2 SIGHT DISTANCE

There are three sight distances which should be considered: 1) the distance ahead to the crossing; 2) the distance to and along the tracks on which a train might be approaching the crossing in either direction (triangle); and 3) the distance along the tracks in either direction from a vehicle stopped at the crossings. For our field study we only measured

the triangle sight distance as a subjective measure of how critical it was for an approaching driver to stop. For example, where the triangle sight distance is obviously limited, a driver should stop to ensure a train is not putting him/her at risk of a crash. There were only two approaches with severe sight distance restriction- southbound 236 street in Nemaha County and southbound Carter road in Shawnee County.

3.3 DETAILS OF GRADE CROSSINGS

The data in the tables in this section was supplied by the Kansas Department of Transportation (KDOT). Note that in the cases of three stop sign locations at passive grade crossings (108th Street, Carter road, and Arn road) the railroad track is parallel to a state highway within 30.48 meters (100 feet). In these cases it is KDOT policy to place a STOP sign at the grade crossing and a YIELD sign at the nearby highway. This practice ensures a driver stopped at the track can determine if there is enough space for his/her vehicle between the tracks and highway or another vehicle stopped for highway traffic. Also, once the driver starts up and crosses the tracks, many times another stop at the highway is not necessary. In the cases where this system is used, there is good sight distance from a vehicle stopped at the tracks and vehicle approaching the intersection on the highway. On the approach away from the highway, there is only a CROSSBUCK.

In the two cases where a STOP sign is used in conjunction with flashing lights and gates (Walnut Street and 69th Street) the reasoning is similar to that described in the above paragraph, i.e. the STOP sign is not used to enhance or supplement the active devices (flashing lights and gates) but to better control vehicle flow and possible queuing between the tracks and the highway at all times and lessons the risk of a vehicle being on tracks when an approaching train presents a danger. As in the case of passive grade crossings with similar geometry, there is a YIELD sign at the highway, on the approaches away from the highways, there is only a CROSSBUCK.

1) Grade Crossing Dot # 813912G/UP @ Walnut Street, Rossville, Shawnee County:

a) From the highway to the grade crossing b) From the grade crossing to the highway

Figure 3: Pictures of Dot # 813912G/UP @ Walnut Street, Rossville, Shawnee County

Table 1: Details of # 813912G/UP @ Walnut Street, Rossville, Shawnee County[1.]

County	Shawnee
Dot #	813912G/UP
City	Rossville
Street	Walnut
AADT	84
Main Tracks	1
Other Tracks	0
Total Trains	10
Through Trains	10
Switch Trains	0
Roughness	0/5 Smooth road
Sight distance on right hand side when approaching towards highway (approx 20 feet)	Pretty open (approx 250 feet)
Sight distance on left hand side when approaching towards highway (approx 20 feet)	Pretty open (approx 400 feet)
Parallel RR line and State Highway with flashing lights gates and "STOP" sign at the crossing leading to the highway intersection which is signed with a "YIELD" sign.	

1. All grade crossing details are from KDOT files.

2) Grade Crossing Dot # 814413U/UP @ Street 236, Nemaha County

a) Towards North b) Towards South

Figure 4: Picture of Dot # 814413U/UP @ Street 236, Nemaha County

Table 2: Details of Dot # 814413U/UP @ Street 236, Nemaha County

County	Nemaha
Dot #	814413U/UP
City	--
Street	236
AADT	227
Main Tracks	1
Other Tracks	1
Total Trains	23
Through Trains	23
Switch Trains	0
Roughness	4/5
Sight distance on right hand side towards south (approx 50 feet away)	Open (approx 470 feet)
Sight distance on left hand side towards south (approx 50 feet away)	Bad. (House at hill, approx 50)
Passive Crossing with "CROSSBUCK" and "STOP" signs both directions.	

3) Grade Crossing Dot # 605343F/UP @ Hays (7th) Road, N. Edge of Alma, Wabaunsee County:

a) Towards East

b) Towards West

Figure 5: Picture of Dot # 605343F/UP @ Hays (7th) Road, N. Edge of Alma, Wabaunsee County

Table 3: Details of Dot # 605343F/UP @ Hays (7th) Road, N. Edge of Alma, Wabaunsee County

County	Wabaunsee
Dot #	605343F/UP
City	N. of edge of Alma
Street	Hays (7th) Road
AADT	61
Main Tracks	1
Other Tracks	0
Total Trains	23
Through Trains	23
Switch Trains	0
Roughness	4/5
Sight distance on right hand side from "X" Buck ahead west.	Open (approx 600 feet)
Sight distance on left hand side from "X" Buck ahead west.	Open (approx 800 feet)
Sight distance on right hand side from "X" Buck ahead east.	Open (approx 200 feet)
Sight distance on left hand side from "X" Buck ahead east.	Open (approx 800 feet)
Passive crossing with "CROSSBUCK" and STOP signs both directions.	

4) Grade Crossing Dot # 818393Y/UP Halstead near K-140, Saline County:

(Note: K-140 is parallel to railroad tracks about 36.58 meters (120 feet))

a) Towards South (From K-140)

b) Towards North

Figure 6: Pictures of Dot # 818393Y/UP Halstead near K-140, Saline County

Table 4: Details of Dot # 818393Y/UP Halstead near K-140, Saline County

County	Saline
Dot #	818393Y/UP
City	--
Street	Halstead @ K-140
AADT	261
Main Tracks	1
Other Tracks	0
Total Trains	8
Through Trains	8
Switch Trains	0
Roughness	4/5
Sight distance on right hand side towards K-140 (50 feet away) *	Open (approx 350 feet)
Sight distance on left hand side towards K-140 (50 feet away) *	Ok (approx 100 feet)
Passive crossing with "CROSSBUCK" and "YIELD" signs both directions.	

(Note: * means it gets bad as the distance increases because of lots of trees.)

5) Grade Crossing Dot # 818399P/UP Muir near K-140, Saline County:

(Note: K-140 is parallel to railroad tracks about 39.62 meters (130 feet))

a) Towards South (from K-140)

b) Towards North

Figure 7: Pictures of Dot # 818399P/UP Muir near K-140, Saline County

Table 5: Details of Dot # 818399P/UP Muir near K-140, Saline County

County	Saline
Dot #	818399P/UP
City	--
Street	Muir @ K-140
AADT	133
Main Tracks	1
Other Tracks	0
Total Trains	8
Through Trains	8
Switch Trains	0
Roughness	4/5
Sight distances on right hand side both sides	Unlimited.
Sight distances on left hand side both sides	Unlimited.
Passive crossing with "CROSSBUCK" only.	

6) Grade Crossing Dot # 602966E/UP 108th near K-61, Hutchinson, Reno County: (Note: K-61 parallel the railroad tracks about 36.58 meters (120 feet))

a) East from K-61

b) West towards K-61

Figure 8: Pictures of Dot # 602966E/UP 108th Street near K-61, Hutchinson, Reno County

Table 6: Details of Dot # 602966E/UP 108th Street near K-61, Hutchinson, Reno County

County	Reno
Dot #	602966E/UP
City	Hutchinson City
Street	108th @ K-61
AADT	88
Main Tracks	1
Other Tracks	0
Total Trains	15
Through Trains	15
Switch Trains	0
Roughness	4/5
Sight distances on right hand side towards K-61 (approx 200 feet away)	Poor. (approx 50 feet) Electric sub-station in between.
Sight distances on left hand side towards K-61 (approx 200 feet away)	Good. (approx 400 feet)
Passive crossing with "CROSSBUCK" and "STOP" on one approach and "CROSSBUCK" on other side.	

7) Grade Crossing Dot # 602960N/UP 69th near K-61, Hutchinson, Reno County: (Note: K-61 parallel the railroad tracks about 30.48 meters (100 feet))

a) West towards K-61 b) East from K-61

Figure 9: Pictures of Dot # 602960N/UP 69th Street near K-61, Hutchinson, Reno County

Table 7: Details of Dot # 602960N/UP 69th Street near K-61, Hutchinson City, Reno County

County	Reno
Dot #	602960N/UP
City	Hutchinson City
Street	69th @ K-61
AADT	383
Main Tracks	1
Other Tracks	0
Total Trains	15
Through Trains	15
Switch Trains	0
Roughness	4/5
Sight distances on right hand side towards K-61 (approx 200 feet away)	Approx 200 feet As the road distance increases site distance decreases (due to trees).
Sight distances on left hand side towards K-61 (approx 200 feet)	Approx 100 feet As the road distance increases site distance decreases (due to trees).
Active crossing with "CROSSBUCK" and flashing lights and gates at the crossing and "STOP" signs both sides of the crossing. The Highway intersection is signed with a "YIELD" sign.	

8) Grade Crossing Dot # 818613S/UP Arn road near US-24, Shawnee County: (Note: US 24 parallel to the railroad tracks about 22.86 meters (75 feet)).

a) South towards US-24

b) North from US-24

Figure 10: Pictures of Dot # 818613S/UP Arn road near US-24, Shawnee County

Table 8: Details of Dot # 818613S/UP Arn road near US-24, Shawnee County

County	Shawnee
Dot #	818613S/UP
City	--
Street	Arn Rd @ US-24
AADT	116
Main Tracks	1
Other Tracks	0
Total Trains	10
Through Trains	10
Switch Trains	0
Roughness	4/5
Sight distances on right hand side towards US-24 (approx 200 feet away)	Open (approx 150 feet).
Sight distances on left hand side towards US-24 (approx 200 feet)	Very good (infinity).
Passive crossing with "CROSSBUCK" and "STOP" on north side and "CROSSBUCK" only on south side. A "YIELD" sign is located at the nearby US-24 highway intersection.	

9) Grade Crossing Dot # 818604T/UP Carter road near US-24, Shawnee County: (Note: US 24 parallel to the railroad tracks about 30.48 meters (100 feet)).

a) South towards US-24

b) North from US-24

Figure 11: Pictures of Dot # 818604T/UP Carter road near US-24, Shawnee County

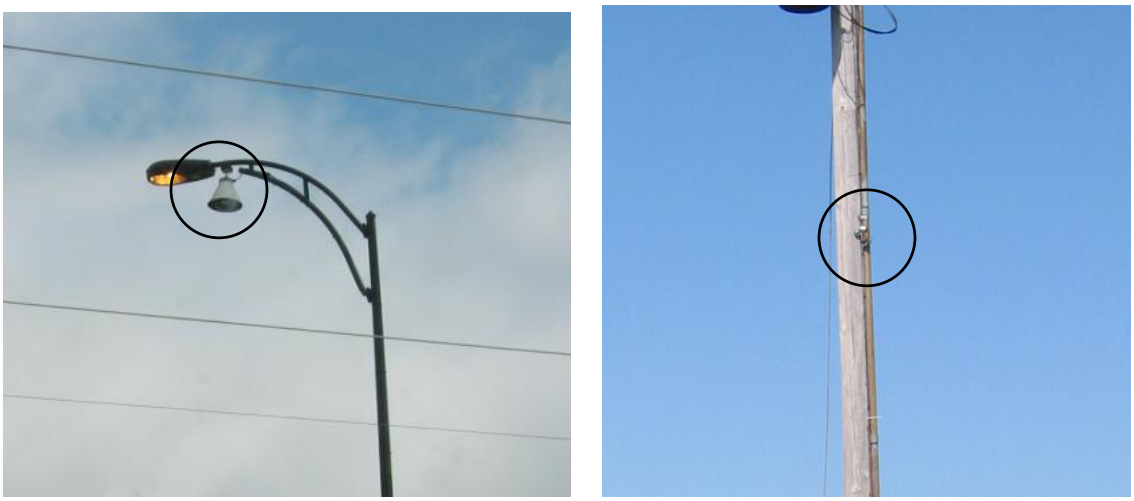
Table 9: Details of Dot # 818604T/UP Carter road near US-24, Shawnee County

County	Shawnee
Dot #	818604T/UP
City	--
Street	Carter @ US-24
AADT	88
Main Tracks	1
Other Tracks	0
Total Trains	10
Through Trains	10
Switch Trains	0
Roughness	4/5
Sight distances on right hand side towards US-24 (approx 100 feet away)	Poor (approx 25 feet). Small hill near the crossing.
Sight distances on left hand side towards US-24 (approx 100 feet)	Approx 50 feet
Passive crossing with "CROSSBUCK" and "STOP" on north side and "CROSSBUCK" only on other side.	

Figures 3 through 11 and Tables 1 through 9 give the details of the grade crossings which were selected for the field study. Data was provided by KDOT or collected while visiting the grade crossing sites.

3.4 STUDY METHODOLOGY

The next phase started with going to each grade crossings and installing a video camera. Two types of video camera were used. One was a fisheye camera and the other was a small security camera. The small security camera had infrared function and thus they were effectively used to capture the action at night. At most of the grade crossings, video cameras were installed on wooden telephone poles. A DVD player, small television and disks or TV/VCR were kept at the ground level in a metal locked box. Figure 12 shows the setup of both the types of the video camera. And figure 13 shows setup of other instruments.



a) Fisheye video camera b) Small security camera

Figure 12: Setup of two types of video camera

Figure 13: Cabinet for TV/VCR or DVD recorder

At every grade crossing the study was carried out for six to seven days. About 14 hours per day were recorded (usually between 7 a.m. and 10 p.m.) with either DVD recorder or VCR recorder. With the video cameras setup for this experiment, it was not possible to measure driver's head movement, thus "looking behavior" could not be recorded, only the vehicle's motion was captured by the cameras. At most of the grade crossings some of the DVDs or VCRs were recorded during nighttime. In the next phase, all the recorded DVDs and video tapes were watched and analyzed. Driver's reaction to the grade crossing was manually recorded forming three categories as full stop, rolling stop and no stop.

3.5 DEFINITION OF FULL STOP, ROLLING STOP AND NO STOP

The three categories that are mentioned above have a specific definition. Full stop means a complete stop where the vehicle is at 0 mph. A rolling stop is where the driver significantly reduces speed of the car and "rolls" across at an estimated speed less than 10 mph. No stop is the case where drivers continue crossing the grade crossings at about the same speed as he/she approached the camera range. The categories mentioned here were

determined subjectively since study resources were too limited to get actual field speed data.

3.6 SUMMARY OF GRADE CROSSINGS

The summary of the nine grade crossings are reviewed and presented in Table 10.

Table 10: Summary of nine grade crossings selected for field study

Dot #	County	City	Street	AADT	Main Tracks	Other Tracks	Total Trains	Thru Trains	Switch Trains	Sign System
605343F/UP	Wabaunsee	N. edge of Alma	Hays (7th) Road	61	1	0	23	23	0	Stop X-Buck
818393Y/UP	Saline		Halstead	261	1	0	8	8	0	X-Buck Yield
818399P/UP	Saline		Muir	133	1	0	8	8	0	X-Buck
818613S/UP	Shawnee		Arn rd	116	1	0	10	10	0	X-Buck Stop
818604T/UP	Shawnee		Carter rd	88	1	0	10	10	0	X-Buck Stop
602966E/UP	Reno		108th	88	1	0	15	15	0	X-Buck Stop
814413U/UP	Nemaha		236	227	1	1	23	23	0	Stop
602960N/UP	Reno		69th	383	1	0	15	15	0	Lights Gates Stop X-Buck
813912G/UP	Shawnee	Rossville	Walnut	84	1	0	10	10	0	Lights Gates Stop X-Buck

The next chapter shows and discusses analysis of the field study results and the different statistical comparisons made between the grade crossings.

CHAPTER 4

RESULTS OF FIELD STUDY & STATISTICAL ANALYSIS

4.1 STATISTICAL TEST

Statistical tests are conducted to find out if there is any statistically significant difference in mean/variance between different populations/samples. In this chapter, for a few comparisons statistical tests were completed to find out if there is any statistically significant difference between different categories. Normal "t" test could have been possible but in our study the sample sizes in categories compared are very small and not equal and in that case the best method to perform the statistical test was using the "pooled estimate" of population variance. The assumption in this method is population variances are equal in different categories.

"Pooled estimate" of population variance is used when the samples are very small, unequal and/or population variances are unknown [27]. To give better explanation, let us consider the problem of estimating the variance of the distribution of the difference between two sample means. Under the assumption that $\sigma_1^2 = \sigma_2^2 (= \sigma^2)$, this variance is given by,

$$\sigma^2_{x_1 - x_2} = \frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2} = \sigma^2 \left(\frac{1}{n_1} + \frac{1}{n_2} \right) \text{..... (1)}$$

And we now estimate σ^2 by "pooling" the two sums of squared deviations from the respective sample means. In other words, we estimate σ^2 by means of,

$$\frac{\sum (x_1 - \bar{x}_1)^2 + \sum (x_2 - \bar{x}_2)^2}{n_1 + n_2 - 2} = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \text{..... (2)}$$

Where $\sum (x_1 - \bar{x}_1)^2$ is the sum of the squared deviations from the mean for the first sample, while $\sum (x_2 - \bar{x}_2)^2$ is the sum of the squared deviations from the mean for the

second sample. We divide by $n_1 + n_2 - 2$, since there are $n_1 - 1$ independent deviations from the mean in the first sample, $n_2 - 1$ in the second, and thus we have $n_1 + n_2 - 2$ independent deviations from the mean to estimate the population variance. Substituting this estimate of σ^2 into the above expression for $\sigma^2_{x_1 - x_2}$ and then substituting the square root of the result into the denominator of the formula for t, we finally obtain,

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - \delta}{\sqrt{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}} \sqrt{\frac{n_1 n_2 (n_1 + n_2 - 2)}{n_1 + n_2}} \text{ .... (3)}$$

Where, $\mu_1 - \mu_2 = \delta$

Since in the above test we assume that population variance is equal. Before proceeding with the above test it is desirable to put this assumption to a test and thus hypothesis concerning two variances test should be performed as shown below,

$$F = \frac{s_1^2}{s_2^2} \text{ .... (4)}$$

If $F > F_\alpha$, null hypothesis can be rejected and on the other hand if $F < F_\alpha$, null hypothesis can not be rejected. The null hypothesis can be stated as there is no statistically significant difference in mean/variance between different populations/samples [27].

4.2 OVERALL GRADE CROSSINGS RESULTS & COMPARISONS

After the field study and analysis of all the recorded data, it was found that a total of 4,318 vehicles passed through the nine grade crossings used in the study. During daytime, 4,088 vehicles and during nighttime, 230 vehicles were recorded at the grade crossings. Tables 11, 12 and 13 show the total number of vehicles recorded at the nine grade crossings and the total number of vehicles recorded during daytime and nighttime respectively.

Table 11: Total number of vehicles recorded at the nine grade crossings

Grade Crossings	Type of warning device	Full Stop by number of vehicles	Rolling Stop by number of vehicles	No Stop by number of vehicles
Hays (7th) Road, N. edge of Alma, Wabaunsee	Stop X-Buck	89	88	278
Arn rd, Shawnee	X-Buck Stop	47	95	509
Carter rd, Shawnee	X-Buck Stop	41	47	183
69th St, Reno	Lights, Gates, Stop, X-Buck	158	240	1085
108th St, Reno	X-Buck Stop	0	4	57
Halstead, Saline	X-Buck Yield	8	42	414
Muir, Saline	X-Buck	5	21	343
236, Nemaha	X-Buck Stop	13	8	129
Walnut, Rossville, Shawnee	Lights, Gates, Stop, X-Buck	37	106	271
Total Number		**398**	**651**	**3269**
Total %		**9 %**	**15 %**	**76 %**

Table 12: Total number of vehicles recorded at the nine grade crossings during daytime

Grade Crossings	Type of warning device	Full Stop by number of vehicles	Rolling Stop by number of vehicles	No Stop by number of vehicles
Hays (7th) Road, N. edge of Alma, Wabaunsee	Stop X-Buck	75	80	257
Arn rd, Shawnee	X-Buck Stop	39	92	448
Carter rd, Shawnee	X-Buck Stop	41	41	179
69th St, Reno	Lights, Gates, Stop, X-Buck	158	238	1067
108th St, Reno	X-Buck Stop	0	4	55
Halstead, Saline	X-Buck Yield	8	42	400
Muir, Saline	X-Buck	5	13	327
236, Nemaha	X-Buck Stop	13	8	126
Walnut, Rossville, Shawnee	Lights, Gates, Stop, X-Buck	33	94	245
Total Number		**372**	**612**	**3104**
Total %		**9 %**	**15 %**	**76 %**

Table 13: Total number of vehicles recorded at the nine grade crossings during nighttime

Grade Crossings	Type of warning device	Full Stop by number of vehicles	Rolling Stop by number of vehicles	No Stop by number of vehicles
Hays (7th) Road, N. edge of Alma, Wabaunsee	Stop X-Buck	14	8	21
Arn rd, Shawnee	X-Buck Stop	8	3	61
Carter rd, Shawnee	X-Buck Stop	0	6	4
69th St, Reno	Lights, Gates, Stop, X-Buck	0	2	18
108th St, Reno	X-Buck Stop	0	0	2
Halstead, Saline	X-Buck Yield	0	0	14
Muir, Saline	X-Buck	0	8	16
236, Nemaha	X-Buck Stop	0	0	3
Walnut, Rossville, Shawnee	Lights, Gates, Stop, X-Buck	4	12	26
Total Number		**26**	**39**	**165**
Total %		**11 %**	**17 %**	**72 %**

From Tables 11, 12 and 13 we can see that a total of 4,318 vehicles were recorded at the grade crossings, out of which 9% (398 vehicles) stopped completely, 15% (651 vehicles) did a rolling stop and 76% (3,269 vehicles) did not stop at grade crossings. After sorting the data for daytime and nighttime it was found that during the daytime 4,088 vehicles were recorded at the grade crossings, out of which 9% (372 vehicles) stopped completely, 15% (612 vehicles) did a rolling stop and 76% (3,104 vehicles) did not stop at grade crossings. During the nighttime 230 vehicles were recorded at the grade crossings, out of which 11% (26 vehicles) completely stopped, 17% (39 vehicles) did a rolling stop and 72% (165 vehicles) did not stop at grade crossings.

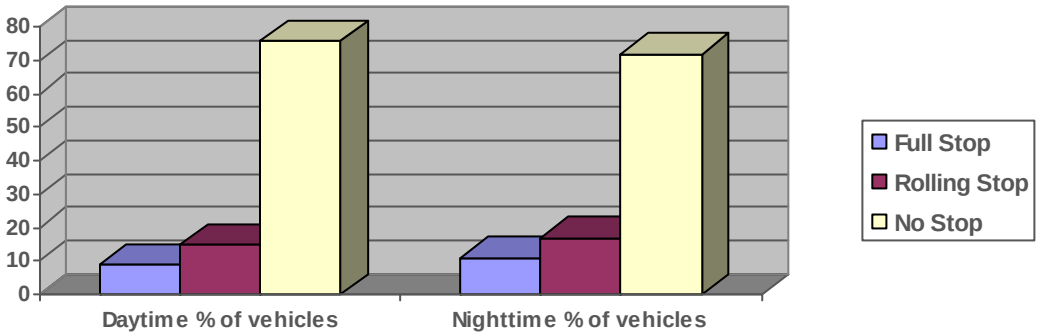


Figure 14: Comparison between vehicles recorded during daytime and nighttime

Figure 14 presents comparison between percentages of vehicles recorded during nighttime and daytime and we can observe that during the nighttime 2% more people completely stopped at the grade crossings as compared to daytime. Also the percentage of people not stopping at the grade crossings is 4% higher during the daytime.

4.3 INDIVIDUAL GRADE CROSSINGS RESULTS & GRAPHS

After the overall grade crossings results were calculated, the data were sorted out by individual grade crossings. The total number of vehicles stopped, did a rolling stop or did not stop were determined for each grade crossing individually. Individual grade crossings data were also sorted by daytime and nighttime category. The data tables and graphs for the grade crossing at 236 Street, Nemaha County is presented as shown below. Similar tables and graphs for the rest of the grade crossings are presented in appendix A.

- **236 Street, Nemaha County, Grade Crossing Dot # 814413U/UP:**

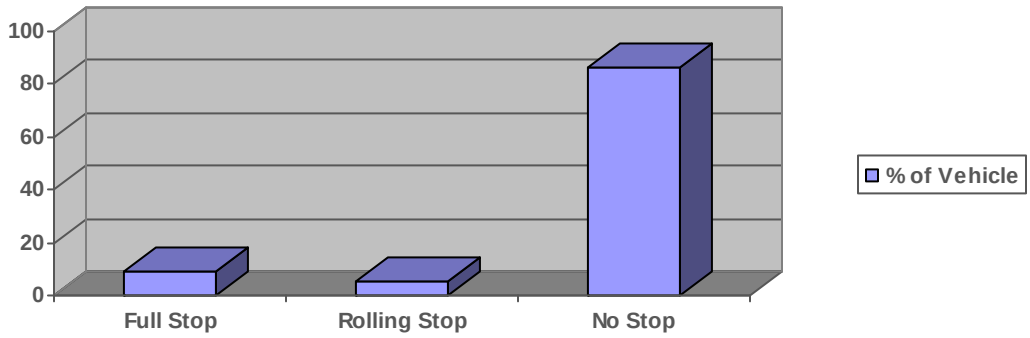


Figure 15: Total percentage of vehicles recorded at 236 Street, Nemaha County, Grade Crossing Dot # 814413U/UP

Table 14: Total number and percentage of vehicles recorded at 236 Street, Nemaha County, Grade Crossing Dot # 814413U/UP

	Number of Vehicles	% of Vehicles
Full Stop	13	9
Rolling Stop	8	5
No Stop	129	86
Total	150	100

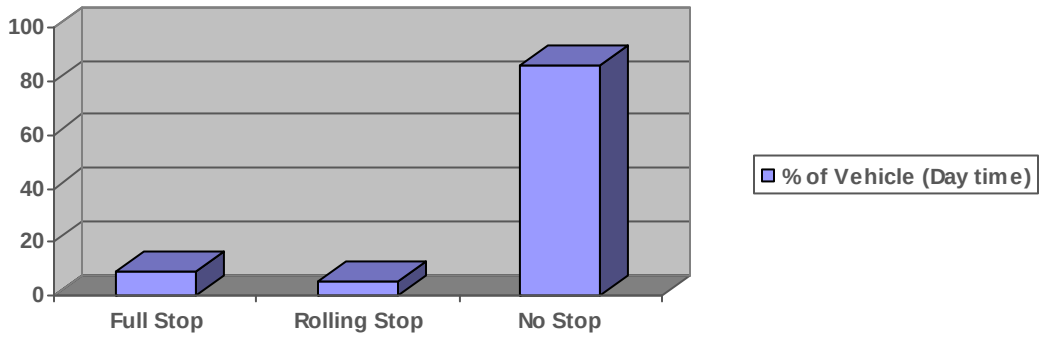


Figure 16: Total percentage of vehicles recorded at 236 Street, Nemaha County, Grade Crossing Dot # 814413U/UP (Daytime)

Table 15: Total number and percentage of vehicles recorded at 236 Street, Nemaha County, Grade Crossing Dot # 814413U/UP (Daytime)

	Number of Vehicles	% of Vehicles
Full Stop	13	9
Rolling Stop	8	5
No Stop	126	86
Total	147	100

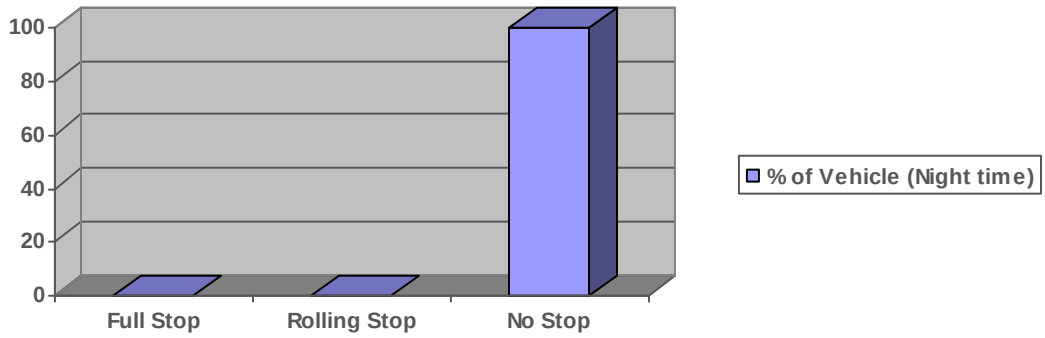


Figure 17: Total percentage of vehicles recorded at 236 Street, Nemaha County, Grade Crossing Dot # 814413U/UP (Nighttime)

Table 16: Total number and percentage of vehicles recorded at 236 Street, Nemaha County, Grade Crossing Dot # 814413U/UP (Nighttime)

	Number of Vehicles	% of Vehicles
Full Stop	0	0
Rolling Stop	0	0
No Stop	3	100
Total	3	100

Looking at Tables 14 through 16 and Tables A1 through A24 in Appendix A and Figures 15 through 17 and Figures A1 through A24 in Appendix A, we can see that the

percentage of drivers not stopping at the grade crossing is more than other two categories at all nine grade crossings. A few grade crossings (236 Street, Nemaha County dot # 814413U/UP , Halstead, K-140, Saline county dot # 818393Y/UP and 108th Street, near Hutchinson, Reno county dot # 602966E/UP) had 100 % of drivers who did not stop at the grade crossing at night. On the positive side at some grade crossings like, Hays (7th) Road, N. Edge of Alma, Wabaunsee county dot # 605343F/UP had 32 % of drivers stop completely and 19 % drivers did a rolling stop during nighttime. At the grade crossing on Carter road, US-24, Shawnee County dot # 818604T/UP, 60% of drivers did a rolling stop at night.

Overall, based on this study we can say that the majority of drivers were ignoring the STOP signs where they were present. The summary of the individual studies during daytime and nighttime are shown below in Tables 17 through 19.

Table 17: Summary of individual grade crossings

Grade Crossing	Signs Present	Full Stop		Rolling Stop		No Stop		Total	
		No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles
236, Nemaha	"X" Buck, "STOP"	13	9	8	5	129	86	150	100
Hays (7^{th}) Road, N. edge of Alma, Wabaunsee	"X" Buck, "STOP"	89	20	88	19	278	61	455	100
Halstead, Saline	"X" Buck, "YIELD"	8	1	42	9	414	90	464	100
Muir, Saline	"X" Buck	5	1	21	6	343	93	369	100
108^{th} St, Reno	"X" Buck, "STOP"	0	0	4	7	57	93	61	100
Arn rd, Shawnee	"X" Buck, "STOP"	47	7	95	15	509	78	651	100
Carter rd, Shawnee	"X" Buck, "STOP"	41	15	47	17	183	68	271	100
Walnut, Rossville, Shawnee	Lights, Gates, "X" Buck, "STOP"	37	9	106	26	271	65	414	100
69th St, Reno	"X" Buck, "STOP", Lights, Gates	158	11	240	16	1085	73	1483	100

Table 18: Summary of individual grade crossings during daytime

Grade Crossing	Signs Present	Full Stop		Rolling Stop		No Stop		Total	
		No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles
236, Nemaha	"X" Buck, "STOP"	13	9	8	5	126	86	147	100
Hays (7^{th}) Road, N. edge of Alma, Wabaunsee	"X" Buck, "STOP"	75	18	80	19	257	63	412	100
Halstead, Saline	"X" Buck, "YIELD"	8	2	42	9	400	89	450	100
Muir, Saline	"X" Buck	5	1	13	4	327	95	345	100
108^{th} St, Reno	"X" Buck, "STOP"	0	0	4	7	55	93	59	100
Arn rd, Shawnee	"X" Buck, "STOP"	39	7	92	16	448	77	579	100
Carter rd, Shawnee	"X" Buck, "STOP"	41	16	41	16	179	68	261	100
Walnut, Rossville, Shawnee	Lights, Gates, "X" Buck, "STOP"	33	9	94	25	245	66	372	100
69th St, Reno	"X" Buck, "STOP", Lights, Gates	158	11	238	16	1067	73	1463	100

Table 19: Summary of individual grade crossings during nighttime

Grade Crossing	Signs Present	Full Stop		Rolling Stop		No Stop		Total	
		No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles
236, Nemaha	"X" Buck, "STOP"	0	0	0	0	3	100	3	100
Hays (7th) Road, N. edge of Alma, Wabaunsee	"X" Buck, "STOP"	14	32	8	19	21	49	43	100
Halstead, Saline	"X" Buck, "YIELD"	0	0	0	0	14	100	14	100
Muir, Saline	"X" Buck	0	0	8	33	16	67	24	100
108th St, Reno	"X" Buck, "STOP"	0	0	0	0	2	100	2	100
Arn rd, Shawnee	"X" Buck, "STOP"	8	11	3	4	61	85	72	100
Carter rd, Shawnee	"X" Buck, "STOP"	0	0	6	60	4	40	10	100
Walnut, Rossville, Shawnee	Lights, Gates, "X" Buck, "STOP"	4	9	12	29	26	62	42	100
69th St, Reno	"X" Buck, "STOP", Lights, Gates	0	0	2	10	18	90	20	100

4.4 COMPARISON BETWEEN STOP SIGN AT ACTIVE GRADE CROSSINGS AND DIFFERENT PASSIVE SIGN SYSTEMS

Out of the nine grade crossings studied two were active grade crossings with flashing lights and gates and a STOP sign, and seven were passive grade crossings with STOP or YIELD with CROSSBUCK only at the crossings. Out of seven passive grade crossings five were with CROSSBUCK and STOP signs, one was CROSSBUCK only and one was with CROSSBUCK and YIELD signs. The next analysis was done between the different warning devices present at the grade crossings.

The reason for the STOP signs at the two active grade crossings was because the crossings were within 100 feet of a state highway parallel to the railroad track. A driver stopping at the STOP sign could be sure there was adequate space for his vehicle between the track and state highway. YIELD signs at the state highway minimizes backup across the grade crossing by maximizing the probability that after starting up and crossing the tracks, a driver may have a gap on the highway and proceed safely.

Table 20: Comparison of total number and percentage of vehicles recorded at grade crossings with different warning devices

	Active Grade Crossings with a STOP sign		**Passive grade Crossings with X-Buck and STOP sign**		**Passive grade Crossings with X-Buck only**		**Passive grade Crossings with X-Buck and YIELD sign**		**All passive grade crossings**	
Action	**No. of vehicles**	**Total %**	**No. of vehicles**	**Total %**	**No. of vehicles**	**Total %**	**No. of vehicles**	**Total %**	**No. of vehicles**	**Total %**
Full Stop	195	10	190	12	5	1	8	2	203	7
Rolling Stop	346	18	242	15	21	6	42	9	305	13
No Stop	1356	72	1156	73	343	93	414	89	1913	80
Total	1897	100	1588	100	369	100	464	100	2421	100

From Table 20 we can see that a total of 1897 vehicles were recorded at the two active grade crossings with a STOP sign, out of which 10% (195 vehicles) came to a full stop,

18% (346 vehicles) did a rolling stop and 72% (1356 vehicles) did not stop. At the two active grade crossings with a STOP sign, driver's reaction at the STOP sign was analyzed while lights and gates were inactive. A total of 1588 vehicles were recorded at passive grade crossings with CROSSBUCK and STOP signs, out of which 12% (190 vehicles) came to a full stop, 15% (242 vehicles) did a rolling stop and 73% (1156 vehicles) did not stop. A total of 369 vehicles were recorded at passive grade crossings with CROSSBUCK signs only, out of which 1% (5 vehicles) came to a full stop, 6% (21 vehicles) did a rolling stop and 93% (343 vehicles) did not stop. A total of 464 vehicles were recorded at passive grade crossings with CROSSBUCK and YIELD signs, out of which 2% (8 vehicles) came to a full stop, 9% (42 vehicles) did a rolling stop and 89% (414 vehicles) did not stop. A total of 2421 vehicles were recorded at all passive grade crossings, out of which 7% (203 vehicles) came to a full stop, 13% (305 vehicles) did a rolling stop and 80% (1913 vehicles) did not stop.

Figure 18 shows a comparison between the two grade crossings with flashing lights and gates (active grade crossings), CROSSBUCK and STOP sign and grade crossings with passive warning signs (passive grade crossings). From this figure we can see that a greater percentage of drivers stop at the active grade crossings with a STOP sign than the passive grade crossings. At the active grade crossings, 10% of the drivers stopped completely in comparison to 7% of drivers at passive grade crossings. At the two active grade crossings 18% drivers did a rolling stop while 13% did a rolling stop at passive grade crossings and finally 72% drivers did not stop at the two active grade crossings with a STOP sign and 80% of the drivers did not stop at passive grade crossings.

This comparison indicates that a higher percentage of drivers stop completely at the STOP sign at the two active grade crossings; 10% vs. 7%. However, to check if the difference is statistically significant or not statistical tests were done at the end of this section. Resources were not available to determine vehicle speed or driver's looking behavior and there was no way to determine if a driver coming to a full stop or rolling stop looked for a train or if a driver not stopping at all did look for a train.

Out of the nine grade crossings selected, one passive grade crossing has CROSSBUCK sign only (Muir grade crossing, Saline County dot # 818399P) and one passive grade crossing has CROSSBUCK and YIELD signs (Halstead grade crossing, Saline County dot # 818393Y). At these grade crossings, legally drivers are not supposed to stop completely. So if we remove these two grade crossings from the comparison between passive grade crossings and active grade crossings with a STOP sign, we can see that the results are totally different. As we can see from the Table 20 (on page 49) that a greater percentage of drivers stop at the passive grade crossings with a STOP sign than the active grade crossings. At the active grade crossings, 10% of the drivers stopped fully in comparison to 12% of drivers at passive grade crossings. At the two active grade crossings 18% drivers did a rolling stop while 15% did a rolling stop at passive grade crossings and finally 72% drivers did not stop at the two active grade crossings with a STOP sign and 73% of the drivers did not stop at passive grade crossings.

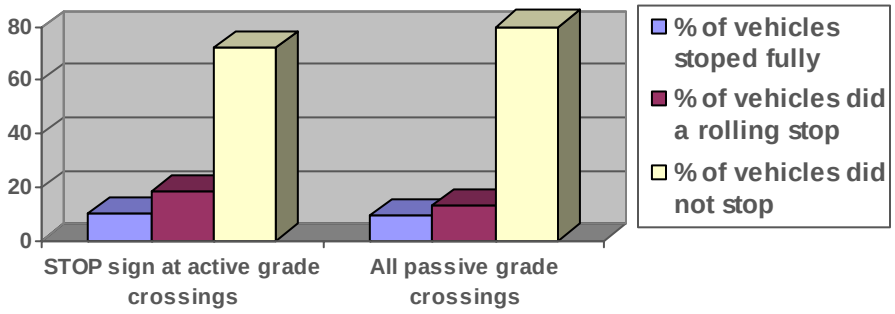


Figure 18: Comparison between stop signs at active grade crossings and passive grade crossings

Figure 19 shows the comparison between different passive warning devices at passive grade crossings. At passive grade crossings with CROSSBUCK and STOP signs as warning devices, 12% (190 vehicles) stopped completely, 15% (242 vehicles) did a rolling stop and 73% (1156 vehicles) did not stop. In fact, passive grade crossings with CROSSBUCK and STOP signs had better stopping behavior than active grade crossings with a STOP sign. Figure 20 represents the comparison between the active grade

crossings with a STOP sign and passive grade crossings with CROSSBUCK and STOP signs.

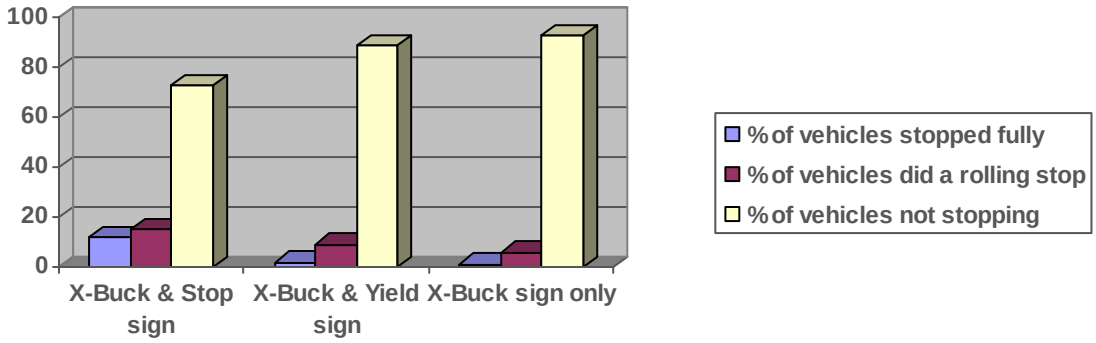


Figure 19: Comparison between passive grade crossings with different sign systems

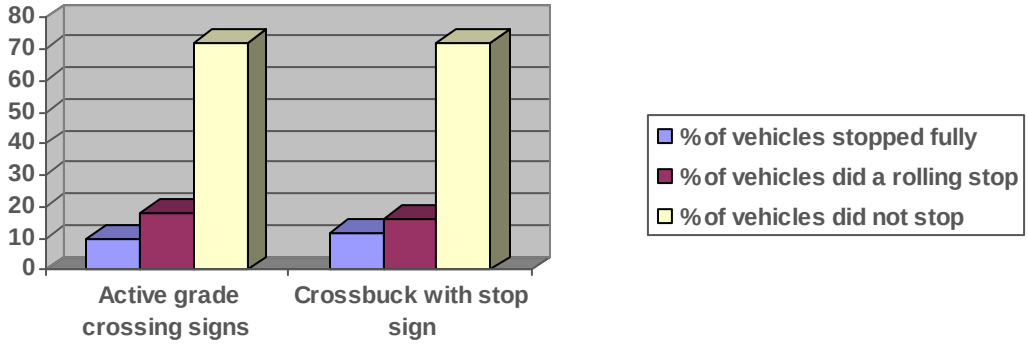


Figure 20: Comparison between STOP sign at active grade crossings and passive grade crossings

→ STATISTICAL TEST

Statistical test using "Pooled Estimate" of population variance between active grade crossing with Stop Sign (Walnut Street, 69th Street) vs. Passive grade crossing with Stop sign (Nemaha Street 236, Alma, 108th Street, Arn road, Carter road)

Table 21: Mean of Full Stop, Rolling Stop and No Stop in active grade crossings with STOP sign and passive grade crossings with STOP sign

Active Grade Crossings With Stop Sign				Passive Grade Crossings With Stop Sign			
	Full Stop	**Rolling Stop**	**No Stop**		**Full Stop**	**Rolling Stop**	**No Stop**
Walnut	37	106	271	Nemaha	13	8	129
69th	158	240	1085	Alma	89	88	278
				108th	0	4	57
				Arn	47	95	509
				Carter	41	47	183
Mean	**97.5**	**173**	**678**	**Mean**	**38**	**48.4**	**231.2**

Case 1: Drivers stopping completely at the grade crossings.

Hypotheses are,

$$H_0 : \mu_1 = \mu_2$$
$$H_1 : \mu_1 \neq \mu_2$$

The null hypothesis is there is no significant difference between the drivers stopping at active grade crossings with Stop sign and passive grade crossings with Stop sign.

$$\sum \left(x_1 - \overline{x_1}\right)^2 = (37 - 97.5)^2 + (158 - 97.5)^2$$
$$= 7320.5$$

$$\sum \left(x_2 - \overline{x_2}\right)^2 = (13 - 38)^2 + (89 - 38)^2 + (0 - 38)^2 + (47 - 38)^2 + (41 - 38)^2$$
$$= 4760$$

$$t = \frac{(97.5 - 38)}{\sqrt{7320.5 + 4760}} \sqrt{\frac{2 * 5 * 5}{7}}$$
$$= 1.445$$

Since value of t, 1.445 is less than 2.571 the value of $t_{0.025}$ for 5 degree of freedom, null hypothesis can not be rejected.

Note: It was assumed that population variance is equal. To check if that has any effect on conclusion or not following test is performed.

$n_1 = 2$

$n_2 = 5$

$$S_1^2 = \frac{7320.5}{n_1 - 1} = \frac{7320.5}{1} = 7320.5$$

$$S_2^2 = \frac{4760}{n_2 - 1} = \frac{4760}{4} = 1190$$

$$F = \frac{7320.5}{1190} = 6.15$$

$$For \alpha = 0.02 ..... F_{0.01}(1,4) = 21.20$$

$$F < F_\alpha$$

Thus Null Hypothesis can not be rejected.

So we can say that there is no significant statistical difference between the drivers stopping completely at active grade crossings with Stop sign and passive grade crossings with Stop sign.

Case 2: Drivers doing rolling stop at the grade crossings.

Hypotheses are,

$$H_0 : \mu_1 = \mu_2$$
$$H_1 : \mu_1 \neq \mu_2$$

The null hypothesis is there is no significant difference between the drivers doing rolling stop at active grade crossings with Stop sign and passive grade crossings with Stop sign.

$$\sum \left(x_1 - \overline{x_1}\right)^2 = (106-173)^2 + (240-173)^2$$

$$= 8973$$

$$\sum \left(x_2 - \overline{x_2}\right)^2 = (8-48.4)^2 + (88-48.4)^2 + (4-48.4)^2 + (95-48.4)^2 + (47-48.4)^2$$

$$= 5373.84$$

$$t = \frac{(173-48.4)}{\sqrt{8973+5373.4}}\sqrt{\frac{2*5*5}{7}}$$

$$= 2.78$$

Since value of t, 2.78 is greater than 2.571 the value of $t_{0.025}$ for 5 degree of freedom, null hypothesis is rejected.

So we can say that there is significant statistical difference between the drivers doing rolling stop at active grade crossings with Stop sign and passive grade crossings with Stop sign.

Case 3: Drivers not stopping at all at the grade crossings.

Hypotheses are,

$$H_0 : \mu_1 = \mu_2$$
$$H_1 : \mu_1 \neq \mu_2$$

The null hypothesis is there is no significant difference between the drivers not stopping at all at active grade crossings with Stop sign and passive grade crossings with Stop sign.

$$\sum \left(x_1 - \overline{x_1}\right)^2 = (271-678)^2 + (1085-678)^2$$

$$= 331298$$

$$\sum\left(x_2-\overline{x_2}\right)^2=(129-231.2)^2+(278-231.2)^2+(57-231.2)^2+(509-231.2)^2+(183-231.2)^2$$
$$=122476.8$$

$$t=\frac{(678-231.2)}{\sqrt{331298+122476.8}}\sqrt{\frac{2*5*5}{7}}$$

$$=1.77$$

Since value of t, 1.77 is less than 2.571 the value of $t_{0.025}$ for 5 degree of freedom, null hypothesis can not be rejected.

Note: It was assumed that population variance is equal. To check if that has any effect on conclusion or not following test is performed.

$n_1=2$
$n_2=5$

$$S_1^2=\frac{331298}{n_1-1}=\frac{331298}{1}=331298$$
$$S_2^2=\frac{122476.8}{n_2-1}=\frac{122476.8}{4}=30619.2$$

$$F=\frac{331298}{30619.2}=10.81$$

$$For\alpha=0.02.....F_{0.01}(1,4)=21.20$$

$$F<F_\alpha$$

Thus Null Hypothesis can not be rejected.

So we can say that there is no significant statistical difference between the drivers not stopping at all at active grade crossings with Stop sign and passive grade crossings with Stop sign.

4.5 COMPARISON BETWEEN STOPPING BEHAVIOR OF SCHOOL BUS, HEAVY TRUCKS AND OTHER VEHICLES AT THE OBSERVED GRADE CROSSINGS

It is very important to know how school bus drivers and heavy truck drivers react to different signs at grade crossings. According to law, school bus drivers are required to stop fully at all grade crossings in all conditions. School buses carry children and risking their life at grade crossing is not acceptable. Heavy trucks are huge vehicles and drivers' viewing angle, sight distance, turning capacity, etc. are very different than normal vehicles. Also, sometimes heavy trucks contain flammable items, or other hazardous materials which can create disastrous accidents if drivers don't take safe action at the grade crossings. Heavy trucks with certain cargo are required to stop at all grade crossings. In this study, it was not possible to separate those vehicles besides school buses that were required to make mandatory stops at all grade crossings. So in this section, school buses, heavy trucks and other vehicles are separated for each grade crossing and are shown in the tables in appendix B. Since there were not any heavy trucks or school buses recorded at grade crossings on Arn road, Carter road and 108th Street, no tables are presented. All of these grade crossings were passive grade crossings with STOP signs and CROSSBUCK.

Table 22: School buses, heavy trucks and other vehicles at all grade crossings

Day	No. of Heavy Trucks	Percentage	No. of School Buses	Percentage	No. of Other Vehicles	Percentage
Full Stop	9	9	7	78	364	7
Rolling Stop	11	11	1	11	590	15
No Stop	80	80	1	11	3025	78
Total	**100**	**100**	**9**	**100**	**3979**	**100**
Night	**No. of Heavy Trucks**	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	2	10	0	0	26	12
Rolling Stop	1	5	0	0	48	23
No Stop	18	85	0	0	135	65
Total	**21**	**100**	**0**	**0**	**209**	**100**
Day + Night Combined						
	No. of Heavy Trucks	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	11	9	7	78	390	7
Rolling Stop	12	10	1	11	638	15
No Stop	98	81	1	11	3160	78
Total	**121**	**100**	**9**	**100**	**4188**	**100**

Tables B1 through B6 in Appendix B shows how school bus drivers and heavy truck drivers react at each of the grade crossings. Table 22 shows the overall grade crossings summation. From Table 22 we can see that most of the heavy truck drivers do not stop at the grade crossings. If you compare heavy truck drivers' action with other vehicle drivers' action, we can see that a higher percentage of heavy truck drivers do not stop at the grade crossings. As mentioned earlier, school bus drivers are required to stop at all grade crossings but from Table 22 we can see that 11% of school bus drivers did not stop at all, 11% did a rolling stop and 78% completely stopped.

The number of school buses is too small to make any statistically reliable conclusions; however, even one school bus not stopping, or doing a rolling stop, should be of concern.

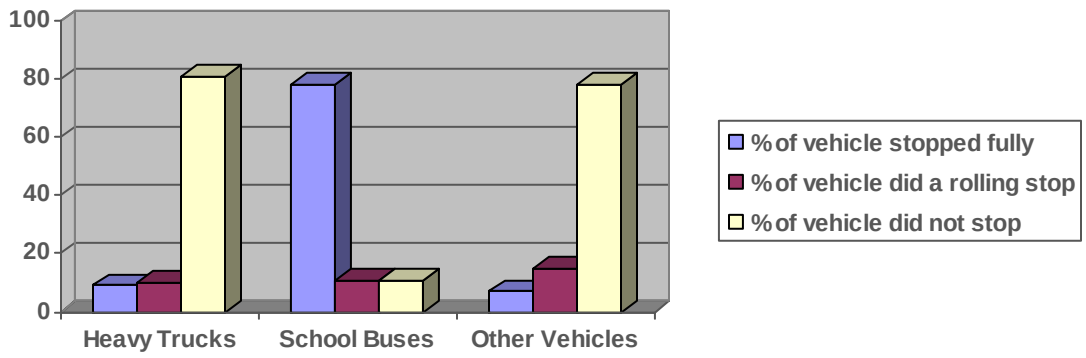


Figure 21: Comparison of school buses, heavy trucks and other vehicles (all grade crossings)

Figure 21 shows the comparison between school buses, heavy trucks and other vehicles at all grade crossings.

4.6 COMPARISON BETWEEN STOP SIGNS AT ACTIVE AND PASSIVE GRADE CROSSINGS WITH SCHOOL BUSES, HEAVY TRUCKS & OTHER VEHICLES SEPERATED

The next comparison was made between active and passive grade crossings separating, school buses, heavy trucks and other vehicles.

Table 23: Active grade crossings with separation of school buses, heavy trucks and other vehicles

Total Active grade crossings						
Day	**No. of Heavy Trucks**	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	0	0	4	80	187	10
Rolling Stop	2	33	0	0	330	18
No Stop	4	67	1	20	1307	72
Total	**6**	**100**	**5**	**100**	**1824**	**100**
Night time	**No. of Heavy Trucks**	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	0	0	0	0	4	6
Rolling Stop	0	0	0	0	14	23
No Stop	0	0	0	0	44	71
Total	**0**	**0**	**0**	**0**	**62**	**100**
Day + Night Combined						
	No. of Heavy Trucks	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	0	0	4	80	191	10
Rolling Stop	2	33	0	0	344	18
No Stop	4	67	1	20	1351	72
Total	**6**	**100**	**5**	**100**	**1886**	**100**

Tables 23 and 24 show the number and percentage of heavy trucks, school buses and other vehicles that completely stopped, performed a rolling stop or did not stop at STOP sign at active and passive grade crossings respectively.

Table 24: Passive grade crossings with separation of school buses, heavy trucks and other vehicles

Total Passive grade crossings						
Day	**No. of Heavy Trucks**	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	9	10	3	75	157	8
Rolling Stop	9	10	1	25	260	12
No Stop	76	80	0	0	1679	80
Total	**94**	**100**	**4**	**100**	**2096**	**100**
Night	**No. of Heavy Trucks**	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	2	10	0	0	32	19
Rolling Stop	1	5	0	0	34	21
No Stop	18	85	0	0	100	60
Total	**21**	**100**	**0**	**0**	**166**	**100**
Day + Night Combined						
	No. of Heavy Trucks	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	11	10	3	75	189	8
Rolling Stop	10	9	1	25	294	13
No Stop	94	81	0	0	1779	79
Total	**115**	**100**	**4**	**100**	**2262**	**100**

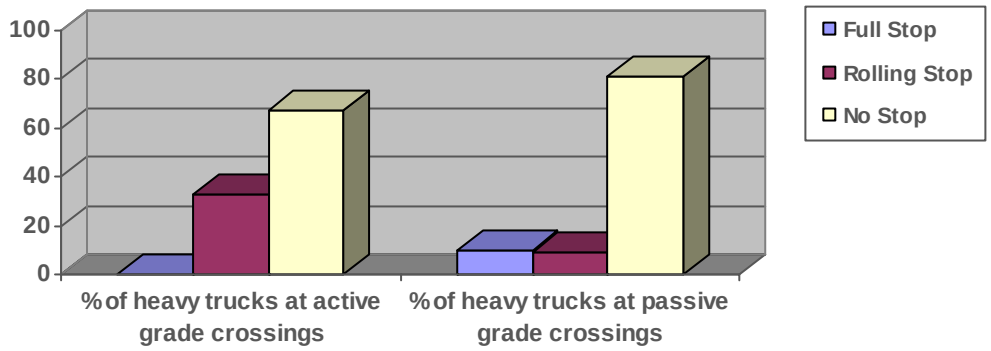


Figure 22: Comparison of heavy truck stopping behavior between STOP signs at active and passive grade crossings

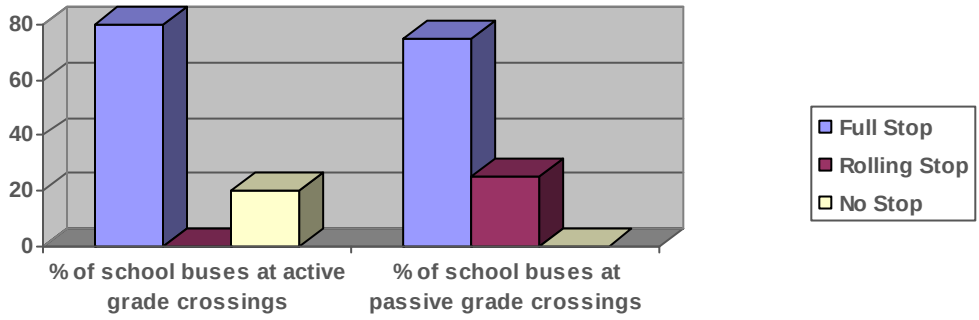


Figure 23: Comparison of School buses stopping behavior between STOP signs at active and passive grade crossings.

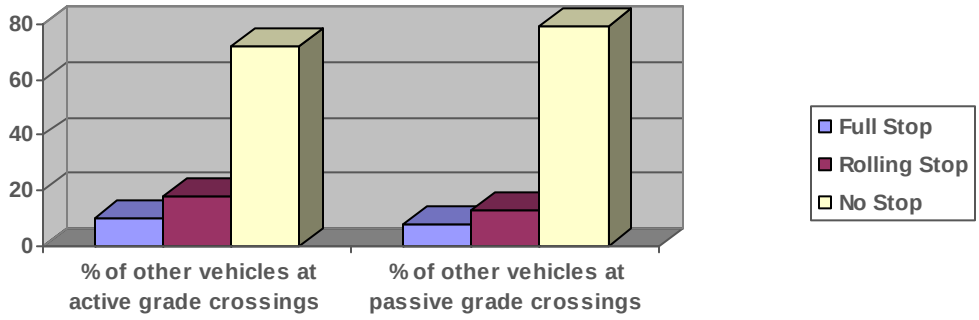


Figure 24: Comparison of all other vehicles stopping behavior between STOP signs at active and passive grade crossings.

Figures 22 through 24 shows comparisons between STOP signs at active grade crossings and passive grade crossings with respect to heavy trucks, school buses and other vehicles. From Figure 22 we can see that at passive grade crossings a higher percentage of heavy trucks completely stopped than at STOP signs at the two active grade crossings. However, a higher percentage of heavy trucks did not stop at passive grade crossings than at active grade crossings. For school buses we can see from Figure 23 that a higher percentage of school buses completely stopped at the STOP sign at the two active grade crossings than at the passive grade crossings and also a higher percentage of school buses did not stop at the STOP sign at the two active grade crossings than at the passive grade

crossings. One point that should be noted is that these numbers are too small to draw any statistically reliable conclusions.

Figure 24 shows that a higher percentage of other vehicles completely stopped at the STOP signs at the two active grade crossings than at the passive grade crossings and a lower percentage of other vehicles did not stop at STOP sign at the two active grade crossings than at the passive grade crossings. A higher percentage of other vehicles did a rolling stop at STOP signs at the two active grade crossings than at the passive grade crossings.

4.7 COMPARISON OF APPROACHES WITH POOR SIGHT DISTANCE AT GRADE CROSSINGS WITH A STOP SIGN

Sight distance was estimated by the research team along the tracks in either direction from various approach distances. Out of the passive grade crossings with STOP signs, two had poor sight distance on one approach. Nemaha County (southbound) and Carter road, (southbound) had restricted sight distance. Figure 25(a) shows the carter road grade crossing and 25(b) shows the Nemaha county, street 236 grade crossing. Nemaha County (southbound) has a hill to the right, while Carter road has a hill, a curve and bushes blocking the view of the eastbound trains generating poor sight distance on the south approach of each grade crossing. Nemaha County, street 236 grade crossing has approximately 15.24 meters (50 feet) of sight distance from 45.72 meters (150 feet) away from the tracks (southbound). Carter road grade crossing has approximately 7.62 meters (25 feet) of sight distance from 30.48 meters (100 feet) away from tracks (southbound). Out of these two grade crossings, Carter road has the more restricted sight distance of the two, and Carter road (southbound), is the most restricted approach of any in this study.

The authors believe that safe driver response at southbound Carter road would definitely be a full stop. It should be noted that for the rolling stop category (less than 10 mph) there

was no way to determine if drivers were going to slowed down because of the grade crossing or because of the highway just past the tracks.

a) Carter road, Shawnee (Southbound)

b) Nemaha (Southbound, with train)

Figure 25: Poor sight distance passive grade crossings

Table 25: Comparison of Nemaha county and Carter road (Southbound approach)

Action	Nemaha County (Southbound)		Carter road (Southbound)	
	No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles
Full Stop	8	12	33	24
Rolling Stop	4	6	35	25
No Stop	56	82	72	51
Total	68	100	140	100

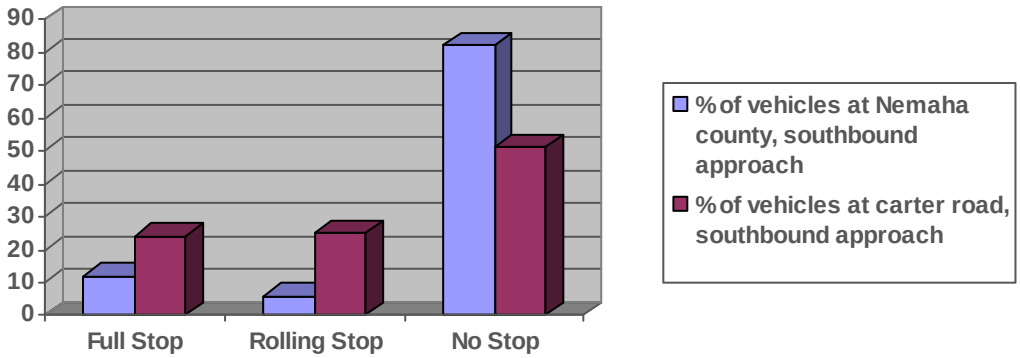


Figure 26: Comparison between southbound approaches (poor sight distance approaches) of Street 236 Nemaha County and Carter road

Figure 26 shows comparison between Nemaha county, southbound approach and Carter road southbound approach. Both the grade crossings have a STOP sign and both the approaches have poor sight distance with Carter road being more restricted. From Figure 26 and Table 25 we can see that a higher percentage of drivers on the southbound approach stopped completely at the Carter road grade crossing and a lower percentage of drivers did not stop. If we consider rolling stop as a safe action, a higher percentage of drivers also did a rolling stop at Carter road.

The next comparison was done between southbound and northbound approach of Nemaha County and Carter road passive grade crossings. Both the passive grade crossings have poor sight distance on southbound approach and good sight distance on the northbound approaches. The comparison is between stopping behavior on a poor sight distance approach vs. stopping behavior on a good sight distance approach. Sight distance on both northbound approaches is basically unlimited.

Table 26: Comparison of both the approaches on street 236 Nemaha county grade crossings

Action	Nemaha County (Southbound)		Nemaha County (Northbound)	
	No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles
Full Stop	8	12	5	7
Rolling Stop	4	6	4	6
No Stop	56	82	73	87
Total	68	100	82	100

Table 27: Comparison of both the approaches on Carter road grade crossings

Action	Carter road (Southbound)		Carter road (Northbound)	
	No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles
Full Stop	33	24	8	7
Rolling Stop	35	25	12	9
No Stop	72	51	111	84
Total	140	100	131	100

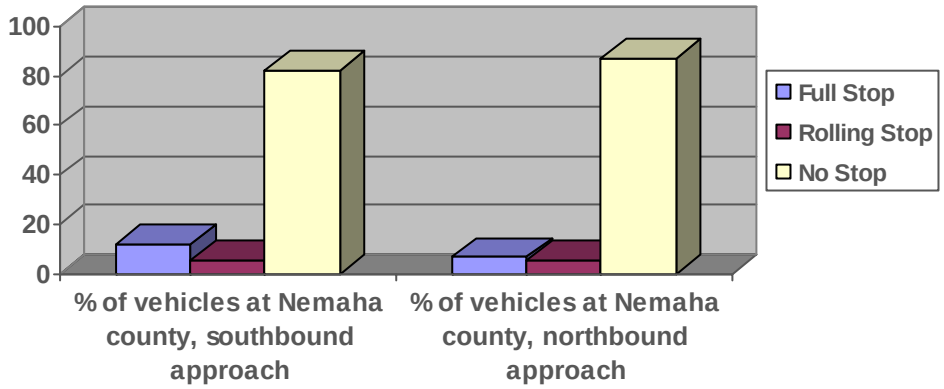


Figure 27: Comparison between southbound approach and northbound approach of Street 236 Nemaha County grade crossing

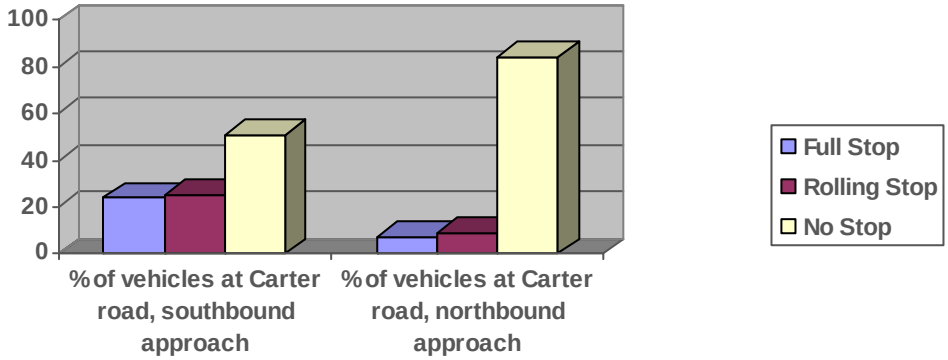


Figure 28: Comparison between southbound approach and northbound approach of Carter road grade crossing

From above comparisons we can see that a higher percentage of drivers stop completely when they were driving on the poor sight distance (southbound) approach. Figures 27 and 28 and Tables 26 and 27 show that a higher percentage of the drivers stopped fully at the southbound approach than at the northbound approach of both Nemaha County and Carter road grade crossings. A lower percentage of drivers on the southbound approach did not stop than on the northbound approach of both of these passive grade crossings.

The next comparison was done between the Carter road, southbound approach (the most restricted sight distance in the study) with all other STOP sign location approaches except Nemaha southbound, i.e. Arn road, Alma, 108th Street.

Table 28: Comparison of southbound approach on Carter road grade crossings and other STOP sign location approaches (Arn road, Alma, 108th Street)

Action	Carter road (Southbound)		Other STOP sign locations (all approaches) (Arn road, Alma, 108th Street)	
	No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles
Full Stop	33	24	136	12
Rolling Stop	35	25	187	16
No Stop	72	51	844	72
Total	140	100	1167	100

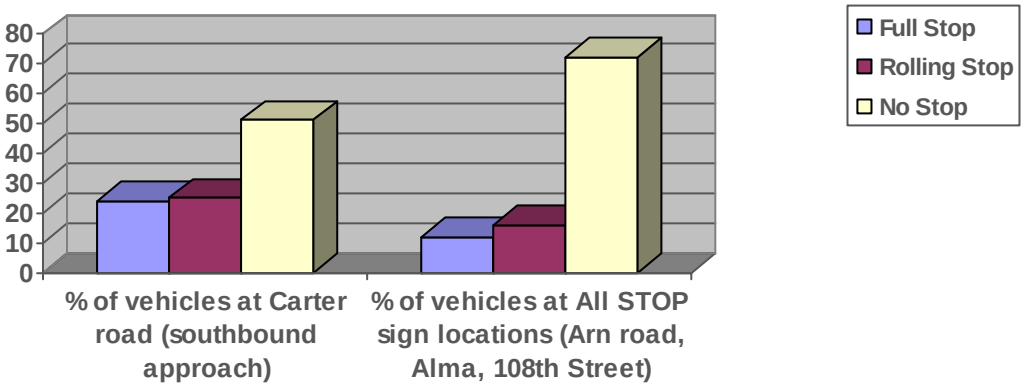


Figure 29: Comparison between southbound approach of Carter road grade crossing and all STOP sign location grade crossings (Arn road, Alma, 108th Street)

From Figure 29 and Table 28 we can see that 24% of the drivers stopped completely on the southbound approach of the Carter road grade crossings, 25% of the drivers did a rolling stop and 51% of the drivers did not stop. On the other hand at all STOP sign location grade crossings with good sight distance on the approaches (Arn road, Alma, and 108th Street) 12% of the drivers stopped completely, 16% of the drivers did a rolling stop and 72% of the drivers did not stop at all.

From the above comparison we can see that a higher percentage of the drivers stopped completely at southbound approach of the Carter road grade crossings. A lower percentage of the drivers did not stop at all at southbound approach of the Carter road grade crossings. Approximately 25% of the drivers did a rolling stop at southbound approach of the Carter road grade crossings but there is no way to determine whether the drivers slowed down for grade crossing or the highway just past the tracks. However, this study indicates that full stops are about double on approaches with restricted sight distance.

4.8 COMPARISON OF ARN ROAD AND CARTER ROAD GRADE CROSSINGS

Arn road, Shawnee County (dot # 818613S) and Carter road, Shawnee County (dot # 818604T) are both passive grade crossings with CROSSBUCK and STOP signs. They both are on tracks parallel to a state highway, US-24 within 30.48 meters (100 feet). Carter road, southbound approach has very limited sight distance while southbound approach of Arn road has good sight distance. Arn road has 45.72 meters (150 feet, RT) and infinity (LT) sight distance from 30.48 meters (100 feet) away from the tracks (southbound) while Carter road has 7.62 meters (25 feet, RT) and 15.24 meters (50 feet, LT) sight distance from 30.48 meters (100 feet) away from the tracks (southbound). Both of these approaches are toward US-24. The next comparison is made between southbound approach of Arn road and Carter road grade crossings.

Table 29: Comparison of Arn road and Carter road (Southbound approach)

Action	Arn road (Southbound)		Carter road (Southbound)	
	No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles
Full Stop	40	12	33	24
Rolling Stop	64	20	35	25
No Stop	220	68	72	51
Total	324	100	140	100

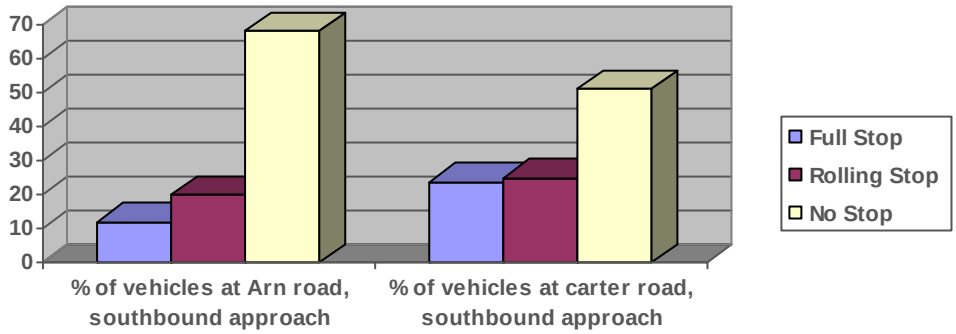


Figure 30: Comparison between southbound approach of Arn road and Carter road

From Figure 30 and Table 29 we can see that a higher percentage of drivers stopped fully at Carter road (southbound approach) than at Arn road (southbound approach). Carter road sight distance is more restricted (7.62 meters (25 feet, RT) and 15.24 meters (50 feet, LT) from 30.48 meters (100 feet) away from tracks) than Arn road southbound. It suggests that poor sight distance leads to higher stopping percentage, possibly proportional to the severity of the sight distance restriction.

4.9 COMPARISON OF GRADE CROSSING WITH PARALLEL HIGHWAY VS. GRADE CROSSING WITH NO PARALLEL HIGHWAY (ALL STOP SIGN WITH CROSSBUCK LOCATIONS)

Grade crossings at the Carter road, Arn road and 108th Street has a state highway parallel to the tracks and grade crossings at the Nemaha Street 236, Alma has no highway parallel to the grade crossings. All of the above grade crossings are passive grade crossings with STOP sign and CROSSBUCK. The objective behind this comparison is to find whether there is any difference in driver's behavior to the STOP sign if there is a state highway parallel to the tracks.

Table 30: Comparison between passive grade crossings (STOP and CROSSBUCK signs) with parallel highway and without parallel highway

Action	Passive grade crossings with parallel highway (Carter road, Arn road, 108th Street)		Passive grade crossings without parallel highway (Nemaha Street 236, Alma)	
	No. of Vehicles	% of Vehicles	No. of Vehicles	% of Vehicles
Full Stop	48	10	62	21
Rolling Stop	80	17	53	18
No Stop	355	73	186	61
Total	483	100	301	100

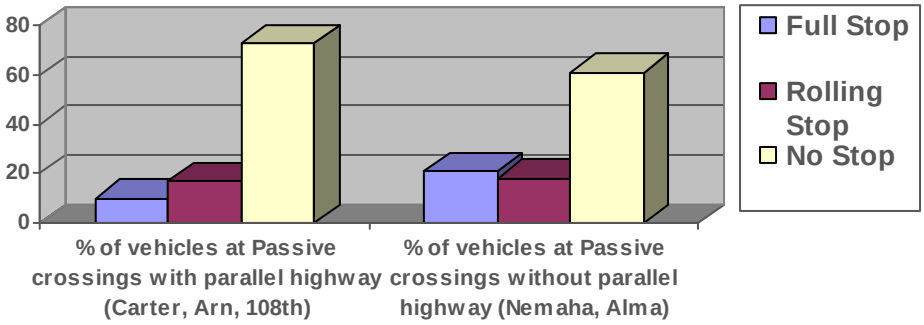


Figure 31: Comparison between passive grade crossings (STOP and CROSSBUCK signs) with parallel highway and without parallel highway

From Table 30 and Figure 31 we can see that a higher percentage of the drivers stopped completely at the passive grade crossings with no parallel highway (Nemaha Street 236, Alma) than the passive grade crossings with parallel highway (Carter road, Arn road, 108th Street). Percentage of the drivers doing a rolling stop is almost equal in both cases. The authors believes that drivers' speed at the passive grade crossings with parallel highway should definitely be slower as drivers are approaching a highway, but in the rolling category it is not possible to determine if drivers slowed down because of the crossings or because of the nearby highway. However, the sum of full stop and rolling stop is higher at the grade crossings without parallel highway, 39% vs. 27%. The authors can think of no reasonable explanation.

To check if there is any statistical difference present between driver's behavior at grade crossings with parallel highway and grade crossings with no parallel highway, statistical test is performed using "pooled estimate" of population variation as shown below:

→ STATISTICAL TEST

Statistical test using "Pooled Estimate" of population variance between grade crossings with parallel highway (Arn road, Carter road, and 108th Street) and grade crossings with no parallel highway (Alma, Nemaha Street 236).

Table 31: Mean of Full Stop, Rolling Stop and No Stop in categories grade crossings with parallel highway and grade crossings with no parallel highway

Grade Crossings with Parallel highway				**Grade Crossings with no Parallel highway**			
	Full Stop	**Rolling Stop**	**No Stop**		**Full Stop**	**Rolling Stop**	**No Stop**
Arn	47	95	509	Alma	89	88	278
Carter	41	47	183	Nemaha	13	8	129
108th	0	4	57				
Mean	**29.33**	**48.7**	**249.65**	**Mean**	**51**	**48**	**203.5**

Case 1: Drivers stopping completely at the grade crossings.

Hypotheses are,

$$H_0 : \mu_1 = \mu_2$$
$$H_1 : \mu_1 \neq \mu_2$$

The null hypothesis is there is no significant difference between the drivers stopping at Passive grade crossings with Stop sign with parallel highway (Arn road, Carter road, 108th Street) vs. passive grade crossings with Stop sign with no parallel highway (Alma, Nemaha Street 236).

$$\sum\left(x_1-\overline{x_1}\right)^2=(47-29.33)^2+(41-29.33)^2+(0-29.33)^2$$

$$=1398.67$$

$$\sum\left(x_2-\overline{x_2}\right)^2=(89-51)^2+(13-51)^2$$

$$=2888$$

$$t=\frac{(29.33-51)}{\sqrt{1398.67+2888}}\sqrt{\frac{3*2*3}{5}}$$

$$=-0.62$$

Since value of t, -0.62 is less than 3.182 the value of $t_{0.025}$ for 3 degree of freedom, null hypothesis can not be rejected.

Note: It was assumed that population variance is equal. To check if that has any effect on conclusion or not the following test is performed.

$n_1=3$

$n_2=2$

$$S_1^2=\frac{1398.67}{n_1-1}=\frac{1398.67}{2}=599.34$$

$$S_2^2=\frac{2888}{n_2-1}=\frac{2888}{1}=2888$$

$$F=\frac{599.34}{2888}=0.20$$

$For\alpha=0.02.....F_{0.01}(2,1)=5000$

$F<F_\alpha$

Thus Null Hypothesis can not be rejected.

So we can say that there is no significant statistical difference between the drivers stopping completely at Passive grade crossings with Stop sign with parallel highway (Arn road, Carter road, 108th Street) vs. passive grade crossings with Stop sign with no parallel highway (Alma, Nemaha Street 236).

Case 2: Drivers doing rolling stop at the grade crossings.

Hypotheses are,

$$H_0 : \mu_1 = \mu_2$$
$$H_1 : \mu_1 \neq \mu_2$$

The null hypothesis is there is no significant difference between the drivers doing rolling stop at Passive grade crossings with Stop sign with parallel highway (Arn road, Carter road, 108th Street) vs. passive grade crossings with Stop sign with no parallel highway (Alma, Nemaha Street 236)

$$\sum \left(x_1 - \overline{x_1}\right)^2 = (95 - 48.7)^2 + (47 - 48.7)^2 + (4 - 48.7)^2$$
$$= 4144.67$$
$$\sum \left(x_2 - \overline{x_2}\right)^2 = (88 - 48)^2 + (8 - 48)^2$$
$$= 3200$$

$$t = \frac{(48.7 - 48)}{\sqrt{4144.67 + 3200}} \sqrt{\frac{3 * 2 * 3}{5}}$$
$$= 0.015$$

Since value of t, 0.015 is less than 3.182 the value of $t_{0.025}$ for 3 degree of freedom, the null hypothesis can not be rejected.

Note: It was assumed that population variance is equal. To check if that has any effect on conclusion or not the following test is performed.

$n_1 = 3$
$n_2 = 2$

$$S_1^2 = \frac{4144.67}{n_1 - 1} = \frac{4144.67}{2} = 2072.33$$
$$S_2^2 = \frac{3200}{n_2 - 1} = \frac{3200}{1} = 3200$$

$$F = \frac{2072.33}{3200} = 0.65$$

$$For \alpha = 0.02 ..... F_{0.01}(2,1) = 5000$$

$$F < F_\alpha$$

Thus Null Hypothesis can not be rejected.

So we can say that there is no significant statistical difference between the drivers doing rolling stop at Passive grade crossings with Stop sign with parallel highway (Arn road, Carter road, 108th Street) vs. passive grade crossings with Stop sign with no parallel highway (Alma, Nemaha Street 236).

Case 3: Drivers not stopping at all at the grade crossings.

Hypotheses are,

$$H_0 : \mu_1 = \mu_2$$
$$H_1 : \mu_1 \neq \mu_2$$

The null hypothesis can be stated as there is no significant difference between the drivers not stopping at all at Passive grade crossings with Stop sign with parallel highway (Arn road, Carter road, 108th Street) vs. passive grade crossings with Stop sign with no parallel highway (Alma, Nemaha Street 236).

$$\sum \left(x_1 - \overline{x_1}\right)^2 = (509 - 249.65)^2 + (183 - 249.65)^2 + (57 - 249.65)^2$$

$$= 108637.24$$

$$\sum \left(x_2 - \overline{x_2}\right)^2 = (278 - 203.5)^2 + (129 - 203.5)^2$$

$$= 11100.5$$

$$t = \frac{(249.65 - 203.5)}{\sqrt{108637.24 + 11100.5}} \sqrt{\frac{3*2*3}{5}}$$

$$= 0.25$$

Since value of t, 0.25 is less than 3.182 the value of $t_{0.025}$ for 3 degree of freedom, the null hypothesis can not be rejected.

Note: It was assumed that population variance is equal. To check if that has any effect on conclusion or not the following test is performed.

$n_1 = 3$

$n_2 = 2$

$$S_1^2 = \frac{108637.24}{n_1 - 1} = \frac{108637.24}{2} = 54318.62$$

$$S_2^2 = \frac{11100.5}{n_2 - 1} = \frac{11100.5}{1} = 11100.5$$

$$F = \frac{54318.62}{11100.5} = 4.89$$

$$For \alpha = 0.02 ..... F_{0.01}(2,1) = 5000$$

$$F < F_\alpha$$

Thus Null Hypothesis can not be rejected.

So we can say that there is no significant statistical difference between the drivers not stopping at all at Passive grade crossings with Stop sign with parallel highway (Arn road, Carter road, 108th Street) vs. passive grade crossings with Stop sign with no parallel highway (Alma, Nemaha Street 236).

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 GENERAL

Looking back, in 1966 Bezkorovainy-Holsinger studied grade crossings in Lincoln, NE and found that 84% of Lincoln drivers violated the law and did not stop at the STOP sign at grade crossings [14]. After 41 years this study showed that the statistics remains basically the same.

After conducting the current field study at the nine grade crossing sites it was found that the majority of drivers did not stop at the STOP signs at the grade crossings and violated the law, i.e. a law requires a full stop. At STOP signs at all passive grade crossings, 80% of drivers did not stop, 13% did a rolling stop and only 7% stopped completely at the STOP sign at the grade crossings. Even if a rolling stop could be considered to be in "compliance" and/or safe, the sum of full stop and rolling stop is only 21%. Seventy nine percent of drivers definitely ignored the STOP sign. At the active grade crossings with a STOP sign 72% of drivers did not stop, 18% did a rolling stop and only 10% stopped completely at grade crossings and if you consider a rolling stop as unsafe, 90% of drivers overall did not stop at the grade crossings and violated the law.

5.2 SPECIFIC COMPARISONS

5.2.1 Comparison Between Daytime and Nighttime

Comparison between nighttime and daytime showed that 2% more drivers came to a full stop during nighttime, 2% more drivers came to a rolling stop during nighttime and the no stop category was 4% less at night. It was not possible to find out if these differences are statistically significant or not as the nighttime sample size was too small.

5.2.2 Range of Stopping Behavior

Results from individual grade crossings showed a range of 1% to 20% for full stop; 5% to 26% for a rolling stop and 65% to 93% for no stop. Based on this comparison we can say that the majority of drivers were ignoring the STOP signs where they were present.

5.2.3 Heavy Truck Stopping Behavior

Results from the comparison between stopping behavior of school bus, heavy truck and other vehicles showed that heavy trucks had a poorer compliance percentage than other vehicles (not including school buses): Full stop (9%), rolling Stop (10%) and no stop (81%).

5.2.4 School Bus Stopping Behavior

The number of school buses was too small to make any statistically reliable conclusion however, only seven came to a full stop as required by law, one did a rolling stop and one did not stop. Even one school bus not stopping or doing a rolling stop, should be of concern.

5.2.5 Comparison of Stopping Behavior on Poor Sight Distance Approaches

Comparison of approaches with poor sight distance at grade crossings with a STOP sign showed that Carter Road (having the most severely restricted sight distance) had a higher percentage of people (24%) stopping completely than Nemaha Street 236 (12%). Also a higher percentage of drivers (25%) performed a rolling stop at Carter Road than Nemaha Street 236 (6%) and finally the not stopping category was 31% less at Carter road.

5.2.6 Comparison of Stopping Behavior Between Poor and Good Sight Distance Approaches

Results from comparison between poor sight distance and good sight distance at Nemaha Street 236 and Carter road showed that a higher percentage of drivers actually stopped at the STOP sign on poor sight distance approach than the good sight distance approach. At Nemaha Street 236 poor sight distance approach 12% of drivers stopped and at Carter Road poor sight distance approach 24% of drivers stopped.

5.2.7 Comparison of Stopping Behavior at Most Restricted Approach and All Other Passive Crossing Approaches

Comparison between southbound approach (most restricted sight distance approach) of Carter road and all other STOP sign location approaches (Arn Road, Alma, 108th Street) showed that a higher percentage of drivers (24%) stopped completely at the southbound approach of Carter Road than the combined percentage at all (Arn Road, Alma, 108th Street) other approaches of STOP sign locations (12%).

5.2.8 Comparison of Stopping Behavior at STOP sign on Grade Crossing Near Parallel Highway With Good and Bad Sight Distance

Comparison between Arn Road and Carter Road both near a parallel highway showed that 12% more drivers came to a full stop at Carter Road, 5% more drivers came to a rolling stop at Carter Road and the no stop category was 17% less at Carter Road, which has severely restricted sight distance. From this comparison we can say that poor sight distance leads to higher stopping percentage. Also, from the previous comparison on stopping behavior at Carter Road vs. Nemaha Street 236, we can see that stopping behavior may possibly proportional to the severity of the sight distance restriction.

5.2.9 Comparison of Stopping Behavior at All Passive Grade Crossings Near a Parallel Highway vs. Passive Grade Crossings With No Parallel Highway

This comparison was done between all grade crossings with parallel highway (Carter road, Arn road, 108th Street) vs. grade crossings with no parallel highway (Nemaha Street 236, Alma). It showed that a higher percentage of drivers (21%) stopped at the grade crossings with no parallel highway than the grade crossings with parallel highway (10%). Almost equal percentage of people performed a rolling stop. The sum of full stop and rolling stop was higher at the grade crossings without a parallel highway, 39% vs. 27%. A Statistical test using "pooled deviation" of population variance was done to see if there is any significant difference between the above comparison and it was found that there was no significant difference in any category (full stop, rolling stop and no stop) between the grade crossings with parallel highway (Carter road, Arn road, 108th Street) and grade crossings with no parallel highway (Nemaha Street 236, Alma).

5.2.10 Comparison Between STOP sign at Passive and Active Grade Crossings

Comparison between STOP sign at active grade crossings and STOP sign at passive grade crossings showed that 3% more drivers came to a full stop at active grade crossings with STOP sign; 5% more drivers came to a rolling stop at active grade crossings with STOP sign and the no stop category was 8% less in case of active grade crossings with STOP sign. Statistical test using "pooled deviation" of population variance was done to see if there is any significant difference between the above comparison and it was found that there was no significant difference between categories full stop and no stop between the active grade crossings with STOP sign and passive grade crossings with STOP sign. But there was statistically significant difference between the category rolling stop between the active grade crossings with STOP sign and passive grade crossings with STOP sign.

5.2.11 Comparison of All Vehicles At STOP sign At Active vs. Passive Grade Crossings

Comparison between STOP signs at active and passive grade crossings with school bus, heavy trucks and other vehicles separated showed that a higher percentage of heavy trucks stopped completely (10%) at passive grade crossings with STOP signs than active grade crossings with STOP signs (0%). However, a higher percentage of school buses (80%) stopped completely at active grade crossings with STOP signs than passive grade crossings with STOP signs (75%). But the numbers of heavy trucks and school buses were too small to draw any conclusion.

5.2.12 Grade crossings with CROSSBUCK only and CROSSBUCK with YIELD signs

At grade crossing with CROSSBUCK only sign (Muir, Saline) and grade crossing with CROSSBUCK and YIELD signs (Halstead, Saline), only 1% of drivers stopped completely which was least amongst the other grade crossings. At grade crossing with CROSSBUCK only sign (Muir, Saline), 6% of drivers performed a rolling stop and at grade crossing with CROSSBUCK and YIELD signs (Halstead, Saline), 9% of drivers performed a rolling stop. Percentages of drivers not stopping at all were 93% and 90% at Muir, Saline and Halstead, Saline grade crossings respectively.

5.3 RECOMMENDATION FOR FUTURE RESEARCH

From this study and the literature, the authors believe that the conclusions and recommendation from the 1978 FHWA Study [17], the 1988 MUTCD which was based on the 1978 FHWA study [17] and the FHWA/FRA 1993 memorandum [17, 23] are still valid today and STOP signs should not be used unless an engineering study confirms that at least four conditions exist:

1. limited sight distance,
2. substantial train traffic, e.g., two trains per day minimum,
3. a road or street of minor importance or low ADT, and

4. local police enforce the sign.

Extenuating circumstances may provide other valid reasons, however; a STOP sign should never be installed without a valid engineering study.

During this study we did not have resources to measure vehicle speed at the grade crossings. Authors feel that speed measuring devices are required to measure the exact speed by which drivers are approaching grade crossings. This would help in determining the exact reaction by the drivers. More studies should be done at grade crossings with CROSSBUCK and YIELD signs. This study had only one location with CROSSBUCK with YIELD signs. It is also important to know if drivers stopped completely at the grade crossings were because of signs or some other reasons. For that multiple cameras should be used to determine drivers' head movements. There is still lot of room for future research to be carried out in this area. Educating people about signs, rules, regulations, and laws are very much essential. Conducting different surveys based on grade crossings could be helpful to people.

REFERENCES

1. http://www.rrc.state.tx.us/division/rail/gxovervw.html "Highway-Rail Grade Crossing Safety," Accessed May 2006.
2. http://www.ntsb.gov/Recs/mostwanted/bus_grade_crossing.htm, National Transportation Safety Board Most wanted, "School Bus/Grade Crossing Safety Improvement," September 2005.
3. Fambro, D. B., Beitler, M. M., and Hubbard, S. M. "Enhancement to Passive Warning Devices at Railroad-Highway Grade Crossings," Research Report 1273-1, Texas A & M University, June 1994.
4. Russell, E. R., Cathcart, A. "The Kansas Grade Crossing Reflectorization Program," Prepared for presentation at International Grade Crossing Symposium, University of Tennessee, Knoxville, Tennessee, October 1998.
5. http://www.fra.dot.gov/us/content/1241, "Railroad Research and Development Program," Updated on November 2003.
6. Burr, T. "Drivers often on their own at train crossings," The Salt Lake Tribune, Article ID # 3344535, December 2005.
7. Russell, E. R., Rys, M., Liu, L. "A Program to Improve Safety at Typical Railroad-Highway Grade Crossings on Low Volume, Rural roads," Proceedings for the 25th CSCE Annual Conference, Canada, May 1997.
8. http://www.tc.gc.ca/tdc/projects/rail/b/5027.htm, "Analysis of the human factors contributing to grade crossing accidents," Accessed June 2006.
9. Paul, S., "Railroad crossing yield to safety," Article in Green Bay Press Gazette, January 2006.
10. Russell, E. R., Kent, W. "Highway-rail Crossing Safety Demonstration," Final Report, Contract Number DTFR53-90-C-00034, USDOT, Federal Railroad Administration, Washington, D.C., 1993.
11. Jones, R., Noyd, D., Bush, B., Wambi, F. "Railroad Grade Crossing Safety Initiatives," Unpublished Data, North Western University, June 2002.
12. Russell, E. R., Rys, M., Liu, L. "Low Volume Roads and the Grade Crossing Problem," Transportation Research Record 1652, Vol. 1, pp.79, 1999.

13. Parham, A. H., P.E., Carroll, R.W., Fambro, D. B. " Enhanced Sign Systems at Passive Highway-Railroad Grade Crossings," Project Summary Report 0-1881-S Texas Transportation Institute, The Texas A & M University System, April 2004.
14. Russell, E.R. "A new look at the value of using STOP signs at Rail-Highway grade crossings to increase safety," Presented at First International Symposium on Transportation Safety, San Diego, California, July 1979.
15. Sanders, J. H., McGee, H. W., Yoo, C. S. "Safety Feature of Stop Signs at Rail-Highway Grade Crossings," FHWA Report # FHWA-RD-78-41, March 1978.
16. Lerner N. D., Llaneras R. E., McGee H.W., Stephens D. E. "Recommended Traffic Control Devices for Railroad-Highway Grade Crossings," Final Report, Copy No. 20, NCHRP 3-57, November 2001.
17. Russell, E.R., Burnham, A. "Guidelines and Practice for the Proper use of Stop signs at Rail-Highway Grade Crossings," ITE Journal, 1999.
18. A. Burnham, "Stop Sign Effectiveness at Railroad Grade Crossing: Abuse Without Excuse," Paper presented at Third International Symposium on Railroad-Highway Grade Crossing Research and Safety, Knoxville, TN, October 1994.
19. National Transportation Safety Board, Safety at Passive Grade Crossings, Volume I: Analysis, NTSB/SS-98/02, Washington, D.C., 1998.
20. "Railroad-Highway Grade Crossing Improvement Program," Participant Notebook, National Highway Institute, February 1997.
21. Coleman, F., Eck. R. W., Russell E.R. "Railroad-Highway Grade Crossing A look forward," Transportation Research Board, 2000.
22. http://mutcd.fhwa.dot.gov/resources/policy/yieldstop_guidememo/yieldstoppolicy.htm , "Guidance for Use of YIELD or STOP Signs with the Crossbuck Sign at Passive Highway-Rail Grade Crossings," March 2006.
23. Russell, E.R. "Discussion of recent highway-railroad passive grade crossings issues: 1) The use of retroreflective materials and 2) The use of Stop and Yield Signs," Written for Presentation and Proceedings of the International Symposium of the American Public Works Association, Seattle, April 1995.
24. Attachment No. 10, Proposed changes to MUTCD guidelines, accepted by National Committee on Uniform Traffic Control Devices, June 2004.

25. Raub, R. “Examination of Highway-Rail Grade Crossing Collisions Over 10 years in Seven Midwestern States,” ITE Journal, v. 76, no. 4, p. 16-22, April 2006.
26. Raub, R. “Examination of Vehicle Crashes Nationally at Highway-Rail Grade Crossings,” ITE Journal, July 2007.
27. Miller I., Freund J. “Probability and Statistics for Engineers,” Second Edition, 1977.
28. http://mutcd.fhwa.dot.gov/pdfs/2003/Ch2B.pdf , MUTCD Guidelines, Section 2B, 2003.

APPENDIX A

DATA TABLES AND GRAPHS FOR INDIVIDUAL GRADE CROSSINGS

- **Walnut Street, Rossville, Shawnee County, Grade Crossing Dot # 813912G/UP:**

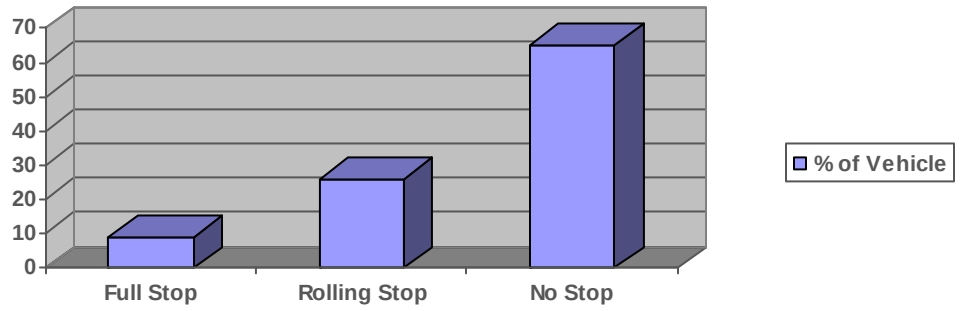


Figure A1: Total percentage of vehicles recorded at Walnut Street, Rossville, Shawnee County, Grade Crossing Dot # 813912G/UP

Table A1: Total number and percentage of vehicles recorded at Walnut Street, Rossville, Shawnee County, Grade Crossing Dot # 813912G/UP

	Number of Vehicles	% of Vehicles
Full Stop	37	9
Rolling Stop	106	26
No Stop	271	65
Total	414	100

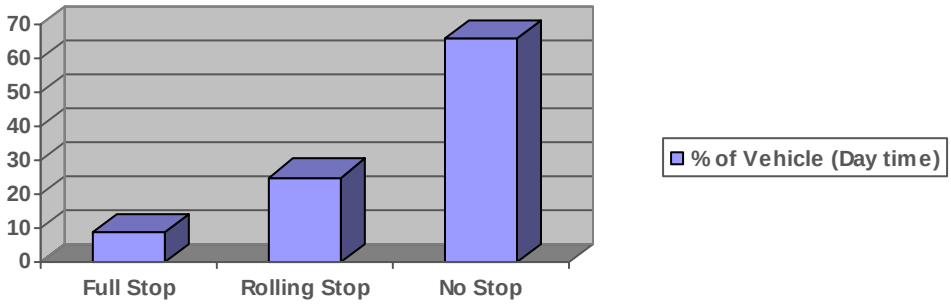


Figure A2: Total percentage of vehicles recorded at Walnut Street, Rossville, Shawnee County, Grade Crossing Dot # 813912G/UP (Daytime)

Table A2: Total number and percentage of vehicles recorded at Walnut Street, Rossville, Shawnee County, Grade Crossing Dot # 813912G/UP (Daytime)

	Number of Vehicles	% of Vehicles
Full Stop	33	9
Rolling Stop	94	25
No Stop	245	66
Total	372	100

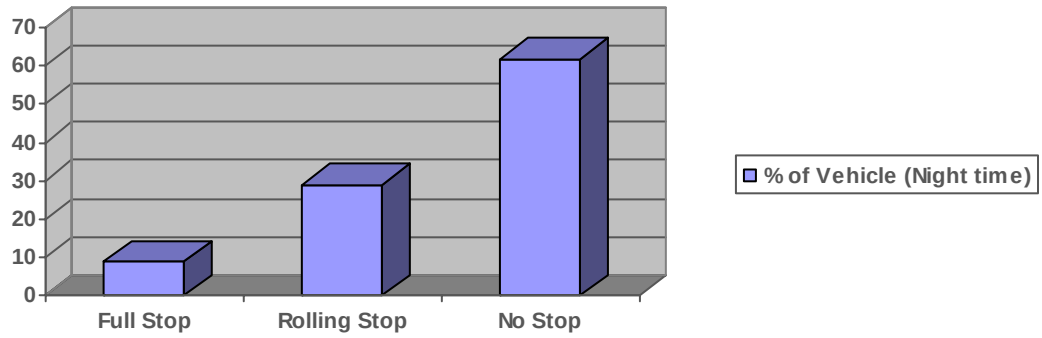


Figure A3: Total percentage of vehicles recorded at Walnut Street, Rossville, Shawnee County, Grade Crossing Dot # 813912G/UP (Nighttime)

Table A3: Total number and percentage of vehicles recorded at Walnut Street, Rossville, Shawnee County, Grade Crossing Dot # 813912G/UP (Nighttime)

	Number of Vehicles	% of Vehicles
Full Stop	4	9
Rolling Stop	12	29
No Stop	26	62
Total	42	100

- **Hays (7th) Road, N. Edge of Alma, Wabaunsee County, Grade Crossing Dot # 605343F/UP:**

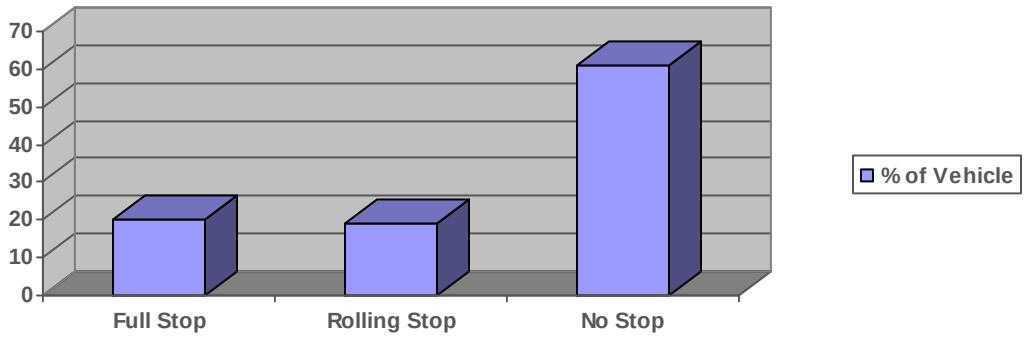


Figure A4: Total percentage of vehicles recorded at Hays (7th) Road, N. Edge of Alma, Wabaunsee County, Grade Crossing Dot # 605343F/UP

Table A4: Total number and percentage of vehicles recorded at Hays (7th) Road, N. Edge of Alma, Wabaunsee County, Grade Crossing Dot # 605343F/UP

	Number of Vehicles	% of Vehicles
Full Stop	89	20
Rolling Stop	88	19
No Stop	278	61
Total	455	100

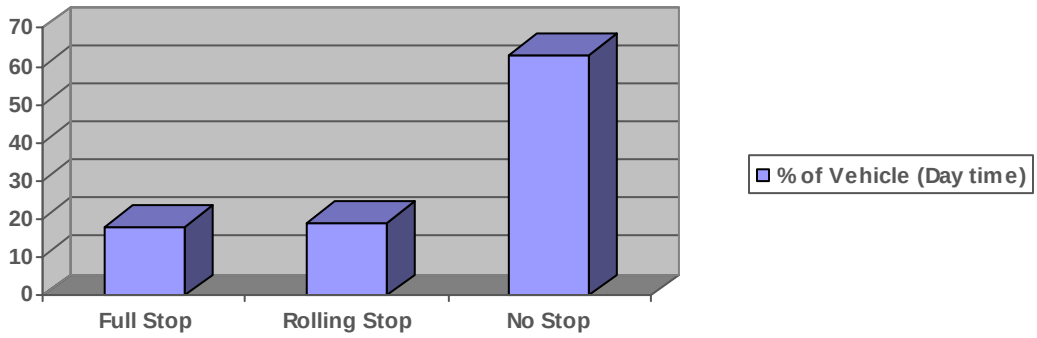


Figure A5: Total percentage of vehicles recorded at Hays (7th) Road, N. Edge of Alma, Wabaunsee County, Grade Crossing Dot # 605343F/UP (Daytime)

Table A5: Total number and percentage of vehicles recorded at Hays (7th) Road, N. Edge of Alma, Wabaunsee County, Grade Crossing Dot # 605343F/UP (Daytime)

	Number of Vehicles	% of Vehicles
Full Stop	75	18
Rolling Stop	80	19
No Stop	257	63
Total	412	100

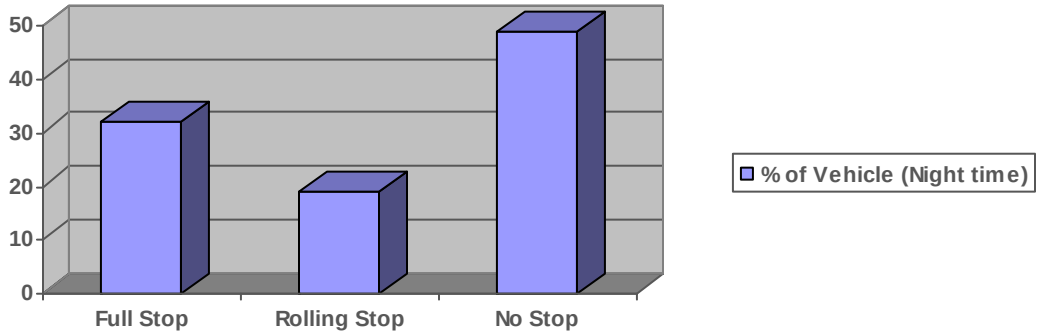


Figure A6: Total percentage of vehicles recorded at Hays (7th) Road, N. Edge of Alma, Wabaunsee County, Grade Crossing Dot # 605343F/UP (Nighttime)

Table A6: Total number and percentage of vehicles recorded at Hays (7th) Road, N. Edge of Alma, Wabaunsee County, Grade Crossing Dot # 605343F/UP (Nighttime)

	Number of Vehicles	% of Vehicles
Full Stop	14	32
Rolling Stop	8	19
No Stop	21	49
Total	43	100

- **Halstead K-140, Saline County, Grade Crossing Dot # 818393Y/UP:**

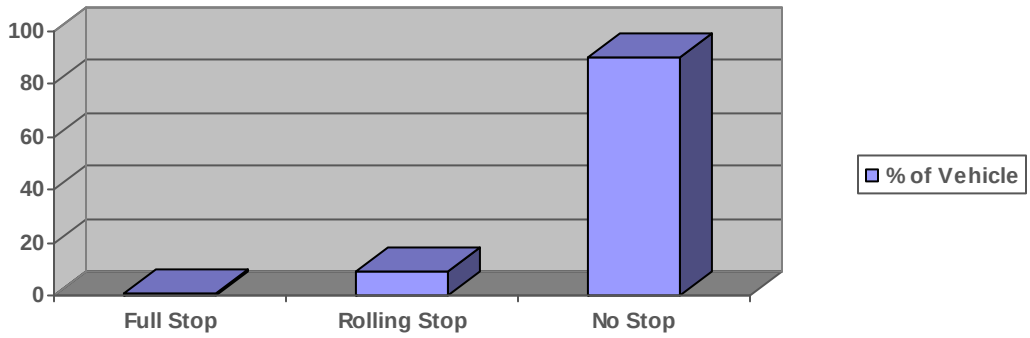


Figure A7: Total percentage of vehicles recorded at Halstead near K-140, Saline County, Grade Crossing Dot # 818393Y/UP

Table A7: Total number and percentage of vehicles recorded at Halstead near K-140, Saline County, Grade Crossing Dot # 818393Y/UP

	Number of Vehicles	% of Vehicles
Full Stop	8	1
Rolling Stop	42	9
No Stop	414	90
Total	464	100

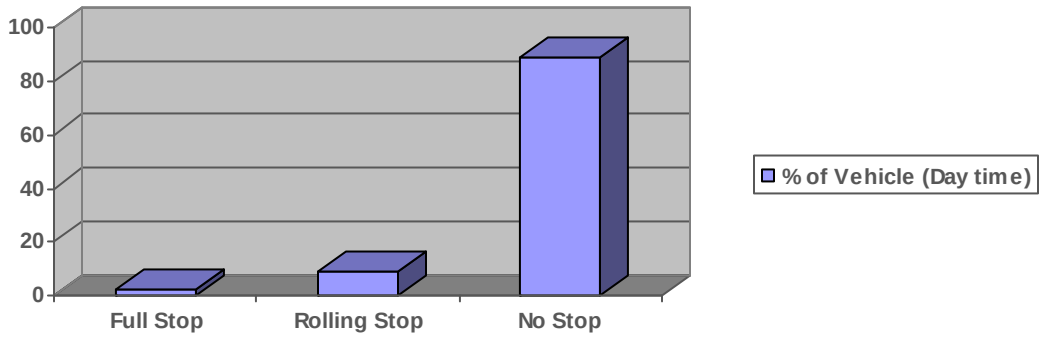


Figure A8: Total percentage of vehicles recorded at Halstead near K-140, Saline County, Grade Crossing Dot # 818393Y/UP (Daytime)

Table A8: Total number and percentage of vehicles recorded at Halstead near K-140, Saline County, Grade Crossing Dot # 818393Y/UP (Daytime)

	Number of Vehicles	% of Vehicles
Full Stop	8	2
Rolling Stop	42	9
No Stop	400	89
Total	450	100

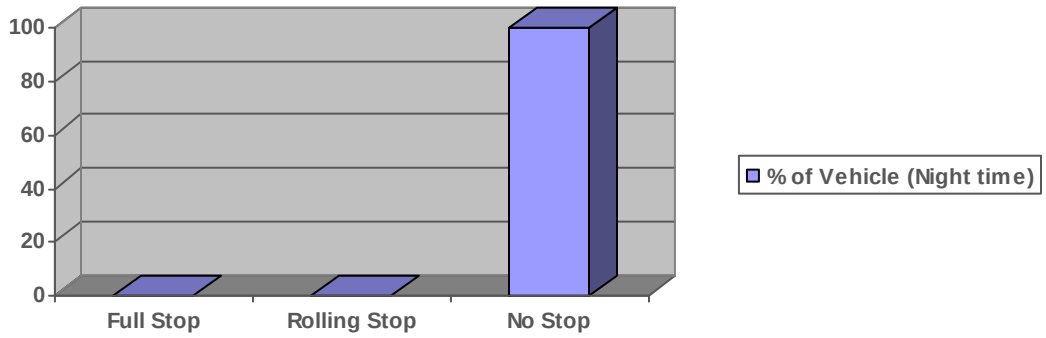


Figure A9: Total percentage of vehicles recorded at Halstead near K-140, Saline County, Grade Crossing Dot # 818393Y/UP (Nighttime)

Table A9: Total number and percentage of vehicles recorded at Halstead near K-140, Saline County, Grade Crossing Dot # 818393Y/UP (Nighttime)

	Number of Vehicles	% of Vehicles
Full Stop	0	0
Rolling Stop	0	0
No Stop	14	100
Total	14	100

- **Muir K-140, Saline County, Grade Crossing Dot # 818399P/UP:**

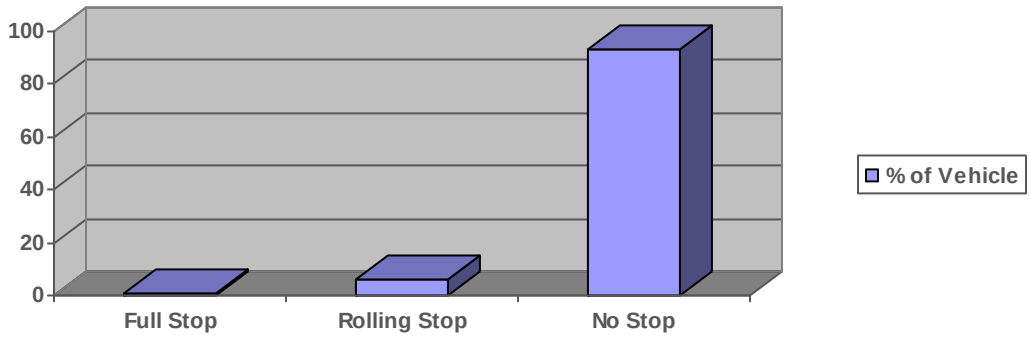


Figure A10: Total percentage of vehicles recorded at Muir near K-140, Saline County, Grade Crossing Dot # 818399P/UP

Table A10: Total number and percentage of vehicles recorded at Muir near K-140, Saline County, Grade Crossing Dot # 818399P/UP

	Number of Vehicles	% of Vehicles
Full Stop	5	1
Rolling Stop	21	6
No Stop	343	93
Total	369	100

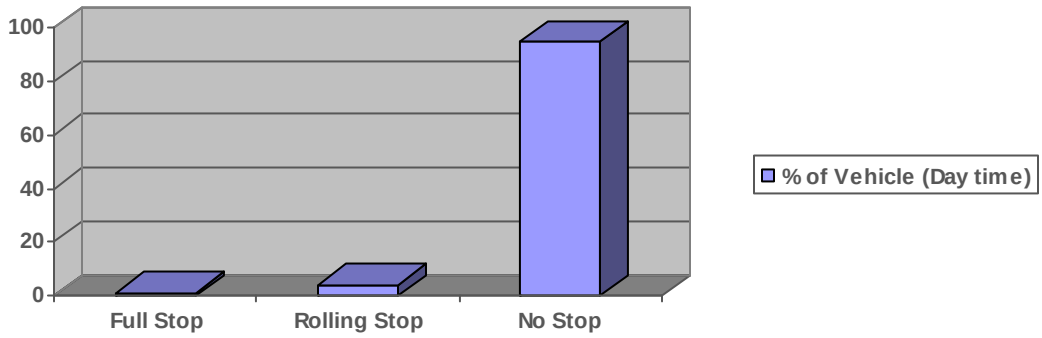


Figure A11: Total percentage of vehicles recorded at Muir near K-140, Saline County, Grade Crossing Dot # 818399P/UP (Daytime)

Table A11: Total number and percentage of vehicles recorded at Muir near K-140, Saline County, Grade Crossing Dot # 818399P/UP (Daytime)

	Number of Vehicles	% of Vehicles
Full Stop	5	1
Rolling Stop	13	4
No Stop	327	95
Total	345	100

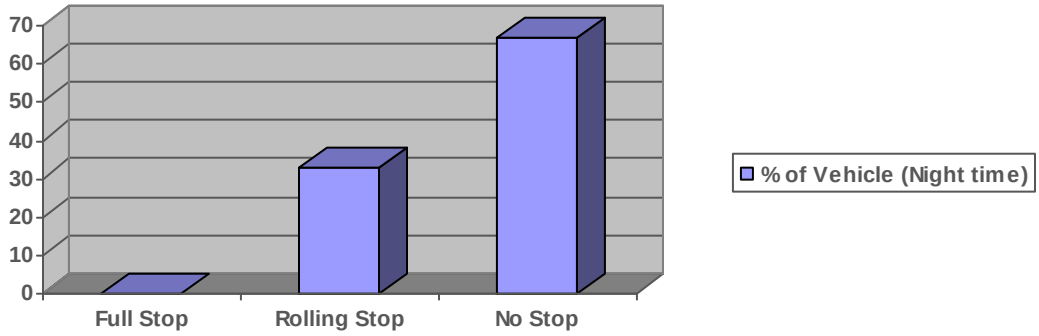


Figure A12: Total percentage of vehicles recorded at Muir near K-140, Saline County, Grade Crossing Dot # 818399P/UP (Nighttime)

Table A12: Total number and percentage of vehicles recorded at Muir near K-140, Saline County, Grade Crossing Dot # 818399P/UP (Nighttime)

	Number of Vehicles	% of Vehicles
Full Stop	0	0
Rolling Stop	8	33
No Stop	16	67
Total	24	100

- **108th Street, near Hutchinson, Reno County, Grade Crossing Dot # 602966E/UP:**

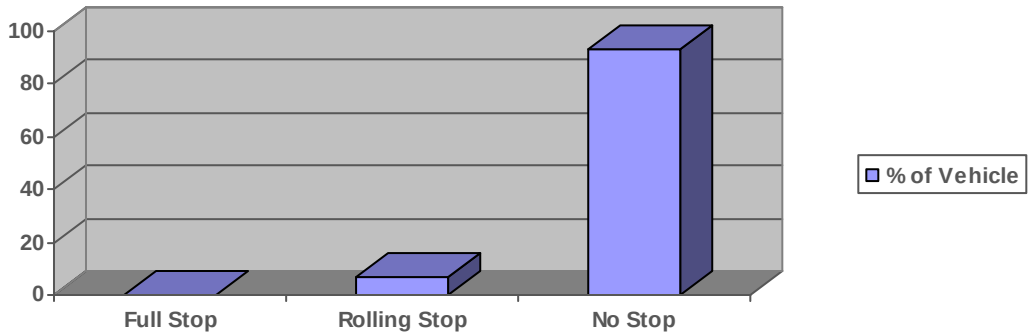


Figure A13: Total percentage of vehicles recorded at 108th Street, near K-61 Hutchinson, Reno County, Grade Crossing Dot # 602966E/UP

Table A13: Total number and percentage of vehicles recorded at 108th Street, near K-61 Hutchinson, Reno County, Grade Crossing Dot # 602966E/UP

	Number of Vehicles	% of Vehicles
Full Stop	0	0
Rolling Stop	4	7
No Stop	57	93
Total	61	100

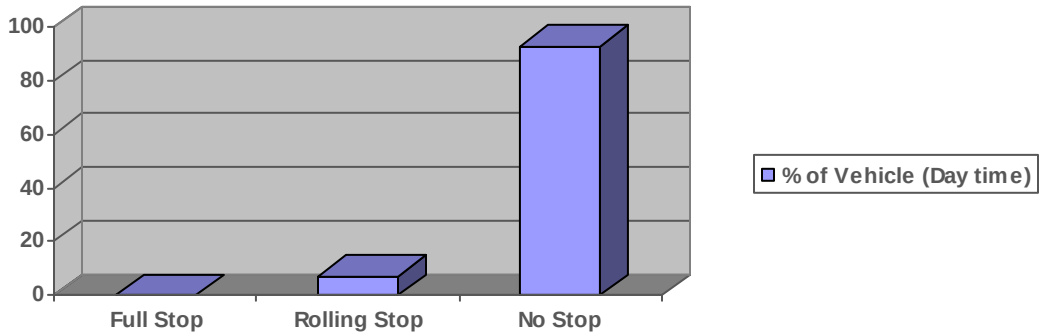


Figure A14: Total percentage of vehicles recorded at 108th Street, near K-61 Hutchinson, Reno County, Grade Crossing Dot # 602966E/UP (Daytime)

Table A14: Total number and percentage of vehicles recorded at 108th Street, near K-61 Hutchinson, Reno County, Grade Crossing Dot # 602966E/UP (Daytime)

	Number of Vehicles	% of Vehicles
Full Stop	0	0
Rolling Stop	4	7
No Stop	55	93
Total	59	100

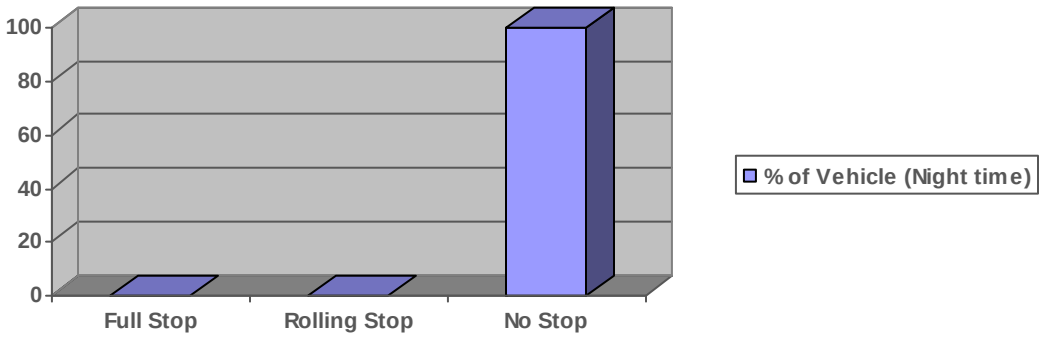


Figure A15: Total percentage of vehicles recorded at 108th Street, near K-61 Hutchinson, Reno County, Grade Crossing Dot # 602966E/UP (Nighttime)

Table A15: Total number and percentage of vehicles recorded at 108th Street, near K-61 Hutchinson, Reno County, Grade Crossing Dot # 602966E/UP (Nighttime)

	Number of Vehicles	% of Vehicles
Full Stop	0	0
Rolling Stop	0	0
No Stop	2	100
Total	2	100

- **69th Street near Hutchinson, Reno County, Grade Crossing Dot # 602960N/UP:**

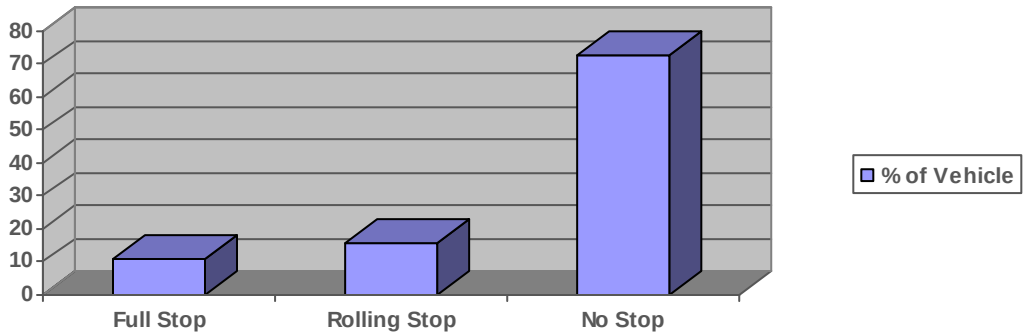


Figure A16: Total percentage of vehicles recorded at 69th Street near K-61 Hutchinson, Reno County, Grade Crossing Dot # 602960N/UP

Table A16: Total number and percentage of vehicles recorded at 69th Street near K-61 Hutchinson, Reno County, Grade Crossing Dot # 602960N/UP

	Number of Vehicles	% of Vehicles
Full Stop	158	11
Rolling Stop	240	16
No Stop	1085	73
Total	1483	100

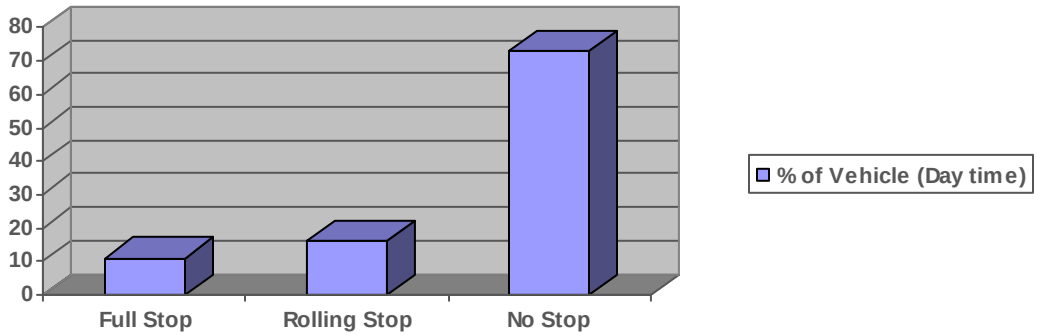


Figure A17: Total percentage of vehicles recorded at 69th Street near K-61 Hutchinson, Reno County, Grade Crossing Dot # 602960N/UP (Daytime)

Table A17: Total number and percentage of vehicles recorded at 69th Street near K-61 Hutchinson, Reno County, Grade Crossing Dot # 602960N/UP (Daytime)

	Number of Vehicles	% of Vehicles
Full Stop	158	11
Rolling Stop	238	16
No Stop	1067	73
Total	1463	100

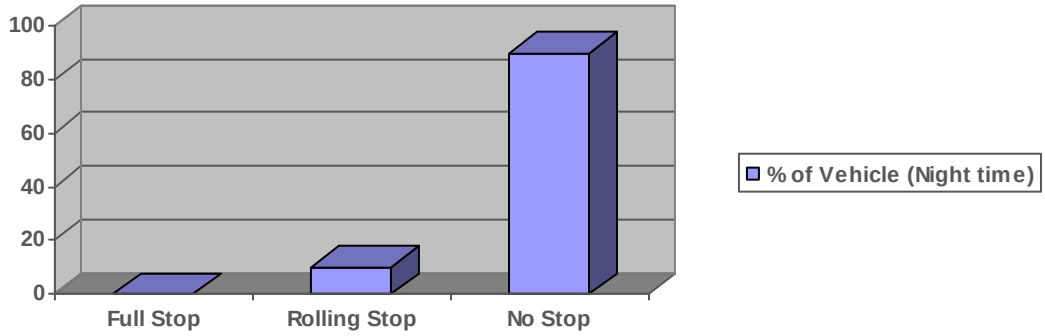


Figure A18: Total percentage of vehicles recorded at 69th Street near K-61 Hutchinson, Reno County, Grade Crossing Dot # 602960N/UP (Nighttime)

Table A18: Total number and percentage of vehicles recorded at 69th Street near K-61 Hutchinson, Reno County, Grade Crossing Dot # 602960N/UP (Nighttime)

	Number of Vehicles	% of Vehicles
Full Stop	0	0
Rolling Stop	2	10
No Stop	18	90
Total	20	100

- **Arn road, US-24, Shawnee County, Grade Crossing Dot # 818613S/UP:**

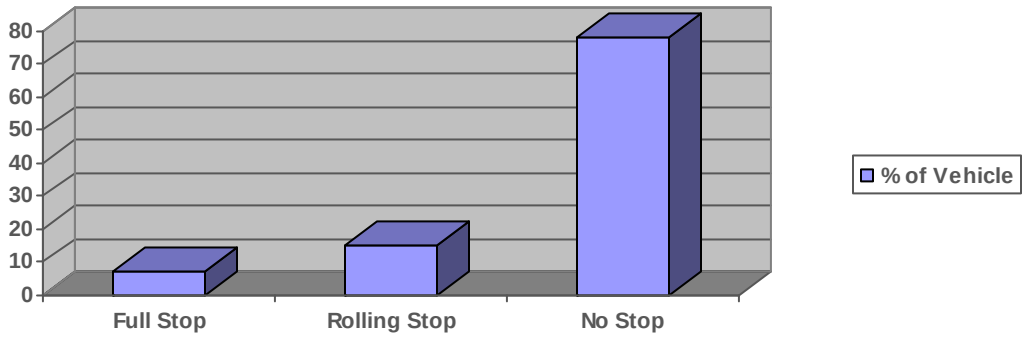


Figure A19: Total percentage of vehicles recorded at Arn road, near US-24, Shawnee County, Grade Crossing Dot # 818613S/UP

Table A19: Total number and percentage of vehicles recorded at Arn road, near US-24, Shawnee County, Grade Crossing Dot # 818613S/UP

	Number of Vehicles	% of Vehicles
Full Stop	47	7
Rolling Stop	95	15
No Stop	509	78
Total	651	100

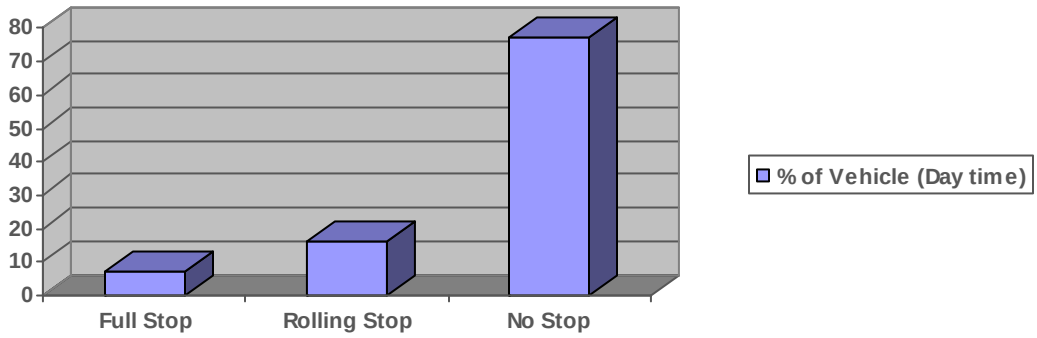


Figure A20: Total percentage of vehicles recorded at Arn road, near US-24, Shawnee County, Grade Crossing Dot # 818613S/UP (Daytime)

Table A20: Total number and percentage of vehicles recorded at Arn road, near US-24, Shawnee County, Grade Crossing Dot # 818613S/UP (Daytime)

	Number of Vehicles	% of Vehicles
Full Stop	39	7
Rolling Stop	92	16
No Stop	448	77
Total	579	100

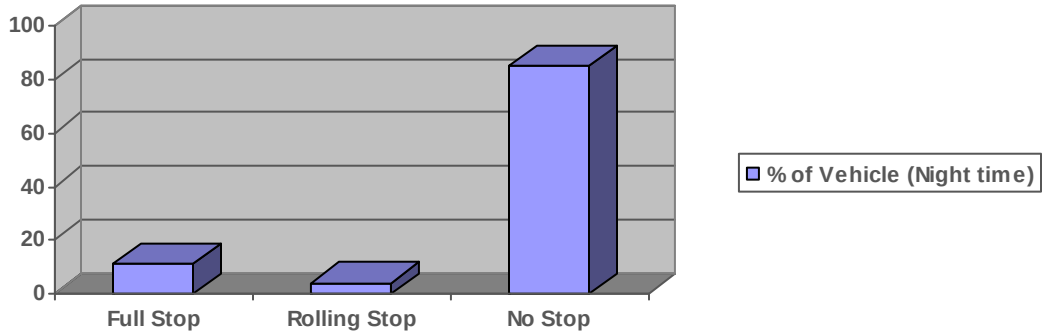


Figure A21: Total percentage of vehicles recorded at Arn road, near US-24, Shawnee County, Grade Crossing Dot # 818613S/UP (Nighttime)

Table A21: Total number and percentage of vehicles recorded at Arn road, near US-24, Shawnee County, Grade Crossing Dot # 818613S/UP (Nighttime)

	Number of Vehicles	% of Vehicles
Full Stop	8	11
Rolling Stop	3	4
No Stop	61	85
Total	72	100

- **Carter road, US-24, Shawnee County, Grade Crossing Dot # 818604T/UP:**

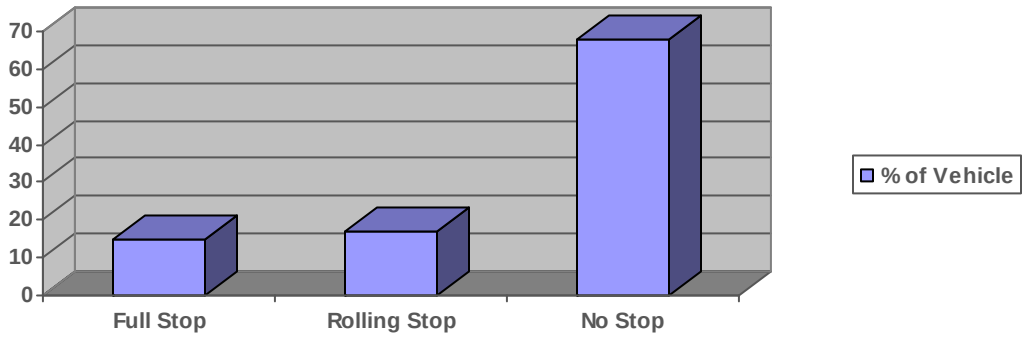


Figure A22: Total percentage of vehicles recorded at Carter road, near US-24, Shawnee County, Grade Crossing Dot # 818604T/UP

Table A22: Total number and percentage of vehicles recorded at Carter road, near US-24, Shawnee County, Grade Crossing Dot # 818604T/UP

	Number of Vehicles	% of Vehicles
Full Stop	41	15
Rolling Stop	47	17
No Stop	183	68
Total	271	100

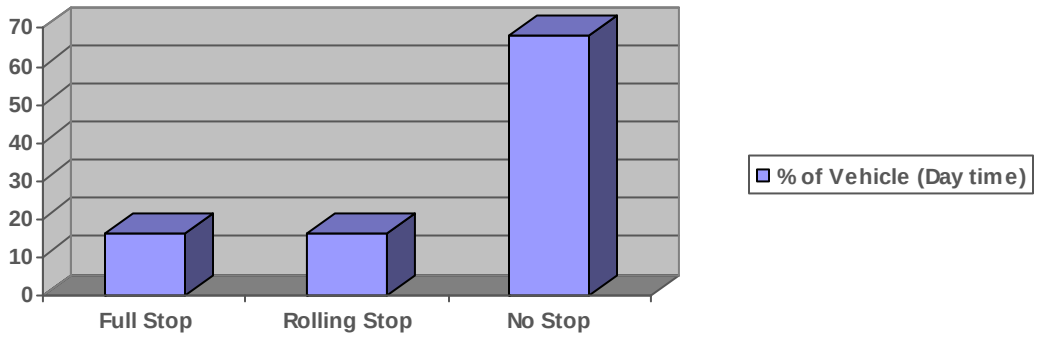


Figure A23: Total percentage of vehicles recorded at Carter road, near US-24, Shawnee County, Grade Crossing Dot # 818604T/UP (Daytime)

Table A23: Total number and percentage of vehicles recorded at Carter road, near US-24, Shawnee County, Grade Crossing Dot # 818604T/UP (Daytime)

	Number of Vehicles	% of Vehicles
Full Stop	41	16
Rolling Stop	41	16
No Stop	179	68
Total	261	100

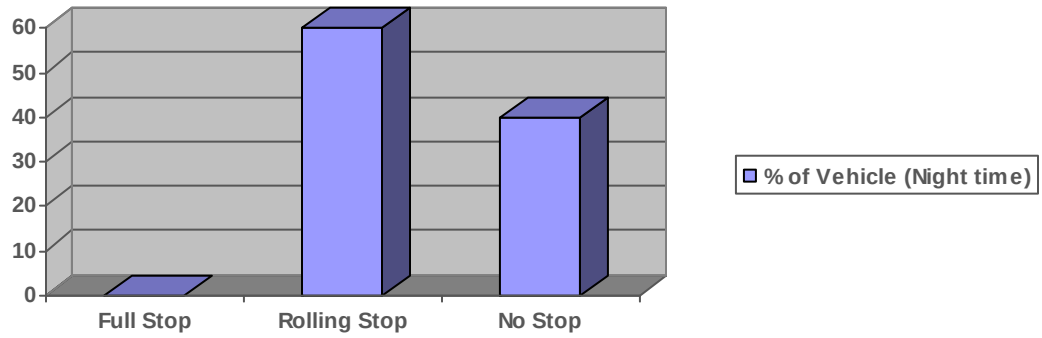


Figure A24: Total percentage of vehicles recorded at Carter road, near US-24, Shawnee County, Grade Crossing Dot # 818604T/UP (Nighttime)

Table A24: Total number and percentage of vehicles recorded at Carter road, near US-24, Shawnee County, Grade Crossing Dot # 818604T/UP (Nighttime)

	Number of Vehicles	% of Vehicles
Full Stop	0	0
Rolling Stop	6	60
No Stop	4	40
Total	10	100

APPENDIX B

SCHOOL BUSES, HEAVY TRUCKS AND OTHER VEHICLES SEPARATION AT INDIVIDUAL GRADE CROSSINGS

- Hays (7th) Road, N. Edge of Alma, Wabaunsee County, Dot # 605343F/UP

Table B1: School buses, heavy trucks and other vehicles separation at Hays (7th) Road, N. Edge of Alma, Wabaunsee County, Dot # 605343F/UP [1]

Day	No. of Heavy Trucks	Percentage	No. of School Buses	Percentage	No. of Other Vehicles	Percentage
Full Stop	5	11	0	0	58	19
Rolling Stop	7	16	0	0	63	20
No Stop	33	73	0	0	187	61
Total	**45**	**100**	**0**	**0**	**308**	**100**
Night	**No. of Heavy Trucks**	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	2	20	0	0	24	26
Rolling Stop	1	10	0	0	17	19
No Stop	7	70	0	0	51	55
Total	**10**	**100**	**0**	**0**	**92**	**100**
Day + Night Combined						
	No. of Heavy Trucks	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	7	13	0	0	82	21
Rolling Stop	8	15	0	0	80	20
No Stop	40	72	0	0	238	59
Total	**55**	**100**	**0**	**0**	**400**	**100**

1: (Passive grade crossings with CROSSBUCK and STOP signs)

- 69th Street near Hutchinson, Reno County, Dot # 602960N/UP

Table B2: School buses, heavy trucks and other vehicles separation at 69th Street near Hutchinson, Reno County, Dot # 602960N/UP [2]

Day	No. of Heavy Trucks	Percentage	No. of School Buses	Percentage	No. of Other Vehicles	Percentage
Full Stop	0	0	4	80	154	11
Rolling Stop	0	0	0	0	238	16
No Stop	0	0	1	20	1066	73
Total	**0**	**0**	**5**	**100**	**1458**	**100**
Night	**No. of Heavy Trucks**	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	0	0	0	0	0	0
Rolling Stop	0	0	0	0	2	10
No Stop	0	0	0	0	18	90
Total	**0**	**0**	**0**	**0**	**20**	**100**
Day + Night Combined						
	No. of Heavy Trucks	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	0	0	4	80	154	10
Rolling Stop	0	0	0	0	240	16
No Stop	0	0	1	20	1084	74
Total	**0**	**0**	**5**	**100**	**1478**	**100**

2: (Active grade crossing with gates, lights and a STOP sign)

- Halstead, Saline County, Dot # 818393Y/UP

Table B3: School buses, heavy trucks and other vehicles separation at Halstead, Saline County, Dot # 818393Y/UP [3]

Day	No. of Heavy Trucks	Percentage	No. of School Buses	Percentage	No. of Other Vehicles	Percentage
Full Stop	0	0	0	0	8	2
Rolling Stop	0	0	1	100	41	9
No Stop	15	100	0	0	385	89
Total	**15**	**100**	**1**	**100**	**434**	**100**
Night	**No. of Heavy Trucks**	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	0	0	0	0	0	0
Rolling Stop	0	0	0	0	0	0
No Stop	2	100	0	0	12	100
Total	**2**	**100**	**0**	**100**	**12**	**100**
Day + Night Combined						
	No. of Heavy Trucks	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	0	0	0	0	8	2
Rolling Stop	0	0	1	100	41	9
No Stop	17	100	0	0	397	89
Total	**17**	**100**	**1**	**100**	**446**	**100**

3: (Passive grade crossings with CROSSBUCK and YIELD signs)

- Muir, Saline County, Dot # 818399P/UP

Table B4: School buses, heavy trucks and other vehicles separation at Muir, Saline County, Dot # 818399P/UP [4]

Day	No. of Heavy Trucks	Percentage	No. of School Buses	Percentage	No. of Other Vehicles	Percentage
Full Stop	0	0	0	0	5	1
Rolling Stop	1	6	0	0	12	4
No Stop	15	94	0	0	312	95
Total	**16**	**100**	**0**	**0**	**329**	**100**
Night	**No. of Heavy Trucks**	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	0	0	0	0	0	0
Rolling Stop	0	0	0	0	8	53
No Stop	9	100	0	0	7	47
Total	**9**	**100**	**0**	**0**	**15**	**100**
Day + Night Combined						
	No. of Heavy Trucks	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	0	0	0	0	5	1
Rolling Stop	1	4	0	0	20	6
No Stop	24	96	0	0	319	93
Total	**25**	**100**	**0**	**0**	**344**	**100**

4: (Passive grade crossings with CROSSBUCK sign only)

- Street 236, Nemaha County, Dot # 814413U/UP

Table B5: School buses, heavy trucks and other vehicles separation at Street 236, Nemaha County, Dot # 814413U/UP [5]

Day	No. of Heavy Trucks	Percentage	No. of School Buses	Percentage	No. of Other Vehicles	Percentage
Full Stop	4	22	3	100	6	5
Rolling Stop	1	6	0	0	7	6
No Stop	13	72	0	0	113	89
Total	**18**	**0**	**3**	**100**	**126**	**100**
Night	**No. of Heavy Trucks**	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	0	0	0	0	0	0
Rolling Stop	0	0	0	0	0	0
No Stop	0	0	0	0	3	100
Total	**0**	**0**	**0**	**0**	**3**	**100**
Day + Night Combined						
	No. of Heavy Trucks	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	4	22	3	100	6	5
Rolling Stop	1	6	0	0	7	5
No Stop	13	72	0	0	116	90
Total	**18**	**100**	**3**	**100**	**129**	**100**

5: (Passive grade crossings with CROSSBUCK and STOP signs)

- Walnut street, Rossville, Shawnee County, Dot # 813912G/UP

Table B6: School buses, heavy trucks and other vehicles separation at Walnut Street, Rossville, Shawnee County, Dot # 813912G/UP [7]

Day	No. of Heavy Trucks	Percentage	No. of School Buses	Percentage	No. of Other Vehicles	Percentage
Full Stop	0	0	0	0	33	9
Rolling Stop	2	33	0	0	92	25
No Stop	4	67	0	0	241	66
Total	**6**	**100**	**0**	**0**	**366**	**100**
Night	**No. of Heavy Trucks**	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	0	0	0	0	4	10
Rolling Stop	0	0	0	0	12	28
No Stop	0	0	0	0	26	62
Total	**0**	**0**	**0**	**0**	**42**	**100**
Day + Night Combined						
	No. of Heavy Trucks	**Percentage**	**No. of School Buses**	**Percentage**	**No. of Other Vehicles**	**Percentage**
Full Stop	0	0	0	0	37	9
Rolling Stop	2	33	0	0	104	25
No Stop	4	67	0	0	267	66
Total	**6**	**100**	**0**	**0**	**408**	**100**

7: (Active grade crossing with gates, lights and a STOP sign)