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Case Studies to Develop a Highway-Rail Grade Crossing Analysis Framework Using Microsimulation

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14. ABSTRACT
There are approximately 126,700 highway-rail at-grade crossings in the U.S. A portion of those involve high-volume public streets where crossing events result in measurable traffic backups and delays to the extent that mitigation efforts are needed. Conventional traffic analysis methods such as those in the Highway Capacity Manual are limited in their ability to quantify the impacts of traffic interruptions due to a train crossing. Microscopic traffic simulation methods are capable of analyzing these events and simulation software has been a part of the practitioner's toolbox now for 30 years. However, there has been no technical guidance nor consistency on how these tools should be applied to evaluate crossing events. Using microscopic simulation, researchers performed two case studies from which a framework has been developed that can be used by practitioners and decision makers for performing traffic operations analyses of at-grade crossings. The framework offers guidance for a consistent approach to the development and application of such models.

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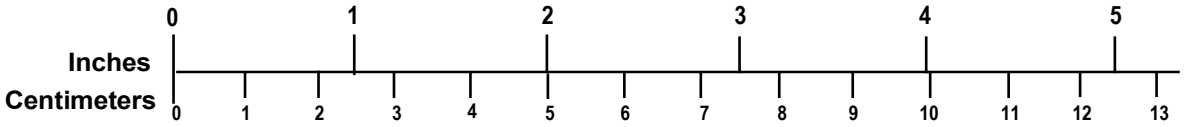

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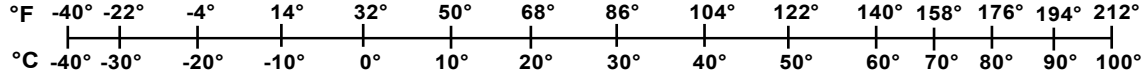

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Contents

Executive Summary 1

1. Introduction 2
   - 1.1 Background 2
   - 1.2 Objectives 2
   - 1.3 Overall Approach 3
   - 1.4 Scope 3
   - 1.5 Organization of the Report 3

2. Literature Review 4
   - 2.1 Highway-Rail Crossing Handbook 4
   - 2.2 Preemption of Traffic Signals Near Railroad Grade Crossings 4
   - 2.3 Manual on Uniform Traffic Control Devices (MUTCD) 6
   - 2.4 GradeDec.Net Reference Manual 6
   - 2.5 NCHRP 812, Signal Timing Manual 7
   - 2.6 NCHRP Synthesis 507 8
   - 2.7 Traffic Engineering Handbook 8
   - 2.8 Highway Capacity Manual 9
   - 2.9 Highway Safety Manual 9
   - 2.10 A Policy on Geometric Design of Highways and Streets (Green Book) 9
   - 2.11 Tydlacka Thesis 10
   - 2.12 Chaudhry Dissertation 10
   - 2.13 University of Nebraska-Lincoln Research 11
   - 2.14 Center for Transportation Research 12
   - 2.15 Rilett and Appiah 12
   - 2.16 Khattak and Lee 12
   - 2.17 Literature Review Summary 13

3. Stakeholders 14

4. Identification of Study Sites 15
   - 4.1 Candidate Sites 16
   - 4.2 Selected Sites 19
   - 4.3 Site Selection Summary 21

5. Development of Traffic Simulation Models 22
   - 5.1 La Grange, Illinois Simulation Model 22
   - 5.2 Cotulla, Texas Simulation Model 30
   - 5.3 Visualization Through Simulation Graphics 41

6. Simulation Framework 42
   - 6.1 Site Identification and Study Area Delineation 42
   - 6.2 Network 43
   - 6.3 Highway Traffic Control 45
   - 6.4 Grade Crossing Traffic Control 46
   - 6.5 Demand 46
   - 6.6 Traffic Diversion 51

6.7 Model Development, Calibration, and Application 52
6.8 Framework Summary 54
7. Conclusion 55
8. References 56
Appendix A. Stakeholder Meeting Summaries 58
Appendix B. La Grange, Illinois, Site Simulation Model Data 71
Appendix C. Cotulla, Texas, Site Simulation Model Data 83
Appendix D. Site Simulation Screen Capture Images 92
Abbreviations and Acronyms 96

Illustrations

Figure 1. Illinois Candidate Urban/Suburban Area Study Sites 17
Figure 2. Illinois Candidate Rural Study Sites..... 18
Figure 3. Texas Candidate Study Sites 19
Figure 4. Urban/Suburban Area Preferred Study Site – La Grange Road at Burlington Avenue and Hillgrove Avenue, La Grange, IL 20
Figure 5. Small Town/Rural Preferred Study Site – SH 97 between Front Street and Keck Street, Cotulla, TX 21
Figure 6. Urban/Suburban Area Simulation Site Area Map – La Grange, IL 22
Figure 7. Simulation Model Network – La Grange, IL, Site 23
Figure 8. Key Lane Groups for Queue Comparisons – La Grange, IL, Simulation Model..... 25
Figure 9. Rail Crossing Locations – La Grange, IL,, Site 26
Figure 10. Duration of Traffic Interruption Due to Train Crossings – La Grange, IL, Site 28
Figure 11. View of the Northbound Queue at Burlington Avenue..... 29
Figure 12. Cotulla, TX, Simulation Grade Crossing Site 30
Figure 13. Cotulla, TX, Site Simulation Network 31
Figure 14. Signalized Intersection with SB Protected/Permitted Phasing..... 32
Figure 15. Example 15-Minute Intersection Turning Movement Counts..... 33
Figure 16. Raised Crossing Profile "Hump"..... 34
Figure 17. Protected/Permitted Left Turn Phasing from a Shared Lane..... 35
Figure 18. Occasional Blockage of Front Street Intersection (Looking Northwest) 36
Figure 19. Duration of Traffic Interruption Due to Train Crossings – Cotulla, TX, Site..... 38
Figure 20. Key Lane Groups for Queue Comparisons 39
Figure 21. Temporal Distribution from Traffic Counts 47
Figure 22. Intersection Turning Volumes..... 48
Figure 23. Origin-Destination Matrix 49
Figure 24. Example Scatter Plot Comparing Traffic Counts to Simulation Volumes..... 53

Tables

Table 1. Illinois Candidate Study Sites 16
Table 2. Texas Candidate Study Sites 18
Table 3. Vehicle Classification – La Grange, IL, Simulation Model 25
Table 4. Percent of Counts Within Difference Thresholds 27
Table 5. Comparison of Observed vs. Simulated Maximum Queues for Critical Movements on La Grange Road 29
Table 6. Vehicle Classification – Cotulla, TX, Simulation Model 34
Table 7. Comparison of Observed vs. Simulated Maximum Queues at Tilden Street Grade Crossing Location 38
Table 8. Comparison of Observed vs. Simulated Maximum Queues at Tilden Street/Main Street 40

Executive Summary

Federal, state, and local transportation agencies have a primary responsibility to protect the traveling public, so great attention is given to the safety aspect of highway-rail grade crossings. Unfortunately, the same amount of attention has not been given to dealing with the traffic impacts associated with these at-grade crossings. Conventional analysis tools like the methods prescribed in the Highway Capacity Manual (HCM) are limited in their ability to quantify the impacts of traffic interruptions due to a train crossing. Because the interruptions are sporadic, such deterministic methods are incapable of accurately quantifying impacts like queue lengths, queue clearance times, vehicular delays, and emissions associated with traffic blockage. Although practitioners sometimes use microscopic traffic simulation for these analyses, there is no established guidance or consistency for performing them.

In August 2021, the Federal Railroad Administration (FRA) contracted with Caliper Corporation to perform case studies showing how microscopic traffic simulation tools can be used to evaluate traffic conditions when a train crossing occurs at an at-grade location. Since this study had national implications, the team chose to conduct research in two different states – Illinois and Texas – to use data more representative of crossings located throughout the United States. Researchers worked with stakeholders to identify the physical study sites, ultimately selecting an urban site in the Chicago suburb of La Grange, IL, and a rural site in the small town of Cotulla, TX. The Caliper team collected data from these sites and performed simulations in the Spring and Summer of 2022.

The research team used TransModeler® Version 7.0 software by Caliper Corporation to simulate traffic conditions associated with grade crossing events. TransModeler is a fully functional, GIS-based, microsimulation platform able to simulate train crossing events, pre-emption of traffic signals associated with the events, and the resulting traffic impacts, including queues and delays on streets and roads in the vicinity of the crossing.

This report discusses the development, calibration, and validation of simulation models for the two selected sites. It describes specific factors that analysts should recognize and incorporate into performing analyses for at-grade crossings. These include traffic signal preemption, vehicle fleet mix, train types (e.g., freight and passenger) and number of tracks in the crossing, commuter train stations in the vicinity, pedestrian activity, roadway geometry, vehicles required to stop at crossings (e.g., school buses and trucks hauling hazardous materials), duration of traffic interruption, traffic speeds, and route diversion.

Using these case studies, the team developed a recommended framework that can be used by practitioners and decision makers for performing traffic operations analyses of at-grade crossings. The framework offers guidance for a consistent approach to the development and application of such models.

1. Introduction

In August 2021, the Federal Railroad Administration (FRA) contracted with Caliper Corporation to perform case studies showing how microscopic traffic simulation tools can be used to evaluate traffic conditions when a train crossing occurs at an at-grade location. Since this study had national implications, the team chose to conduct research in two different states – Illinois and Texas – to use data more representative of crossings located throughout the United States. Researchers worked with stakeholders to identify the physical study sites, ultimately selecting an urban site in the Chicago suburb of La Grange, IL, and a rural site in the small town of Cotulla, TX. The Caliper team collected data from these sites and performed simulations in the Spring and Summer of 2022. Using these case studies, the team developed a recommended framework that can be used by practitioners and decision makers for performing traffic operations analyses of at-grade crossings. The framework offers guidance for a consistent approach to the development and application of such models.

1.1 Background

Federal, state, and local transportation agencies have a primary responsibility to protect the traveling public, so great attention is given to the safety aspect of highway-rail grade crossings. Nationally recognized documents like the *Highway Safety Manual*, *Highway-Rail Crossing Handbook*, *Manual on Uniform Traffic Control Devices*, and others provide guidance and tools for enhancing motorist safety at highway-rail grade crossings.

Unfortunately, the same amount of attention has not been given to dealing with the traffic impacts associated with these at-grade crossings. Conventional analysis tools like the methods prescribed in the *Highway Capacity Manual* are limited in their ability to quantify the impacts of traffic interruptions due to a train crossing. This is especially true when a crossing is not isolated, but instead is located along an urban street where traffic backups extend into adjacent intersections and onto side streets. Because the interruptions are sporadic, such deterministic methods are incapable of accurately quantifying impacts like queue lengths, queue clearance times, vehicular delays, and emissions associated with traffic blockage. Although practitioners sometimes use microscopic traffic simulation for these analyses, there is no established guidance or consistency for performing them.

Microscopic traffic simulation involves the modeling of individual vehicle movements on a second or sub-second basis to assess the performance of highway and street systems. Simulation software is used to apply a variety of mathematical models for driver behavior and traffic flow theory to simulate traffic phenomena. Microscopic simulation holds numerous advantages over deterministic tools like the methods described in the *Highway Capacity Manual*; simulation can incorporate stochastic events like highway-rail grade crossings into an overall analysis. Microscopic traffic simulation is commonly used by State Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), and their consultants.

1.2 Objectives

The project objectives were to perform case studies showing how microscopic traffic simulation tools can be used to evaluate traffic conditions when a train crossing occurs at an at-grade location, and then use these case studies to develop a recommended framework that can be used

by practitioners and decision makers for performing traffic operations analyses of at-grade crossings.

1.3 Overall Approach

Since this study had national implications, the team chose to conduct research in two different states – Illinois and Texas – to use data more representative of crossings located throughout the United States. Researchers worked with stakeholders to identify the physical study sites, ultimately selecting an urban site in the Chicago suburb of La Grange, IL, and a rural site in the small town of Cotulla, TX. The Caliper team collected data from these sites and performed simulations in the Spring and Summer of 2022.

For each at-grade crossing location, the team collected and processed data and developed traffic simulation models from which the recommended framework for developing such models was produced. Finally, researchers developed example applications for using these models to address current or future traffic impacts related to grade crossing events.

1.4 Scope

This was a 15-month study beginning in August 2021 that included the following tasks:

- Perform Literature Review
- Identify Stakeholder Group
- Identify Study Sites and Develop Data Collection Plan
- Collect and Process Data
- Simulate At-Grade Crossing Study Sites
- Develop Highway-Rail Grade Crossing Analysis Framework

1.5 Organization of the Report

This final report documents the research study process. Section 2 discusses results of a literature review. Section 3 presents the stakeholders and the discussions the team had with them. From those conversations, lists of candidate study sites in two states – Texas and Illinois - were developed and are presented in Section 4. Section 5 describes the collection and evaluation of data, development of traffic simulation models, and calibration/validation of those models for the two crossing sites. Section 6 presents a recommended framework for developing traffic simulation models of at-grade crossings that can be used to quantify and mitigate the operational impacts of traffic interruption resulting from crossing events.

2. Literature Review

The research team conducted a literature review to identify the existing knowledge and state of practice associated with traffic operational analyses that include highway-rail grade crossings. Traditionally, these types of analyses have focused on measurable and/or predictable parameters that quantify traffic conditions on urban streets, especially delay and queue length. While interruptions to traffic flow and their impacts on the street system at highway-rail grade crossings are important, public safety is arguably more important. Traffic operational analyses are not safety focused, but there are operational parameters which have significant safety impacts, **especially traffic signal preemption and queue management**. By simulating highway-rail crossing events, these parameters can be used as a check to support decisions made to maximize public safety at these locations while managing traffic impacts. This is especially true for scenario planning when operations based on future travel demand are anticipated to differ from existing conditions.

2.1 Highway-Rail Crossing Handbook

The *Highway-Rail Crossing Handbook, Third Edition* [1] is a compendium of recommended safety engineering treatments for at-grade highway-railroad crossings which summarizes current, noteworthy, or best practices and provides a range of options for consideration. As stated, the purpose of the handbook is not to establish standards, but to provide guidance about how existing standards and recommended practices may be applied in developing safe and effective treatments for crossings.

The handbook provides a comprehensive glossary of terms related to highway-railroad grade crossings. It also includes a chapter on preemption of traffic signals that provides definitions and supporting diagrams for key preemption parameters such as Clear Storage Distance (CSD) and Minimum Track Clearance Distance (MTCD). The chapter heavily references the Institute of Transportation Engineers (ITE) *Preemption of Traffic Signals Near Railroad Crossings, Second Edition* [2], which is discussed in Section 2.2.

The handbook also provides guidance on queue prevention strategies when traffic congestion precludes using standard traffic control signal preemption. At some locations, it may not be practical or possible to clear vehicles from the tracks by preempting the downstream traffic signals. For example, if the roadway corridor extending downstream from the crossing is heavily congested, preempting the downstream traffic signals still may not allow motor vehicles to move forward enough to clear the crossing because of downstream congestion. If the level of traffic congestion is substantial, it may be necessary to preempt several downstream traffic signals, which requires an approaching train to be detected (and predicted) several minutes before it arrives at the crossing.

The handbook also includes an introduction to FRA's GradeDec.Net highway-railroad grade crossing investment analysis tool, which is discussed in Section 2.4.

2.2 Preemption of Traffic Signals Near Railroad Grade Crossings

ITE's *Preemption of Traffic Signals Near Railroad Grade Crossings, Second Edition* [2] represents the current state of traffic signal preemption. It defines Simultaneous Preemption (i.e., notification of approaching rail traffic is forwarded to the highway traffic signal controller unit

and railroad or light rail active warning devices at the same time) and Advance Preemption (i.e., notification of approaching rail traffic is forwarded to the highway traffic signal controller unit and railroad or light rail active warning devices in advance of the activation of these devices). The document is a comprehensive reference of all terms and concepts concerning signal preemption, including queue management strategies like pre-signals and queue-cutter signals.

The document advises that if the distance between a highway signal intersection and a grade crossing is less than 200 feet, the likelihood of a queue extending across the tracks must be determined by one or more methods:

- Anecdotal evidence
- Traffic engineering calculations
- Traffic simulation modeling
- Field observations

A deterministic equation is presented to provide a simple but reasonable estimate of the 95th percentile queue length (i.e., a longer queue would be anticipated only five percent of the time). The estimated queue is a function of the arrival traffic flow rate, percentage of trucks and buses in the traffic stream, and combined yellow plus red times in the signal cycle. The equation is applicable when the demand (the arrival rate) is less than the capacity for the intersection approach. When the demand approaches capacity (i.e., when the demand-volume-to-capacity ratio, or v/c, is between 0.90 and 1.00), a modified form of the equation is used. When demand exceeds capacity (i.e., v/c is greater than 1.00), the guide directs users to methods in the *Highway Capacity Manual, Sixth Edition* (see Section 2.8), which are more capable of dealing with oversaturated conditions.

Guidance on queue management is provided in the document. When considering pre-signals (i.e., signal control faces on a grade crossing approach that are part of the intersection control and are in advance of the crossing), the volume of trucks and buses must be examined and a vehicle classification study may be warranted. A pre-signal is a primary signal and not a supplemental signal. There may be times when a pre-signal indication is red while the downstream signal is green as the queue clearance process is underway. Some states consider pre-signals to be standard treatments, while other states do not use them at all.

Queue-cutter signals are different from pre-signals in that they are operated independently from the intersection signals and are located farther away from the crossing, typically more than 450 – 500 feet away. The document provides guidance on their placement and operation, including the use of loop detectors in the pavement.

The ITC document provides detailed discussion (with diagrams) of simultaneous preemption operation and advance preemption operation and offers guidance on when they should be used. It goes on to state that advance preemption time may be the greatest safety consideration in selecting the type of preemption. Advance preemption may be beneficial where a large amount of time may be needed to clear the tracks. Balanced against this is acknowledgement that long warning times can contribute to undesirable motorist behavior (e.g., driving around lowered crossing gates). The document also provides a detailed discussion of the “preempt trap” that can occur with advance preemption, which can allow motorists to enter the crossing during a queue clearance interval because grade crossing warning devices may not have activated yet.

2.3 Manual on Uniform Traffic Control Devices (MUTCD)

Chapter 8 of the *Manual on Uniform Traffic Control Devices (MUTCD)* [3] contains a section on Traffic Control for Railroad and Light Rail Transit Grade Crossings. Chapter 8C provides standards, guidance, and other information on flashing-light signals, gates, and traffic control signals. Section 8C.09 provides a standard that, if preemption is provided, the normal sequence of traffic signal control indications shall be preempted upon the approach of trains to avoid entrapment of highway vehicles on the highway-railroad grade crossing. It offers further guidance that, if a highway-railroad grade crossing is located within 50 feet (or within 75 feet for a highway that is regularly used by multi-unit vehicles) of an intersection controlled by a traffic control signal, the use of pre-signals to control traffic approaching the grade crossing should be considered.

Regarding the location of traffic control signals at or near highway- light rail transit (LRT) grade crossings (Section 8C.10), the *MUTCD* states that when a highway-LRT grade crossing equipped with a flashing-light signal system is located within 200 feet of an intersection or midblock location controlled by a traffic control signal, the traffic control signal should be provided with preemption. It also states that coordination with the flashing-light signal system should be considered for traffic control signals located more than 200 feet from the crossing. Factors to be considered should include traffic volumes, highway vehicle mix, highway vehicle and LRT approach speeds, frequency of LRT traffic, and queue lengths. The 200-foot minimum distance was codified in 49 CFR § 234.225, but several of the reviewed references have acknowledged that queueing analyses may identify the need for preemption at distances greater than 200 feet.

2.4 GradeDec.Net Reference Manual

GradeDec.Net is a web-based decision support tool that is used by federal, state, and local agencies and decision makers to evaluate the benefits and costs of highway-railroad grade crossing upgrades, separations, and closures. The tool was developed by FRA and includes research findings from Volpe National Transportation Systems Center and the National Cooperative Highway Research Program (NCHRP). *GradeDec.Net Reference Manual* [4] presents model components, computational algorithms, and descriptions of data inputs to the model.

For at-grade crossings, *GradeDec.Net* includes delay and time-in-queue models for use in benefit-cost analyses. Traffic demand, either present or future forecasted, is estimated based on average annual daily traffic (AADT), along with diurnal distributions where AADT is divided into 24 one-hour periods. The *GradeDec.Net* user interface lets the user select from 21 pre-set traffic distributions, which include:

- Uniform
- Peak a.m.
- Peak p.m.
- Day Flat
- Night Flat

The remaining 16 are representative distributions for a range of urban and rural facility types. The default distributions are for convenience; they can be modified or new ones can be created to more accurately correspond to travel patterns.

GradeDec.Net employs a time-in-queue/delay model based on research from 1997. It is an adaptation of a classic input-output diagram used to determine spatial and temporal extents of a queue upstream of a bottleneck. The model computes average crossing blockage time (CBT) as a factor of the average train length, average number of cars per train, average crossing speed, locomotive length, etc., and adds 36 seconds to account for warning lead time or closure prior to the arrival of a train. CBT is an estimated average based on available corridor data. The method estimates shares (i.e., proportion) of directional traffic weighted by the passenger car equivalent (PCE) for the principal (d_1) and non-principal (d_2) directions. The PCEs are:

- Autos – 1.0
- Trucks – 1.8
- Buses – 2.73

The number of lanes is also a parameter. The arrival rate is expressed in directional vehicles per second per lane. Total vehicular delay and time in queue are then computed. Computations for Delay for Traffic Segment in Time-of-Day Period and Time-in-Queue for Traffic Segment in Time-of-Day Period are weighted averages of total delay and time in queue divided by number of vehicles. It should be noted that these estimates of delay and time-in-queue are deterministic and assume a constant arrival rate over the analysis period. They do not account for fluctuations in traffic demand during the period.

The *GradeDec.Net* framework includes a desired objective to re-assign traffic away from high-exposure and/or high-risk crossings during peak exposure periods of the day using traffic management measures like signage and signaling. However, the tool is intended for use (in the corridor model only) with long-term or permanent actions like closing a grade crossing or providing grade separation. The diversion model is a simplistic model based on AADT at the subject and adjacent crossings, along with distances between those locations.

2.5 NCHRP 812, Signal Timing Manual

NCHRP 812, Signal Timing Manual, Second Edition [5] describes the state of practice for traffic signal preemption associated with highway-railroad grade crossings. As described in the manual, preferential treatment is an application that can be employed at signalized intersections to adjust operations in favor of a particular user. In the case of a highway-railroad grade crossing, this occurs in the form of preemption where normal operations are suspended so that the "preferred vehicle" can receive service. The manual describes five main steps that define the preferential treatment process:

1. Upstream Detection – the preferred vehicle (i.e., train) sends the system a "request" for preferential treatment via an upstream detector
2. Transition Selection – the controller or central system selects which signal timing transition to apply
3. Timing Transition – preferential treatment is activated and the controller begins a right-of-way transfer procedure

4. Dwell Stage – the controller dwells in the preferential treatment stage until the preferred vehicle clears
5. Recover – the signal begins the recovery stage to return to normal operations

The manual describes various methods that can be used to accommodate preferential treatment. Applicable to this project, limited service phases encompass all movements that do not conflict with preemption movements and should continue to operate in order to minimize delay and queuing. These phases need to be identified for each preemption movement.

The primary purpose for considering preemption at crossings is to clear any vehicles that are stopped over the tracks before the arrival of a train. Modern railroad systems use track circuits that estimate the speed and direction of a train as it enters the detection zone, which is then used to predict the time of arrival at the crossing. Advance preemption provides additional time to clear the tracks where it is determined to be needed. The manual includes an extended discussion on advance preemption and the "preempt trap" that can occur if it is not employed correctly.

2.6 NCHRP Synthesis 507

NCHRP Synthesis 507 [6] presents a review of literature prior to 2017 relevant to traffic signal preemption at intersections near highway-railroad grade crossings. The synthesis documents current practices of traffic signal preemption deployed at intersections adjacent to grade crossings in the U.S. and Canada and summarizes survey responses from 40 of 49 U.S. state departments of transportation and 4 Canadian provinces. It also includes detailed case studies from three states.

The synthesis provides additional insights on the state of practice, including lessons learned, challenges, and gaps in information. It includes helpful illustrations along with definitions of important concepts and terminology. Some of the graphics from these illustrations are incorporated into ITE's *Preemption of Traffic Signals Near Railroad Grade Crossings, Second Edition* (Section 2.2). There is an extended discussion on addressing the preempt trap, which can occur when there is advanced preemption. There is also an extended discussion on queue management, which is defined as a "…proactive approach to reducing the potential for vehicles stopping on the railway tracks."

2.7 Traffic Engineering Handbook

ITE's *Traffic Engineering Handbook* [7] offers a discussion on drivers and driver behavior at grade crossings. Driver behavior at crossings depends on seeing and comprehending warning devices, detecting the presence of a crossing and train, judging closing speed, and deciding what action to take. Grade crossings have a dilemma zone similar to that of signalized intersections. Research has shown that crashes at grade crossings are largely due to driver error.

Credibility of signals is important. Drivers expect a train to arrive within about 20 seconds of activation of a signal; they begin to lose confidence in the warning if the warning time exceeds 40 seconds for flashing lights and 60 seconds for gates. A study in Texas found that 69 percent of drivers committed a "flashing light violation" where a driver crosses the track between the time the lights activate and two seconds after the gates begin to descend. Research also suggests driver impatience increases with increased warning times.

There are three classes of driver error types at grade crossings: recognition, decision, and action. Inadequate visibility of trains (i.e., sight distance) is sometimes a contributing factor in recognition errors. A minimum sight distance equivalent to 11 seconds of travel time by the train should be available to a truck driver to accommodate the acceleration ability and length of large trucks, which are considered to be the design vehicle at these locations. The manual also points out that sight distance is reduced when tracks and the highway do not cross at a ninety-degree angle.

2.8 Highway Capacity Manual

While the *Highway Capacity Manual (HCM)* [8] is considered the definitive reference for performing traffic operations analyses, highway-railroad grade crossings are not addressed specifically in the manual. Light rail transit is addressed separately in the *Transit Capacity and Quality of Service Manual*, but that document provides a framework for measuring transit availability, comfort, and convenience from a passenger point of view, and is not included in this literature review.

Within the *HCM*, Chapter 19 (Signalized Intersections) and Chapter 31 (Signalized Intersections: Supplemental) describe methods to quantify delay and queue lengths due to interruptions in traffic flow caused by traffic signals. Chapter 19 includes analytical methods to quantify delay as a result of a traffic signal. This is defined as control delay and is the performance measure on which Level of Service at signalized intersections is based. Chapter 31 describes analytical methods to estimate back-of-queue size (i.e., queue length). A percentile back-of-queue estimate (i.e., Q%) can be computed using a statistical distribution and appropriate Z-score correlating with the desired percentile (e.g., 50%, 85%, 95%).

The *HCM* methods are macroscopic, deterministic methods for average conditions over an analysis period (typically 15 minutes or 60 minutes). They are not applied on a cycle-by-cycle basis, nor do they consider variations in demand. There is no guidance in the *HCM* on evaluating intermittent interruptions to traffic flow resulting from train crossings.

2.9 Highway Safety Manual

The *Highway Safety Manual (HSM)* [9] is generally focused on heavy freight rail, although it is also applicable to passenger rail. There is a good description of Passive Control vs. Active Control, but this is not unique to the *HSM*. The *HSM* offers information on the potential crash effects (i.e., reduction in crash frequencies) associated with installing different types of traffic control. This information is typically in the form of recommended crash modification factors (CMFs) that are applied to estimated or calculated average annual crash frequencies where change in the average frequency is anticipated as a result of these treatments.

HSM's Appendix 16A (i.e., the appendix to Chapter 16, which includes the discussion on highway-railroad grade crossings) presents general information, trends in crashes and/or user behavior because of treatments, and a list of treatments for which information is currently not available.

2.10 A Policy on Geometric Design of Highways and Streets (Green Book)

Highway-railroad grade crossing information contained in the American Association of State Highway and Transportation Officials (AASHTO) publication *A Policy on Geometric Design of*

*Highways and Streets (*commonly referred to as *"The Green Book")* [10] is focused primarily on geometric design guidelines. Chapters 5, 6 and 7 provide guidelines for grade crossings with local, collector, and arterial streets and roads, respectively. *The Green Book* points to the *Manual on Uniform Traffic Control Devices* (Section 2.3) for guidance and details on the application of traffic control devices at grade crossings.

Chapter 9 of *The Green Book* includes a detailed discussion on design sight distance at grade crossings. Absence of train-activated warning devices is the base (i.e., worst case) scenario for which sight distances must be considered in the design of a highway-railroad grade crossing. Two events related to determining sight distance are: 1) a vehicle operator can observe an approaching train in a sight line that will allow adequate time to pass through the crossing prior to the train's arrival; and 2) a vehicle operator can observe an approaching train in a sight line that will allow adequate time to bring the vehicle to a stop prior to the train's arrival. *The Green Book* provides equations and look-up tables to compute design sight distance for both cases. It also provides guidance for computing design sight distance for a vehicle to accelerate from a stopped position and clear the tracks prior to the arrival of a train.

2.11 Tydlacka Thesis

Several of the documents reviewed also mentioned the importance of providing adequate warning and clearance time for pedestrians at grade crossing locations where they are present. A Master's degree thesis by Tydlacka [11] included a detailed discussion on when a pedestrian phase is included and whether the full Pedestrian Clearance Interval (PCI) should be used in preemption or whether it should be truncated or omitted. The thesis points out that, if the pedestrian phase is served in its entirety, a much longer right-of-way transfer time (RTT) will be necessary which will result in a longer delay for motorists. If the pedestrian phase is truncated, pedestrians are placed at risk because they will be in the crossing when the track clearance phase begins (i.e., pedestrian cutoff). Thus, as time given to pedestrian intervals at the onset of preemption is increased, the number or probability of pedestrian cutoffs is decreased, but average intersection delay to motorists increases.

2.12 Chaudhry Dissertation

A dissertation by Chaudhry [12] focuses on an analysis of queue characteristics at signalized intersections near highway-railroad grade crossings and provides a comparison of analytical (i.e., deterministic) vs. stochastic (i.e., simulation-based) tools for estimating queue lengths, delay, and other measures to be considered when determining preemption control parameters.

The study identifies several methods that have been used for estimating traffic associated with highway-railroad grade crossings when field observations are not available (or applicable, such as for future traffic scenarios). These include the 95th percentile queue estimation model presented in ITE's *Preemption of Traffic Signals Near Railroad Grade Crossings* (Section 2.2), the *HCM* back-of-queue estimation method (Section 2.8), a nomograph contained in the 1991 *Manual of Traffic Signal Design* (not included in this review), a queue length model contained in Synchro traffic analysis software, and simulation-based stochastic queueing models. The research focused on comparing analytical/macroscopic queue estimation models (*HCM*, Synchro) with stochastic models in the simulation programs Vissim and SimTraffic. It points out that the analytical models are limited to their model assumptions under certain conditions (e.g., undersaturated conditions and uniform arrival patterns) and are unable to capture variations in

traffic flow in traffic conditions that vary from the assumptions. The research was limited in that it focused only on those tools mentioned, did not involve model calibration and validation, and only included two field study sites.

Other significant points made by the dissertation that apply to this project are:

- Default vehicle lengths in analytical tools have a significant impact on estimated queue lengths.
- Simulation models assume probability-based functions for vehicle arrivals and headway distributions, while analytical tools are not able to incorporate this level of randomness.
- Predicted queues in simulation models may be greater in length than in analytical models because analytical models may not consider all conditions that exist (e.g., spillback, forced lane changes, unbalanced lane uses, etc.).
- Saturation flow rates in analytical models are based on ideal saturation flow rates with "real-world" adjustments applied, compared to simulation model equivalents to saturation flow (contained in car-following models) that are based on probability distribution functions.
- Analytical tools use passenger-car equivalents to model trucks, while simulation tools simulate actual lengths and performance characteristics of various truck types.
- Delay is defined differently in analytical models such as the *HCM* and Synchro when compared to simulation tools.

2.13 University of Nebraska-Lincoln Research

A research project at the University of Nebraska-Lincoln [13] developed an adaptive corridor-wide signal timing optimization methodology for a traffic network with multiple highway-railroad grade crossings. For this type of facility with multiple crossings and heavy train traffic, traffic safety and efficiency problems become more complicated due to the randomness of train arrivals and frequent abruptions of normal signal timing operation of the whole corridor. Researchers developed a signal timing optimization technology specially designed for such a corridor/network.

The optimization methodology architecture consists of two modules: a simulation module using Vissim software and an optimization module. The optimization module consists of a genetic algorithm (GA)-based optimizer, train arrival prediction model, and preemption logic algorithm. The train arrival prediction model predicts train arrival time as a function of train speed and rate of speed change. A transition preemption strategy algorithm was developed for dual-track corridors having multiple highway crossings. These parameters are then passed to a GA-based optimization program developed to optimize traffic signal timings on highway-railway corridors. The GA routines are carried out in Matlab and a Visual Basic program is used to copy candidate signal timing plans and apply them in simulation using Vissim.

Pedestrian phase truncations and preemption traps are already included in the transition preemption strategy algorithm and therefore not included in the optimization objective function; however, they are included as effectiveness safety measures in the evaluation of the optimization results. Delay minimization was the traffic objective function of the optimization algorithm and

was evaluated 1) for each intersection, 2) for the corridor, and 3) for the network (which included the corridor of interest plus all other streets under evaluation).

2.14 Center for Transportation Research

A research project by the Center for Transportation Research (CUTR) at the University of South Florida [14] examined coordinated "pre-preemption" of traffic signals along an arterial road. Pre-preemption is defined as a special traffic mode that uses advance (i.e., early) warning time to clear congested vehicle traffic before a train's arrival. It provides "extra" green time to the movements blocked by a train before the train's arrival at the crossing to 1) mitigate congestion on the arterials near railways and 2) reduce train-vehicle and/or vehicle-vehicle conflicts adjacent to at-grade crossings.

The coordinated pre-preemption strategy developed in this study aims to clear the through traffic at several intersections along an arterial as much as possible before a train's arrival. Coordinated pre-preemption is easy to implement on existing traffic controllers as all pre-preemption phases are pre-timed. The detection subsystem detects an approaching train at a much longer distance upstream from a railroad at-grade crossing than the classic train detection system. The activation or deactivation of existing preemptions at upstream intersections along a railway corridor can be used as the pre-preemption trigger at the target intersections. This offers an attractive alternative for train detection in that it does not require installation of new devices or new permissions from rail companies.

The study demonstrated that pre-preemption can be coordinated to clear through traffic along an arterial before a train's arrival. A generic pre-preemption plan was developed to provide guidance on implementing the pre-preemption strategy in Florida. The generic plan provides the procedure to 1) identify the needs of pre-preemptions, 2) activate pre-preemptions using upstream preemption signals, 3) predict train estimated time of arrival (ETA) using upstream preemptions, and 4) configure the modular central transportation management platform Advanced Train Management System (ATMS) widely used in Florida to implement the pre-preemption strategy.

2.15 Rilett and Appiah

Research by Rilett and Appiah [15] used traffic simulation software to examine the usefulness of supplementing railroad preemption operations at highway-railroad grade crossings with variable message signs. The simulation software Vissim was used to investigate the effects of different train dwell times on grade crossing operations as well as different levels of driver response to a variable message sign in the vicinity of the crossing. The study demonstrated the potential usefulness of variable message signs for preventing lengthy queues and illustrated the importance of explicitly considering the delay experienced by vehicles on the blocked roadway.

2.16 Khattak and Lee

A research study by Khattak and Lee [16] investigated the benefits for highway-railroad grade crossing safety improvements by diverting motorists to alternate routes. Use of a variable message sign was found to affect the motorists' decision to take an alternate route to avoid delay due to the presence of a train at a crossing. However, diversion was measured only by comparing intersection turning volumes near the crossing location with and without the use of variable message signs. No route choice model was used to predict diversion.

2.17 Literature Review Summary

This literature review was not exhaustive, but it did cover a broad range of topics and parameters that have impacts associated with traffic stoppage at highway-railroad grade crossings. It includes documents representing the state of the practice for traffic control at crossings. The review includes sources that offer tools or methods for estimating traffic queues due to crossing events and guidance for queue management to improve safety and reduce delays. Several of the sources explained and provided best practices for signal preemption. Others discussed driver characteristics, behaviors, and common errors made at highway-railroad grade crossings, with guidance on ways to reduce or avoid these errors. Several discussed extra measures that are needed to enhance pedestrian safety during crossing events.

By their absence from the literature identified and reviewed, there are two impact aspects of simulating highway-railroad grade crossing events that should be studied: 1) the variable nature of traffic demand, both within the day and over the course of a year; and 2) the likelihood that motorists will divert from a route containing an at-grade crossing to a route with a grade-separated crossing, given prior knowledge or probability of blockage on the route with an at-grade crossing. Traffic analyses and queue prediction models typically focus on a peak hour, but demand is assumed to be constant over that peak hour. The reality is that demand can vary greatly within that peak hour, over the course of a day, and from one day to the next. Also, when demand approaches or exceeds capacity, deterministic models have a tendency to significantly underestimate delay and even queue lengths. Driver route choice significantly impacts demand at grade crossings during a crossing event, but none of the literature reviewed reflected anything more than cursory means to account for this diversion.

3. Stakeholders

Due to project budget constraints, the scope of this research was limited to performing simulations at two study sites. Geographic diversity was a factor in site selection, as was the closely related goal of finding state transportation agencies with an interest in the project who were willing to assist through coordination and provision of data. The states selected for study were Illinois and Texas.

In Illinois, the highway-rail grade crossing program is the responsibility of the Illinois Commerce Commission (ICC), Rail Safety Section. In this research, the ICC served as a proxy for both the Illinois Department of Transportation and the BNSF Railway, owner of the rail line at the Illinois site. The ICC provided details about operation of traffic signals in the vicinity of the study site, as well as preemption plans for those signals immediately adjacent to the crossing.

The research team met with the ICC on February 28, 2022. The purpose of the meeting was to review the background for the study, the objectives, the project scope of work, desirable study site characteristics, and anticipated data collection items. The meeting also served as a venue for discussing candidate study sites that had been identified for consideration by the ICC. A summary of the meeting is presented in Appendix A.

In Texas, the grade crossing program is the responsibility of the Texas Department of Transportation (TxDOT), Rail Division. Researchers conducted several calls with the TxDOT Rail Division to coordinate the identification of candidate sites and the selection of a study site. A separate meeting was held on July 12, 2022, with Union Pacific, owner of the railroad at the Texas study site. Materials for that meeting also are provided in Appendix A.

4. Identification of Study Sites

At the beginning of this project, the research team developed several criteria for selecting study sites. Because budget constraints limited the project scope to performing simulations at only two sites, geographic diversity was an important factor, but another closely related factor was finding a state transportation agency that had an interest in the project and was willing to assist through coordination and provision of data. The team selected sites in Illinois and Texas for the study.

In Illinois, the highway-rail grade crossing program is the responsibility of the ICC Rail Safety Section. In Texas, the TxDOT Rail Division is responsible for the program. Representatives from both agencies were helpful in developing and providing a candidate list of sites, then discussing those sites with the project team, which enabled an informed selection of sites for study.

The team decided that one of the sites should be in an urban or suburban location, with the other one being in a more rural setting. This would offer a better range of example applications that might be encountered for agencies and consultants referring to this guidance for conducting simulation analyses. For urban and suburban areas, a system approach must be taken and there are several factors that should be considered:

- Density of the street network and proximity of adjacent intersections that are impacted by traffic backups
    - These adjacent intersections may necessitate the need for signal preemption and either pre-signals or queue cutter signals to mitigate intersection approach queues that extend to a grade crossing.
- Type of trains at the crossing – freight or passenger
    - Factors related to train type include length of the train and speed through the crossing. Freight trains are typically longer and slower than passenger trains, resulting in longer duration crossing events. Passenger train crossings typically occur more frequently and at higher speeds.
- Pedestrian and bicyclist activity
    - Foot traffic and cyclist activity are much more likely in an urban or suburban setting compared to rural locations.

In rural areas, the focus of the study was primarily on the crossing location itself and, where applicable, an immediate adjacent intersection. Rail traffic activity is characteristically freight in nature and crossings are generally less frequent than in urban and suburban areas. While highway traffic volumes over the crossings may be less than in urban and suburban areas, truck volumes as a percentage of total traffic may be higher. Approach grades can be an issue at some rural sites, especially when there is a “hump” that causes operational (and potentially safety) problems for trucks having low undercarriage clearance.

The team shared a list of desirable study site characteristics with ICC and TxDOT at the onset of the study and asked the agencies to provide a list of candidate sites for consideration. These factors included:

- Multiple daily crossings
- Variable train crossing speeds

- Multiple tracks
- Mixture of freight and passenger rail (if possible)
- Closely spaced adjacent intersections
- Signal preemption – simultaneous or advance
- Pre-signal and/or queue cutter signal
- Cross-street AADT 5,000 or greater
- Significant truck volumes as part of the crossing street traffic

Data collection was another factor in the site selection. Selected sites needed a sufficient volume of highway traffic and crossing train traffic to make the data collection feasible. Proximity to a major airport also was important so that travel expenses for site review and data collection personnel could be kept to reasonable levels.

Although not a primary factor with respect to this study, safety was an issue that was taken into consideration for site selection, as operational issues (particularly with traffic queues and adjacent intersections) ultimately can lead to safety issues. Some of the nominated sites by ICC and TxDOT have had safety issues.

4.1 Candidate Sites

A list of candidate sites was provided after initial conversations with ICC and TxDOT. The lists are not comprehensive for the desirable characteristics requested but are representative of the types of sites being sought for this project.

4.1.1 Illinois

A summary list of candidate sites in Illinois sites is provided in Table 1. These urban/suburban area sites are located within the Chicago Metro area and the rural sites are scattered across the state. The urban/suburban area sites are shown on the map in Figure 1, while the rural area sites are mapped in Figure 2.

Table 1. Illinois Candidate Study Sites

Area Type	Map ID	Location	Town/City	FRA ID	Railroad
Urban/Suburban	IL-U-1	River Road at Miner Street (US 45)	Des Plaines	173908X	Union Pacific
Urban/Suburban	IL-U-2	Lehigh / Caldwell / Devon	Chicago	386379G	Metra, Amtrak, 8 CP freight
Urban/Suburban	IL-U-3	US 12-20-45 (LaGrange Road) at Burlington Ave./Hillgrove Ave.	LaGrange	079508Y	BNSF
Urban/Suburban	IL-U-4	Harlem Avenue near W. 26th Street	Berwyn	079493L	BNSF
Urban/Suburban	IL-U-5	IL 83 (Main St.) / US 14	Mt. Prospect	176912X	Union Pacific
Urban/Suburban	IL-U-6a	Harlem Avenue near Grand Avenue	Elmwood Park	372126H	NIRC (Metra)
Urban/Suburban	IL-U-6b	S. Main Street near Front Street/Liberty Drive	Wheaton	174957X	Union Pacific
Urban/Suburban	IL-U-6c	Main Street at Duane Street/Pennsylvania Ave.	Glen Ellyn	174950A	Union Pacific
Urban/Suburban	IL-U-6d	Willmette Ave. at Green Bay Road	Wilmette	176548M	Union Pacific
Urban/Suburban	IL-U-7	Busse / Oakton / Dee	Park Ridge	173904V	Union Pacific

Area Type	Map ID	Location	Town/City	FRA ID	Railroad
Urban/Suburban	IL-U-8	IL 19 at Roselle Road	Roselle	372196X	NIRC (Metra)
Urban/Suburban	IL-U-9	IL 19 at Wood Dale	Wood Dale	372177T	NIRC (Metra)
Urban/Suburban	IL-U-10a	94th Street at Kedzie Ave.	Chicago	283149U	CSX
Urban/Suburban	IL-U-10b	95th Street at Kedzie Ave.	Chicago	283151V	CSX
Rural	IL-R-1	IL 113 (Main St) at IL 129/IL 53	Braidwood	290507T	Union Pacific
Rural	IL-R-2	Reynolds Street at Ladd Street	Pontiac	290759U	Union Pacific
Rural	IL-R-3	IL 108 (Main St.) at Chiles Street/Alton Road	Carlinville	294388A	Union Pacific
Rural	IL-R-4	US 34 at Duvick Ave.	Sandwich	079597T	BNSF
Rural	IL-R-5	IL 53 at IL 29 (Stripmine Road)	Wilmington	290503R	Union Pacific
Rural	IL-R-6	US 45 at Curtis Road	Savoy	289084Y	Illinois Central

*Source: Illinois Department of Transportation

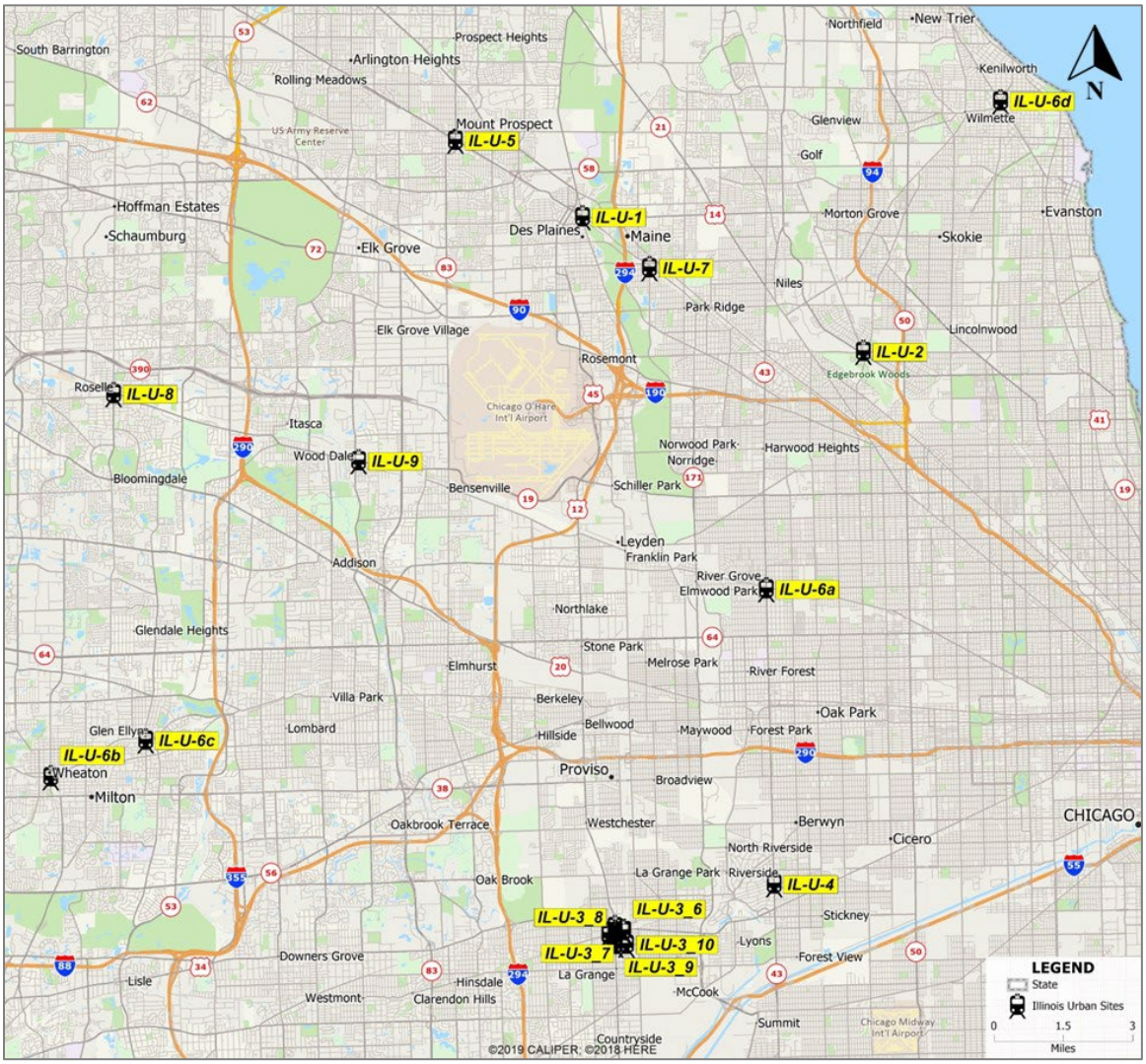


Figure 1. Illinois Candidate Urban/Suburban Area Study Sites

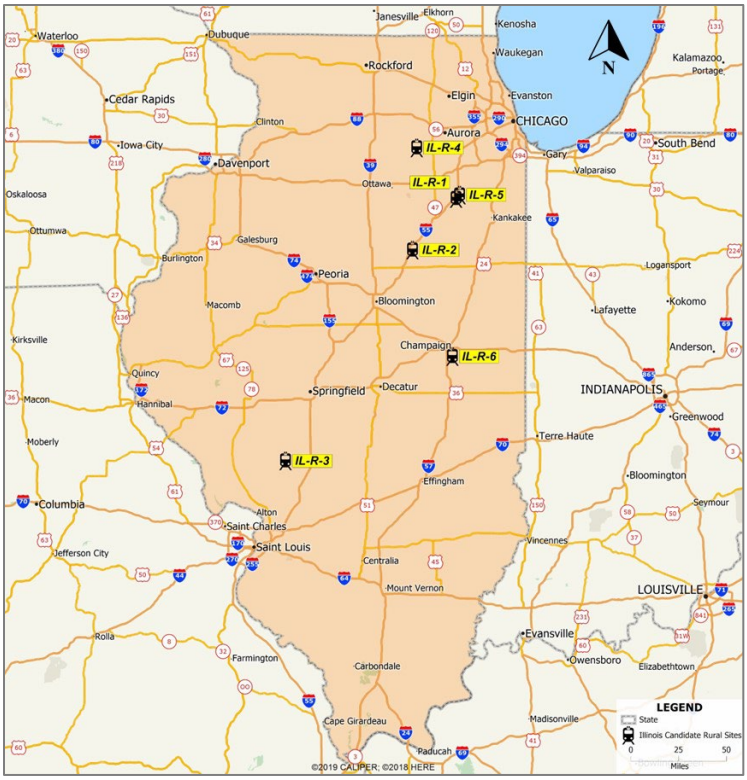


Figure 2. Illinois Candidate Rural Study Sites

4.1.2 Texas

The Texas candidate sites are listed in Table 2 and are shown on the map in Figure 3.

Table 2. Texas Candidate Study Sites

Area Type	ID	Location	Town/City	FRA ID	Railroad
Rural	TX-R-1	US 79 at CR 424	Thrall	446559W	Union Pacific
Rural	TX-R-2	CR 1250 at Business 20	Odessa/ Midland	796312G	Union Pacific
Rural	TX-R-3	Holleman Road at Wellborn Road	College Station	745037Y	Union Pacific
Rural	TX-R-4	SH 97 at N. Front Street	Cotulla	448996Y	Union Pacific
Urban	TX-U-1	SH 49 (W. Broadway) west of Walcott Street	Jefferson	794573A	Union Pacific
Urban	TX-U-2a	Zarzamora Street near IH 35	San Antonio	435955G	Union Pacific
Urban	TX-U-2b	SB IH-35 Frontage Road	San Antonio	435954A	Union Pacific
Urban	TX-U-2c	NB IH-35 Frontage Road	San Antonio	435438T	Union Pacific
Urban	TX-U-3a	IH-35 SB Frontage Road at McNeil Road	Round Rock	448435K	Union Pacific
Urban	TX-U-3b	IH-35 NB Frontage Road at McNeil Road	Round Rock	448427T	Union Pacific
Urban	TX-U-4a	N. Westmoreland Road	Dallas	794926K	Union Pacific
Urban	TX-U-4b	N. Westmoreland Road	Dallas	794926K	Union Pacific

* Source: Texas Department of Transportation, 2020 District Traffic Web Viewer

** Estimate; these are frontage road locations

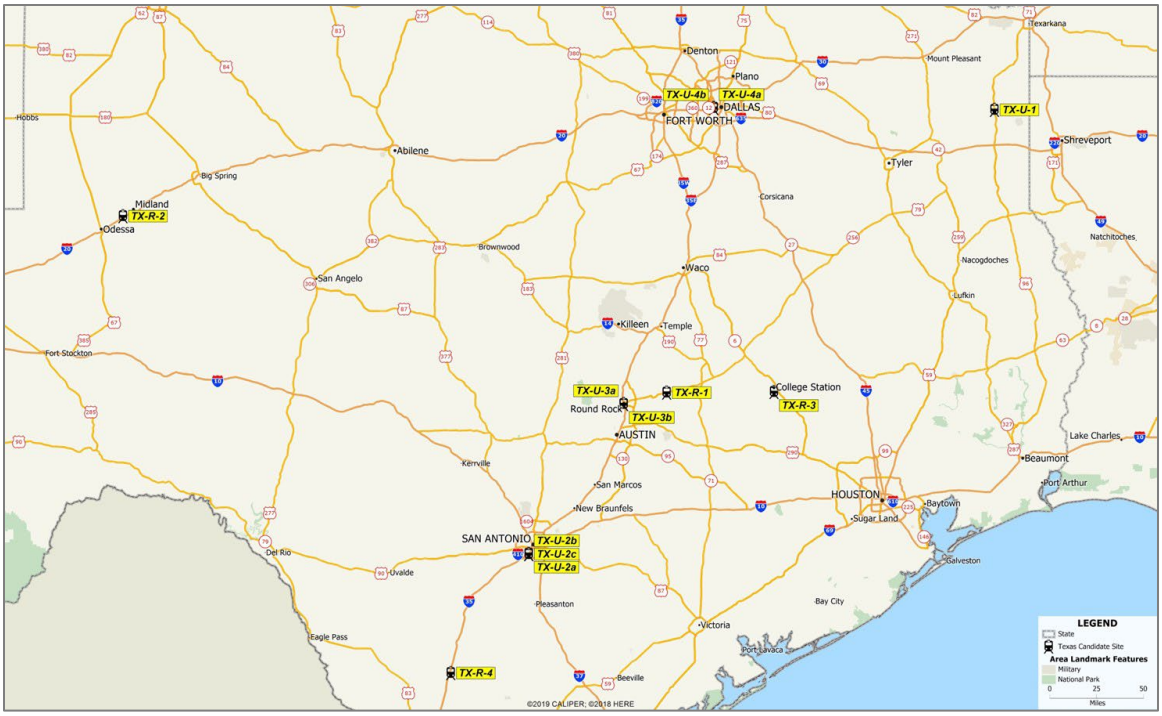


Figure 3. Texas Candidate Study Sites

4.2 Selected Sites

In each state, a preferred study site was selected and an alternate site was identified in case the preferred location was not available. The preferred urban/suburban site was in La Grange, a suburb in the Greater Chicago area in Illinois. The preferred rural site was in Cotulla, Texas, a small town between San Antonio and Laredo.

The preferred and alternate sites are discussed below.

4.2.1 Urban/Suburban

Preferred: La Grange, Illinois (IL-U-3) – La Grange Road (US 45) at Burlington Avenue and Hillgrove Avenue

Alternate: Des Plaines, Illinois (IL-U-1) – River Road at Miner Street (US 14)

The La Grange site was selected because it met numerous preferred site criteria. There are four signalized intersections – two north of the crossing and two to the south – that are adjacent or close to the crossing that necessitate signal preemption at this location. Thus, the simulation could be used to model and demonstrate how preemption is used to clear the tracks in the event of an approaching train. The BNSF triple track line at this location is extremely active; in fact, it operates at capacity, facilitating both passenger (i.e., Metra commuter) and freight trains. As this line runs through the La Grange downtown area, there is significant pedestrian and bicycle activity for inclusion in signal preemption plans. Finally, the study area network was "right-sized" – large enough to demonstrate how a system approach must be taken in an urban or suburban area, but not so large that an extremely complex modeling effort was required. A satellite image of the urban/suburban preferred crossing site in La Grange, Illinois is shown in Figure 4.

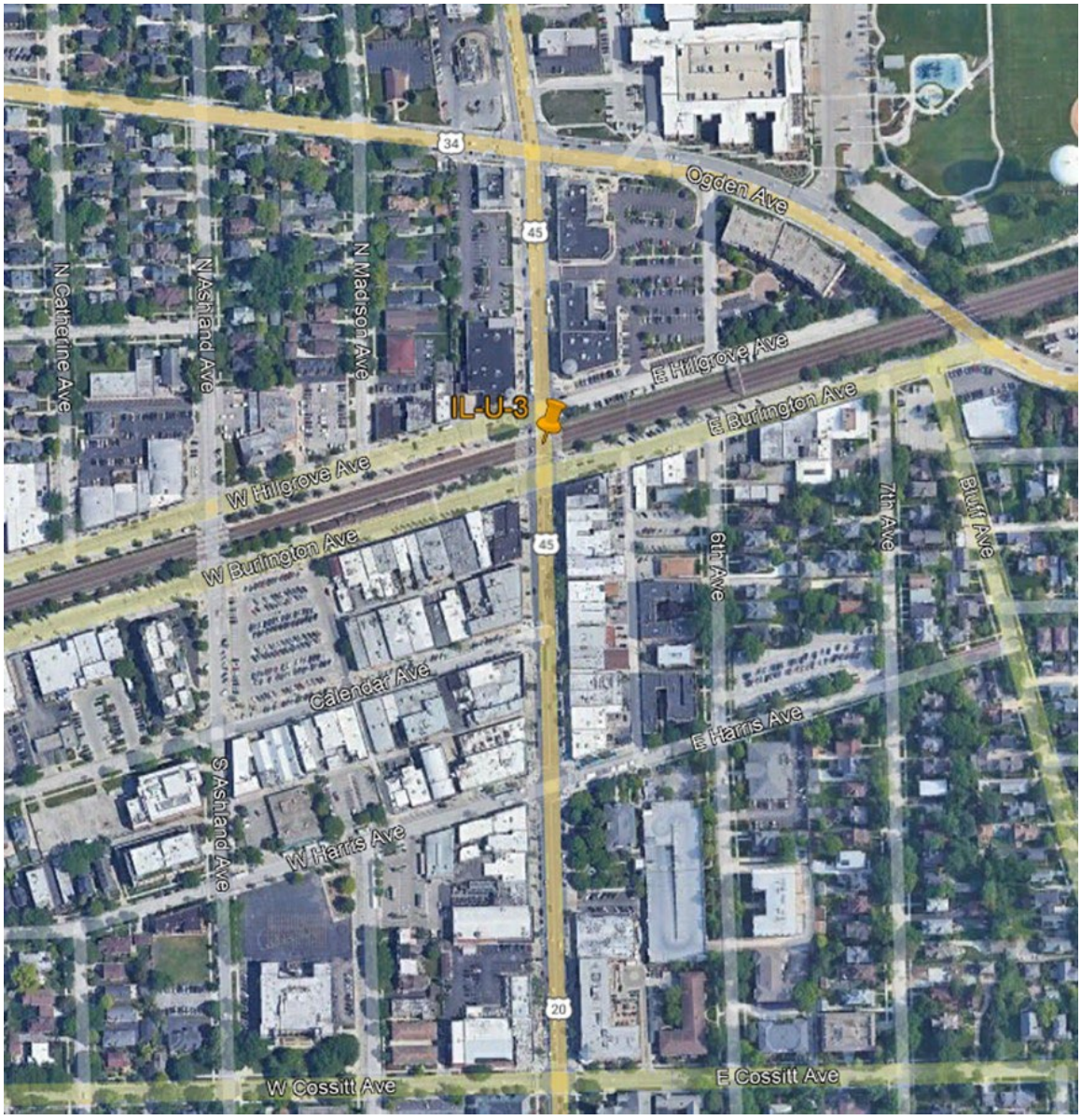


Figure 4. Urban/Suburban Area Preferred Study Site – La Grange Road at Burlington Avenue and Hillgrove Avenue, La Grange, IL

4.2.2 Small Town/Rural

Preferred: Cotulla, Texas (TX-R-4) – SH 97 between Front Street and Keck Street

Alternate: Thrall, Texas (TX-R-1) – US 79 at CR 424

The Cotulla site was selected for study because although it is a small, rural town it still has enough vehicular and train activity to provide a valuable simulation demonstration. According to the Rail Division contact at TxDOT, even though a bypass to the north was built several years ago, there remains a significant volume of truck traffic crossing this location due to the proximity of industry in the area. TxDOT also is considering implementation of a queue cutter signal on the westbound approach to this crossing. A satellite image of the small town/rural preferred crossing site in Cotulla, Texas is shown in Figure 5.

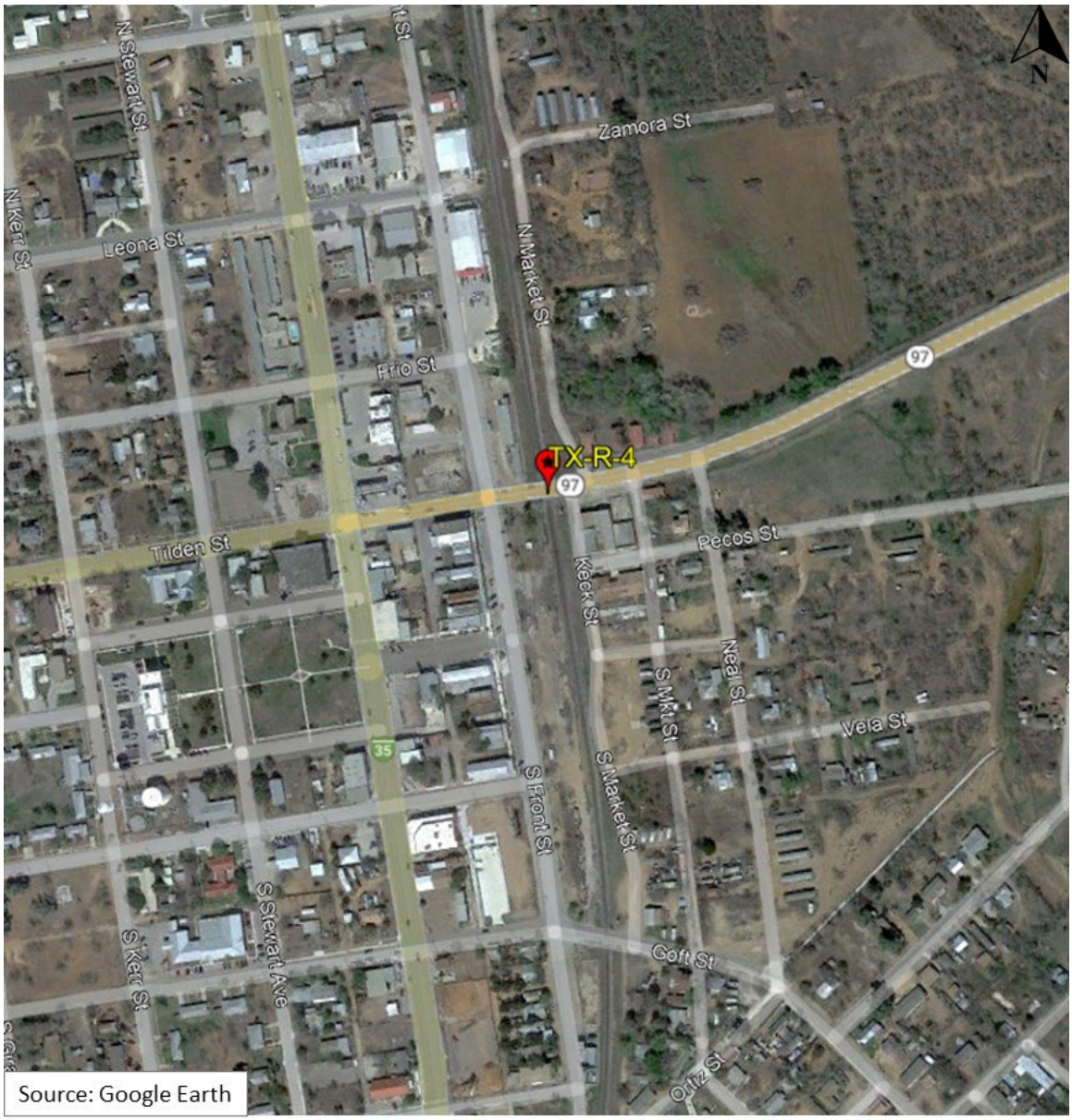


Figure 5. Small Town/Rural Preferred Study Site – SH 97 between Front Street and Keck Street, Cotulla, TX

4.3 Site Selection Summary

The process of coordinating with partner states and developing a list of desirable site characteristics produced a good list of candidate sites in Illinois and Texas, including study locations that were deemed to be very qualified examples of highway-rail grade crossings and which will serve as case study examples.

5. Development of Traffic Simulation Models

The research team used TransModeler® Version 7.0 by Caliper Corporation to simulate traffic conditions associated with the grade crossing events. TransModeler is a fully functional, Geographic Information System (GIS)-based microsimulation platform able to simulate train crossing events, pre-emption of traffic signals associated with the crossing, and resulting traffic impacts, including queues and delays on streets and roads in the vicinity of the crossing.

5.1 La Grange, Illinois Simulation Model

5.1.1 Study Area and Model Network

The grade crossing is located along US 45 (La Grange Road) just south of US 34 (Ogden Avenue) in downtown La Grange, Illinois. Average daily traffic volumes are 20,500 for US 45 and 26,000 for US 34 (source: Illinois Department of Transportation). An area map that includes the project site is shown in Figure 6.

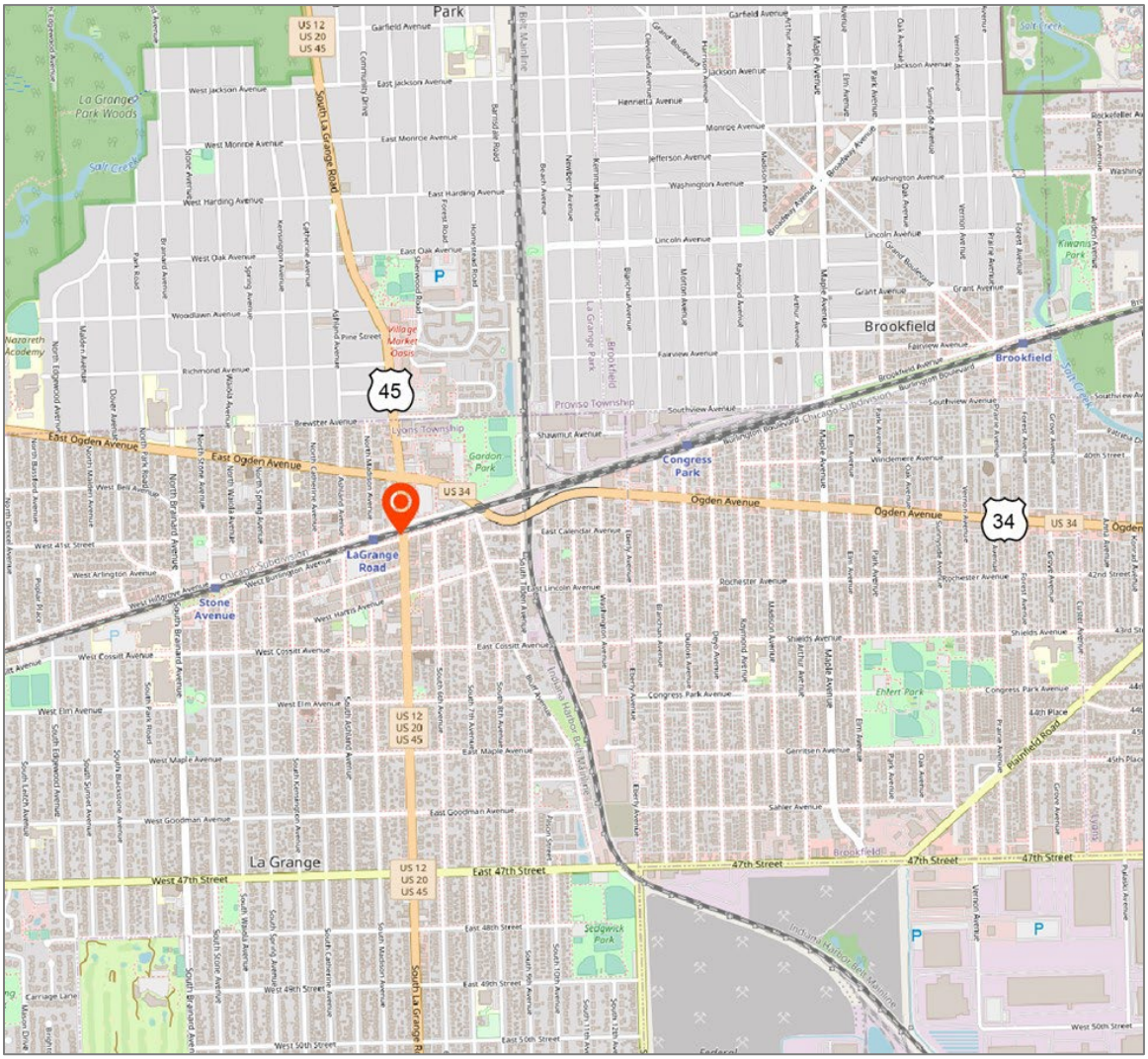


Figure 6. Urban/Suburban Area Simulation Site Area Map – La Grange, IL

The crossing is a triple track owned by the BNSF Railway. The line serves both freight and passenger trains and a Chicago Metra commuter rail station (BNSF line to Aurora) is located just to the west of the crossing. Two local streets are adjacent and run parallel to the tracks – Hillgrove Avenue to the north and Burlington Avenue to the south. A map of the simulation model network and surrounding streets is shown in Figure 7.

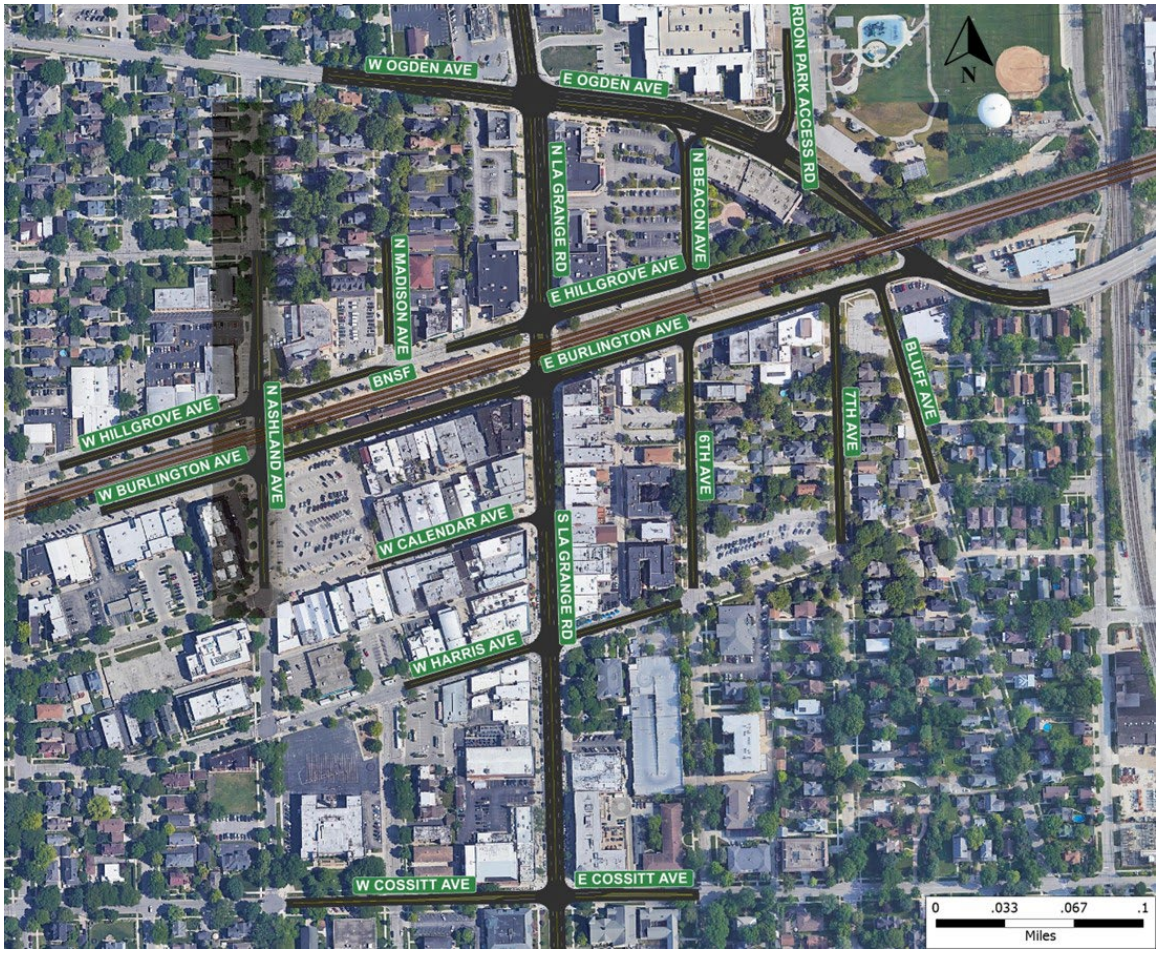


Figure 7. Simulation Model Network – La Grange, IL, Site

Within the study area, La Grange Road is a four-lane, undivided principal arterial with center left-turn lanes at Ogden Avenue and at Hillgrove Avenue and Burlington Avenue just north and south of the crossing. The posted speed limit through this section of downtown La Grange is 20 mph. At the crossing, Hillgrove Avenue and Burlington Avenue are classified as major collector streets, each having average daily traffic volumes of about 2,100 and a speed limit of 20 mph.

5.1.2 Traffic Control

There are five signalized intersections in the model located along the La Grange Road corridor whose timing plans were obtained from the Illinois Department of Transportation. The intersections of La Grange Road with Hillgrove Avenue (north of the at-grade rail crossing) and Burlington Avenue (south of the at-grade rail crossing) are both preempted by rail crossings. When an oncoming train triggers preemption, the timing plan displays green to clear the portion of La Grange Road between Hillgrove Avenue and Burlington Avenue of vehicles. While the

train is crossing, eastbound and westbound movements at both intersections are given green, except for turning movements toward the rail crossing, until the train crossing is over.

5.1.3 Simulation Periods

Data were collected at the site on Tuesday, June 7, 2022, using video cameras that were mounted throughout the study area. Data collected included:

- Intersection turning movement volumes, vehicle classifications, and pedestrian volumes
    - N. LaGrange Road – Ogden Avenue
    - N. LaGrange Road – Hillgrove Avenue
    - S. LaGrange Road – Burlington Avenue
    - S. LaGrange Road – Harris Avenue
    - S. LaGrange Road – E. Cossitt Avenue
    - N. Ashland Ave – W. Hillgrove Avenue
    - S. Ashland Ave – W. Burlington Avenue
    - Bluff Ave – E Burlington Avenue
    - E. Ogden Ave – E. Burlington Avenue
- Beginning-of-cycle queue length data at the five signalized intersections along La Grange Road
- Train crossing events at the La Grange Road at-grade crossing – for each crossing event, the following items were recorded:
    - Time of warning system actuation
    - Time the lead train engine enters the crossing
    - Time the last train car clears the crossing
    - Time that traffic flow resumes
    - Number of cars in the train
    - Type of train (e.g., freight or passenger)
    - Train direction of travel (e.g., northbound/southbound)

Data were collected from video cameras that were mounted throughout the study area. After the data were reviewed, the following time periods were selected for simulation:

- 8:30 a.m. – 10:30 a.m.
- 1:00 p.m. – 3:00 p.m.

The team selected these periods as being the busiest times for traffic volumes in the study area and train crossing events.

5.1.4 Demand

For the simulation periods established, intersection turning movement counts were processed from the video data and aggregated into 15-minute intervals for input into TransModeler. The turning movement data used in the development of the site simulation model are included in Appendix B.

Vehicle classification information was collected along with the intersection turning movement counts. Using the classification data collected, the following vehicle class breakdown was used in the development of the models, as shown in Table 3.

Table 3. Vehicle Classification – La Grange, IL, Simulation Model

Vehicle Classification	Percentage
Automobiles, Pickup Trucks, SUVs	93.2%
Single Unit (Medium) Trucks	3.5%
Heavy Trucks	1.9%
Buses	0.6%
Bicycles	0.6%
Motorcycles	0.2%
Total	100.0%

Vehicle queue data were collected along the La Grange Road corridor. After the simulation periods were identified, cycle-by-cycle maximum queue data were observed at the intersection from the video files. However, at times the maximum queues extended beyond the video scope. Two movements were determined to be most important for model validation – the southbound movement at Hillgrove Avenue and the northbound movement at Burlington Avenue. These are shown in Figure 8. The queue data for these lane groups are included in Appendix B.

Figure 8. Key Lane Groups for Queue Comparisons – La Grange, IL, Simulation Model

5.1.5 Unique Site Characteristics

To the west of the La Grange Road crossing, there is another at-grade crossing at Ashland Avenue. To the east, there is a grade-separated crossing at Ogden Avenue. In Figure 9, the at-grade rail crossings are highlighted by yellow circles and the grade-separated crossing at Ogden is highlighted by a pink circle. Given that the eastbound left turn movement from Burlington Avenue onto Ogden Avenue headed northbound (the pink arrow in Figure 9) is not allowed, northbound traffic using this intersection to divert during rail crossings did not seem viable. Southbound traffic could potentially use this intersection as a diversion route, but this behavior was not observed in the field. In the other direction, the presence of the at-grade crossing at Ashland also makes diversion routes off of La Grange Road unlikely.

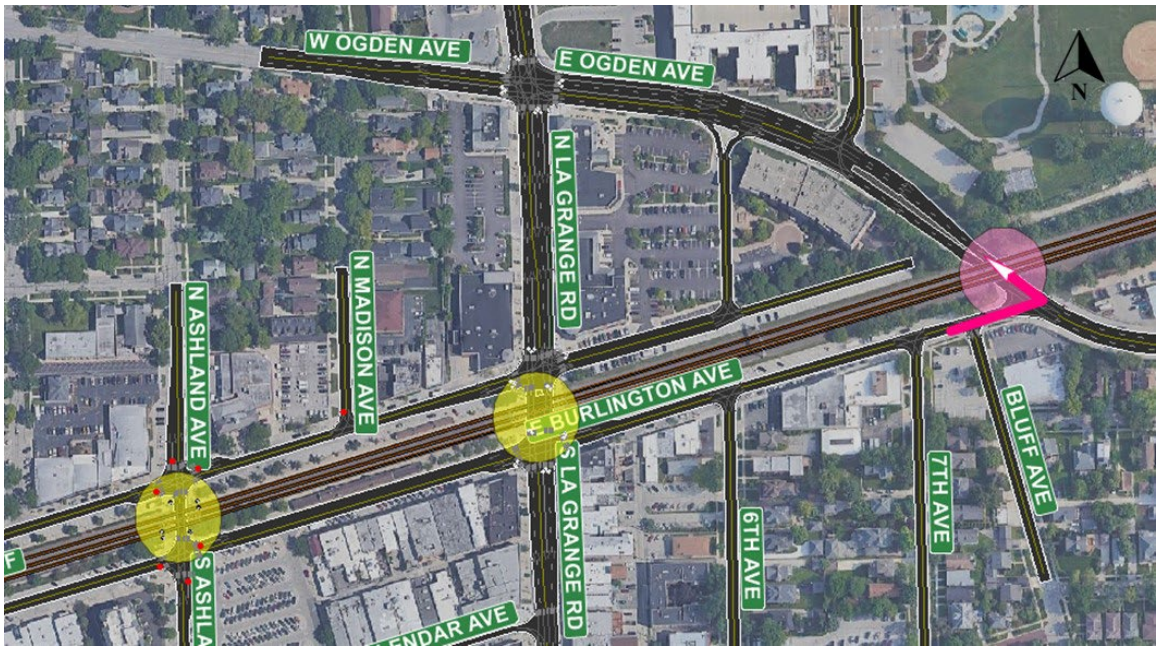


Figure 9. Rail Crossing Locations – La Grange, IL, Site

5.1.6 Train Crossing Events

Both commuter trains and freight trains commonly use the at-grade crossing at La Grange Road., Some of the commuter trains stop at the train station just to the west of La Grange Road and traffic on La Grange is preempted while a train is at the station. Other commuter trains pass through the crossing without stopping. On the dates the data were collected, trains varied from 5 to 131 cars in length. From 8:30 a.m. to 10:30 a.m., there were 12 trains that crossed during 10 crossing events, where a crossing event is each time the rail crossing gates are lowered. From 1:00 p.m. to 3:00 p.m., there were 13 trains that crossed during 11 crossing events. The number of trains that crossed is not equal to the number of crossing events because sometimes more than one train crossed during a crossing event.

The average interruption to traffic was slightly over two minutes during both periods (2:22 during the a.m. period and 2:09 during the p.m. period) and ranged from as short as 0:37 mins to as long as 4:02 mins. Train crossing data for the La Grange, IL, site are provided in Appendix B.

5.1.7 Model Calibration and Validation

Model calibration involves the adjustment of parameters in a simulation model to improve its ability to reflect what has been observed in the field. Typically, this process is focused on performance measures related to 1) travel time or speed and 2) bottlenecks. Calibration efforts were focused on replicating traffic interruptions due to train crossings as well as queues at the crossing.

Turning movement data collected in the field represent the number of served vehicles rather than actual demand. When traffic is light, demand and served vehicles are the same. However, when there are congested conditions, traffic counts are often less than the actual demand because traffic counts can only capture traffic that was served.

A comparison of 15-minute field count data and simulated traffic was conducted for all movements at the nine intersections for which turning movement data was collected. Out of these 720 movement-time interval combinations, 94 percent of a.m. simulated volumes and 88 percent of p.m. simulated volumes were within 5 vehicles of the observed count data, as shown in Table 4. Similarly, 100 percent of a.m. and 97 percent of p.m. volumes were within 15 vehicles of the observed counts data. The few p.m. movement-time interval combinations that were outside of the error threshold were high volume movements and were within 25 vehicles. As a frame of reference, the highest volume for a 15-minute interval was 305 vehicles. When looking at the total a.m. period volume for all 90 movements, 96 percent and 100 percent were within 10 percent of the counts during the a.m. and p.m. periods, respectively.

Table 4. Percent of Counts Within Difference Thresholds

Range	A.M.	P.M.
-5 to 5	91%	88%
-10 to 10	97%	95%
-15 to 15	99%	97%

In the La Grange model, each observed train crossing was modeled explicitly. Because trains varied significantly in length (e.g., the first train was 8 cars long and the second train was 131 cars long), a custom vehicle class was created for each of the crossings so that the number of cars could be edited for each individual train. Because train speed data were unavailable, a speed of 50 mph was assumed for each train. Four shorter passenger trains and likely express routes were allowed to travel at higher speeds to better match the field data. As the duration of the traffic interruption and the number of cars in each train was collected, the length of train cars was varied to match the interruption-to-traffic data. The amount of time traffic interrupted by rail crossings was calibrated for each of the 21 instances the rail crossing gates were lowered. Figure 10 demonstrates that the amount of time traffic was interrupted by the rail crossing during the simulation very closely matches the amount of time traffic was interrupted in the field.

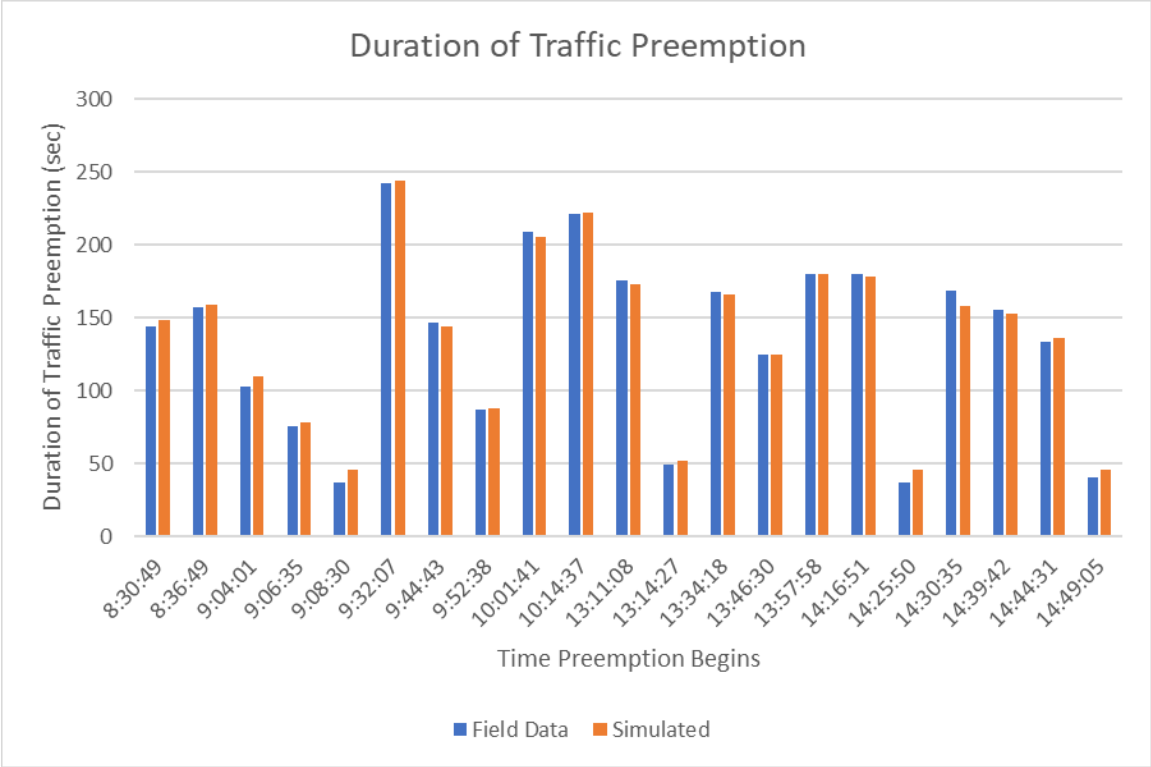


Figure 10. Duration of Traffic Interruption Due to Train Crossings – La Grange, IL, Site

As train traffic can vary daily, especially since freight trains do not run on set schedules, modeling each train trip is not always necessary. The La Grange model was simulated this way to demonstrate modeling train trips explicitly as an option.

For model validation purposes, queueing data were collected along La Grange Road, and queues observed in the field were compared to the simulated queues resulting from TransModeler runs. As described earlier, the vehicle class distribution was modified to represent the observed data.

The key movements in the La Grange study area are the two movements headed toward the rail crossing as shown earlier in Figure 8: the northbound queue at Burlington Avenue and the southbound queue at Hillgrove Avenue. The cameras for these two queues could show queues up to 7 and 10 vehicles long, respectively, with precision. Data for longer queues were more difficult to determine given the angle and distance from the camera. Figure 11 shows an example of the camera view of the northbound queue at Burlington Avenue.

Figure 11. View of the Northbound Queue at Burlington Avenue

Due to this constraint, the queue analysis compares observed queues with simulated queues with maximum queues capped at 10 vehicles in the southbound direction and 7 vehicles in the northbound direction. As shown in Table 5, the maximum queue of 10 vehicles was observed in every interval except one in the southbound direction, and the maximum queue of 7 vehicles was observed in every interval except two in the northbound direction. The simulated queues closely mirror the observed queues with differences in a few instances of only a few vehicles. These differences in queue lengths are largely a function of the arrival patterns of vehicles, the point in the traffic signal cycle vehicle arrive, and the impact of train crossings.

Table 5. Comparison of Observed vs. Simulated Maximum Queues for Critical Movements on La Grange Road

Start Interval (Military Time)	SB at Hillgrove Ave.		NB at Burlington Ave.	
	Observed	Simulated	Observed	Simulated
8:30	10	10	7	7
8:45	10	8	6	6
9:00	10	8	6	7
9:15	4	8	7	7
9:30	10	10	7	7
9:45	10	10	7	7
10:00	10	10	7	7
10:15	10	10	7	7
13:00	10	10	7	7
13:15	10	6	7	7
13:30	10	10	7	7
13:45	10	10	7	7
14:00	10	10	7	7
14:15	10	10	7	7
14:30	10	10	7	7
14:45	10	7	7	7

5.1.8 Applications

The La Grange site simulation model was developed for illustrative purposes. As this is a heavily traveled crossing and signal preemption is used currently, there was no need to use such a model to test its effectiveness. However, the model would be good to test any proposed changes to timing plans for the coordinated signal system along La Grange Road. The model also could be used to evaluate "What if?" scenarios for longer or more frequent trains (i.e., longer interruptions to traffic flow).

5.2 Cotulla, Texas Simulation Model

5.2.1 Study Area and Model Network

The simulation project site is located in Cotulla, Texas, a town with a population of 4,133 located along Interstate 35, midway between San Antonio and Laredo. The grade crossing is located on the east side of town, just east of the intersection of Business Loop 35 and State Highway (SH) 97. Average daily traffic volumes are 6,100 for Business Loop 35 north of SH 97 and 5,000 for SH 97 at the crossing (source: Texas Department of Transportation). A map of the project site is shown in Figure 12.

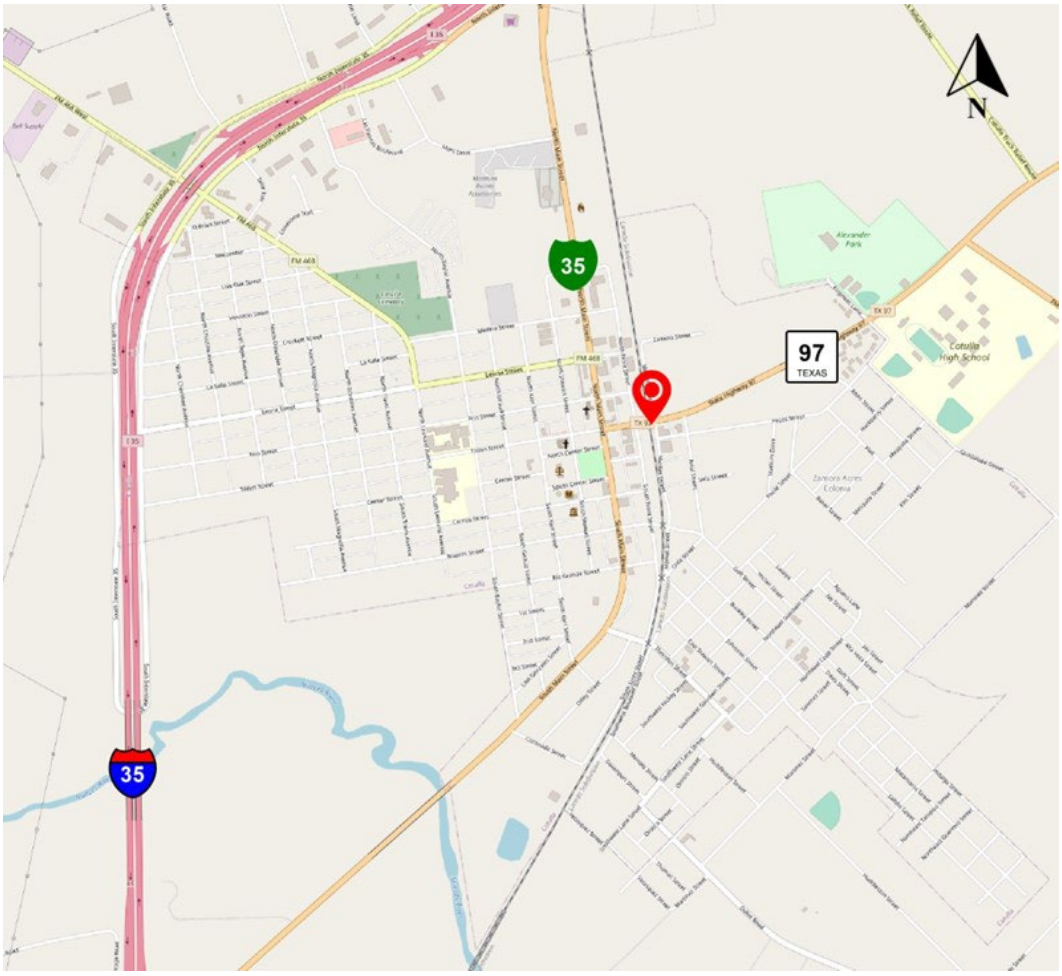


Figure 12. Cotulla, TX, Simulation Grade Crossing Site

In this section of Cotulla, the highest traffic volumes occur at the intersection of Main Street (Business Loop 35) with Tilden Street (SH 97). The grade crossing with the Union Pacific Railroad is located approximately 470 feet to the east. Review of the project site revealed that traffic impacts associated with grade crossing events were limited to Tilden Street from Main Street to the crossing location. This includes the intersection with Front Street, which runs north-south parallel to the railroad between the crossing and Main Street. A map of the simulation model network is shown in Figure 13.

Figure 13. Cotulla, TX, Site Simulation Network

Through the study area, Main Street is a four-lane minor arterial with a posted speed limit of 35 mph. Tilden Street is a two-lane minor arterial with a posted speed limit of 35 mph. Front Street is two-lane urban collector having a posted speed limit of 30 mph.

5.2.2 Traffic Control

There is one signalized intersection in the model, located at Tilden Street and Main Street. This is a fully actuated signal with a unique phasing plan, as shown in Figure 14. The northbound and southbound approaches contain shared lanes – each approach has a shared through/left turn lane and a shared through/right turn lane. For the Main Street phases, there is an exclusive southbound phase followed by a northbound + southbound phase with permitted left turns, even without the presence of an exclusive southbound left turn lane. The opposing northbound through traffic is light at this intersection, making this type of phasing possible.

Timing plans for the Tilden Street/Main Street signal were obtained from the Texas Department of Transportation. The signal operates in an isolated mode (i.e., not interconnected with any other signals).

At the Tilden Street intersection with Front Street, there is STOP-control on the Front Street approaches only. There are active warning devices (e.g., flashing lights, bells, and automated gates) at the grade crossing.

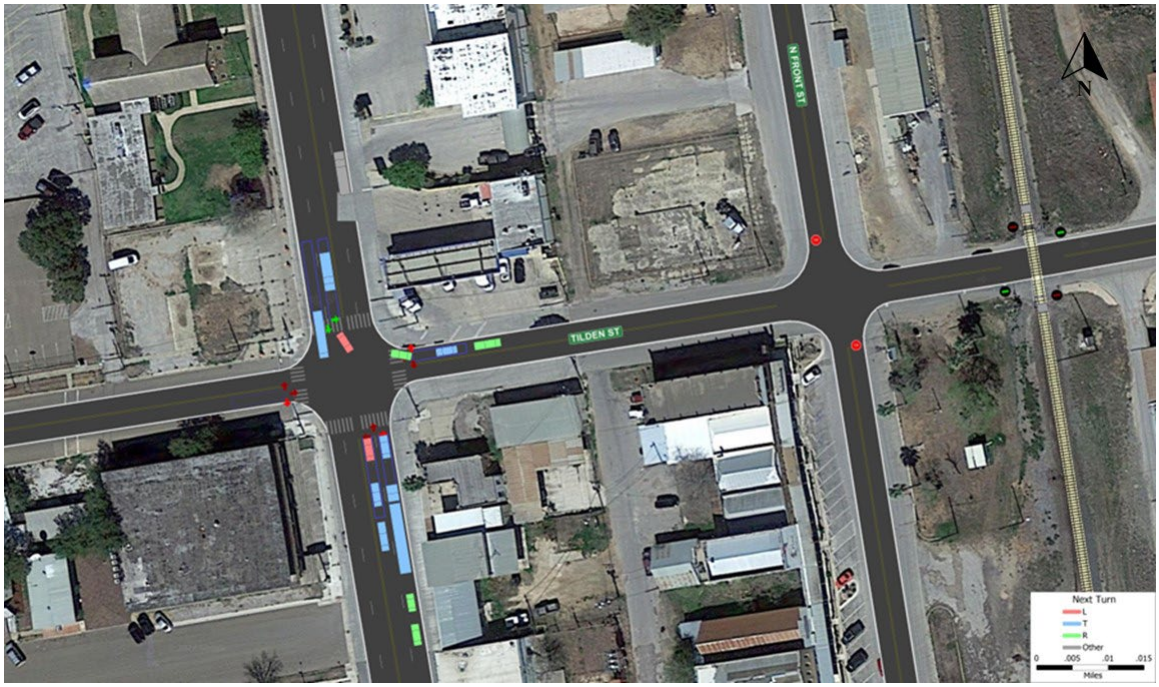


Figure 14. Signalized Intersection with SB Protected/Permitted Phasing

5.2.3 Simulation Periods

Data were collected at the site on Wednesday, April 20, and Thursday, April 21, 2022. Data collected included:

- Intersection turning movement volumes and vehicle classifications
    - Tilden Street at Main Street
    - Tilden Street at Front Street
- Pedestrian crossings on Tilden Street at Main and Front streets
- End-of-cycle queue length data by lane at Tilden Street intersections with Main and Front streets
- Train crossing events at the Tilden Street at-grade crossing – for each crossing event, the following items were recorded:
    - Time of warning system actuation
    - Time the lead train engine enters the crossing
    - Time the last train car clears the crossing
    - Time that traffic flow resumes
    - Number of cars in the train

- Type of train (freight or passenger)
- Train direction of travel (northbound/southbound)

Data were collected for a continuous 48-hour period from video cameras that were mounted throughout the study area. After the data were reviewed, the following time periods were selected for simulation:

- Wednesday, April 20, 2022, from 3:15 p.m. until 5:30 p.m.
- Thursday, April 21, 2022, from 5:00 p.m. until 7:00 p.m.

The team selected these periods as being the busiest times for traffic volumes in the study area and train crossing events.

5.2.4 Demand

For the simulation periods established, intersection turning movement counts were processed from the video data for the Tilden Street intersections at Main Street and Front Street. The counts were processed at 5-minute intervals but were aggregated to 15-minute intervals for input into TransModeler. An example of how the 15-minute volumes were displayed is shown in Figure 15. The turning movement data used in development of the simulation model for the site are included in Appendix C.

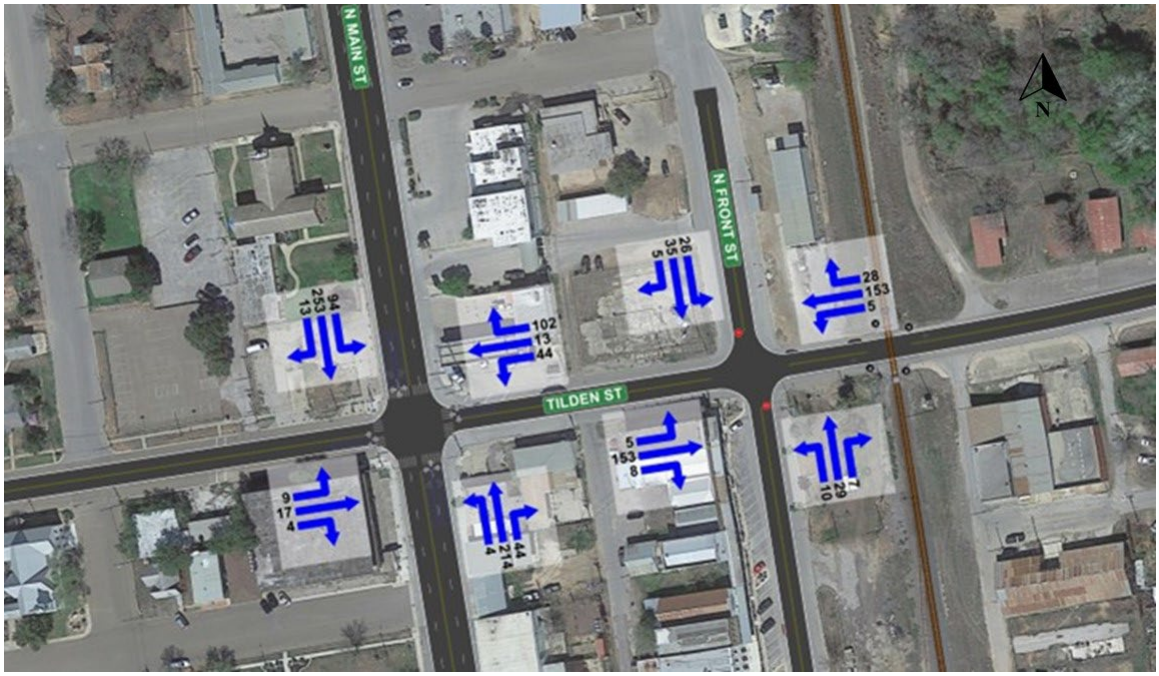


Figure 15. Example 15-Minute Intersection Turning Movement Counts

Vehicle classification information was collected along with the intersection turning movement counts. The percentages of vehicle classes varied slightly between the two intersections and across the days the data were collected. The TransModeler simulation software applies a single vehicle class table to the simulation scenarios. Using the classification data collected, the following vehicle class breakdown was used in the development of the models, as shown in Table 6.

Table 6. Vehicle Classification – Cotulla, TX, Simulation Model

Vehicle Classification	Percentage
Automobiles, Pickup Trucks, SUVs	84.3%
School Buses (standard size)	2.7%
Mini School Buses	2.6%
Single Unit (Medium) Trucks	6.1%
Heavy Trucks	2.3%
Heavy Trucks (HAZMAT)	2.0%
Total	100.0%

School buses were separated into two categories, as approximately half of the observed vehicles were mini school buses that are shorter in length and have a reduced passenger capacity. Heavy trucks also were separated into two categories – those hauling hazardous materials and those that were not. All school buses and those trucks hauling hazardous materials are required to stop prior to advancing across the tracks.

Vehicle queue data were collected at the Tilden Street/Main Street intersection and at the grade crossing. At the intersection, cycle-by-cycle queue data were observed from the video files after the simulation periods were identified. Two lane groups were determined to be most important for model validation – the southbound Main Street left/through approach and the westbound Tilden Street approach (left turn, through, and right turn movements all occur from a single lane). The queue data for these lane groups are included in Appendix C.

5.2.5 Unique Site Characteristics

Several unique site characteristics were deemed to be factors in traffic operations for this location and were incorporated into the simulation model. These included:

- At the crossing, the profile is raised, which has a slight "speed hump" effect of vehicles slowing down as they cross the tracks (see Figure 16). In TransModeler, this was modeled as a speed bump with a maximum speed of 25 mph.

Figure 16. Raised Crossing Profile "Hump"

- All school buses and trucks carrying hazardous materials were required to stop prior to the crossing before proceeding.
- Two sizes of school buses were observed – standard size buses (about 35 feet long) and minibuses (20 to 25 feet long). The distribution of these two sizes was roughly 50-50 from field observations.
- Main Street (Business Loop 35) is a four-lane undivided arterial through this portion of Cotulla. There are no exclusive left turn lanes at the intersection with Tilden Street (SH 97), yet there is protected/permitted left turn signal phasing for the southbound approach, as illustrated in Figure 17. The opposing northbound through traffic movement is relatively light, which permits this scheme to function acceptably.

Figure 17. Protected/Permitted Left Turn Phasing from a Shared Lane

- The intersection of Tilden Street with Front Street has STOP-control on the Front Street approaches only; through traffic on Tilden Street is not required to stop. When a queue has formed in front of this intersection – either an eastbound queue at the grade crossing or a westbound queue extending from Main Street – the intersection is blocked sometimes but not always (see Figure 18). From the on-site inspection and review of the video files, this appears to be related to whether or not a vehicle was stopped on one of the Front Street approaches prior to the queue forming along Tilden Street. If no vehicle was stopped, drivers moving along Tilden Street tend to ignore this intersection when stopped in a queue. TransModeler does not simulate this behavior specifically; the team determined that it was not necessary to write a specialized add-in for the software as this scenario occurs infrequently.

Figure 18. Occasional Blockage of Front Street Intersection (Looking Northwest)

- There is no railroad preemption for the traffic signal at Main Street and Tilden Street as the intersection is located approximately 470 feet from the crossing. Any westbound queues that have formed just prior to activation of the warning devices are dissipated through normal signal operations. For the scenarios that were simulated, the maximum queue length was 250 feet, or roughly half the distance between the intersection and the crossing.

5.2.6 Train Crossing Events

There were 16 crossings during the 48-hour data collection period. One of those was not a train, but instead a railroad maintenance truck traveling along the tracks, briefly interrupting traffic flow at the crossing. During the periods selected for simulation, there were four crossings on April 20 and three on April 21. For all crossing events, the average interruption to traffic was slightly over 2 minutes, ranging from 0:39 to 4:24. Train crossing data for the Cotulla, TX, site are provided in Appendix C.

5.2.7 Model Calibration and Validation

Model calibration involves the adjustment of parameters in a simulation model to improve its ability to reflect what has been observed in the field. Typically, this process is focused on performance measures related to 1) travel time or speed and 2) bottlenecks. The Cotulla study site is unique in that the model network is relatively small and focused in areas where traffic is stopped (i.e., the at-grade crossing and signalized intersection). Speeds over these network segments are relatively slow and highly variable due to the stop-and-go nature of the traffic, so

the calibration efforts were focused on queues at the crossing and critical movements at the Tilden Street/Main Street intersection.

At a macroscopic level for signalized intersections, saturation flow rate is defined as the equivalent hourly rate at which previously queued vehicles can traverse an intersection approach under prevailing conditions. The saturation flow rate is based on vehicular headway, which is the time between two successive vehicles as they pass a point on the roadway. The higher the saturation flow rate on an intersection approach, the greater the opportunity to serve the demand at an intersection and the higher the likelihood of minimizing queued vehicles.

Headway buffer is the microscopic traffic flow equivalent to macroscopic saturation flow in the TransModeler simulation software. It consists of a stopped gap between a following vehicle and the one in front plus an additional time (i.e., headway) buffer that a driver would employ to maintain additional spacing for reasons of safety or other considerations. This has an effect on residual queues that form during the red portion of a signal cycle. In small towns or rural areas, there is a lack of "traffic pressure" that can be seen in greater distances between vehicles as they approach an intersection. This can have an effect on the number of vehicles queued and the length of the queues. The HCM advises use of a saturation flow rate of 1,750 passenger cars per hour per lane for areas with a population less than 200,000. For the Cotulla simulation model, the headway buffer distribution in TransModeler was adjusted to reflect an equivalent macroscopic saturation flow rate of 1,750.

Vehicle classification mix is another parameter that can have an impact on traffic queues, particularly the proportion of heavy trucks and school buses. Vehicle classification counts at this location reflected a higher proportion of heavy trucks than the default distribution in TransModeler, so the distribution was modified to reflect the percentages computed from the traffic count data collected. Furthermore, a vehicle category for mini school buses (20 to 25 feet long) was introduced in the simulation model, which could also impact queue lengths (see Section 5.2.4).

Finally, traffic counts revealed that there were no heavy trucks on certain street segments – namely Front Street north and south of Tilden Street and the segment of Tilden Street west of Main Street. Traffic distributions at these entry/exit points to the network were adjusted to eliminate heavy trucks.

For model validation purposes, queueing data were collected at the Tilden Street/Main Street intersection and at the grade crossing. For the analysis periods, the queues observed in the field were compared to the simulated queues resulting from TransModeler runs.

Due to the nature of the video data collection, it was not possible to determine queue lengths in feet, but the number of queued vehicles could be observed. Thus, comparisons between observed and simulated queues were in number of queued (i.e., stopped) vehicles.

During the periods that were simulated based on the data collected (3:15 p.m. to 5:30 p.m. on 4/20/2022 and 5:00 p.m. to 7:00 p.m. on 4/21/2022), there were a total of seven crossings (see Appendix A). In the Cotulla model, each observed train crossing was modeled explicitly. Because trains varied significantly in length (observed train lengths ranged from 2 to 169 cars), a custom vehicle class was created for each of the crossings so that the number of cars could be edited for each individual train. Train speed data were unavailable, but an estimated average train

speed of 43 mph produced simulated traffic interruption times that were a very close match to the observed data, as shown in Figure 19.

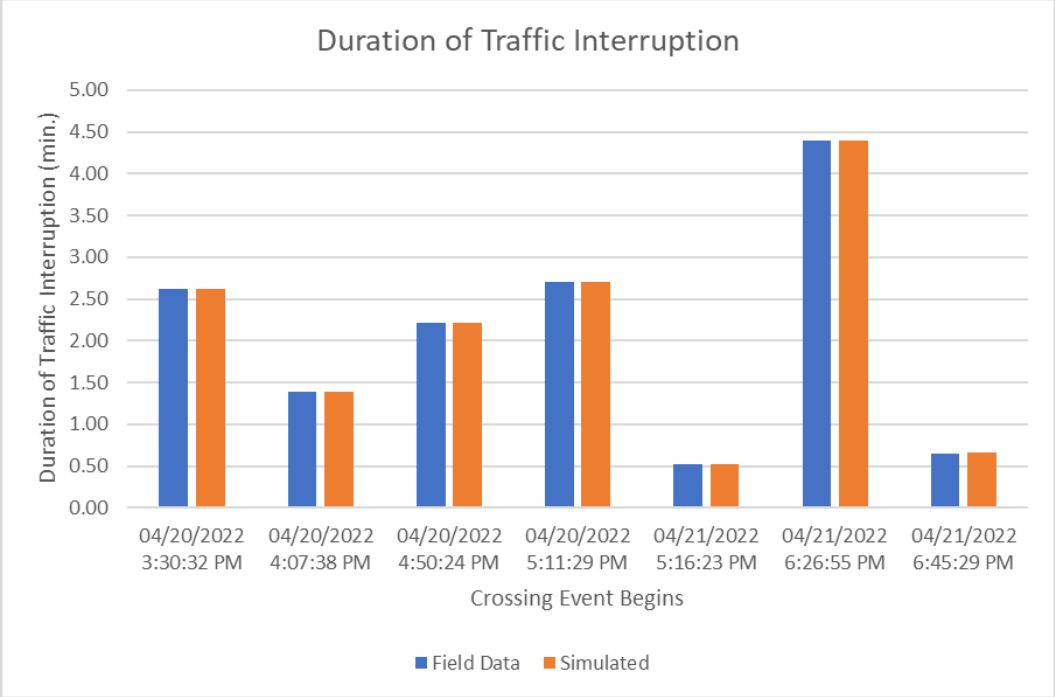


Figure 19. Duration of Traffic Interruption Due to Train Crossings – Cotulla, TX, Site

A comparison of observed queues from the video data with simulated queues from the TransModeler simulation software is provided in Table 7.

Table 7. Comparison of Observed vs. Simulated Maximum Queues at Tilden Street Grade Crossing Location

Time of Crossing	Eastbound		Westbound	
	Observed	Simulated	Observed	Simulated
4/20/2022				
3:30:32 p.m.	11	9	7	10
4:07:38 p.m.	7	4	6	5
4:50:24 p.m.	2	4	5	5
5:11:29 p.m.	6	6	15	8
4/21/2022				
5:16:23 p.m.	1	2	1	2
6:26:55 p.m.	7	6	10	9
6:45:29 p.m.	1	1	0	1

In most instances, the simulated number of vehicles in the queue at the end of the crossing event compared closely to the number observed in the field. For the one outlier (4/20/2022 at 5:11:29 p.m., westbound, 15 queued vehicles observed vs. 8 queued vehicles simulated), the difference can be attributed to a very brief spike in the observed flow that dissipated over the 15-minute interval for which these counts were summarized. Explaining this further, there was a very brief increase (i.e., "pulse") in the westbound traffic flow just prior to the crossing event. It is likely that this spike in traffic was attributable to multiple traffic generators to the east (Cotulla High School plus several industry sites) all generating traffic at the same time. Traffic counts collected

at the site were summarized in 15-minute intervals and were input that way into the TransModeler simulation software. The spike within the 15-minute interval was not captured fully by the simulation and resulted in a difference between the observed and simulated queue for this one event. It is important to note that aggregating traffic demand from counts in 15-minute intervals is considered to be the optimum level of "granularity" for traffic simulation studies. Larger intervals (e.g., one hour) are insensitive to the peaks that may occur within the interval. Intervals smaller than 15 minutes are more accurate but are cumbersome to manage and labor intensive.

Queues also were compared for two lane groups at the Tilden Street/Main Street intersection that were deemed to be most important to this particular application – the westbound approach, which is a single lane serving all movements, and the southbound through/left-turn lane. These are highlighted in Figure 20.

Figure 20. Key Lane Groups for Queue Comparisons

The number of queued vehicles at the beginning of each green phase for each of the two approaches was recorded from the video data collected on-site. The study periods were disaggregated into 15-minute intervals and the maximum observed queue for each interval was noted. These are compared to simulated corresponding maximum queues for the same 15-minute intervals. The comparisons are shown in Table 8.

Table 8. Comparison of Observed vs. Simulated Maximum Queues at Tilden Street/Main Street

Interval Beginning	SB Left Turn		WB LT/TH/RT	
	Observed	Simulated	Observed	Simulated
4/20/2022				
3:15 p.m.	4	2	5	2
3:30 p.m.	4	6	4	4
3:45 p.m.	4	3	9	6
4:00 p.m.	3	3	5	7
4:15 p.m.	4	2	4	3
4:30 p.m.	2	3	4	4
4:45 p.m.	2	4	5	2
5:00 p.m.	5	2	6	4
5:15 p.m.	3	3	7	7
4/21/2022				
5:00 p.m.	5	2	3	3
5:15 p.m.	3	3	4	5
5:30 p.m.	3	2	3	3
5:45 p.m.	3	1	4	3
6:00 p.m.	4	1	3	3
6:15 p.m.	3	2	4	2
6:30 p.m.	2	1	2	4
6:45 p.m.	2	1	3	1

In most instances, the maximum difference between observed and simulated maximum queues was one or two vehicles; there were three occasions where the difference was three vehicles. Given the relatively low volumes, the inherent randomness of simulation, and considering the uniqueness of the protected/permitted left turn phasing for the southbound shared lane approach, this simulation model was deemed to provide a reasonable replication of observed traffic operations at this intersection.

5.2.8 Applications

While the Cotulla, TX, site simulation model was developed for illustrative purposes, there are several potential applications for which this model could be used. These are described below.

- The simulation model that was developed was based on weekday afternoon traffic conditions. While this period may reflect the highest regularly occurring traffic volumes, there may be special events that generate even higher volumes, if only for a brief period. For example, the Cotulla High School campus lies just east of this crossing. Friday night football game traffic may be of concern with respect to traffic queues along Tilden Street between the crossing and Main Street in the event of a train passing through at that time.
- The Texas Department of Transportation is considering queue cutter signals at certain sites throughout the state. This site is one of those being considered; specifically, a potential queue cutter signal along westbound Tilden Street in advance of the crossing. This model could be used to identify growth scenarios and resulting queue lengths along Tilden Street for which a queue cutter signal might be warranted.
- Currently there is no signal preemption for the Tilden Street/Main Street intersection, as the distance between the crossing and that intersection is greater than the recommended

200 feet. However, there may be future situations or growth scenarios where this might need to be considered, based on queues.

- Roughly 10 percent of the traffic mix consists of single unit and heavy trucks. Combined with school buses and large pickup trucks pulling trailers, it is estimated that 15 to 20 percent of the vehicles are longer than standard passenger cars and pickups. Any growth in the immediate area, particularly new industry or businesses generating truck traffic, could result in increased traffic along SH 97/Tilden Street that would increase queues.

5.3 Visualization Through Simulation Graphics

Apart from providing numerous analytical performance measures to evaluate traffic operations during crossing events, microsimulation models provide the added benefit of visualization through animation of the simulation in both 2D and 3D formats. These pictures are of great value in helping to "tell the story" that numbers alone cannot. Some examples are included in Appendix D, where the GIS functionality of TransModeler is used to highlight signal preemption state (Figure D-1), control delay (Figure D-2), vehicle classification (Figure D-3), and vehicle speeds (Figure D-4) during simulated crossing events at the La Grange, IL, and Cotulla, TX, sites.

6. Simulation Framework

This framework contains recommended items and factors that should be considered when performing a traffic operations analysis of a highway-rail grade crossing event. While not entirely comprehensive, the framework identifies the questions to be answered and the information needed to simulate common crossing events and from which traffic operations assessments can be made.

6.1 Site Identification and Study Area Delineation

It is good practice to provide the reasoning for a particular site being selected for analysis. Are current traffic conditions such that disruptions caused by crossing events result in long backups and high delays on the approaches? Are there concerns about future traffic growth at a location and the resulting traffic impacts? In the latter case, traffic simulation becomes a scenario planning tool enabling analysts and decision makers to answer the "What," "When," and "What if" questions. For example, the proximity of an adjacent signalized intersection may be such that advance preemption is not needed for current traffic conditions, but future growth may necessitate consideration of advance preemption and/or other traffic control measures, such as queue cutter signals.

Information about the crossing itself is needed, including the number of tracks, train types (e.g., freight, commuter heavy rail, light rail) and train frequencies. Multiple track crossings, especially in urban areas, accommodate both freight and passenger trains. If the tracks accommodate passenger trains, is there a nearby station or platform that impacts the crossing? Impacts associated with nearby stations could include extended crossing times and the resulting traffic blockages along with increased pedestrian activity near the crossing.

Train frequency and duration of crossing are also factors to consider. Particularly in urban areas with high train volumes, crossing events may occur frequently during peak traffic periods, exacerbating traffic delays and backups. At multiple track locations, it is possible to have two trains occupying the crossing at the same time, creating a prolonged disruption. The simulation tool should have the functionality to model this occurrence.

Area type is an important consideration. Is the crossing in a rural, suburban, or urban area? These areas have distinctly different characteristics that must be considered.

Rural crossings are characteristically occupied by freight trains that may have train crossing speeds of 50 mph or more. Pedestrian activity is commonly very light. Trucks (including those hauling hazardous materials) and buses may form a significant contribution to the overall vehicle mix. Both trucks hauling hazardous materials and school buses are required by law to stop before proceeding across railroad tracks. With respect to time frame, peak traffic periods are typically confined to one hour or less in the morning and again in the afternoon.

Crossings in urban or suburban areas are typically quite different. These locations are more likely to include multiple tracks that serve both freight and passenger rail. Where there is a passenger station nearby, stopped train cars may actually extend into or across the roadway at the crossing. Trucks carrying hazardous materials may be prohibited from using these crossings, and fewer vehicle types may be required to stop before crossing the tracks. Public transit buses, which may not be required to stop at the crossing, could make up a significant portion of the

traffic stream. Peak traffic periods typically extend longer than one hour and can include a midday peak along with "traditional" a.m. and p.m. peaks.

In urban areas, transit bus activity may be a factor. Are there bus stops along the route? Are the stops in the traffic lane or are there pull-off bus bays? This activity should be included in the simulation of traffic operations.

The size of the study area is important. While safety analyses are typically focused on the grade crossing itself, traffic operations analyses must include the roadway network approaching the crossing and those streets impacted by backups and delays on the approaches.

In determining the size of the study area around the crossing, the proximity of signalized intersections that could affect the crossing should be considered. Current guidance says that if the distance between a highway signalized intersection and a grade crossing is less than 200 feet, the likelihood of a queue extending across the tracks must be determined. Actual conditions and traffic demands may increase this distance beyond 200 feet. Field observations and conversations with local officials are very helpful in determining the extent to which nearby intersections are impacted by train crossings and should be part of the study area.

For any modeling project and especially for an at-grade crossing that is to be modeled, a field site review should be performed. Even with the presence of online mapping, satellite imagery and virtual "drive-through," a field review should be conducted for the following reasons:

1. To verify other data and supporting facts that have been obtained
2. To note anything that has changed since data and other supporting facts have been obtained
3. To obtain a sense or "feel" of traffic conditions and operations at a grade crossing site, especially during actual crossings

The review should include photographic documentation along with needed sketches or diagrams, notes, etc.

Summary Items

- Reasoning for site selection
- Crossing information: number of tracks, train types, train frequency, duration of traffic interruption, presence of stations/platforms
- Area type: rural, suburban, urban
- Study area limits including streets impacted by backups and delays associated with the train crossing and any diversion, as well as proximate signalized intersections
- Field site review

6.2 Network

Accurately modeling a grade crossing event begins with developing an accurate model of the street and highway network to be evaluated. Information that will be needed to develop the network includes:

- Roadway type(s) and functional classification

- Roadway geometry – number of lanes, lane widths, grade/profile, horizontal curvature
- Posted speed limits
- Intersection geometry – lane use, lane restrictions, turn lane/storage bay lengths and taper rates
- Pedestrian crosswalks – at intersections and mid-block locations
- Bike lanes
- On-street parking areas
- Number and width of railroad tracks and direction of train traffic

For roadway segments, simulation tools typically use highway functional class to estimate other traffic flow parameters, namely average free-flow speed and lane capacity or base saturation flow rates.

Roadway grades impact speeds for vehicles approaching a crossing. This effect can be significant for trucks, both in deceleration as a truck approaches the crossing and in acceleration to clear the crossing. Vertical profile information for those affected links should be included in the simulation model network. At some locations, particularly in rural areas, the track is raised at the crossing, which has the effect of a "speed hump" for vehicles passing over the tracks.

At intersections, it is important to correctly model not only the number of lanes and lane use on approaches but also the length of turn lanes, as they provide storage for queued traffic. The taper area at the upstream end of a turn lane, where the turn lane begins before it reaches its full width, can offer additional storage for one or two vehicles. This should be noted when performing a site inspection. In urban areas with streets running parallel to railroad tracks, there may be turning movement restrictions at intersections that include at-grade crossings.

In urbanized areas, the presence of pedestrian crosswalks and bicycle lanes should be noted and included in the network. Pedestrian crosswalks may be located at intersections or mid-block. With regard to pedestrian crossings at mid-block locations, state laws and local ordinances may vary on how and when motorists must yield to pedestrians. These should be consulted and verified as part of the site review.

Summary Items

- ☐ Roadway type(s) and functional classification
- ☐ Roadway geometry – number of lanes, lane widths, grade/profile, horizontal curvature
- ☐ Posted speed limits
- ☐ Intersection geometry – lane use, lane restrictions, turn lane/storage bay lengths, and taper rates
- ☐ Pedestrian crosswalks – at intersections and mid-block locations
- ☐ Bike lanes
- ☐ On-street parking areas
- ☐ Number and width of railroad tracks and direction of train traffic

6.3 Highway Traffic Control

Traffic operations on surface streets are highly dependent on traffic control, such as traffic signals, stop signs, and yield signs. Where there are signalized intersections in the study area, simulation tools must accurately replicate the operation of these signals, whether they operate as pre-timed or actuated. If actuated, the signal control must include detectors or sensors that pass detection information to the controller. When part of a coordinated system, whether pre-timed or actuated, the simulation model must include the coordination parameters (e.g., background cycle length, offset, reference point, etc.). Some arterial systems may use volume-density operations, so the simulation software should include those parameters as well.

Urbanized area signals typically operate under different timing plans tailored for specific times of day. Simulation and analysis of a grade crossing location may span a period where two or more timing plans are involved. Actual signals in the field transition from one timing plan to another when this is the case, and there are various approaches to accomplish this transition. Simulation software should be capable of replicating this transition and consultation with the operating agency should be involved to determine how timing plans are transitioned.

Preemption at signals adjacent to the rail crossing is necessary when it has been determined that the proximity between the grade crossing and an adjacent intersection is close enough that there exists the potential for queues at the signalized intersection to extend onto the crossing. The preemption plan should include one or more phasing sequences designed to clear the adjacent intersection of vehicles and pedestrians and to discharge any queue that may extend from the intersection downstream of the crossing back to the crossing. When a train approaches a crossing, the railroad traffic control system notifies the appropriate highway traffic signal controller(s) to initiate the preemption plan.

Preemption can be simultaneous or advanced. This has to do with when information about an approaching train is relayed to highway traffic signals so that preemption plans to clear those adjacent intersections can be initiated. When there is simultaneous preemption, notification of approaching rail traffic is forwarded to the highway traffic signal controller unit and railroad or light rail active warning devices at the same time. For advance preemption, notification of approaching rail traffic is forwarded to the highway traffic signal controller unit and railroad or light rail active warning devices in advance of the activation of these devices.

The simulation model should also accurately replicate right-turn-on-red movements at signalized intersections, as well as movements that are prohibited or restricted (e.g., left turns). Stop- and yield-controlled movements may be present at some locations within the network, particularly side streets that connect to the street on which the grade crossing is located.

Summary Items

- Traffic signal timings
  - Pretimed or actuated
  - Sensors, if actuated
  - Coordination parameters, if applicable
  - Volume-density operations parameters, if applicable
  - Time-of-day operations including transition type, if applicable
  - Preemption settings

- Right turn on red (RTOR) settings and other restricted movements

- Stop and yield signs

6.4 Grade Crossing Traffic Control

Grade crossing traffic control can be either active (e.g., flashing lights, bells, gates) or passive (e.g., signs and pavement markings). Regardless, it is defined as the interruption to highway traffic as a result of a crossing event that is being modeled using simulation tools.

Where a crossing is located close to a highway intersection, pre-signals may exist as a queue management strategy. Pre-signals are traffic signal control faces located in advance of a crossing that are part of the intersection control. A pre-signal is a primary signal and not a supplemental signal. Pre-signals are a type of queue management strategy, and there may be times when a pre-signal display is red while a downstream signal is green as the process to clear a queue is underway. These must be modeled correctly in simulation, including the location of detectors associated with the signals.

Queue management strategies can also include queue-cutter signals. Queue-cutter signals are different from pre-signals in that they operate independently from intersection signals and are located farther away from the crossing, typically 450 – 500 feet. As the name suggests, the purpose of a queue-cutter signal is to "cut the queue" in advance of a crossing so that drivers approaching a crossing are not joining the back of a queue propagating from a downstream intersection while on the tracks.

Simulation of traffic operations where pre-signals and queue-cutter signals are involved provides a valuable scenario planning tool, especially for those locations where queue management strategies are not needed at present but may be necessary at some point in the future. Operation of pre-signals and queue-cutter signals should be coordinated with the responsible agencies.

Other rules that may impact traffic flow at grade crossing should be included in the simulation model. For example, vehicular restrictions that require school buses and trucks hauling hazardous materials to stop before proceeding through a crossing should be simulated.

Summary Items

- Type of grade crossing control

- Presence of pre-signals or queue-cutter signals

- Vehicle types that must stop at the rail crossing

6.5 Demand

It is important to distinguish between traffic counts and demand. Traffic counts are observations of traffic volumes in the field, either manually or by automated means. Demand is the quantification of the desire to travel over a roadway segment or through an intersection. When conditions on a facility are not congested, traffic counts will be the same as the demand (i.e., all the demand to travel on a facility is served). When conditions are congested, the demand to travel on a facility has exceeded the facility's capacity, and conditions are said to be oversaturated. Oversaturated conditions are characterized by longer backups (i.e., queues) at intersections and higher delays. Train crossing events during these periods of congestion serve to exacerbate the conditions.

An accurate traffic analysis of any type would evaluate operations using demand to properly reflect any congestion that builds up in the study area. Traffic counts usually are the basis for quantifying the demand, but when conditions are oversaturated, only the maximum flow rate can be counted. The additional incremental demand that is not served (and therefore not counted) must be estimated. Indeed, if the demand is not correctly estimated, intersection approach queues resulting from the simulation will be smaller than queues observed in the field. There are various methods for estimating travel demand from traffic counts when conditions are oversaturated. This framework does not identify and discuss those methods; rather, it highlights the importance of using demand in comparison to observed traffic volumes. Again, when conditions are undersaturated, observed traffic volumes (i.e., counts) and demand are the same.

Having distinguished between traffic counts and demand, traffic counts are then used to calibrate traffic simulation models. The analyst should determine the duration of the analysis period(s) and the time frame for which traffic counts should be obtained.

Traffic volumes vary over time, generally having a.m. and p.m. peaks. Even within the same hour, the rate of flow often varies. As inputs to simulation models, traffic counts should be summarized at short intervals – 15 minutes is recommended – in order to reflect the variation in demand. For estimated demand when conditions are oversaturated or for future year travel forecasts, it is common to apply a distribution developed from existing counts to the estimated demand, assuming the variation within the period will be the same. An example of a distribution developed from traffic counts is shown in Figure 21.

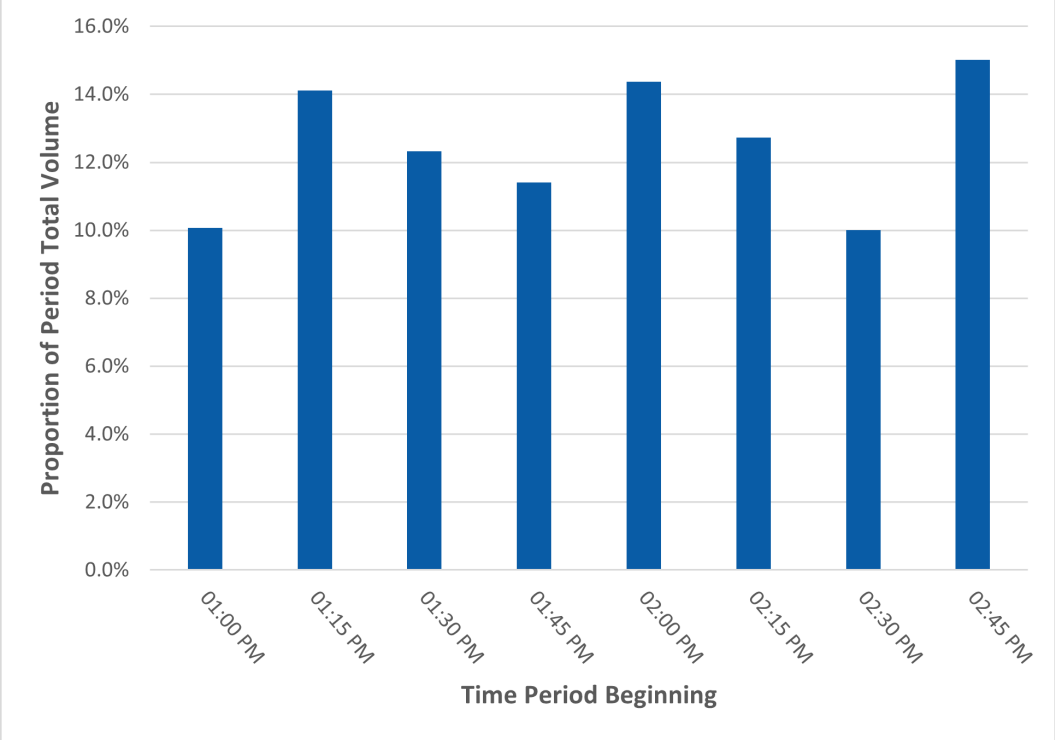


Figure 21. Temporal Distribution from Traffic Counts

Traffic counts must include vehicle classifications (e.g., autos and pickups, medium trucks, heavy trucks, buses, motorcycles, etc.). The distribution of various vehicle types based on field data must be included in the simulation model. This is particularly important due to the length

and operational characteristics of trucks and buses, which can have significant impacts on queues.

Analysts should differentiate between transit buses and school buses. School buses may vary in length, depending on the location and the types of schools they serve, and school bus drivers are required to stop in advance of grade crossings before proceeding. Transit buses may not stop at grade crossings, but may stop upstream or downstream of those sites to service passengers. These characteristics should be verified by field review.

Depending on site characteristics, traffic makeup, and the simulation tool being used, it may be necessary to create additional vehicle types with their own unique performance characteristics. Those performance characteristics can include size, mass (i.e., weight), mass-to-power ratio (important for trucks), maximum acceleration and deceleration rates, and maximum speed. The analyst should consult the simulation software manual for further instruction on how to add or modify vehicle classes.

The vehicle class distribution may vary in different parts of the network. Depending on the site being evaluated, steps may be necessary to restrict certain vehicle types from particular parts of the network. The various simulation tools accomplish this in different ways and the analyst will need to consult the documentation of the tool being used.

Auto demand is typically input into simulation tools in one of two ways: as intersection turning movements or in an origin-destination matrix. Each way has advantages and disadvantages.

Intersection turning movement counts are straightforward and traffic count data are commonly obtained in this manner, as seen in Figure 22.

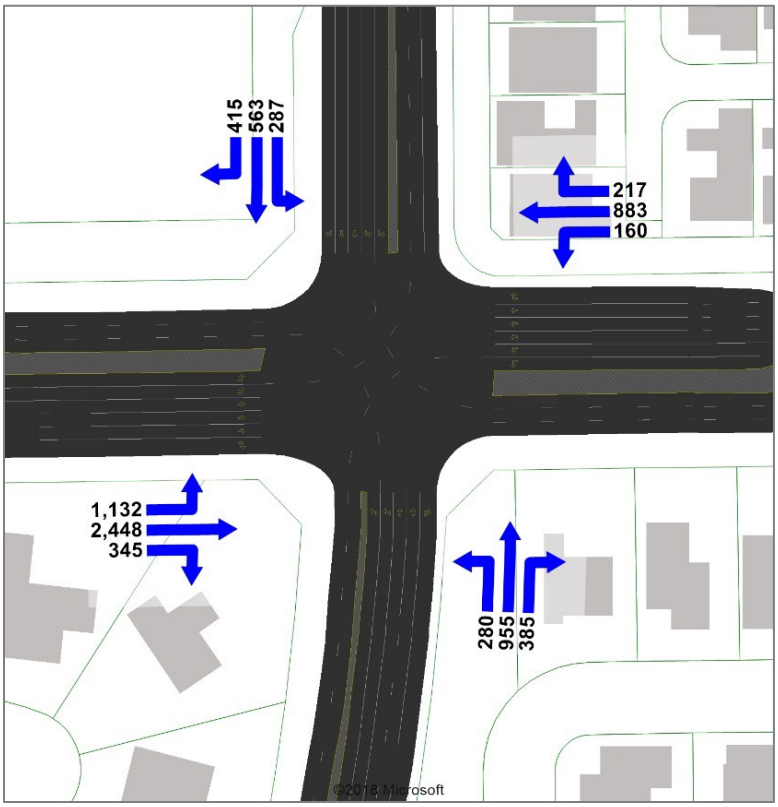
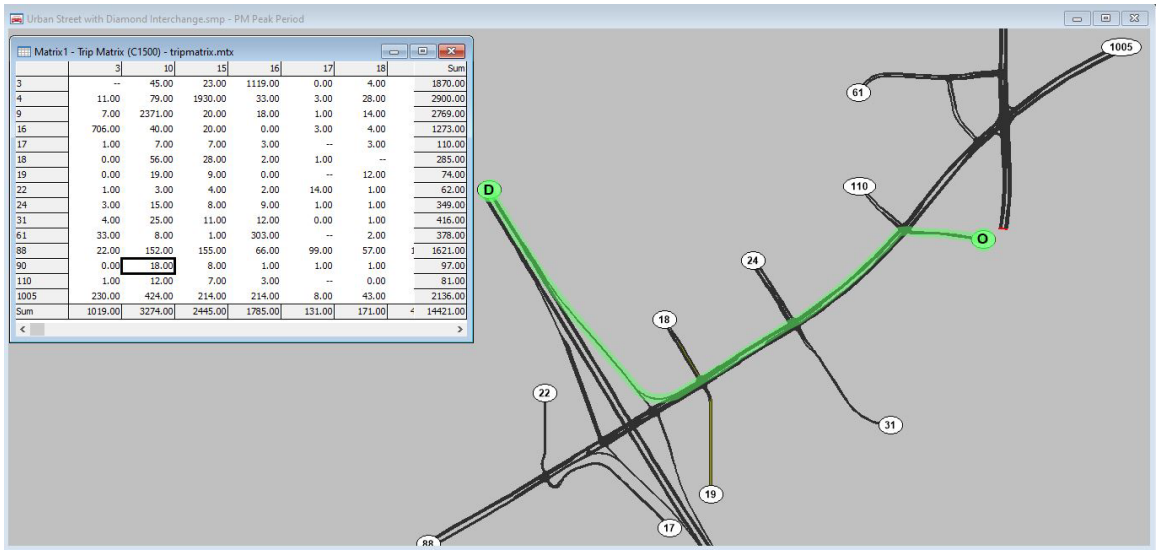


Figure 22. Intersection Turning Volumes

While deterministic methods quantify demand at intervals of one hour or 15 minutes, simulation tools can quantify demand at smaller intervals. A tighter demand characterization generally improves the simulation. The major disadvantage to this method is that turning movement data do not inherently have any path information; they only provide the number of turns at a specific intersection. They do not provide information on the origin or destination of those vehicles, and thus the path they took on their trip.

When using turning movement data, if the volumes are not balanced between adjacent intersections (i.e., the sum of departure volumes at one intersection is not equal to the total arrival volumes at an adjacent intersection), the analyst should investigate how to handle the imbalance. Imbalances occur because vehicular ingress and egress movements at driveways along the connecting segments typically are ignored. Also, some vehicles that pass through one intersection do not reach the adjacent intersection by the time counting is finished. Finally, there can be data collection errors. Various simulation tools deal with these imbalances in different ways; the analyst should consult the documentation.

An alternative way to quantify the demand input is through an origin-destination (OD) matrix (see Figure 23). This is a table that summarizes trip volumes between all potential origins and destinations in the network. For larger networks, an OD matrix has many benefits including resulting in more reasonable paths. If such a flow matrix can be constructed from observed trips, the process is straightforward. However, if origin/destination field data are not available, additional steps are needed to estimate an OD matrix from turning movements. Additionally, when more than one potential path exists between any OD pair, the simulation tool must be capable of routing those trips properly. Referred to as traffic assignment, this also requires additional analysis steps. The analyst should have a good understanding of OD matrix estimation methods and traffic assignment if this approach is used.



	3	10	15	16	17	18	Sum
3	--	45.00	23.00	1119.00	0.00	4.00	1870.00
4	11.00	79.00	1930.00	33.00	3.00	28.00	2900.00
9	7.00	2371.00	20.00	18.00	1.00	14.00	2769.00
16	706.00	40.00	20.00	0.00	3.00	4.00	1273.00
17	1.00	7.00	7.00	3.00	--	3.00	110.00
18	0.00	56.00	28.00	2.00	1.00	--	285.00
19	0.00	19.00	9.00	0.00	--	12.00	74.00
22	1.00	3.00	4.00	2.00	14.00	1.00	62.00
24	3.00	15.00	8.00	9.00	1.00	1.00	349.00
31	4.00	25.00	11.00	12.00	0.00	1.00	416.00
61	33.00	8.00	1.00	303.00	--	2.00	378.00
88	22.00	152.00	155.00	66.00	99.00	57.00	1621.00
90	0.00	18.00	8.00	1.00	1.00	1.00	97.00
110	1.00	12.00	7.00	3.00	--	0.00	81.00
1005	230.00	424.00	214.00	214.00	8.00	43.00	2136.00
Sum	1019.00	3274.00	2445.00	1785.00	131.00	171.00	14421.00

Figure 23. Origin-Destination Matrix

Pedestrian demand at both intersection crosswalks and at mid-block crossings should also be included. These volumes should be summed in the same time intervals as the vehicular volumes. Similarly, vehicular volumes should include bicycles and motorcycles if they are included in the traffic stream.

Bus transit demand should be included in the model. If the study site includes bus transit stops, information should be obtained to simulate the impacts on traffic operations correctly. Some simulation tools only allow for an average stopped time for buses, while other tools include a mean, standard deviation, and distribution of stopped times.

Train crossing demand is clearly a critical component to be simulated. Is the crossing a single event during the analysis period or are there multiple crossings? Is the train a passenger train with a station nearby such that a stopped train occupies the crossing? The duration of the event during which traffic is stopped and whether the train is stopped or moving through the crossing, are also critical inputs. The most likely simulation scenario will be for existing train crossings, so it is important to obtain data on crossing events that include the time that traffic flow stops (i.e., gates blocking the roadway) and the time that it resumes. Where there is signal preemption, actuation of grade crossing warning devices will initiate preemption phases at nearby intersections.

Other attributes may be helpful in animating the crossing event (e.g., direction of train travel, speed through the crossing, etc.) but the interruption to traffic flow is the most important parameter to be quantified. Data should be collected for each train crossing separately. When modeling existing conditions, ideally each crossing would be modeled specifically in order to replicate field-collected delays and queues more faithfully. If that is not possible, a mean interruption time and standard deviation can be computed to model the crossing as a probability distribution. If the latter approach is taken, the simulated results should be compared with observed crossing events as part of the model calibration. This would include the possibility of multiple trains occupying the crossing at the same time where there are two or more tracks.

Summary Items

- Traffic counts vs. demand
- Determine the duration of the analysis period and time frame to collect traffic data
- Collect data in short intervals (e.g., 15 minutes) to reflect changes in demand over time
- Collect vehicle classification data, including differentiating between school buses and transit buses, because some may need to stop at rail crossings and others may stop at bus stops
- Vehicle classification may vary in different parts of the network
- Demand can be shown as turning movement data or O-D matrices. Counts are typically collected as turning movement counts, which do not contain any path information. O-D matrices can be synthesized using origin-destination matrix estimation (ODME).
- When using turning movement counts, assess how to handle unbalanced counts
- Collect pedestrian demand both at intersections and mid-block
- Collect bus transit demand and note presence and operation of bus stops
- Collect train crossing demand with a focus on how long traffic is interrupted during a crossing event; other information that should be collected include direction of train travel, train speed, time traffic flow stops, time traffic resumes, and how often two trains arrive during the same event

6.6 Traffic Diversion

Some at-grade crossings are located such that another grade-separated crossing may be relatively close. This is particularly true in urban areas with dense street networks, as in the La Grange, IL, site, where a grade-separated crossing with US 34 (Ogden Avenue) lies just to the east of the simulation study site. In some situations, drivers could alter their intended routes and divert to grade-separated crossings to avoid delays at the at-grade crossing. While this diverted trip may result in a longer distance traveled, drivers may perceive not having to wait in queue during the crossing event as more desirable.

There are three kinds of diversionary actions that a driver can take to avoid crossing delay:

1. Before the trip even begins, choose a different route based on prior experience of departing at that time
2. Depart a little earlier or later to minimize the probability of being stopped at the crossing
3. See a train (or the back of a queue strongly suggesting a train) on the approach and choose to turn off the corridor and reroute

Accounting for advance diversion in Action #1 requires running Dynamic Traffic Assignment (DTA), which produces time-varying congested travel times that drivers can use to evaluate their route choice. In other words, if a train causes traffic delays every day at 8:00 a.m., a driver likely would choose a different route if they were going to encounter the 8:00 a.m. delays, assuming another route exists that would take less time. To accurately capture this route choice behavior, a good DTA tool needs a well-known, consistent train schedule for which the delays are predictable and a small enough analysis time resolution (e.g., 5-minute intervals) to get a proper accounting of the impacts. In a larger window (e.g., 15 minutes), the effects of a smaller interruption may be substantially diluted. However, even if the train schedule was consistent, it is doubtful that most drivers' perceptions would be so well-tuned to train crossings, which only last minutes and probably shift from one 5-minute window to the next on any given day. Thus, Action #1 would not generally be applicable to most at-grade crossing analyses.

Action #2 is also not likely to be applicable to most at-grade crossing analyses because the assumed time shift would be small. The analyst would need to obtain driver trip survey data over multiple days to quantify the trip profiles associated with Action #2. Moreover, for the sake of analysis, the impacts from this action can be assumed to be relatively small and therefore could be ignored.

Action #3 is the most likely applicable route diversion behavior that should be considered in modeling, should field observations confirm this behavior. While there is no known standard modeling methodology or tool to capture this type of diversion behavior, some simulation software packages have an application programming interface (API) that can invoke specially developed algorithms that model driver diversion decisions to model these effects. However, this would normally fall beyond the typical grade crossing simulation application.

In most cases, any diversion that might occur would be accounted for already in the traffic counts at the site, though the individual driver decisions about route choice would remain unknown. Diversion decisions will depend on several factors including the anticipated duration of the delay, availability of an alternate route choice, anticipated time savings (if any) from taking the alternate route, and trip purpose (e.g., peak time commute trip vs. off-peak shopping trip). When considering the effectiveness of potential operational and/or geometric

improvements, the analyst may need to consult other tools, such as regional planning models or "big data" (e.g., Global Positioning System (GPS) or location-based service origin-destination data) to assist in estimating diversion and change in travel demand at the at-grade crossing being evaluated.

Summary Items

- When a grade-separated crossing is nearby, some drivers may choose to divert to that grade-separated crossing to avoid at-grade crossing delays
- The most likely type of route choice diversion for at-grade rail crossings would occur when drivers see the train or the queue associated with the train crossing, rather than choosing a different route or departure time before the trip even begins
- Simulating this type of route choice diversion upon seeing the train or queue would likely require development of a custom diversion model implemented through a software package's API
- In most cases, modeling route diversion will not be necessary

6.7 Model Development, Calibration, and Application

While the building blocks of model development have been discussed in the previous sections, analysts and decision makers must keep in mind the need for the tool and the purpose for which it will be used. Are there congestion issues to be mitigated? Are queues such that they could potentially result in safety issues like track blockage? What would be the effectiveness of mitigation strategies such as queue-cutter signals? What would be the impacts of railroad preemption on congestion and queues at nearby intersections? Clearly identifying the objectives at the outset will better ensure the efficient development of the proper tool. This includes identifying the performance measures that will be used to quantify traffic conditions within the study area and evaluate mitigation or improvement strategies. These performance measures include but are not limited to:

- Traffic volumes or flow rates
- Queue length and/or overflow
- Delay
- Speed

This framework is not a comprehensive reference on the development of microscopic traffic simulation models and assumes the audience will have some level of familiarity and experience with their development and application. For a more comprehensive set of guidelines, the reader is directed to consult the Federal Highway Administration's *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software* [17].

Model calibration involves the verification of inputs and adjustment of model parameters to improve its ability to reproduce or replicate traffic conditions for the site being modeled. Each microsimulation program comes with its own set of user-adjustable parameters that allow the model to be calibrated to match local conditions. Thus, after verifying model inputs are correct, the objective is to identify those model parameters that best replicate observed measures of performance.

A final step in the calibration process is model validation, which compares measures of performance estimated by the model to observed measures. The user should focus on key performance measures for which quality observed data are available (e.g., traffic volumes, queue lengths, or roadway segment speeds). An example scatter plot comparing field traffic counts to estimated volumes from a traffic simulation model is shown in Figure 24. In a perfectly calibrated and validated model, the counts and model flows would be exactly the same; that is, all of the dots in the graph would fall directly on the diagonal line. A calibration statistic (Percent Root Mean Square Error, or %RMSE) is also shown.

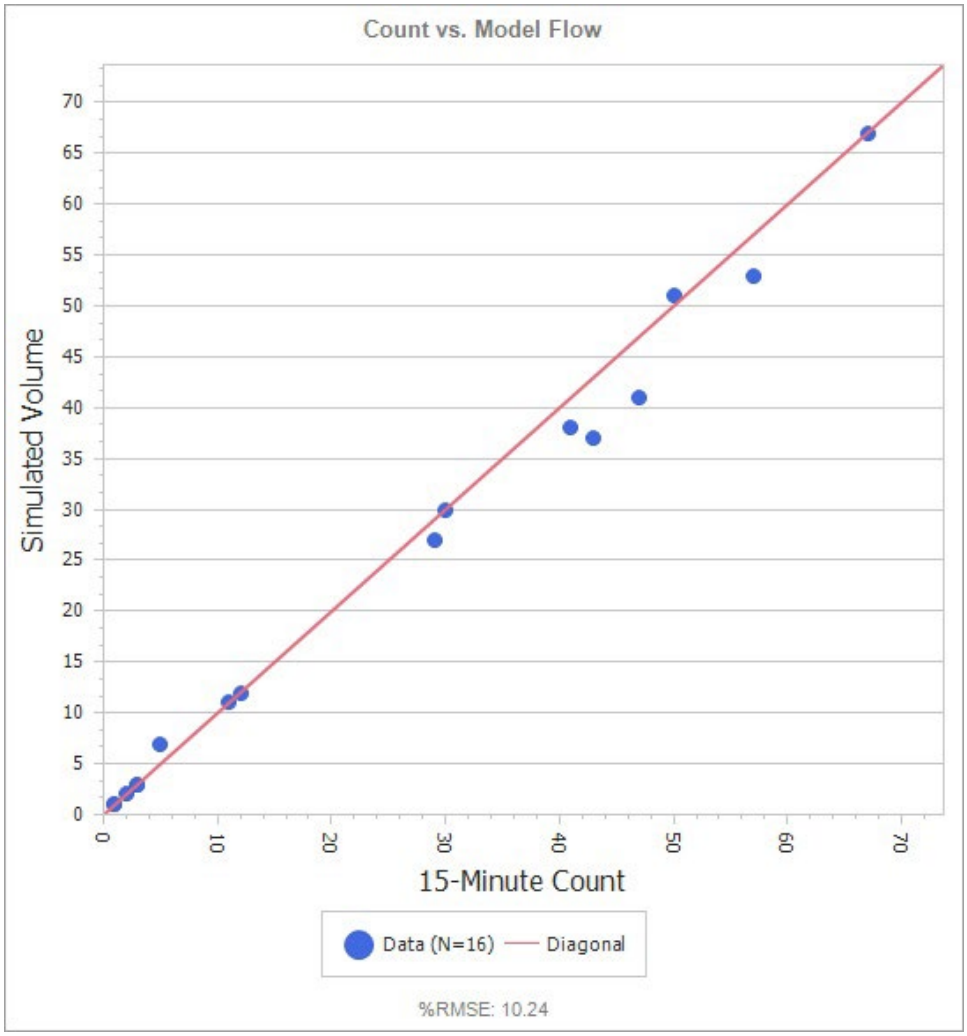


Figure 24. Example Scatter Plot Comparing Traffic Counts to Simulation Volumes

Detailed guidance for model calibration and validation is contained in the previously referenced toolbox.

Traffic simulation tools apply a variety of mathematical models of driver behavior and traffic flow theory to simulate traffic phenomena. They are stochastic in nature, meaning they use probability functions to predict random variables. This randomness is seen in the variation from one period (i.e., day) to the next, even when both are considered "typical." Thus, when applied in practice, multiple simulation model runs are made and descriptive statistics (e.g., average or mean, minimum/maximum, confidence intervals, etc.) are used to describe traffic conditions.

When applying a model to compare alternative treatments/strategies or to determine the effectiveness of a proposed treatment, this randomness must be considered by determining the required number of runs to satisfactorily assess statistical validity. Based on the desired tolerance and level of confidence for key performance measures, the required number of model runs needed to produce meaningful statistics can be determined. Performance measures of particular relevance to this framework are queue lengths and queue spillback (where the end of a queue extends beyond a turn lane, into a neighboring through lane), as well as delay. However, while queues can be measured easily in the field, vehicular delay is more difficult to "observe." More recently, third-party providers of location-based cell phone and GPS data are using algorithms to estimate vehicular delay from these "big data" sources.

Summary Items

- Clearly identify study objectives at the outset for efficient development of the model
- Identify performance measures (e.g., traffic volumes, queue length, queue overflow, delay, speed)
- Verify inputs, adjust model parameters, and validate the model (this process may be iterative)
- Identify the number of runs needed for statistical validity

6.8 Framework Summary

Due to the brevity of highway-rail grade crossing events, deterministic tools are incapable of accurately quantifying resultant traffic operational impacts like delays and queues. This is primarily because deterministic methods assume variables like traffic flow to be homogeneous over time periods longer than the crossing itself. Microscopic traffic models, however, simulate traffic flow for individual vehicles over much smaller time periods, making them the best choice for analyzing traffic backups, delays, emissions, and other impacts when traffic flow is interrupted because of a train crossing.

This framework was developed with the understanding that the reader has a basic understanding of microscopic traffic simulation models – their development, calibration and validation, and application. While there are several commercially available and open source simulation software platforms in use today, this framework is "software agnostic" in that it is focused on what should be done when simulating a crossing site and not how it should be done using a specific software package.

While crossing sites have been evaluated using simulation in the past, there has been no established guidance on how this should be done, what factors should be considered that make grade crossings unique, and how these should be incorporated within a simulation modeling environment.

Finally, although accident rates are usually the most important factor used to evaluate grade crossings, it should be pointed out that predictive safety tools depend on proper measures of exposure (i.e., traffic flow). More detailed and accurate characterization of flow rates by time of day, with the confluence of train crossings, provides a better assessment of impacts and will provide better benefit-cost analyses of possible improvements. Furthermore, detailed mapping of grade crossings through simulation may reveal otherwise hidden factors that impact safety and road performance.

7. Conclusion

There are approximately 126,700 highway-rail at-grade crossings in the United States. A portion of those involve high-volume public streets where crossing events result in measurable traffic backups and delays for which mitigation efforts are needed. While much attention has been given to the safety aspect of these crossings, little guidance is available for evaluating the traffic operational impacts at these locations so that mitigation measures can be developed.

Conventional traffic analysis methods, such as those detailed in the *Highway Capacity Manual,* are limited at best in their ability to quantify the impacts of traffic interruptions due to a train crossing. This is especially true when a crossing is not isolated, but instead is located along an urban street where traffic backups extend into adjacent intersections and onto side streets. Alternatively, microscopic traffic simulation methods are capable of analyzing these events and simulation software has been a part of the practitioner's toolbox for 30 years. However, there has been no technical guidance or consistency on how these tools should be applied to evaluate crossing events. The team performed a literature review that bears this out.

The project objective was to perform case studies that were then used to create a recommended framework for developing simulation models that can be used to evaluate the traffic impacts of highway-rail grade crossings. In August 2021, FRA contracted with Caliper Corporation to perform case studies to illustrate how microscopic traffic simulation tools can be used to evaluate traffic conditions resulting from a train crossing at an at-grade location. As this study has national implications, Caliper selected sites in two different states – Illinois and Texas – in order to be more representative of crossings located throughout the United States for which the results and conclusions of this research might apply. Caliper then worked with stakeholders and identified physical study sites later in 2021. The team chose an urban site in the Chicago suburb of La Grange and a rural site in the small town of Cotulla, Texas. For these sites, the Caliper team collected the data and simulated the sites in the spring and summer of 2022. The study concluded in September, 2022.

Together, these two sites included a wide array of factors necessary to model and evaluate at-grade crossings properly. Those factors included traffic signal preemption, vehicle fleet mix, train types (i.e., freight and passenger) and number of tracks in the crossing, commuter train stations in the vicinity, pedestrian activity, roadway geometry, vehicles required to stop at crossings (e.g., school buses and trucks hauling hazardous materials), duration of traffic interruption, traffic speeds, and route diversion.

This report documents the development of simulation models for those two sites, along with the calibration and validation of those models. From these efforts, a recommended framework has been developed that can be used by practitioners and decision makers for performing traffic operations analyses of at-grade crossings. This framework is presented in Section 6. It offers guidance for a consistent approach to the development and application of such models.

8. References

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[17] Wunderlich, K.E., Vasudevan, M., & Wang, P. (April 2019). *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software, 2019 Update to the 2004 Version* (Report No. FHWA-HOP-18-036). Federal Highway Administration.

Appendix A.
Stakeholder Meeting Summaries

Illinois Site Coordination Meeting Summary
February 28, 2022
Participants:

Brian Vercruysse, Illinois Commerce Commission
Stephen Laffey, Illinois Commerce Commission
Stanley Milewski, Illinois Commerce Commission
Christopher Murauski, Illinois Commerce Commission
Aaron Toliver, Illinois Commerce Commission
Adrian Dominguez, Illinois Commerce Commission
Karen McClure, Federal Railroad Administration
Howard Slavin, Caliper Corporation
Tom Creasey, Caliper Corporation

Discussion Items

Tom Creasey reviewed the background for the study, the objectives, project scope of work, desirable study site characteristics, and anticipated data collection items. Those are contained in the presentation slides attached to this meeting summary. Tom explained that microscopic traffic simulation software (Caliper's TransModeler software) will be used to demonstrate how this should be done in a couple of case studies and from those, a recommended framework for simulating a train crossing event and the resulting traffic impacts will be developed.

Tom explained that the study scope of work is to simulate two sites – one in Illinois and one in Texas. In the event there are additional funds or that a simulation cannot be performed at the preferred site, an alternate site will be selected in each state. Thus, for the purpose of this meeting, input is to be obtained for the ultimate purpose of selecting a preferred site and a backup or alternate site.

Earlier in the study, Caliper had developed a list of desirable study site characteristics. These include but are not limited to:

- Urban or Suburban Location (need to have traffic signal control nearby)
- Multiple daily crossings
- Variable train crossing speeds
- Multiple tracks
- Freight and passenger rail (not a necessity, but would be nice for at least one site)
- Closely spaced adjacent intersections
- Signal preemption – Simultaneous or Advance
- Pre-signal and/or queue cutter signal
- Cross-street AADT 5,000 or greater
- Significant truck volumes as part of the crossing street traffic

The characteristics are to be used as a guide in selecting site. Tom expressed his appreciation to Brian and the ICC members for compiling the list of candidate sites that Caliper has been reviewing. Those are listed and shown on slides 9-10 of the attached presentation. Tom clarified that Caliper would focus on the urban/suburban sites for Illinois and focus on sites more rural in nature in Texas.

Regarding approach speeds of trains, Stan Milewski asked how Caliper intends to collect speed data on-site. Tom clarified that an estimate of train approach speeds should be sufficient, that the emphasis is really on how long the gates are down during a crossing event. With respect to signal preemption, yes, it would be good to have a reasonably accurate speed so that the transfer of right-of-way from street signals to the railroad can be modeled accurately. Karen McClure said that FRA can reach out to the railroads for cooperation and help.

Howard Slavin suggested the team consider video and site suitability for video in identifying study sites. Regarding individual train crossing events and their duration, Stan advised that the team consider downloading event logs from the railroads. Depending on the location, this may require some assistance on-site from a signal technician. ICC should have railroad signal preemption parameters for each of the locations.

Many of the candidate locations were discussed. It was agreed that no single site will satisfy all of the desirable site characteristics that have been identified and that several criteria are of primary importance due to the nature of the study (e.g., highway traffic volumes, adjacent signalized intersections, train crossing frequency, both passenger and freight trains, signal preemption, etc.). Sites were identified by the alphanumeric ID assigned by Caliper and a summary of those individual site discussions follows. The sites are listed on Slide 9 of the attached and are shown on a map on Slide 10.

IL-U-3, LaGrange Avenue at Burlington Avenue/Hillgrove Avenue, LaGrange, IL

This site satisfies multiple criteria. There are adjacent signalized intersections to the north (Ogden Avenue) and south (Harris Avenue) and there is coordination north-south along LaGrange Avenue. Side street volumes are relatively low here, but that is a secondary issue. This a very active rail line with both commuter and freight trains. Being in a downtown area, there is a lot of pedestrian activity at this location. There are left-turn restrictions onto the crossing from the parallel street approaches at Burlington Avenue and Hillgrove Avenue, but these intersections are signalized, so there are four signalized intersections in the 1,500-foot section of LaGrange Avenue that contains the crossing. This one seemed to be the leading candidate for the preferred site.

IL-U-4, Harlem Avenue near W 26th Street, Berwyn, IL

This location has the same type of activity as the LaGrange site. There are high train volumes and multiple offset intersections along the north-south alignment of Harlem Avenue, which is an extremely busy street. However, there are no major intersections close by. This location has a lot of freight trains operating at different speeds.

IL-U-1, US 14 at River Road, Des Plaines, IL

There is potential roadwork at the US 14/Busse Highway T-intersection to the east that would affect operations at US 14/River Road. This is a triple track that carries mostly Metra commuter trains, with not much freight activity. There are pre-signals on the River Road northbound approach. Both streets carry heavy traffic and there is good pedestrian activity.

IL-U-5, River Road (US 14) at Main Street (SR 83), Mt. Prospect, IL

There is one controller for everything. This location is similar to the others.

IL-U-2, Devon Avenue-Caldwell Avenue-Central Avenue, Chicago

There is a lot going on here, as these streets form a triangle and there are three at-grade crossings and four signalized intersections. The traffic signals operate at pretimed control and the intersections are not interconnected. Getting signal timing data from the City may be difficult. While this is an intriguing and challenging study, it was agreed by the group that its complexities are beyond what is desired for this project.

IL-U-7, Busse Highway/Dee Road/Oakton Street, Park Ridge, IL

This location also includes multiple crossings, although the two are tied together to operate as one. There is simultaneous preemption for both. There is one traffic signal controller for the three intersections to the north. This location is not quite as busy as IL-U-3 (LaGrange).

IL-U-6a, Harlem Avenue at Grand Avenue, Elmwood Park, IL

There are traffic signals on Harlem Avenue on both sides of the rail line. The traffic signals are pre-timed and there is no vehicle detection. The primary intersection (Grand Avenue) is to the north and there is a pre-signal in the northbound direction. This line is owned by Metra (NIRC) and is not as busy as the BNSF line. There are some freight trains, although the majority of the rail traffic is commuter. Harlem Avenue ADT is about 25,000, while Grant Avenue traffic is in the 10,000 – 15,000 range.

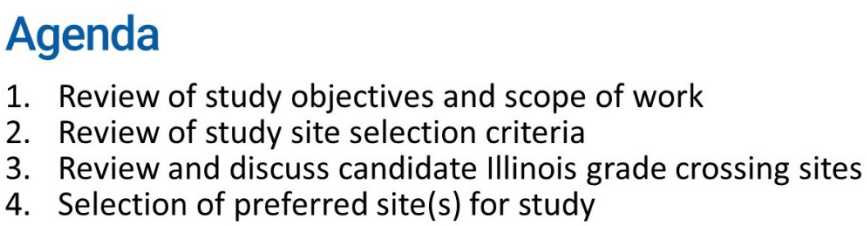
IL-U-8, Roselle Road at Irving Park Road (SR 19), Roselle, IL

It was stated that there are probably better candidates than this site. The rail traffic consists of mostly Metra trains, with some freight traffic. There are two signalized intersections – one on either side of the crossing. They are coordinated but operate with separate controllers.

IL-U-9, Irving Park Road (SR 19) at Wood Dale Road, Wood Dale, IL

There is a pre-signal in the southbound direction on Wood Dale Road. The two crossings are tied together and operate as a single crossing. As a result, the warning times can be long because of the two crossings and the severe skew angle on Irving Park Road. The Irving Park Road is equipped with automated enforcement devices because of the high frequency of driver violations here. Irving Park Road ADT is about 25,000, while the Wood Dale Road ADT is about 10,000 – 15,000.

The group agreed that the LaGrange Avenue site (IL-U-3) satisfied the most criteria and would be the best choice for study among the sites presented. Final thoughts from the group will be obtained before confirming that as the preferred site. The other locations will be reviewed and an alternate site will be selected as well.



Background

- Much attention has been given to safety aspect of highway-rail grade crossings (and rightfully so)
- Less attention has been given to traffic operational impact
  - Of particular interest, delays and queues
  - Conventional analysis tools like methods prescribed in Highway Capacity Manual (HCM)limited in their ability to quantify impacts
- Challenges
  - How do you quantify traffic impacts of a crossing event?
  - How do you quantify effectiveness of potential mitigation measures (e.g., queue cutter signal)?

Background (cont.)

- Microsimulation provides an alternative approach to conventional deterministic tools (such as HCM)
- No established guidance on how these types of analyses should be performed

Objective

- Perform case studies that will be used to develop recommendations for an operational framework and methodology for evaluating traffic impacts of highway-rail grade crossings using microscopic traffic simulation.
- Recommended framework will consider how to quantify delay and queue lengths
  - As function of train lengths and traffic demands
  - Detailed enough to consider traffic signal settings and other operational parameters at crossings
- Provide engineers, planners and decision makers better tools for managing traffic impacts at highway-rail grade crossings
- Should provide secondary safety benefits (including peds and bikes)

Project Scope of Work

Task 1. Literature Review
Task 2. Identification of Stakeholder Group
Task 3. Identify Study Sites and Develop Data Collection Plan
- Illinois
- Texas
- One primary site and one alternative in each state
- Combination of urban and suburban/rural

Task 4. Data Collection and Processing
Task 5. Simulate Rail Grade Crossing Study Sites
Task 6. Develop Highway-Rail Grade Crossing Analysis Framework
Task 7. Prepare Research Study Final Report

Desirable Study Site Characteristics

- Urban or Suburban Location (need to have traffic signal control nearby)
- Multiple daily crossings
- Variable train crossing speeds
- Multiple tracks
- Freight and passenger rail (not a necessity, but would be nice for at least one site)
- Closely spaced adjacent intersections
- Signal preemption – Simultaneous or Advance
- Pre-signal and/or queue cutter signal
- Cross-street AADT 5,000 or greater
- Significant truck volumes as part of the crossing street traffic

Data Collection Items

Railroad
- Type of preemption
- Preemption timing parameters
  - Phases
  - Phase durations
- Train schedules/frequencies
- Gates – 2-quad or 4-quad
- Pre-signals
- Queue-cutter signals

Geometry
- Intersection configuration/lane use
- Grade
- Number of lanes

Traffic
- AADT (for screening purposes)
- Demand at 15-minute intervals
- Vehicle mix
- Vehicle speeds (especially trucks through the crossing)

Traffic Control
- Posted speed limit
- Signal timing plans
- Yield/STOP control (if applicable)
- Signal pre-emption parameters

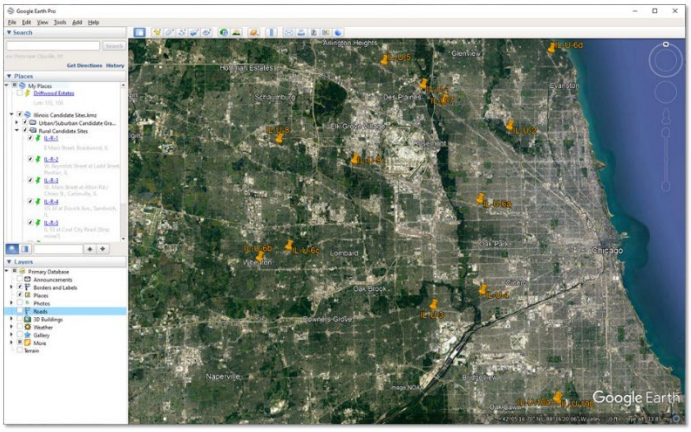
Note: List is not inclusive; more items may be added

Illinois Candidate Sites

Illinois Candidate Sites

Area Type	ID	Location	Town/City	Crossing ID	Railroad	Crossing Street AADT	Notes
Urban/Suburban	IL-U-1	US 14 at River Road	Des Plaines	173908X	Union Pacific	22,000	Bold crosswalk demarcation suggests significant pedestrian activity.
Urban/Suburban	IL-U-2	Lehigh / Caldwell / Devon	Chicago	386379G	Metra, Amtrak, BCP freight	22,400	Very complex - three crossings of a "triangle"
Urban/Suburban	IL-U-3	US 12-20-45 (LaGrange Avenue) at Burlington Ave./Hillgrove Ave.	LaGrange	079508Y	BNSF	18,500	Parrallel cross streets on either side of the tracks; some cross street LT's prohibited.
Urban/Suburban	IL-U-4	Harlem Avenue near W. 26th Street	Berwyn	079493L	BNSF	27,300	Pre-signals on NB/SB approaches. Sign: "Shortened walk time when train approaches". Triple track.
Urban/Suburban	IL-U-5	IL 83 (Main St.) / US 14	Mt. Prospect	176912X	Union Pacific	15,400	Triple track. Parallel crossing with next street - consider as single crossing. Pre-signals on NB/SB approaches.
Urban/Suburban	IL-U-6a	Harlem Avenue near Grand Avenue	Elmwood Park	372126H	NIRC (Metra)	23,000	Sight distrance restrictions on NB approach. Nearby cross streets serve as pre-signals.
Urban/Suburban	IL-U-6b	S. Main Street near Front Street/Liberty Drive	Wheaton	174957X	Union Pacific	15,100	Signals coordinated as queue cutters on NB/SB Main Street? Any interconnect?
Urban/Suburban	IL-U-6c	Main Street at Duane Street/Pennsylvanie Ave.	Glen Ellyn	174950A	Union Pacific	6,450	This would be better suited as a rural/location. No traffic signals.
Urban/Suburban	IL-U-6d	Willmette Ave. at Green Bay Road	Wilmette	176548M	Union Pacific	2,100	Adjacent intersections serve as pre-signals.
Urban/Suburban	IL-U-7	Busse / Oakton / Dee	Park Ridge	173904V	Union Pacific	14,800	Triple track.
Urban/Suburban	IL-U-8	IL 19 at Roselle Road	Roselle	372196X	NIRC (Metra)	18,600	Signals coordinated as queue cutters on NB/SB Roselle Road? Any interconnect?
Urban/Suburban	IL-U-9	IL 19 at Wood Dale	Wood Dale	372177T	NIRC (Metra)	24,900	Severe skew.
Urban/Suburban	IL-U-10a	94th Street at Kedzie Ave.	Chicago	283149U	CSX	21,200	SB Kedzie Ave. approach - queue cutter signal?
Urban/Suburban	IL-U-10b	95th Street at Kedzie Ave.	Chicago	283151V	CSX	30,700	Works as a system with IL-U-10a?
Rural	IL-R-1	IL 113 (Main St) at IL 129/IL 53	Braidwood	290507T	Union Pacific	1,600	Low AADT, but pre- signals on approaches. Coordinated?
Rural	IL-R-2	Reynolds Street at Ladd Street	Pontiac	290759U	Union Pacific	6,900	Pre-signal on WB Reynolds Street approach. Queue cutter for US 66? 800+ feet
Rural	IL-R-3	IL 108 (Main St.) at Chiles Street/Alton Road	Carlinville	294388A	Union Pacific	5,800	
Rural	IL-R-4	US 34 at Duvick Ave.	Sandwich	079597T	BNSF	2,450	Adjacent trucking facility (Plano Molding Co.)
Rural	IL-R-5	IL 53 at IL 29 (Stripmine Road)	Wilmington	290503R	Union Pacific	4,900	Pre-signals on EB/WB approaches
Rural	IL-R-6	US 45 at Curtis Road	Savoy	289084Y	Illinois Central	5,700	Pre-signal on WB Curtis Road approach

Illinois Candidate Sites



Texas Site Coordination Meeting Summary
July 12, 2022
Participants:

Andreas Mohammad, Union Pacific
Anthony Anderson, Union Pacific
Paul Rathgeber, Union Pacific
Erik Lewis, Union Pacific, Union Pacific
Karen McClure, Federal Railroad Administration
Tom Creasey, Caliper Corporation

Case Study to Develop a Highway-Rail Grade Crossing Analysis Framework

Union Pacific Railroad Coordination Meeting

July 12, 2022

Caliper

Agenda

1. Reason for the Study
2. Objectives and Benefits
3. Scope of Work and Deliverables
4. TransModeler Traffic Simulation Software
5. Study Sites
6. Data Collection Elements
7. Simulation Models
8. Stakeholder Coordination Items
9. Wrap-Up

Reason for the Study

- Much attention has been given to safety aspect of highway-rail grade crossings (and rightfully so)
- Less attention has been given to traffic operational impact
  - Of particular interest, delays and queues
  - Conventional analysis tools limited in their ability to quantify impacts
- Challenges
  - How do you quantify traffic impacts of a crossing event?
  - How do you quantify effectiveness of potential mitigation measures (e.g., queue cutter signal)?
- Microsimulation provides an alternative approach to conventional tools
- No established guidance on how these types of analyses should be performed

Objective

- Perform case studies that will be used to develop recommendations for an operational framework and methodology for evaluating traffic impacts of highway-rail grade crossings using simulation.
- Recommended framework will consider how to quantify delay and queue lengths
  - As function of crossing duration and traffic demands
  - Detailed enough to consider traffic signal settings and other operational parameters at crossings
- Benefits
  - Provide engineers, planners and decision makers better tools for managing traffic impacts at highway-rail grade crossings
  - Should provide secondary safety benefits (including pedestrians and bikes)

Project Scope of Work

Task 1. Literature Review

Task 2. Identification of Stakeholder Group

Task 3. Identify Study Sites and Develop Data Collection Plan
- Illinois
- Texas
- One urban, one suburban/rural

Task 4. Data Collection and Processing

Task 5. Simulate Rail Grade Crossing Study Sites

Task 6. Develop Highway-Rail Grade Crossing Analysis Framework

Task 7. Prepare Research Study Final Report

Timeline

Task	Description	2021 Aug	Sep	Oct	Nov	Dec	2022 Jan	Feb	Apr	May	Jun	Jul	Aug	Sep
1	Literature Review ✓ *Summary Technical Memorandum*													
2	Identify Stakeholders • *List of Stakeholders and Contact Info*													
3	Identify Sites/Develop Data Collection Plan ✓ *Study Site Selection Technical Memorandum* ✓ *Data Collection Plan*													
4	Data Collection and Processing													
5	Simulate Rail Grade Crossing Study Sites • *Sumary Technical Memorandum*													
6	Develop Grade Crossing Analysis Framework • *Sumary Technical Memorandum*													
7	Prepare Research Study Final Report • *Final Report Document*													

TransModeler Simulation Software

Case Study to Develop a Highway-Rail Grade Crossing Analysis Framework

TransModeler Simulation Software

Case Study to Develop a Highway-Rail Grade Crossing Analysis Framework

Data Collection Items

Railroad

- Type of preemption
- Preemption timing parameters
  - Phases
  - Phase durations
- Train schedules/frequencies
- Gates – 2-quad or 4-quad
- Pre-signals
- Queue-cutter signals

Geometry

- Intersection configuration/lane use
- Grade
- Number of lanes

Traffic

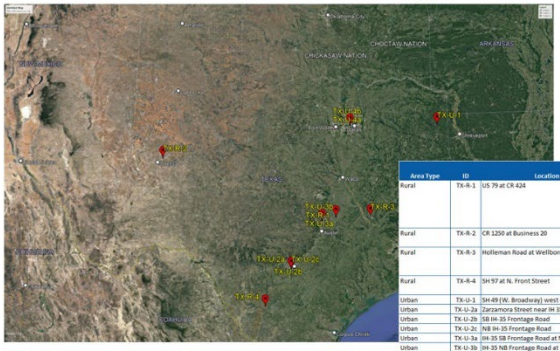
- AADT (for screening purposes)
- Demand at 15-minute intervals
- Vehicle mix
- Vehicle speeds (especially trucks through the crossing)

Traffic Control

- Posted speed limit
- Signal timing plans
- Yield/STOP control (if applicable)
- Signal pre-emption parameters

Note: List is not inclusive; more items may be added

Texas Candidate Study Sites



Area Type	ID	Location	Town/City	FRA Crossing ID	Railroad	Highway AADT
Rural	TX-R-1	US 79 at CR 424	Thrall	446559W	Union Pacific	1,100
Rural	TX-R-2	CR 1250 at Business 20	Odessa/ Midland	796312G	Union Pacific	6,000
Rural	TX-R-3	Holleman Road at Wellborn Road	College Station	745017Y	Union Pacific	11,400
Rural	TX-R-4	SH 97 at N. Front Street	Cotulla	448996Y	Union Pacific	7,000
Urban	TX-U-1	SH 49 (W. Broadway) west of Walcott Street	Jefferson	794573A	Union Pacific	6,800
Urban	TX-U-2a	Zarzamora Street near IH 35	San Antonio	435955G	Union Pacific	8,800
Urban	TX-U-2b	SB IH-35 Frontage Road	San Antonio	435954A	Union Pacific	27,000**
Urban	TX-U-2c	NB IH-35 Frontage Road	San Antonio	435438T	Union Pacific	27,000**
Urban	TX-U-3a	IH-35 SB Frontage Road at McNeil Road	Round Rock	448435K	Union Pacific	13,900
Urban	TX-U-3b	IH-35 NB Frontage Road at McNeil Road	Round Rock	448427T	Union Pacific	13,900
Urban	TX-U-4a	N. Westmoreland Road	Dallas	794926K	Union Pacific	24,100
Urban	TX-U-4b	N. Westmoreland Road	Dallas	794926K	Union Pacific	24,100

Texas Selected Site

Texas Selected Site

Cotulla, TX

Cotulla, TX (cont.)

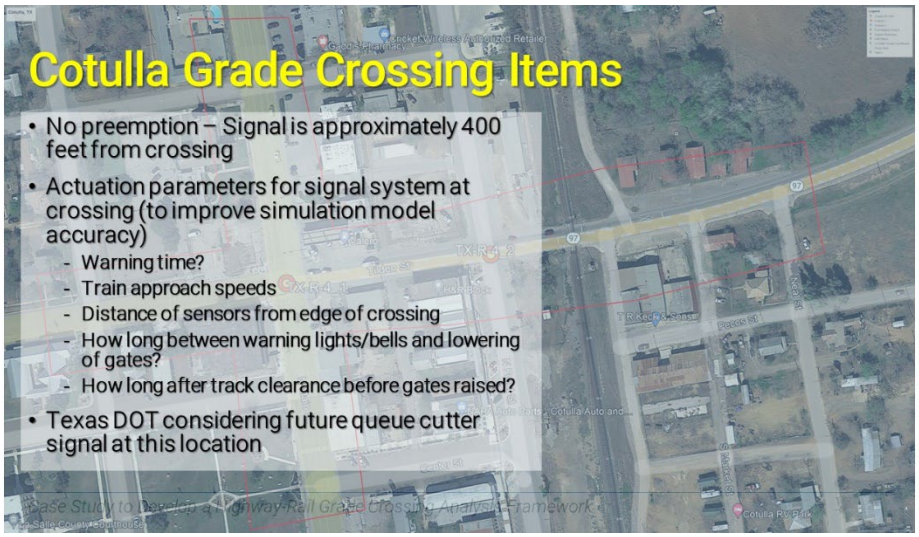
Data Collection 4/20-21/2022 Crossing Events

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: Tilden St btwn Front St and Keck St
Date: 4/20/2022
Time: 7:00 AM - 7:00 PM
Site Code: 15753320

Crossing Event Number	Crossing Actuation	Lead Train Car Crosses	Last Train Car Crosses	Traffic Resumes	Did the Train Stop?	Number of Train Cars	Type of Train (Passenger/Freight)	Train Directionality (NB/SB)
1	8:24:44 AM	8:24:57 AM	8:26:33 AM	8:26:46 AM	No	100	Freight	NB
2	9:17:26 AM	9:17:41 AM	9:18:45 AM	9:19:03 AM	No	55	Freight	NB
3	10:25:17 AM	10:25:18 AM	10:25:18 AM	10:25:39 AM	No	N/A	N/A	SB
4	11:17:11 AM	11:17:25 AM	11:18:39 AM	11:18:55 AM	No	71	Freight	SB
5	1:58:42 PM	1:58:56 PM	2:00:33 PM	2:00:44 PM	No	96	Freight	NB
6	3:30:10 PM	3:30:25 PM	3:32:38 PM	3:32:47 PM	No	153	Freight	SB
7	4:06:59 PM	4:07:13 PM	4:08:10 PM	4:08:22 PM	No	59	Freight	NB
8	4:49:42 PM	4:49:55 PM	4:51:45 PM	4:51:55 PM	No	114	Freight	SB
9	5:10:50 PM	5:11:01 PM	5:13:20 PM	5:13:32 PM	No	103	Freight	SB
10	6:44:50 PM	6:45:04 PM	6:45:45 PM	6:45:56 PM	No	57	Freight	NB

Notes:
Crossing event 3 is not a train, but instead a pickup truck driving on top of the tracks. The crossing bar still lowers to block oncoming traffic as though it were a train.



Coordination

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Appendix B.
La Grange, Illinois, Site Simulation Model Data

Intersection Turning Movement Counts

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: N LaGrange Rd – Ogden Ave
Date: 6/7/2022
Site Code: 15782513

	N LaGrange Rd Southbound				Ogden Ave Westbound				N LaGrange Rd Northbound				Ogden Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
08:30 AM	33	121	61	0	108	156	11	0	9	99	23	0	20	123	38	0
08:45 AM	27	100	74	0	95	129	12	0	4	104	11	0	20	130	41	0
09:00 AM	13	101	80	0	72	114	18	0	2	93	12	0	24	119	46	0
09:15 AM	22	109	59	0	80	117	8	0	9	116	24	0	24	115	39	0
09:30 AM	15	93	65	0	70	113	15	0	8	102	28	0	14	96	38	0
09:45 AM	22	100	59	0	79	121	13	0	16	113	27	0	16	126	38	0
10:00 AM	14	99	53	0	47	120	9	0	4	94	26	0	20	101	39	0
10:15 AM	18	99	63	0	56	103	13	0	10	105	19	0	22	89	44	0
Total	164	822	514	0	607	973	99	0	62	826	170	0	160	899	323	0

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: N LaGrange Rd – Ogden Ave
Date: 6/7/2022
Site Code: 15782514

	N LaGrange Rd Southbound				Ogden Ave Westbound				N LaGrange Rd Northbound				Ogden Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
01:00 PM	21	135	71	0	67	111	14	0	13	93	24	0	17	149	50	0
01:15 PM	25	144	71	0	84	122	11	0	14	143	26	0	16	138	34	0
01:30 PM	34	148	87	0	64	109	18	0	15	113	29	0	12	163	36	0
01:45 PM	21	141	92	0	71	88	21	0	12	108	19	0	16	172	35	0
02:00 PM	17	151	69	0	78	103	16	0	9	137	30	0	16	174	45	0
02:15 PM	18	137	92	0	86	137	20	0	12	117	18	0	18	217	42	0
02:30 PM	25	134	110	0	112	121	16	0	10	111	17	0	8	176	37	0
02:45 PM	21	157	104	0	99	125	15	0	22	144	29	0	7	147	29	0
Total	182	1147	696	0	661	916	131	0	107	966	192	0	110	1336	308	0

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: N LaGrange Rd – Hillgrove Ave
Date: 6/7/2022
Site Code: 15782515

	N LaGrange Rd Southbound				Hillgrove Ave Westbound				N LaGrange Rd Northbound				Hillgrove Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
08:30 AM	4	132	0	0	0	6	0	0	1	118	0	0	3	5	13	0
08:45 AM	9	132	1	0	1	5	0	0	2	121	0	0	7	5	8	0
09:00 AM	3	120	3	0	3	2	0	0	5	95	0	0	2	8	10	0
09:15 AM	5	133	3	0	2	6	0	0	8	133	1	0	3	4	6	0
09:30 AM	2	97	3	1	3	8	0	0	4	125	0	0	0	3	11	0
09:45 AM	6	113	1	0	3	2	0	0	6	133	0	0	5	4	10	0
10:00 AM	5	121	3	0	4	1	0	0	9	106	1	0	5	5	16	0
10:15 AM	4	108	8	0	3	11	0	0	1	120	0	0	9	8	14	0
Total	38	956	22	1	19	41	0	0	36	951	2	0	34	42	88	0

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: N LaGrange Rd – Hillgrove Ave
Date: 6/7/2022
Site Code: 15782516

	N LaGrange Rd Southbound				Hillgrove Ave Westbound				N LaGrange Rd Northbound				Hillgrove Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
01:00 PM	6	119	3	0	1	13	0	0	4	110	0	0	5	8	13	0
01:15 PM	6	166	3	0	2	12	0	0	13	166	0	0	5	9	13	0
01:30 PM	11	143	3	1	2	10	1	0	5	141	0	0	13	5	10	0
01:45 PM	9	134	3	0	2	13	1	0	7	122	0	0	4	10	14	0
02:00 PM	2	173	4	0	4	16	0	0	6	157	0	0	13	14	13	0
02:15 PM	5	142	7	0	5	3	0	0	5	146	0	0	10	16	17	0
02:30 PM	3	115	3	0	2	12	0	0	7	97	0	0	6	11	24	0
02:45 PM	8	177	6	0	3	15	0	0	7	171	0	0	5	9	19	0
Total	50	1169	32	1	21	94	2	0	54	1110	0	0	61	82	123	0

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: S LaGrange Rd – Burlington Ave
Date: 6/7/2022
Site Code: 15782517

	S LaGrange Rd Southbound				Burlington Ave Westbound				S LaGrange Rd Northbound				Burlington Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
08:30 AM	4	130	0	0	6	26	0	0	6	111	4	0	7	11	0	0
08:45 AM	6	132	0	0	8	21	1	0	6	113	6	0	8	10	0	0
09:00 AM	3	117	0	0	5	17	1	0	5	96	5	0	4	13	0	0
09:15 AM	7	128	0	0	12	7	1	0	2	130	11	0	3	3	0	0
09:30 AM	6	94	0	0	8	11	0	0	3	118	10	0	2	9	0	0
09:45 AM	5	108	0	0	12	12	0	0	2	128	7	0	9	13	0	0
10:00 AM	5	127	0	0	12	26	0	0	6	99	6	0	7	9	1	0
10:15 AM	3	117	0	0	8	28	0	0	11	115	13	0	5	10	0	0
Total	39	953	0	0	71	148	3	0	41	910	62	0	45	78	1	0

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: S LaGrange Rd – Burlington Ave
Date: 6/7/2022
Site Code: 15782518

	S LaGrange Rd Southbound				Burlington Ave Westbound				S LaGrange Rd Northbound				Burlington Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
01:00 PM	7	117	0	0	8	19	0	0	7	107	9	0	11	10	0	0
01:15 PM	11	155	0	0	17	12	0	0	4	161	6	0	23	16	0	0
01:30 PM	7	156	0	0	14	13	1	0	9	132	5	0	11	14	0	0
01:45 PM	3	141	0	0	10	18	1	0	4	120	9	0	4	18	0	0
02:00 PM	7	179	0	0	13	17	0	0	7	149	5	0	7	13	0	0
02:15 PM	4	148	0	0	20	17	0	0	10	133	6	0	11	7	0	0
02:30 PM	11	112	0	0	9	23	1	0	8	95	2	0	7	17	0	0
02:45 PM	12	169	0	0	14	24	0	0	5	169	4	0	14	21	0	0
Total	62	1177	0	0	105	143	3	0	54	1066	46	0	88	116	0	0

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: S LaGrange Rd – Harris Ave
Date: 6/7/2022
Site Code: 15782519

	S LaGrange Rd Southbound				Harris Ave Westbound				S LaGrange Rd Northbound				Harris Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
08:30 AM	13	131	9	0	7	8	7	0	7	101	7	0	8	4	1	0
08:45 AM	5	132	11	1	8	6	7	0	6	112	7	0	10	4	3	0
09:00 AM	8	125	3	0	2	3	4	0	5	113	9	0	3	5	1	0
09:15 AM	9	117	14	0	17	4	6	0	6	140	11	0	7	2	3	0
09:30 AM	9	96	8	0	8	11	9	0	6	113	5	0	9	2	2	0
09:45 AM	12	118	8	0	6	10	10	0	9	123	10	0	6	2	3	0
10:00 AM	6	137	6	0	6	16	15	0	10	102	5	0	6	0	5	0
10:15 AM	19	112	7	1	8	7	14	0	6	120	8	0	9	9	4	0
Total	81	968	66	2	62	65	72	0	55	924	62	0	58	28	22	0

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: S LaGrange Rd – Harris Ave
Date: 6/7/2022
Site Code: 15782520

	S LaGrange Rd Southbound				Harris Ave Westbound				S LaGrange Rd Northbound				Harris Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
01:00 PM	16	151	14	0	7	6	10	0	10	131	10	0	12	8	8	0
01:15 PM	16	179	10	0	6	5	11	0	9	148	13	0	10	6	6	0
01:30 PM	17	131	12	0	9	7	17	0	3	108	12	0	8	6	5	0
01:45 PM	12	176	13	0	13	5	8	0	10	124	7	1	15	6	4	0
02:00 PM	14	183	5	0	9	8	8	0	4	134	7	0	8	4	7	0
02:15 PM	13	151	10	0	11	9	10	0	5	133	7	0	6	3	4	0
02:30 PM	10	157	7	0	11	5	10	0	2	132	10	0	5	4	2	0
02:45 PM	17	177	12	0	6	18	13	0	12	126	6	0	2	8	5	0
Total	115	1305	83	0	72	63	87	0	55	1036	72	1	66	45	41	0

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: S LaGrange Rd – E Cossitt Ave
Date: 6/7/2022
Site Code: 15782521

	S LaGrange Rd Southbound				E Cossitt Ave Westbound				S LaGrange Rd Northbound				E Cossitt Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
08:30 AM	5	135	2	0	7	18	27	0	25	102	3	0	10	22	1	0
08:45 AM	12	138	4	0	11	16	24	0	40	129	6	0	4	12	4	0
09:00 AM	6	116	5	0	5	7	22	0	28	117	5	0	6	18	2	0
09:15 AM	10	117	5	0	9	4	18	0	22	137	5	0	2	6	9	0
09:30 AM	4	103	2	0	10	14	29	0	20	124	5	0	7	12	2	0
09:45 AM	7	121	8	0	6	8	18	0	28	139	6	0	9	10	3	0
10:00 AM	9	140	8	0	5	21	32	0	25	109	2	0	9	9	4	0
10:15 AM	9	124	3	0	7	9	22	0	12	125	7	0	5	12	11	0
Total	62	994	37	0	60	97	192	0	200	982	39	0	52	101	36	0

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: S LaGrange Rd – E Cossitt Ave
Date: 6/7/2022
Site Code: 15782522

	S LaGrange Rd Southbound				E Cossitt Ave Westbound				S LaGrange Rd Northbound				E Cossitt Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
01:00 PM	9	149	12	0	8	23	27	0	22	148	9	0	11	17	6	0
01:15 PM	9	180	7	0	7	5	24	0	24	140	7	0	8	15	5	0
01:30 PM	6	141	7	0	12	11	23	0	22	115	3	0	7	15	1	0
01:45 PM	11	183	6	0	4	13	29	0	21	161	10	0	10	18	4	0
02:00 PM	5	193	3	0	6	9	24	0	24	131	5	0	9	12	6	0
02:15 PM	8	158	9	0	5	18	31	0	27	146	5	0	11	18	3	0
02:30 PM	5	167	6	0	7	15	25	0	36	149	5	0	11	13	10	0
02:45 PM	9	181	9	0	7	15	31	0	41	128	11	0	11	24	5	0
Total	**62**	**1352**	**59**	**0**	**56**	**109**	**214**	**0**	**217**	**1118**	**55**	**0**	**78**	**132**	**40**	**0**

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: N Ashland Ave – W Hillgrove Ave
Date: 6/7/2022
Site Code: 15782523

	N Ashland Ave Southbound				W Hillgrove Ave Westbound				N Ashland Ave Northbound				W Hillgrove Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
08:30 AM	9	15	3	0	4	11	10	0	4	12	12	0	2	19	10	0
08:45 AM	2	15	1	0	6	14	6	0	11	17	11	0	8	9	1	0
09:00 AM	1	7	3	0	3	5	4	0	7	16	8	0	2	11	3	0
09:15 AM	7	9	2	0	5	5	10	0	7	10	6	0	4	8	3	0
09:30 AM	3	12	2	0	4	7	12	0	10	10	12	0	1	9	2	0
09:45 AM	7	16	3	0	4	8	11	0	13	16	5	0	6	9	3	0
10:00 AM	7	9	4	0	2	9	7	0	8	12	12	0	4	19	6	0
10:15 AM	4	12	5	0	6	13	13	0	15	14	5	0	2	24	3	0
Total	**40**	**95**	**23**	**0**	**34**	**72**	**73**	**0**	**75**	**107**	**71**	**0**	**29**	**108**	**31**	**0**

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: N Ashland Ave – W Hillgrove Ave
Date: 6/7/2022
Site Code: 15782524

	N Ashland Ave Southbound				W Hillgrove Ave Westbound				N Ashland Ave Northbound				W Hillgrove Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
01:00 PM	3	12	3	0	8	15	16	0	8	18	8	0	6	19	4	0
01:15 PM	1	13	0	0	4	18	18	0	7	19	14	0	6	17	2	0
01:30 PM	5	14	8	0	8	18	18	0	11	17	15	0	2	14	1	0
01:45 PM	4	12	5	0	6	17	17	0	8	17	6	0	4	19	5	0
02:00 PM	6	19	7	0	6	12	8	0	13	18	14	0	3	19	7	0
02:15 PM	0	12	8	0	8	18	13	0	11	18	10	0	2	28	5	0
02:30 PM	2	11	2	0	7	15	10	0	15	14	9	0	5	25	2	0
02:45 PM	2	13	6	0	9	18	14	0	19	29	12	0	6	21	2	0
Total	**23**	**106**	**39**	**0**	**56**	**131**	**114**	**0**	**92**	**150**	**88**	**0**	**34**	**162**	**28**	**0**

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: S Ashland Ave – W Burlington Ave
Date: 6/7/2022
Site Code: 15782525

	S Ashland Ave Southbound				W Burlington Ave Westbound				S Ashland Ave Northbound				W Burlington Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
08:30 AM	6	17	4	0	9	19	3	0	2	19	3	0	2	11	1	0
08:45 AM	1	23	5	0	16	15	2	0	6	22	2	0	5	15	0	0
09:00 AM	1	11	1	0	7	13	1	0	0	24	1	0	2	11	1	0
09:15 AM	1	20	1	0	8	9	6	0	4	14	1	0	1	6	0	0
09:30 AM	2	19	4	0	15	15	6	0	1	16	2	0	3	9	1	0
09:45 AM	3	25	5	0	7	11	3	0	4	23	2	0	4	10	4	0
10:00 AM	1	18	1	0	15	13	12	0	2	17	0	0	5	9	0	0
10:15 AM	4	18	4	0	9	13	11	0	5	23	3	0	5	7	3	0
Total	19	151	25	0	86	108	44	0	24	158	14	0	27	78	10	0

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: S Ashland Ave – W Burlington Ave
Date: 6/7/2022
Site Code: 15782526

	S Ashland Ave Southbound				W Burlington Ave Westbound				S Ashland Ave Northbound				W Burlington Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
01:00 PM	6	22	7	0	13	15	13	0	6	21	1	0	8	5	0	0
01:15 PM	6	22	8	0	12	13	7	0	5	27	1	0	8	12	1	1
01:30 PM	2	24	9	0	16	8	11	0	6	25	5	0	4	15	2	0
01:45 PM	1	27	4	0	8	9	7	1	4	22	4	0	4	9	1	0
02:00 PM	2	25	4	0	17	11	8	0	2	27	5	0	11	12	1	0
02:15 PM	4	21	2	0	13	12	11	0	3	24	1	0	9	11	2	0
02:30 PM	4	17	4	0	13	12	10	0	2	25	2	0	2	15	0	0
02:45 PM	4	21	8	0	15	18	11	0	9	43	1	0	10	16	2	0
Total	29	179	46	0	107	98	78	1	37	214	20	0	56	95	9	1

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: E Ogden Ave – E Burlington Ave
Date: 6/7/2022
Site Code: 15782529

	E Ogden Ave Southbound				E Burlington Ave Westbound				E Ogden Ave Northbound				E Burlington Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
08:30 AM	33	167	0	0	0	0	0	0	0	257	33	0	20	0	0	0
08:45 AM	23	186	0	0	0	0	0	0	0	251	44	0	10	0	0	0
09:00 AM	20	188	0	0	0	0	0	0	0	175	37	0	17	0	0	0
09:15 AM	19	168	0	0	0	0	0	0	0	215	26	0	14	0	0	0
09:30 AM	12	148	0	0	0	0	0	0	0	205	36	0	27	0	0	0
09:45 AM	20	187	0	0	0	0	0	0	0	205	29	0	18	0	1	0
10:00 AM	16	153	0	0	0	0	0	0	0	173	34	0	39	0	1	0
10:15 AM	18	146	0	0	0	0	0	0	0	168	39	0	34	0	0	0
Total	161	1343	0	0	0	0	0	0	0	1649	278	0	179	0	2	0

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: E Ogden Ave – E Burlington Ave
Date: 6/7/2022
Site Code: 15782530

	E Ogden Ave Southbound				E Burlington Ave Westbound				E Ogden Ave Northbound				E Burlington Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
01:00 PM	21	229	0	0	0	0	0	0	0	192	32	0	24	0	0	0
01:15 PM	14	214	0	0	0	0	0	0	0	212	35	0	25	0	0	0
01:30 PM	21	250	0	0	0	0	0	0	0	193	23	0	31	0	0	0
01:45 PM	21	254	0	0	0	0	0	0	0	187	22	0	26	0	0	0
02:00 PM	16	265	0	0	0	0	0	0	0	207	33	0	28	0	0	0
02:15 PM	23	305	0	0	0	0	0	0	0	220	28	0	26	0	0	0
02:30 PM	22	290	0	0	0	0	0	0	0	256	33	0	28	0	0	0
02:45 PM	27	266	0	0	0	0	0	0	0	250	33	0	47	0	0	0
Total	**165**	**2073**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1717**	**239**	**0**	**235**	**0**	**0**	**0**

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: Bluff Ave – E Burlington Ave
Date: 6/7/2022
Site Code: 15782527

	Bluff Ave Southbound				E Burlington Ave Westbound				Bluff Ave Northbound				E Burlington Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
08:30 AM	0	0	0	0	0	47	19	0	3	0	10	0	1	16	0	0
08:45 AM	0	0	0	0	0	47	20	0	1	0	9	0	3	11	0	0
09:00 AM	0	0	0	0	0	38	19	0	2	0	3	0	3	14	0	0
09:15 AM	0	0	0	0	0	32	13	0	5	0	5	0	1	10	0	0
09:30 AM	0	0	0	0	0	40	10	0	9	0	6	0	1	19	0	0
09:45 AM	0	0	0	0	0	33	15	0	5	0	6	0	5	12	0	0
10:00 AM	0	0	0	0	0	40	11	1	16	0	14	0	0	24	0	0
10:15 AM	0	0	0	0	0	51	6	0	11	0	3	0	0	22	0	0
Total	**0**	**0**	**0**	**0**	**0**	**328**	**113**	**1**	**52**	**0**	**56**	**0**	**14**	**128**	**0**	**0**

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: Bluff Ave – E Burlington Ave
Date: 6/7/2022
Site Code: 15782528

	Bluff Ave Southbound				E Burlington Ave Westbound				Bluff Ave Northbound				E Burlington Ave Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
01:00 PM	0	0	0	0	0	37	17	0	1	0	10	0	4	22	0	0
01:15 PM	0	0	0	0	0	34	16	0	4	0	8	0	4	25	0	0
01:30 PM	0	0	0	0	0	29	15	0	6	0	6	0	5	21	0	0
01:45 PM	0	0	0	0	0	30	14	0	2	0	7	0	2	25	0	0
02:00 PM	0	0	0	0	0	36	12	0	4	0	9	0	2	23	0	0
02:15 PM	0	0	0	0	0	35	17	0	6	0	12	0	4	20	0	0
02:30 PM	0	0	0	0	0	42	12	0	5	0	9	0	7	26	0	0
02:45 PM	0	0	0	0	0	39	20	0	6	0	9	0	4	36	0	0
Total	**0**	**0**	**0**	**0**	**0**	**282**	**123**	**0**	**34**	**0**	**70**	**0**	**32**	**198**	**0**	**0**

Location: Crosswalk on S LaGrange Rd north of Calendar Ave
Date: 6/7/2022
Site Code: 15782534

	Crossing S LaGrange Rd	
Start Time	Westbound	Eastbound
08:30 AM	3	2
08:45 AM	1	1
09:00 AM	0	1
09:15 AM	2	3
09:30 AM	1	2
09:45 AM	1	0
10:00 AM	0	2
10:15 AM	4	1
Total	12	12

Location: Crosswalk on S LaGrange Rd north of Calendar Ave
Date: 6/7/2022
Site Code: 15782535

	Crossing S LaGrange Rd	
Start Time	Westbound	Eastbound
01:00 PM	1	4
01:15 PM	5	0
01:30 PM	5	7
01:45 PM	4	6
02:00 PM	7	2
02:15 PM	2	2
02:30 PM	1	11
02:45 PM	5	6
Total	30	38

Vehicle Queues

Site Code: 15782502
Date: 6/7/2022
Location: La Grange Rd & Hillgrove Ave
Time: 8:30 AM - 10:30 AM
Direction: Southbound

Start of Light Cycle	End of Light Cycle	SBR/T Vehicle Count	SBR/T Length in Feet	SBT Vehicle Count	SBT Length in Feet	SBL Vehicle Count	SBL Length in Feet
8:30:10 AM	8:30:52 AM	2	44	12	264	0	0
8:33:27 AM	8:34:11 AM	10	220	16	352	0	0
8:35:21 AM	8:36:07 AM	6	132	5	110	0	0
8:39:38 AM	8:40:18 AM	15	330	18	396	0	0
8:41:24 AM	8:42:05 AM	14	308	19	418	0	0
8:43:16 AM	8:44:04 AM	10	220	11	242	0	0
8:45:30 AM	8:46:33 AM	8	176	9	198	1	22
8:48:00 AM	8:48:59 AM	9	198	11	242	0	0
8:50:19 AM	8:51:17 AM	4	88	8	176	0	0
8:52:32 AM	8:53:22 AM	2	44	1	22	0	0
8:54:35 AM	8:55:27 AM	1	22	1	22	0	0
8:56:42 AM	8:57:32 AM	1	22	2	44	0	0
8:58:47 AM	8:59:37 AM	2	44	3	66	1	22
9:00:54 AM	9:01:42 AM	2	44	5	110	0	0
9:03:30 AM	9:04:00 AM	5	110	4	88	1	22
9:06:08 AM	9:06:41 AM	10	220	7	154	1	22
9:08:02 AM	9:10:13 AM	8	176	9	198	0	0
9:09:21 AM	9:10:06 AM	7	154	12	264	0	0
9:11:12 AM	9:12:05 AM	2	44	8	176	1	22
9:13:04 AM	9:14:26 AM	1	22	7	154	0	0
9:15:24 AM	9:16:20 AM	4	88	3	66	1	22
9:17:31 AM	9:18:19 AM	1	22	2	44	0	0
9:19:38 AM	9:20:24 AM	3	66	3	66	0	0
9:21:42 AM	9:23:03 AM	2	44	2	44	2	44
9:23:46 AM	9:24:42 AM	5	110	4	88	0	0
9:25:53 AM	9:26:48 AM	4	88	3	66	0	0
9:27:53 AM	9:28:53 AM	0	0	2	44	0	0
9:30:04 AM	9:30:47 AM	2	44	7	154	0	0
9:36:22 AM	9:37:04 AM	20	440	16	352	1	22
9:38:32 AM	9:39:08 AM	12	264	12	264	2	44
9:40:18 AM	9:41:08 AM	7	154	6	132	0	0
9:42:10 AM	9:43:12 AM	9	198	8	176	0	0
9:47:18 AM	9:48:03 AM	16	352	14	308	1	22
9:49:15 AM	9:49:49 AM	5	110	5	110	0	0
9:51:04 AM	9:52:30 AM	3	66	2	44	1	22
9:54:20 AM	9:55:09 AM	9	198	8	176	0	0
9:56:10 AM	9:56:59 AM	6	132	9	198	0	0
9:57:56 AM	9:58:47 AM	8	176	3	66	0	0
9:59:56 AM	10:00:50 AM	6	132	6	132	0	0
10:01:24 AM	10:01:45 AM	8	176	5	110	2	44
10:05:29 AM	10:06:12 AM	14	308	18	396	0	0
10:07:35 AM	10:08:07 AM	11	242	8	176	1	22
10:09:26 AM	10:09:59 AM	3	66	1	22	0	0
10:11:19 AM	10:12:06 AM	1	22	1	22	0	0
10:13:28 AM	10:14:22 AM	5	110	2	44	0	0
10:18:35 AM	10:19:19 AM	15	330	14	308	0	0
10:20:41 AM	10:21:18 AM	10	220	10	220	1	22
10:22:35 AM	10:23:10 AM	5	110	7	154	1	22
10:24:25 AM	10:25:10 AM	4	88	5	110	0	0
10:26:35 AM	10:27:15 AM	7	154	8	176	0	0
10:28:39 AM	10:29:20 AM	9	198	8	176	0	0

Quality Counts
DATA THAT DRIVES COMMUNITIES

Site Code: 15782502
Date: 6/7/2022
Location: La Grange Rd & Hillgrove Ave
Time: 1:00 PM - 3:00 PM
Direction: Southbound

Start of Light Cycle	End of Light Cycle	SBR/T Vehicle Count	SBR/T Length in Feet	SBT Vehicle Count	SBT Length in Feet	SBL Vehicle Count	SBL Length in Feet
1:00:51 PM	1:01:33 PM	5	110	6	132	0	0
1:02:49 PM	1:03:38 PM	8	176	10	220	0	0
1:05:01 PM	1:05:43 PM	6	132	9	198	0	0
1:07:06 PM	1:07:48 PM	10	220	8	176	1	22
1:09:04 PM	1:09:52 PM	2	44	4	88	2	44
1:15:36 PM	1:16:20 PM	16+	462	16+	462	0	0
1:17:39 PM	1:18:11 PM	4	88	4	88	0	0
1:19:34 PM	1:20:09 PM	6	132	7	154	0	0
1:21:33 PM	1:22:23 PM	6	132	3	66	0	0
1:23:43 PM	1:24:28 PM	3	66	5	110	0	0
1:25:52 PM	1:26:33 PM	6	132	7	154	0	0
1:27:53 PM	1:28:38 PM	6	132	9	198	0	0
1:29:48 PM	1:30:43 PM	4	88	1	22	0	0
1:31:54 PM	1:32:48 PM	3	66	5	110	1	22
1:37:30 PM	1:38:14 PM	18+	462	18+	462	1	22
1:39:40 PM	1:40:12 PM	14	308	17+	462	0	0
1:41:21 PM	1:42:12 PM	14	308	12	264	1	22
1:43:40 PM	1:44:40 PM	8	176	14	308	0	0
1:46:03 PM	1:46:21 PM	6	132	5	110	0	0
1:48:44 PM	1:49:51 PM	13	286	20+	462	1	22
1:51:06 PM	1:51:39 PM	3	66	6	132	1	22
1:53:02 PM	1:53:36 PM	8	176	8	176	1	22
1:54:47 PM	1:55:43 PM	15	330	20	440	1	22
1:57:05 PM	1:57:48 PM	4	88	2	44	0	0
2:01:27 PM	2:02:07 PM	17	374	17+	462	0	0
2:03:04 PM	2:03:49 PM	5	110	4	88	1	22
2:04:59 PM	2:05:49 PM	15	330	12	264	1	22
2:07:25 PM	2:08:11 PM	11	242	13	286	0	0
2:09:37 PM	2:10:18 PM	6	132	6	132	0	0
2:11:38 PM	2:12:23 PM	9	198	4	88	0	0
2:13:43 PM	2:14:28 PM	2	44	4	88	1	22
2:15:45 PM	2:16:33 PM	3	66	7	154	2	44
2:20:03 PM	2:20:58 PM	13	286	13	286	1	22
2:22:26 PM	2:23:00 PM	6	132	9	198	2	44
2:24:18 PM	2:24:54 PM	14	308	4	88	1	22
2:26:54 PM	2:27:37 PM	13	286	13	286	1	22
2:28:56 PM	2:29:29 PM	10	220	7	154	0	0
2:33:40 PM	2:34:31 PM	17+	462	21+	462	0	0
2:35:42 PM	2:36:17 PM	20+	462	17	374	2	44
2:37:28 PM	2:38:12 PM	12	264	14	308	0	0
2:42:39 PM	2:43:22 PM	15+	462	19+	462	0	0
2:47:03 PM	2:47:46 PM	19+	462	23+	462	0	0
2:50:06 PM	2:50:49 PM	19+	462	21+	462	0	0
2:52:08 PM	2:52:44 PM	18+	462	19	418	1	22
2:53:55 PM	2:54:29 PM	13+	462	18	396	0	0
2:55:39 PM	2:56:10 PM	8	176	16	352	0	0
2:57:28 PM	2:58:11 PM	5	110	6	132	1	22
2:59:29 PM	3:00:16 PM	11	242	4	88	3	66

Notes:
Queues continued through Ogden Ave for some time frames. Instances where this occurred are marked with a "+" next to the vehicle count value.

Quality Counts
DATA THAT DRIVES COMMUNITIES

Site Code: 15782503
Date: 6/7/2022
Location: La Grange Rd & Burlington Ave
Time: 8:30 AM - 10:30 AM
Direction: Northbound

Start of Light Cycle	End of Light Cycle	NBR/T Vehicle Count	NBR/T Length in Feet	NBT Vehicle Count	NBT Length in Feet	NBL Vehicle Count	NBL Length in Feet
8:29:57 AM	8:30:49 AM	8	176	7	154	1	22
8:33:10 AM	8:34:07 AM	11	242	9	198	2	44
8:35:09 AM	8:35:58 AM	1	22	5	110	0	0
8:39:27 AM	8:40:18 AM	11	242	10	220	0	0
8:41:12 AM	8:42:01 AM	1	22	1	22	1	22
8:43:04 AM	8:44:01 AM	10	220	9	198	0	0
8:45:14 AM	8:46:30 AM	5	110	2	44	1	22
8:47:42 AM	8:48:56 AM	4	88	3	66	2	44
8:50:08 AM	8:51:13 AM	1	22	1	22	0	0
8:52:17 AM	8:53:18 AM	2	44	2	44	1	22
8:54:23 AM	8:55:23 AM	6	132	7	154	0	0
8:56:27 AM	8:57:28 AM	6	132	1	22	1	22
8:58:31 AM	8:59:33 AM	6	132	8	176	1	22
9:00:36 AM	9:01:38 AM	2	44	5	110	2	44
9:03:20 AM	9:04:01 AM	6	132	6	132	0	0
9:05:46 AM	9:06:33 AM	6	132	6	132	2	44
9:07:52 AM	9:08:17 AM	6	132	9	198	0	0
9:09:10 AM	9:10:01 AM	2	44	4	88	0	0
9:11:14 AM	9:11:55 AM	6	132	7	154	0	0
9:13:05 AM	9:13:55 AM	1	22	2	44	0	0
9:15:09 AM	9:16:14 AM	4	88	5	110	1	22
9:17:14 AM	9:18:18 AM	5	110	6	132	2	44
9:19:21 AM	9:20:23 AM	2	44	3	66	2	44
9:21:26 AM	9:22:27 AM	7	154	16	352	1	22
9:23:31 AM	9:24:33 AM	5	110	8	176	1	22
9:25:36 AM	9:26:37 AM	13	286	8	176	2	44
9:27:41 AM	9:28:43 AM	4	88	4	88	0	0
9:29:48 AM	9:30:46 AM	7	154	8	176	3	66
9:36:05 AM	9:37:02 AM	17	374	19+	418	2	44
9:38:09 AM	9:39:00 AM	20	440	13	286	5	110
9:40:05 AM	9:40:51 AM	15	330	7	154	0	0
9:42:05 AM	9:43:10 AM	6	132	8	176	0	0
9:44:26 AM	9:44:41 AM	4	88	7	154	1	22
9:47:06 AM	9:47:58 AM	14	308	19	418	1	22
9:49:03 AM	9:49:43 AM	6	132	5	110	2	44
9:50:49 AM	9:51:33 AM	9	198	7	154	1	22
9:54:01 AM	9:54:59 AM	7	154	9	198	1	22
9:55:58 AM	9:56:38 AM	8	176	7	154	1	22
9:57:44 AM	9:58:29 AM	4	88	4	88	0	0
9:59:41 AM	10:00:34 AM	6	132	7	154	1	22
10:01:11 AM	10:01:41 AM	1	22	2	44	2	44
10:05:16 AM	10:06:07 AM	12	264	15	330	0	0
10:07:18 AM	10:08:01 AM	3	66	3	66	1	22
10:09:09 AM	10:09:54 AM	5	110	4	88	1	22
10:11:04 AM	10:12:01 AM	5	110	4	88	1	22
10:13:12 AM	10:14:16 AM	3	66	4	88	1	22
10:18:17 AM	10:19:13 AM	16	352	13	286	1	22
10:20:25 AM	10:21:12 AM	15	330	13	286	2	44
10:22:23 AM	10:23:05 AM	15	330	10	220	0	0
10:24:08 AM	10:25:06 AM	4	88	8	176	1	22
10:26:15 AM	10:27:10 AM	7	154	7	154	3	66
10:28:20 AM	10:29:17 AM	3	66	3	66	2	44

Quality Counts
DATA THAT DRIVES COMMUNITIES

Site Code: 15782503
Date: 6/7/2022
Location: La Grange Rd & Burlington Ave
Time: 1:00 PM - 3:00 PM
Direction: Northbound

Start of Light Cycle	End of Light Cycle	NBR/T Vehicle Count	NBR/T Length in Feet	NBT Vehicle Count	NBT Length in Feet	NBL Vehicle Count	NBL Length in Feet
1:00:36 PM	1:01:31 PM	4	88	4	88	3	66
1:02:42 PM	1:03:37 PM	12	264	8	176	0	0
1:04:46 PM	1:05:41 PM	4	88	5	110	3	66
1:06:51 PM	1:07:46 PM	15	330	6	132	3	66
1:09:08 PM	1:09:51 PM	6	132	6	132	0	0
1:15:35 PM	1:16:19 PM	20+	506	21	462	0	0
1:17:38 PM	1:18:09 PM	21+	506	18	396	0	0
1:19:20 PM	1:20:07 PM	20	440	18	396	1	22
1:21:33 PM	1:22:21 PM	6	132	8	176	1	22
1:23:33 PM	1:24:26 PM	7	154	6	132	2	44
1:25:38 PM	1:26:31 PM	2	44	4	88	3	66
1:27:43 PM	1:28:36 PM	1	22	0	0	1	22
1:29:57 PM	1:30:52 PM	10	220	9	198	0	0
1:32:02 PM	1:32:46 PM	13	286	8	176	0	0
1:33:57 PM	1:34:08 PM	5	110	2	44	1	22
1:37:17 PM	1:38:12 PM	14	308	15	330	2	44
1:39:28 PM	1:40:10 PM	9	198	7	154	1	22
1:41:21 PM	1:42:10 PM	13	286	8	176	1	22
1:43:38 PM	1:44:38 PM	3	66	5	110	1	22
1:46:00 PM	1:46:20 PM	3	66	3	66	0	0
1:48:46 PM	1:49:50 PM	13	286	12	264	6	132
1:51:05 PM	1:51:37 PM	9	198	8	176	0	0
1:52:49 PM	1:53:34 PM	7	154	9	198	2	44
1:54:57 PM	1:55:41 PM	7	154	7	154	0	0
1:56:53 PM	1:57:46 PM	5	110	1	22	1	22
2:01:09 PM	2:02:06 PM	17	374	19	418	1	22
2:03:14 PM	2:03:47 PM	7	154	11	242	0	0
2:04:59 PM	2:05:48 PM	6	132	6	132	1	22
2:07:10 PM	2:08:10 PM	7	154	4	88	2	44
2:09:22 PM	2:10:17 PM	7	154	6	132	2	44
2:11:27 PM	2:12:21 PM	5	110	2	44	1	22
2:13:34 PM	2:14:27 PM	5	110	3	66	1	22
2:15:49 PM	2:16:32 PM	6	132	5	110	0	0
2:20:04 PM	2:20:56 PM	19	418	9	198	1	22
2:22:14 PM	2:22:59 PM	15	330	11	242	1	22
2:24:22 PM	2:24:53 PM	6	132	3	66	0	0
2:26:40 PM	2:27:37 PM	16	352	14	308	2	44
2:28:45 PM	2:29:29 PM	9	198	9	198	2	44
2:33:37 PM	2:34:30 PM	20+	506	21+	506	1	22
2:35:43 PM	2:36:16 PM	21+	506	18	396	0	0
2:37:33 PM	2:38:11 PM	21+	506	17	374	0	0
2:42:28 PM	2:43:21 PM	19+	506	22+	506	1	22
2:47:03 PM	2:47:49 PM	20+	506	21+	506	0	0
2:48:49 PM	2:48:55 PM	19	418	23	506	2	44
2:49:54 PM	2:50:48 PM	19	418	23	506	1	22
2:52:10 PM	2:52:43 PM	16	352	19	418	0	0
2:54:00 PM	2:54:28 PM	21	462	14	308	0	0
2:55:28 PM	2:56:09 PM	17	374	15	330	1	22
2:57:17 PM	2:58:10 PM	16	352	17	374	1	22
2:59:35 PM	Video End	12	264	9	198	0	0

Notes:
Queues continued through Harris Ave for some time frames. Instances where this occurred are marked with a "+" next to the vehicle count value.

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: La Grange N&S of RxR
Date: 06/07/22
Time: 8:30am-10:30am
Site Code: 15782512

Crossing Event Number	Crossing Actuation	Lead Train Car Crosses	Last Train Car Crosses	Traffic Resumes	Duration of Traffic Interruption	Track	Number of Train Cars	Type of Train (Passenger/Freight)	Train Directionality (NB/SB)	Did the Train Stop?	Train Stops Moving	Train Starts Moving Again	Dwell Time
1	8:30:49 AM	8:31:15 AM	8:32:53 AM	8:33:13 AM	02:24	South	8	Passenger	East	Yes	8:31:26 AM	8:32:24 AM	00:59
2	8:36:49 AM	8:37:22 AM	8:39:10 AM	8:39:27 AM	02:38	North	131	Freight	West	No			
		8:38:21 AM	8:38:29 AM			South	9	Passenger	East	No			
3	9:02:17 AM	N/A	N/A	9:03:18 AM	01:01	N/A	N/A	N/A	N/A	N/A			
4	9:04:01 AM	9:04:27 AM	9:05:30 AM	9:05:44 AM	01:43	South	8	Passenger	East	Yes	9:04:32 AM	9:05:39 AM	01:07
5	9:06:35 AM	9:07:09 AM	9:07:26 AM	9:07:51 AM	01:16	North	8	Passenger	West	No			
6	9:08:30 AM	9:08:46 AM	9:08:54 AM	9:09:07 AM	00:37	Mid	8	Passenger	East	No			
7	9:32:07 AM	9:32:40 AM	9:35:49 AM	9:36:09 AM	04:02	South	119	Freight	East	No			
8	9:44:43 AM	9:45:46 AM	9:46:50 AM	9:47:10 AM	02:27	South	7	Passenger	East	Yes	9:45:57 AM	9:46:27 AM	00:29
9	9:52:38 AM	9:53:07 AM	9:53:44 AM	9:54:05 AM	01:27	South	26	Freight	East	No			
10	10:01:41 AM	10:02:25 AM	10:02:52 AM	10:05:10 AM	03:29	North	8	Passenger	West	Yes	10:02:59 AM	10:03:40 AM	00:41
11	10:01:41 AM	10:03:17 AM	10:05:00 AM	10:05:10 AM	03:29	South	5	Passenger	East	Yes	10:03:24 AM	10:04:40 AM	01:16
12	10:14:37 AM	10:15:06 AM	10:18:01 AM	10:18:18 AM	03:41	South	102	Freight	East	No			

Notes:
Gate arms come down without train crossing at 9:02

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: La Grange N&S of RxR
Date: 06/07/22
Time: 1:00pm-3:00pm
Site Code: 15782512

Crossing Event Number	Crossing Actuation	Lead Train Car Crosses	Last Train Car Crosses	Traffic Resumes	Duration of Traffic Interruption	Track	Number of Train Cars	Type of Train (Passenger/Freight)	Train Directionality (NB/SB)	Did the Train Stop?	Train Stops Moving	Train Starts Moving Again	Dwell Time
1	1:11:08 PM	01:11:49 PM	01:13:56 PM	1:14:04 PM	02:56	Mid	106	Freight	East	No			
2	1:14:27 PM	01:14:52 PM	01:15:05 PM	1:15:17 PM	00:50	North	7	Passenger	West	No			
3	1:34:18 PM	01:34:46 PM	01:36:56 PM	1:37:06 PM	02:48	Mid	97	Freight	West	No			
4	1:46:30 PM	01:48:07 PM	01:48:25 PM	1:48:35 PM	02:05	South	7	Passenger	East	Yes	1:47:18 PM	1:48:00 PM	00:42
5	1:57:58 PM	01:58:26 AM	02:00:45 PM	2:00:58 PM	03:00	Mid	131	Freight	West	No			
		02:00:27 PM	02:00:43 PM			North	8	Passenger	West	Yes	2:00:56 PM	2:01:44 PM	00:48
6	2:16:51 PM	02:17:27 PM	02:19:42 PM	2:19:51 PM	03:00	South	115	Freight	East	No			
7	2:25:50 PM	02:26:11 PM	02:26:19 PM	2:26:27 PM	00:37	North	10	Passenger	West	No			
8	2:30:35 PM	02:30:54 PM	02:31:20 PM	2:33:24 PM	02:49	North	28	Freight	West	No			
		02:31:27 PM	02:33:15 PM			Mid	91	Freight	West	No			
9	2:39:42 PM	02:40:05 PM	02:42:07 PM	2:42:17 PM	02:35	Mid	124	Freight	West	Yes			
10	2:44:31 PM	02:46:13 PM	02:46:33 PM	2:46:45 PM	02:14	South	7	Passenger	East	No	2:45:17 PM	2:46:10 PM	00:53
11	2:49:05 PM	02:49:27 PM	02:49:27 PM	2:49:46 PM	00:41	North	9	Passenger	West	No			

Appendix C.
Cotulla, Texas, Site Simulation Model Data

Intersection Turning Movement Counts

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: N Main St & Tilden St
Date: 4/20/2022
Site Code: 15753302

Start Time	N Main St Southbound				Tilden St Westbound				N Main St Northbound				Tilden St Eastbound			
	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
03:15 PM	2	18	8	0	9	1	3	0	1	14	1	0	0	0	0	0
03:20 PM	0	20	9	0	4	0	2	0	0	21	1	0	1	3	1	0
03:25 PM	1	28	17	0	2	1	0	0	2	15	0	0	0	1	1	0
03:30 PM	2	29	8	0	9	2	3	0	6	10	0	0	1	1	0	0
03:35 PM	1	29	18	0	10	4	0	0	2	13	0	0	0	1	1	0
03:40 PM	1	15	8	0	9	1	2	0	6	17	0	0	0	1	1	0
03:45 PM	1	14	11	0	7	5	6	0	2	22	2	0	0	4	0	0
03:50 PM	0	19	8	0	8	4	7	0	10	14	1	0	2	9	2	0
03:55 PM	0	13	10	0	12	8	16	0	4	11	0	0	1	0	1	0
04:00 PM	0	16	8	0	9	3	5	0	4	16	0	0	0	3	1	0
04:05 PM	1	16	14	0	6	3	9	0	2	11	0	0	0	4	2	0
04:10 PM	0	23	3	0	17	2	4	0	6	20	0	0	0	0	5	0
04:15 PM	1	17	13	0	7	3	1	0	3	11	0	0	0	0	2	0
04:20 PM	0	11	9	0	6	0	3	0	1	15	0	0	0	0	0	0
04:25 PM	2	12	9	0	6	1	1	0	3	17	0	1	1	0	0	0
04:30 PM	2	11	14	0	11	4	4	0	2	10	0	0	1	1	0	0
04:35 PM	1	22	11	0	2	0	3	0	3	14	0	0	0	2	2	0
04:40 PM	0	22	3	0	15	2	6	0	1	14	0	0	0	1	0	0
04:45 PM	2	18	11	0	8	1	2	0	1	19	0	0	1	1	0	0
04:50 PM	2	21	7	0	7	1	2	0	1	19	1	0	0	2	0	0
04:55 PM	0	18	5	0	8	1	1	0	1	13	1	0	3	0	2	0
05:00 PM	0	20	13	0	11	3	4	0	1	23	1	0	2	2	1	0
05:05 PM	0	9	10	0	8	2	4	0	5	32	0	0	0	0	0	0
05:10 PM	1	21	7	0	10	0	3	0	6	12	0	0	0	1	2	0
05:15 PM	3	20	12	0	9	2	4	0	4	21	1	0	3	2	1	0
05:20 PM	2	36	15	0	13	2	4	0	1	20	0	0	0	0	2	0
05:25 PM	0	26	5	0	11	1	4	0	1	14	0	0	0	1	0	0
Total	**25**	**524**	**266**	**0**	**234**	**57**	**103**	**0**	**79**	**438**	**9**	**1**	**16**	**40**	**27**	**0**

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: N Main St & Tilden St
Date: 4/21/2022
Site Code: 15753304

	N Main St Southbound				Tilden St Westbound				N Main St Northbound				Tilden St Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
05:00 PM	1	13	13	0	9	4	3	0	6	20	0	0	1	5	3	0
05:05 PM	1	29	11	0	8	2	3	0	4	28	1	0	0	2	0	0
05:10 PM	3	22	7	0	8	1	6	0	4	19	1	0	1	3	0	0
05:15 PM	1	25	9	0	6	0	3	0	5	17	1	0	0	5	1	0
05:20 PM	1	26	9	0	5	3	5	0	5	21	0	0	0	1	1	0
05:25 PM	0	25	7	0	6	0	6	0	1	16	0	0	0	0	1	0
05:30 PM	2	18	12	0	9	0	3	0	4	16	0	0	0	0	1	0
05:35 PM	1	22	4	0	18	1	4	0	3	18	0	0	0	0	1	0
05:40 PM	1	20	8	0	8	2	2	0	5	18	0	0	2	0	0	0
05:45 PM	0	20	5	0	10	0	2	0	2	19	0	0	0	1	0	0
05:50 PM	2	17	4	0	10	0	4	0	4	10	1	0	0	0	1	0
05:55 PM	0	16	5	0	5	0	3	0	1	12	0	0	0	0	0	0
06:00 PM	0	20	8	0	15	4	3	0	3	17	0	0	1	0	0	0
06:05 PM	0	16	4	0	7	1	3	0	1	14	1	0	0	2	0	0
06:10 PM	0	17	6	0	9	0	5	0	1	10	1	0	1	0	0	0
06:15 PM	1	25	8	0	5	3	4	0	4	22	0	0	0	0	0	0
06:20 PM	0	22	6	0	7	1	4	0	5	17	1	0	0	0	0	0
06:25 PM	1	23	4	0	2	1	3	0	1	5	1	0	0	0	1	0
06:30 PM	0	18	3	0	15	4	2	0	7	18	0	0	2	0	0	0
06:35 PM	0	17	4	0	7	0	0	0	0	15	0	0	0	1	0	0
06:40 PM	0	20	7	0	12	1	1	0	2	18	4	0	0	0	0	0
06:45 PM	0	16	9	0	2	0	2	0	3	14	1	0	0	0	0	0
06:50 PM	2	13	2	0	4	0	0	0	5	11	2	0	1	0	1	0
06:55 PM	0	21	6	0	4	0	0	0	2	18	1	0	0	0	1	0
Total	**17**	**481**	**161**	**0**	**191**	**28**	**71**	**0**	**78**	**393**	**16**	**0**	**9**	**20**	**12**	**0**

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: N Front St & Tilden St
Date: 4/20/2022
Site Code: 15753306

	N Front St Southbound				Tilden St Westbound				N Front St Northbound				Tilden St Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
03:15 PM	2	1	2	0	2	9	2	0	1	0	1	0	0	8	1	0
03:20 PM	2	3	3	0	3	4	3	0	2	2	1	0	2	11	1	0
03:25 PM	1	1	3	0	2	6	2	0	1	1	1	0	1	16	1	0
03:30 PM	1	3	3	0	1	13	0	0	0	0	0	0	1	12	1	0
03:35 PM	0	2	3	0	2	12	0	0	2	5	0	0	0	19	1	0
03:40 PM	2	4	3	0	5	12	1	0	3	3	0	0	2	15	1	0
03:45 PM	3	2	2	0	2	12	1	0	2	1	2	0	1	17	0	0
03:50 PM	1	0	1	0	8	21	0	0	2	1	0	0	0	27	1	0
03:55 PM	1	4	2	0	10	31	0	0	2	2	0	0	0	17	1	0
04:00 PM	1	4	4	0	0	18	2	0	0	4	0	0	1	12	0	0
04:05 PM	2	1	1	0	4	16	0	0	1	0	2	0	2	17	2	0
04:10 PM	3	4	0	0	2	19	1	0	0	1	0	0	1	6	0	0
04:15 PM	3	2	0	0	5	9	5	0	1	3	1	0	1	19	0	0
04:20 PM	0	4	4	0	1	10	0	0	0	3	1	0	1	9	1	0
04:25 PM	0	3	2	0	2	7	0	0	1	2	0	0	1	11	0	0
04:30 PM	1	5	1	0	0	19	0	0	0	3	1	0	1	13	2	0
04:35 PM	0	2	1	0	1	5	1	0	1	0	0	0	0	16	2	0
04:40 PM	1	5	3	0	1	26	0	0	0	2	1	0	0	7	0	0
04:45 PM	2	2	1	0	1	8	0	0	0	1	1	0	0	14	2	0
04:50 PM	0	0	0	0	1	11	0	0	0	1	0	0	1	8	0	0
04:55 PM	0	5	0	0	2	9	1	0	0	3	1	0	1	8	0	0
05:00 PM	2	3	0	0	2	16	0	0	1	3	2	0	2	15	0	0
05:05 PM	3	4	2	0	4	13	2	0	1	3	1	0	1	15	1	0
05:10 PM	0	2	2	0	5	14	1	0	0	1	0	0	0	11	0	0
Total	**31**	**66**	**43**	**0**	**66**	**320**	**22**	**0**	**21**	**45**	**16**	**0**	**20**	**323**	**18**	**0**

Quality Counts
DATA THAT DRIVES COMMUNITIES

Location: N Front St & Tilden St
Date: 4/21/2022
Site Code: 15753308

	N Front St Southbound				Tilden St Westbound				N Front St Northbound				Tilden St Eastbound			
Start Time	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn	Right	Thru	Left	U-Turn
05:00 PM	1	3	3	0	4	14	0	0	0	2	1	0	1	21	0	0
05:05 PM	0	2	2	0	2	12	0	0	1	6	1	0	1	15	0	0
05:10 PM	0	5	1	0	1	17	0	0	0	2	1	0	2	13	0	0
05:15 PM	1	0	1	0	2	9	1	0	0	0	1	0	0	19	2	0
05:20 PM	1	2	3	0	3	12	0	0	0	3	2	0	2	13	1	0
05:25 PM	0	3	3	0	4	12	1	0	3	3	1	0	0	10	1	0
05:30 PM	0	3	4	0	1	11	0	0	0	1	1	0	0	15	0	0
05:35 PM	0	3	2	0	0	21	1	0	2	4	1	0	1	9	0	0
05:40 PM	1	3	3	0	5	8	2	0	0	1	1	0	1	13	0	0
05:45 PM	1	2	2	0	2	13	0	0	0	3	0	0	0	11	1	0
05:50 PM	0	5	1	0	4	13	0	0	0	3	0	0	0	7	0	0
05:55 PM	0	4	1	0	0	11	0	0	1	1	0	0	0	7	0	0
06:00 PM	0	3	0	0	1	21	0	0	1	4	0	0	1	10	0	0
06:05 PM	2	4	1	0	1	5	0	0	1	3	2	0	1	9	0	0
06:10 PM	1	1	0	0	3	14	0	0	1	3	0	0	1	7	0	0
06:15 PM	0	1	3	0	2	13	1	0	0	1	0	0	4	8	0	0
06:20 PM	1	3	3	0	2	10	0	0	1	2	0	0	0	11	0	0
06:25 PM	0	2	0	0	1	4	0	0	0	2	1	0	1	4	0	0
06:30 PM	0	2	2	0	4	20	1	0	1	3	1	0	0	12	1	0
06:35 PM	0	1	0	0	2	6	2	0	0	2	1	0	0	5	1	0
06:40 PM	0	2	0	0	0	12	1	0	1	1	2	0	1	9	0	0
06:45 PM	0	1	0	0	4	5	1	0	0	3	1	0	1	9	1	0
06:50 PM	0	4	1	0	1	5	0	0	0	3	0	0	1	9	1	0
06:55 PM	1	2	0	0	2	2	2	0	0	4	2	0	0	6	0	0
Total	**10**	**61**	**36**	**0**	**51**	**270**	**13**	**0**	**13**	**60**	**20**	**0**	**19**	**252**	**9**	**0**

Vehicle Queues

Quality Counts
DATA THAT DRIVES COMMUNITIES

Site Code: 15753301
Date: 4/20/2022
Location: N Main St & Tilden St
Time: 3:15 PM - 5:30 PM
Direction: Southbound

Start of Light Cycle	End of Light Cycle	SBR/T Number of Vehicles	SBR/T Length in Feet	SBL Number of Vehicles	SBL Length in Feet
3:16:05 PM	3:16:31 PM	0	0	0	0
3:16:47 PM	3:17:09 PM	2	44	1	22
3:17:41 PM	3:18:22 PM	2	44	4	88
3:18:37 PM	3:19:23 PM	1	22	1	22
3:19:40 PM	3:20:26 PM	1	22	2	44
3:20:44 PM	3:21:06 PM	1	22	0	0
3:21:25 PM	3:22:29 PM	1	22	0	0
3:22:43 PM	3:23:09 PM	0	0	0	0
3:23:26 PM	3:24:42 PM	0	0	1	22
3:24:54 PM	3:26:11 PM	1	22	1	22
3:26:29 PM	3:27:10 PM	2	44	2	44
3:27:27 PM	3:28:48 PM	1	22	2	44
3:29:11 PM	3:29:36 PM	1	22	0	0
3:29:48 PM	3:30:17 PM	1	22	1	22
3:30:32 PM	3:31:06 PM	1	22	0	0
3:31:26 PM	3:32:02 PM	0	0	0	0
3:32:22 PM	3:32:59 PM	1	22	1	22
3:33:12 PM	3:33:44 PM	1	22	2	44
3:34:08 PM	3:34:42 PM	2	44	1	22
3:34:56 PM	3:35:38 PM	1	22	1	22
3:35:52 PM	3:36:32 PM	0	0	4	88
3:36:46 PM	3:37:55 PM	1	22	1	22
3:38:14 PM	3:39:01 PM	2	44	2	44
3:39:26 PM	3:40:25 PM	0	0	1	22
3:41:01 PM	3:42:12 PM	0	0	1	22
3:42:25 PM	3:43:40 PM	1	22	0	0
3:44:10 PM	3:45:01 PM	1	22	3	66
3:45:36 PM	3:45:59 PM	1	22	0	0
3:46:10 PM	3:46:54 PM	2	44	0	0
3:47:10 PM	3:48:21 PM	0	0	1	22
3:48:43 PM	3:49:10 PM	0	0	0	0
3:49:23 PM	3:50:10 PM	0	0	0	0
3:50:22 PM	3:51:13 PM	0	0	2	44
3:51:46 PM	3:52:33 PM	1	22	2	44
3:53:05 PM	3:53:30 PM	1	22	0	0
3:53:52 PM	3:54:07 PM	0	0	0	0
3:54:41 PM	3:55:25 PM	0	0	3	66
3:55:53 PM	3:56:41 PM	0	0	4	88
3:57:19 PM	3:57:56 PM	1	22	1	22
3:58:31 PM	3:59:21 PM	2	44	2	44
3:59:44 PM	4:00:53 PM	1	22	0	0
4:01:25 PM	4:02:32 PM	1	22	0	0
4:02:45 PM	4:03:04 PM	1	22	0	0
4:03:27 PM	4:04:07 PM	1	22	0	0
4:04:28 PM	4:05:11 PM	2	44	1	22
4:05:28 PM	4:06:09 PM	2	44	2	44
4:06:22 PM	4:06:59 PM	0	0	3	66
4:07:20 PM	4:07:41 PM	0	0	0	0
4:08:17 PM	4:09:04 PM	0	0	3	66
4:09:30 PM	4:10:26 PM	0	0	1	22
4:10:47 PM	4:11:23 PM	2	44	2	44
4:11:33 PM	4:12:27 PM	1	22	1	22
4:13:02 PM	4:15:05 PM	2	44	0	0
4:15:16 PM	4:15:38 PM	1	22	0	0
4:15:54 PM	4:17:09 PM	0	0	4	88
4:17:25 PM	4:18:04 PM	1	22	2	44
4:18:19 PM	4:19:38 PM	0	0	0	0
4:19:50 PM	4:20:13 PM	1	22	0	0
4:20:25 PM	4:22:10 PM	0	0	0	0
4:22:28 PM	4:23:16 PM	1	22	4	88
4:23:31 PM	4:24:14 PM	1	22	0	0
4:24:32 PM	4:25:22 PM	1	22	1	22
4:25:34 PM	4:28:45 PM	0	0	0	0
4:29:07 PM	4:29:59 PM	0	0	0	0
4:30:32 PM	4:30:52 PM	0	0	1	22
4:31:06 PM	4:32:02 PM	1	22	0	0
4:32:20 PM	4:33:27 PM	0	0	0	0
4:33:39 PM	4:34:19 PM	1	22	1	22
4:34:39 PM	4:35:19 PM	4	88	2	44
4:35:31 PM	4:36:27 PM	1	22	0	0
4:36:35 PM	4:37:05 PM	1	22	1	22
4:37:21 PM	4:37:50 PM	0	0	1	22
4:38:02 PM	4:39:08 PM	0	0	0	0
4:39:20 PM	4:40:19 PM	1	22	0	0
4:40:52 PM	4:41:36 PM	2	44	1	22
4:41:58 PM	4:42:47 PM	2	44	1	22
4:43:15 PM	4:44:08 PM	3	66	1	22
4:44:22 PM	4:44:54 PM	1	22	0	0
4:45:10 PM	4:45:54 PM	1	22	2	44
4:46:15 PM	4:46:49 PM	0	0	0	0
4:47:00 PM	4:50:20 PM	0	0	0	0
4:50:33 PM	4:51:22 PM	0	0	1	22
4:51:56 PM	4:53:06 PM	3	66	0	0
4:53:21 PM	4:55:29 PM	1	22	0	0
4:56:14 PM	4:56:42 PM	0	0	0	0
4:56:56 PM	4:57:44 PM	0	0	1	22
4:57:58 PM	4:58:26 PM	2	44	1	22
4:58:40 PM	4:59:03 PM	1	22	1	22
4:59:32 PM	5:01:11 PM	1	22	1	22
5:01:36 PM	5:02:43 PM	3	66	2	44
5:03:15 PM	5:05:33 PM	1	22	2	44
5:06:02 PM	5:06:59 PM	0	0	1	22
5:07:26 PM	5:08:12 PM	0	0	1	22
5:08:23 PM	5:09:10 PM	1	22	2	44
5:09:27 PM	5:11:10 PM	2	44	2	44
5:11:23 PM	5:12:04 PM	0	0	0	0
5:12:18 PM	5:12:45 PM	0	0	0	0
5:13:23 PM	5:14:04 PM	2	44	5	110
5:14:39 PM	5:16:02 PM	1	22	4	88
5:16:20 PM	5:17:25 PM	0	0	2	44
5:17:48 PM	5:18:28 PM	1	22	1	22
5:19:01 PM	5:19:55 PM	1	22	2	44
5:20:16 PM	5:21:00 PM	1	22	2	44
5:21:11 PM	5:21:37 PM	2	44	3	66
5:21:55 PM	5:23:16 PM	1	22	1	22
5:23:36 PM	5:24:24 PM	1	22	1	22
5:24:36 PM	5:25:39 PM	0	0	1	22
5:26:13 PM	5:26:52 PM	3	66	1	22
5:27:07 PM	5:27:28 PM	0	0	2	44
5:27:51 PM	5:30:46 PM	2	44	2	44

Quality Counts
DATA THAT DRIVES COMMUNITIES

Site Code: 15753301
Date: 4/20/2022
Location: N Main St & Tilden St
Time: 3:15 PM - 5:30 PM
Direction: Westbound

Start of Light Cycle	End of Light Cycle	WB Number of Vehicles	WB Length in Feet
3:17:34 PM	3:17:47 PM	2	44
3:18:17 PM	3:18:38 PM	1	22
3:18:56 PM	3:19:39 PM	3	66
3:20:02 PM	3:20:42 PM	1	22
3:21:03 PM	3:23:01 PM	3	66
3:23:29 PM	3:24:22 PM	1	22
3:24:41 PM	3:25:05 PM	1	22
3:25:27 PM	3:28:13 PM	1	22
3:28:49 PM	3:30:06 PM	5	110
3:30:29 PM	3:30:51 PM	4	88
3:31:13 PM	3:32:27 PM	1	22
3:32:48 PM	3:33:16 PM	1	22
3:33:36 PM	3:34:50 PM	2	44
3:35:27 PM	3:36:08 PM	4	88
3:36:37 PM	3:36:38 PM	2	44
3:37:02 PM	3:37:31 PM	1	22
3:38:11 PM	3:38:55 PM	3	66
3:39:20 PM	3:40:10 PM	1	22
3:40:37 PM	3:41:22 PM	1	22
3:42:08 PM	3:43:17 PM	2	44
3:43:50 PM	3:44:07 PM	1	22
3:45:16 PM	3:45:36 PM	5	110
3:46:40 PM	3:47:14 PM	3	66
3:47:35 PM	3:47:51 PM	2	44
3:48:31 PM	3:49:24 PM	1	22
3:50:00 PM	3:52:12 PM	1	22
3:52:51 PM	3:53:25 PM	8	176
3:54:10 PM	3:54:42 PM	5	110
3:55:07 PM	3:55:29 PM	4	88
3:55:46 PM	3:56:23 PM	7	154
3:57:01 PM	3:57:27 PM	7	154
3:58:16 PM	3:58:55 PM	3	66
3:59:34 PM	4:00:08 PM	9	198
4:00:56 PM	4:03:02 PM	4	88
4:03:28 PM	4:03:44 PM	1	22
4:04:10 PM	4:04:18 PM	2	44
4:04:41 PM	4:05:04 PM	3	66
4:05:45 PM	4:06:17 PM	2	44
4:06:49 PM	4:08:03 PM	1	22
4:08:38 PM	4:09:00 PM	1	22
4:09:19 PM	4:09:51 PM	5	110
4:10:42 PM	4:11:20 PM	4	88
4:12:02 PM	4:12:42 PM	2	44
4:12:53 PM	4:13:11 PM	1	22
4:14:07 PM	4:14:40 PM	3	66
4:15:26 PM	4:16:27 PM	3	66
4:16:44 PM	4:16:57 PM	2	44
4:17:15 PM	4:17:56 PM	2	44
4:18:48 PM	4:19:21 PM	3	66
4:19:48 PM	4:20:11 PM	2	44
4:21:16 PM	4:20:49 PM	1	22
4:21:17 PM	4:22:06 PM	1	22
4:23:47 PM	4:24:11 PM	2	44
4:24:37 PM	4:25:02 PM	3	66
4:25:52 PM	4:26:05 PM	2	44
4:27:01 PM	4:27:17 PM	4	88
4:30:24 PM	4:30:46 PM	4	88
4:31:32 PM	4:32:09 PM	2	44
4:32:26 PM	4:33:57 PM	4	88
4:34:15 PM	4:34:41 PM	1	22
4:35:04 PM	4:36:15 PM	1	22
4:36:58 PM	4:37:14 PM	1	22
4:38:44 PM	4:38:59 PM	2	44
4:39:29 PM	4:39:40 PM	1	22
4:40:46 PM	4:41:01 PM	2	44
4:41:58 PM	4:42:31 PM	2	44
4:42:31 PM	4:43:35 PM	2	44
4:44:15 PM	4:44:54 PM	2	44
4:45:33 PM	4:45:58 PM	1	22
4:46:32 PM	4:46:47 PM	1	22
4:47:29 PM	4:47:46 PM	2	44
4:48:22 PM	4:48:38 PM	0	0
4:49:33 PM	4:49:39 PM	0	0
4:51:55 PM	4:52:08 PM	0	0
4:52:58 PM	4:53:31 PM	5	110
4:54:44 PM	4:54:58 PM	0	0
4:57:06 PM	4:57:51 PM	1	22
4:58:21 PM	4:58:31 PM	0	0
4:59:13 PM	4:59:37 PM	1	22
4:59:56 PM	5:00:18 PM	0	0
5:00:39 PM	5:01:08 PM	6	132
5:02:47 PM	5:03:15 PM	1	22
5:04:19 PM	5:04:52 PM	2	44
5:07:09 PM	5:07:36 PM	6	132
5:08:41 PM	5:09:00 PM	2	44
5:09:48 PM	5:10:03 PM	1	22
5:10:45 PM	5:11:03 PM	2	44
5:12:47 PM	5:12:58 PM	0	0
5:13:39 PM	5:13:53 PM	0	0
5:14:18 PM	5:15:01 PM	3	66
5:15:46 PM	5:16:17 PM	7	154
5:17:38 PM	5:17:58 PM	0	0
5:18:59 PM	5:19:25 PM	2	44
5:20:04 PM	5:20:39 PM	5	110
5:21:34 PM	5:21:52 PM	3	66
5:22:34 PM	5:22:46 PM	1	22
5:23:20 PM	5:23:29 PM	0	0
5:24:52 PM	5:25:15 PM	0	0
5:26:01 PM	5:26:14 PM	1	22
5:27:15 PM	5:27:15 PM	2	44
5:28:27 PM	5:28:45 PM	2	44
5:29:03 PM	5:29:30 PM	3	66

Quality Counts
DATA THAT DRIVES COMMUNITIES

Site Code: 15753301
Date: 4/21/2022
Location: N Main St & Tilden St
Time: 5:00 PM - 7:00 PM
Direction: Southbound

Start of Light Cycle	End of Light Cycle	SBR/T Number of Vehicles	SBR/T Length in Feet	SBL Number of Vehicles	SBL Length in Feet
5:00:13 PM	5:01:34 PM	0	0	5	110
5:02:06 PM	5:03:02 PM	0	0	2	44
5:03:24 PM	5:04:28 PM	2	44	2	44
5:04:53 PM	5:05:58 PM	0	0	1	22
5:06:11 PM	5:06:50 PM	1	22	2	44
5:07:13 PM	5:09:35 PM	0	0	1	22
5:09:51 PM	5:10:17 PM	5	110	3	66
5:10:37 PM	5:11:18 PM	1	22	0	0
5:11:38 PM	5:12:00 PM	0	0	0	0
5:12:14 PM	5:12:33 PM	2	44	2	44
5:12:54 PM	5:13:36 PM	1	22	2	44
5:14:08 PM	5:15:06 PM	0	0	1	22
5:15:18 PM	5:16:54 PM	4	88	3	66
5:17:28 PM	5:18:20 PM	1	22	2	44
5:18:39 PM	5:19:42 PM	3	66	3	66
5:20:11 PM	5:21:25 PM	1	22	1	22
5:21:48 PM	5:22:27 PM	0	0	2	44
5:22:51 PM	5:24:49 PM	1	22	0	0
5:25:01 PM	5:27:39 PM	1	22	0	0
5:27:51 PM	5:28:17 PM	0	0	1	22
5:28:26 PM	5:30:16 PM	0	0	3	66
5:30:44 PM	5:32:38 PM	2	44	3	66
5:33:07 PM	5:35:36 PM	3	66	1	22
5:36:14 PM	5:36:54 PM	1	22	0	0
5:37:21 PM	5:37:44 PM	0	0	1	22
5:38:15 PM	5:38:56 PM	1	22	1	22
5:39:03 PM	5:40:12 PM	1	22	0	0
5:40:31 PM	5:43:15 PM	1	22	1	22
5:43:33 PM	5:43:58 PM	1	22	1	22
5:44:12 PM	5:45:59 PM	1	22	1	22
5:46:17 PM	5:47:07 PM	0	0	2	44
5:47:24 PM	5:50:56 PM	1	22	2	44
5:51:19 PM	5:51:33 PM	2	44	2	44
5:52:05 PM	5:52:43 PM	1	22	0	0
5:53:15 PM	5:54:24 PM	0	0	0	0
5:54:37 PM	5:58:48 PM	1	22	0	0
5:59:04 PM	5:59:36 PM	1	22	1	22
5:59:50 PM	6:00:41 PM	0	0	3	66
6:00:54 PM	6:01:23 PM	1	22	2	44
6:01:46 PM	6:03:01 PM	0	0	1	22
6:03:17 PM	6:03:46 PM	0	0	0	0
6:04:08 PM	6:04:24 PM	0	0	1	22
6:04:39 PM	6:05:27 PM	2	44	1	22
6:05:49 PM	6:06:30 AM	2	44	0	0
6:06:45 PM	6:08:15 PM	0	0	0	0
6:08:34 PM	6:10:21 PM	0	0	1	22
6:10:48 PM	6:11:21 PM	0	0	4	88
6:38:00 PM	6:12:47 PM	0	0	1	22
6:12:59 PM	6:14:44 PM	0	0	0	0
6:14:58 PM	6:16:08 PM	0	0	0	0
6:16:20 PM	6:16:42 PM	1	22	0	0
6:17:02 PM	6:18:14 PM	1	22	0	0
6:18:29 PM	6:19:06 PM	0	0	3	66
6:19:28 PM	6:20:45 PM	0	0	2	44
6:20:58 PM	6:22:42 PM	0	0	1	22
6:22:51 PM	6:23:11 PM	1	22	0	0
6:23:42 PM	6:24:05 PM	0	0	0	0
6:24:22 PM	6:25:23 PM	0	0	3	66
6:25:42 PM	6:27:08 PM	1	22	0	0
6:27:21 PM	6:27:39 PM	1	22	1	22
6:27:52 PM	6:28:18 PM	1	22	0	0
6:28:28 PM	6:30:45 PM	2	44	2	44
6:31:08 PM	6:31:48 PM	2	44	0	0
6:32:06 PM	6:33:48 PM	1	22	1	22
6:34:07 PM	6:35:32 PM	0	0	0	0
6:35:42 PM	6:37:15 PM	0	0	0	0
6:37:30 PM	6:39:06 PM	1	22	2	44
6:39:14 PM	6:41:18 PM	1	22	2	44
6:41:53 PM	6:42:27 PM	0	0	1	22
6:42:42 PM	6:44:47 PM	0	0	1	22
6:45:00 PM	6:46:00 PM	2	44	2	44
6:46:30 PM	6:51:45 PM	0	0	0	0
6:52:00 PM	6:57:10 PM	0	0	0	0
6:57:20 PM	6:58:23 PM	0	0	1	22
6:58:35 PM	6:59:06 PM	0	0	1	22

Quality Counts
DATA THAT DRIVES COMMUNITIES

Site Code: 15753301
Date: 4/21/2022
Location: N Main St & Tilden St
Time: 5:00 PM - 7:00 PM
Direction: Westbound

Start of Light Cycle	End of Light Cycle	WB Number of Vehicles	WB Length in Feet
5:00:28 PM	5:01:03 PM	1	22
5:02:07 PM	5:02:40 PM	1	22
5:03:34 PM	5:04:13 PM	3	66
5:05:00 PM	5:05:24 PM	1	22
5:06:30 PM	5:06:45 PM	2	44
5:07:23 PM	5:07:45 PM	3	66
5:08:40 PM	5:08:52 PM	2	44
5:10:06 PM	5:10:23 PM	0	0
5:10:50 PM	5:11:12 PM	1	22
5:11:35 PM	5:12:10 PM	2	44
5:12:34 PM	5:12:48 PM	1	22
5:13:10 PM	5:13:48 PM	2	44
5:14:15 PM	5:14:42 PM	1	22
5:15:40 PM	5:15:53 PM	1	22
5:17:32 PM	5:18:02 PM	3	66
5:20:20 PM	5:20:46 PM	3	66
5:21:56 PM	5:22:22 PM	4	88
5:23:02 PM	5:23:25 PM	2	44
5:25:20 PM	5:25:35 PM	1	22
5:27:32 PM	5:27:50 PM	2	44
5:28:12 PM	5:28:25 PM	1	22
5:28:43 PM	5:29:00 PM	1	22
5:29:56 PM	5:30:11 PM	1	22
5:30:50 PM	5:31:15 PM	2	44
5:37:17 PM	5:33:41 PM	3	66
5:35:39 PM	5:35:51 PM	1	22
5:36:12 PM	5:36:49 PM	3	66
5:37:28 PM	5:37:50 PM	1	22
5:38:20 PM	5:38:50 PM	1	22
5:39:31 PM	5:39:37 PM	2	44
5:40:44 PM	5:41:04 PM	1	22
5:42:33 PM	5:42:46 PM	1	22
5:43:47 PM	5:44:02 PM	2	44
5:44:30 PM	5:44:45 PM	2	44
5:46:31 PM	5:46:45 PM	1	22
5:47:40 PM	5:47:50 PM	0	0
5:48:55 PM	5:49:10 PM	4	88
5:51:30 PM	5:51:53 PM	1	22
5:52:10 PM	5:52:40 PM	2	44
5:53:17 PM	5:53:47 PM	4	88
5:54:56 PM	5:55:05 PM	1	22
5:59:20 PM	5:59:34 PM	2	44
6:00:10 PM	6:00:21 PM	1	22
6:01:14 PM	6:01:25 PM	2	44
6:01:56 PM	6:02:18 PM	1	22
6:02:40 PM	6:02:50 PM	2	44
6:03:35 PM	6:03:50 PM	2	44
6:04:19 PM	6:04:35 PM	3	66
6:05:00 PM	6:05:09 PM	1	22
6:06:00 PM	6:06:20 PM	3	66
6:07:05 PM	6:07:15 PM	1	22
6:08:47 PM	6:09:00 PM	1	22
6:09:50 PM	6:10:07 PM	0	0
6:11:06 PM	6:11:22 PM	1	22
6:11:56 PM	6:12:17 PM	1	22
6:13:14 PM	6:13:32 PM	0	0
6:15:10 PM	6:15:30 PM	0	0
6:16:42 PM	6:16:53 PM	1	22
6:17:24 PM	6:17:38 PM	0	0
6:18:50 PM	6:19:04 PM	0	0
6:19:42 PM	6:20:03 PM	2	44
6:21:18 PM	6:21:30 PM	1	22
6:23:13 PM	6:23:22 PM	0	0
6:23:45 AM	6:24:15 PM	4	88
6:24:38 PM	6:24:53 PM	2	44
6:25:57 PM	6:26:15 PM	3	66
6:26:56 PM	6:27:07 PM	1	22
6:27:43 PM	6:27:53 PM	1	22
6:28:15 PM	6:28:24 PM	1	22
6:28:50 AM	6:29:02 PM	0	0
6:31:15 PM	6:31:41 PM	1	22
6:32:28 PM	6:32:40 PM	1	22
6:33:24 PM	6:33:39 PM	1	22
6:34:25 PM	6:34:42 PM	2	44
6:36:03 PM	6:36:17 PM	1	22
6:37:50 PM	6:38:01 PM	1	22
6:39:34 PM	6:39:48 AM	2	44
6:41:50 PM	6:42:25 PM	1	22
6:43:04 PM	6:43:17 PM	1	22
6:45:23 PM	6:45:35 PM	1	22
6:46:36 PM	6:47:03 PM	3	66
6:52:20 PM	6:52:32 PM	0	0
6:53:31 PM	6:53:44 PM	0	0
6:57:44 PM	6:57:55 PM	0	0
6:58:57 PM	6:59:08 PM	0	0

Train Crossings

Site Code: 15753303
Date: 4/20/2022
Location: RXR & Tilden St
Time: 3:15 PM - 5:30 PM

Train crossing begins - Gate closes	Train crossing ends - Gate opens	EB Number of Vehicles	Extends Beyond View?	WB Number of Vehicles	Extends Beyond View?
3:30:32 PM	3:33:25 PM	11	Yes	6	No
4:07:38 PM	4:08:59 PM	7	Yes	6	No
4:50:24 PM	4:52:36 PM	2	Yes	5	No
5:11:29 PM	5:14:11 PM	6	Yes	15	Yes

Site Code: 15753303
Date: 4/21/2022
Location: RXR & Tilden St
Time: 5:00 PM - 7:00 PM

Train crossing begins - Gate closes	Train crossing ends - Gate opens	EB Number of Vehicles	Extends Beyond View?	WB Number of Vehicles	Extends Beyond View?
5:16:23 PM	5:16:46 PM	1	No	1	No
6:26:55 PM	6:31:14 PM	7	Yes	10	No
6:45:29 PM	6:46:02 PM	1	No	0	No

Appendix D.
Site Simulation Screen Capture Images

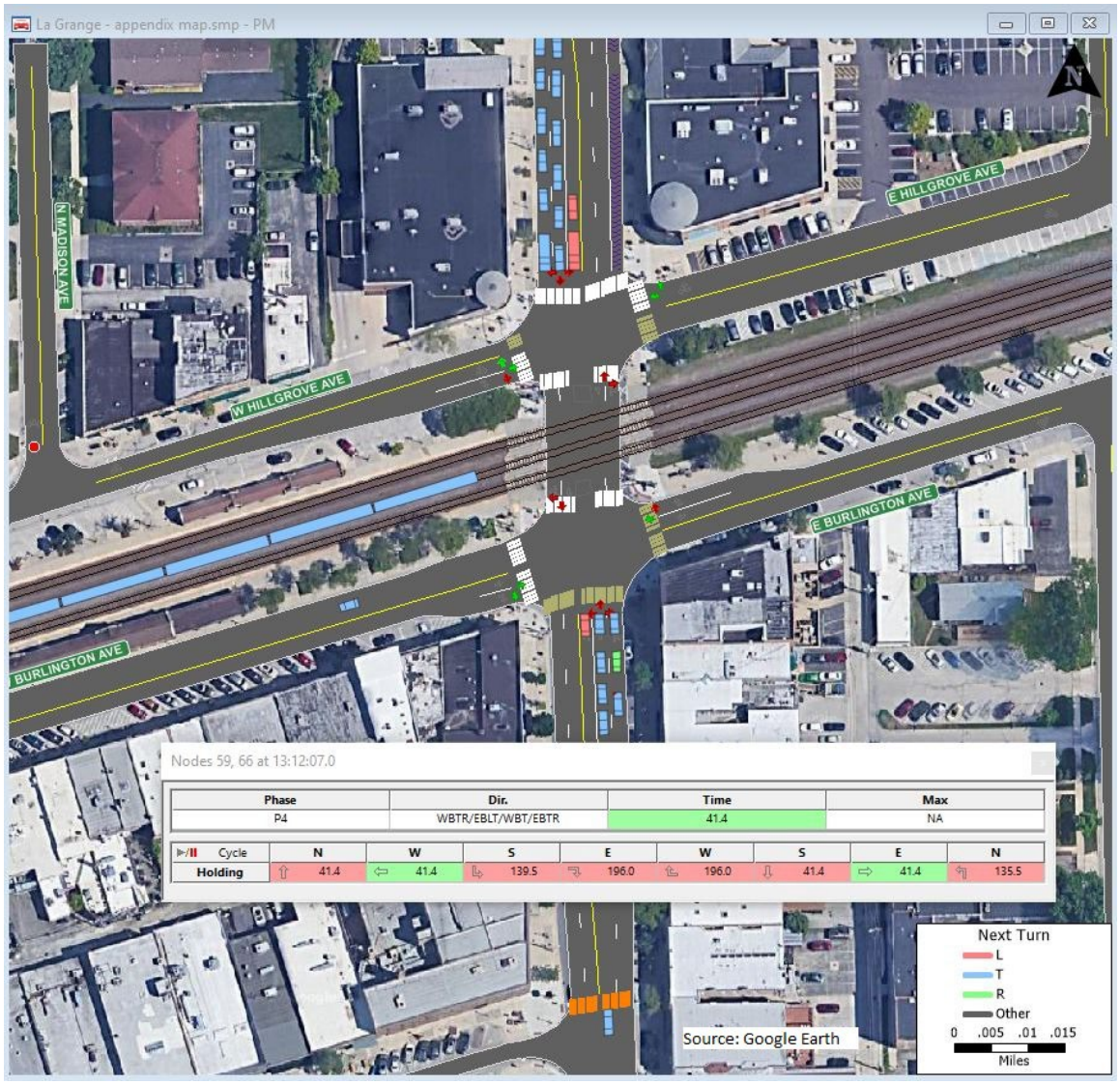

Figure D-1. Signal Preemption State – La Grange, IL, Site Simulation

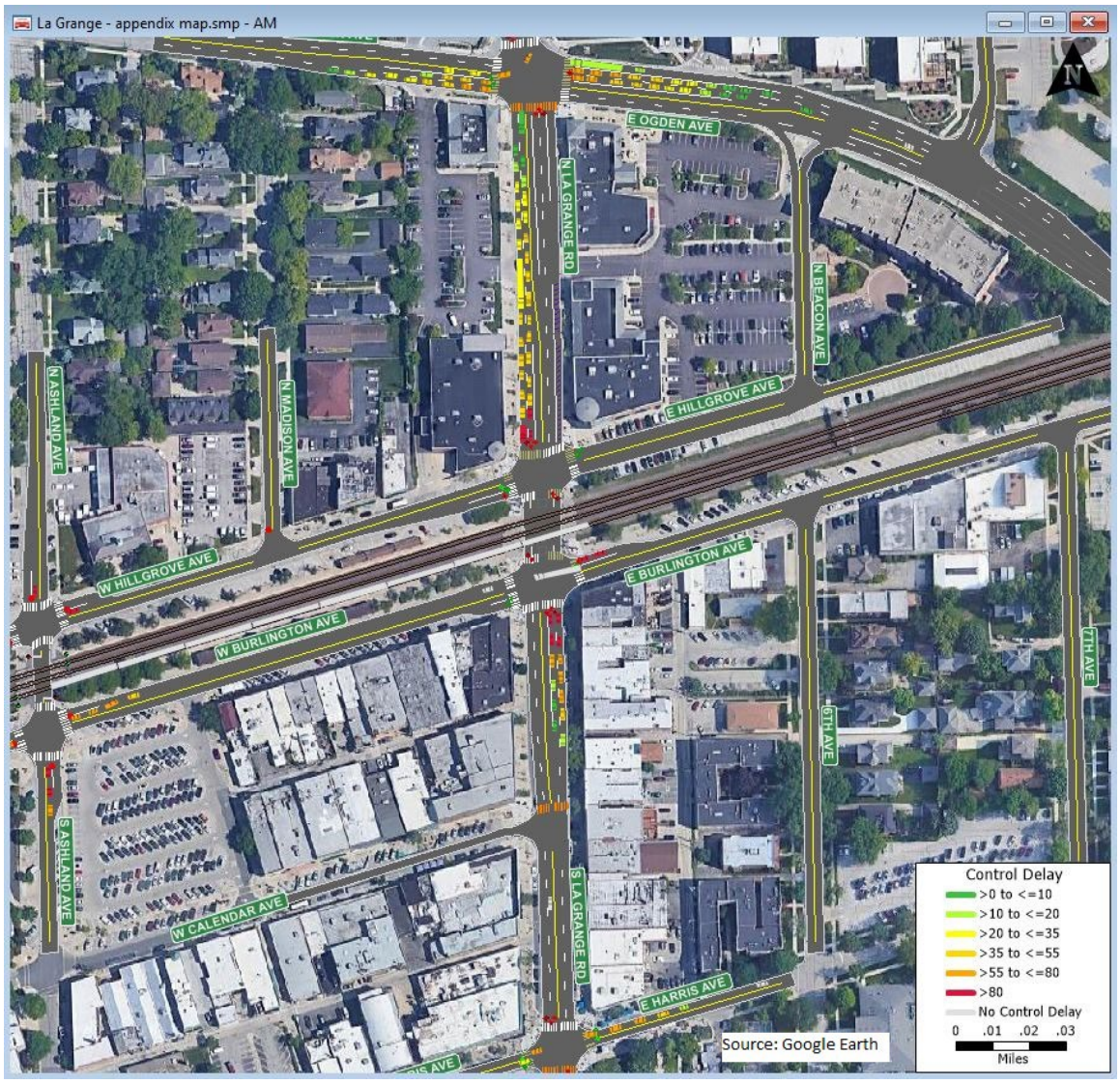

Figure D-2. Vehicular Control Delay – La Grange, IL, Site Simulation

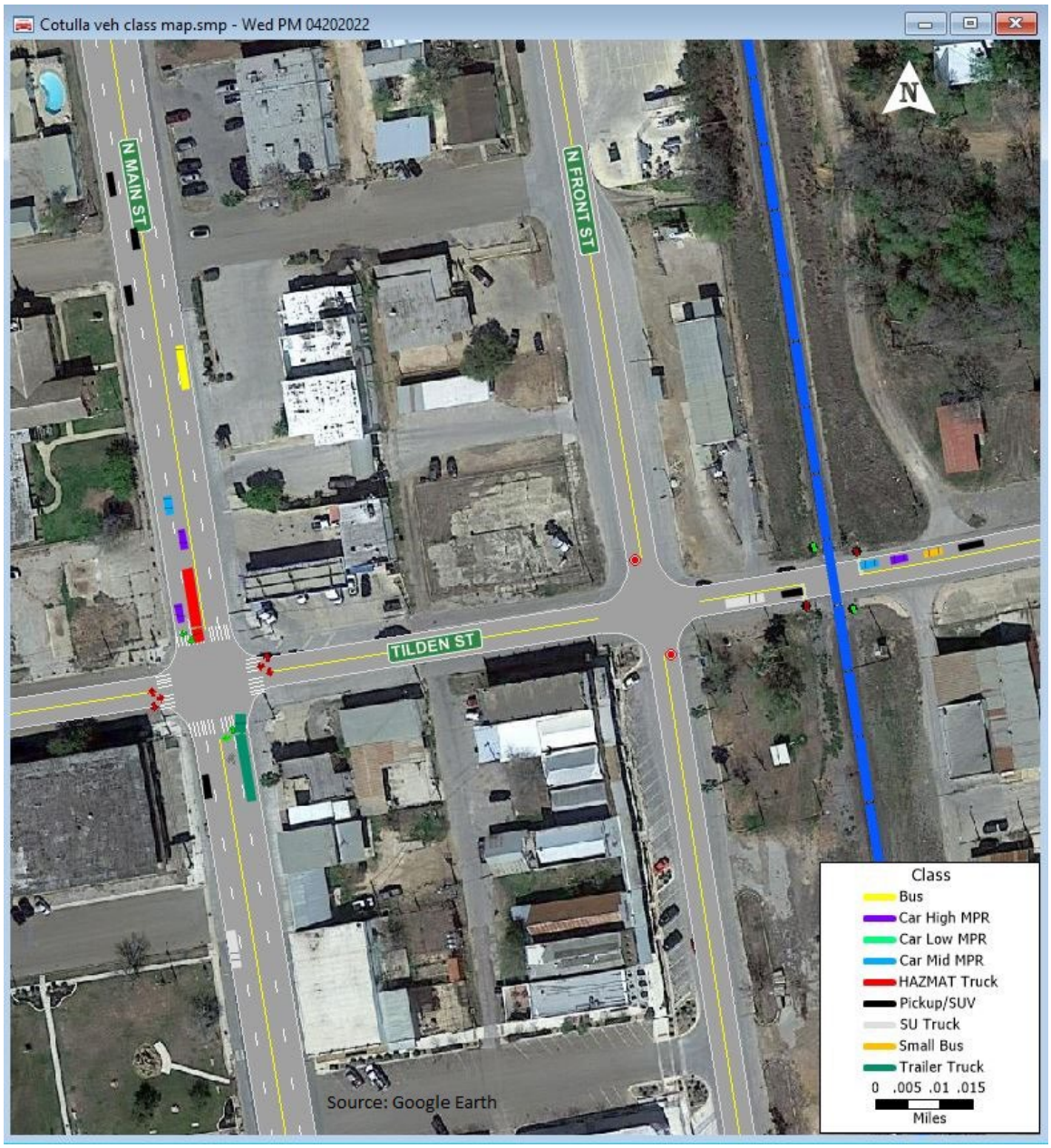

Figure D-3. Vehicle Classification – Cotulla, TX, Site Simulation

Figure D-4. Vehicle Speeds – Cotulla, TX, Site Simulation

Abbreviations and Acronyms

ACRONYM	DEFINITION
AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
API	Application Programming Interface
CMF	Crash Modification Factors
DTA	Dynamic Traffic Assignment
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
GA	Genetic Algorithm
GIS	Geographic Information System
GPS	Global Positioning System
HCM	Highway Capacity Manual
HSM	Highway Safety Manual
ICC	Illinois Commerce Commission
ITE	Institute of Transportation Engineers
MPO	Metropolitan Planning Organization
MUTCD	Manual on Uniform Traffic Control Devices
NCHRP	National Cooperative Highway Research Program
OD	Origin-Destination
ODME	Origin-Destination Matrix Estimation
PCI	Pedestrian Clearance Interval
RMSE	Root Mean Square Error
RTOR	Right Turn On Red
RTT	Right-of-Way Transfer Time
SH	State Highway
TxDOT	Texas Department of Transportation