PRESIGNALS AT GRADE CROSSINGS

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DEDICATION

In 1982, a fatal vehicle/train accident claimed the life of Carla Schneider, a high school student I never met. I was in elementary school at the time, but her story stayed with me over the years, influenced me, and led me to pursue this topic. I have often thought about her and all of the things she could have accomplished if this tragedy had been averted. If this dissertation saves one Carla Schneider, all of my hard work will be worth it.

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ABSTRACT

Highway/railroad grade crossings present a danger to vehicular traffic. According to the USDOT Bureau of Transportation Statistics, in 2009, there were 1,887 crashes at highway/rail crossings resulting in 248 fatalities (FRA, 2009). The installation of presignals at grade crossings decreases crashes and fatalities at highway/rail crossings. There are no Federal standards that provide guidance for the installation of presignals. Therefore, current practices do not conform to any set of consistent nationwide standards except for guidelines specified in the MUTCD. These guidelines state that a presignal should be considered where the at-grade highway/rail crossing is located within 50 feet of a signalized intersection. The MUTCD also gives the option of installing a presignal at a distance greater than 50 feet, if an engineering study determines a need; however, no specific guidelines are provided for such studies.

This work uses a case study to determine which measures are needed to warrant a presignal and examines if the distance criterion of 50 feet between signalized intersections and highway/rail crossings is adequate. It also explores the need for consistent national standards to provide guidance to practitioners in determining the needs for the installation of such signals.

The study finds that distance criterion should not be used as the sole indicator for the installation of a presignal and therefore, engineering studies must be performed in all cases to determine presignal needs. Furthermore, the work concluded that the MUTCD

must be modified to provide standards and guidelines that can be used nationwide for systematic quantitative assessment in determining when presignals are warranted near railroad crossings. This study proposes that presignals be installed based on warrants that consist of crash data, queue distance and no gates at the crossing. The proposed modifications include describing presignal types, defining their purpose, developing presignal warrants, and creating guidelines that can be used by practitioners. The changes and revisions recommended by this research work include queue length analysis, signal phasing and timing modifications, and existing intersection infrastructure needs. The resulting warrants and guidelines for presignal installation can be used nationally to provide uniform guidance and recommendations in performing presignal studies.

CHAPTER 1: INTRODUCTION

1.1. History of the Railroad

Railroad transportation began in the United States during the 1820's with the construction and operation of the Granite Railway in Massachusetts. The railway was approximately three miles long and locomotion functioned by a combination of horses and gravity. Wooden cars with iron wheels traversed over wooden rails fastened to a continuous foundation of granite blocks (Grant, 2005).

Over the next twenty years, engineers developed prototypes for the modern railroad incorporating some features from the Granite Railway, including the basic track structure. However, by the 1840's this basic granite track structure became difficult to construct over long distances and therefore, railroad pioneers began placing track on graded soil (Wheeler, 1973). Through the 1860's America experimented with track and engines using expertise from Great Britain to enhance their systems. During this time, railroad pioneers also had ideas for a railroad that would reach from the east coast to the west coast, a transcontinental line.

In July 1862, Congress approved the Railroad Act to standardize the gauge of track and set a uniform width from the Pacific coast to the Missouri River (Taylor, 1956). However, because there were two competing gages, this Act left the final decision up to President Lincoln. Five feet was the standard width used in the Sacramento Valley and in the South. Railroads in the Eastern United States used a gauge of four feet, eight and one-half inches (Streissguth, 2000). In January 1863, after much discussion with the

Cabinet and area railroad stakeholders, Lincoln signed an order that would call for the transcontinental railroad to be set at a gauge of five feet. After much influence from the Eastern politicians, the Senate and the House overturned this order and voted in favor of the narrower gauge. In March 1863, the final act was signed by President Lincoln setting the transcontinental railroad to four feet, eight and one-half inches (Streissguth, 2000). The track width for all future railroads in the United States was set.

In January 1863, the Central Pacific rail lines held their official groundbreaking ceremony in Sacramento, California, commencing the Pacific Railroad (Streissguth, 2000). Weather was a challenge with some record breaking snow storms creating major obstacles during the construction of the Pacific Railroad. The Central Pacific was also struggling with mountainous terrain forcing the building of bridges and blasting of tunnels.

At the same time, the Union Pacific Railroad began surveying land in Iowa to determine the most opportune track location. Unsure of the eastern terminus for the transcontinental railroad, the railroads forced President Lincoln to make the decision. In November 1863, Lincoln issued an executive order fixing the eastern terminus at Council Bluffs, Iowa. This forced Union Pacific to construct an expensive and long bridge across the Missouri River as their first task. This order was never overturned, but quietly disobeyed by the general manager of Union Pacific and the eastern terminus simply started in Omaha on the Western bank of the Missouri River (Wheeler,1973).

In March 1864, Union Pacific began constructing the track bed, and sped across easy level terrain. They were not without their challenges, because stretches of track crossed certain areas. Workers had to fight battles with Native Americans along the right of way (Streissguth, 2000).

The Federal Government supported the growth of the railroad lines, assisting financially in the construction with land grants and loans. Congress passed the Railroad Act of 1864 which doubled the federal land grants to 12,800 acres per mile and gave the Central Pacific four years to reach the California-Nevada border (Streissguth, 2000). Because of the generous support of the federal government, this bill allowed the transcontinental railroad to be completed.

In May 1869, the last spike was driven into the track connecting the Union Pacific to the Central Pacific rail lines in Promontory, Utah thereby completing the transcontinental railroad (Ambrose, 2000). Five days after joining the rails, the nation’s first transcontinental railroad announced passenger service. After one full year of service, nearly 150,000 passengers had ridden the line between Omaha and Sacramento (Wheeler, 1973).

Within the next 30 years, four more transcontinental lines were constructed. These systems were completed by integrating main lines, feeders, and spurs. The transcontinental lines: Atchison, Topeka & Santa Fe, Great Northern, Northern Pacific, Southern Pacific and Union Pacific, coupled with connection rail line routes, linked the

United States and created unrivaled travel opportunities (Withuhn, 1993). By 1916, the network reached its greatest extent of over 250,000 track miles.

The development of the railroad in the United States reduced transportation time and cost, allowing migration towards the west. Railroads increased the accessibility of goods to consumers, thus allowing individuals and capital to flow westward. Prior to the rail service, a trip overland from New York to San Francisco took months, but with the transcontinental rail lines, the same trip only took about 85 hours (Ambrose, 2000). As the railroad lines were constructed, they facilitated the establishment of growth near the tracks by rapidly moving people, goods and information along the tracks.

In the east, the railroads were allowed to build their tracks across existing streets to avoid the high costs of grade separation. While the result was the same, the development was slightly different in the west. Towns were built parallel along the railway lines because the community was dependent upon the goods that the railway provided. Railroad companies sold their extra property along the track at low cost to settlers to encourage a growing customer base. Once settlements occurred along the rail lines, streets and highways were then constructed as the needs arose, and crossings were usually built at grade because communities could not afford to construct grade separated roadways for financial reasons (FHWA, 1986).

Crossings over the railroad were often provided for every street, with an average of 10 crossings per mile. These grade crossings were not an issue from the 1920’s through the 1960’s with low to moderate vehicular crossing counts. However, as both train and vehicular traffic increased, safety concerns arose with the high number of at grade crossings. By 1980, there were over 350,000 at grade crossings in the United States (FHWA, 1986). Safety concerns intensified with the high number of at-grade crossings.

In 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) established a special program to fund safety improvements at highway-rail grade crossings on corridors that were designated as high-speed intercity passenger rail corridors based on their present utility and their potential for future development (FRA, 2009). The Federal Railroad Administration and Federal Highway Administration worked jointly on 5 designated rail line corridors to develop long range plans for the treatment of corridor crossings and initiated detailed projects to specific crossings. Projects that were undertaken involved both existing and advanced technologies. Additionally, ISTEA granted states and local authorities discretionary authority to install stop or yield signs at highway rail crossings without automatic traffic control devices when two or more trains operated along the rail line per day (FRA, 2009).

The Transportation Equity Act for the 21st Century (TEA-21) expanded the highway-rail grade crossing hazard elimination program to include: railroad crossing closures, crossing consolidation or grade separation; installation or upgrade of automated warning devices to include bells, flashing lights and/or gates; improvements to track circuitry, crossing surface upgrades, crossing sight distances or illumination; installation of advanced train control or traffic control systems; and other related project development and engineering activities (FRA, 2009). The Federal Railroad Administration and Federal

Highway Administration (FHWA), both agencies of the U.S. Department of Transportation, jointly manage the program.

In 2005, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was authorized. This program set aside approximately 220 million dollars per year from 2006 through 2009 to reduce the number of fatalities and injuries at public highway-rail grade crossings through the elimination of hazards and the installation of protective devices at crossings (SAFETEA-LU, 2009). Using this program, 50% of each State's apportionment must be set aside for the installation of protective devices at railway-highway crossings.

With the assistance of the railroad lines, states are closing at-grade crossings and improving the safety features at the crossings. Since 1993, funding under the TEA-21and SAFETY-LU programs resulted in nearly 300 highway-rail crossing improvement projects, 116 highway grade crossing closures, and the design and construction of five grade separated crossings (FRA, 2009). Currently, there are approximately 150,000 public and 100,000 private at-grade railroad crossings throughout the United States (FRA, 2009). Of the 150,000 public crossings, approximately 35,500 have gates, 25,000 have flashing lights, and 1,250 have presignals, wigwags, and bells (FHWA, 2009).

At grade crossings, the right of way for the train tracks is owned by the railway company that owns and operates the gates and lights alerting drivers of an approaching train. The traffic signal at the nearby intersection is owned by the governmental agency with jurisdiction over the roadway. Therefore, the railroad's warning control system and the jurisdiction's traffic control system operate independently of each other.

After much research and development through ISTEA, TEA-21 and SAFETY –LU the railway companies and the governmental agencies have worked in cooperation to improve safety at grade crossings. Some of the methods that have been implemented through funding within these three programs include signal preemption and the installation of protective devices at grade railroad crossings, including presignals.

1.2. Crash History

Because trains are heavy, travel at rapid speeds, and are unable to deviate from the tracks, the stopping distance is great. By the time the train engineer sees a vehicle or pedestrian on the tracks, it is too late to stop the train because the stopping distance is longer than the sight of the engineer. As a result, a collision is imminent, unless the driver or pedestrian are able to move from the tracks. More than ten percent of all crashes that involve a train and an automobile are fatal. In 2009, there were 1,887 highway-rail incidents, which lead to 248 fatalities (FRA, 2009). Figure 1.1 presents the yearly total number of fatalities and collisions that resulted from train/vehicle incidents between highway users and the rail lines over the last 34 years.

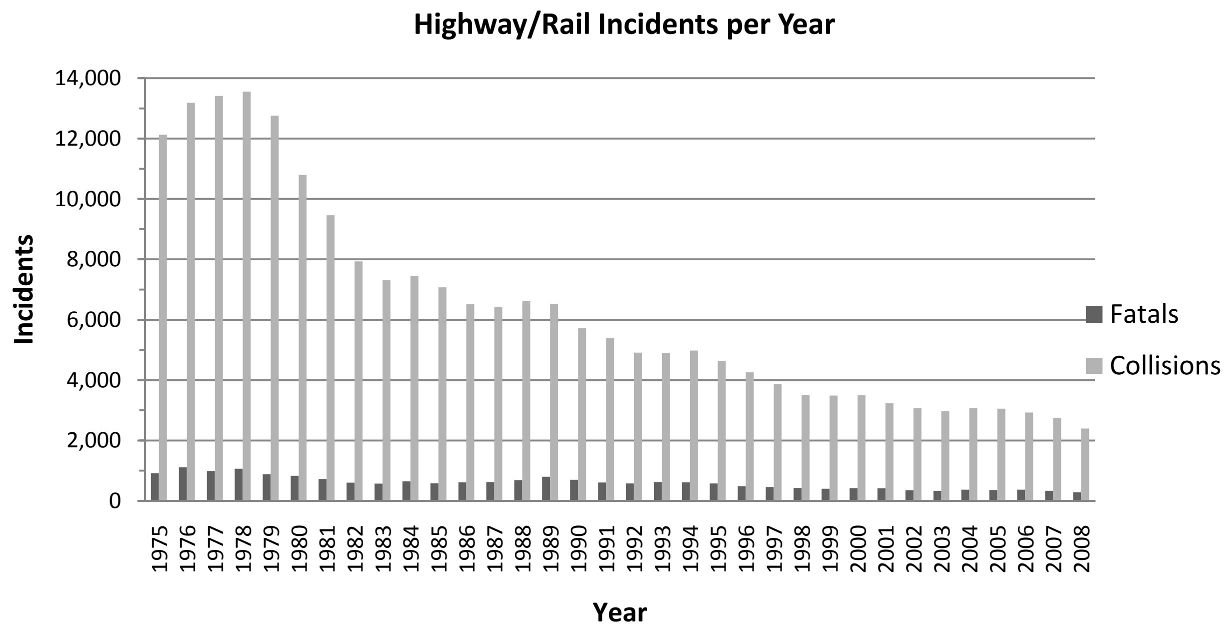

Figure 1.1: Highway/Rail Incidents per Year (FRA, 2009)

In 1994, the Federal Railroad Administration set goals to reduce the number of crashes at grade crossings by fifty percent. After studying the crossings, the safety recommendations included closing 41,000 crossings and installing automatic gates and flashing lights at 4,000 locations (Mead, 2005). Figure 1.1 shows that the Federal Railroad Administration was successful in reducing incidents at grade crossings based on these recommendations. Since 1994, there has been a 48 percent reduction in total crashes and 46 percent reduction in fatalities. However, the crash history from 2001 through 2008 shows that over 250 fatalities are still occurring at grade crossings throughout the United States yearly. The Federal Railroad Administration is continuing efforts to improve safety. The Department reviewed at-grade crossing crash reports from 2001 through 2006 (Sposato, 2006). The reports indicate that nearly half of the crashes occurred with active warning devices. Therefore, it can be reasonably deduced that automatic warning devices alone do not prevent all crashes. More importantly, continued progress to improve crash reduction rates will be challenging because the railroad crash reports showed that ninety-one percent of these crashes were attributed to reckless or inattentive drivers (Sposato, 2006). Data provided in the FRA railroad crossing crash database does not indicate whether a signalized intersection is located within close proximity to the at-grade crossing and if the complexity of the intersection interacting with the crossing may have contributed to the crash. This important geometric data could be included on the police crash record and collected by the officer at the scene for inclusion in the FRA database as a future reference.

1.3. Problem Statement

Signalized intersections adjacent to at-grade crossings present a danger. Usually one approach to the intersection is burdened because of the proximity of the at-grade railroad crossing to the intersection. Occasionally traffic queues from the signal and extends over the railroad tracks creating unsafe conditions. Safety measures, such as railroad gates, have been used as a deterrent to keep vehicles from stopping on the tracks. However, there are instances where this alone does not keep the tracks clear as drivers occasionally misjudge the distance and are forced to idle on the tracks, thus increasing the probability of a crash. Therefore, additional measures must be implemented to advise the driver when it is safe to cross the railroad tracks, giving motorists more protection from a moving train.

One method used to improve safety is to install a presignal at the approach to the railroad tracks. A typical presignal configuration is presented in Figure 1.2. A presignal is a common traffic signal, coupled with a stop bar, used at the highway/rail intersection. The presignal is placed upstream of the rail crossing on the near side of the tracks and causes vehicular traffic to stop ahead of the crossing. The stop bar is placed in advance of the grade crossing. The presignal reduces the likelihood of vehicles stopping within the railroad track area, and restricts traffic queues across the at-grade crossing. Vehicles are then required to stop at the red signal indication prior to the grade crossing or storage zone between the grade crossing and the downstream intersection (Ogden, 2001).

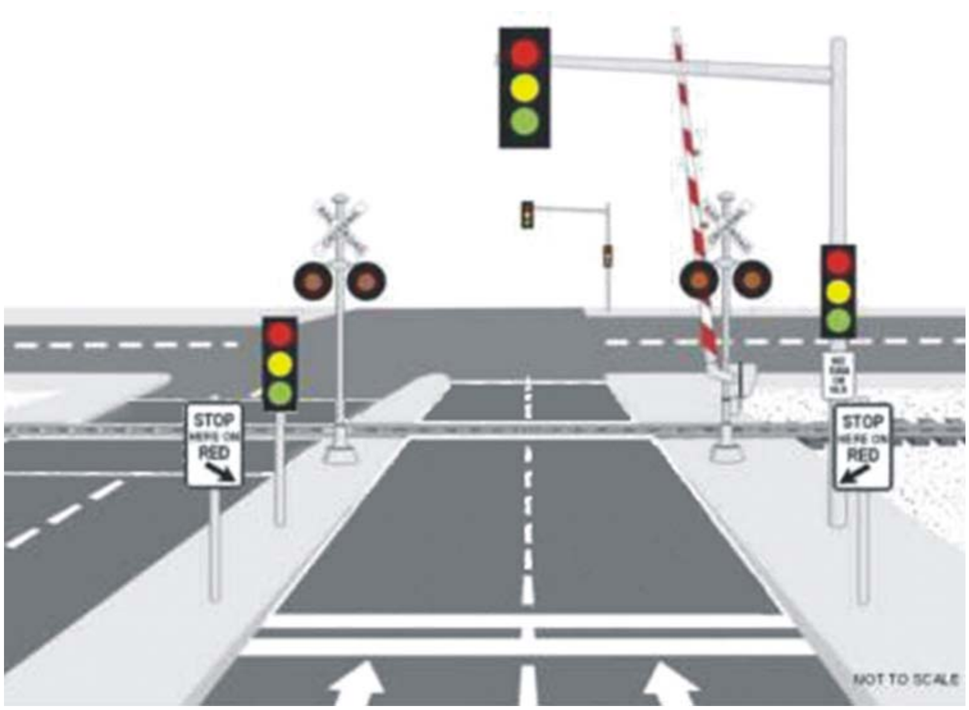

Figure 1.2 Presignal at Highway/Rail Intersection

There are currently no systematic procedures that quantitatively determine when presignals are warranted near railroad crossings that are reasonably quick to apply nationwide for use by practitioners. The Manual of Uniform Traffic Control Devices (MUTCD) gives guidance that a presignal should be considered at locations where an at-grade highway/rail crossing is located within 50 feet of an intersection controlled by a traffic signal. The MUTCD also gives the option of installing a presignal at a distance greater than 50 feet, if an engineering study determines a need. The MUTCD gives no suggestions for the types of engineering studies that may be necessary to adequately address if a presignal should be installed at locations were the distance is greater than 50 feet.

The work in this dissertation examines the need for presignals as it relates to the distance between the intersection and the at-grade railroad crossing. It is claimed that the 50 foot distance requirement is irrelevant and should not be used as criteria for the installation of a presignal. Therefore, no distance requirements should be provided in the MUTCD. No support can be found in any literature for the 50 foot requirement and no basis has been provided for such a requirement. In fact, the continued use of the current practice as defined in the MUTCD could actually cause additional safety concerns if vehicle queues are present at grade crossings over 50 feet from the downstream intersection. This research will demonstrate that an engineering study should be performed to determine the need for the installation of a presignal in all cases, regardless of the distance. Warrants that define the criteria to which a presignal should be installed need to be developed and incorporated into the MUTCD to provide guidance and uniformity throughout the United States. Presignal guidelines are then developed that instruct practitioners on performing presignal warrant studies. The new warrants and guidelines will eliminate confusion when used and followed. These warrants and guidelines should accurately define the types of presignals and should demonstrate the need for specific types of systems depending on the intersection geometry. They should include criteria that accommodate real time signal coordination, existing intersection conditions, vehicle detection needs and queue length.

1.4. Glossary of Terms, Acronyms and Abbreviations

The following is a list of terms that are used throughout this dissertation. For ease and clarity, the major terms are defined below. Other terms will be defined and clarified in the text.

Active Highway-Rail Grade Crossing Warning Devices: The railroad flashing light signals with or without gates, together with the necessary control equipment, used to inform road users of the approach or presence of trains at highway-rail grade crossings.

ADOT: Arizona Department of Transportation.

Advance Head: A presignal system where the presignal and downstream intersection are timed simultaneously using one controller, meaning there is no offset between the red, green and yellow indications at the two signals (Ogden, 2001).

Approach: A set of lanes accommodating all left turn, through, and right turn movements arriving at an intersection from a given direction.

At-Grade Crossing: The intersection of a roadway and a railroad track at the same elevation or grade.

Clear Storage Distance: The distance available to store vehicles from the minimum track clearance nearest the intersection to the intersection stop bar.

Design Vehicle: The longest vehicle permitted by statute (state or other) on that roadway.

Dynamic Envelope: The clearance required for the train and its cargo; noted in the Railroad-Highway Grade Crossing Handbook 2007, as 6 feet on either side of the tracks.

Keep Clear Zone: The striped area that delineates the clear storage distance and minimum track clearance distance.

Interconnected signals: Traffic signals that are connected together by some means (hardwire or radio wave) primarily for the purpose of establishing a definite timing relationship between the signals.

Minimum Track Clearance Distance: The length along the highway at one or more railroad tracks measured from the near centerline of railroad stop line, 12 feet to 6 feet beyond the far rail.

MUTCD: Manual of Uniform Traffic Control Devices, a federal manual used by roadway managers that defines and standardizes the signs, signals, and pavement markings in the United States.

Preemption Control: The transfer of normal signal control operations to a special control mode of the signal triggered by a vehicle other than normal vehicular traffic.

Presignal: A common traffic signal placed upstream of a highway/rail intersection which causes vehicular traffic to stop ahead of the railroad crossing. The presignal is usually timed with an offset between it and the downstream intersection (Gilleran, 2006).

Queue Clearance Time: The time required for the design vehicle stopped within the minimum track clearance distance to start up and move through the minimum track clearance.

Queue Cutter Signal: A presignal system where the distance between the highway/rail intersection and the downstream intersection is significant (Campbell, 2007).

CHAPTER 2: LITERATURE REVIEW

The notion that pre-signals can be installed at grade railroad crossings has been around since the 1940's. However, the installation of this type of device has not been readily used because many issues exist that have not been addressed. These issues are wide spread and range from coordination with the railroads to signal timing and vehicular queuing. Additionally, low traffic volumes from the 1940's through the 1960's did not lead to major concerns at or near grade crossings because train/vehicle crashes were rare. However, these types of crashes increased dramatically from the 1970's through the 1990's. Currently, the federal government is working to reduce vehicle/train crashes through major research, state government assistance and community support.

In 1948, the MUTCD stipulated that interconnection between the grade crossing and the intersection was necessary to improve safety. The MUTCD recommended that grade crossings within 500 to 1000 feet of an intersection should be interconnected to "flashers, wigwags or gates". By 1961, the length was shortened to 200 feet, except under unusual conditions. The 1988 MUTCD includes the discussion on preemption, but did not include pre-signals as a mechanism to improve safety at grade crossings. By 2000, the MUTCD mentions pre-signals; however, it does not give any recommendations as to when a pre-signal should be installed. The manual simply gives a definition of the pre-signal itself. The current edition of the MUTCD states that pre-signals should be used under guidance if the grade crossing is less than 50 feet, and suggests that engineering judgment be used if vehicles are queuing over the tracks at greater distances from the signalized intersection.

The Railroad Highway Grade Crossing Handbook revised in 1986 suggested that if preemption and lengthened warning times were not feasible, an additional signal located on the intersection side of the tracks may be installed to control only the track approach. The Handbook suggested that a double clearance interval be provided to terminate green indications at the crossing signals prior to the termination of the green at the intersection signal. In August 2007, the Railroad-Highway Grade Crossing Handbook was revised. Practices within the revised Handbook discuss active traffic control devices, including practices regarding the use of presignals. This Handbook cites the ITE recommended practices and recommends that presignals be installed where the clear storage distance is 50 feet or less between the downstream signal and the at-grade crossing. The 2007 Handbook also discusses queue cutter signals and differentiates them from presignals. The Handbook recommends that queue cutter signals be used when the clear storage distance exceeds 120 feet and an extending queue from the downstream signal is about to extend into the minimum track clearance. The Handbook then states that a field analysis and review should be conducted to determine whether to pursue coordination of the queue cutter with the downstream signal, but gives no information on recommended guidelines or practices.

From 2000 through 2007, many articles have been published in transportation journals about signal preemption at grade crossings and give some discussion about presignals. For example, the "ITE Recommended Practice for Preemption of Traffic Signals near Railroad Crossings," states that at short distances between the crossing and the intersection, if there is not sufficient distance to safely store a design vehicle, if no gates are present or if vehicles queue across the tracks, then a pre-signal should be considered (ITE, 2006). This document states that an engineering study should be performed to support its recommendation. However, no information is given on what documentation is needed to support the use of a pre-signal. Additionally, ITE has published a number of articles in their monthly ITE Journal, April and May 2006. These articles discuss using presignals as a specialized tool when signalizing near at grade railroad crossings. They also address differences in presignal types, meaning they differentiate between a queue cutter and a presignal. The major differences that they discuss include distance from the at-grade intersection to the downstream intersection and the need for preemption; however, the queue cutter signal may or may not be integrated with the downstream signal.

The Transportation Research Board (TRB) also publishes information on at-grade crossings. The article, Presignals-Current Applications and Issues, defines differences in the types of presignal operations and elaborates on the spacing between the at-grade intersection and the downstream intersection. This article states that presignals should be used at locations where the clear storage distance is 50 feet or less, subject to an engineering study of queue length and site specific conditions. However, no justification is given for the 50 foot value. This article also explains that one of the outstanding issues for presignals is that there are no warrants for installation (Ogden, 2001).

Dr. Prassas at Polytechnic University for the National Cooperative Highway Research Program (NCHRP) conducted a study that consists of studying stop controlled intersections near highway/rail grade crossings to determine if the downstream intersection should be signalized even though it does not necessarily meet the signal warrants as presented in the MUTCD (Prassas, 2007). Therefore, a specific warrant is being developed that will consider the proximity of rail lines in relation to the downstream intersection. A signal may assist with these locations where vehicles queue over the tracks. This research effort addresses signalization of the downstream signal; however, it does not address the need for a presignal at the grade crossing.

Presignals are becoming popular for light rail in populated areas where the light rail vehicles operate at speeds greater than 35 miles per hour. Before and after evaluation studies report the effectiveness of presignals at highway/rail intersections specifically related to motorist behavior (Korve, 2001). These reports show that drivers respect signals significantly more often than rail crossing signs and devices. During the observation periods, there were a multiple crossing movements that represented a threat of a collision with the rail system but did not become a crash. These risky behaviors were documented and may prove to be a better indicator of the need for presignals than actual crash statistics, because actual vehicle/train collisions at at-grade crossings are relatively infrequent and the number of collisions is of limited statistical significance (Korve, 2001).

A variety of presignal studies were conducted showing the effectiveness of adding the presignal at the at-grade crossing. Individual states performed the studies after multiple fatal crashes occurred between vehicles and trains. Illinois and New York wrote policies that address presignals and present warrants for the installation. Illinois presignal warrants state that where the at-grade railroad crossing lies within 200 feet of an intersection, the design efforts should address efforts to keep vehicles from stopping or storing on the tracks. Illinois recommends the installation of a CAUTION XX FEET BETWEEN TRACKS AND HIGHWAY sign on all highway approaches to railroad grade crossings where the distance is 80 feet or less (Korve, 2001). These signs are to be used as an interim measure until the presignals are installed. New York's written guidelines for presignal installation are coupled with their interconnection guidelines. This information was obtained from a phone interview with the New York State Department of Transportation (Ramos, 2009).

The research reviewed maintains that South Carolina is in the process of writing presignal warrants. A phone interview with South Carolina Department of Transportation staff concluded that South Carolina does have presignal guidelines (Shepard, 2009). The guidelines are found in the South Carolina Department of Transportation Traffic Signal Design Guidelines, and state that a presignal should be installed if there are no gates installed or planned and vehicles queue between the signal and the railroad tracks. Additionally, a presignal can be installed when advance preemption is used, or when a signal offset is needed to manage vehicular traffic (SCDOT, 2009). There is no mention of distance criteria for the installation of a presignal in the Traffic Signal Guidelines.

In October 2007, the California Department of Transportation, Caltrans, held an Interconnection of Highway-Rail Grade Crossing Warning Systems and Traffic Control Signals Seminar. Mr. Rick Campbell presented a section on presignal applications at highway-rail grade crossings. The information presented correlates to the MUTCD. Additionally, ITE is quoted as saying either an upstream presignal or a downstream presignal can be used, meaning that the presignal can be placed on the near side or the far side of the railroad tracks. The main point here is that the signal is placed a minimum distance away from the stop bar of at least 40 feet (Campbell, 2007). Additionally, in the information provided, presignal phasing and operations are discussed. The handouts from the seminar make a clear distinction between a queue cutter signal and a presignal. The distinction between the two signal types are: if the clear storage distance is greater than 120 feet, the queue cutter signal may or may not function as part of the downstream intersection signals, and the queue cutter signal utilizes downstream vehicle detection to change the red signal indication to prevent vehicles from storing onto the tracks. Presignals are used when the clear storage distance is 50 feet or less.

Based on this literature review, engineering studies conclude that presignals are becoming an accepted technique for at grade rail crossings. Reviews also indicate that there are subtle yet distinct differences between the operation of a queue cutter signal and a presignal. Based on the information provided, a number of agencies are developing guidelines to determine: when and where pre-signals should be installed, and how presignals should be designed and timed.

During the literature review process, special focus was centered around presignal design criteria. Based on phone interviews and the research review, it appears that the only design criteria found were from the State of Illinois (Korve, 2001). The New York Department of Transportation and the South Carolina Department of Transportation both stated that they were aware of presignal guidelines; but an extensive search failed to produce the guidelines. Information that was obtained from before and after presignal studies coupled with qualitative evaluations from presignal installation in three states resulted in the development of presignal guidelines. (Korve, 2001). The criteria and applicability of the presignal in this TCRP report states that presignals should be placed on the near side of the rails when the distance between the grade crossing and the vehicular intersection are 50 feet or less. This report also states that if the distance between the rails and the vehicular intersection is between 50 and 120 feet, then a presignal should be installed subject to an engineering study. At a distance over 120 feet, this report states that the signal at the highway/rail crossing should not be considered a presignal, but a queue cutter signal. Therefore, the highway/rail grade crossing should then be treated as a separate midblock crossing. No information or guidelines are given for highway/rail signal installations at distances greater than 120 feet.

In summary, the majority of authors agree that presignals are defined differently than queue cutter signals. Distance, signal interconnect and loop detectors all play a role in the definitions of each. Based on this literature review, the problem statement in this dissertation shows that there still remains a significant question. Is it necessary to place a 50 foot distance requirement, as stipulated in the MUTCD, for the use of presignals? And, if the distance is greater than 50 feet, what type of engineering study is necessary to justify the installation of a near side signal at the grade crossing? Additionally, this literature research shows that a queue cutter signal should be defined and presented in the MUTCD, as the literature shows that there are different definitions of presignals depending on the operation of the signal and the distance from the downstream intersection to the railroad tracks. There are no specific standards, guidelines or policies on the installation of a presignal or queue cutter signal regardless of the clear distance.

CHAPTER 3: METHODOLOGY

This chapter describes the set of procedures used to develop the presignal warrants and guidelines. This set of procedures and the evaluating process is not intended for the practitioner, but for the researcher to gain an understanding of the development, the logic, and evaluation process in developing the presignal warrants. Once developed, the final recommended warrants are stand alone guiding principles that assist the practitioner in determining the need for a presignal at a grade crossing. This chapter defines the process of developing the warrants based on the case study and extensive research effort. Hence, this chapter serves the researcher interested in understanding the development of the presignal warrants, solely.

In order to develop warrants, all measures that might be used to evaluate the need for a presignal must be created or thought up through the case study, logic, or trial and error. Measures comprise of any calculated or collected data value that could possibly be used in the recommended presignal warrants. The measures that could be used to develop the warrants must then be evaluated to determine their true necessity and worth. Ultimately, the measures that legitimately show value by improving safety and/or increasing mobility will progress into the presignal warrants created for use by traffic engineers and practitioners.

The measures that could be analyzed include empirical values such as traffic volumes on the highway to more complicated assessments such as how site geometry could impact the need for a presignal using engineering judgment. Therefore, using a case study and guidance provided by State Transportation Departments, these measures are individually evaluated to determine which of the measures are mandatory and relevant in developing presignal warrants for practitioners.

In order to assess each measure, some require the development of mathematical models to estimate their value and evaluate their importance because traffic data collection efforts may not be easily available, or impossible to gather if the downstream signal is not yet installed and operational. For example, the estimation of queue lengths and time movement from the back of the queue to a location outside of the track clearance zone may require mathematical models if this data cannot be collected. Therefore, within this methodologies portion of the dissertation, the estimation models are developed to determine if these measures are relevant and necessary to the installation of a presignal. Should these measures be selected, the mathematical models will then be considered for use in the guidelines to assist practitioners in determining the need for a presignal if traffic engineering simulation software is not available.

Using a matrix, the measures are considered individually and compared to determine which measures provide significant value and are essential to the installation of a presignal. The matrix is used as a tool to show the need for each measure or a combination of measures as a comparison guide the evaluation process to develop the presignal warrants. The higher the ranking based on the case study and the state reviewed presignal guidelines, the greater the need for the specific measure in the development of the warrant criteria. The criteria in determining if a measure should be used as a presignal warrant are based on a point system. Points are awarded to each measure based on safety and need. Additionally, points are awarded, if a state currently uses the specific measure as one of their installation warrants. The criteria includes: improved safety and enhanced mobility.

The results of the matrix allow the researcher to develop warrants based on the most significant and influential measures. The matrix, evaluation criteria, and point system are solely documented for the interested researcher. Once developed, the practitioner will have easy to follow presignal warrants similar to the existing signal warrants, available for use in the MUTCD.

As a portion of this dissertation, presignal report guidelines are created for the practitioner. The purpose of the presignal report guidelines are to "guide" the practitioner into creating uniform, standardized documents that clearly and precisely define when a presignal is warranted for a specific location. Additionally, the guidelines present construction installation details and standards that lead the practitioner in uniform presignal design drawings nationwide.

3.1. Review of State Guidelines for the Installation of Presignals

The first step in developing the measures and ultimately the presignal warrants, engineering report guidelines, and standards to presignal installation is to contact each state department of transportation and perform a document review to determine what existing information is available and the current practice in the installation of presignals. Currently, there are at least five states using presignals as an alternative safety measure at grade crossings (Korve, 2001). Conversations with all of the state agencies will provide an increase in the understanding of presignal warrant and installation measures on a state by state basis.

The primary focus of the conversation with the state agencies is with respect to distance requirements, their process for determining if a presignal is needed, and installation requirements of presignals. The mechanism that warrants a presignal is noted, along with a brief summary of the operating characteristics of each state that uses presignals. The location of the presignal on the near or far side of the tracks is of importance and will be documented if the state interviewed has guidelines. Additionally, the location of the motorist stop bar, the used of cantilevered flashing lights with presignals and the location of the presignal are the primary design features, in addition to the used of automatic gates with presignal installation.

3.2. ADOT Test Case

A case study is used to evaluate the need for a presignal regardless of the storage distance between the grade crossing and the downstream signalized intersection. Specifically, the test case incorporates a grade crossing and a downstream intersection into the analysis. The Arizona Department of Transportation proposed the intersection of SR347/Maricopa Casa Grande Highway for a test site because the downstream intersection currently meets warrants for a signal installation and the railroad tracks cross approximately 250 feet south of the intersection on SR347. For the test case, data collection, queuing analyses, and time movement are all a part of the study process.

Each measure developed will be used at the test case site to determine its relevance. The relevance is significant in that, it will be used to assist in the matrix and points awarded to determine if the measure should be used by practitioners as an actually presignal warrant. Because this test case is not in compliance with the MUTCD's recommendations for the installation of a presignal, it lends itself to the opportunity of deciding if a measure is applicable and necessary.

The transportation models developed for the engineering guidelines that include queue length and time movement must be applied to a test case intersection in Arizona. Because the test case does not currently have a downstream signal, it is essential to estimate the queues from the downstream signal and the likelihood that these queues will back into the track clearance zone.

Signal timing, phasing, detector locations, and train preemption are also important factors that are included in this dissertation. These factors do not directly affect the warrants for a presignal; however, it is extremely important that when a presignal is installed, the above factors are considered and should be addressed within the presignal guidelines for practitioners. Therefore, the empirical study and the proposed presignal guidelines will address the need and concerns regarding signal timing, phasing, detector locations and train preemption.

3.3. Development of Presignal Warrants

It is necessary to develop uniform engineering specifications for the installation of presignals. Presignal warrants will direct practitioners and engineers to perform studies and warrant analyses that are consistent and standard throughout the nation. The presignal warrants will bring consistency and standardization to their need and installation. Using the state government agency document review and ADOT test case, measures that could affect the need for a presignal will be evaluated and thereafter, presignal warrants will created for engineering use. The engineering presignal warrants will eventually be included in governmental standard and guideline manuals to provide the required continuity of presignal installation throughout the nation.

3.3.1. Presignal Warrants

The purpose of creating presignal warrants is to provide a standardized procedure to decide whether grade crossings near downstream signals warrant the installation of a near side signal. The warrants are formulated by analyzing and evaluating presignal measures including but not limited to: queue length criteria, time movement criteria, train preemption time, crash data, train frequency, number of tracks, and daily delay caused by the trains. As with signal warrants, presignal warrants are based on the minimum requirements for the installation of a presignal. However, satisfaction of a warrant will not necessarily be justification or a mandate for the installation of a presignal. These warrants should be viewed as guidelines, not as absolute values. Satisfaction of a warrant does not guarantee the installation of a presignal. This warrant analysis is a tool to be used in determining if a presignal should be installed. Engineering judgment should always be used in making the final determination. In all cases, at least one of the warrants should be fully met before a presignal is considered.

3.3.2. Mathematical Models to Develop Warrant Measures

Mathematical modeling for queue distances, time movement and vehicle delay are significant and necessary traffic estimate measures. If these measures are selected as warrants after the evaluation process, then the mathematical modeling procedures will be incorporated into the presignal warrant procedures for practitioners. These models define an approximating methodology to develop a procedure that can be implemented nationwide, using readily available traffic data to quickly and easily determine when vehicles are most likely to queue across the railroad tracks. Design factors at the intersection; such as geometrics, signal timing configurations, and peak hour turning movement counts are required to accurately estimate queue distances, time movement and vehicle delay. The mathematical models are necessary in the presignal measure evaluation process to determine if these values are significant in the installation of a presignal. Therefore, the models are created prior to the evaluation of the presignal warrants to address their importance. There are other models that could be used to determine queue length, time movement and vehicle delay at grade crossings; however, these may be too complex to be used as presignal warrants and general guidelines for practicing traffic engineers. Easy-to-use software has been chosen as the preferred method to determine these mathematical models and can be incorporated into the guidelines for use by traffic engineers throughout the nation. As traffic engineering software improves, and new ways to estimate queue lengths are developed, these warrants and guidelines should be upgraded to the latest available software with the most accurate results.

3.3.2.1. Queuing Model

A major concern with at-grade crossings near downstream signalized intersections is vehicles queuing all the way back across the railroad tracks. Prior to the installation of a downstream signal, queuing should be estimated to determine the need for a presignal. Estimation of the queue size is a critical factor in the determination of presignal installation.

The queue is calculated by determining both the arrival and departure rate of vehicles per hour. Because the arrival and service times are assumed to be continuous and constant for a signalized intersection, deterministic queuing analysis at the macroscopic level is selected for this research effort. The traffic signal software, Synchro 6 for the macroscopic analysis, is used to estimate queue lengths at the downstream signalized intersection. The queue reports for Synchro produce 50^{th} percentile and 95^{th} percentile queue lengths. The 50^{th} percentile queue represents the average length of the queue, while the 95^{th} percentile queue represents the maximum distance where vehicles stop during a cycle (Husch, 2003).

Equation 3-1 is used to calculate the 50^{th} percentile queue distances in Synchro. The equation is as follows (Husch, 2003):

$$\mathrm{Q} = \frac{v}{3600} * (R-6) * \left[1 + \frac{1}{\frac{s}{v-1}}\right] * \frac{L}{n*fLU} \qquad (3\text{-}1)$$

Where:

R = red time (s)

s = saturation flow rate (vph)

v = arrival rate (vph)

L = length of vehicles including space between (ft)

n = number of lanes

fLU = lane utilization factor

Equation 3-1 is simplified to assume that all of the vehicles stored in the queue exit the queue on the cycle immediately following. Synchro also estimates queue lengths when vehicles are stored for multiple cycle lengths. However, Synchro calculates the queue length as the maximum queue after two cycles. This equation is as follows: (Husch, 2003)

$$Q' = v * (C-6) + \left(v - s * \frac{g}{C}\right) * \frac{C}{3600} \quad (3\text{-}2)$$

Where:

Q' = queue length for a saturated link

C = cycle length

The 95th percentile queue length is calculated by increasing the arrival rate to account for the variations in traffic arrival. Therefore, the volume is unadjusted by the peak hour factor. Equation 3-3 presents the 95th percentile arrival rate (Husch, 2003).

$$v95 = v * PHFx * \left[1 + 1.64 * \frac{\sqrt{vc}}{vc}\right] \quad (3\text{-}3)$$

Where:

v95 = 95th percentile arrival rate (vph)

vc = vehicles per cycle

PHFx = minimum of PHF or .9

The vehicles per cycle is calculated as:

$$vc = v*C/3600 \qquad (3\text{-}4)$$

Therefore, the 95th percentile queue can be calculated using v95 rather than v in equation 3-3.

3.3.2.2. Time Movement Model

It is necessary to know how long a vehicle takes to travel from the end of the queue to a safe location out of the clear zone of the railroad tracks. This mathematical model estimates that time in seconds that a vehicle waits in the queue and moves a given distance (Marshall, 1997). Therefore, this time estimate can then be used to determine the warning time required by the railroad to safely move vehicles in the back of the queue to a safe distance from the tracks prior to the train's arrival. Because trains can have preset signal preemption times, this model is important to make certain that the preset times are correlated with the actual distance between the railroad tracks and the downstream intersection.

A presignal or a queue cutter signal can manage queue lengths by operating in coordination with the downstream signalized intersection. Either the queue can be split on either side of the tracks, or the downstream signal can be timed with an offset to clear the queue, while storing vehicles at the presignal prior to the tracks. Therefore, it is necessary to conduct queue and preemption timing calculations to make certain that the proper amount of time has been allotted to adequately and safely clear vehicles prior to the arrival of the train.

The dynamics of starting a stopped queue are then analyzed to determine the time required to clear vehicles approximately 30 feet from the railroad tracks. There are two equations required to calculate the time it takes to clear one vehicle from the tracks. This time solely moves the last vehicle in the queue across the tracks, not the entire clear distance between the tracks and the downstream signal. The first equation determines the start-up time for a vehicle sitting on the tracks as a function of the distance between the downstream intersection and the grade crossing. According to Marshall and Berg, start-up time is calculated as shown in equation 3-5.

$$T_1 = (L * k_j)/(2.94 * S) \qquad (3\text{-}5)$$

Where:

T_1 = start up time (seconds)

L = length of queue to be cleared (feet). Measured from the intersection stop line to the point where a vehicle needing to be cleared may be stopped.

k_j = jam density (vpm)

S = saturation flow rate (vpm) 1600 for through movements and 1400 for designated turn lanes

Next, the time it takes to clear a vehicle from the tracks a safe distance into the clear storage area is calculated using equation (5-13).

$$T_2 = 0.5[2(L+2D+W)/a] \quad (3\text{-}6)$$

Where:

T_2 = time to clear vehicle from tracks (seconds)

L = length of design vehicle (feet)

D = clearance distance on either side of the tracks (default 15 feet)

W = width of the crossing, or distances between outermost rails (feet)

a = acceleration rate for the design vehicle

4.4 ft/sec^2 = P vehicle

2.5 ft/sec^2 = SU vehicle

1.6 ft/sec^2 = MU vehicle

Therefore, the total time required to move a vehicle from the tracks is calculated by adding equation 3-5 to equation 3-6.

$$T_t = T_1 + T_2 \quad (3\text{-}7)$$

Where:

T_t = total time required (sec)

The Tt time calculated should then be equal to or lower than the total railroad preemption time set by the operating railroad.

3.3.2.3. Vehicle Delay Model

There are two main measures of delay at highway-rail grade crossings that include: the total gate down time in minutes for each train that crosses and the vehicle-hours of delay per day. The vehicle delay model used for this analysis was developed from the Alameda Corridor Draft EIS in 1992, the San Gabriel Valley Grade Crossing Study in 1997, and the Riverside Rail Crossing Priority Analysis in 2004. This model was developed to estimate the existing delay at grade crossings, including the consideration of delay to motorists trying to cross the railroad tracks. These formulas calculate the total crossing gate down time and the vehicle-hours of delay experienced by roadway traffic at each grade crossing location. In addition, these formulas produce an estimate of the length of roadway traffic queue due to the gate down interval caused by the trains through the crossing. Therefore the gate down time for each train is calculated in formula (3-8).

$$GDT = 0.603 + (\{60*[TL+50+12*(N)]\}/5280*S\}) \qquad (3\text{-}8)$$

Where:

GDT = Gate Down Time (minutes)

0.603 = time for gate to lower and raise (minutes)

50 = distance from gate preempt to edge of roadway (feet)

TL = train length (feet)

N = number of lanes (feet)

60 = conversion factor (min per hour)

12 = average lane width (feet)

S= train speed (mph)

5280 = conversion factor (ft per mi)

Next, the vehicle delay can be calculated for each train by equation 3-9.

$$D = (\{[GDT^2] * VQ / \{2 * (1-VQ / VDR]\}/60) * N \qquad (3\text{-}9)$$

Where:

D = Vehicle delay for each train (seconds)

VQ = vehicle queue per lane

VDR = Vehicle Departure Rate (ft/sec2)

60 = conversion factor (sec per minute)

N = number of lanes

3.3.3. Presignal Warrant Matrix

A matrix is created to evaluate and analyze the many measures that could possibly affect the installation of a presignal. The recommended measures, or a combination of the measures ultimately become the presignal warrants that will be used by practitioners nationwide. The measures are evaluated using gathered research literature from the State Department of Transportation agencies, mathematical models, and the case study.

3.3.3.1. Presignal Warrant Measures

Presignal warrant measures are any factor that could possibly play a role in the installation of a presignal. These measures will be developed from the state agency reviews, literature review, case study, and engineering judgment. Some of the measures that may be included in the analysis are: geometrics, distance from the tracks to the downstream signal, vehicle delay, and queue distance. As information is reviewed and the case study is performed, additional unforeseen measures will be included and analyzed that are not currently considered.

3.3.3.2. Criteria for Analysis

Criteria must be defined to evaluate and recommend measures for selection to actual presignal warrants that are practical and critical in the overall presignal warrant analysis process. Because safety is by far the most significant measure in the success of a presignal, it is the main criteria in determining if a measure should become a presignal warrant. Additional criteria that address weather a measure should be considered as a presignal warrant include vehicle mobility and efficiency, and also if it is noted that a state agency is using a specific criteria to warrant a presignal.

A point system is used to determine if a measure should become a warrant. The criteria are weighted depending on importance. For safety, a maximum of 10 points can be awarded if the measure will improve the safety at the grade crossing. Because safety and a reduction in vehicle/train collisions is the most important factor in the installation of a presignal, safety is given the most points for use within the matrix. The next criterion is mobility. A total of 5 points can be awarded for mobility, meaning that a presignal will improve the vehicular mobility at the grade crossing. And the last criterion is previous usage. If a measure has been stated and used as warrant criteria within state agency guidelines, then 3 points are awarded for the measure.

3.4. Presignal Report Guidelines

To ensure consistency and standardization in the installation of presignals, engineering report guidelines are prepared. The procedures outlined within this dissertation provide government officials and engineers information necessary to make well informed decisions on the need for a presignal. In general, the purpose of these guidelines is to identify the need for a presignal and to provide standardization of the presignal installation process. Presently, some of the design standardization issues include: which presignal system to use, location of stop bar for presignals, the clear storage distance, the design vehicle and the affects of heavy vehicles within the storage area.

CHAPTER 4: ADOT SPONSORED RESEARCH AND DESIGN

Arizona Department of Transportation (ADOT) advertised a research project in June 2006 to study the need for presignals in Arizona. Presently, the railroad lines are double tracking the existing single track lines throughout the state. Therefore, additional delay and driver frustration may result as the train capacity is increased at grade crossings throughout Arizona. The state of Arizona took a proactive approach in determining alternative methods by soliciting engineers to research innovative safety measures at train crossings once the double tracks are installed and operational. Therefore, a portion of this research effort was funded by ADOT to determine what other states are doing in regards to presignals and if ADOT should consider presignals as one of their tools that will improve safety on the state roadway system. A railroad crossing review throughout the state determined that there are many locations in Arizona were railroad crossings are within 50 to 300 feet of a downstream signalized intersection. Because the MUTCD does not give guidance on presignal needs above 50 feet, ADOT's best practice was to conduct a literature review of state methods for the installation of presignals, analyze existing state presignal installation measures and develop guidelines for the installation of presignals within Arizona.

4.1. Presignal Research Efforts

In June 2006, research was conducted for ADOT to determine if presignals could be warranted at locations where the railroad grade crossing was greater than 50 feet from a signalized intersection. Upon the initial research efforts, it was noted that presignals are named and defined by their location and function with the downstream signalized intersection. The three types of presignal systems include: advance heads, pre-signals, and queue cutter signals. Therefore, presignal systems were defined in the preliminary research efforts, section 1.5 of this dissertation, to eliminate confusion of the types of systems. For a majority of this report, presignals refers the overall concept of presignals, not specifically any one of the three specific types.

State policies, standards and guidelines were researched and reviewed to determine if any state standards were developed and set that recommend installing presignals at a specific distance between the grade crossing and the downstream intersection greater than that specified in the MUTCD. The guidelines were also reviewed for criteria that may determine when a presignal should be installed and specific installation measures for presignals, if the signal is warranted and constructed.

4.1.1. State Guidelines for Presignals

The Institute of Transportation Engineers (ITE) conducted a questionnaire in 2003 in order to determine the current practices within the United States for warrants of traffic signals near highway rail crossings. They conducted a phone survey of the 50 states, and 34 states responded to ITE. Based on the information gathered on the phone, ITE then created a comprehensive questionnaire and sent it to 13 states, based on their phone responses. Five states sent detailed responses back to ITE for analysis. These states include: Illinois, Michigan, Nevada, New York, and South Carolina. Illinois is by far the most progressive state with the installation of over 80 presignals (ITE Highway/Rail

Report, Appendix D). Additionally, Illinois created warrants for installing presignals at grade crossings in the late 1990's. South Carolina has installed over 60 presignals on span wire. South Carolina is in the process of creating written guidelines for presignals. However, their general rule of thumb is if gates are not present and queuing occurs within the track area, then presignals are installed. New York has installed approximately 40 presignals. They also have written policies for the installation of presignals. However, none of the other states interviewed have presignal warrants or policies in place according to the ITE research.

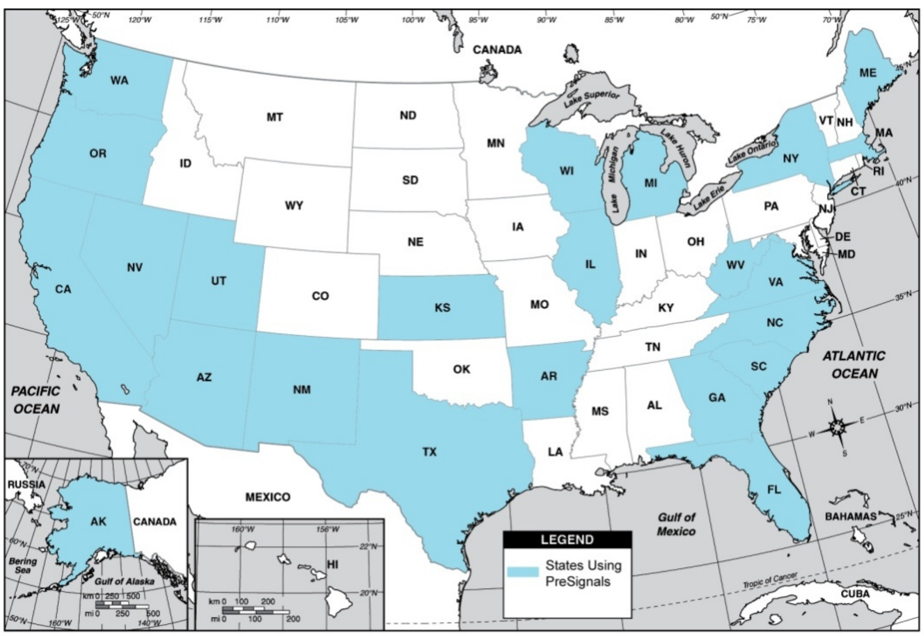

Figure 4.1 States Using Presignals

In 2008, phone interviews were conducted with each state to supplement and update data previously collected by ITE. Based on these phone interviews, Figure 4.1 illustrates that 24 states currently use presignals. However, at the time of the phone interviews, only Illinois had actual written presignal guidelines and South Carolina was preparing presignal guidelines; all other states did not have guidelines and are using the current practices in the MUTCD as a basis for presignal needs and installation.

4.1.2. Test Case

A field test case site was chosen to study the effects of placing a presignal over 50 feet from a downstream signalized intersection. ADOT staff recommended that a number of locations be reviewed to determine the best site for the field test case. Each field test case site candidate location required two primary characteristics: (1) there must be an at-grade crossing downstream from a signalized intersection/or warranted signalized intersection and (2) the nearby intersection must be on a State highway. Ideally, the grade crossing would have vehicular congestion caused by queuing from the downstream signal and also be caused by the high frequency of train activity. Upon a thorough review and comparison matrix of the crash history, vehicle count data and intersection geometry for sixteen grade crossing locations, the best alternative for the test case was concluded to be the intersection of State Route 347 and Maricopa-Casa Grande Highway in Maricopa, Arizona. This intersection was preferred by ADOT because the railroad tracks cross the highway, rather than the minor leg of the intersection; the traffic volumes on the state route are high; and vehicles are likely to queue over the tracks when the intersection of State Route 347/Maricopa-Casa Grande Highway is signalized. Additionally, other factors weighted into this field test case decision. These factors are as follows: the intersection currently warrants a traffic signal; heavy vehicles account for approximately 15% of the vehicle make-up; pre-emption alone may not clear the queue over the tracks; the geometry of this intersection is skewed, causing State Route 347 to curve, limiting sight visibility; and the Union Pacific Railroad will be double tracking through Arizona in the near future, which will double the number of daily train crossings.

4.2. Presignal Engineering Study

Based on the guidelines from the MUTCD, a presignal engineering study was conducted to determine if a presignal is warranted at the intersection of SR347/Maricopa Casa Grande Highway at the grade crossing. The study intersection is a “T” with State Route 347 running north-south and Maricopa-Casa Grande Highway running east from the state route. Approximately 250 feet south of the intersection on State Route 347 a railroad grade crossing exists that runs east-west, parallel to Maricopa-Casa Grande Highway. This is an active at grade crossing with advance warning signs, crossbucks, pavement markings, bells, gates and flashing lights. At the time of this study, the intersection of State Route 347 and Maricopa Casa Grande Highway was controlled by stop signs on the Highway. Figure 4.2 illustrates the existing site conditions from an aerial photograph.

Figure 4.2 Aerial of State Route 347/ Maricopa-Casa Grande Highway Maricopa, AZ

Due to the vehicle volumes and crash history, the intersection of State Route 347 and Maricopa-Casa Grande Highway warrants a signal. Based on signal warrant analyses and queue calculations using Synchro, a signal at this intersection will likely cause vehicles to queue approximately 300 feet upstream from the signal, or over 50 feet beyond the at-grade railroad crossing and create an unsafe condition. Three alternatives were recommended at the grade crossing that could be implemented to assist motorists. These alternatives included railroad pre-emption, presignals, or a combination of both. Based on the volumes of vehicular traffic projected in this area, coupled with the knowledge that train frequency will be doubling within the next year, railroad pre-emption was not considered a viable option, solely. Thus, the installation of a presignal, coupled with railroad preemption as an additional safety measure, was determined to be the recommended alternative. The presignal should be installed at the grade crossing to discourage motorists from resting on the tracks at a red indication downstream. The preliminary traffic study deemed that a presignal would improve the safety at the grade crossing while not significantly impacting delay times at the signalized intersection downstream.

The next step in the process is to determine which type of presignal system to install. The presignal system should adapt into the existing geometric conditions and be fully compatible with the railroad equipment. The advanced signal system, presignal system, and queue cutter system were evaluated to develop the best presignal for the site. The advanced signal system is defined by placing traffic signals upstream of the grade crossing adjacent to the downstream signalized intersection. The two signals are interconnected to the downstream signal controller and also the railroad controller. With an advanced signal system set-up, the two signal timings are set with no offset, (no lag) between the presignal and the downstream signal. This system works well when the grade crossing is near the downstream signalized intersection, say 50 feet or less. The result is that no vehicles are queued between the downstream signal and the railroad tracks.

The presignal system is defined similar to the advanced signal system in that a signal is placed upstream at the grade crossing and at the downstream intersection. However, with the presignal system set-up, the two signal timings are set with an offset between the signals so that there is a lag between the presignal and the downstream signal. This system works well when the grade crossing is located further away from the downstream signalized intersection, over 100 feet. The result is that no vehicles are stopped on the tracks. However, depending on the distance and the signal timing offset, vehicles may or may not store between the downstream signal and the railroad crossing.

The queue cutter signal system consists of placing a signal at the upstream grade crossing. The queue cutter signal may or may not be interconnected with the overall signal system. The queue cutter signal works with a series of loop detectors that are strategically placed. When the loop detector is activated by a vehicle queued over it, a call is made to the signal to change its indication to red. Therefore, the queue cutter system works independently of a downstream signalized intersection. The result is that the queue is cut and that no vehicles are stopped on the track.

Each presignal system was evaluated for the test case location on functionality, safety, least vehicle delay and operability. Due to the distance between the presignal and the downstream signal, the advance signal was not chosen as the best alternative because the distance requires offset timing to provide the safest system with the least vehicle delay to motorists. The queue cutter signal was reviewed, and could work as a viable option. However, because this system is not tied into the overall signal controller system, it was not recommended as the preferred alternative. Therefore, a presignal installation was chosen for this location because it interconnects into the downstream signal controller and will also tie into the train preemption which is highly recommended at this location.

4.3 Determining the Need for a Presignal in the Test Case

Because there are no current standards for the installation of a presignal, and the MUTCD states that a presignal should be installed when the railroad tracks are within 50 feet of a downstream signal, there were no evaluation criteria for determining if a presignal should truly be installed at the test site location. Therefore, throughout the literature evaluation and through discussions with State Department of Transportation officials and railroad authorities, evaluation measures were continually discussed. ADOT engineers questioned the necessity of a presignal, and requested an evaluation performance review that listed all of the factors that could be measured. Hence, a complete list of presignal measures were developed and documented. As measures were formulated, they were also evaluated. It was thought that if enough measures could be satisfied and show substantial benefits to safety with the installation of a presignal, then its justification would be warranted. The list began to develop with many ideas on factors that would justify a presignal. The list of presignal measures for consideration in the installation of a presignal that was developed from the ADOT test case is as follows:

- Vehicle queue caused by the downstream signalized intersection
- Intersection and at-grade crossing location geometrics
- Motorist sight distance at the grade crossing
- Distance from the at grade crossing to the downstream signalized intersection
- Daily vehicle delay caused by the train
- Average daily traffic volumes
- Vehicle classification using the roadway
- Posted speed along the roadway
- Train length
- Train frequency
- Train speed
- Track configuration and grade
- Station or yard near at grade crossing causing numerous train stops on the tracks over the roadway
- Gates at the grade crossing – 2 or 4
- Crash history

Each of these measures were then reviewed to determine if a presignal were installed at the grade crossing, would safety be increased and does this measure have an impact. Hours of discussions were held to determine what truly affects the installation of a presignal. Through this preliminary research, it was determined that the most influential factor in deciding the need for a presignal is if there is a possibility that vehicles could queue over the tracks, or if the presignal would eliminate the driver deciding when they could cross the tracks and safely fit on the far side of the tracks, even when a queue of vehicles were present. The presignal in the test case was finally approved based on one condition, using existing traffic volumes, the 95% queue length.

The 95% queue length was calculated using existing volumes in Synchro. Based on the output reports, the 95% queue was estimated to be greater than the storage between the railroad tracks and the downstream intersection. The 95% queue length was chosen for this test case based on work and research by Mystkowski titled Estimating Queue Lengths using Signal 94, Synchro, Transyt-7F, Passer II-90 and Corsim. The research shows that the 95% queue as calculated in Synchro compares to the maximum queue length observed at six studied locations. The results of this study conclude that over 60% of the time, the estimated queue in Syncho is greater than or equal to the observed maximum queue (Mystkoski, 1998).

4.4. Preparing the Presignal Study for the Test Case

In order to justify that a presignal should be installed in addition to the signal at the SR347/Maricopa Casa Grande Highway intersection, a presignal study was conducted for ADOT. The presignal study was developed to validate the need for the presignal. The presignal study estimated queue lengths based on the mathematical models presented in Chapter 3. Additionally, the time to move from the n^{th} position to the i^{th} position were also calculated to make certain that the advance warning time for the gates, which was already in use of 25 seconds, was adequate to move vehicles and clear them from the tracks when the downstream signal turned green with preemption to clear a vehicle from the near side of the tracks.

4.4.1. Queuing Calculations of the Downstream Signal

The queues were estimated to determine the need for a presignal at SR 347/Maricopa Casa Grande Highway. Using Synchro and collected turning movement counts during the morning and evening peak hours, the 95% queue was estimated to be approximately 255 feet. Therefore, the queue could potentially traverse over the tracks during the morning and evening peak hours from the downstream signal. Based on the intersection geometrics, and the clear distance from the tracks, the intersection should not stack past 190 feet. Therefore, it is likely that vehicles will stack within the clear distance of the tracks creating unsafe motorist conditions.

4.4.2. Time Movement Calculations on SR347 at the Grade Crossing

The installation of a presignal should keep the tracks clear through signal timing and loop detection because both the presignal and the downstream signal would be interconnected. However, in the rare instance that a driver would disobey the presignal and be stopped on the near side of the tracks, within the clear zone, signal preemption must be available to clear the tracks as secondary precaution measure. Therefore, the time needed to clear the queue between the railroad tracks and the intersection when the train activates the preemption device must be evaluated. Based on the track width and the clear distance for this site, the clearing distance constitutes moving the last vehicle in the queue an approximate distance of 30 feet from the rail crossing and not necessarily completely clearing the entire queue upon the arrival of the train. This de-storage time must be less than the 25 seconds of advance train warning under normal conditions. When the train activates the signal, the minimum yellow clearance of 4 seconds and an all red time of 2 seconds are needed before the intersection signal can change to green and begin dissipating the queue.

The dynamics of starting a stopped queue must be analyzed to determine the time required to clear vehicles approximately 30 feet from the railroad tracks. Therefore the mathematical model as presented in section 3.3.2.2. Time Movement Model, was used to estimate the time required to move a queue of n vehicles to the i position to clear the last vehicle in the queue from the railroad tracks. Because it is not necessary to clear the entire queue for this scenario, but to move the last vehicle in the queue 30 feet away from the tracks, it was assumed that five vehicle would need to clear the intersection and the remaining 6 vehicles would move up far enough in the queue to allow a minimum of 30 feet of clearance at the tracks. Based on the queuing model, the time required to move the last vehicle in the queue of eleven vehicles from a stopped condition approximately 30 feet was calculated to be 15.9 seconds.

The yellow clearance time and all red time must be added to the time movement to accurately determine of the train warning is reasonable, or additional time must be added when presignals are considered. Therefore, assuming a time movement of 16 seconds and all red of 2 and yellow clearance of 4, the 22 total seconds of time to move the queue is considered reasonable.

It is important to note that the calculations for the test case are based on estimated queue lengths and vehicle volumes. All of the calculations were performed under normal operating conditions. With these calculations, stalled vehicles or crashes within the storage area between the intersection and the railroad tracks were not taken into consideration because it is impossible to predict the location if an incident. Therefore, should an incident occur, it is assumed that drivers are aware of the dangers of parking on or near the railroad tracks even though a presignal is installed and preemption is in use.

4.5. Presignal Design

The completion of the ADOT state document review, literature review and presignal engineering study, combined with the signal design criteria specified in the MUTCD resulted in the development of the presignal system design for the intersection of SR347/Maricopa Casa Grande Highway. The design incorporated many aspects of a typical signal design along with design guidelines from the State of Illinois (IDOT, 1997). The design criteria specified herein apply to the presignal system installed on SR 347/Maricopa Casa Grande Highway in Maricopa, Arizona. However, these guidelines are modified to produce standard guidelines and specifically address design details regarding advance signals, presignal systems, and queue cutter signals in Chapter 6: Presignal Guidelines.

4.5.1. SR 347/Maricopa Casa Grande Highway Presignal Design Details

Traffic presignal design plans were prepared for the installation of a permanent presignal on SR347 near the railroad tracks in Maricopa, Arizona. These plans were designed and coordinated with signal plans at the intersection of SR347/Maricopa-Casa Grande Highway. The plans allowed for vehicles to store within the area between the downstream signal and the railroad tracks. Major presignal design issues are discussed that include: pole placement, presignal design, connectivity to the traffic signal controller and railroad controller, stop bar placement, signing and striping.

The presignal pole placement is critical at the grade crossing. This is because the technology is fairly new and currently the railroad grade crossing is signed, marked, and has flashing lights and gates. Therefore, when a driver approaches an at-grade crossing the presignal must be completely visible and easily understood. The presignal mast arm pole should be located upstream from the railroad crossing. The pole must be located to maintain visibility of the flashing railroad crossing lights. The presignal shall be placed at least four feet from the nearest railroad crossing device (i.e. gate arm or railroad cantilever.) The signal pole and equipment shall in no way restrict the view of the existing railroad lights or equipment. On SR 347, the presignal pole was placed approximately 45 feet from the center of the railroad crossing to best provide driver visibility.

The MUTCD provides standards for the installation of signals. These standards must also be followed when designing a presignal. The size, number and location of signal faces on the approach to the at-grade crossing must meet the minimum standards as specified in the MUTCD. For example, a minimum of two signal faces shall be provided for the major movement on the approach (MUTCD, 2003). Presignal heads must align with the roadway lanes as specified in the MUTCD. For the SR 347 presignal, a 30 foot mast arm was used in the test case. Three signal heads were installed, two on the mast arm for each through lane of traffic and an additional head was installed on the presignal pole.

Interconnecting traffic signals allows one controller to run the signal timing scheme and the preemption for both the traffic signal and the presignal. The presignal is interconnected with downstream traffic signal controller and the railroad controller via wireline. Therefore, three inch conduit was placed from the presignal to the downstream traffic signal cabinet with the required conductors.

The proper signing must accompany the presignal at the grade crossing. Signing is required at grade crossings in accordance with the MUTCD. Stop Here On Red and Do Not Stop On Tracks signing should be installed at the stop bar, which is located no closer than 40 feet from the presignal heads. If the downstream signalized intersection is close, with insufficient clear storage distance, then No Turn On Red signs shall be posted for the approach that crosses the railroad tracks. Two new R8-8 (Do Not Stop On Tracks) signs were installed for this presignal design, one on the mast arm of the presignal pole, and the other at the stop bar. Additionally, a R10-6a (Stop Here On Red) sign was installed at the stop bar. All other signs remained in place.

Striping should adhere to the guidelines specified in the current edition of the MUTCD. The striping shall consist of all roadway lane markings along with the required railroad crossing markings. No passing markings shall be installed on all two lane roadways at the grade crossing. The striping should not continue over the railroad crossing panels, however, the striping should align on both sides of the tracks. No new striping or striping modifications were required for the presignal design on SR 347.

The stop bar for the presignal and the stop bar for the railroad should be the only limit lines upstream of the railroad crossing. When the presignal is installed, the stop bar should be placed 40 feet from the presignal location. The stop bar should be located so that vehicles which make a mandatory stop at all grade crossings are not required to stop twice before crossing the railroad tracks. However, there must be sufficient sight distance down the track to allow enough time for a stopped vehicle to start crossing the railroad tracks before a train arrives (Ogden, 2007). An 18 inch stop bar was installed on SR 347 approximately 40 feet back from the presignal pole. The sight distance down the tracks was checked in the field to confirm adequacy with the placement of the new stop bar. However, at this specific location, the presignal pole and the stop bar placement made it impossible for heavy vehicles to stop only once if the presignal has a red indication. Therefore, it was assumed that vehicles required to stop, will do so near the tracks and therefore, the railroad crossing stop bar remained at 15 feet from the railroad tracks.

4.5.2. SR347/Maricopa Casa Grande Highway Presignal Phasing and Timing Operations

The presignal intervals were phased and timed with the downstream signal to provide delay adequate to clear vehicles from the track area and the downstream intersection. The phasing of a signal determines the order that movements are serviced while the timing of a signal determines the amount of allocated green time to each traffic movement at the intersection. When the presignals are timed, the queue clearance time must be long enough to allow the design vehicle to move over the at-grade crossing and through the downstream intersection or onto the clear storage area. Figure 4.3 illustrates the phasing scheme for the downstream signal and the presignal installation at the intersection of SR347/Maricopa Casa Grande Highway under normal operating conditions.

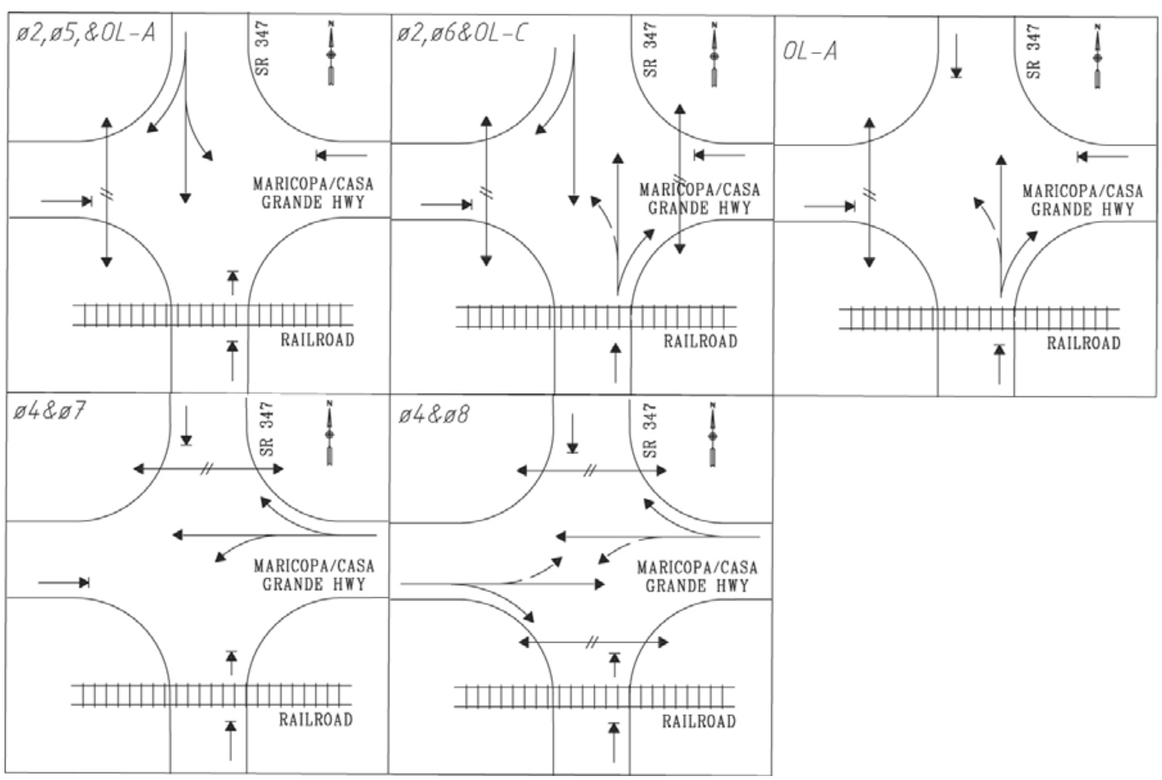

Figure 4.3: Phasing Scheme for Normal Operating Conditions

For normal operations, meaning the presignal is non-preempted, the presignal rests in recall on the main approaches, usually phases 2 and 6. The presignal usually cycles through the green to yellow to red sequence before the downstream signal, also known as the presignal offset. The presignal offset is a calculated time (depending on the distance from the at-grade crossing to the downstream signal) and terminated prior to the downstream indication. This prevents vehicles from stopping on the crossing deck or near the gates and allows a moment of time for vehicles to clear the tracks at every signal cycle, clear track green interval. Next the downstream signal terminates the main approach phases and the turning movements or minor approach phases are serviced, usually 4 and 8. Finally, after the traffic signals go through their sequencing for the other movements, the presignals change to green before the traffic signals at the intersection do, allowing traffic to approach the upcoming green signal at the intersection.

When the railroad preempts the signal system, a call is received from the railroad notifying the controller that a train is approaching. However, the crossing should be clear of vehicles because traffic should have stopped at the presignals. As an additional safety measure, the downstream signal still cycles through the clear track interval to allow any motorist that did not stop at the presignal to move away from the tracks. If the downstream signal is servicing the minor approaches or turning lanes, that phase will be terminated immediately, and the downstream signal will call the green indication on the major approach to provide track clearance for any vehicle near the tracks. Additionally, the pre-signal will terminate its phase and immediately turn to a red indication. Once the track clearance has timed, the signal can service other phases of the downstream signalized intersection that do not conflict with the at-grade crossing during the train occupation. When the train clears the area, the signal will terminate wherever it is. This allows the vehicles to clear that are held by the presignal or more specifically, the train. The signal will then resume to normal operation after the vehicles clear on the main approach. Figure 4.4 illustrates the phasing required when the train activates the preemption device at the intersection of SR347 and Maricopa Casa Grande Highway.

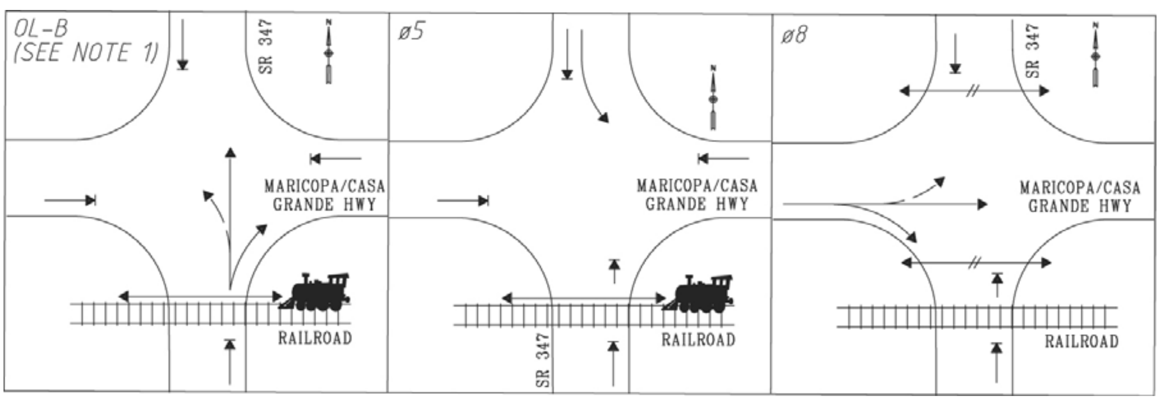

Figure 4.4: Phasing Scheme for Preemption Operation Conditions

4.6. Presignal Installation

In 2008, upon design approval of the plan set and construction bid documents, ADOT in coordination with Union Pacific Railroad installed a presignal on the SR347 northbound approach to the Maricopa Casa Grande Highway at the railroad crossing. ADOT installed the presignal to increase safety, due to the estimated queuing lengths from the downstream signal. This proactive effort will deter motorists that may have stopped on the railroad tracks during the red light indication from the downstream signal. Because this presignal installation did not meet the MUTCD guidelines, this location was evaluated in an attempt to answer the following questions:

- Did the presignal improve the safety of motorists at the railroad crossing?
- Did the presignal improve the operation of traffic at the railroad crossing?
- What impacts were associated with the presignal installation due to its non-conformance to the MUTCD standards?
- Should presignals be considered statewide?

No geometric changes to the roadway, grade crossing, or downstream intersection were proposed with the installation of the SR 347/Maricopa Casa Grande Highway signal and presignal at the railroad crossing. No changes were made to the advance warning time, existing flashing light signals and the automatic gate system at the crossing. The signal equipment was installed and the signals were coordinated using one controller to operate both the signal and the presignal timing and phasing. The phasing implemented is shown in Figures 3.3 and 3.4. Additionally, a 7 second offset was programmed between the downstream signal and the presignal to allow vehicles time to clear the tracks on each cycle.

A review of the presignal operations was conducted to determine if the presignal is operating as it was intended. The presignal does cut the queue at the end of every cycle, therefore reducing the ability of motorists to stop on the railroad tracks during a downstream red signal indication. Occasionally, drivers were observed running the red light of the presignal. However, this did not adversely impact the operations of the presignal and in fact; the signal timing offset allowed the red light runners storage on the far side of the railroad tracks. Therefore, these drivers were not in danger of stopping on or near the tracks. During the observation period, no vehicles were observed queuing onto the tracks. As motorists approached the tracks, the presignal seemed to minimize driver confusion with the typical green, yellow and red indications that motorists understand and are accustom to. Drivers were given the yellow clearance interval compared to the flashing light signal indications are normally associated with an at-grade crossing. This may reduce the occurrence of vehicles slamming on their brakes when the railroad flashers activate. However, the yellow clearance interval of the presignal is active at the same time as the flashing lights when a train preempts the presignal.

Because a downstream signal and the presignal were installed at this location simultaneously, before and after studies at the grade crossing were not conducted because the issues of vehicles queuing on the railroad tracks was foreseen, not actual. Observations of driver behavior after the presignal was installed indicate that the presignal will reduce the number of drivers that could stop on the tracks and eliminates the decision making process of the driver to determine if their vehicle can “fit” into a space prior to the tracks yet leaving the back end of their vehicle on or near the tracks.

A general assessment of the presignal operations at the SR347 grade crossing near the Maricopa-Casa Grande Highway is summarized regarding the installation and operation of the presignal. The presignal improves the safety of the at grade crossing because it significantly reduces the ability for motorists to stop on the railroad tracks. The presignal also improves the visibility of the railroad tracks as it notifies the driver that there is an intersection ahead. The presignal does not appear to improve the delay or operation of traffic at the grade crossing. In fact, there may even be a slight delay due to the offset between the presignal and the downstream signal. The installation of the presignal over 250 feet from the downstream intersection improved safety at the test case location. The distance between the signalized intersection and the presignal did not compromise the safety or operations and in fact showed that distance had no impact. Therefore, this measure should not be used in the MUTCD.

CHAPTER 5: PRESIGNAL WARRANTS

In order to assure that the advantages outweigh the disadvantages of installing a presignal, a series of warrants was developed to define the minimum conditions when further consideration of a presignal is appropriate. The presignal warrants were developed though extensive research using a variety of traffic engineering measures created through many open house meetings and technical advisory committee meetings with state officials, railroad officials and interested citizens on what constitutes a presignal installation. Presignal warrants are necessary to provide consistency in the installation of presignals. However, simply meeting the warranting criteria does not automatically justify the installation of a presignal. There are unique factors at every train crossing that impact the effectiveness of a presignal and these factors should be evaluated before a decision to install a presignal is made. Failure to meet any of the warranting criteria indicates that a presignal should not be installed.

It would appear that presignal warrants could be derived simply by reviewing the derivation of signal warrants as presented in the MUTCD and modifying those warrants to develop the presignal warrants. However, this is not the case. Signal warrants have been included in the MUTCD since its earliest edition in the 1930’s, and the original warrants were developed through a consensus of practicing traffic engineers in the late 1920’s deciding the threshold of where traffic volumes seemed to result in improved safety and enhanced mobility with the installation of a traffic signal (USDOT, 2010). Improvements to the MUTCD signal warrants have been occurring almost continuously with each new edition. Until the 1970's, changes in the warrants also reflected only engineering consensus and, as far as is known, were not based on any research. (USDOT, 2010). The 4-hour and Peak Hour warrants were first developed with research by KLD Associates for NCHRP and included in the 1978 MUTCD. These warrants were new to traffic engineers and were created utilizing network simulation models (USDOT, 2010). Therefore, there is no documentation or research knowledge of MUTCD signal warrant development.

The presignal warrants that are developed as a large portion of this dissertation are based on engineering consensus and research. These presignal warrants are based on traffic engineering measures that may constitute the installation of a presignal at a location. The weighting of the measures and the criteria for which they are analyzed to develop the presignal warrants is only of interest to the researcher. The outcome of determining significant measures is refined to express the actual presignal warrants that the traffic engineer will use in everyday practice.

5.1. Presignal Measures

Presignal measures are any traffic engineering value either calculated or observed that may relate to the installation of a presignal. The list of measures was developed through a consensus of discussions with railroad operators, traffic engineers, researchers and key stakeholders with an interest in improving at-grade crossings. Each measure was evaluated based on criteria and the recommended measures were refined and developed into presignal warrants for practitioners to use in daily operations. The presignal measures were developed by listing all of the possible factors that could be considered with a presignal. These measures were developed from requirements based on knowledge gained from the test case, literature research and conversations with many state agency signal operations departments. The measures are then analyzed to determine their need and importance. The following is a list of the reasonable measures that were considered based on key input from a variety of sources:

- Vehicle queue length caused by the downstream signalized intersection
- Intersection and at grade crossing location geometrics
- Motorist sight distance at the grade crossing
- Distance from the at grade crossing to the downstream signalized intersection
- Daily vehicle delay caused by the train
- Average daily traffic volumes
- Train length
- Train frequency
- Station or yard near at grade crossing causing numerous train stops on the tracks over the roadway
- Gates at the grade crossing
- Crash history at the grade crossing

5.2. Evaluation Criteria

The evaluation criteria for the presignal measures were derived based on the conclusions and recommendations from the literature review and the field case study. The evaluation criteria are used to recommend which measures should ultimately be actual presignal warrants. Not all of the measures are directly applicable to presignal warrants and should therefore, not be used. The main reasons to install a presignal are to enhance motorist safety and traveler efficiency. Therefore, these were the only criteria in determining if the presignal measures should be used and recommended as actual warrants for presignal installation. Additionally, because Illinois Department of Transportation and South Carolina Department of Transportation already have some documented criteria for the install a presignal, that information was also reviewed and considered in determining which measures are viable and should be converted to presignal warrants.

Two criteria were used to determine if a possible presignal warrant should be actually used as warrant to determine if a presignal is needed. The first criterion that was used to assess if a presignal measure was applicable for use as the presignal warrant selection is *safety*. Enhanced safety at a grade crossing could save a life and therefore, safety is awarded the most points if the installation of a presignal has an effect on the measure. The grading system for safety is ranked from one to ten points with ten points awarded being the greatest safety measure to the motoring public. This means that if a presignal installation can satisfactorily improve safety when considering a presignal measure, then that measure is ranked with higher points. The second criterion is *vehicle efficiency*. A measure is given points for vehicle efficiency, if this measure actually improves vehicle efficiency with the installation of a presignal. An example includes assigning the right of way which allows for enhanced vehicle mobility over the grade crossing. A total of five points are awarded if it is believed that the possible warrant can enhance mobility with a presignal where it would otherwise not.

5.3. The Presignal Measures Matrix

The following is the presignal measures matrix. Table 5.1, shows the points awarded for each possible presignal measure that could be used to determine the need for a presignal. The measures with the highest points awarded are considered for presignal warrants. A detailed description of the point award system for each possible presignal measure follows.

Possible Presignal Measure	Selection Criteria		Total Points
	Safety	Efficiency	
Queue Length	10	5	15
Intersection Geometrics	4	0	4
Sight Distance Limitations	5	5	10
Distance	8	0	8
Daily Vehicle Delay	0	0	0
Average Daily Traffic	0	0	0
Train Length	4	0	4
Train Frequency	4	0	4
Yard Near-by	6	2	8
No Gates	10	5	15

Table 5.1: Presignal Warrant Determination Table

Vehicle queue length caused by the downstream signalized intersection - the length of the queue affects the safety at the site. Vehicles queuing from the signalized intersection over the tracks could create a severe safety condition. Therefore, the maximum points were awarded, 10. Vehicle efficiency and mobility is enhanced with a presignal for queued vehicles because the signal creates a gap in traffic and allows queues to clear with the installation of a presignal therefore, the maximum points, 5 are awarded.

Intersection and at grade crossing location geometrics – the at-grade crossing geometrics could be located on a vertical or horizontal curve. A presignal could warn drivers of the at-grade crossing, and improve safety. Therefore, a total of 4 points are awarded. The use of a presignal for varying geometric conditions will not increase efficiency; therefore, 0 points are awarded for efficiency.

Motorist sight distance limitations at the grade crossing – If no gates are present, sight distance limitations near an at-grade crossing can be fatal; however, if gates are present, then the motorist will be forced to stop with the gates and therefore 0 points would be awarded. Therefore, 5 points were awarded, overall for sight distance limitations. A presignal will assist in the efficient movement of vehicle if there are sight distance limitations therefore, 5 points are awarded.

Distance from the at grade crossing to the downstream signalized intersection – the closer the at-grade crossing is to the signalized intersection, the more of a need for a presignal due to queuing over the tracks. Therefore, this possible warrant is directly related to vehicles queuing on the tracks. Therefore, 8 points are awarded because a presignal will enhance safety by creating a gap in a traffic queue or by forcing vehicles not to queue within clear distance of the tracks. Mobility is not affected by the distance. Therefore, 0 points are awarded.

Daily vehicle delay caused by the train – A presignal will not enhance safety with respect to average vehicle delay or increase mobility from delay caused by a train. Therefore, 0 points are awarded.

Average daily traffic volumes – A presignal will not enhance safety or increase mobility regardless of the volume of traffic that traverses over the at-grade crossing. Therefore, 0 points were awarded.

Train length – 4 points were awarded for safety due to train length because the longer the train, the more likely that a motorist may try to beat the train, regardless of the use of gates. Mobility will not be enhanced due to the train length, therefore 0 points were awarded.

Train frequency - 4 points were awarded for safety due to train frequency because the more often a train arrives, the more likely that a motorist may try to beat the train, regardless of the use of gates. Mobility will not be enhanced due to the train frequency, therefore 0 points were awarded.

Station or yard near at-grade crossing causing numerous train stops on the tracks over the roadway – If a station or yard is located near the tracks, the train may have a tendency to stop on the at grade crossing, or reverse over it, therefore a signal will notify motorists of this action, and 6 points were awarded. Mobility could be enhanced with the installation of a presignal, therefore, 2 points were awarded.

Gates at the grade crossing – If no gates are installed at the grade crossing, then a presignal will enhance safety. Therefore 10 points were awarded. Additionally, 5 points were awarded because a presignal will enhance safety when gates are not present.

5.4. Crash History

Crash history is listed as a measure to determine if a presignal should be installed. However, crash history was not included in the matrix and evaluation process. Train/vehicle collisions are rare but the severity is devastating so crash records must be reviewed and evaluated over a 10 year period at the grade crossing for each presignal engineering report. The evaluation of the crash history is significant and plays a vital role in the installation of a presignal and therefore cannot be analyzed similarly to each of the other measures listed using the evaluation criteria above.

Depending upon the existing situation, crash data may or may not determine the need for a presignal. The configuration of traffic control devices, the possibility of vehicle currently queuing on the tracks and the surrounding area and engineering judgment may clearly show that a presignal can significantly improve safety and therefore should be installed on crash data, solely. However, crash data may not be an easy indicator and the presignal warrants should then be used to justify a presignal.

Two very different scenarios that explain crash data analysis are the ADOT test case studied within this report and a location where a signal already exists at the downstream intersection. In the first example, the ADOT test case, crash data is not an indicator of the need for a presignal, in that, presently the downstream intersection is controlled by stop signals and vehicle queuing does not affect the grade crossing with stop control. Therefore, historical crash data will not show that the installation of a presignal will improve the safety because there is not a current problem with vehicles queuing over the at-grade crossing. Eventually vehicles will queue back onto the railroad tracks, and therefore, a presignal should be installed based on other presignal warrants, prior to developing an unsafe grade crossing condition. The second example is a case where vehicles are queuing onto the railroad tracks presently due to traffic operations at a downstream intersection. Therefore, the review and analysis of prior crashes plays a significant role in determining the need for a presignal. Hence, depending on whether the queuing of vehicles is observed or estimated in a future horizon year, crash records can alone dictate the need for a presignal.

Train/vehicle collisions are caused for a variety of reasons; therefore, crash records must be reviewed manually to decipher which crashes are related to the crossing and could be correctible by a presignal installation. Crashes occur at grade crossings because of stalled vehicles on the tracks, drivers trying to outrun a train, drivers consciously maneuvering around the gates, vehicles running into the gates, rear-end collisions, and vehicles queued across the tracks. Crashes correctable by the installation of a presignal should then be documented, and a presignal installed based on crash history.

Because train accidents are infrequent but deadly, additional research and analyses must be performed to develop presignal warrants based on crash history. Therefore, crash history as it relates to creating a warrant for presignal installation should be reviewed in further detail at a later date. Details on how the crash data correlates into a logical and meaningful presignal warrant need to be studied and refined separate from this dissertation effort. The development of this presignal warrant could be as simple as a specific value of crashes over a given period of time, or as detailed as listing types of crashes correctible by a presignal and incorporating specific intersection and at-grade crossing characteristics. Forecasting crashes based on the surroundings at the grade crossing may even affect this warrant and should be reviewed.

5.5. Presignal Warrants

Interpreting the information presented in the matrix based upon the point system, presignals should be installed whenever vehicle queues back over the railroad tracks. Additionally, presignals should be installed wherever railroad warning devices only consist of flashing signal lights. However, this can result in conflicting signal indications between the flashing red lights at the crossing and a display of track clearance green beyond the crossing. Therefore, when installing presignals due to field hardware conditions, the installation of gates maybe required in addition to the presignal installation (Campbell, 2007). Presignals could be considered when sight distance is restricted and gates are not present, when a storage yard or station is located near the grade crossing, which causes trains to stop or back over the at grade crossing, and when the distance between the at-grade crossing and the downstream intersection are so close that the motoring public is confused by the intersection and the tracks. High train frequencies, train lengths, the average daily traffic volume and vehicle delay do not appear to create the need for a presignal, individually. However, a combination of these factors may influence the need and should be examined more thoroughly, because, when vehicle traffic volumes are great at the grade crossing, and train lengths are long with great frequency, this combination could create a significant number of conflict periods throughout the day. Presignals should also be considered when crash history clearly shows that specific crashes are correctible with the installation of a presignal.

Based on the conclusions of the presignal measures matrix, crash history, and using engineering judgment, presignal warrants for practitioners are derived from the recommendations as follows: Presignal Warrant A: Crash History; Presignal Warrant B: Queue Length; Presignal Warrant C: At-Grade Crossings without Gates; and Presignal Warrant D: Yard or Station near a Grade Crossing.

5.5.1. Warrant A: Crash History

The need for a presignal shall be reviewed and considered when a crash occurred that is correctible by a presignal installation. This presignal warrant needs further research and documentation. However, crash data cannot be overlooked at this time. Therefore, the engineer must use their judgment to determine if a presignal installation will reduce crashes based on crash history. If the engineer reports that a presignal will in fact reduce crashes, then the presignal should be installed and monitored over a two year period, post construction.

5.5.2. Warrant B: Queue Length

The need for a presignal shall be considered if vehicles from the downstream signal queue within the minimum track clearance distance. The vehicle queue should be field measured and verified during the morning, evening and weekend peak periods to make certain that the queues are ending at least 30 feet in distance from the minimum track clearance area. If a queued vehicle is observed within this area, a presignal should be installed.

At times, development and growth within a region or area dictates the need for a new downstream intersection signal, or signal modification. Therefore, traffic volume estimates and queuing estimates are necessary to adequately determine if a presignal is warranted. Syncho Traffic Engineering software should be used to calculate the 50% and the 95% queue lengths for the downstream signal. These queue estimates will then give the engineer a reasonable estimate of the projected queue lengths based on the intersection geometrics and signal timing estimates. The 95% queue length should be used to determine if vehicles will queue into the minimum track clearance area and require presignal installation. As traffic engineering software improves and queues are more accurately estimated, these guidelines should be upgraded to the latest available software with the most accurate results.

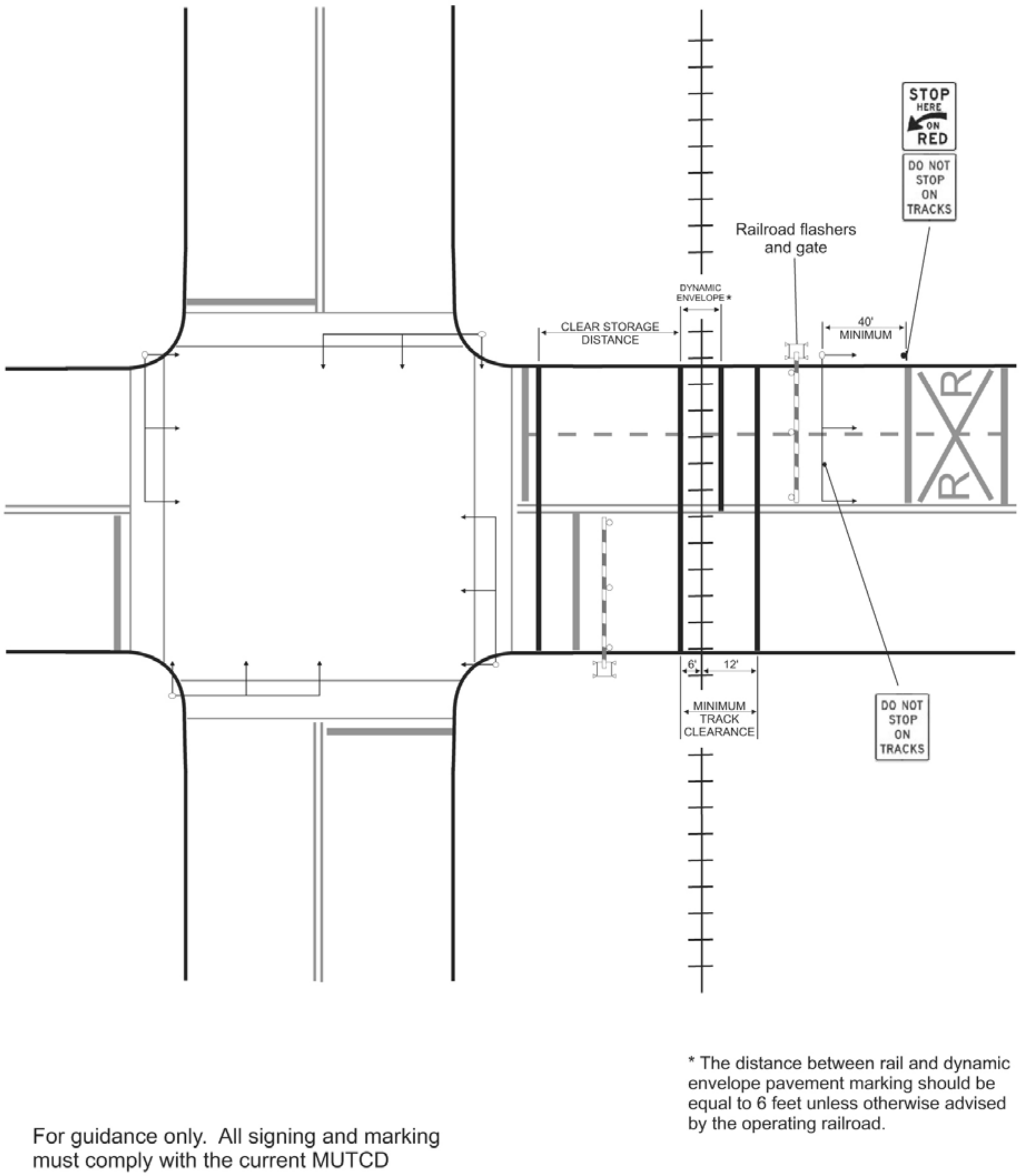

Figure 5.1. Stored Vehicles for Queue Warrant

5.5.3. Presignal Warrant C: At-Grade Crossings without Gates

Presignals should be installed wherever railroad warning devices only consist of flashing signal lights, which relates to a class 2 track and a maximum train speed of 39 mph. The presignal indications provide the driver with a clear and uniform indication of when the track is clear and the driver can safety traverse across the railroad tracks. The designer must carefully note that conflicting signal indications could exist between the flashing red lights at the crossing and a display of green track clearance indications. Therefore, when installing presignals due to field hardware conditions, the installation of gates maybe required in addition to the presignal installation (Campbell, 2007).

Because a train always has the right of way, sight distance is an important factor in determining the need for a presignal. Presignals should be considered when the line of sight for the motorist is not adequate and gates are not present. Some causes for reduced line of sight include skewed tracks, horizontal or vertical alignment of the roadway, horizontal or vertical alignment of the railroad tracks, or out parcels in within the sight distance triangles. Therefore, presignal may be warranted at a highway-rail grade crossing when the approach sight distance to the at-grade crossing is inadequate and gates are not present (FRA, 2002). While driving at the posted speed limit, the motorist must be able to see an approaching train from either the left or the right and stop in sufficient time to remain outside the clear zone, 15 feet from the near rail. The driver must then be able to see far enough down the tracks to determine if they can move their vehicle safely across the tracks to a point 15 feet from the from the far rail, prior to the arrival of a train

(FRA, 2002). When limited sight conditions exist, motorists are forced to substantially reduce their speed. The stopping sight distance is the ability to see a train or the traffic control devices at the crossing with sufficient time so that the motorist can bring the vehicle to a safe and controlled stop at least 15 feet from the nearest railroad track. Inadequate sight distance creates unsafe conditions because there is insufficient time for any vehicle, proceeding from a complete stop, to safely traverse the crossing within the time allowed by maximum train speed. Therefore, a presignal should be installed to assist the driver in determining when it is clear to cross the tracks. Insufficient stopping sight distance is often due to poor roadway geometry and outlying parcels within the surrounding topography. If the sight distance cannot be corrected by removing structures or vegetation, then the deficiency must be corrected by installing a presignal.

5.5.4. Presignal Warrant D: Yard or Station near a Grade Crossing

A storage facility, station or yard near an at-grade crossing causes driver confusion and may unnecessarily hold up vehicles when they could otherwise traverse the tracks safely. Therefore a presignal may be warranted when a facility or station is present and near to a grade crossing. With this warrant, the engineer must use their judgment to determine if the presignal will enhance the conditions and allow vehicles traverse the tracks by giving them the right of way, while a train stopped and loading.

5.6. Data Collection for a Presignal Warrant Analysis

Prior to completing a presignal warrant analysis, traffic data must be gathered to assess the need for installation. Data collection is an important part of completing the presignal warrant study. Data on traffic conditions, collision history, train conditions, and physical intersection geometrics should be collected and reviewed to determine if warrants apply for the installation of a presignal. Traffic data that is instrumental in the warrant study process includes average daily traffic volumes, peak hour vehicular traffic counts, vehicle classifications, vehicle speeds across the railroad crossing, turning movement counts, and queue lengths. Data that should be collected for the train conditions includes train frequency, average train length and train speed. Additionally, a scalable condition diagram should be drawn that includes all roadway geometrics including number of tracks at the grade crossing, railroad crossing traffic control at the crossing, fixed utility features, distance between grade crossing and downstream signal, sight distance at the grade crossing, pavement markings and signage, and downstream intersection conditions and adjacent land uses. This data can be collected in a variety of ways including past traffic analysis reports, government agencies, the railroad company, and by actual data collection methods.

5.7. Type of Presignal System

If the need for a presignal is determined, then the type of presignal system required for the given roadway and railroad grade crossing geometrics must be determined. The three systems include: advanced signal systems, presignal systems and queue cutter signals. Each system has a unique set of characteristics that will enhance the safety of the grade crossing when the correct system is chosen. Therefore, the engineer must decide the need at the given location and the specific purpose of the presignal installation.

Advanced Signals is a system where signals are placed both upstream of the at-grade crossing and also at the downstream intersection. Both the advance signal heads and the intersection signal heads are timed simultaneously (ITE Report 2003). Meaning, when the signal indication turns yellow, both the at-grade crossing and the intersection signal turn yellow at the same time, and therefore, a vehicle may not clear both the advance signal and the intersection. With this type of system, the vehicle that traversed the grade crossing on yellow may be forced to stop in the storage area between the at-grade crossing and the intersection. This system reduces queuing on the tracks because newly arriving vehicles stop upstream of the grade crossing during the red phase (ITE Report 2003). Figure 5.2 illustrates an advanced signal system.

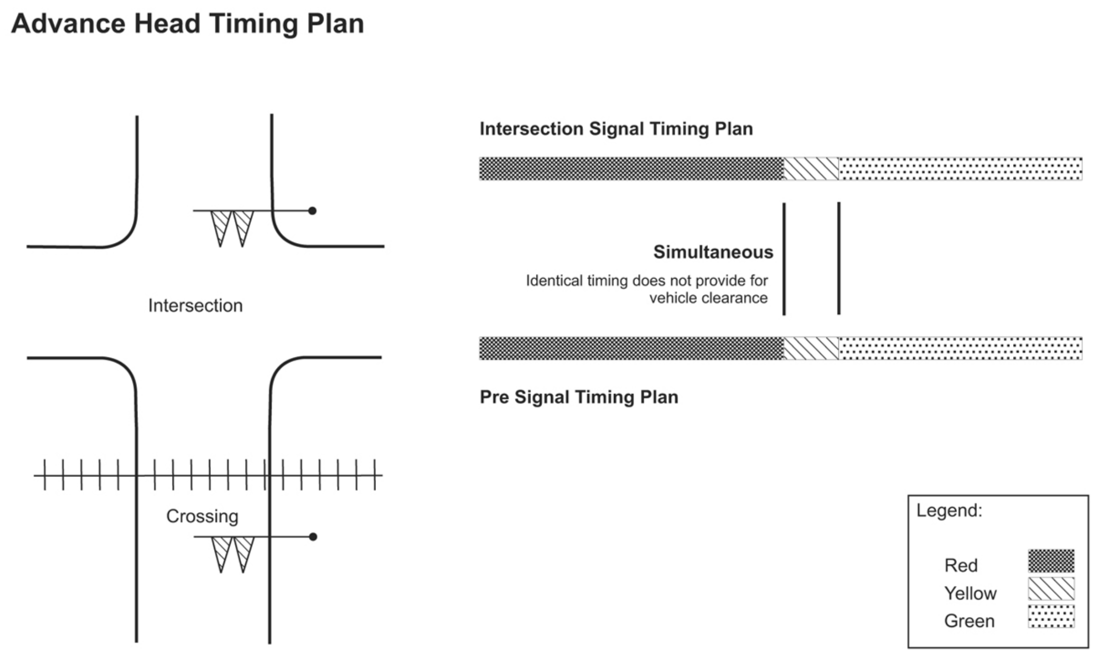

Figure 5.2: Advanced Signal System

A presignal installation is similar to the advance heads system, in that the signals are placed at the upstream grade crossing and at the downstream intersection. The difference with this system is that the signals are timed with an offset, meaning the upstream grade crossing signal indication turns red prior to the downstream intersection signal indication. Therefore, this system is timed to clear the storage area. This type of system works well when there is adequate vehicle storage area within the clear storage distance.

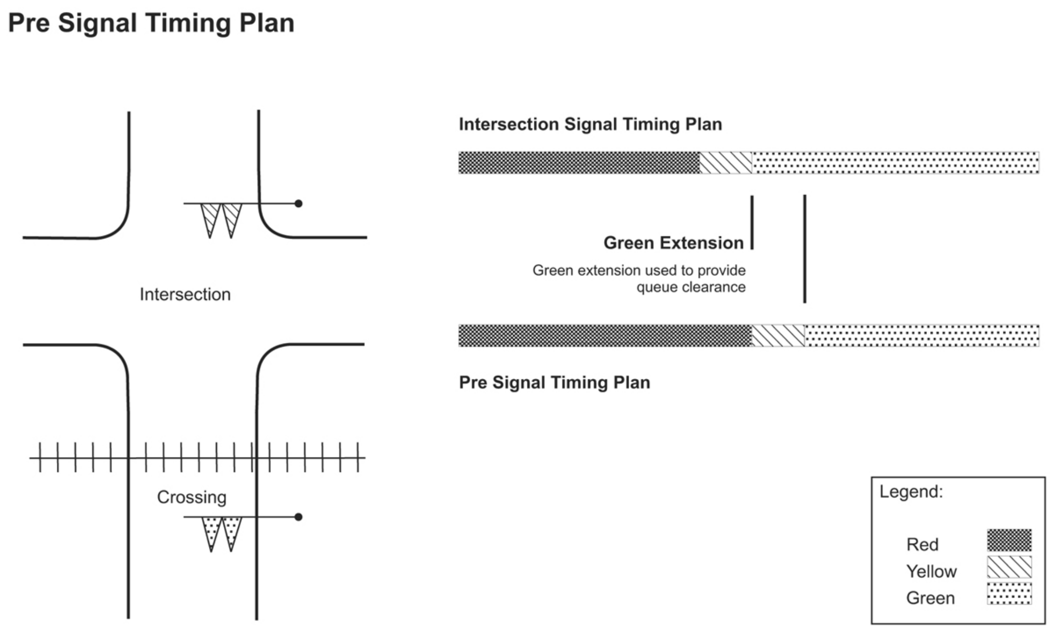

Figure 5.3: Presignal System

Queue cutter systems are similar to the advance head system and the presignal installation. However, a queue cutter signal system is usually determined by the substantial distance between the at-grade crossing and the intersection (usually several hundred feet or more) (ITE Report, 2003). With a queue cutter system, the signal is placed upstream of the at-grade crossing, and the spacing between the intersection and the crossing is large enough to store a fixed number of vehicles, without allowing a vehicle to queue onto the railroad tracks. The signal timing for a queue cutter system can either be implemented with or without a green offset. If the system is implemented without an offset, the signal at the intersection turns red at the same time as the signal at the crossing, after the signal breaks the flow of traffic, the vehicle queue compresses as the cars not stopped continue to creep toward the downstream traffic signal and the track area clears (Ogden, 2001). There are varying engineering opinions on inner connecting queue cutter signals with the downstream intersection.

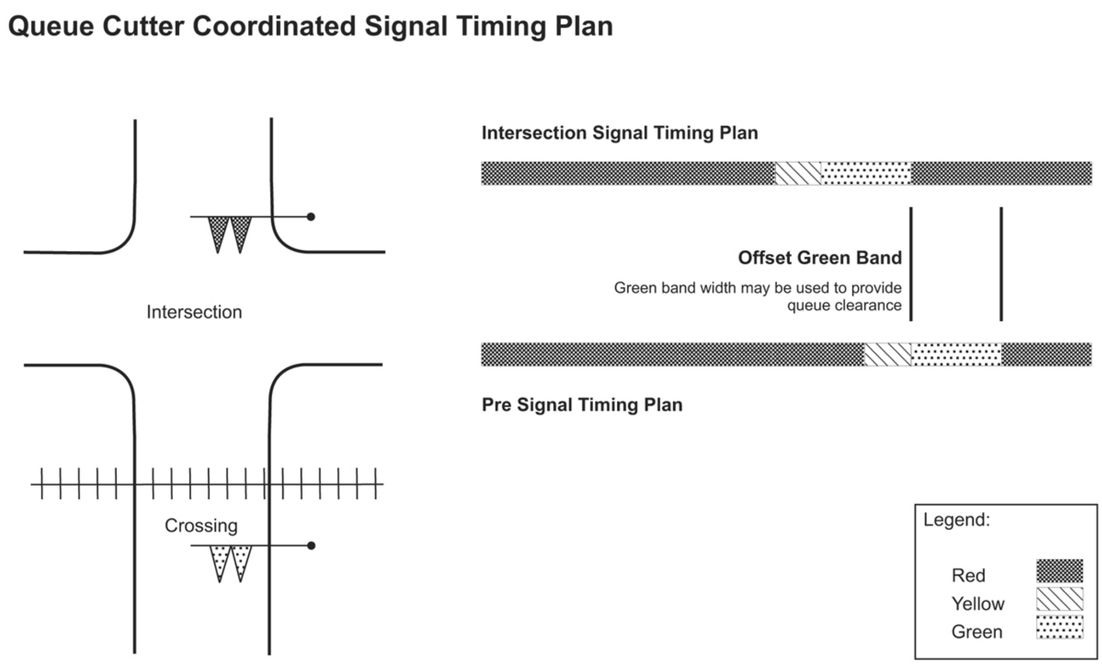

Figure 5.4: Queue Cutter System

The main difference between these three presignal types is distance from the downstream signal and the type of signal timing and phasing used. Table 5.1 assists the engineer in determining the presignal system required for the given geometric distance between the grade crossing and the downstream signal.

Table 5.2: Presignal Type Determination Table

Distance from the Downstream Signal	Recommended Presignal System
0 – 50 feet	Advanced Signal System
50-250 feet	Presignal System
>250 feet	Queue Cutter Signal System

CHAPTER 6: GUIDELINES FOR INSTALLATION OF A PRESIGNAL

The purpose of this chapter is to provide engineering study and design guidelines for the installation of presignals. These guidelines serve as a resource for local and state agencies that use the services of practitioners for presignal warrant studies and preparation of engineering plans; and act as a reference for traffic engineers to assist with consistency and accuracy in the presignal warrant study process and design of presignal plans. They are intended to organize the presignal reporting process and assembly of design plans by providing clear concise warrant methods and a systematic approach to the design procedures for the installation of presignals near grade crossings.

The guidelines that follow for both presignal studies and engineering design identify general criteria that should be addressed when assessing the need for additional traffic control at grade crossings. These guidelines standardize the submission of information regarding the need for a presignal. These guidelines are not intended as a substitute for solid working knowledge, experience and judgment of the principles of traffic signal design, but rather as a guideline to uniformity and to provide the engineer with sufficient information to prepare accurate and reliable presignal studies and design plans.

6.1. Report Guidelines for Presignals

6.1.1. Introduction

State, county, and local governmental agencies are responsible for ensuring the safety and welfare of the public on the street system. Guidance in the preparation of presignal warrant studies is necessary to ensure that presignal installation is performed in a uniform and systematic process. Presignal warrant studies provide guidance to the railroad and the governmental agency through the identification of needed improvements at the grade crossing to improve safety, and accommodate existing and projected traffic volumes. The goal of presignal warrant studies is to provide an objective evaluation of the need for a presignal at the grade crossing. The presignal warrant study shall be signed and sealed by a registered professional engineer licensed to practice in the state.

6.1.2. Determination of Need

The governmental agency which has jurisdiction over the roadway at the grade crossing retains the right to determine the need for a presignal engineering study. Grade crossings that could possibly be impacted by a downstream signalized intersection (present or future) should be analyzed according to the guidelines specified herein.

The installation of a presignal reduces the frequency of motorists stopping on the railroad tracks during a red light indication at the downstream signalized intersection. The basic questions that should be asked with the installation of a presignal are:

Does the presignal improve the safety of the grade crossing?

Does the presignal improve the operation of traffic at the downstream signal?

6.1.3. Study Area

The study area to be addressed by the engineer should include the intersections that affect the grade crossing, plus the crossing itself. The area to be studied should be discussed with the governmental agency that has the jurisdiction over the roadway along with the railroad agency. The extent of the study area will be determined by the impact of the downstream intersection on the railroad crossing and the anticipated queue length that will impact the surrounding area due to trains at the grade crossing.

6.1.4. Data Collection

A complete presignal warrant study requires the collection of sufficient data on the physical, traffic and operational characteristics of the grade intersection and downstream intersection. Data can be difficult and time consuming to collect; however, it is the foundation of the engineering study. A variety of traffic count data must be collected for the roadway, railroad and any existing traffic control devices within the study area. Examples of the type of data collected are shown in Table 6.1.

Table 6.1: Data Collection Needs

HIGHWAY
Geometric data - number of lanes, alignment, medians, traffic control devices
Average daily traffic volumes
Speed (posted and operating)
Functional classification
Desired level of service
Proximity of other intersections (note active device interconnections)
Intersection turning movement counts (peak hour)
Intersection queue lengths
Intersection arrival rates
Intersection departure rates
Crash data
RAILROAD
Number of tracks
Type of tracks (FRA classification, mainline, siding, spur)
Average number of trains per day (freight, passenger, other)
Maximum train speed and variability
Proximity of rail yards, stations and terminals
Crossing signal control circuitry

TRAFFIC CONTROL DEVICES
Active or passive train preemption
Intersection signal phasing and timing
Railroad crossing equipment

6.1.5. Presignal Warrant Study Report Requirements

The information contained in this section is required for a complete and thorough presignal warrant study. It is incumbent on the engineer to have all of the required data obtained timely and information clearly identified within the study. Text contained in the required chapters shall be comprehensive and compete. All maps, charts, graphs, tables and figures shall be clearly drawn and labeled. The following outline should be used as a guide to assist the engineer in making certain all required information is within the report.

Executive Summary – The first section of the report should be the executive summary. This summary shall define the purpose of the study, identify the engineer performing the work, and describe the project location. The executive summary should be a condensed stand alone document that summarizes the report, clearly stating the conclusions and recommendations.

Introduction – The introduction to the presignal report should present a project overview and answer the fundamental question whit this presignal warrant study is required for the proposed location. Additionally the site location, study boundaries and vicinity map should be included. A brief description of the site and the surrounding area should be provided that includes general terrain features and any other notable features.

Existing Conditions – The engineer shall provide a description of the existing traffic conditions within the study area. A map should be prepared that presents all collected traffic and train data. The traffic volumes and queue data shall be no more than 6 months old, and the source of the data collection shall be stated. Summaries of all current traffic counts and field data sheets with the collected traffic data should be included in the appendix.

At a minimum, a condition diagram should be prepared and include the at grade crossing and downstream intersection, distance between the intersections, influences on the grade crossing, number of tracks at the grade crossing, all existing roadway signing, striping and traffic control devices, posted speed limits, general terrain features and existing structures along the roadside that may impact roadway capacity including: roadway lane widths, number of travel lanes, medians, driveways, number of railroad crossings and sight distance. If the downstream intersection is signalized, the existing queue length shall be measured and documented on the conditions diagram.

A collision diagram of all crashes within the last five years should be created for the study area. The collision diagram should include the date of the crash, the manner in which the vehicles collided, and the correct symbols for the severity of the crash.

The existing morning and evening peak hour levels of service should be determined for the downstream intersection within the study area based on the procedures in the latest edition of the Highway Capacity Manual. The existing roadways shall also be analyzed based on a daily volume to capacity ratio where the threshold capacities are defined by roadway designation. Existing train frequencies, traffic volumes and levels of service should be recorded on the existing volume map.

If a traffic signal is currently present at the downstream intersection, the existing queues during the morning peak, evening peak, off peak, and weekend peak hours must be recorded on an existing scalable queue map. Queue data should be collected in accordance with standard engineering practice and the ITE Traffic Engineering Studies Manual current edition. If a traffic signal is warranted at the downstream intersection based on current traffic volumes, then traffic simulation using Synchro should be conducted to estimate the queue lengths back to the at-grade crossing, within the clear storage distance. The queue lengths should be estimated for the same peak periods as would be collected for existing queues.

Future Conditions – Proposed new development can induce traffic enhancements within a study area. Therefore, traffic forecasts may be necessary when completing a presignal warrant study. If this is the case, future forecasts shall be explained clearly. The recommended forecast volume methodology must be documented with sufficient detail to replicate the findings. If a traffic signal is warranted at the downstream intersection based on forecasted traffic volumes and analyses from the MUTCD, traffic simulation models shall be completed to estimate queue lengths of the downstream signal within the clear storage distance. These queue length projections coupled with the corresponding horizon years shall be illustrated on a scalable figure for reference and the presignal warrant analysis process.

Presignal Warrant Analysis – Presignal warrants A through D as defined in Chapter 5 shall be applied to the site location using all of the gathered data. These warrants should be conducted for the current year using existing information and for each horizon year using forecasted traffic volumes. If a presignal is warranted, then the type of presignal system must also be defined.

Special Analysis/Issues – This section allows the governmental agency to request specific focused traffic analyses germane to the grade railroad crossing and downstream signal. These issues could include but are not limited to: train preemption, access control, grade separated crossings, crash and safety concerns, railroad traffic control devices, minor site improvements, sight distance requirements, signal coordination, and signal timing needs.

Mitigation Measures/Recommendations – The location, nature and extent of the traffic improvements recommended for the grade crossing must be explicitly stated in the recommendations. A recommendations schematic illustrating the improvements should accompany the written explanation. All geometric improvements such as pavement markings, signs, train traffic control devices, gates, flashing lights, signal equipment placement shall be included in the scalable schematic, preferably on a current aerial map. Sufficient dimensions shall be identified to facilitate the review of the overall plan. If right of way is required for the improvements at the intersection, then the right of way must also be identified on the schematic.

All improvement possibilities should be identified within the mitigation measures of the report. The cost of the improvements shall not be considered a limiting constraint within the context of the presignal warrant study. The goal of the evaluation is to identify constructible cost effective measures that improve safety; however, it is important to at least identify all of the solutions so that decision makers are cognizant of all of the options at the grade crossing.

6.2. Design Elements for the Installation of Presignals

These design guidelines were developed to assist engineers in preparing the design plans for the installation of presignals. The guidelines are secondary to the MUTCD, National Electric Code, and the National Electric Safety Code current editions. These guidelines are intended to be a general and shall not substitute for engineering analysis and engineering design recommendations. Each presignal design presents a unique set of challenges. The following are design details that have been extrapolated from the literature review and/or developed from the presignal design at the field test study case in Maricopa, Arizona.

6.2.1. Basic Presignal Design

6.2.1.1. Signal Heads

Traffic signal heads shall be placed in accordance with the MUTCD, current edition. Two presignal heads should be used for the through movement across the railroad tracks. One additional head can be placed on the signal pole if necessary. The signal heads should be vertically aligned with 12-inch signal lenses and light emitting diodes in all instances.

The downstream traffic signal faces at the roadway intersection that control the same approach as the presignal may be equipped with programmable heads or louvers as appropriate. The purpose of the programmable heads or louvers is to limit visibility of the downstream signal faces to the area from the intersection stop line to the location of the first vehicle behind the presignal stop line. This is to prevent vehicles stopped at the railroad crossing stop line from seeing the distant green signal indication during the clear track green (ITE, 2004). If the presignals are located upstream of the railroad crossing, it may not be possible to have both signal faces located more than 40 ft beyond the stop line unless the stop line is relocated. A presignal located in the roadway median should be mounted at a minimum of 4 ft 6 in above the median island grade, but below any railroad flashing lights (ITE, 2004).

6.2.1.2. Pole Placement

Pre-signal mast arm poles should be located upstream from the railroad crossing when possible. Should a location upstream not be viable, then the pole can be located downstream in special cases. However it must be noted that the signal will be blocked by the train. In all cases, pre-signal poles must be located to maintain visibility of the railroad flashing lights. If a cantilever exists, the presignal head can be mounted to the cantilever, upon approval of the railroad or regulatory agency (Campbell, 2007). The cantilever could also be removed and a signal pole and mast arm be installed in its place. If the cantilever is removed, then the railroad flashing lights must be installed on the right side of the road and in the median on multiple lane approaches (MUTCD, 2003). If the signal heads are on a separate mount and the flashing indications remain on the cantilever, then the signal pole must be located to avoid blockage or interference with the visibility of the railroad flashing lights. Railroad flashing lights should be located as specified in the *MUTCD*.

6.2.1.3. Cabinet

The cabinet should be located for convenience access by signal maintenance staff. The cabinet location should have reasonable access by signal technician vehicles with minimal blocking of travel lanes. If possible, the cabinet should be located near the power source. Location should also be sensitive to vehicular movements that could hit the cabinet. The cabinet should be placed to allow personnel a view of the controller face and the detector amplifiers, and also should provide a good view of the vehicle at the intersection and traffic signal indications. If the presignal ties into an existing signal system, then the downstream intersection will dictate the placement of the signal cabinet.

When a presignal is installed, it must be provided with a battery backup that is equivalent to that provided for the railroad warning devices (Gilleran, 2006). A presignal that flashes in red during a power outage will give the wrong indication to motorists that it is safe to proceed with caution, even if this is not the case.

6.2.1.4. Pull Boxes

Two sizes of pull boxes can be used with the presignal design. The small boxes (12”x18”) are primarily used for the interconnect to the railroad cabinet and the signal cabinet and for loop detectors when needed for a queue cutter signal system. The large pull boxes (19”x30”) are typically placed near the signal pole and at the signal cabinet to accommodate multiple conduits. The pull boxes shall be constructed and approved per the specifications of the reviewing agency.

6.2.1.5. Conduit

Three inch conduct should be used in presignal design. No conduit shall be filled greater that 40% of its capacity in accordance with the NEC. All underground conduit shall be Schedule 40 PVC. Rigid metal shall be used or all conduits above the ground. 2 inch conduit can be used for electric service conductors and detector cable if approved by the reviewing agency.

6.2.1.6. Cable

IMSA approved cable in 20 conductor, 14 gauge should be provided along with a bare 8 gauge bonding conductor. The cable shall be installed and conform to the reviewing agencies requirements for cable installation.

6.2.1.7. Detection Systems

Depending on the type of presignal installation, detection may be required in the presignal design. The detector design should offer safe operation and minimize maintenance of the detection system. The detection system should conform to the reviewing agencies requirements for detector systems. Types of detections systems in use include: inductive loop detection, microwave presence, and video detection.

6.2.1.8. Median Installation

A median may be required upstream of the grade crossing to increase the visibility of the railroad crossing traffic devices. Presignal equipment could be placed in the median if the approach is multi lane. The median also serves to reduce the ability for vehicles to traverse through the track when the gates are closing, or closed.

6.2.1.9. Close Spacing between the Grade Crossing and the Downstream Intersection

If the railroad crossing is located near or at the downstream signal, then it is likely that vehicles will queue over the tracks at every signal cycle. Therefore, it may be necessary to eliminate the stop bar at the downstream signal and only use the stop bar for the presignal. With this scenario, the signals must be timed together and the intersections must operate as a combined unit. It is also important to note that the yellow clearance interval should be extended accordingly to compensate for the additional distance to the signalized intersection (Ogden, 2007). When the downstream signal and the grade crossing are within 50 feet, programmable signal heads should be considered for the downstream signal to avoid driver confusion. Where the clear storage distance is inadequate to store a design vehicle clear of the minimum track clearance distance and when crossing gates are present, the installation of vehicle detection should be considered for installation within the clear storage distance to prevent vehicles from being trapped within the minimum track clearance distance by extending the clear track green interval (Campbell, 2007).

6.2.1.10. Skewed Crossings

At skewed railroad crossings, where the angle between the striping and the tracks is less than 20 degrees, the striping should be sloped in the opposite direction (Korve, 2001). If the tracks run diagonal to the roadway, then the Keep Clear Zone should be designated from the nearest track. At locations where a presignal is installed and the downstream distance to the nearest signalized intersection is 50 feet or less, the Keep Clear Zone should be extended the entire length to the downstream signal.

6.2.1.11. Keep Clear Zone Striping

Additional striping can be added to designate the Keep Clear Zone. This striping consists of six inch diagonal white stripes at 45 degrees, and separated five feet between the stripes (Korve, 2001). The Keep Clear Zone should normally extend 15 feet past the railroad tracks. However, this can be reduced to a minimum of 12 feet if roadway geometrics do not allow for the full 15 feet of Keep Clear Zone.

6.2.1.12. Signing

Signing must be modified with the installation of a presignal. When the distance between the downstream signal and the presignal is less than 50 feet, No Turn On Red signage should be considered at the presignal to deter motorists from making a right turn on red and crossing the tracks.

6.2.1.13. Stop Bar

The stop bar should not be located closer than 40 feet from the presignal, meaning the presignal will not be visible to motorists it the stop bar is located any closer. Therefore, the presignal would not be an effective traffic control device. In cases where the presignal is located closer than 40 feet to the stop bar, motorists are tempted to pull out onto the tracks when the track clearance green interval is displayed at the downstream signalized intersection as they miss their presignal red indication.

6.2.1.14. Signal Timing

Presignals should be timed with the downstream signal to provide adequate time to clear vehicles from the minimum track clearance area at every cycle. Signal timing philosophy will vary depending on the clear storage distance. For locations with no or very little clear storage distance, the timing should be set so that at each cycle there are no vehicles stored within the clear storage distance. This can be done by providing little or no offset depending on the intersection geometrics. Vehicles that are required to make a mandatory stop such as school buses, vehicles hauling hazardous materials should be considered when determining the timing to ensure that they will not be stopped within the minimum track clearance distance, where the distance between the downstream signal and the grade crossing is less than adequate to store the design vehicle, say 75 feet. As the clear storage distance increases, the signal timing can be developed with an offset between the downstream signal and the presignal to allow vehicles to queue within the clear storage distance; however, not within the minimum track clearance.

The MUTCD requires 20-second minimum time for the railroad system to activate warning devices prior to arrival of the train. This may not be sufficient when highway traffic signals and presignals are interconnected to the railroad crossing with active warning devices. Therefore, advance preemption must be addressed and signal timing revised accordingly to allow enough time for a vehicle to clear the tracks during every downstream signal cycle change (ITE 2004). Therefore, the following items should be considered when timing the downstream signal and presignal system operation:

The approach speed of trains and vehicles

Intersection and railroad crossing geometry

Vehicle volumes

Frequency of trains

Train stops within the approach to the crossing especially where stations are located in close proximity to the crossing

Vehicle queue lengths and dissipation rates

The design vehicle or special classes of vehicles (buses and large trucks)

Types of railroad traffic control devices (flashing lights and gates)

The variability in warning time due to the acceleration and deceleration of the train once the warning is activated.

If advanced warning times need to be extended, greater than 20 seconds, due to timing constraints at the presignal and the downstream signal, there are two ways this can be accomplished. First, the advanced warning times for both the railroad and the traffic signal controller can provide simultaneous preemption, however this causes the traffic devices for the train to activate earlier than recommended and may create addition driver delay and frustration. Second, advance preemption can start the highway traffic signal system and equipment, however, the gates and railroad warning preemption devices can be set to maintain activation at 20 seconds. Both options are viable and should be reviewed and discussed with the operating railroad during the design process (ITE, 2004).

CHAPTER 7: CONCLUSIONS

With over 2,000 collisions and 250 fatalities occurring every year at railroad grade crossings, the use of presignals can be an effective tool in reducing collisions caused by vehicles queuing over the railroad tracks. Unfortunately, when vehicles stop on the tracks there is a great potential for the motorist to be involved in a train/vehicle collision. The careful consideration and proper installation of presignals can help alleviate this condition. Presignals assign the right of way to the vehicle when the railroad tracks are clear. This method eliminates the need for the driver to be able to decide when there is adequate clearance to begin movement, cross the tracks, and clear the tracks in front of an oncoming train. The warrants and guidelines created as a portion of this dissertation will assist traffic engineers throughout the nation in determining the need for installation and proper placement of the presignal when warranted. By using presignals, the number of collisions can be greatly reduced. Presignals help clear the track area and keep the crossing clear for trains.

There is little guidance to determine the need for a presignal. Current practice states that a presignal should be considered at locations where an at grade highway-rail crossing is located within 50 feet of an intersection controlled by a traffic signal. However, presignals should be considered for installation based on the following reasons. Crash history indicates a presignal will improve safety at the grade crossing. Vehicle queues back over the grade crossing from the downstream intersection. The studied at-grade crossing is operating without gates. Stations or yards are placed near grade crossings and a presignal will assign the right of way, while the train is stopped.

Traffic engineers will find presignals an extremely useful tool where their use is necessary and appropriate. Situations in which the downstream signal causes vehicular queues to form back within the track clearance area can be successfully mitigated with presignal installation. An effective presignal design includes selecting the correct type of presignal to design. Each system, advanced signals, presignal, and queue cutter signals have specific and unique capabilities that when applied correctly can be used at grade crossings regardless of the distance between the railroad crossing and the downstream signal.

Although accurate measurements can be determined from a detailed site investigation, there are many locations where the queue length may need to be estimated due to rapid development within an area or prior to the installation of the downstream signal. Therefore, the installation of a presignal may be justified on forecasted traffic volumes and queue estimates prior to the installation of the downstream signal. This process allows for the presignal and the downstream signal to be designed and constructed simultaneously.

As illustrated within this paper, the guidelines for presignal installation as specified in the MUTCD are not appropriate for the case study which did indeed require a presignal. In this case study, the traffic volumes were high enough to extend queues significantly past the grade crossings. When dealing with grade crossings and downstream intersections it is important to consider presignals regardless of the distance in between. The presignal supplements the operation of the signal at the intersection and prevents lengthy queues as well as provides significant protection and safety at the grade crossing, which would otherwise not be available.

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