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A NEEDS ASSESSMENT OF HIGHWAY STAKEHOLDERS OF AN
AT-GRADE HIGHWAY-RAILROAD INTERSECTION IN LINCOLN, NEBRASKA

by

Ryan Haas

A THESIS

Presented to the Faculty of
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Under the Supervision of Professor Elizabeth G. Jones

Lincoln, Nebraska

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A NEEDS ASSESSMENT OF HIGHWAY STAKEHOLDERS OF AN
AT-GRADE HIGHWAY-RAILROAD INTERSECTION IN LINCOLN, NEBRASKA

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University of Nebraska, 2010

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The University of Nebraska-Lincoln has deployed a data collection test bed along a rail corridor in the City of Lincoln. The test bed spans about 2.5 miles along the corridor which parallels Cornhusker Highway, with the focus placed on the Adams Street highway rail grade crossing (HRGC). The test bed currently has some data-collecting capabilities, but the possibility exists that there is additional data that could be useful to various users of the rail crossings.

To gauge these possible unmet data needs of highway stakeholders, a needs assessment was carried out by the author. A comprehensive literature review was done to highlight many HRGC aspects and quantifiable data that are currently available or could potentially be available to interested highway stakeholders. The results of the literature review were used to form the framework of the needs assessment, including formulating questions and topics for the stakeholder discussions. From these discussions, the adequacy of the current test bed's ability to meet highway stakeholders' needs could then be evaluated. Based on those evaluations some possible strategies could then be identified for further sensor deployments and other future research along the test bed.

Discussions were conducted with seven highway stakeholders. The results of these discussions were analyzed and used to identify data commonly available or easily collected and to identify which of these data were desired by stakeholders. The data needs, both met and unmet, seemed to follow general trends depending on the type of stakeholder.

The unmet data needs could possibly be provided in the future with various sensors and equipment. The implementation of any of these recommended treatments along the test bed could be the basis for future projects to collect, refine, and provide to various stakeholders additional data better targeted to their needs.

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Thanks finally to my wife Haley, for all of her patience and motivation.

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CHAPTER 1. INTRODUCTION

The intersection of two different modes of transportation, such as a highway rail intersection (HRI), presents a set of unique safety concerns. Careful consideration must be given when deciding which safety strategies to employ at an HRI. This includes deciding what type of control devices to install on the roadway, how to accommodate vehicle traffic characteristics and roadway geometry, and even whether or not to separate the grade of the road and railway.

Highway rail grade crossings (HRGCs), a type of HRI in which the roadway and railway intersect at grade, are unique in multimodal transportation systems in that one approach, the railway, always has the right-of-way. Failure of a vehicle on the roadway to yield to an on-coming train can therefore lead to hazardous situations, whether due to driver decision error, failure of the motor vehicle driver to recognize the potential hazard, mechanical failure, or any other reason. Figure 1 illustrates the increased hazard level at HRGCs as opposed to other roadway vehicle-only intersections.

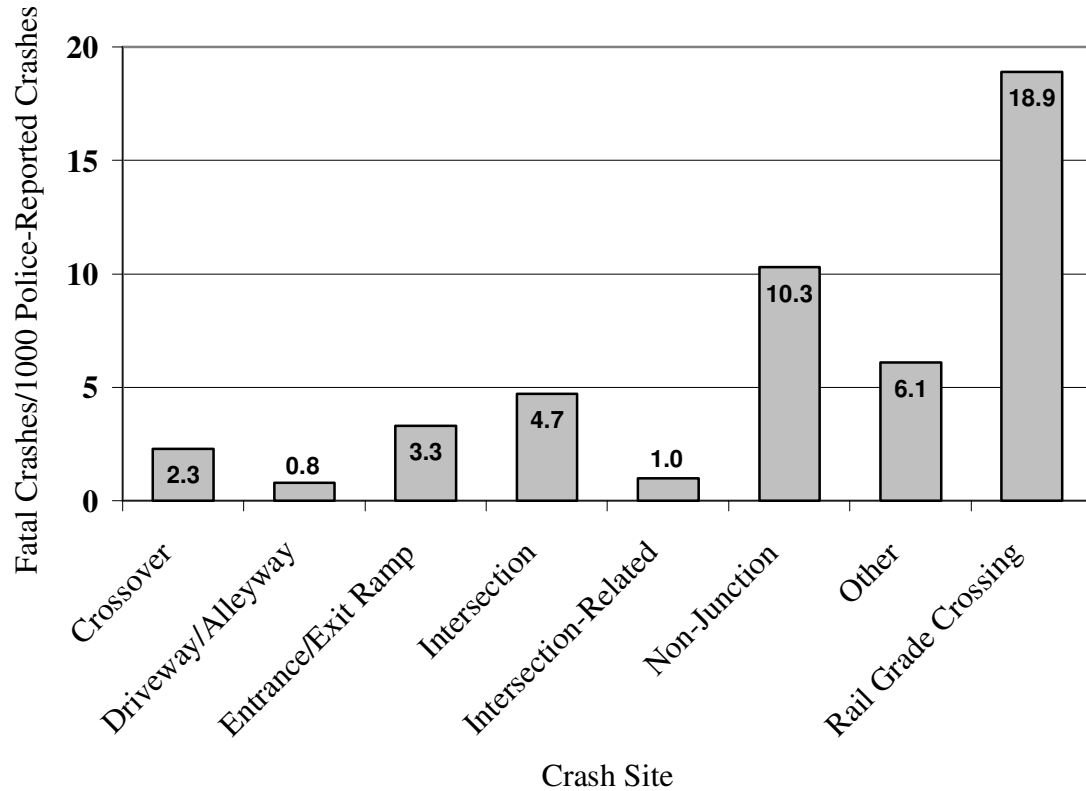


FIGURE 1 Rate of fatal crashes per 1,000 police-reported crashes by relation to junction in 2000 (Campbell 2004).

In 1994, the Federal Railroad Administration (FRA) reported 4,979 incidents at HRGCs, with 615 fatalities. By 2007, those numbers had dropped to 2,754 incidents and 335 fatalities, a percent reduction of 44.7 and 45.5, respectively. Over that same time span, the incident rate at HRGCs dropped from 7.60 incidents per one million train miles to 3.49, a reduction of 54.1 percent (Railroad Safety Statistics 2007). Despite the recent downward trend in the number of crashes and fatalities at HRGCs, improving safety continues to be a priority.

1.1 Control of HRGCs

Because of the elevated hazard level at HRGCs, motor vehicle drivers need to be provided with information alerting them to the potential danger. This information is provided through one of two main traffic control systems: passive and active warning systems.

1.1.1 Passive Versus Active Control

Passive devices at HRGCs are any signals that warn the motor vehicle driver of the potential for a hazardous situation, but leave the decision as to the course of action up to the driver. The devices themselves typically take the form of pavement markings and “crossbuck” signs, yield signs, stop signs, and other advance warning signs (MUTCD 2009). Passive devices generally tend to be used at HRGCs in rural settings or those with either low train or low roadway vehicle traffic. The lower absolute volume of roadway vehicles and trains reduces the exposure, or the number of potentially hazardous situations. When these situations arise, however, there are a number of safety concerns which are absent at actively controlled HRGCs, such as lowered motor vehicle driver expectancy of a train arrival (Caird 2002), reduced visibility under low-light conditions (HRGC TWG 2002), and increased likelihood of motor vehicle driver decision error (NTSB 1998).

Active warning devices, unlike passive devices, inform the motor vehicle driver when a train is actually approaching or is present at the crossing. Active warning serves two purposes: to notify the motor vehicle driver of an impending train arrival and to make the signal more conspicuous than signs or pavement markings alone, thus increasing the likelihood of driver recognition of the device.

Ideally, all HRGCs would have some type of active warning device present at the crossing; however, the high cost of installing active controls makes this prohibitive. A 1998 estimate for the cost to upgrade every public passively controlled HRGC in the U.S. was \$14 billion (NTSB 1998). Passive warning control is therefore much more common. As of 2007, there were 224,771 public and private HRGCs in the United States. Of these, about 71 percent were passively controlled (Railroad Safety Statistics 2007). Similarly, 73 percent of the 3,053 public HRGCs in the state of Nebraska were passively controlled as of 2007 (Railroad Safety Statistics 2007). Table 1 shows the split between actively and passively controlled public HRGCs.

TABLE 1 Summary of Public HRGCs in the U.S. and Nebraska in 2007 (Margin of Error Due to "Unknown" and "Other" Warning Device Categories) (Railroad Safety Statistics 2007)

| Location | Total Number of Public HRGCs | Actively Controlled | | Passively Controlled | |
|----------|------------------------------|---------------------|---------|----------------------|---------|
| | | Number | Percent | Number | Percent |
| U.S. | 137,634 | 64,195 | 46.6 | 66,932 | 48.6 |
| Nebraska | 3,053 | 813 | 26.6 | 2,158 | 70.7 |

1.1.2 Types of Active Control

There are several levels of active control, each providing motor vehicle drivers with a varying degree of warning. All HRGCs with active control employ post-mounted flashing lights (in addition to crossbucks, and usually additional passive control devices such as lane markings and advance warning signs). Each set of lights consists of two lights which face approaching traffic and flash alternately. Additionally, bells or some other audible warning device are typically used in combination with flashing lights. Audible warnings are primarily targeted toward non-vehicle users of an HRGC, including pedestrians and bicyclists (MUTCD 2009).

Certain types of roadways, such as divided highways and multi-lane one-way streets, require the placement of post-mounted flashing lights on both sides of each approach. At crossings where extra emphasis is warranted – such as in the case of sight restrictions or multi-lane approaches – overhead-mounted warning lights may be installed in addition to post-mounted lights (MUTCD 2009).

In addition to flashing lights and warning bells, actively controlled crossings may utilize automatic gates. An automatic gate consists of a retroreflectorized arm which, when fully deployed, is horizontally positioned and blocks all the lanes on one traffic approach (see Figure 2). The arm has at least three lights mounted upon it; when activated, the outermost light remains solid, while the remaining lights flash in alternating order together with the post-mounted flashing lights. When a train clears the tracks and no other trains are approaching, the gate arms return to vertical and all lights in the system disengage. As a fail-safe, in the event of a system failure or malfunction, the gate arm automatically assumes the horizontal position (MUTCD 2009).

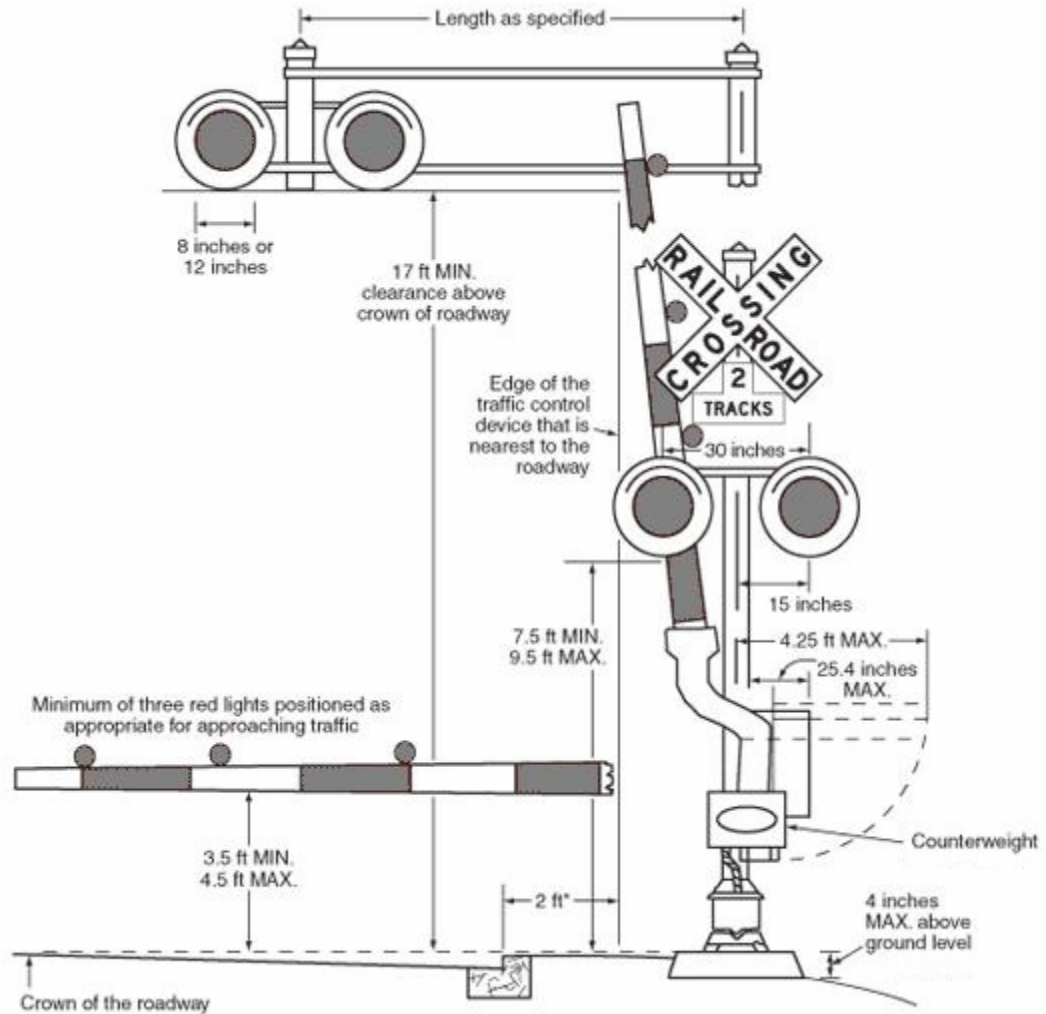


FIGURE 2 Composite drawing of active traffic control devices for highway-rail grade crossings showing clearances (MUTCD 2009).

While warning gates are effective at reducing the number of crashes, they can introduce additional safety hazards. One such hazard occurs when motor vehicle drivers drive around a gate that is closing or completely lowered.

One solution to this problem is four-quadrant gates. This system consists of the two standard arms located right-of-center on the roadway approaches, called *entry arms*, and two additional arms on the left side of each roadway approach, or *exit arms*. This

combination of gates restricts access to the track crossing area. When a train approaches the crossing, the warning lights and bells are activated. After a brief period, the entry arms are activated. Once they are completely lowered, there is a short delay to allow any cars in the crossing area to clear the tracks, and then the exit arms are lowered. The time between the activation of the entry and exit arms is dependent on the characteristics of each site (MUTCD 2009).

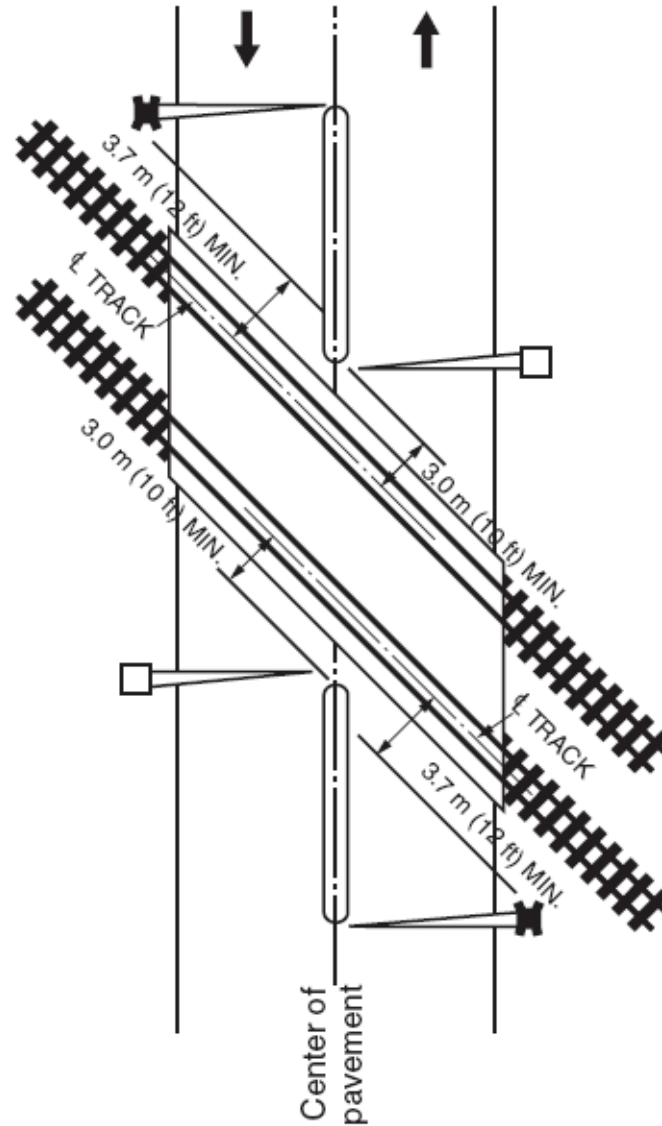


FIGURE 3 Example of location plan for flashing light signals and four-quadrant gates (MUTCD 2009).

The centerline barrier itself has been shown to alter the behavior of motor vehicle drivers approaching HRGCs. Researchers observed a 37 percent decrease in the number of aggressive motor vehicle drivers rushing through warning gates that were closed or closing as a train approached when a centerline barrier was added. Whether the barriers

were erected such that they extended all the way to the gates or whether they were left short had no effect on motor vehicle driver behavior (Khattak 2007).

1.1.3 Train Detection Technologies to Provide Active Warning

The primary function of all active warning systems is to provide adequate warning – at least 20 seconds for the fastest possible train (MUTCD 2009) – to motor vehicle drivers at HRGCs. However, train detection data can also be used to improve overall operations at a crossing, whether by providing more accurate and constant warning times or by using such information to better operate traffic signals near the HRGC in response to train operations, such as in the case in traffic signal preemption (Korve 1999). Traffic signal preemption alters the behavior of the traffic signal controller such that roadway vehicles are cleared off of the tracks at the HRGC and that traffic signals allowing movements that would conflict with the train at the crossing are restricted (Korve 1999).

The methods and precision of the systems which gather this data at HRGCs have improved over time through various technological advances. The following is a discussion of that progression.

1.1.3.1 First Generation

First generation train detection systems use circuitry in the track to detect a train's presence and to activate the active warning signal. A battery sends current through a portion of a track to a relay and back, as in Figure 4a. When a train's wheels short the current, the relay is de-energized and the warning signal at the HRGC is activated (Figure 4b). By design, the system is fail-safe, as it activates the signals either in the presence of a train or if a component of the system fails. In the latter case, the signals will remain activated until the system is repaired (Korve 1999).

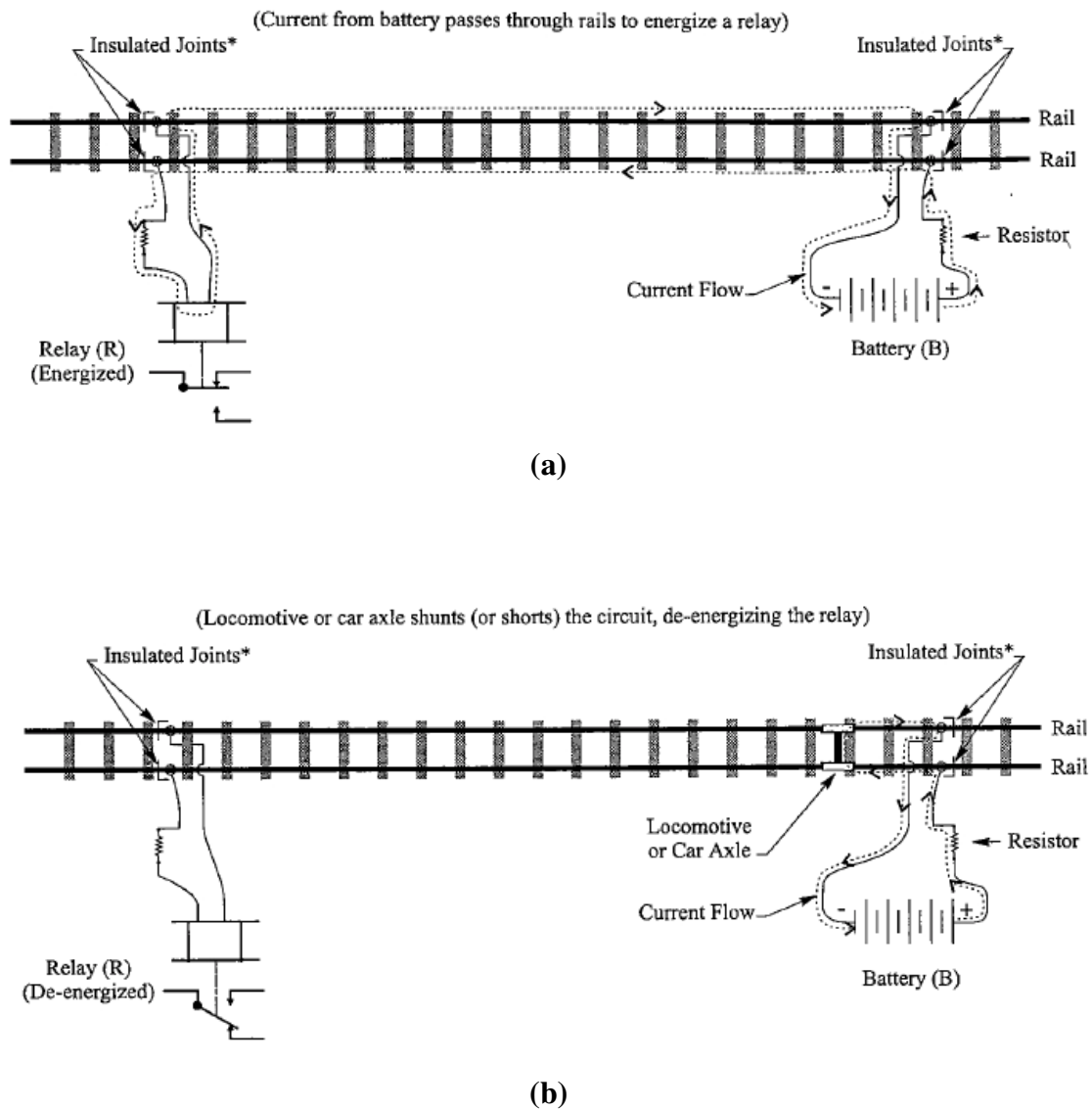


FIGURE 4 Track circuitry for first-generation detection, with (a) train absent and (b) train present (Korve 1999).

The drawback of a simple first generation system is that it cannot determine a train's speed. A fixed-distance warning time (FDWT) system must allow a minimum of 20 seconds of warning time for the fastest possible train (MUTCD 2009). A slow train could therefore cause excessive wait times for roadway vehicles at the crossing.

Constant warning time (CWT) systems help reduce excessive delays for motor vehicle drivers by measuring a train's speed and more accurately predicting its arrival time. To accomplish this, the system uses impedance measurements from the track circuitry. CWT systems are an improvement over FDWT systems, but they still have drawbacks. A train which accelerates after being measured by the system might reach the HRGC before the required 20 seconds; conversely, a train which decelerates might still cause excessive delays after the warning signals have been activated (Korve 1999).

1.1.3.2 Second Generation

Second generation detection utilizes speed detection technologies such as sonar, microwave, radar, or video detection to predict a train's arrival time. Second generation systems are advantageous in that the equipment is located outside of railroad right-of-way. Additionally, their deployment is relatively inexpensive (Estes 2000).

Second generation detectors can also be placed further up the track than first generation track circuits. This allows for more time than afforded by first generation systems for signal preemption to take place at roadway intersections adjacent to the HRGC.

1.1.3.3 Third Generation

Third generation detection provides more frequently updated information as to the train's location and speed. One type of third generation system uses automatic vehicle identification systems and a system of radio frequency antenna "readers." A train's information is scanned as it passes by each reader. The system's main drawback is that it is effective only if a sufficient number of readers exist to maintain an accurate figure for the train's speed (Cho 2003).

Another third generation system utilizes global positioning system (GPS) technology to pinpoint a train's speed and location (Cho 2003). In March of 2005, the FRA revised its signal and train-control regulations to allow for the utilization of third-generation technologies such as GPS (Federal Register "Standards..." 2005). Recently, Burlington Northern Santa Fe (BNSF) Railway became the first railroad carrier to receive FRA approval to begin implementing an Electronic Train Management System (ETMS). ETMS utilizes train location and speed data from GPS to provide information to crews in an onboard computer. When a train's speed exceeds the maximum allowed or a train approaches a known obstruction or hazard, a warning is displayed for the crew on the onboard computer. If no action is taken by the crew, the ETMS automatically begins the braking process on the train (BNSF "ETMS" 2007).

1.2 Problem Statement

Concerns for safety and efficiency exist at every HRGC, regardless of the type of warning device or technology implemented. It is important to address these concerns at each HRGC based on acceptable standards. Each HRGC possesses a set of characteristics based on the surrounding area and on the users of the HRGC. Besides being directly measured or observed, another way of gauging these characteristics is by better understanding the data needs of stakeholders of an HRGC.

It is hypothesized that an assessment of data needs of HRGC stakeholders will lead to a better understanding of which data should be collected at HRGCs. This will facilitate and improve understanding of HRGC operations. Thus a needs assessment will be performed to identify which data will aid in better understanding the operations of the HRGCs. Many of these data are already available to the users on the railroad side of

HRGCs, but these are not shared with other users. Therefore, the needs assessment will focus on highway stakeholders – regular users of the roadway at HRGCs.

1.2.1 Needs Assessments

Generally speaking, a needs assessment is “a systematic set of procedures undertaken for the purpose of setting priorities and making decisions about program or organizational improvement and allocation of resources. The priorities are based on identified needs” (Witkin 1995). Needs assessments are conducted by a wide variety of entities, including government agencies, community groups, businesses, hospitals, and social service agencies (Witkin 1995). A needs assessment bridges the gap between an existing situation and a desired outcome. This gap is comprised of the needs themselves; needs are defined as “gaps in results, consequences or accomplishments” (Kaufman 1993). There are many forms a needs assessment can take, but most follow the same basic framework: a “pre-assessment” phase, a “main assessment” phase, and a “post-assessment” phase (Witkin 1995).

Most non-technical needs assessments are conducted using five main methods: the public forum approach, where information is gathered from the general public in a series of public meetings; the nominal group process technique, in which smaller groups of people use brainstorming and dialogue to generate and prioritize ideas; the Delphi technique, which is similar to the nominal group process technique except that instead of group discussions the process is carried out through an iterative questionnaire process; the key informant approach, where individuals with professional training or technical experience are queried to obtain data not readily available from the general public; and the survey approach, which utilizes the administration of a collection instrument to a

sample of a large population to gather data (Carter 1992) (University of Illinois 2007). These five strategies differ in targeted audience, source of collected data, and data collection methods, but they all follow the pre-/main-/post-assessment framework.

The key informant approach is of particular interest to this project, as the desired information may be too technical and narrowly focused to be provided by persons lacking adequate expertise or knowledge. A list of questions is prepared for these informants, and discussions are conducted with each one individually. The results are then compiled and compared (University of Illinois 2007).

Data needs assessments are more technical than general needs assessments, and are therefore more common in information technology applications. However, “Most of the published literature pertaining to data needs assessment methodologies bespeaks of methods for the more efficient organization of data, rather than providing guidance on how to strategically assess data needs” (NCHRP 1997). Regardless, the same universal approach – planning, execution, and processing – applies to data needs assessments.

1.2.2 Application of Needs Assessment

The data identified in this project are expected to adequately quantify most, if not all, relevant operational features of an HRGC, including human factors, train operations, and traffic operations. In the planning phase of the needs assessment, relevant HRGC aspects and data will be identified from past literature for consideration and review.

The data are expected to relate to the concerns of any stakeholders who use the roadway at the HRGC. This needs assessment will require feedback from knowledgeable and experienced individuals, and will therefore utilize an approach similar to the “key

informant” method of assessment. The key informants will be representatives of stakeholders who are familiar with how their entities are affected by HRGCs.

The post-assessment phase of the needs assessment will consist of a summary and analysis of the main assessment results, with the end goal being to identify data commonly available or easily collected and which of these data are desired by highway stakeholders, which data are desired but not readily available, and what steps could be taken to make lacking data available.

These data needs will be presented as *data flows* from the National ITS Architecture. The National ITS Architecture, which was created by the U.S. Department of Transportation, is “a common, established framework for developing integrated transportation systems” and “the definitive framework that will guide deployment of intelligent transportation systems in the U.S.” (National ITS 2010). Data flows are discrete pipelines along which information is passed (National ITS 2010). They are an effective way of presenting the stakeholder needs as well-defined rudimentary elements.

1.3 Research Objectives

As part of an existing research project at the University of Nebraska-Lincoln, an intelligent highway-railway intersection test bed has been established in Lincoln, NE, at the Adams Street grade crossing, located on Adams Street immediately east of its intersection with Cornhusker Highway. The test bed will enable the collection of data for a broad range of applications with a focus on improving traffic signal preemption for trains. This location will have at least two cameras with video detection capabilities. Two other upstream locations will have one or two cameras and at least one radar device installed to collect upstream train data. These will be located near the 44th Street crossing

and at the Antelope Valley overpass (see Figure 5). The upstream locations will provide the train information for signal preemption at 35th Street and Cornhusker Highway that is needed to better handle the grade crossing traffic at the Adams Street crossing.

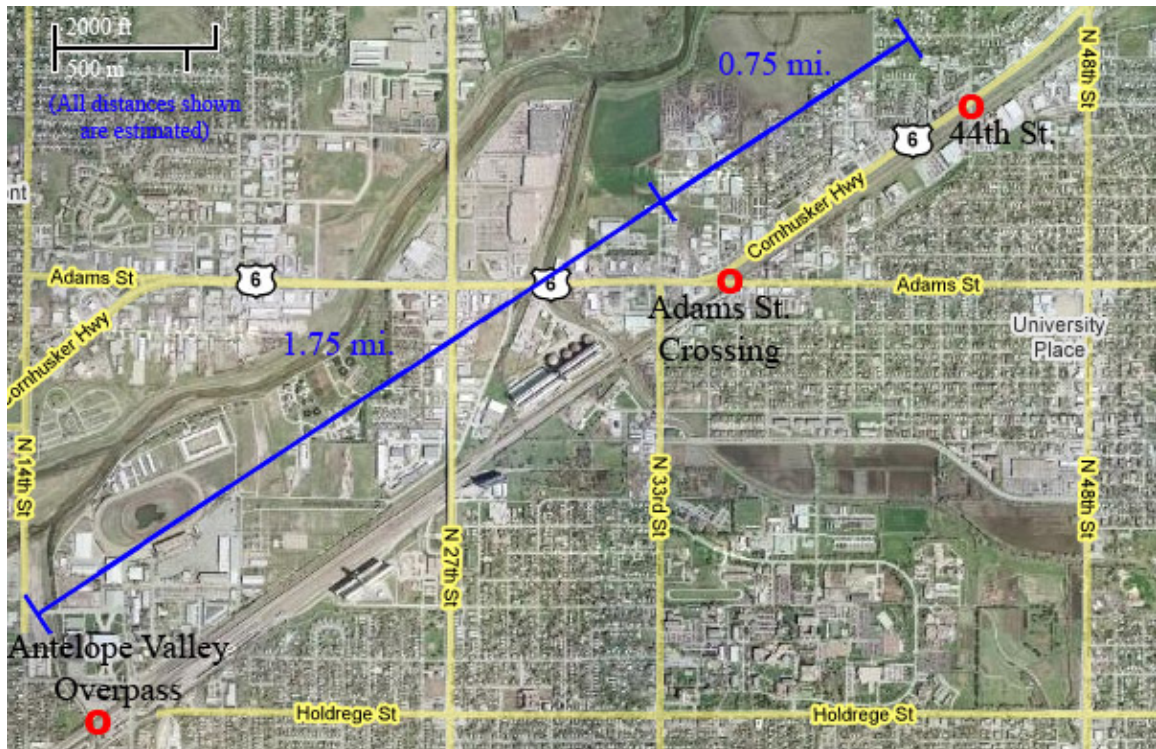


FIGURE 5 Map of Adams Street HRGC test bed location in Lincoln, NE.

1.3.1 Adams Street HRGC

The Adams Street HRGC is one of the most hazardous in Lincoln, according to the FRA's Web Accident Prediction System (WBAPS) (WBAPS 2009). This system takes into account an HRGC's physical characteristics and crash history data to determine predicted collisions per year. It does not rank crossings as more dangerous to less dangerous. It simply is a reflection, based on the inputted data, that one HRGC could be more hazardous than another. The ten HRGCs identified by WBAPS as possibly being

the most hazardous are listed in Table 2, along with crash history dating to 1975 for each crossing (Railroad Accident History Statistics 2009). The crossing at Adams Street was tied for the highest number of crashes at any crossing, which is an indication that it is among the most dangerous HRGCs in Lincoln. Further testament to the hazard level at the Adams Street HRGC is its placement on a short list of crossings to eventually be closed or modified by the City of Lincoln Railroad Transportation Safety District (RTSD) (“Current” RTSD 2010), a political subdivision utilized by the City of Lincoln and Lancaster County to provide funding for railroad safety improvement projects. Even though this grade crossing is expected to eventually be closed, this HRGC is expected to remain as is for at least the next 10 years.

TABLE 2 Crash Histories Since 1975 of Ten Most Hazardous HRGCs in Lincoln According to WPABS (WBAPS 2009) (Railroad Accident History Statistics 2009)

| Location | Number of Crashes | Number of Fatalities | Number of Injuries |
|-----------------------------|--------------------------|-----------------------------|---------------------------|
| S. 14th St.* | 6 | 0 | 5 |
| 70th Street | 7 | 0 | 2 |
| N. Cotner Blvd. | 2 | 0 | 1 |
| Fletcher Ave. Spur Lines | 0 | 0 | 0 |
| Folsom Street | 4 | 1 | 0 |
| South Street | 4 | 0 | 1 |
| Adams Street | 10 | 2 | 1 |
| 33rd Street | 8 | 3 | 1 |
| Park Blvd. | 5 | 0 | 0 |
| 3rd & South | 10 | 0 | 2 |

* Closed or scheduled to be closed

Another factor impacting the hazard level at crossings is the recent increase of train and roadway vehicle traffic. Figure 6 illustrates the increase in highway vehicle-miles traveled in the U.S. over the last 30 years, as well as the recent upward trend in train-miles. While higher volumes of train and roadway vehicle traffic do not necessarily

translate to more crashes at HRGCs, they certainly create the potential for an increased number hazardous situations.

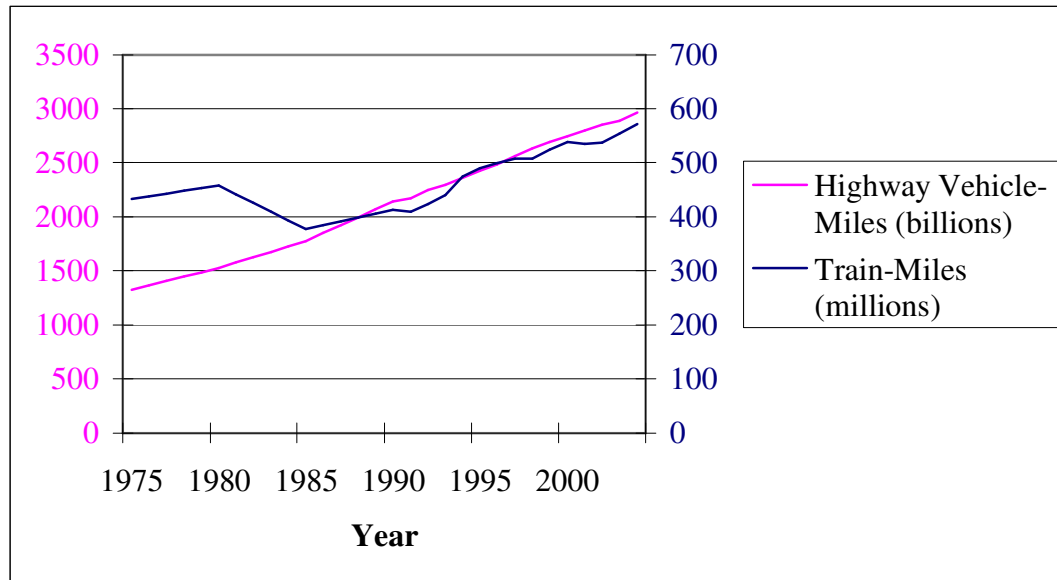


FIGURE 6 Billions of highway vehicle-miles and millions of train-miles traveled annually in the U.S. since 1975 (BTS 2006).

Train traffic in Lincoln, Nebraska seems to be mirroring the national trend. During 2005, BNSF, one of the two major rail carriers which pass through the city, saw a 12-month increase in train traffic through Lincoln of 16 percent, to bring the current total volume to between 85 and 100 trains per day (BNSF Lincoln Journal Star 2007). That increase was expected to be from six to eight percent annually for each of the three subsequent years (BNSF Lincoln Journal Star 2007).

1.3.2 Main Objectives

The purpose of this project is to identify as many potential highway stakeholders as possible for the HRGC at the test bed and to perform a needs assessment to identify what the stakeholders' data needs are and how the test bed can be used to meet them.

Stakeholders will be asked about their data needs both at the Adams St. crossing and at

HRGCs in general. Once the data needs are assessed, the current data collection system at the HRGC will be evaluated in regards to its ability to collect the data identified in the needs assessment. Recommendations will be made on which other sensors might be installed at the test bed and where they should be installed to collect a richer data set that better responds to the needs of stakeholders.

1.4 Organization

In Chapter 2, a comprehensive literature review will highlight many HRGC aspects and quantifiable data that are currently available or could potentially be available to interested highway stakeholders. The secondary data derived from this review of existing literature will be summarized, and then used to help formulate other parts of the pre-assessment. In Chapter 3, the steps of the needs assessment (pre-assessment, assessment, and post-assessment) will be outlined, including steps already completed and those remaining to be carried out. Chapter 4 will detail the completion of the pre-assessment, including identifying the major needs areas and determining which data to collect, where it will come from, and the data collection approach. In addition, this chapter will contain the completion of the main analysis, including the formulation of the data collection instrument and the identification of highway stakeholders with whom to discuss data needs. This is the point in the project when stakeholder discussions will take place. The post-assessment phase of the needs assessment will compose Chapter 5. Based on the results it will be possible to identify data commonly available or easily collected and which of these data are desired by stakeholders, which data are desired but not readily available, and which steps could be taken to make the lacking data available. In Chapter 6, the results of Chapter 5 will be used to evaluate the adequacy of the current test bed in

meeting stakeholders' needs. Additional data that could be viably collected at the test bed will be identified and discussed. This discussion will include where additional cameras or other types of detectors should be located. Chapter 7 concludes this thesis and presents avenues for future research.

CHAPTER 2. LITERATURE REVIEW

A review of past research in the area of HRGCs is necessary to gain a better understanding of possible highway stakeholder needs. The goal will be to identify and investigate any previously reported data that a highway stakeholder of an HRGC might find valuable. Any quantifiable data collected at an HRGC or the means to collect such data will be examined, especially in the area of human factors.

2.1 Human Factors

Human factors is the study of how people respond psychologically and physically to a given stimulus or environment. Human factors issues are of particular interest at HRGCs because most safety hazards at crossings are the direct result of some psychological or physical error on the part of the motor vehicle driver (Raslear 1996). Overall, human error is responsible for 70 to 90 percent of transportation crashes (Raslear 1996).

2.1.1 Motor Vehicle Driver Behavior

Virtually all potential safety failures at an HRGC are due to motor vehicle driver error, which highlights the importance of understanding how motor vehicle drivers behave at a crossing. This can include physical and mental aspects of driving, both of which can be affected by a large number of factors. For example, it has been shown that when motor vehicle drivers decelerate while approaching an HRGC, they do so because the crossing itself is rough, and that the amount of speed reduction depends on the bumpiness of the crossing (Sanders 1976). Even in a sample size as small as 33 hours, it is possible to observe a multitude of crossing violations at an HRGC due to motor vehicle driver error, such as roadway vehicles stopping on the tracks, vehicles stopping past the gate arm, and vehicles passing under a closing gate (Villatoro 2006).

2.1.1.1 Risk-taking

Risk-taking is a type of decision error, an error in which the motor vehicle driver recognizes a hazardous situation and makes a decision to proceed with a maneuver – as opposed to recognition error, an error that occurs when the motor vehicle driver fails to identify a hazard or hazardous situation properly (Berg 1982). Statistically speaking, risk-taking rarely results in a collision; however, motor vehicle drivers carrying out risky maneuvers put themselves at an elevated hazard level, or at the very least violate regulations at the crossing.

Of more importance is the possibility for positive reinforcement for safely executing a risky maneuver. If even one particular instance of a risky maneuver is carried out safely by a motor vehicle driver, a false sense of security may develop and lead to the driver making critical decision errors in the future. Additionally, surveys have shown that anywhere from six (Hughes 1999) to ten (Witte 2000) percent of motor vehicle drivers found it exciting to try to “beat” a train, while 14 percent reported the willingness to circumvent crossing gates and pass over the tracks, even with the lights flashing and a train visible (Witte 2000).

2.1.1.2 Perception of Hazards at HRGCs

One aspect which may directly contribute to the level of caution that motor vehicle drivers use at an HRGC is how dangerous they actually perceive the crossing to be. A survey of 752 professional motor vehicle drivers found that 46 percent did not believe HRGCs presented “significant driving hazard above normal driving” (Benekohal 2004). Another study showed that the majority of the public understands the tremendous force exerted by a train on a roadway vehicle in the event of a collision. Nine out of ten

respondents in the study had seen a train strike a car (either in person or on television), and 86 percent correctly identified the force of a train-car collision as equivalent to a car running over a soda can (Hughes 1999). While respondents had an overwhelming grasp of the magnitude of force of a train-car collision, 37 percent estimated that a train arrives at least a minute after gates are lowered at a crossing (three times longer than the minimum 20 seconds) (Hughes 1999). Additionally, 14 percent of respondents thought that a fully loaded train traveling at 55 miles per hour could come to a full stop in less than 300 feet (as opposed to the one mile or more actually required) (Hughes 1999).

Perception and compliance can be swayed through enforcement and public education. A broad study of more than 60,000 train events before and after a public education and enforcement effort showed that the program reduced the number of motor vehicle driver and pedestrian violations at actively controlled rail crossings by 30.7 percent (Sposato 2006). Additionally, the enforcement and education program was key in reducing the most risky violations – those where the motor vehicle driver or pedestrian crossed the tracks after the warning gate arms are fully deployed – by 71.4 percent (Sposato 2006).

2.1.1.3 Photo Enforcement at HRGCs

Strategies for enforcing traffic laws at HRGCs to prevent motor vehicle drivers from taking hazardous risks have been somewhat limited in number. The conspicuous presence of law enforcement curbs illegal maneuvers and enables punishment of those who perform them (Carroll 2002).

One emerging alternative is the installation of cameras to automatically detect and document illegal maneuvers. This implementation is a variation of the cameras already used to catch red-light runners. There are concerns regarding traffic cameras involving

privacy rights, accuracy, and due process; therefore, the cameras are not yet legal in all jurisdictions. Where it has been employed, however, photo enforcement has been shown to be effective in curbing traffic violations (Carroll 2002).

Photo enforcement has been implemented at HRGCs in North Carolina, Texas, California, Illinois, Florida, and other locations. The implementation usually occurs at sites that commonly see warning device violations, car-train collisions, or both. The HRGCs where photo enforcement systems are installed universally show a reduction in both violations and collisions. While the initial cost of installation of a photo enforcement system can reach six figures, the funds generated by fines enable the system to pay for itself in as little as three to four years. Additional cost-cutting measures include installing the housing for the cameras and sensors at multiple locations, then rotating the actual equipment; in this way, the public cannot perceive whether or not the equipment is actually present, and illegal and hazardous behavior is curbed even if the cameras and sensors are absent (Carroll 2002).

Research by the Federal Railroad Administration (FRA) has also been conducted to show that surveillance equipment can be used to curb railroad right-of-way trespassers (daSilva 2006). While right-of-way trespassing falls outside the scope of this project, the detection aspect of the FRA study proves useful here. The procedure of the study involved the installation of detection equipment at a railroad bridge. The equipment was designed to detect intrusions and electronically contact a remote security company in the event of a trespasser. The study stated that electronic detection technology, especially digital video and broadband communications technologies, has evolved rapidly in recent years. One large advantage to the increase in detection quality and accuracy is that it can

more readily be installed outside of railroad right-of-way (making such systems usable by any entities, not just railroads) (daSilva 2006).

2.1.1.4 Looking for Trains

A motor vehicle driver must physically look for a train to see one approaching and perceive it as a threat. This can be carried out by eye or head movement; it is sometimes neglected altogether. The information provided to motor vehicle drivers at an HRGC has an impact on how carefully a driver looks for a train, if at all. For example, improved sign configurations at crossings with passive warning devices can increase the frequency of motor vehicle driver head movement by up to 5 percent (Kozioł 1978).

The level of warning provided becomes more critical when a motor vehicle driver cannot see or perceive a situation with an elevated hazard level. It has been shown that an approach to an HRGC that has a sight restriction produces no change in a motor vehicle driver's response as opposed to an approach with a clear view of the tracks (Wigglesworth 2001).

2.1.1.5 Indirect Study of Motor Vehicle Driver Behavior

Some aspects of motor vehicle driver behavior can be indirectly studied by measuring various vehicle characteristics, such as vehicle speed, position, gaps and headways relative to other vehicles, and traffic volumes. Inferences can be made by utilizing one or more of these basic traffic variables for a broad range of applications, including: complex equations for modeling traffic being built around basic traffic parameters (Zhang 1997); measuring the effectiveness of route diversion strategies (Cuneo 2004); and utilizing basic traffic flow variables to help improve system performance (Zhang 1995).

These applications use data based on motor vehicle driver behavior to draw conclusions in areas unrelated to the behavior itself, but some research has even attempted to quantify motor vehicle driver behavior based on observation of vehicles. One study quantified motor vehicle driver aggression by examining traffic and looking for motor vehicle drivers who engaged in aggressive activities such as cutting in front of other vehicles, honking, and following too closely (Shinar 2004).

Other research has focused specifically on how motor vehicle driver behavior can affect the operation of traffic at or near HRGCs. One study found that one of the main components affecting the clearance of a vehicular queue off the railroad tracks is startup delay (Long 2003), which can be an indirect measure of motor vehicle driver behavior.

2.1.2 Motor Vehicle Driver Physical Characteristics

Motor vehicle drivers' physical characteristics play an important role in crash avoidance. Some physical aspects can be the cause of potential hazards (such as an elderly motor vehicle driver not being able to see as well in the dark as a younger driver), while others can be an accurate predictor of the likelihood of being in a hazardous situation (such as tendencies based on age).

2.1.2.1 Motor Vehicle Driver Gender

Some research has shown that a motor vehicle driver's gender can be an accurate predictor of an increased likelihood for hazardous situations. For example, males have been shown to be more likely to take risks at HRGCs (Witte 2000); this is a possible explanation for males being responsible for almost 70 percent of crashes at public HRGCs in 2007 (Railroad Safety Statistics 2007) and 77 percent of fatal crashes over the first 17 years of the National Highway Traffic Safety Administration's (NHTSA) Fatal

Accident Reporting System (FARS) (Klein 1994). However, many aspects of motor vehicle driver behavior at an HRGC are independent of gender. Males and females show the same level of recognition and understanding of traffic control devices at HRGCs (Richards 1988).

2.1.2.2 Motor Vehicle Driver Age

Despite having a superior set of physical driving skills (such as vision and reaction time), young motor vehicle drivers are more than three times more likely to be in a crash than older drivers (Evans 1985). Additionally, one study showed that motor vehicle drivers under the age of 19 (as well as drivers above age 54) had difficulty with the recognition and understanding of warning signs and traffic control devices at HRGCs (Richards 1988).

In 2007, 16- to 25-year-olds were involved in 19.2 percent of all HRGC crashes, while 26- to 35-year-olds were responsible for 18.9 percent of incidents (Railroad Safety Statistics 2007). Historic data show similar trends for young motor vehicle drivers: over a 17-year stretch, 16- to 24-year-olds accounted for 31.8 percent of fatal crashes at crossings, while 25- to 34-year-olds were involved in 23.8 percent of such incidents (Klein 1994).

2.1.3 Motor Vehicle Driver Performance

Motor vehicle driver performance can be affected by physiological and psychological factors. Feeling alert and attentive or having prior knowledge and experience about a given situation or setting can both enhance a motor vehicle driver's ability to make safe decisions behind the wheel; conversely, having a deficiency in one of these areas can pose an increased risk for hazardous behaviors.

2.1.3.1 Motor Vehicle Driver Fatigue

Fatigue is a concept that is different from “muscular fatigue” or impairment. Fatigue deals with the psychological aspect of a person performing a task or tasks past the threshold where the person can perform the task efficiently and with self-assurance (Brown 1994). Fatigue can cause “reactive inhibition,” which can slow reaction times and even cause “mistimed responses” (such as a motor vehicle driver crossing an HRGC when a train arrival is imminent) (Brown 1994).

2.1.4 Prior Knowledge and Experience of Motor Vehicle Driver

2.1.4.1 Motor Vehicle Driver Familiarity with Intersections

Motor vehicle drivers having a familiarity with an HRGC may be more aware of train arrival frequency and schedules, sight restrictions, and other characteristics unique to that HRGC. It has been shown that motor vehicle drivers’ prior personal experiences with HRGCs have a larger influence on their behavior than do the environmental aspects of the HRGC (Witte 2000). However, a motor vehicle driver might also become complacent at a familiar or frequently traveled crossing, or use his or her knowledge as a justification to circumvent the warning signals. One study of Australian fatal car-train crashes found that 86% of the victims were persons who lived in the vicinity of the HRGC (Wigglesworth 2001).

2.1.4.2 Motor Vehicle Driver Experience

The skill set and experience of motor vehicle drivers has a direct effect on their performance in various roadway situations. Motor vehicle drivers who drive more than 20,000 miles a year have been shown to have a better knowledge and recognition of traffic control devices at HRGCs than less experienced drivers (Richards 1988). Even

when taught proper driving techniques and safety concerns in a classroom setting (such as in driver's education classes), motor vehicle drivers are no more likely to avoid crashes than those without formal training (Evans 1985), which would appear to highlight the value of raw experience behind the wheel.

2.2 HRGC Warning Signals

Motor vehicle driver behavior varies based on the type of warning signal installed at an HRGC. Several main types of warning signals exist, each with a unique impact on motor vehicle driver behavior and safety.

2.2.1 Passive Warning Devices

About half of the 137,634 public HRGCs in the U.S. are controlled by passive warning devices (Railroad Safety Statistics 2007). A constant challenge facing planners is identifying which of these passively protected crossings warrant being upgraded to active control to improve safety. Ideally, all such crossings would be closed or improved to active protection, but clearly this strategy is impractical and cost prohibitive; a 1998 estimate of the average cost of installing active signals at one crossing was about \$100,000 (Bowman 1998). Maintenance costs for active control devices are also significantly higher than for passive control devices. Additionally, simply improving the quality and extent of passive devices at a crossing with additional signage and lane markings (a strategy that is much less costly than installing active warning devices) has been shown to have little or no improvement on motor vehicle driver behavior and safety (Parsonson 1982).

Some work has been done in finding middle ground between strictly passive warning protection and the installation of full active protection. Noyce and Fambro developed a

sort of hybrid passive crossing. They added a loop detector which activated an additional warning strobe mounted on an advance warning sign. The strobe and additional warning sign were shown to effectively increase motor vehicle driver caution and safety (Noyce 1998). Bowman also showed that adding train-activated flashing beacons to passive warning signs caused motor vehicle drivers to significantly reduce their speed as compared to the warning sign with no activated beacon (Bowman “Analysis” 1987).

2.2.2 Active Warning Devices

Active warning devices have long been shown to improve safety at HRGCs. It has been shown that installing active warning devices reduces not just the frequency of crashes at crossings, but also the crashes that are most severe. Schulte observed a drastic decrease (70 to 90 percent) in crashes, injuries, and deaths in California during the 1960s due to the installation of active warning devices (Schulte 1976). One limited study showed that the addition of half-barrier gates at an HRGC that previously had only flashing lights and warning bells reduced the rate of motor vehicle drivers crossing in front of an oncoming train by almost half (Meeker 1997). Additionally, warning gates were shown to have a marked impact on the HRGC regardless of the pre-existing situation and warning devices (Schulte 1976). A crash prediction model of Canadian HRGCs showed a reduction in the number of expected crashes at a given crossing of 58 percent by upgrading from passive control to flashing lights and 63 percent by upgrading from passive control to gates (Saccomanno 2005).

While active signals provide a marked improvement in safety over passive signals, the majority (60.4 percent) of crashes at HRGCs in 2007 occurred at crossings with active signals (Railroad Safety Statistics 2007). This is generally attributed to a

deficiency in motor vehicle driver response to the warning signal (Richards “Assessment” 1990). Even though actively controlled HRGCs tend to have higher train and roadway vehicle traffic and possibly more complex geometries, human error is the overriding factor in the safety deficiencies of active crossings. For example, one study showed that more than half of motor vehicle drivers ignored the advance warning provided by flashing lights before and during gate activation and crossed the HRGC without stopping (Richards “Assessment” 1990).

2.2.2.1 Four-Quadrant Gates

Four-quadrant gate active warning systems have been shown to be effective at improving safety by preventing motor vehicle driver error. In one study, an intersection with standard gates had violations in which roadway vehicles drove around closed gates at a rate of 84 of every 100 train arrivals, with 260 violators over the same interval (Heathington 1990). The installation of a four-quadrant system reduced both of these rates to 0 per 100 arrivals (Heathington 1990). Another study in North Carolina showed a 98 percent reduction in violations after four-quadrant gates and median barriers were installed (Hughes 1999).

The MUTCD recommends that four-quadrant gate systems be used only at crossings in which CWT detection systems are in place (MUTCD 2009). The safety benefits of this setup are twofold: the four-quadrant gates physically prevent motor vehicle drivers from circumventing the system, and the CWT detection increases credibility of the warning time, which reduces the motor vehicle drivers’ psychological urge to bypass the system.

The installation of gates to a passively-controlled crossing may create the unintended consequence of motor vehicle drivers traveling around the gates; similarly, the installation of four-quadrant gates can have unintended consequences. Roadway vehicles can become trapped in the middle of the crossing between the two sets of gates. This problem is easily solved by delaying the deployment of the exit arms by a few seconds. Therefore, the most dangerous scenario at a crossing with four-quadrant gates is one in which a roadway vehicle drives around the entry arms and past the exit arms before they deploy. However, this can occur only immediately following the detection of an oncoming train, meaning the train would still be 20 seconds from the crossing. By contrast, a car driving around the gate arms at a normal actively controlled could do so at any point before, during, or after a train arrival.

Four-quadrant gate systems are clearly a highly effective safety strategy, and they cost only marginally more to install than a regular active device. The cost to install a four-quadrant gate system at a passively controlled crossing is about \$150,000 (Pickett 2005). One alternative to upgrading a crossing from existing standard warning gates to four-quadrant gates is to add a centerline barrier to supplement the gates. Doing so has been shown to reduce aggressive motor vehicle drivers rushing closed or closing gates by 37 percent (Khattak 2007).

2.2.2.2 Constant Warning Time

As mentioned previously, CWT systems increase the credibility of the warning time at a crossing. An approaching slow-moving train at a crossing with a FDWT system will cause excessively long deployment of warning devices, which increases motor vehicle driver frustration and the chances of a driver circumventing the device while it is

activated. Richards and Heathington (Richards “Assessment” 1990) observed that long and variable warning times at an HRGC negatively impact motor vehicle driver behavior. Additionally, it has been shown that as the length of time between active warning signal activation and train arrival increases, the more likely a motor vehicle driver is to circumvent the signal (Carlson 1999).

Systems that provide CWT for motor vehicle drivers have been shown to reduce by more than three times the number of vehicles crossing the track per train arrival at intersections with flashing lights (Richards “Evaluation” 1990). However, it should be noted that because the physical differences between CWT and FDWT systems are indistinguishable to the motor vehicle driver, the benefits of CWT systems could be hampered by a perceived lack of credibility of all HRGCs due to excessive warning times at crossings with FDWT (Halkias 1987).

2.2.2.3 Railroad Quiet Zones

On June 24, 2005, the FRA enacted a Final Rule on train horn use at HRGCs. This Final Rule stipulated that a train was required sound its horn at every public HRGC. The Final Rule also laid out provisions for establishing “quiet zones,” which are stretches of railway in which trains are not required to sound their horns at HRGCs. A quiet zone may be established by a jurisdiction or multiple jurisdictions after it has been demonstrated that each public crossing’s risk index falls under an established threshold. If necessary, additional safety measures (such as four-quadrant gates or wayside horns – horns located at the HRGC which focus the sound on roadway vehicles at the crossing and reduce sound levels in the area) must be deployed to reduce a crossing’s risk index to acceptable levels (FRA 2008).

The City of Lincoln is working to establish two quiet zones within its limits. The first is a 6.5-mile stretch of rail line which includes the Adams Street crossing and portions of UNL's test bed ("City" Lincoln Journal Star 2007) ("Current" RTSD 2010). In order to meet the FRA's risk index requirement, wayside horns will be installed at the Adams Street crossing ("Update" Lincoln Journal Star 2008). Figure 6 shows the location of the new quiet zone, which is scheduled to be enacted in 2008 ("Current" RTSD 2010).



FIGURE 7 Map of quiet zone to be established in Lincoln in 2008 ("Current" RTSD 2010).

2.2.3 Highway Traffic Signals and HRGCs

Hazardous situations can arise from a signalized highway intersection being located in close proximity to an HRGC. The most likely hazard in this situation is the queue of roadway vehicles extending over the HRGC, typically due to a red traffic signal.

Signalized highway intersections located within 200 feet of an HRGC are recommended

to be able to be preempted in the event of a train (MUTCD 2009). Preemption is also recommended if the distance between the HRGC and the highway intersection is greater than 200 feet but queueing still occurs at the HRGC, or if an engineering study finds preemption appropriate (MUTCD 2009) (Tustin 1986).

The preemption sequence consists of a clearance period, which provides adequate green time to clear queued roadway vehicles from the approach where the crossing is located, and a holding period, where roadway vehicle movements onto the crossing approach are restricted (see Figure 8) (Korve 1999). The clearance period terminates the green intervals of all opposing movements at the intersection; any termination of a green interval must be done using standard yellow and all-red phases. Green time is then given to the roadway which crosses the tracks to ensure they are clear of vehicles when the train arrives. During the holding period, vehicle movements which do not conflict with the HRGC are permitted. The use of blank out “No Left Turn” or “No Right Turn” signs for such restricted movements is recommended (MUTCD 2009) (Tustin 1986) (Korve 1999).

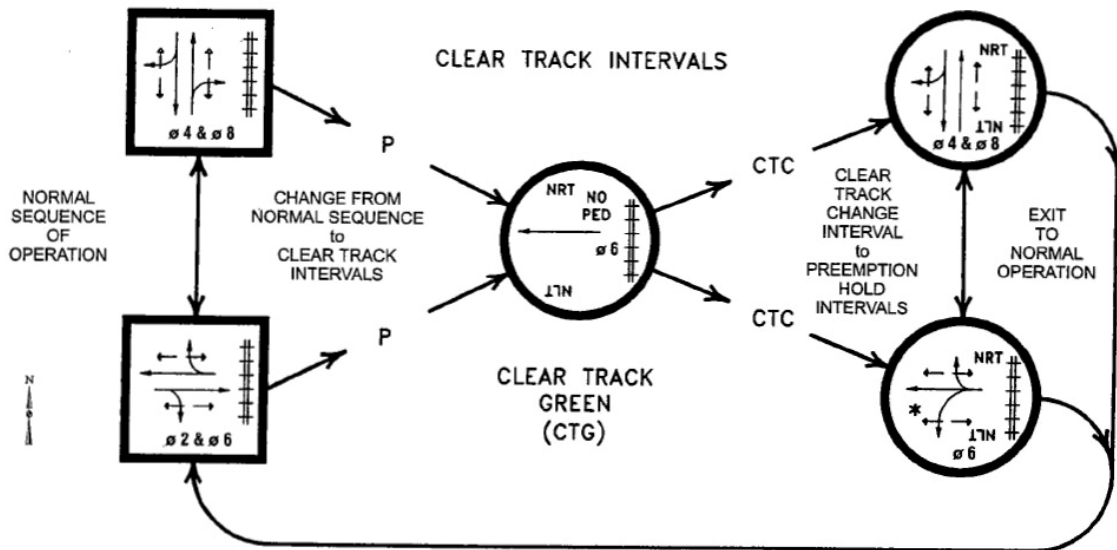


FIGURE 8 Example of signal preemption phasing at an intersection adjacent to an HRGC (Korve 1999).

At intersections utilizing advance preemption, there is a risk of creating a situation called a “preempt trap.” A preempt trap occurs when the green phase of the clearance interval terminates before the warning devices at the HRGC have been activated. If roadway vehicles at the signal queue back to the tracks (since they will not receive green time until after the train departs), it creates the possibility of vehicles stuck on or near the tracks when the warning devices at the crossing activate (Engelbrecht 2002). There are different approaches to avoiding the preempt trap, including: installing a “not-to-exceed” timer on the rail crossing warning devices, which prevent them from engaging until a certain time after the preempt call is received; installing a “gate down” sensor, and beginning the clearance interval only after the traffic signal controller has received indication that the warning gates are fully deployed; and the LADOT approach, which

uses advanced software and hardware to include more comprehensive information for the improvement of traffic signal operations (Sun 2007).

2.3 HRGC Physical Features

The physical layout and characteristics of a rail crossing can create demanding circumstances for a motor vehicle driver. Additionally, hazardous physical attributes of a crossing may not be immediately apparent to the motor vehicle driver as posing a hazard.

2.3.1 Sight Obstructions

Obstructions in sight lines pose a safety hazard, particularly at HRGCs with passive warning signals in which the motor vehicle driver must make a decision on whether or not it is safe to cross the intersection. Permanent and semi-permanent objects such as buildings, trees, and utility structures can all reduce the ability of the motor vehicle driver to adequately be able to detect an approaching train. When it is not possible to remove sight obstructions, other strategies must be used to maintain acceptable safety levels at the HRGC, such as reducing the speed limit on the roadway or installing additional warning devices.

Another cause of reduced sight lines is vegetation. A study in Finland showed that vegetation restricting sight distances was the most common safety deficiency at HRGCs (Kallberg 2002). Clearing vegetation on a regular basis can maintain proper sight lines and adequate safety levels at a crossing.

One study showed that the most important factor to motor vehicle drivers when making a decision on whether or not to cross the HRGC was the actual sight of the train (Hughes 1999). Additionally, “judgment of time until train reaches crossing” and “perceived speed of the train” were ranked second and third, respectively; both of these

factors are also contingent on the visibility of the train (Hughes 1999). These common perceptions underscore the importance of sight lines and visibility at an HRGC.

2.3.2 *Nighttime Visibility*

Visibility becomes a concern in low-light conditions at HRGCs, particularly those with slow-moving trains or trains that block the crossing for a significant period of time. The concern with this set of circumstances is that motor vehicle drivers who fail to recognize a train's presence at the crossing will drive in front of the train or, more typically, run into the side of it (Russell 1980). When these situations exist or when crash history indicates visibility restrictions exist, the MUTCD recommends the installation of illumination (MUTCD 2009).

Russell and Konz estimated that roughly 11 percent of all car-train collisions at HRGCs in the U.S. during an eight year period involved a roadway vehicle running into the train under nighttime conditions. They determined that motor vehicle driver perception dictated the best configuration for illuminating an intersection to be four lights, one on each side of the roadway on each side of the track. For streets that weren't one-way, they recommended a minimum of at least one lamp on either side of the tracks, as "silhouetting," or having a light source only behind the train, was not an effective means of making the train visible to the motor vehicle driver (Russell 1980).

Noyce and Fambro showed that a modified passively controlled crossing can improve motor vehicle driver awareness in nighttime conditions. The addition of a detector loop-activated strobe and special warning sign on the roadway approach caused an alteration in motor vehicle drivers' behavior, with overall reduced speeds, increased caution, and even activation of roadway vehicle high beam lamps (Noyce 1998).

2.3.3 *Geometry*

The geometric layout of an HRGC can affect the hazard level of the crossing, especially at a passively controlled crossing. Proper sight lines are crucial to a motor vehicle driver's recognition of an approaching train. Neglecting all roadside visual obstructions, the HRGC layout that provides optimal sight lines is a right-angle intersection of straight sections of the rail line and the highway (Carroll 1995). Conditions are less favorable at a crossing that is at an obtuse angle to the roadway (where the rail line runs from the rear-left quadrant to the front-right quadrant relative to the roadway approach). In this situation, a motor vehicle driver has a favorable view to the right, but must look back over his or her left shoulder to see whether or not a train is approaching from the left. Even less favorable is a crossing that is at an acute angle to the roadway (where the rail line runs from the rear-right quadrant to the front-left quadrant). Again, the motor vehicle driver has a favorable view to one side, this time to the left. However, to check for the presence of a train coming from the right, the motor vehicle driver must look over his or her right shoulder. Except in the case of a motorcycle, there are at least some sight obstructions when looking back through a roadway vehicle. The situation is even worse for roadway vehicles with no back window, such as tractor trailers and other heavy trucks (Carroll 1995).

Roadway intersections in close proximity to an HRGC can also pose hazards to motor vehicle drivers, especially unsignalized roadway intersections. The placement of roadway intersections near railroad tracks is discouraged by the American Railway Engineering and Maintenance-of-Way Association (AREMA), as is constructing roadways close to and parallel with to railroad tracks ("Manual" AREMA 2001).

In addition to the orientation of the rail line with respect to the roadway, the number of tracks also has an effect on safety at an HRGC. In an extensive study of crash histories in California from 1960 to 1970, Schulte found that crashes were 80 percent more likely at crossings with two or more main-line tracks than at crossings with only one track (Schulte 1976). The increased crash risk was uniform, regardless of whether the crossing had active warning or passive warning devices installed.

2.4 HRGC Crash Prediction Models

While collisions involving roadway vehicles at HRGCs are a serious concern, on a per-crossing basis they are rare events. This rarity poses a problem in predicting and modeling the potential for crashes at any given crossing. Because of the infrequency of actual collisions, other variables must also be used in developing crash prediction models. Some examples of such variables are traffic volume, train volume, the number of roadway lanes, and the type of warning device at the crossing. There are two main types of crash prediction models: relative models and absolute models. Several nationally recognized models will be discussed in this section.

2.4.1 Relative Crash Prediction Models

Relative crash prediction models rate a crossing's "hazard index," the hazard level or potential for a crash at a crossing, and are useful for relative comparisons of one crossing to another or for ranking potentially hazardous crossings.

2.4.1.1 The Ohio Method

The Ohio Method was developed in 1959, and takes into account a broader set of physical crossing characteristics than the New Hampshire Formula. Among these characteristics are train speed, the grade of the roadway approach, the angle of the

roadway relative to the tracks at the crossing, the number of tracks, and sight distance at the crossing (Saccomanno 2003). The formula for the Ohio Method is expressed as:

$$H.I. = A_f + B_f + G_f + L_f + N_f + SDR \quad (1)$$

Where:

H.I. = Hazard index of crossing

A_f = Collision probability factor

B_f = Train speed factor

G_f = Approach gradient factor

L_f = Angle of crossing factor

SDR = Sight distance rating

2.4.1.2 The City of Detroit Formula

The City of Detroit Formula, developed in 1971, uses a large number of physical crossing attributes as well as crash history data in determining a crossing's hazard index. Some of the factors used are overall train volume, train volume by type of train (passenger, freight, switch), sight distance, number of tracks, the condition of the crossing, the type of warning device installed at the crossing, and the occurrence of collisions (Saccomanno 2003). The City of Detroit formula is given as:

$$H.I. = \frac{T}{1000} \left(\frac{P}{10} + \frac{F}{20} + \frac{S}{30} \times SDR + N_f + X_f + R_f \right) (100\% - P_f \%) + 2A_e \quad (2)$$

Where:

H.I. = Hazard index of crossing

T = Average 24 hour train volume

P = Number of passenger trains in 24 hours

F = Number of freight trains in 24 hours

S = Number of switch trains in 24 hours

SDR = Sight distance rating

N_f = Number of tracks factor

X_f = Condition of crossing factor

R_f = Road approach factor

P_f = Protection factor

A_e = Collision occurrence

2.4.1.3 The New Hampshire Formula

The New Hampshire Formula was developed in 1971, and utilizes three basic crossing characteristics to determine the hazard index: roadway vehicle traffic, train traffic, and the type of warning device installed at the crossing (Tustin 1986). The New Hampshire Formula is expressed as:

$$H.I. = V \times T \times P_f \quad (3)$$

Where:

$H.I.$ = Hazard index of crossing

V = Average annual daily traffic

T = Average annual daily train traffic

P_f = Warning equipment protection factor

- Automatic gate: 0.10 or 0.13

- Flashing light: 0.20, 0.33, or 0

- Signs only: 1.00

2.4.2 Absolute Crash Prediction Models

Absolute models project the number of crashes expected over a given time frame.

2.4.2.1 Peabody-Dimmick Formula

The Peabody-Dimmick Formula, also referred to as the Bureau of Public Roads Formula, was developed in 1941. It uses daily roadway vehicle and train traffic and a protection coefficient to estimate the number of crashes that are expected over a five year period (Tustin 1986). The Peabody-Dimmick Formula is stated as:

$$A_5 = 1.28 \frac{(V^{0.170})(T^{0.151})}{P^{0.171}} + K \quad (4)$$

Where:

A_5 = Expected number of crashes in 5 years

V = Average annual daily traffic

T = Average annual daily train traffic

P = Protection coefficient

K = Additional parameter

2.4.2.2 NCHRP Report 50

The National Cooperative Highway Research Program (NCHRP 1997) Report 50, released in 1968, provides a complex crash prediction model that can be simplified and used in conjunction with several tables and graphs. The main crossing characteristics utilized are train and roadway vehicle traffic and a constant based on the type of warning device (Tustin 1986). The simplified NCHRP Report 50 Formula is expressed as:

$$EAF = (A)(B)(CTD) \quad (5)$$

Where:

EAF = Expected crash frequency

A = Average annual daily traffic

B = Safety constant for warning device

$CTD =$ Average annual daily train traffic

2.4.2.3 Coleman-Stewart Model

The Coleman-Stewart Model, developed in 1976, uses roadway vehicle traffic, train traffic, and four coefficients to determine the predicted number of collisions at a crossing. Each of the four coefficients has 12 possible values based on two subsets of crossing characteristics. The first crossing characteristic is the type of warning device used at the crossing – passive, flashing lights only, or flashing lights and automatic gates. The second subset of crossing characteristics is whether the crossing is single-track in an urban setting, single-track rural, multi-track urban, and multi-track rural (Coleman 1976).

The Coleman-Stewart Model equation is expressed as:

$$\log \bar{A} = C_0 + C_1 \log \bar{V} + C_2 \log \bar{T} + C_3 (\log \bar{T})^2 \quad (6)$$

Where:

\bar{A} = Average number of crashes per crossing-year

\bar{V} = Weighted average of daily traffic volume

\bar{T} = Weighted average of train volume

2.4.2.4 U.S. DOT Model

The U.S. Department of Transportation (DOT) Model, which was refined and revised throughout the 1970s and early 1980s before being finalized in 1986 (Hellman 2007), uses two equations in determining the number of predicted crashes at a crossing. The first equation is based on a crossing's characteristics, including highway and train traffic, the number of tracks, the number of trains during daylight, whether or not the highway is paved, maximum train speed, the type of highway, and the number of highway lanes (Tustin 1986). The first portion of the U.S. DOT Model is expressed as:

$$a = K \times EI \times MT \times DT \times HP \times MS \times HT \times HL$$

Where:

a = Initial crash prediction (crashes per year)

K = Formula constant

EI = Exposure index factor

MT = Main tracks factor

DT = Day train traffic factor

HP = Paved highway factor

MS = Maximum train speed factor

HT = Highway type factor

HL = Highway lanes factor

Each of these factors must be determined from a given table, and each can range in value depending on the type of warning device used at the crossing – passive, flashing lights only, or flashing lights with automatic gates.

The second formula in the U.S. DOT Model combines the basic first formula with crash history data to determine the final predicted number of crashes (Tustin 1986). The second formula is stated as:

$$A = \frac{T_0}{T_0 + T}(a) + \frac{T}{T_0 + T}\left(\frac{N}{T}\right) \quad (8)$$

Where:

A = Final crash prediction (crashes per year)

a = Initial crash prediction from basic formula

T_0 = Formula weighing factor

T = Number of years

N = Number of observed crashes in T years

2.4.3 *Crash Severity Prediction Models*

In addition to models which calculate a crossing's hazard index or predict the number of expected crashes at a crossing, models have been developed to predict the severity of a crash should one occur.

2.4.3.1 **Coleman-Stewart Severity Prediction**

In addition to their crash prediction model, Coleman and Stewart developed crash severity predictors in 1976 (Coleman 1976). These predictors were not expressed as a formula, but rather as tables with rates of fatalities and injuries depending on several factors, including train speed, roadway vehicle speed, and whether or not the crossing utilized crossbucks or flashing lights as warning signals (Coleman 1976).

2.4.3.2 **DOT Severity Prediction Formulas**

The U.S. DOT severity prediction formulas, finalized in 1986 (Hellman 2007), can be used to predict either the number of expected fatal crashes or the number of expected casualty crashes. Fatal crashes are those in which a person dies, while casualty crashes are those in which a person dies or is injured (fatal crashes are a subset of casualty crashes). The prediction formulas for both fatal crashes and casualty crashes have the same structure. Given that a crash occurred, the probability that a fatal or casualty crash occurred is found. These probability equations are based on factors such as maximum train speed, the number of through trains per day, the number of switch trains per day, whether the crossing is urban or rural, and the total number of tracks at the crossing (Farr

1987). The probability of the occurrence of a fatal crash, given that a crash occurred, is stated by the formula:

$$P(FA | A) = \frac{1}{(1 + KF \times MS \times TT \times TS \times UR)} \quad (9)$$

Where:

$$KF = 440.9$$

$$MS = ms^{-0.9981}$$

$$TT = (tt + 1)^{-0.0872}$$

$$TS = (ts + 1)^{0.0872}$$

$$UR = e^{(0.3571) * ur}$$

$$ms = \text{Maximum train speed}$$

$$tt = \text{Through trains per day}$$

$$ts = \text{Switch trains per day}$$

$$ur = \text{Urban or rural crossing (0 for rural crossing, 1 for urban)}$$

The probability of the occurrence of a casualty crash, given that a crash occurred, is expressed as:

$$P(CA | A) = \frac{1}{(1 + KC \times MS \times TK \times UR)} \quad (10)$$

Where:

$$KC = 4.481$$

$$MS = ms^{-0.343}$$

$$TK = e^{(0.1153) * tk}$$

$$UR = e^{(0.2960) * ur}$$

tk = Number of tracks

The conditional probabilities are then multiplied by the expected number of total collisions at the crossing. This gives the final number of expected fatal crashes (Equation 11) and casualty crashes (Equation 12) per crossing per year.

$$FA = A \times P(FA | A) \quad (11)$$

$$CA = A \times P(CA | A) \quad (12)$$

2.5 Detection and Data Collection Technologies

As discussed previously, first generation detection systems used to provide active warning at HRGCs have proven over many years to be highly safe and reliable. Sensors utilizing second and third generation detection technologies not only provide an alternative to first generation detection at rail crossings, but also possess other potential detection and data collection capabilities. In addition to train detection, some sensors can detect roadway vehicle and even pedestrian intrusions at an HRGC, while others can detect trespassers at train bridges and tunnels (daSilva 2006). As an illustration of data collection capabilities, it has been shown that video detection holds some promise in the area of automated flagging, annotation, and archiving of events at HRGCs. Even without full automation of data collection, video detection can reduce the time for manual extraction of data (Villatoro 2006).

Each type of sensor has advantages and drawbacks inherent to its technological characteristics, although some sensors combine technologies to reduce deficiencies. For example, two roadway vehicle intrusion systems – one combining low power laser and video and the other combining passive infrared and ultrasonic detection – were shown to

be highly effective when compared to systems relying on only one technology (Reiff 2001). Many of these technologies have the additional advantage of being located outside of the roadway and track, which reduces the cost and disruption of maintenance and installation. This aspect also gives the opportunity for third parties to gather train data. It should be noted that none of these next generation detection technologies have had a full-scale implementation as a replacement for track circuitry (Reiff 2001) (Klein 2006). The following sections will detail several detection technologies, including the advantages and disadvantages of each.

2.5.1 Video Image Processors

Video image processors typically consist of a video camera, a computer processing unit, and software for translating video images into data. The video processor analyzes the video feed, typically by examining variations in the pixels from frame to frame against a “learned” background or by searching for unique connected areas of pixels (Klein 2006). Data are extracted from the video using any of a number of algorithms (Klein 2006) (Mimbela, 2007).

One major advantage to video image processing is the ability of a human to inspect the sensor output (the video feed) either in real-time or from an archive. These sensors can also offer a wide range of data. One video image processing unit can be used on multiple lanes, and altering the area being monitored is quick and efficient (Mimbela, 2007).

Video image processing is most effective when the camera is mounted overhead, though proper mounting locations aren’t always immediately available. Lower mounting locations result in greater error in speed measurement (Klein 2006). Wind and vibrations

on the camera can reduce the performance of the system. Also, since this type of sensor relies on video cameras, system performance can be affected by ambient conditions – anything from rain, snow, or fog to dust or condensation on the camera lens. Light conditions can also be problematic. Shadows from roadway vehicles in adjacent lanes, glare from the sunlight, transition from daytime to nighttime, and poorly lit nighttime conditions can all cause problems for a video image processing system (Klein 2006) (Mimbela 2007). However, systems utilizing two video cameras to create a stereo image have been shown to diminish the effect of light on the sensor (daSilva 2007).

2.5.2 *Microwave Radar*

Microwave radar sensors use radar operating at an FCC-regulated frequency. The sensor works by emitting energy at the area desired for detection. A sensor can transmit either continuous wave Doppler waves or frequency modulated continuous waves (Klein 2006). When a roadway vehicle or train passes through the detection area, some of the energy is reflected back towards the sensor, which then converts the signal to data. Sensors can be mounted overhead or to the side, but are more effective if mounted overhead. Overhead-mounted microwave radar is capable of producing volume, occupancy, speed, and roadway vehicle/train length data (Mimbela 2007).

For the purposes of detection or data collection (where the range between the sensor and detection zone is short), microwave radar sensors are unaffected by adverse weather conditions. The sensor is capable of multiple detection zones, and can directly measure speeds. Some microwave radar sensors can monitor traffic flow in as many as eight lanes (Klein 2006) (Mimbela 2007).

Some types of microwave radar cannot detect the presence of a stationary object; additionally, some perform poorly as counters (Mimbela 2007).

2.5.3 *Infrared*

Active infrared sensors emit low-power infrared light from two sets of laser diodes. The sensor then measures the time when the roadway vehicle/train enters each beam and can calculate its speed. These sensors can be mounted either overhead or to the side, and are capable of collecting speed, length, classification, roadway vehicle/train and queue length, and can provide presence detection (Mimbela 2007).

Passive infrared sensors measure differences in the emissivity and temperature in the detection zone (Klein 2006). When mounted overhead, passive infrared sensors can have the same data collection capability as active infrared sensors (Mimbela 2007).

Infrared sensors can provide an abundance of data, and are capable of multiple detection zones. Sun glare and sudden changes in lighting have little impact on these sensors (Klein 2006). Among their disadvantages are that heavy fog and blowing snow hamper the effectiveness of active infrared sensors. Also, some passive infrared sensors provide substandard presence detection (Mimbela 2007).

2.5.4 *Ultrasonic*

Ultrasonic sensors transmit sound energy above the threshold of human hearing at the detection zone. It then senses differences in the energy reflected from the background and derives detection and data from this signal. Ultrasonic sensors may be mounted either overhead or to the side of the desired detection zone. Most of these sensors are capable of detecting occupancy, count, and presence data (Klein 2006) (Mimbela 2007).

One strength of ultrasonic sensors is that some models are capable of multiple detection zones. Among the sensors' weaknesses is the fact that air turbulence and temperature variances can adversely affect their performance, though some sensors are manufactured with temperature regulation (Klein 2006) (Mimbela 2007).

2.5.5 Laser

Laser detection sensors utilize a set of one or more optical transmitters and a set of one or more receivers to calculate the speed of roadway vehicles (Klein 2006). Several other types of sensors have been deployed on a limited or experimental basis. Laser radar has shown promise as a detection option. In limited deployment in Sweden, laser radar systems had the ability to distinguish between roadway vehicles and pedestrians at an HRGC. The system was mounted on a pole to the side of the tracks, had a range of 100 meters, and could even wirelessly transmit picture or video (daSilva 2007). This same laser radar system has also been successfully deployed to detect people, animals, and even projectiles in the railway (daSilva 2007).

2.6 On-Train Data

Train data may be collected from onboard the train itself, though these data are not typically available to the public. The railroads collect data to aid in operations and to provide information in the event of a crash at an HRGC (BNSF 2005). Train data are also continuously recorded in-train to aid investigators should a train crash occur. These data are not available to any entity except in the event of a crash (Evans 1999).

2.6.1 Event Data Recorders

Since 1993, the FRA has required trains which travel over 30 mph to be equipped with event data recorders (Dobranetski 1999). These event recorders are required to log data

for “train speed, direction of travel, distance traveled, throttle position, brake application, cab and/or wayside signals, and applicable communications” over the most recent 48 hour span (Dobranetski 1999). The primary purpose of the recorders is to aid the National Transportation Safety Board (NTSB) in its investigation of train crashes. Recommendations for operational or equipment safety improvements can then be made by the NTSB based on these investigations.

Since its enactment, the requirement for event data recorders has been modified to update hardware specifications and to address crashworthiness concerns. For example, by June of 2009, older magnetic tape recorders must be replaced by recorders with memory modules (Federal Register “Locomotive...” 2005). Furthermore, standards have been established for data recorders’ “survivability from fire, impact shock, crush, fluid immersion, and hydrostatic pressure” (Federal Register “Locomotive...” 2005). The NTSB has also recommended that in-cab voice recording be included in the event data recorders to further aid in crash investigation (Dobranetski 1999).

2.6.2 On-Train Video

Although it is not required by the FRA, many railroads utilize on-train video technology. Monitors may be placed in the cab to use video feeds to eliminate blind spots in the cab. Recorded video can help the railroads ensure operational efficiency of their crews, and can be used for training purposes (Dobranetski 1999). Recorded video is also a useful tool in attempting to learn about the circumstances leading up to a crash.

Railroads can supplement on-train video cameras with other sources of train data to create an entire proprietary data-collection system. For example, Norfolk Southern’s “RailView” system provides video information (such as weather, visibility, warning

signal deployment, and track conditions), operational characteristics of the train (train speed and direction, and brake application), and audio from outside of the locomotive cab (to record train horn deployment) (Norfolk Southern 2003). Figure 9 shows the placement of the camera in the locomotive's cab. The system is capable of recording 40 hours of data. RailView is beneficial both to Norfolk Southern and to federal crash investigators. It has curbed the number and size of lawsuits against Norfolk Southern resulting from HRGC crashes by replacing unreliable or erroneous witness testimony (Norfolk Southern 2003). RailView data can be used as a supplemental tool to a train's event data recorder for understanding factors that led up to a train crash event. Norfolk Southern began installation of RailView on an experimental basis in 1997, and has since been phasing in a full implementation of the system on its locomotives (Norfolk Southern 2003).



FIGURE 9 Norfolk Southern's RailView system features a camera mounted in the windshield of the locomotive's cab (Norfolk Southern 2003).

Union Pacific Railroad began deploying its digital video and audio recording system, “Track Image Recorders” (TIR) in 2004 (UPRR 2004). The TIR system uses an in-cab video recorder and a digital microphone outside the cab. The system can record up to five days of audio and video data, which is time synchronized with the locomotives’ event data recorders. The purpose of the system is to supplement the event data recorders during the investigation in the event of a train crash. Union Pacific has been retrofitting its locomotives with TIR in phases (UPRR 2004), and plans to have almost 90 percent of its 6,000-locomotive fleet equipped with TIR by the end of 2008 (UPRR 2008). Figure 10 shows a near collision at an HRGC from the camera of a Union Pacific TIR system.



FIGURE 10 Image of a near collision at an HRGC taken from the camera of a Union Pacific TIR system (UPRR 2008).

Burlington Northern Santa Fe Railway began installing in-cab cameras on an experimental basis in 2004; they began deploying cameras on new locomotives and retrofitting their current locomotives on a wide scale in 2005 (BNSF 2005). Their video archiving system also consists of a windshield-mounted camera in the locomotive cab and a microphone outside the cab to capture train horn audio data. Like Union Pacific's TIR system, BNSF's video and audio recording system is synchronized with each train's event data recorder, but does not itself collect or record train operational data. BNSF's system is capable of recording 70 hours of video and audio data. Its primary purpose is to review motorist behavior, HRGC warning device deployment, and other visual and audio information in the event of an incident at an HRGC (BNSF 2005).

2.6.3 *Positive Train Control*

As defined by the FRA, “Positive Train Control (PTC) refers to technology that is capable of preventing train-to-train collisions, overspeed derailments, and casualties or injuries to roadway workers” (FRA “1265” 2007). In practice, “PTC systems are comprised of digital data link communications networks, continuous and accurate positioning systems such as NDGPS, on-board computers with digitized maps on locomotives and maintenance-of-way equipment, in-cab displays, throttle-brake interfaces on locomotives, wayside interface units at switches and wayside detectors, and control center computers and displays” (FRA “784” 2007). PTC systems may be utilized by railroads to improve safety and efficiency at a system-wide level (FRA “784” 2007). In 2005, the FRA established regulations which supported the advancement of PTC for implementation by the railroads (FRA “1265” 2007). Since the establishment of these regulations, several systems have been developed or implemented to some degree in the United States.

After a successful pilot program in Illinois beginning in 2003, the FRA granted BNSF approval for further implementation of its Electronic Train Management System (ETMS). In 2007, BNSF began implementing ETMS on a 300-mile corridor from Kansas to Texas, and it plans to implement ETMS in other areas of its network in the near future (BNSF “ETMS” 2007)(FRA “1265” 2007). The ETMS system is an overlay which helps safeguard against train collisions and excessive train speeds. If the system detects a situation which requires braking, it informs the crew of the locomotive. If the crew does not then initiate braking, ETMS will do so automatically (BNSF “ETMS” 2007).

Union Pacific is planning to launch pilot programs for its communication-based train control and anti-collision systems in 2008 in Wyoming and Washington state (UPRR 2007)(FRA “1265” 2007). This system, the Vital Train Management System (VTMS), is a variation on BNSF’s ETMS (FRA “1265” 2007).

Norfolk Southern is in the process of implementing its own variation of the ETMS called Optimized Train Control (OTC). The testing of the OTC system will begin in 2008 in South Carolina (FRA “1265” 2007) (Norfolk Southern 2007).

2.7 Closure

This review of literature has highlighted many aspects of highway railroad grade crossings. These secondary data will provide an important background for developing the data collection instrument – the list of questions for potential stakeholders. This will be covered in Chapter 4, after a summary of the literature review identifying current and possible future sources of data for the highway stakeholders of the Adams Street HRGC. The following chapter will outline these and all other steps necessary to perform the needs assessment.

CHAPTER 3. METHODOLOGY

Having reviewed existing related literature in the previous chapter, this chapter's focus will shift to the methodology used to carry out the needs assessment. As covered in the Introduction, a needs analysis will be performed to determine highway stakeholder data needs at the Lincoln test bed. The needs analysis will consist of three main phases: pre-assessment, assessment, and post-assessment.

3.1 Pre-Assessment

To ensure overall thoroughness of the needs assessment and to maximize the efficiency of the assessment phase, adequate preparation is required. These preparations are referred to collectively as the pre-assessment phase. The pre-assessment phase establishes the framework of the needs assessment. For this project, pre-assessment will be accomplished through several main steps: identifying and defining the purpose and scope of the assessment; investigating pre-existing data (what is already known); identifying the major needs areas; and determining which data to collect, where it will come from, and the data collection approach.

As a point of clarification, it is important to distinguish between the two uses of the word "data" in this section. One usage describes quantifiable aspects of HRCGs. These include numerical descriptors of HRGC operational characteristics identified in the literature review (for example, the arrival time of a train, in seconds), as well as any potential numerical output of the Adams Street test bed. The other usage of "data" refers to the qualitative information to be gathered during the process of the needs assessment. For example, feedback from discussions with stakeholders is the "primary data" sought after in the needs assessment.

3.1.1 Completed Pre-Assessment Tasks

Some of the pre-assessment tasks are completed at this point. The first step in the pre-assessment phase, determining the purpose and scope of this assessment, was laid out in Chapter 1. The literature review in Chapter 2 focused on the collection of secondary data. In addition, unlike many needs assessments, the major needs areas for this project do not need to be independently identified, as they are inherent in the project goal: to identify the needs of highway stakeholders at the Adams Street HRGC test bed in Lincoln.

3.1.2 Investigation of Pre-Existing Data

There are two different approaches for gathering qualitative data in a needs assessment. One approach, primary data collection, is what comprises the assessment phase of a needs assessment (as will be discussed in Section 3.2). The other data collection approach, secondary data collection, is the review and analysis of existing data, and will be a main part of the pre-assessment phase for this project. Chapter 2 highlighted many HRGC aspects and quantifiable data that are currently available or could potentially be available to interested highway stakeholders. The secondary data derived from this review of existing literature will be summarized, and will be used to help formulate other parts of the pre-assessment.

3.1.3 Stakeholder Selection

The next step in the pre-assessment phase will be to identify which qualitative data to collect and where they will come from. The data that are desired are the highway stakeholder needs at the HRGC test bed. Therefore, a list of highway stakeholders should be specifically identified.

The list of highway stakeholders to be interviewed may be broken down into three categories: agencies in charge of traffic control and pedestrians at crossings; day-to-day users of crossings who have no role in their operations, including emergency personnel, commercial vehicle operators, and other carrier operators; and any entities or other researchers who might have potential use for data gathered. While it was important to make the distinction in the literature review, since this project is focused on the highway side of HRGCs, “vehicles” will refer to roadway vehicular traffic for the remainder of this thesis.

The first group of highway stakeholders consists of any agencies which control vehicle and pedestrian traffic at HRGCs; this group includes the City of Lincoln, the Nebraska Department of Roads (NDOR), and the City of Omaha. For Lincoln, the entity most directly responsible for the safety of highway vehicular and pedestrian traffic is the Street and Traffic Operations section of their Public Works Department; for Omaha this entity is the Traffic Engineering division of their Public Works Department; and for NDOR, the entity is the Rail and Public Transportation Division. The City of Omaha will not be included in the main analysis and results of this project, since they are not a stakeholder of the Adams Street HRGC and test bed. Rather, they are included in the list of stakeholders to illustrate how other municipalities may handle railroad crossings differently, given a different level of proliferation of HRGCs.

Another group of highway stakeholders is organizations which utilize the HRGC at the test bed location (or similar HRGCs in the area), but are not involved in its operation. Like any stakeholder, safety at HRGCs would be a concern to this second group of stakeholders, but this group does not control policies, infrastructure, maintenance, or any

other factors directly affecting safety at the HRGC like the first group does. These users include the City of Lincoln Fire and Rescue Department, Lincoln Public Schools Custodial and Transportation Services (school bus operators), and the Nebraska Trucking Association (other commercial vehicle operators). These three stakeholders were chosen because collectively, they represent a large spectrum of the non-general-public highway traffic at the crossing.

The Lincoln Fire and Rescue Department is divided into two branches: Operations and Support Services. All of the Department's functions, including fire response, ambulance/EMS operations, and dispatching, fall under one of these two branches; therefore, the heads of each of these two branches will be able to provide all of Lincoln Fire & Rescue's data needs. Lincoln Public Schools Custodial and Transportation Services (LPS) is the entity in Lincoln responsible for busing school children for the public school system. The Nebraska Trucking Association represents 800 trucking companies of various sizes in the state of Nebraska, which makes them ideally suited to give insights on the data needs of commercial carriers.

Any other potential users of data collected at the test bed should be considered. For this project, this group will be represented by the City of Lincoln and Lancaster County Railroad Transportation Safety District (RTSD). The RTSD is an entity created by Lincoln and Lancaster County under the authority of the Nebraska Legislature. The RTSD "identifies crossings in need of work, prioritizes projects and conducts studies to plan future work" ("Current" RTSD 2010). The RTSD Board of Directors consists of three Lincoln City Council members and three Lancaster County Commissioners. Roger Figard, Lincoln City Engineer, serves as the Executive Director of the RTSD. He will be

the stakeholder representative for the RTSD (as opposed to the City of Lincoln), since he is more closely and directly involved with the RTSD.

As mentioned in Chapter 1, there is a wide range of data already available to the users on the rail side of HRGCs (which are not necessarily shared with other users). It is for this reason that rail stakeholders, including Burlington Northern Santa Fe Railway, Union Pacific Railroad, and the Federal Railroad Administration, were not included on the stakeholder list, and that the focus was instead placed on the highway stakeholders of HRGCs.

3.1.4 Data Collection Approach

At this point, the potential needs of each highway stakeholder should be considered and the final result of the pre-assessment phase can then be completed: the determination of the data collection approach.

Using the potential needs of the highway stakeholders and the knowledge gained in the secondary data collection, a primary data collection method can be formulated. First, the specific data collection instrument or instruments to be used will be identified. With these in mind, the questions to be posed to the stakeholders will be selected.

3.2 Assessment

The assessment phase of a needs assessment is the phase in which the primary data are collected. Having completed the pre-assessment phase, it is now known what kinds of data are sought, from whom the data will be collected, and which instrument will be utilized in collecting the data.

The highway stakeholders identified in the pre-assessment will be contacted to request time to discuss with them their data needs at HRGCs. The questions developed in

the pre-assessment will be used to help guide the discussion with all stakeholders willing to participate. The general approach to each stakeholder discussion will be to describe the Adams St. test bed, to describe the purpose of this project, and then to use the data collection instrument as a guide in determining the data needs of the stakeholder. The stakeholders will be asked about their data needs not only at the Adams St. HRGC, but also at HRGCs in general; this is so all possible data needs can be identified for the sake of future consideration and research, not just those needs that apply to this specific crossing. Upon completion of the discussions, written transcripts of the discussions and the summaries from this thesis will be sent to each of the stakeholders for the verification of accuracy and to give each the opportunity for follow-up discussions.

3.3 Post-Assessment

Once primary data have been collected from the highway stakeholders, the data will be summarized and discussed. After describing in detail the existing test bed, the results of these discussions will be used to identify the data flows from the National ITS Architecture which correspond to the stakeholder data needs. These data flows are an effective way of presenting the stakeholder needs as well-defined rudimentary elements. Using these data flows, the adequacy of the test bed in meeting stakeholders' needs can be assessed. Additional data that could be viably collected at the test bed will be identified and discussed. This discussion will include where additional cameras or other types of detectors should be located.

CHAPTER 4. ASSESSMENT

Now that the general procedure of the needs assessment has been outlined, the pre-assessment will be completed. This chapter will cover the identification of the major needs areas and the determination of which data to collect, where it will come from, and the data collection approach. The completion of the main analysis will also be carried out, including the creation of the data collection instrument to be used in the stakeholder discussions. This is the point in the project when stakeholder discussions will take place.

4.1 Pre-Assessment

The planning stage of a needs assessment is critical to its success. The following sections highlight the steps required to lay the groundwork for the needs assessment.

4.1.1 Investigation of Pre-Existing Data

Chapter 2 provided a background in pre-existing literature involving potential and current data sources, as well as other aspects of HRGCs. This was a critical step in the pre-assessment phase, but the secondary data were broad and unrefined. To further implement these secondary data in the formulation of the primary data collection instrument, the literature review will now be summarized. This summary will be divided into two categories: data that are currently available at HRGCs, both in general and at the Lincoln test bed, and data that could potentially available at the Lincoln test bed.

4.1.1.1 Summary of Human Factors

The first section in the literature review covered human factors. Some aspects of human factors would be either cost prohibitive or nearly impossible to quantify with data collection. For example, motor vehicle driver fatigue plays a role in a driver's performance and decision-making, but even if one were able to query every driver to pass

through a crossing, fatigue is difficult to gauge and consistently quantify from one person to the next. Also, several motor vehicle driver attributes which may be useful to quantify and record, including drivers' ages, familiarity with the HRGC, perceptions of hazards, and driving experience, are impossible to record with an automated data collection instrument and would be cost prohibitive to collect on a permanent basis.

Although there are limitations with the direct collection of data on many human factors elements, there are some indirect ways to study motor vehicle driver behavior. The example cited in the literature review took observations of vehicles to quantify the aggression level of motor vehicle drivers (Shinar 2004). Any number of basic characteristics of a vehicle in traffic can be quantified through direct measurement, and each of these characteristics is a way of measuring motor vehicle driver performance, which can reflect different aspects of driver behavior. By combining multiple characteristics of a vehicle and of its surroundings, a clearer understanding of a driving situation or of motor vehicle driver behavior can be reached.

As an example, a red-light running camera system combines two "triggers" – a vehicle's position at which it is likely entering the intersection combined with the traffic signal being in its red state. Each of the two triggers gives little or no information on a motor vehicle driver's behavior, but when combined they indicate that a red light running violation is occurring.

Much in the same way, triggers could be used at an HRGC to observe and record motor vehicle driver behavior, including driver violations. For instance, shorter headways have been linked with higher motor vehicle driver aggression (Laagland 2005).

Therefore, short headway between approaching vehicles combined with an approaching train could be a trigger for an increased likelihood of a violation at an HRGC.

There has been shown a strong correlation between a motor vehicle driver's gender and his or her crash risk at an HRGC – namely, males are much more likely to be responsible for injury and fatality crashes than women. Data on motor vehicle driver gender might be able to be collected by recording video of the roadway approaches at an HRGC. However, the data would have to be produced by a researcher analyzing the video and would therefore likely be cost prohibitive on a permanent basis. Additionally, the accuracy of such data may be difficult to ascertain given possible issues with visibility of the motor vehicle driver on the video and human error in classifying each driver.

Looking for trains plays a significant role in a motor vehicle driver's decision-making at an HRGC. However, as with motor vehicle driver gender, collecting data on motor vehicle drivers' looking for trains would involve a person reviewing video from the HRGC and would likely be cost prohibitive on a permanent basis. The same video visibility issues would present themselves here, as well as difficulty determining to what degree motor vehicle drivers are looking (i.e., eye movement would be difficult to detect).

As discussed in Section 2.2.1, motor vehicle driver error accounts for almost all potential safety breakdowns at an HRGC. These erroneous motor vehicle driver behaviors can include actions such as stopping the vehicle on the tracks, passing under a closing gate, or stopping the vehicle past the gate arm. Such motor vehicle driver behavior occurring while a train approaches a crossing is one human factors area which is

easy to record – using video cameras and some type of storage media. Again, the video would have to be processed by a person to extract data. However, unlike broad categories of data involving every motor vehicle driver to cross through the HRGC, quantifying how drivers react to a train event only requires a few seconds of video review before a train’s arrival and after its departure. Moreover, there is some potential in automating some or most of the process of extracting data from video (Villatoro 2006). Using these collection methods can yield a wealth of information about motor vehicle driver behavior at the crossing – especially in regards to risky behavior.

4.1.1.2 Summary of HRGC Warning Signals

The electronic communications and signals which key the operations of the HRGC warning signals are a critical source of information regarding the operational characteristics of a crossing. Capturing (where possible) the train presence and preemption data or mimicking the sensors utilized by the warning devices and traffic signals in detecting and reacting to a train event could yield crucial information regarding train arrival and departure at a crossing and the time that the gates will be deployed.

For example, a system developed by researchers at Texas A&M University was capable of providing real-time train information to users. The TransLink system utilized a combination of cameras and radar sensors (“Rail Monitoring” Texas A&M 2008). The project’s goal was to provide information to transportation management centers, emergency service providers, transit operators, local traffic control, and motorist information systems. The system also featured a web-based graphical interface, which was available to the public via the Internet (see Figure 11). TransLink was capable of delivering the location, direction, speed, length, estimated arrival time, estimated

departure time, and the crossing occupancy time of trains along a rail corridor in College Station, Texas (“Rail Monitoring” Texas A&M 2008).

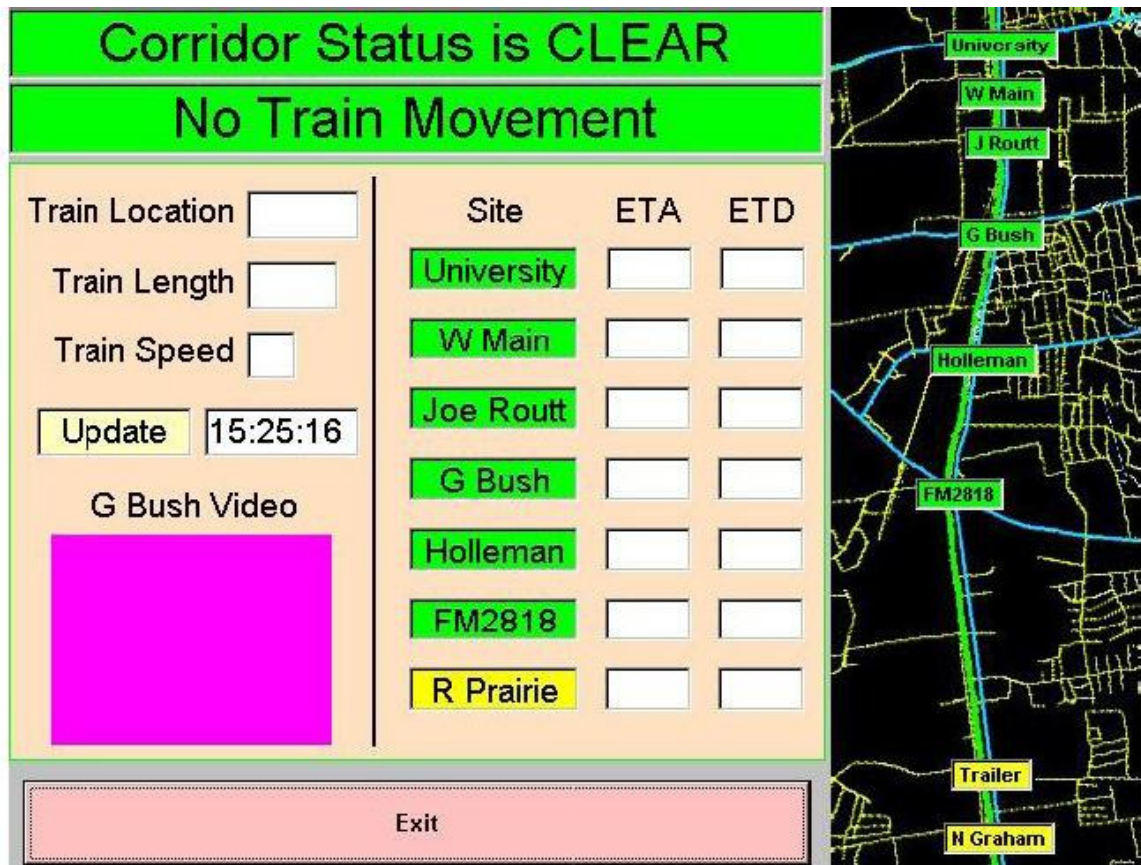


FIGURE 11 The TransLink® rail monitoring project’s web-based graphical interface (“Rail Monitoring” Texas A&M 2008).

Information derived from a system such as TransLink could also be distributed to motor vehicle drivers via variable message signs in advance of HRGCs. These signs would be placed far enough in advance of the crossing to allow motor vehicle drivers to make alternate decisions about route selection.

While the data they could potentially provide may be coveted by highway stakeholders, the warning devices themselves and their attributes are probably not of interest to highway stakeholders who are day-to-day users of the crossing in this project.

4.1.1.3 Summary of HRGC Physical Features

The Adams Street crossing in Lincoln has several unusual attributes, including a skewed angle of roadway approach, unusual roadway geometry, and a highway intersection immediately adjacent to the crossing. These issues would probably be of interest to government entities or other agencies responsible for traffic control and safety. However, highway stakeholders who are day-to-day users of the HRGC would be unlikely to find use in data regarding a specific crossing's physical features. This is not to diminish the role of a crossing's physical features on the hazards posed its users. A route which crosses a poorly lit HRGC with the roadway approach at an angle and sight obstructions would certainly be less desirable than a route with an "average" crossing. So while being affected by a crossing's physical features, day-to-day users would be unlikely to have any use for the quantifiable parameters describing those features.

4.1.1.4 Summary of HRGC Crash Prediction Models

Crash prediction models were included in the review to illustrate the HRGC characteristics and aspects that different groups have used in the past to attempt to quantify a specific crossing's hazard level. From a broader standpoint, a highway stakeholder may be interested in utilizing crash prediction models in route selection. For example, given two similar routes – each crossing a separate HRGC – a highway stakeholder may wish to assess the safety of each crossing and select the route with the less hazardous crossing.

The variables in most crash prediction models are historical in nature (i.e. crash history) or inherent to the crossing (i.e. highway type factor, maximum train speed factor). Several models utilize factors which require current data, namely vehicles per

day and trains per day at the crossing. These are items which government or other regulatory entities may find useful.

Like HRGC physical features, data from the crash prediction models for one crossing may not be of much use to highway stakeholders who are day-to-day users of the crossing.

4.1.1.5 Summary of Detection and Data Collection Technologies

This section was included to highlight different data collection technologies, their strengths and weakness, and their potential applications. It will not be covered in this section, but rather may be utilized in the conclusions in Chapter 6.

4.1.1.6 Summary of On-Train Data

This section covered several areas of new data collection systems which currently are available only to the railroads. Typically, most of this information is not shared due to security interests and to protect operational practices (although one exception will be detailed later in this section). Some of the data recorded on-train, namely those logged by in-train data recorders and video and sound recorders, become available only in the unfortunate event of a crash. These data and data from PTC systems would be extremely beneficial from an HRGC operational standpoint – to be able to pinpoint the precise location, direction, length, cargo, and speed of every train in real-time. However, it is unlikely that this information will be available outside of each rail carrier.

On a smaller level (for example, a rail corridor several miles long such as was used in the TransLink project) the on-train data collection capabilities of the railroads can be mimicked to a certain extent. As will be the case in the rail corridor adjacent to the Adams Street crossing in Lincoln, data collection sensors can be located immediately

outside of railroad right-of-way. Data available via these sensors, such as train presence, speed, and direction, cover many of the operational attributes previously available only to the railroads. These data will likely be of interest to all highway stakeholders in the Adams Street crossing.

There are a few instances of railroads sharing data with other agencies. For example, CSX Transportation has embarked in one-year pilot partnerships with the states of New York, Kentucky, and New Jersey and the Transportation Security Administration and a six-month partnership with the state of Maryland (“State” Baltimore Sun 2008). These partnerships allow state security and law enforcement officials to view the status of hazardous CSX cargo in real time. In the event of a train crash involving hazardous cargo, these state officials can notify local first-responding emergency crews with information regarding what types of materials were involved; the local emergency crews would then be better equipped to handle the crash (CSX 2008). These data-sharing programs are the first of their kind in the rail industry. When the pilot programs expire, CSX may opt to extend the terms of each program (“State” Baltimore Sun 2008) (CSX 2008).

With each of the sections of the literature review in Chapter 2 having now been summarized, the approach for collecting the primary data must be formulated.

4.1.2 Primary Data Collection Approach

To determine the primary data collection approach, it is necessary to consider potential highway stakeholder data needs, select a data collection instrument, and refine the instrument by formulating questions. This section describes the primary data collection approach for this project.

4.1.2.1 Consider Potential Highway Stakeholder Needs

The needs of each highway stakeholder will likely vary, but there will probably be a few trends. This section will detail the hypotheses of the author as to which data elements in which each of the highway stakeholders will find interest.

Day-to-day users of the crossing will likely be the most interested in data which provides information on operational characteristics of the HRGC, such as train arrival/departure times and the time a train occupies the crossing. Table 3 maps these data elements and denotes which of the day-to-day HRGC users it is hypothesized will find the data elements useful. Data elements of possible interest to stakeholders are not necessarily limited to those listed in the table.

TABLE 3 Hypothesized Highway Stakeholder Needs by Data Element (Denoted with an “X”) for Day-to-day Users of HRGCs

| Data Elements | <i>Highway Stakeholders</i> | | |
|---------------------------------------|-----------------------------|----------------------|---------------------|
| | Lincoln Fire Department | Lincoln School Buses | Commercial Vehicles |
| Human Factors | | | |
| Driver Behavior at HRGC | X | X | X |
| HRGC Warning Signals | | | |
| Train Arrival/Departure Information | X | X | X |
| HRGC Physical Features | | | |
| Angle of Roadway Approach to Tracks | | | |
| Geometric Layout | | | |
| Highway Intersection Adjacent to HRGC | X | X | X |
| Sight Obstructions at Crossing | X | X | X |
| HRGC Crash Prediction Models | | | |
| HRGC Hazard Level | X | X | X |
| HRGC Crash History | | | |
| Other Model Variables | | | |
| HRGC On-Train Data | | | |
| Train Speed | X | X | X |
| Train Direction | X | X | X |
| Train Length | X | X | X |
| Train Location | X | X | X |
| Train Cargo | X | | |

The day-to-day users listed in Table 3 would probably be interested in the behavior of their drivers at HRGCs, to ensure compliance with rules and regulations. While it was important to make the distinction in the literature review, for the remainder of this thesis the term “driver” will refer to drivers of motor vehicles on the highway, since the focus of this project is on the highway side of HRGCs. Train arrival and departure information would probably be of great use to these users, since many of their vehicles operate in a

time-critical environment. A highway intersection adjacent to an HRGC should be of concern to each of the entities, since each utilizes large vehicles which would be less able than passenger vehicles to maneuver out of harm's way in the event of a queue extending back across the tracks as a train approaches. Moreover, it may be more difficult for a driver of a large vehicle to judge exactly how far back the vehicle extends; the rear of the vehicle may be hanging over the tracks or close enough to the tracks to be struck by an oncoming train. Sight obstructions at crossings and the hazard level at HRGCs may be useful to day-to-day users of crossings, as such information could weigh into route planning decisions; for example, it may not be worth a modest time savings to regularly traverse a particular crossing if it is difficult to navigate or if it can be shown to be more dangerous than an alternate route. Train speed, direction, length, and location information would be useful to each of the day-to-day users of crossings, mainly because these data can be used to derive the aforementioned train arrival and departure information. Also, a train's location and cargo could be of use to the Lincoln Fire and Rescue Department if the train's cargo is a hazardous material, as this information would be critical in how they would respond to an incident involving such a train (or conversely, that a train's cargo was benign and no hazardous materials-related response was necessary).

Governmental and other regulatory agencies will probably have more broad data needs for planning and other applications. These hypotheses are listed in Table 4.

TABLE 4 Hypothesized Highway Stakeholder Needs by Data Element (Denoted with an “X”) for Governmental and Regulatory Agencies at HRGCs

| Data Elements | <i>Highway Stakeholders</i> | |
|---------------------------------------|-----------------------------|---------------------|
| | City of Lincoln | Neb. Dept. of Roads |
| Human Factors | | |
| Driver Behavior at HRGC | X | X |
| HRGC Warning Signals | | |
| Train Arrival/Departure Information | X | X |
| HRGC Physical Features | | |
| Angle of Roadway Approach to Tracks | X | X |
| Geometric Layout | X | X |
| Highway Intersection Adjacent to HRGC | X | X |
| Sight Obstructions at Crossing | X | X |
| HRGC Crash Prediction Models | | |
| HRGC Hazard Level | X | X |
| HRGC Crash History | X | X |
| Other Model Variables | | |
| HRGC On-Train Data | | |
| Train Speed | X | X |
| Train Direction | X | X |
| Train Length | X | X |
| Train Location | X | X |
| Train Cargo | X | X |

Because of the responsibility of governmental and regulatory agencies to provide for the safety of their constituents, they would likely have use for any kind of data that could lend itself to safety improvements. For this reason, they would probably be interested in most or all available or potentially available data.

The third group of highway stakeholders identified in the previous section includes any other users of data from the test bed. Table 5 lists the hypothesized data needs for this group.

TABLE 5 Hypothesized Highway Stakeholder Needs by Data Element (Denoted with an “X”) for Other Data Users at HRGCs

| Data Elements | <i>Highway Stakeholders</i> |
|---------------------------------------|-------------------------------|
| | Lincoln/Lancaster RTSD |
| Human Factors | |
| Driver Behavior at HRGC | X |
| HRGC Warning Signals | |
| Train Arrival/Departure Information | |
| HRGC Physical Features | |
| Angle of Roadway Approach to Tracks | X |
| Geometric Layout | X |
| Highway Intersection Adjacent to HRGC | X |
| Sight Obstructions at Crossing | X |
| HRGC Crash Prediction Models | |
| HRGC Hazard Level | X |
| HRGC Crash History | X |
| Other Model Variables | X |
| HRGC On-Train Data | |
| Train Speed | X |
| Train Direction | X |
| Train Length | X |
| Train Location | X |
| Train Cargo | |

Like governmental and regulatory entities, the City of Lincoln and Lancaster County RTSD is also concerned with improving safety at HRGCs. However, its focus seems to be more on a planning level than on an operations level, and the hypothesized highway stakeholder needs in Table 5 reflect that fact. Their concern with driver behavior at HRGCs probably wouldn't be as much with individual incidents as it would be with a pattern of problem behavior that could be rectified with a project or other course of action. Likewise, the RTSDs interest with on-train data would probably be more from a long-term trends standpoint than a real-time data standpoint.

4.1.2.2 Data Collection Instrument

As discussed in Chapter 1, there are five main methods for primary data collection in a needs assessment: the public forum approach, the nominal group process technique, the Delphi technique, the key informant approach, and the survey approach (Carter 1992) (University of Illinois 2007).

The public forum approach is implemented by gathering a large number of people and holding a forum to ask questions and gather primary data. The nominal group process technique is a variation of the public forum approach where the forum is broken down into smaller sections for discussion (Carter 1992). Neither technique is appropriate for this project, as the scope of the project is too narrow for the data that would most likely be collected from these methods. In addition, both methods require training facilitators and gathering a large number of people, making preparation and implementation impractically time- and labor-intensive.

The Delphi technique is implemented by selecting a group of respondents and distributing to them a questionnaire. Each respondent generates his or her own feedback, then returns the questionnaires. Based on the results of the initial survey, new questionnaires are distributed, and the process is repeated as many times as is necessary (Carter 1992). While the Delphi technique is more efficient than the first two methods with respect to time and labor costs, its results would still be too broad for the scope of this project.

The key informant approach uses as a source of data individuals with expertise or knowledge not typically available in the general public. A list of questions is prepared for these informants, and discussions are conducted with each one individually. The

results are then compiled and compared (University of Illinois 2007). The key informant approach is ideal for this project, since the desired feedback is technical in nature and requires expertise and knowledge specific to HRGCs. In addition, it is one of the most efficient methods to systematically assess needs (Carter 1992). The representatives of the highway stakeholders will be considered the key informants.

The survey approach uses the general public as a data source. After selecting a sample and deciding on which survey instrument to use, a survey is conducted to gather data from the general public. Again, the results are compiled and analyzed (Carter 1992). The major drawback of the survey approach is that it has the highest time and labor costs of any of the data collection approaches (Carter 1992). Since almost all relevant data to be gathered can be derived using the key informant approach, and since data gathered from the survey approach would be ancillary at best, the benefit-to-cost ratio of conducting a survey is very low and precludes it from consideration for this project.

4.1.2.3 Questions for Highway Stakeholders

The ultimate goal of the stakeholder interviews is to determine which data are commonly available and which of these data are desired by highway stakeholders, to identify which data are desired but not readily available, and to identify how the test bed can be used to provide the needed information. There are several main areas to consider when deciding what should be asked of stakeholders.

The first step in a stakeholder interview would be to identify which data from the HRGC, if any, are currently being used. Some data could be readily available to one highway stakeholder or group of stakeholders but not to others. For example, train arrival times at a crossing are available to the railway operators, but as mentioned

previously, in the interest of security and to protect operational practices this information is not shared (with the exception of a brief advance warning for signal preemption). If a stakeholder is currently using data from the HRGC, the type of data and the form that it takes should be identified. The following are examples of questions regarding this section:

- Are you currently using data from an HRGC or are there data from the HRGC that are readily available to you?

- If so, describe the data. What form do they take? How do you use these data? How long have you been using these data?

The main objective of each interview is to determine the data needs of each highway stakeholder. It should be determined whether or not the stakeholder must make assumptions in its dealings with the HRGC due to lack of sufficient data, as well as whether or not there is any information that would improve the stakeholder's safety or efficiency at the crossing. The interview should gauge the stakeholder's interest in (and if so, which types of) data relating to train operations, human factors, and traffic operations. Questions in this area will include (but will not be limited to):

- What type of information from the HRGC do you need?
- What information would help you with safety or efficiency at the crossing?
- Would human factors-related data be useful to you?
- If so, which type?
- Would HRGC operational data be useful to you (such as train arrival/departure times and traffic data)?

For any data desired, the highway stakeholder should specify how soon they would be needed. The data would be identified as either immediately useful to the stakeholder, or as useful in a future application (in which case the application should also be described). These questions would be follow-ups to any of the above questions in which the stakeholder showed interest. For example:

- Is this information that would be immediately desirable or helpful to you?
- Would the information possibly be useful to you in the future?
- If so, in what way?

The highway stakeholder should be questioned to gain a further understanding of the desired form of the data. The test bed will be capable of producing real-time data, as well as archived data. The stakeholder's preference for either real-time or archived data (or both) should be determined for each set of desired information. In the case of archived data, the stakeholder should specify the desired parameters of the data, such as whether or not they should be processed or sorted in any way and what level of aggregation is desired. Questions in this section will include:

- Would your data needs include real-time data? Archived data? Both?
- If archived data are desirable, would the data be useful in raw form or would they need to be processed or sorted in any way?

Questions for the stakeholders will not be limited to those listed here. These questions will provide the basic framework for the discussion; data and concepts from the literature review will augment these questions. Any other potentially valuable information from stakeholders will also be gathered and recorded.

4.2 Assessment

Stakeholder discussions were conducted using the data collection instrument as described above. The stakeholders included the City of Omaha, the City of Lincoln, the Nebraska Department of Roads, the City of Lincoln Fire & Rescue Department, Lincoln Public Schools Custodial and Transportation Services, the Nebraska Trucking Association, and the City of Lincoln and Lancaster County Railroad Transportation Safety District. The results are covered in the next chapter.

CHAPTER 5. RESULTS

Having carried out the pre-assessment preparations and used the data collection instrument to conduct highway stakeholder data-needs discussions in the assessment phase, the results of the stakeholder discussions will now be analyzed in the post-assessment phase of the needs assessment.

5.1 Post-Assessment

The following sections detail the results of stakeholder discussions with governmental and regulatory agencies, day-to-day users of HRGCs, and other data users.

5.1.1 Results for Governmental and Regulatory Agencies

The three highway stakeholders representing governmental and regulatory agencies were the City of Lincoln, the Nebraska Department of Roads, and the City of Omaha.

5.1.1.1 The City of Lincoln

The City of Lincoln was represented by Scott Opfer, Operations Manager, and by Larry Jochum, Senior Engineering Specialist. The discussion took place on March 26, 2009, at 1:30 PM. Appendix A contains an abridged transcript of the discussion with the City of Lincoln. The City's primary concern is how trains at HRGCs affect traffic from an operational standpoint. For the most part they are already receiving most of the data they would find useful at HRGCs.

The City of Lincoln currently receives arrival time information from the railroads at HRGCs with adjacent traffic signals. They utilize this information to preempt the traffic signal timing to allow for clearance of any vehicle queues from the tracks, and to run the signals to prevent vehicular movements onto the HRGC while the a train is present. The City relies on the railroads to calculate train arrival time. Immediately upon receiving the

initiation from the railroad cabinet, the City commences the preemption sequence at the intersection.

Besides the preemption of traffic signals for each train event, the City of Lincoln also looks at preemption information on a macroscopic scale. They observe preemption trends to see how many times per day and at what time of day signals are being preempted. This information can give them a better idea of how the signal timing on roadways adjacent to HRGCs is being affected. For example, the traffic signal on Cornhusker Highway near the Adams St. crossing is preempted about 70 times per day by the City's estimation, which means that 70 times per day the signal is knocked out of coordination for the several minutes during the preemption sequence plus the time it takes for the signal to transition back into coordination.

Another area in which the City of Lincoln currently tracks data is crash information. The City tracks crashes on and near HRGCs, including crashes that don't necessarily involve a train directly (for example, a rear end crash caused by the gates coming down).

The City of Lincoln identified a couple of areas where they have data needs. In establishing the quiet zone along the rail corridor that includes the Adams St. crossing, the City had to install additional safety measures at the crossing, including raised medians. The City would find it useful to be able to log data about driver violations (for example, a driver jumping the medians and driving around the gates when a train is approaching).

The City of Lincoln also expressed interest in being able to deliver train information to drivers in advance of HRGCs to aid drivers in finding alternate routes in the event of a train at a crossing. They actually installed two Changeable Message Sign (CMS) boards

at the intersection of 27th St. & Old Cheney Rd. several years ago, but then Burlington Northern lost a contract for hauling coal, virtually eliminating train traffic on the Highway 2 rail corridor and rendering the CMS boards of no use for train-related activity. When there was train traffic along that corridor, the signs were installed with the intention of warning motorists on eastbound or westbound Old Cheney that the tracks at 27th & Highway 2 (roughly a mile to the north) were blocked and would suggest that drivers use an alternate route. The City expressed interest in the installation of a similar system along the Cornhusker Highway rail corridor. They identified northbound and southbound 33rd St. and westbound Adams St. as the three approaches along the corridor that would benefit the most from such an advance warning system. They dismissed the other approaches along the rail corridor for the following reasons: eastbound Cornhusker/Adams, since drivers can easily see a train at the Adams St. crossing and simply continue along Cornhusker to use the 48th St. underpass; 44th St. is not an arterial street; and 70th St., due to its light traffic volumes and the availability of alternate routes. In addition to the advance locations north and south of the Adams St. crossing on 33rd St., the City identified the intersections 27th & Cornhusker and 20th & Cornhusker as desirable locations for advance warning CMSs.

5.1.1.2 Nebraska Department of Roads

The Nebraska Department of Roads (NDOR) was represented by Ellis Tompkins, Division Manager of the Rail and Public Transportation Division, and by Abe Anshasi, Public Transportation Engineer. The discussion took place on June 16, 2010, at 1:00 PM. Appendix G contains an abridged transcript of the discussion with NDOR. Almost all of

NDOR's data needs are already being met, as they could only identify one piece of desired information.

NDOR already collects some data which describes the characteristics of the crossing. In their inventory, they keep track of the following information about public HRGCs: whether the warning devices are active or passive; if the warning devices are active, what the types of active devices are; crossing surface type; the pavement type of the adjacent roadway; the number of railroad tracks; whether or not the tracks are main line tracks; whether or not there are advance warning signs or other signage; the rating of the crossing's condition; vehicular traffic counts; and train counts. NDOR does operate some traffic signals at a few locations around the state which are interconnected to railroad control cabinets at nearby HRGCs, for the purposes of traffic signal preemption. There are also some advance warning signs along Cornhusker Highway in Lincoln near the test bed which provide drivers messages such as "No Left Turn" as appropriate during train events. Finally, NDOR tracks incidents at HRGCs; crash information is catalogued by DOT crossing number.

The only HRGC data need identified by NDOR is to have more up-to-date traffic and train counts. While they currently have train and vehicular traffic data in their inventory, they stated a desire that this data be more recent than what can typically be found there.

5.1.1.3 The City of Omaha

The City of Omaha was represented by Todd Pfitzer, City Traffic Engineer, and by Glenn Hansen, Signal Timing Engineer. The discussion with Todd Pfitzer took place on March 26, 2009, at 10:00 AM, while the discussion with Glenn Hansen took place on June 29,

2010. Appendix B contains an abridged transcript of the discussion with the City of Omaha.

Like Lincoln, Omaha has a BNSF and a Union Pacific main line which runs through the city. However, unlike Lincoln, Omaha only has a few HRGCs on those main lines, and those only cross minor arterial streets. None of Omaha's main line crossings are adjacent to traffic signals. There are some HRGCs with side tracks or industrial lines in Omaha, and a few of those are adjacent to traffic signals. At some of those locations, the City's traffic signals are interconnected with the railroad for preemption. On that basic level, the City has interest in data at HRGCs (the train arrival times), which are provided by the railroads. Also, the City archives crash data, including crashes occurring in the vicinity of HRGCs. That is the extent of Omaha's concern with HRGC's, though. Due to a number of factors, perhaps including differences in topography and the configuration of past railroad construction, Omaha's treatment of HRGCs is far different from Lincoln's. Whereas Lincoln has their Railroad Transportation Safety District in an ongoing effort to carry out safety improvement projects, Omaha does not have the same need and instead just monitors HRGCs for potential safety issues. No railroad safety improvement projects have been necessary in Omaha in the recent past, and none are projected there for the foreseeable future. Table 6 illustrates the differences between the HRGCs in the two cities.

TABLE 6 Comparison of Number of Preempted Traffic Signals by City

| | <i>Municipality</i> | |
|---------------------------------------------------------------------------------|------------------------|----------------------|
| | City of Lincoln | City of Omaha |
| Total Number of Traffic Signals | 430 | 900 |
| <i>Percentage of Total Traffic Signals</i> | <i>100%</i> | <i>100%</i> |
| Number of Traffic Signals with Railroad Preemption | 10 | 6 |
| <i>Percentage of Total Traffic Signals</i> | <i>2.33%</i> | <i>0.67%</i> |
| Number of Traffic Signals with Railroad Preemption at Railroad Main Line | 10 | 0 |
| <i>Percentage of Total Traffic Signals</i> | <i>2.33%</i> | <i>0.00%</i> |

Again, the purpose of including of the City of Omaha here was to illustrate the differences that can exist in how different cities address HRGCs, depending on their situations. Omaha will not be included in the results and analysis sections of this project.

5.1.1.4 Summary of Results for Governmental and Regulatory Agencies

The primary concern of each of the governmental and regulatory stakeholders was the impact on vehicular traffic on and around HRGCs. Each of these stakeholders currently receives train arrival data from the railroads for the preemption of a traffic signal adjacent to an HRGC, as well as vehicle-train crash information. NDOR's utilization of train volumes, highway vehicular volumes, and the physical characteristics of HRGCs rounds out the list of data currently available to and utilized by each of these entities.

The City of Lincoln expressed strong interest in a system which would deliver train information to drivers in advance of HRGCs. The only human factors-related data that either of these stakeholders had interest in was the City of Lincoln wanting to log driver violations at HRGCs which were located in a railroad quiet zone. The results of the stakeholder discussions with governmental and regulatory agencies are summarized in Table 7.

TABLE 7 Summary of Highway Stakeholder Needs by Data Element for Governmental and Regulatory Agencies at HRGCs (Hypothesized Element Denoted with an “X”, Actual Result Denoted with a “Y”)

| Data Elements | Highway Stakeholders | |
|---------------------------------------|----------------------|---------------------|
| | City of Lincoln | Neb. Dept. of Roads |
| Human Factors | | |
| Driver Behavior at HRGC | X Y | X |
| HRGC Warning Signals | | |
| Train Arrival/Departure Information | X Y | X Y |
| HRGC Physical Features | | |
| Angle of Roadway Approach to Tracks | X | X Y |
| Geometric Layout | X | X Y |
| Highway Intersection Adjacent to HRGC | X Y | X Y |
| Sight Obstructions at Crossing | X | X |
| HRGC Crash Prediction Models | | |
| HRGC Hazard Level | X Y | X Y |
| HRGC Crash History | X Y | X Y |
| Other Model Variables | | |
| HRGC On-Train Data | | |
| Train Speed | X Y | X Y (hypothetical) |
| Train Direction | X Y | X Y (hypothetical) |
| Train Length | X Y | X Y (hypothetical) |
| Train Location | X Y | X Y (hypothetical) |
| Train Cargo | X | X |

It was hypothesized that both governmental and regulatory stakeholders would find data on driver behavior at HRGCs useful, but that only turned out to be the case for Lincoln. Likewise, NDOR was the only one of the two stakeholders concerned with the geometric layout of crossings and the angle of the roadway approach to the tracks at a crossing. Other data elements that were incorrectly hypothesized to be of interest to each of these stakeholders were train cargo and sight obstructions at crossings. Data on train cargo may pertain more to emergency response entities. Sight obstructions may be too broad or indirectly related to the concerns associated with operating traffic and pedestrians at or near HRGCs.

The data elements which were both hypothesized and confirmed to be of interest to each of the two governmental highway stakeholders were those that either directly affect the operations of roadway traffic on and around HRGCs, or elements that could help identify deficiencies in the safety of that roadway traffic.

5.1.2 Results for Day-to-Day Users

The three highway stakeholders representing day-to-day users of HRGCs were the City of Lincoln Fire & Rescue Department, Lincoln Public Schools Custodial and Transportation Services (the school bus system), and the Nebraska Trucking Association.

5.1.2.1 City of Lincoln Fire & Rescue Department

The City of Lincoln Fire & Rescue Department (Lincoln F&R) was represented by John Huff, Associate Chief of Support Services, and by Rich Furasek, Assistant Fire Chief.

The discussion took place on April 28, 2009, at 3:00 PM. Appendix C contains an abridged transcript of the discussion with the City of Lincoln Fire & Rescue Department.

Lincoln F&R currently does not utilize any data from HRGCs. They used to receive a train occupancy signal at their North Cotner station near the intersection of Cotner Blvd. and Vine St. There was an HRGC located at the intersection, and the signal would alert emergency personnel leaving the station that they needed to select an alternate route. This signal was installed as a result of a fatality crash involving a fire engine and a train at the HRGC. This rail line has since been abandoned, so the advance warning beacon no longer exists.

Due to the unpredictability of both train events and emergencies which require Lincoln F&R response, Lincoln F&R identified train arrival information and advance warning for route selection as major areas of concern in its operations. Since response

time is critical for firefighting and rescue operations, delay to responders caused by trains is a detriment to public safety. Lincoln F&R cited train arrival/departure information, as well as train event time-of-day and frequency historical information as data that they would find useful.

Lincoln F&R also discussed the possibility of providing video of crossings on its fire trucks for the purposes of route selection. They currently have mobile data capability on their vehicles, which is used to deliver dispatch call information, including street addresses, time of call, and patient complaints. This recently upgraded system is a cellular-based system, which provides a large increase in bandwidth over the previous system. This would be the avenue used to deliver video of HRGCs to the emergency vehicles. Even if video weren't an option, Lincoln F&R stated that using their information delivery system to send advance train warnings, including train arrival and departure times, would be beneficial.

Another area of concern they cited was the geographical layout of the south side of Lincoln. There is only one fire station on the south side of the Highway 2 rail corridor, an area that Lincoln F&R approximated to be about 20 percent of the city. Many emergency calls in this area are closest to stations which are on the north side of the tracks, requiring emergency response vehicles to cross the tracks. Obviously, this can be problematic if a train is occupying one or more of the HRGCs. To circumvent this problem, they dispatch units from two stations, one towards the front of the train and one towards the rear; when it becomes apparent that one unit will be the first to arrive on the scene of the emergency, the other unit then returns to its station. In the meantime, however, this second unit is not available to respond to other calls.

If Lincoln F&R had train speed and location data, they could integrate it into their computer aided dispatch system so that they would only dispatch the emergency vehicle which would reach the destination the fastest. There would be no need for a second unit to be dispatched, so it would be available to respond to other emergencies. This would ensure the shortest possible response time for all areas, regardless of whether a train or trains were traveling along the corridor.

5.1.2.2 Lincoln Public Schools Custodial and Transportation Services

The Lincoln Public Schools Custodial and Transportation Services (referred to hereafter as “LPS”) was represented by Bill McCoy, Director of Operations, and by Fred Craigie, Assistant Supervisor for Transportation Services. The discussion took place on April 28, 2009, at 1:30 PM. Appendix D contains an abridged transcript of the discussion with LPS.

LPS does not currently utilize any data from HRGCs. They stated that they try to avoid having routes cross HRGCs if possible, but that this is not always practical. They identified the Adams St. HRGC as one of the crossings traveled most by LPS buses.

For the HRGCs that they do have to have buses cross, LPS listed several data that they would potentially find useful. They identified a couple of things that would be useful to input into their routing software to increase routing safety and efficiency: train volumes at HRGCs and the hazard level of each crossing. The routing software would factor in these variables automatically in selecting the ideal routes for buses. Also, LPS said that they have recently been considering the possibility of equipping their buses with GPS systems. While they didn’t think they would be able to integrate real-time routing based on bus locations, they did say that such a system would be useful.

LPS showed strong interest in archived video data from HRGCs, for two main reasons. For one, having video data available to them (and especially data where violations were flagged) would help ensure driver compliance with regulations at crossings. Also, similarly to the railroads with their on-train cameras, archived video would help LPS with liability concerns.

Finally, LPS stated that an advance train warning information delivery system would be helpful to its drivers. As mentioned previously, through their routing system, they instruct drivers to avoid many crossings. For those crossings where this is not an option, LPS said that having advance information available to the drivers would help them make better route choices.

5.1.2.3 The Nebraska Trucking Association

The Nebraska Trucking Association (NTA) was represented by Larry Johnson, President of the NTA. Also present at the meeting was Tom Micek, Regional Manager, Field Safety Support for the BNSF Railway Company; Mr. Micek, like Mr. Johnson, serves on the board of directors of Operation Lifesaver. The discussion took place on May 26, 2009, at 2:00 PM. Appendix F contains an abridged transcript of the discussion with the Nebraska Trucking Association.

Like the other two day-to-day users of HRGCs, the NTA does not currently utilize data from crossings. They did present a short list of data needs. They stated that being able to receive real-time train data would have little or no benefit to most trucks and cited several reasons for this fact. For parcel delivery carriers such as UPS or FedEx, such information would have minimal benefit because the route of each truck is different every day, and because the route isn't a "Point A to Point B" movement, but rather many

destinations scattered in various locations. For freight delivery carriers such as Pegler Sysco or Yellow Freight, trucks are loaded in a specific order with a specific route in mind, so if a route is altered (to avoid a train at a crossing), the truck would have to be partially or completely unloaded and reloaded just to access the proper freight for the out-of-turn destination. The only types of trucks that the NTA thought would derive some benefit from real-time train data were trucks with routes that consistently include many or all addresses in an area; as an example, they cited garbage collection trucks.

The NTA did identify a few other data needs. They stated that data showing the number and classification of trucks at a HRGCs would be useful. They also identified video that could log truck driver violations at crossings as being useful, both to help ensure driver compliance with regulations and to protect carriers liability-wise.

5.1.2.4 Summary of Results for Day-to-Day Users

None of the three highway stakeholders in the day-to-day HRGC user category currently utilizes data from crossings. All three of these stakeholders expressed interest in archived video from HRGCs, both to ensure driver compliance at crossings, and in the interest of liability protection. The three stakeholders were also interested in real-time train information from crossings, although the NTA felt this kind of data would be useful only to a small segment of its constituents. The results for the data needs of day-to-day users of HRGCs are summarized in Table 8.

TABLE 8 Summary of Highway Stakeholder Needs by Data Element for Day-to-Day Users at HRGCs (Hypothesized Element Denoted with an “X”, Actual Result Denoted with a “Y”)

| Data Elements | <i>Highway Stakeholders</i> | | |
|---------------------------------------|-------------------------------|----------------------------|------------------------|
| | Lincoln Fire Department | Lincoln School Buses | Commercial Vehicles |
| Human Factors | | | |
| Driver Behavior at HRGC | X Y | X Y | X Y |
| HRGC Warning Signals | | | |
| Train Arrival/Departure Information | X Y | X Y | X |
| HRGC Physical Features | | | |
| Angle of Roadway Approach to Tracks | | | |
| Geometric Layout | | | |
| Highway Intersection Adjacent to HRGC | X | X | X |
| Sight Obstructions at Crossing | X | X | X |
| HRGC Crash Prediction Models | | | |
| HRGC Hazard Level | X | X Y | X |
| HRGC Crash History | | | |
| Other Model Variables | | | |
| HRGC On-Train Data | | | |
| Train Speed | X Y | X Y | X |
| Train Direction | X Y | X Y | X |
| Train Length | X Y | X Y | X |
| Train Location | X Y | X Y | X |
| Train Cargo | X | | |

Train arrival and departure information, and the on-train data that would be used for the derivation thereof, was not listed in Table 8 as a proven hypothesis for the Nebraska Trucking Association, since they stated that these data would be of no use to almost all commercial vehicles. However, as mentioned above, they listed a small segment of vehicles which are the exception and would derive some benefit to train arrival data. The only other data element identified as useful or potentially useful by the NTA was the

number and classification of trucks at HRGCs, but none of the data elements listed in the table matched up with this need and so it omitted from the table.

As with governmental and regulatory agencies, none of the day-to-day users had use for data involving highway intersections in proximity to an HRGC or for sight obstructions at crossings, again perhaps because these elements were too broad in scope.

Only LPS identified data on HRGC hazard level as being useful or potentially useful, and, curiously, Lincoln F&R did not identify train cargo data as being of use.

Not surprisingly, LPS and Lincoln F&R both expressed a strong interest in data elements which would provide their drivers with more information on train arrival and departure.

5.1.3 Results for Other Data Users

The final highway stakeholder, the City of Lincoln and Lancaster County Railroad Transportation Safety District (RTSD), could have been categorized with the other governmental and regulatory agencies since it is a governmental entity. However, the primary focus of the RTSD is to improve safety at crossings, so it was included in its own category due to its more narrow scope.

5.1.3.1 The City of Lincoln and Lancaster County Railroad Transportation Safety District

The City of Lincoln and Lancaster County Railroad Transportation Safety District was represented by Roger Figard, Executive Director of the RTSD and City Engineer of the City of Lincoln. The discussion took place on July 2, 2008, at 8:30 AM. Appendix E contains an abridged transcript of the discussion with the RTSD.

The RTSD currently utilizes some basic data from HRGCs. These data include train volumes and the volume of vehicles crossing HRGCs. These two criteria are the primary factors used to identify crossings which are eligible for grade separation projects. The RTSD currently tracks crash history at HRGCs. Also, they have a comprehensive GIS map and database which contains information on the physical characteristics of all the crossings in Lincoln and Lancaster County (see Figure 12).

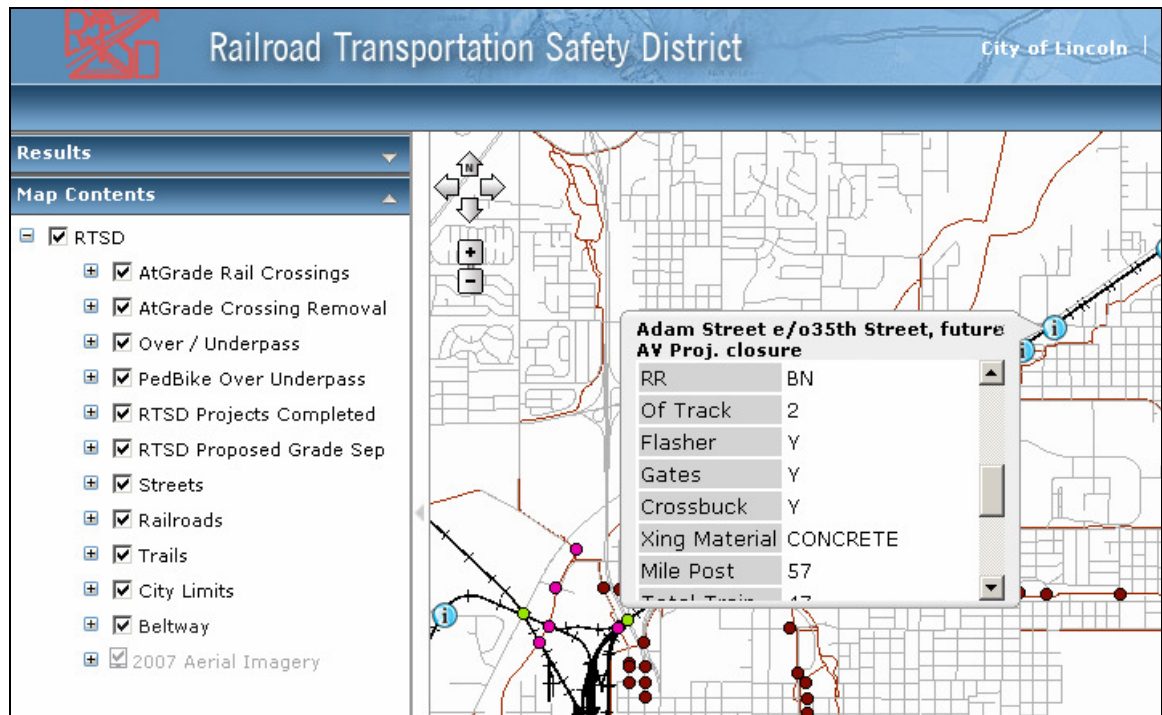


FIGURE 12 The City of Lincoln and Lancaster County Railroad Transportation Safety District’s interactive GIS map of railroad crossings (“Interactive” RTSD 2009).

The data needs of the RTSD, both real-time and archived, were fairly extensive. First, they cited operational characteristics of crossings as being potentially useful. These operational characteristics include the time the crossing is closed for each train, the time frequency between trains, the delay to vehicular traffic for each train event, and the number of vehicles stopped at the crossing for each train event. They mentioned utilizing

archived and real-time data as a check to verify that existing warning devices and equipment are functioning properly; the RTSD also suggested this as a treatment for any new deployments resulting from this or any related projects (for example, predicted train arrival times).

The RTSD stated that since it is not possible to separate or close every crossing (which would be the ideal situation from a safety standpoint), that a good interim measure would be to provide drivers with an early advance warning system to alert drivers of possible upcoming conflicts with trains at HRGCs. They suggested that such a system provide drivers with information on the train arrival time, the train's duration at the crossing, and to provide drivers with suggestions for alternate routes.

In the area of human factors, the RTSD showed significant interest in driver violations. Video data of driver violations at HRGCs would be useful to the RTSD in two respects: to be able to quantify the number of violations occurring and to gain a better understanding of the cause of the violations (to help them better identify preventative solutions). The RTSD stated that they would find it useful to know whether or not there was a threshold of acceptable delay to drivers before frustration caused them to violate warning devices at a crossing, and if such a threshold existed at what point in time it took place. The RTSD emphasized the desire to have more data on HRGC violations at crossings within railroad quiet zones. They also expressed interest in violation cameras at HRGCs, similar to red-light running cameras (although they acknowledged such technology is not currently permitted in the state of Nebraska).

The RTSD was concerned about the safety of pedestrians and bicyclists at HRGCs. As more crossings are closed over time, they are increasingly concerned that pedestrians

and bicyclists will trespass and cross the tracks at a location other than a crossing, rather than go out of their way to cross at an HRGC. They wanted to observe pedestrian and bicyclist behavior on archived video to try to draw conclusions about their tolerance for wait time at a crossing would be, as well as the distance out of the way pedestrians and bicyclists were willing to travel to cross at an HRGC.

The RTSD showed strong interest in being able to utilize archived audio data at HRGCs. Citizen train horn complaints are lodged on a regular basis; usually these are complaints that the horn was sounded too far in advance or was maintained too far past the crossing. By deploying audio sensors and syncing archived audio data with archived video, train speed, and train position data, the complaints could be addressed. In this way, it would be possible to determine the exact location at which a train began to sound its horn, the duration of the horn, whether the horn was loud enough, if the proper sounding pattern was used, and if the horn ended at the appropriate location. Either the citizen would be informed that the train sounded its horn in compliance with regulations or based on an atypical situation (trespassers, violations at HRGCs, workers in the area), or the complaint was accurate and the horn was not sounded properly, in which case the railroads would be notified of the violation. While these train horn compliance issues exist at all HRGCs, the RTSD pointed out that these issues would be even more critical at crossings located within railroad quiet zones.

5.1.3.2 Summary of Results for Other Data Users

The results for the RSTD data needs are summarized in Table 9.

TABLE 9 Summary of Highway Stakeholder Needs by Data Element for Other Data Users at HRGCs (Hypothesized Element Denoted with an “X”, Actual Result Denoted with a “Y”)

| Data Elements | <i>Highway Stakeholders</i> |
|---------------------------------------|-------------------------------|
| | Lincoln/Lancaster RTSD |
| Human Factors | |
| Driver Behavior at HRGC | X Y |
| HRGC Warning Signals | |
| Train Arrival/Departure Information | Y |
| HRGC Physical Features | |
| Angle of Roadway Approach to Tracks | X Y |
| Geometric Layout | X Y |
| Highway Intersection Adjacent to HRGC | X Y |
| Sight Obstructions at Crossing | X Y |
| HRGC Crash Prediction Models | |
| HRGC Hazard Level | X Y |
| HRGC Crash History | X Y |
| Other Model Variables | X Y |
| HRGC On-Train Data | |
| Train Speed | X Y |
| Train Direction | X Y |
| Train Length | X Y |
| Train Location | X Y |
| Train Cargo | X |

As hypothesized, the City of Lincoln and Lancaster County RTSD had the most data needs of any of the highway stakeholders. The only data element for which they did not express interest was data on train cargo.

5.2 Closure

In this chapter, the results of the stakeholder discussions were given. These results were compared to the hypothesized data needs from Chapter 4.

A few general data needs trends include the City of Lincoln having a much higher interest in data available from HRGCs than does the City of Omaha (due to the comparative number of crossings within each city), the Lincoln RTSD having the most

data of interest of any of the stakeholders, none of the stakeholders identifying train cargo as a data element of interest, and a widespread strong interest among the stakeholders in a system which would deliver advance train crossing information to drivers.

With the results of the stakeholder discussions now established, recommendations for possible enhancements to the UNL test bed can now be made.

CHAPTER 6. ANALYSIS – RECOMMENDATIONS FOR ENHANCEMENTS TO THE EXISTING UNL HRGC TEST BED

With the stakeholder discussions having been completed and summarized in Chapter 5, the current test bed's ability to meet highway stakeholder data needs can now be evaluated, data which is currently unavailable at the test bed will be identified, and possible solutions will be identified to bridge the gap between data currently available and those highway stakeholder data needs.

6.1 Data Currently Available at the Test Bed

Currently, the UNL HRGC test bed provides train presence, direction, and speed data at the Adams St. crossing by utilizing a surveillance camera, a video server for the conversion of analog video for digital transmission, and a hardened fiber switch to receive data from a standard network cable and transmit it over fiber optic cable.

Depending on the location in the system and on its format, the data travels over coaxial cable, standard network cable, or fiber optic cable on its way from the test bed to City of Lincoln and UNL networks (Franca 2009).

Additionally, video and radar sensors at two locations adjacent to the Adams St. crossing provide the same train presence, direction, and speed data upstream along the rail line. The radar side of the sensor system at each of the two locations features a Doppler radar stationary speed sensor and a media converter to change the raw serial signal to data that could be transmitted over standard network cable (Franca 2009). The video side of the sensor system features a day/night video camera, a video image processor (VIP), and a digital video recorder (DVR) for data recording. The camera feeds raw video into both the DVR, where it is recorded, and into the VIP. The VIP

transmits processed video to the DVR where it is also recorded, and train speed data which is transmitted to a hardened fiber switch. The hardened fiber switch collects raw and processed video from the DVR, video speed data from the VIP, and radar speed data from the media converter; these data streams can all then be transferred via fiber optic cable to City of Lincoln and UNL networks (Franca 2009).

From the data available at the test bed, train arrival times for the Adams St. crossing can be predicted. The City of Lincoln also receives train arrival time data from the railroads via the track circuitry, so there is overlap in this data area for what the City currently receives and what could be provided to them by the test bed. The City of Lincoln, the RTSD, and LPS all expressed interest in train volume data, which are currently available from the test bed.

6.2 Stakeholder Data Needs Currently Unavailable at the Test Bed

The informational items identified by the highway stakeholders which are currently unavailable at the UNL test bed are as follows: information on general public driver violations at HRGCs, archived video of drivers to ensure compliance with rules and regulations at HRGCs, an advance train crossing information delivery system for vehicular drivers, HRGC status information for real-time routing, streaming video of HRGCs for route selection, historical train event trends for routing, archived video of HRGCs for liability purposes, the classification and volume of trucks at HRGCs, HRGC operational characteristics, the verification of the functionality of HRGC warning devices, detailed information on driver violations at HRGCs for determining causes and possible solutions, automatic driver violation cameras at HRGCs, more information on pedestrians/bicyclists at HRGCs, and archived audio for the verification of proper train

horn sounding. These currently unavailable end uses are summarized by stakeholder in Table 10.

**TABLE 10 Summary of Currently Unavailable End Uses by Highway Stakeholder
(Denoted with an “X”)**

| Currently Unavailable End Uses | Highway Stakeholders | | | | | |
|------------------------------------------------------------|----------------------|------------------------------------|--------------------------|---------------------------|-------------------------------------|-----------------------------------------------|
| | City of Lincoln | Nebraska Department of Roads | Lincoln Fire & Rescue | Lincoln Public Schools | Nebraska Trucking Association | Railroad Transportation Safety District |
| General Public Driver Violations | X | | | | | X |
| Video - Employee Driver Compliance | | | | X | X | |
| Advance Train Warning System for Drivers | X | | | X | X | X |
| Real-Time Routing | | | X | X | | |
| Streaming Video for Route Selection | | | X | | | |
| Historical Train Event Trends (for Routing) | | | X | | | |
| Archived Video (for Liability) | | | | X | X | |
| Classification and Volume of Trucks | | | | | X | |
| HRGC Operational Characteristics | | X | | | | X |
| Warning Device Functionality Verification | | | | | | X |
| More Information on Violations | | | | | | X |
| Automatic Violation Cameras | | | | | | X |
| More Information on Pedestrians/Bicyclists | | | | | | X |
| Audio for Verification of Proper Train Horn Sounding | | | | | | X |

The informational items from HRGCs which are currently utilized by the highway stakeholders are: train arrival/departure times for traffic signal preemption, general preemption trends along the rail corridor for use in signal timing plans, information on accidents at HRGCs, vehicular volumes at HRGCs, train volumes at HRGCs, and the physical characteristics of HRGCs. These currently utilized end uses are shown in Table 11.

TABLE 11 Summary of Currently Utilized End Uses by Highway Stakeholder (Denoted with an “X”)

| Currently Utilized End Uses | Highway Stakeholders | | | | | |
|-----------------------------------------------|----------------------|------------------------------|-----------------------|------------------------|-------------------------------|-----------------------------------------|
| | City of Lincoln | Nebraska Department of Roads | Lincoln Fire & Rescue | Lincoln Public Schools | Nebraska Trucking Association | Railroad Transportation Safety District |
| Train Arrival Time for Signal Preemption | X | X | | | | |
| General Preemption Trends (for Signal Timing) | X | | | | | |
| HRGC Accidents | X | X | | | | X |
| Vehicular Volumes at HRGCs | | X | | | | X |
| Train Volumes at HRGCs | | X | | | | X |
| HRGC Physical Characteristics | | X | | | | X |

Having identified both the unavailable and the currently utilized end uses of stakeholder needs at HRGCs, each of the end uses will now be broken down into its individual data elements, each of which will be comprised of data flows from the National ITS Architecture.

6.2.1 *General Public Driver Violations*

General public driver violations can be broken down into three data flows:

incident_analysis_data, incident_video_image, and traffic_image_data.

incident_analysis_data “contains processed traffic sensor data that can be analyzed for the possible presence of incidents” (National ITS 2010). incident_video_image “contains a high resolution digitized image of a potential or current incident at a particular point on the road” (National ITS 2010). traffic_image_data “contains the data produced by processing image data obtained from visual detection systems” and “can be obtained from systems such as traffic surveillance” (National ITS 2010). By combining these three data flows, incidents at HRGCs could be detected, recorded, and logged.

6.2.2 *Video – Employee Driver Compliance*

Video to ensure driver compliance with rules and regulations at HRGCs can be broken down into three data flows: incident_analysis_data, incident_video_image, and traffic_image_data. incident_analysis_data. Again, by combining these three data flows, a highway stakeholder could have access to video of their vehicles at HRGCs to observe their drivers’ behavior at the crossing.

6.2.3 *Advance Train Warning System for Drivers*

To be able to provide for an advance train crossing information delivery system for vehicular drivers, the data flows train_dynamics and train_alert would be necessary. train_dynamics “is a set of parameters associated with a specific train (and) are sufficient that a process can determine the arrival time of a train at an (HRGC) and determine how long the (HRGC) will be occupied by that train” (National ITS 2010). train_alert “represents a binary indication that a train is either approaching or a train is not

approaching the (HRGC)” (National ITS 2010). By having access to these two data flows, a highway stakeholder could determine the arrival and departure times of trains approaching an HRGC, and then use their infrastructure to disseminate this data to its constituents as appropriate.

6.2.4 Real-Time Routing

For highway stakeholders wanting to have access to train arrival and departure times for the purpose of real-time routing, the requisite data flows would be `train_dynamics` and `train_alert`. The stakeholder would be able to use these data flows with its own processing software and communications infrastructure to deliver real-time route instructions to its constituents.

6.2.5 Streaming Video for Route Selection

To provide highway stakeholders with streaming video for route selection, it would be necessary to use the data flow `traffic_video_image`, which “contains a video image of sufficient fidelity to support operator monitoring applications” (National ITS 2010). The stakeholder could then deliver the video stream as appropriate, for example by using a video server.

6.2.6 Historical Train Event Trends (for Routing)

For historical train event trends to use for routing decisions, the data flow `hri_closure_data` would be necessary. `hri_closure_data` “contains a log of all (HRGC) closings over a fixed period for use in strategy planning, travel demand management etc.” (National ITS 2010).

6.2.7 Archived Video for Liability

Similarly to the end use for video to ensure driver compliance, to provide archived video for liability purposes would require the data flows `incident_analysis_data`, `incident_video_image`, and `traffic_image_data`. These three data flows would make available to the highway stakeholder a video record of events in case of an incident.

6.2.8 Classification and Volume of Trucks

For highway stakeholders who want to know the classification and volume of trucks at HRGCs, the data flows `fbcv-vehicle_characteristics` and `vehicle_count` would be necessary. `fbcv-vehicle_characteristics` includes “data such as size, number of axles, use of trailer, etc.” of commercial vehicles (National ITS 2010). `vehicle_count` “contains a count of the number of vehicles which have been detected by a detector located on the highway” (National ITS 2010). Combining information from these two data flows would give the stakeholder the desired truck count and classification information.

6.2.9 HRGC Operational Characteristics

For highway stakeholders who desire information on the operational characteristics of HRGCs, there are four necessary data flows: `train_dynamics`, `vehicle_count`, `frtf-vehicle_presence`, and `vehicle_queue_length`. `frtf-vehicle_presence` is the data flow which “represents the presence of a vehicle” (National ITS 2010). `vehicle_queue_length` “contains a measure of the length of queue as measured by a traffic sensor” (National ITS 2010).

6.2.10 Warning Device Functionality Verification

To provide highway stakeholders with information to verify the functionality of HRGC warning devices, the `train_dynamics` and the `hri_device_status` data flows would be required. `hri_device_status` “represents the current status of the devices used at an HRI

and includes pertinent information relative to wayside equipment status, (as well as being) used to determine the overall health and status of the HRI” (National ITS 2010).

6.2.11 More Information on Violations

For stakeholders wanting more information on driver violations at HRGCs for the purpose of examining possible causes and solutions, the data flows `incident_analysis_video`, `incident_video_image`, and `traffic_image_data` would need to be provided.

6.2.12 Automatic Violation Cameras

For highway stakeholders interested in cameras which automatically detect violations and photograph the offending vehicles and drivers, the following data flows would be necessary: `traffic_video_image`, `trf-vehicle_presence`, `hri_device_status`, and `vehicle_license`. `vehicle_license` “contains the data read from a vehicle which may be used to identify state, province, or other origin data as well as the vehicle license number” (National ITS 2010). `trf-vehicle_presence` and `hri_device_status` would be the two triggers: when a vehicle was detected in an area of the HRGC it is not supposed to be when the HRGC warning devices are activated, `traffic_video_image` and `vehicle_license` would record the license plate and images of the offending vehicle and driver.

6.2.13 More Information on Pedestrians/Bicyclists

To be able to provide highway stakeholders with more information on pedestrians and bicyclists at HRGCs, the data flows `fp-pedestrian_images` and `fp-pedestrian_data` would be necessary. `fp-pedestrian_images` “contains visual information (analog data) about pedestrians waiting to cross, or approaching the crossing points, or in the crosswalk of roads and highways from which pedestrian surveillance data can be obtained by image

processors” (National ITS 2010). fp-pedestrian_data “contains analog data about the presence of pedestrians waiting to cross, or approaching the crossing points of roads and highways from which pedestrian surveillance data such as pedestrian demand, numbers of pedestrians, etc. can be obtained by sensors” (National ITS 2010).

6.2.14 Audio for Verification of Proper Train Horn Sounding

If highway stakeholders wanted audio information to verify that train horns were being sounded properly in a quiet zone, it would require the following data flows:

incident_analysis_data, incident_video_image, traffic_image_data, secure_audio, and fwe-train_data. secure_audio “contains the direct digitized audio output of surveillance equipment” (National ITS 2010). fwe-train_data “include(s) data sufficient for the (HRGC) to determine crossing close time, and the anticipated closing duration” (National ITS 2010). The incoming train would trigger the recording of audio and video data (synched together).

6.2.15 Summary of Data Flows

The summary of both currently unavailable end uses and currently utilized end uses by data flow are shown in Tables 12 and 13, respectively.

TABLE 13 Summary of Currently Utilized End Uses by Data Flow (Denoted with an “X”)

| Currently Utilized End Uses | <i>Data Flow</i> | | | |
|-----------------------------------------------------|--------------------|-------------------------|----------------------|--------------------------------|
| | train_alert | hri_closure_data | vehicle_count | (Non-ITS Data Flow) |
| Train Arrival Time for Signal Preemption | X | | | |
| General Preemption Trends (for Signal Timing) | | X | | |
| HRGC Accidents | | | | X |
| Vehicular Volumes at HRGCs | | | X | |
| Train Volumes at HRGCs | | | | X |
| HRGC Physical Characteristics | | | | X |

Finally, Tables 14 and 15 show the data flows for highway stakeholder data needs by stakeholder for both currently unavailable end uses and for currently utilized end uses, respectively.

TABLE 14 Summary of Data Flows for Currently Unavailable End Uses by Highway Stakeholder (Denoted with an “X”)

| Data Flows for Currently Unavailable End Uses | Highway Stakeholders | | | | | |
|-----------------------------------------------------|----------------------|------------------------------------|--------------------------|---------------------------|-------------------------------------|-----------------------------------------------|
| | City of Lincoln | Nebraska Department of Roads | Lincoln Fire & Rescue | Lincoln Public Schools | Nebraska Trucking Association | Railroad Transportation Safety District |
| incident_analysis_data | X | | | X | X | X |
| incident_video_image | X | | | X | X | X |
| traffic_image_data | X | | | X | X | X |
| train_dynamics | X | X | X | X | X | X |
| train_alert | X | | X | X | X | X |
| traffic_video_image | | | X | | | |
| hri_closure_data | | | X | | | |
| fbcv-vehicle_ characteristics | | | | | X | |
| vehicle_count | | X | | | X | X |
| ftrf-vehicle_presence | | X | | | | X |
| vehicle_queue_length | | X | | | | X |
| hri_device_status | | | | | | X |
| vehicle_license | | | | | | X |
| fp-pedestrian_images | | | | | | X |
| fp-pedestrian_data | | | | | | X |
| secure_audio | | | | | | X |
| fwe-train_data | | | | | | X |

TABLE 15 Summary of Data Flows for Currently Utilized End Uses by Highway Stakeholder (Denoted with an “X”)

| Data Flows for Currently Utilized End Uses | Highway Stakeholders | | | | | |
|--------------------------------------------------|----------------------|------------------------------------|--------------------------|---------------------------|-------------------------------------|-----------------------------------------------|
| | City of Lincoln | Nebraska Department of Roads | Lincoln Fire & Rescue | Lincoln Public Schools | Nebraska Trucking Association | Railroad Transportation Safety District |
| train_alert | X | X | | | | |
| hri_closure_data | X | | | | | |
| vehicle_count | | X | | | | X |
| (Non-ITS Data Flow) | X | X | | | | X |

6.3 Test Bed Solutions to Meet Stakeholder Data Needs

Each highway stakeholder data need currently unavailable at the UNL test bed will now be addressed. As in Section 6.2, the data needs will be grouped by the end uses identified by the stakeholders. The assessment of each data need will include a description of what additional sensors and equipment would make collection of the data possible.

6.3.1 General Public Driver Violations

The City of Lincoln and the RTSD expressed the desire for access to archived video at HRGCs to quantify driver violations at the crossing. All three of the data flows, incident_analysis_data, incident_video_image, and traffic_image_data, can be provided by a video archiving system.

If the assumption is made that a system could automatically identify and record all incidents at HRGCs, as has been suggested as a possibility (Villatoro 2006), then the processing portion of the video archiving system would be set up to be automated. Until

the time when such a system is proven to be effective and accurate, the video archiving system would be deployed with the same sensors, but would simply have to record all train events.

In either case, a video camera or multiple video cameras would need to be positioned around the HRGC. It would probably be beneficial to have at least one camera on either side of the tracks to prevent a train at the crossing from blocking part of the field of view. These cameras would need to be linked by a data link, most likely wirelessly, to a data storage unit. The data storage unit would consist of digital media (i.e. hard drives) upon which to record the video data. Video would need to be stored with a running time stamp for reference. Somewhere in the system, it may be beneficial to have video and radar detectors to provide train presence/speed/detection information. In this way, the system would only be engaged and recording video when a train was a specified distance from the crossing as it approached until the train was a specified distance from the HRGC after it left. This would save the system the burden of recording an empty crossing, during which time no driver violations can occur anyway.

The system as described in the previous paragraph would be the basic setup for both an automated system and a passively-recording non-automated system. The only difference in the two systems is that the automated system would need some sort of logical processor to erase train events during which no incidents occurred.

6.3.2 Video – Employee Driver Compliance

Lincoln Public Schools and the NTA also expressed interest in access to archived video at HRGCs, but their desire was to be able to ensure driver compliance with regulations at the crossing. The data flows and the setup for the system would be the same as those

listed in the previous section, with the difference being that the system would record video when one of the stakeholders' constituents traversed the HRGC (instead of when there was an incident).

6.3.3 Advance Train Warning System for Drivers

The desired information identified by the highest number of stakeholders was an advance train crossing information delivery system to deliver alternate route suggestions in advance of crossings in the event of a train. This was identified as a need or potential need by the City of Lincoln, Lincoln F&R, LPS, the NTA, and the RTSD.

The amount and placement of equipment and sensors would depend on the distance in advance of the tracks that drivers would need to be alerted to still have alternate routes available to them. The further in advance of the HRGC that point is, the further up the rail line the "coverage zone" of the train sensors would need to extend. These train sensors would best be placed at a location along the rail line that would still be able to provide advance warning for vehicular drivers in the event of a train traveling at the maximum allowable speed.

A typical deployment would need to have video and radar sensors to detect train presence, speed, and direction along the rail line. Either at the location of the train sensors or at a centralized location within the system, there would need to be a processor which could predict the window of time during which the HRGC would be occupied by a train. This set of equipment would provide the data flow train_dynamics.

To convey the information to roadway drivers in advance of the HRGC, there would need to be a Dynamic Message Sign (DMS) or several DMSs placed at appropriate locations along the roadway. A traffic signal controller would be placed near the DMSs,

and it would receive the train information from the processor and activate the signs. This incoming information would be the train_alert data flow. There would need to be a data link (probably wireless) between the processor and the DMS traffic signal controller.

Due to its regulatory control over traffic in Lincoln, and the fact that the elements of this system would be placed entirely on public right-of-way, the City of Lincoln would have to be directly involved in the deployment of an advance train crossing information delivery system, perhaps in a partnership of some kind.

6.3.4 Real-Time Routing

Both Lincoln F&R and LPS identified the potential data need for train information to be used in a real-time routing application.

In order to be able to deliver real-time routing information to its drivers, stakeholders would need to have train presence, direction, and speed data available to them (the train_dynamics data flow). To this end radar and video detection sensors and a processor would determine when and where a train would cross at any given HRGC, and would then have a data link back to the stakeholder (to deliver the train_alert data flow). It would then be up to the stakeholder to either input the data into real-time route selecting software and deliver real-time route suggestions which take into account train movements to its drivers, or to send the train information directly to its vehicles and leave the route selection up to the drivers based on that information.

6.3.5 Streaming Video for Route Selection

Lincoln F&R identified streaming video in their trucks as potentially beneficial data. The setup for such a system would be fairly straightforward. At any crossing where there were cameras, a data link would need to be provided to run the live video feed back to a

data server; this would be the traffic_video_image data flow. Sufficient bandwidth would need to be available for hosting a streaming video server. From there, it would be up to Lincoln F&R how they would want to retrieve the real-time video from the server and disseminate it to their drivers. Most likely, each fire house would continuously be connected to the streaming video server. Emergency responders would then be able to access the video using the cellular-based system that Lincoln F&R is currently implementing.

6.3.6 Historical Train Event Trends (for Routing)

Lincoln F&R identified historical train event trends as something that would be beneficial when making routing decisions. To provide them with the necessary hri_closure_data data flow, logs would need to be kept containing information on each train event, including time/date information for the HRGC warning signal activation and deactivation for each train.

6.3.7 Archived Video (for Liability)

Lincoln Public Schools and the NTA expressed interest in access to archived video at HRGCs, not only for driver compliance, but for liability concerns as well. The data flows (incident_analysis_data, incident_video_image, and traffic_image_data) and the setup for the system would also be the same as those listed in Section 6.3.2, again with the system recording video when one of the stakeholders' constituents traversed the HRGC.

6.3.8 Classification and Volume of Trucks

The NTA stated a desire to see truck volume and classification information from HRGCs. Detailed classification data, for example weight or axle information, would likely be beyond the scope of what is feasible at the test bed. However, video sensors do have the

ability to categorize vehicles by length, so that basic part of the fbcv-vehicle_characteristics data flow would be available. Video cameras and processors also have the ability to provide vehicle count data, so they would be able to provide the vehicle_count data flow as well.

6.3.9 HRGC Operational Characteristics

The RTSD expressed interest in data pertaining to various operational characteristics at HRGCs. There are several ways that the test bed could provide the train_dynamics, vehicle_count, ftrf-vehicle_presence, and vehicle_queue_length data flows, depending on the operational characteristic. For example, finding the time that a crossing is closed for trains could be achieved by utilizing video detection at the crossing. The video camera would need to be able to detect changes in the state of the gate arm. The time of day would be logged for both the lowering of the gate arm when the train is approaching and the raising of the gate arm upon the train's departure, as well as for the cumulative time between those two events.

The RTSD also expressed interest in data pertaining to the time between trains at a crossing. Again, this would be done by utilizing video detection of the gate arms at the crossing. Again, the time of day would be logged for both the lowering of the gate arm when the train is approaching and the raising of the gate arm upon the train's departure, but in this instance the time would be logged between one train's departure and the next train's arrival.

To provide the RTSD with delay to vehicular traffic, again there would need to be video detection of the gate arms. When the gate arms are activated, a separate camera – or, more likely two additional cameras, one for each side of the track – would begin

logging presence data for vehicles approaching the crossing. The video cameras would need to log the time of each vehicle's arrival. By comparing this time to the time of the train's departure, the approximate delay to each vehicle can be calculated, and the sum of all these values for each train event would give the approximate delay to vehicular traffic for each train event.

The RTSD also stated interest in the vehicular queue length stopped at a crossing for a train event. This could be provided by the same setup as in the previous paragraph, except instead of detecting the presence of vehicles approaching the crossing, the cameras would count each vehicle and log the data. This would give the number of vehicles in the queue. If the RTSD wanted to know how far back the queue extended for each train, the cameras could be set up with presence detection at various thresholds within the field of view. As the queue grew, a new threshold would be reached. The presence detection zone furthest from the crossing to be activated during each train event would give an indication of how far back the queue extended.

6.3.10 Warning Device Functionality Verification

Providing the RTSD with data verifying the proper activation of existing signals could be achieved by combining two detection sensor deployments discussed previously: the radar and video detection combination to provide train presence, direction, and speed information (the train_dynamics data flow), and cameras at the crossings aimed at the gate arms (for the hri_device_status data flow). When the camera and radar sensor combination indicate that a train is within the appropriate distance from the crossing, the camera aimed at the gate arms would detect whether or not the arms activated in time to provide drivers with minimum warning time, and whether they activated at all. This

would be a good way to verify that the track circuitry and active warning devices are functioning properly for every train event.

Audio sensors could also be deployed to ensure that the warning bells, if present, sound at the appropriate time. Archived audio data will be further discussed below.

6.3.11 More Information on Violations

The RTSD stated that they would like to be able to gather more information on violations for the purpose of examining possible causes and solutions. As in Section 6.3.1, the requisite data flows (`incident_analysis_data`, `incident_video_image`, and `traffic_image_data`) can be provided by a video archiving system.

6.3.12 Automatic Violation Cameras

The RTSD expressed interest in cameras that could automatically take photographs when drivers commit violations at HRGCs (similar to red light running camera systems), although they recognized that there is currently no way to punish offenders in the state of Nebraska. Hypothetically, such a system would be possible to set up at an HRGC. To provide the `hri_device_status` data flow, a video sensor would need to be able to detect when the gate arm activates. For the `ftrf-vehicle_presence` data flow, there would need to be a video camera on each roadway approach of interest which would detect a vehicle entering the crossing after the gates had activated. If the gate arm detector had sensed an activation, and the vehicle detection camera sensed a vehicle presence, then a third set of cameras would photograph the vehicle from either the rear of the vehicle (some states don't require license plates on the front of vehicles), or both the front and the rear so as to have a picture of the driver as well; this is how the `traffic_image_data` and `vehicle_license` data flows would be provided.

If punishing offenders caught by this system were legal, a ticket would then be mailed to the owner of the vehicle. The system could still be installed as a way to increase public awareness; instead of a ticket, other materials could be sent to offenders, possibly including a notification that they committed a violation, and materials or literature highlighting the importance of safety at railroad crossings.

6.3.13 More Information on Pedestrians/Bicyclists

To provide archived pedestrian and bicycle video data (the fp-pedestrian_images and fp-pedestrian_data data flows) desired by the RTSD, a system modeled after previously deployed pedestrian detection systems near railroads would need to be implemented. The system would detect when pedestrians or bicyclists approached an HRGC and initiate the recording of the video. With this configuration, video from all other times when pedestrians or bicyclists were absent would not need to be recorded or analyzed.

The pedestrian/bicyclist detection component of the system would consist of several sensors, including a motion detection sensor using Doppler microwave technology for motion detection and a passive infrared sensor for heat detection. Also, an infrared light would be needed to illuminate the detection area at night (daSilva 2006). When a pedestrian or bicyclist was detected, the camera would begin recording time-stamped video for further analysis. The post-processing of the video would need to be done by a person, as pedestrian/bicyclist behavior is far more random than vehicular behavior (since they are not restricted to a given path, like vehicles are on the roadway). If “hot-spots” of pedestrian trespassing existed at sites away from an HRGC, this system could be set up at those locations as well.

6.3.14 Audio for Verification of Proper Train Horn Sounding

The RTSD stated that they would find audio data useful at crossings, particularly at those that fall within railroad quiet zones. This data (secure_audio) would need to be coupled with time-stamped video data (incident_analysis_data, incident_video_image, and traffic_image_data) to give a complete recreation of every train event. The system would require a video/radar combination of sensors to provide train location, speed, and direction data. There would need to be an outdoor-rated microphone at the crossing to record the ambient sound. The audio data recorder should also be able to log the decibel level of the train horn. This setup would provide all the necessary elements to be able to recreate a train event and show exactly where the train was when it blew its horn, what pattern of horn sounding was used, at what point along the tracks it ceased the sounding of the horn, and what the conditions were at the crossing.

6.4 Conclusion to Test Bed Enhancement Recommendations

This chapter took the end uses of information provided by the stakeholders and broke them down into data flows from the National ITS Architecture. These data flows represented the ultimate goal of the needs assessment: the stakeholder data needs. Each of the data flows was then examined in the context of the stakeholder end use to develop recommended sensor and other equipment deployments at the test bed.

CHAPTER 7. CONCLUSIONS

This chapter concludes this thesis and identifies future research possibilities.

7.1 Summary

Several main steps were required to carry out a needs assessment of various highway stakeholders at the Adams Street HRGC in the UNL test bed. The first task was to conduct a comprehensive literature review to identify data both currently available and potentially available to highway stakeholders. This literature review served as a collection of secondary data which was used later in the pre-assessment.

The three main steps in a needs assessment – the pre-assessment, the assessment, and the post-assessment – were then defined and tailored to the requisite steps specific to this project. To perform the pre-assessment, the literature review was summarized, with a more narrow focus on data that would potentially be useful to highway stakeholders. The stakeholders were identified and classified into three groups according to similarities among the agencies. Possible data needs of each of the three stakeholder groups were hypothesized. The primary data collection instrument was developed by first identifying the best type of needs assessment for the project (the key informant approach), and by then developing questions for the stakeholders.

To carry out the assessment phase of the needs assessment, the stakeholder discussions were completed through a series of meetings with representatives of each of the highway stakeholders: the City of Lincoln, the City of Omaha, the Nebraska Department of Roads, the City of Lincoln Fire and Rescue Department, Lincoln Public Schools Custodial and Transportation Services, the Nebraska Trucking Association, and the City of Lincoln and Lancaster County Railroad Transportation Safety District.

For the post-assessment, the results of each stakeholder discussion were then presented, including data that the stakeholder identified as being of interest and data that were of no use to the stakeholder. These results were compared to the hypothesized stakeholder needs.

Finally, the focus was placed on the highway stakeholder data needs currently unavailable at the test bed. Each currently unavailable data need was identified, and then a strategy was presented which would enable the test bed to provide the data to the stakeholders. Each strategy identified both the locations and the types of sensors or other devices that would be necessary for the data collection and delivery.

7.2 Conclusions and Recommendations on Future Research

Data which are already available at the test bed are train presence, train direction, train speed, and predicted train arrival times.

End uses for data needs identified by highway stakeholders which are not currently available at the test bed include information on general public driver violations at HRGCs, archived video of drivers to ensure compliance with rules and regulations at HRGCs, an advance train crossing information delivery system for vehicular drivers, HRGC status information for real-time routing, streaming video of HRGCs for route selection, historical train event trends for routing, archived video of HRGCs for liability purposes, the classification and volume of trucks at HRGCs, HRGC operational characteristics, the verification of the functionality of HRGC warning devices, detailed information on driver violations at HRGCs for determining causes and possible solutions, automatic driver violation cameras at HRGCs, more information on pedestrians/bicyclists at HRGCs, and archived audio for the verification of proper train horn sounding.

As discussed in section 6.3, these data needs could possibly be provided in the future with various sensors and equipment, including: radar and video detectors at additional locations along the rail corridor; wireless data links; interconnectivity with the traffic signal system; centralized servers for data processing, data archiving, controlling of various devices, and video dissemination; dynamic message signs; traffic signal controllers; video cameras for recording video to be archived, and data storage for this archived video; additional video sensors at the crossing for purposes other than those currently provided by the test bed, for example vehicle counts or pedestrian/bicyclist detection; audio sensors; motion detection sensors using Doppler microwave technology; passive infrared sensors for heat detection; and photography equipment.

This project was an important first step in improving the Adams St. HRGC test bed to provide stakeholders with data currently unavailable to them; the implementation of any of the recommended treatments along the test bed could be the basis for future projects to collect, refine, and provide to various highway stakeholders additional data better targeted to their needs.

APPENDIX A City of Lincoln Discussion Transcript

March 26, 2009

1:30 PM

Attendees:

Scott Opfer, *Operations Manager, City of Lincoln*

Larry Jochum, *Senior Engineering Specialist, City of Lincoln*

Ryan Haas

RH: So basically, what we've got going on is...currently I work for the City of Omaha but I'm working on my master's thesis through UNL, Lincoln's program, and they have been working with the FRA and setting up a test bed – a data collection test bed along a rail corridor here in Lincoln, the one that parallels Cornhusker Highway. They have sensors set up in several locations, cameras, radar and things of that nature, and they're starting to get some really good data from that, different types of data – train arrival, train speed, detection, that kind of thing. The FRA wanted to get an idea of what kinds of data needs or potential data needs that the various stakeholders of the HRGCs would have. So that's what my project is, just looking at what kinds of things that people are currently using or would find potentially useful as far as information or data at these grade crossings.

CoL: Specifically related to the trains themselves?

RH: Yeah.

CoL: So like speeds, a train – when they're going to get there – things like that is what you're talking...

RH: Right, right. And this is kind of broad, it's kind of open-ended, we're kind of looking for what things that you are using or could find useful. So I guess to start off, is there anything that you guys are using other than train arrival times for signal preemption, or is that...

CoL: That's pretty much it.

RH: Do you use constant warning time to provide the...

CoL: The ones up north I believe (inaudible) has the calculated arrival time based on train speed is what I think they use up there. So we just get the signal from them, I think it's a minimum of a 30 second advance warning is what they give us. We tie into...when their cabinet decides to initiate their sequencing it also sends us a signal at the same time, so we're basically going off of what they're giving us, we rely on them to calculate the train arrival time.

RH: And then you initiate your preemption sequence on the signals – the traffic signals...

CoL: The signal, yeah, we get it from them then we kick in immediately, we don't have a delay or anything like that. I think usually they get...there's a four second delay in the time that they get the signal and their arm will start moving, but we kick it in right away. So we try to accommodate as much of the train clearance time as we possibly can.

RH: Now besides the...you're already getting pretty good information from the railroad as far as train arrival time. Is there anything that you could possibly see improving safety or efficiency from a traffic operation standpoint, any other types of data...

CoL: Not really. We kick in right away...is there any...I guess, not really. Our stuff is based on totally what MUTCD says we need to do as far as clearance and all that kind of stuff. And, actually, I'm going over all of our intersections now to make sure we're doing a constant situation at all of the grade crossings. And prompted that is that they changed their calculation...instead of clearing from track to intersection, from track to stop bar, you're supposed to clear now from the back of the longest design vehicle, which they figure to be a 55' semi. So we've got to calculate from the track back that extra 55', so it's adding on a few seconds of clearance time, which on the fixed time ones down south is a little bit of a problem; the ones up north shouldn't be, because their speed should allow us to get in preemption a little quicker, but the ones down south is the ones we're having some problems with.

RH: Part of the project is looking at different uses for archived data, historical information, that kind of thing. Is there anything other than basic accident histories that you guys look at, as far as gauging hazards or safety issues at the rail crossings?

CoL: One thing that I use a lot is frequency of preemption. I'll look at that and see how many times a day are we getting preempted, what time of day, that type of thing, to see what that's doing to – in this case you're probably familiar with Cornhusker Highway because that's where the study is, and it does disrupt signal timing, it kicks us out of coordination for quite a bit. We're looking at I think an average of about 70 trains a day, and that's 70 times for at least a five minute period that we're running out of coordination, plus the transition back into coordination. So, train frequency is one thing we look at quite a bit. Crash – that all comes in – the crash data comes in...daily, and I don't look at that too often, because frankly we don't really have a crash problem. The frequency of the trains is one thing that we try to keep an eye on.

Yeah, we already track the crash information, anything railroad-related, we pull that out of our crash data already. So even if it's a rear-end crash related to the gates coming down we consider that a railroad-related crash, or someone running into the gate or whatever. We have very few car-train crashes, or vehicle-train crashes. But we already track that. I'm trying to think if there's anything related to...that corridor, we're processing by the end of the summer and we'll have quiet zones along there and I'm trying to think if there's anything related to that.

RH: Part of the area of focus of what I'm looking at...one of the main areas of focus is human factors-related information, driver behavior, that kind of thing. Is that something where you would find use for that kind of data, how the drivers are reacting to the preemption sequences, to see if the quiet zone is still maintaining acceptable safety levels? Is there any interest on your end in human factors-related data, or is that something that's more abstract than what you guys are looking at?

CoL: Well, I think all of that's valuable information to see if we have people, if you look at the quiet zones, you'll build medians at three locations to help ensure that they don't go around gates. If we've got people jumping medians and going around gates, that's information you'd want to know and see if you need to do something when you design the next quiet zone...because when we build a second quiet zone on the corridor going south, probably in the next couple of years...

RH: You say you had to build raised medians, was that...if I understand quiet zones correctly, you have to get the threshold, the safety level below a certain threshold, and there's some hazard index, is that something that you had to do to get under that? Or is it just a voluntary thing to build them?

CoL: I don't know...no, that something the railroad required. You have to build these medians back a certain distance, so that people can't just go around gates.

RH: Going back to, we talked about when trains came through it threw off your coordination, would there be...and this something that's down the road...but would there be some interest in a system that could warn drivers ahead of time, say...and maybe it's not so much with coordination but more like route selection. Say, okay, "A train's going to be at this crossing in X number of minutes, consider alternate route," that kind of thing. Would there be interest in something like that? Because ultimate those are some of the kinds of things that could come out of research like this is, um, driver information systems, and...which would help reduce delay with traffic, but probably even more importantly can potentially help with emergency vehicles and that kind of thing...is that something that...

CoL: Oh definitely, definitely. 33rd Street's probably the biggest one, between 33rd and 70th, I mean 44th St. is not an arterial street so there's less of an impact there, but those are the only three at-grades left on that corridor, and have information where maybe you place boards at 27th & Cornhusker or something like that to where you notify people of the train and – I guess I forgot Adams in there too, I consider those about the same – yeah, where you could notify people so they could take a different route, there's definitely some interest in that.

We looked at that quite a few years ago and got some boards put up on Old Cheney down south, to try to do that situation but we got it put up and now all of a sudden U.P. says "well, we lost our contract for coal," so the tracks down south along Highway 2 are basically unused. So we kind of...okay, we'll wait and see what happens, if they get

their contract back. We don't want to pour money into it if we'll only use it, like now only once a month. We kind of started on that situation, I don't know if you're familiar with that part of town.

RH: It kind of parallels Highway 2...

CoL: It does. Well we've got a fairly good arterial down at Old Cheney, which is a mile south, and that's where we put the DMS boards to warn people as they were approaching 27th signal... "East- or westbound at 27th St. tracks will be closed by train for so long, use alternate route." Up north, they're so fast, it's not blocked a long time, but it's blocked frequently, and that would be a possibility.

(Inaudible) down at 14th St., 14th St. in my mind anyway was probably the biggest problem, because...and that's why I don't really consider Adams too much of a problem because, the Adams crossing you see it a lot, people go up, they're going to use Adams but they see the train's coming or is present, they'll just on east a lot of times to 48th where they've got a (inaudible) underpass. That's pretty common.

Well conversely, the westbound traffic take that little offshoot, there's kind of a little offshoot that goes back to 33rd, and that's where 33rd helps out. And honestly a lot of U-turners are turning in that parking lot. North-south on 33rd is what was the problem.

Yeah, that's probably the biggest problem, 70th I don't think is a huge problem –

It's not that busy –

It's not that busy, plus I think they've got an alternate route around, too, if they wanted to, with Cotner, but...the one thing that reminds me a lot...do you work with Kirkham Michael at all?

RH: I've had some dealings with them, yeah.

CoL: Murthy, how do you pronounce his last name...

RH: Koti.

CoL: Murthy actually was involved with, I believe involved with the study that, I don't know (name) who works in this office as well, but Murthy was working with (name) back when we put those boards up. And I think at the time he worked for Iteris, he made (inaudible) at the University of Nebraska. He actually did a study, and that's where the boards at 27th & Old Cheney actually came – they came as a result or at least partly as a result of that study. So he may be a good resource to find out what type of information he gathered, I think he did some of that with his major, with his masters, it might have been a part of that.

RH: Has that ever been considered for the Cornhusker rail corridor? Those kind of signs? Or is that just something that...

CoL: Yeah, we've definitely considered that.

We were going to try to get the one down south working, and then maybe expand. But we got a...there was no reason to continue down there so we just kind of said "well, we'll just put our money somewhere else for now."

And plus we've got three message boards out at what we call 56th & Cornhusker, 55-X & Cornhusker, which is between 70th & Havelock, basically out in that area. We also have one between Havelock and 48th primarily for undercrossing things, but that also happens to be our incident management route for when I-80 is closed for some reason. So when we basically, we lost the ability to be able to study that 27th & Highway 2, the one we had put the signs up for, we decided we were going to put our boards in places we could use them for other (inaudible) and different things. But 27th & Cornhusker would be a great area for message boards, we put them out all the time, the portable ones, for football and for various things. So a dual-purpose (board) could obviously be, "hey the crossing at 33rd is closed, take alternate route." Put one back at 20th St. and let people know so they get off at 27th and go over the overpass. So yes, that's something we'll definitely want to consider down the road.

RH: I think that might have covered everything. Some of this stuff is more abstract than you guys probably deal with.

CoL: One thing before you leave too, I don't know that it would be of any value to you at all, but we had a University of Nebraska intern with us, it's been three or four years ago, it was Katie...Glock? I can't remember what her last name was. What she spent the whole summer doing was basically looking at, she went through and compiled a GIS map and database for every railroad crossing in the county. It's a really accurate map, it's on our internet from what I'm told, and I'd just have to go find it. But that's what I would show you, that you can actually go to a crossing and it brings up data, like five lane street, has crossing arms or not, or...

RH: Characteristics of the crossing –

CoL: The characteristics of the crossing. But that's on our website, so I don't know if that has any value to you with this thing or not. But we could see if we could find it, I'm sure I could find it because I think it's under the RTSD stuff. And maybe that's something you could at least know it's there if you need it for something.

RH: And so that's online, I can access that.

CoL: I believe so.

RH: I'll speak with Dr. Jones and if I have any follow-up questions maybe can I give you a – send you an email or give you a phone call or...

CoL: You bet. Yeah, either one. If you need crash information, our database is pretty much up-to-date. We're a couple, maybe a month or two behind of actually inputting data in to the level of where we separate out regular type crashes, identify railroad-type crashes. If you need information on railroad crashes or anything, we've got a pretty good database on that.

And then one of the engineers in our area is actually leading the quiet zone project too, so if you have any questions about that...and then Libby I know has worked with Dave Burke in our area with putting up some of the sensors and helping try to gather some of that data, so I know she's already worked with some of these people back here, in our area anyway.

Accuracy verification:

RE: Ryan Haas - UNL Thesis Discussion

From: **Larry L. Jochum**
Sent: Thu 6/10/10 12:26 PM
To: 'Ryan Haas'

Hey Ryan

It all looks fine, but if you have any questions in the future, please feel free.

Good Luck

Larry

RE: Ryan Haas - UNL Thesis Discussion

From: **Scott A. Opfer**
Sent: Wed 6/16/10 8:18 AM
To: 'Ryan Haas'
1 attachment
[The City ...doc](#) (28.0 KB)

Good morning Ryan,

Sorry for not getting this back to you sooner. I have attached what you call The City of Lincoln.doc with some minor changes. Just let me know if you need anything more.

Thanks and good luck.

Scott A. Opfer, Manager
Street & Traffic Operations
City of Lincoln, Nebraska

APPENDIX B City of Omaha Discussion Transcript

March 26, 2009

10:00 AM

Attendees:

Todd Pfitzer, *Traffic Engineer, City of Omaha*

Ryan Haas

RH: (Is Omaha) currently using any data from grade crossings other than basic track circuitry indicating train arrival time, (Omaha doesn't) collect any data like that...

TP: Not that I'm aware of, I'm afraid I may not be the best person for you to be interviewing about this, because I've not been involved with anything like that since I've been here. Other than that spur line crossing that you and I worked together on, on 156th out there.

RH: So if there was a way to collect data, would there be something that we would find useful at any of the main line or even the spur line crossings...train arrival time, train speed, direction, location...

TP: That would be the biggest thing for me is the frequency of trains and the duration that they block the street, because when you're trying to figure out capacity and things like that, like you said, Omaha doesn't have very many rail crossings that affect our capacity. But as you get onto busier streets, if we did, theoretically, say we had a train that crossed 90th St. twice a day, you'd want to be able to figure out when that was happening because a train crossing at 10, 11 o'clock at night, is not as big a deal as one crossing at 7:30 in the morning, obviously. So yeah, the time and duration it's closed, and the amount of advance warning that motorists received would all be interesting pieces of data.

RH: So that's the operational side. Would there be any interest in how that affects traffic, the average delay to traffic that kind of thing...

TP: Oh sure, yeah.

RH: Is there any information that could potentially be gathered that you feel might improved safety or efficiency at any of the crossings...

TP: You know, I guess the railroad is, in my opinion, very, very safe about...they don't cut corners, we've approached them about wanting to do this, wanting to do that, and their answer's always "no, this is the way it is, this is the way it has to be." Just like the crossing arms on the side track there on Bob Boozer...do we need to spend an extra \$100k on that? So I guess as far as safety goes, I pretty much trust that the railroad's going to have that stuff figured out. I can't think of the last time we had some sort of a

rail-related problem in Omaha that we, being the traffic department, could have affected. So, it's not that I'm not interested in that, it's just that I think they've got that base covered. So it wouldn't be something that, if somebody came along and said "hey, we want you to spend money on this," I'd say "oh, great, then we can finally get the data we need," because they pretty much have all that calc'ed out. So safety...what was the other you asked me?

RH: Efficiency...

TP: Efficiency's obviously interesting because that's something that I don't think the railroad cares about, I don't think they care if they affect our efficiency. The bottom line is they've got a train to move, and they feel like that's their authority to do so, and that's what they do. So certainly, efficiency is something that I would be interested in.

RH: (Are human factors issues) something that (Omaha) would find useful?

TP: I think so...

RH: Driver compliance, or that kind of thing...

TP: Yeah, because I think that behavior generally apply towards red lights and yield signs and different things like that, too, so any time I can read about trends that involve driver behavior or driver expectancy...

RH: ...and as they relate to – at railroad crossing.

TP: Yes.

RH: Those are operational kinds of things, would (Omaha) have any use for archived data, historical data, that kind of thing, where a sensor compiles the data and then you look at historical trends. The big thing would be accident history, what is there out there – is there an indication that there's a safety problem with accidents, but is there anything else that you could see -

TP: Other than for accident history, no, I can't think of a huge use for archived data like that, but for accident history, absolutely.

RH: So there wouldn't be any need for an information delivery system, like an advance warning thing, "select alternate route," I guess, again, that's kind of a Lincoln thing because they have so many in a row...

TP: Yeah I can see that there would be if you had, I'll use 72nd St., or Dodge St.... say you had a train that crossed Dodge St. at 82nd, five times a day, then I could see where you'd want advance warning signs at maybe 72nd or 90th to let people know "hey, there's a train coming in, expect significant delays," and they might want to use Pacific or Blondo or whatever the case might be. The reason my answer to that is "no" is because

we just don't have that issue in Omaha, but if we did, yeah, absolutely. It would be just like an incident on I-80, we're working on that with our ITS program out there. You've got an accident that shuts down such a main corridor like that, yeah, you can give advance warning and give alternative signal timings for those routes, yeah, I think you'd want to do the same thing with a train. Although that would be tough to coordinate that.

Accuracy verification:

RE: Ryan Haas - UNL Thesis Discussion

From: **Pfitzer, Todd (PWKs)**

Sent: Wed 6/30/10 4:32 PM

To: Ryan Haas

I have reviewed and don't have any changes.

Glenn Hansen

Signal Timing Engineer, City of Omaha

June 29, 2010

Glenn Hansen

Ryan Haas

[truncated]

RH: So Omaha has fewer crossings (with preemption) than Lincoln, I think you said six?

GH: At most six.

RH: At most six out of Omaha's 900 or so signals, whereas Lincoln has 10 or 11 with preemption out of 300 or 350 or so. So first of all, so data that Omaha is currently using is really just train arrival and departure times for preemption, is that correct?

GH: Yeah, that's all we're taking right now. We don't store anything, we don't keep anything.

RH: You don't look at trends?

GH: No.

RH: If there was a crossing, say for example there was a signal right next to a crossing, and there was an incident or several incidents where it became apparent there was maybe a safety issue there, would that be something that you would maybe go seek safety funds to fix the problem? In a roundabout way what I'm asking is, are accident something you track? If there was an accident problem, would you do something...

GH: If we saw that there was an accident issue with a rail crossing close to an intersection, yes, we would want to address it somehow. Whether it would be through the intersection or through the rail crossing through additional devices or whatever to warn people.

RH: But it just so happens that you don't?

GH: We really don't. I think the last time we had something with a rail line and an accident was a person was walking on a bridge, or walking along a rail line and they got hit. It's not been vehicles getting hit.

RH: But otherwise, is there anything else that you can think of, from a timing standpoint or otherwise...

GH: I think if we could find, if we could predict when trains would be there that would be a great tool, there's no doubt about it. If we could say through a history or through – I think Lincoln is a little bit different than Omaha because that's a main line – so, it's a fixed schedule, you've got to be here at this time. And so their prediction would probably be an added benefit to them to know when that train's going to be there, look at the previous history so that if they have a fire incident or something, they know that there's a good chance at this time they're going to be able to get the truck through there so they can route the truck using that crossing based on past history. Omaha, a lot of our lines are not main lines, just spur lines, and so it's a slower moving train. It's not something that's going through at 40 or 50 miles per hour; in the downtown area they actually walk the train through the crossing if I remember right, and press the button. The only one that might be close to high speed would be at 156th & West Center, and I think that the vehicle traffic is moving faster than the train traffic. I guess that probably isn't all that uncommon. That line itself I don't think is a high speed – I know it's not a high speed, I don't know how slow a speed they run on there, but it's a spur line, it's not a main line. So if we could track the data and if we could over a period of time be able to say, especially on a main line, you know that on Tuesdays at 2:00 a train comes through, you could then monitor it to make sure that it is, and then warn the people. But then at the same time if you had this history, you could use it for routing emergency vehicles. Because you could have it come up that you're going to route them on this route, and you know from past history that this is happened and you have a train there, so you may want to route a different way.

[truncated]

RH: But as far as where we have the spur lines, that's nothing that Omaha would...

GH: It's nothing that we would, no, because I think the use of spur lines are pretty much, they call, they need the goods, they need them in the next 20 days, we're going to bring them in, and that schedule varies too much.

RH: Any other information that Omaha would find useful?

GH: If there's a way to – if you're asking about accident data, if you're asking if we were able to put together accident data related to rail crossings and if we would seek safety funds for something like that, if someone were to put together that data, sure we would do that. And try to get funds to correct the issue.

[truncated]

Accuracy verification:

RE: Ryan Haas - UNL Thesis Discussion

From: **Hansen, Glenn (PWks)**

Sent: Wed 6/30/10 8:04 AM

To: Ryan Haas

Yes

APPENDIX C City of Lincoln Fire and Rescue Department Discussion Transcript

April 28, 2009

3:00 PM

Attendees:

John Huff, *Associate Chief of Support Services – City of Lincoln Fire and Rescue Department*

Rich Furasek, *Assistant Fire Chief – City of Lincoln Fire and Rescue Department*

Ryan Haas

Dr. Jones

[already in progress, truncated]

LFR: ...company used to be on the south side, and the hydrant was on the north side, so that was always a challenge for us.

DJ: [truncated]

LFR: I think our biggest challenge is the unpredictability of their use of the crossing and ours. We have two unpredictable events that are going to occur, that sometimes conflict with each other. We have emergent response that has to cross the grade crossing and we have a train that has to cross the grade crossing, and both of them are not on a routine that is really predictable...the trains, yeah, to a certain degree, you could say they have the same train schedule maybe for a month. But our business, we look at in terms of years, and over the year's time, you can't say that on the first Thursday of every month that there's always going to be a train here, forever. Because they do – they use the tracks when they need to, understand that. But that unpredictability of those two components, to me, probably is one of our most significant problems with grade crossings where we have conflict.

LFR2: And the problem is, is the station that's closest and would run into that all the time has no – I mean they have no advance warning, it isn't something like at one of our stations, when we come out the door – and I'm thinking of over here at 2nd & N St., you know, we have the crossings over there on J St. to get into this neighborhood, we're having a meeting tonight concerning that – but there's no indication when you go out there, you can come out the door, stop, and look, if you see train then you know you've got to change your route. If you make a commitment coming out of 33rd & Holdrege where you're going north figuring you're going to go into – you don't know until you crest that hill and you see the arms down, and “uh-oh, now I've got to go around.” And then you eventually went by – at that time you've been by the main street that's going to either take you to 27th St., and then you're in a neighborhood that you start jogging around a lot.

LFR: So that unpredictability is our challenge. Now, the really cool thing that we're doing, we have mobile data capability on our vehicles today. We've been working on an 800 MHz radio backbone to transmit some information, primarily dispatch call information like street address, time, patient complaints...very basic stuff. But because of the bandwidth available to us, we couldn't do a whole lot. We – we're migrating all that over now to a cellular-based system with a whole lot more bandwidth. I mean, we could theoretically stream video of anything we wanted to look at, anywhere we wanted to look at it. So that's pretty exciting in my mind, right now, so if we knew we were going to establish a corridor that involved a grade crossing like that, we could theoretically look ahead.

DJ: [truncated]

LFR: I don't care about the middle of the train, I just want to know when the front of the train's there, and when the back end of the train is gone.

DJ: [truncated]

LFR: We now have a method – in theory anyway – to have that information available, relatively readily available. Now, when we did the traffic preemption system in Lincoln, one of the things – and that was primarily done for our benefit, law enforcement doesn't have any association with it – all of our emergency response vehicles have preemption capability, and we screw up traffic routinely, every day, lots of times. But, we think that gets us there safely, that's why we do it. When we did that, we realized that we couldn't control every intersection, it just wasn't cost effective. So we actually established corridors that were routes that we most frequently run from our existing facilities. And we don't control traffic in every direction, maybe just the direction that we're most commonly going to travel to get safely down O St., or safely down Cotner St., or whatever it is. And I would envision if we're going to do something with these rail crossings that we'd identify those same kinds of corridors. I'm not telling you how engineer it, but to me that makes sense rather than just trying to – if we say well, we want to control every grade crossing, the cost would cause a project like that to collapse under its own weight, it's just too expensive. But to come back and do some key ones...

DJ: To be honest you're not going to control the grade crossings.

LFR: Well, I understand that. But when I say "control," I mean to have the information that we need.

DJ: [truncated]

LFR: See, from my perspective, our dispatch center probably would not be the place to send that image. I'd rather put that on the unit, if I can, so that the units that are actually responding know what lies ahead, so to speak. And then they can plan their route, if they think they're going to go there they grab the camera at this intersection or that one and see what's happening, because they know that they're three minutes or two minutes away

from that intersection. Dispatch is just, for us in Lincoln, they're pretty much – they catch the 911 call, and they dispatch the appropriate unit based on the computer recommendation and they're done with us.

DJ: [truncated]

LFR: They just don't do much to support our operations, it's pretty much they just kick us out the door and then we're on our own.

LFR: If asked, they can give us cross streets, but that's not something that they do automatically.

LFR: Their call volume and their staffing patterns, there just isn't enough people there to help us do that, from our experience with asking for help. And that's fine, we understand that. If technology can support it and deliver it to us as a – somehow or another – as an image or as some kind of information packet or something...the intersection is clear or do you expect a train in 90 seconds. Well, we know we're not going to be there in 90 seconds so let's take an alternate route.

LFR: Is this in conjunction with the quiet zone that's going on there?

DJ: [truncated]

LFR: Because the only other one that I can think of is over at 40th St....40th St. is the only other crossing then all the way to 70th.

DJ: [truncated]

LFR: Weren't they looking at putting a road next to the railroad track that would run from 27th St. ... originally, well the old Northeast Radial. Wasn't there some plan now to tie a street in that goes – that ties Downtown Campus and East Campus together?

[truncated – discussion about future of Adams St. crossing]

DJ: ...what we're looking at is if we were to put more sensors out to gather more information, what information we would be gathering.

RH: What would you guys find useful, or what would you have need for now or potentially?

LFR: The thing that pops into my mind is how frequently these intersections are blocked. Time of day, and frequency, so we can start looking at and saying, "How does that correlate to our call volumes, and is there a better time of day that we have to be more aware of an intersection being unusable," basically.

RH: So both the real-time data when you're out on the actual call, and then historically if you had access to archived data.

LFR: Or if you're going to study it over a certain period of time, gather that information if it's not readily available right now.

LFR: If I'm not mistaken, I know they're running like 180 trains through here a day.

DJ: About 50 trains on the BNSF main line.

LFR: 50 a day, okay, but I know that there's a time from like 3:30 in the afternoon that the amount of trains that go through increases tremendously. There is a slow time, am I correct?

DJ: Yes, you can definitely see daily patterns. You definitely see patterns by day of the week, Sunday is a pretty light day for train traffic...

LFR: You know Highway 2, that Burlington line that runs parallel, there's a bunch of conflicts there for us: 10th St., 20th St., 27th St., 40th St., 48th St., all the way out. We run all those streets to get to the other side. We only have one fire station on the other side of the tracks, so to speak. So that's a problem for us, for all of our response basically to what I would call the south 20 percent of the city. That line causes us some grief.

DJ: [truncated]

LFR: Our work-around for that is we can send this unit instead of that one, because they're at the back end of the train or the front end of the train and they can cross before it gets there. But having the information and understanding when those intersections are clear or just after.

LFR: But that would be something that would have to be routed through dispatch because they're looking at that and they know that these [inaudible] get tied up, then okay, we're going to send one of the rigs on the backside of it.

DJ: Yeah, actually I think in College Station they were actually dispatching two.

LFR: And we do the same thing.

DJ: Because they weren't sure what was going on, whichever one got across first, was the-

LFR: We have a meeting tonight with the Near South Neighborhood Association about that very issue, because there's an area down there that's constantly blocked by trains from our 2nd and N St. location, and so we have literally duplicated our dispatch into that area, we actually send one unit from both sides all the time. We double up our response because that's the only way we can make sure that somebody's going to get there.

DJ: But then you take away a unit away from-

LFR: Well, absolutely, that's the problem.

LFR: They're getting the best of all worlds, because they know that they're going to get something-

LFR: They're getting the best protection in town.

LFR: When we go out to south Lincoln, if there's a train on 48th or 56th, all the way to 40th, now our engine is on 48th & Claire St., and Claire is on the north side of the tracks and they're whole area is covered, if you've got a long coal train that comes through there.

DJ: [truncated] So it's probably both dispatch and then the engine -

LFR: Having both, and dispatch would help us. I'm not sure how we would use it. If we could build it behind the scenes so it's automated, so the CAD – Computer Aided Dispatch – recommendation takes that into account, and just dispatches the right unit, then it would work. But to be relying on a dispatcher that would actually look at it and decide who can get around the train quickest-

DJ: [truncated] [In College Station] they must have had some type of automated thing, but they wanted a visual to verify that yes, there is a train there and it's not kids running around in their pickup trucks. So they ended up putting a camera out there anyway, and if you're going to put a camera out there anyway, you might as well add on the video detection that's available for not much more.

LFR: I was trying to look at the map and see – it's a pretty significant chunk of Lincoln that only has one fire station on the other side of the tracks. When we built-

LFR: See, along here is Highway 2, and Station 6 is right here, and they're on the north side of the tracks. If there's a train...I don't know how often the trains come through, you know, otherwise they run them straight south. And it goes up around Gooch's Mill, that way. But I know there's a train because, boy, you tie up that Highway 2 and 14th St. right by the penitentiary and that screws everything up. And there's a lot of traffic that goes down that.

DJ: We've been so focused in on the other railroad tracks up north that we've quit looking at the tracks-

LFR: Coming from your perspective, that intersection has a lot of stuff to study, there's no doubt. But just from our perspective, there are other grade crossings that are still problematic for us.

DJ: [truncated]

LFR: Now in Lincoln, the Rock Island line was abandoned years ago, it's a bicycle path now. But it used to go through the north part of the city and right past our fire station on North Cotner. The last line of duty death we had in Lincoln was a firefighter that was killed when a train hit the fire engine. And as a result of that accident, that station was equipped with a light bulb that lit up every time the grade crossing arms were down. That was, unfortunately, after the fact. The reason – well, there were a lot of reasons – that track was so infrequently used, and our people were really used to not seeing trains there, and the sun was out of the west, the train was coming out of the west, lots of contributing factors. But the reality is, they were complacent, didn't realize a train was coming.

DJ: [truncated]

LFR: Well, certainly technology can be our friend. If you guys can figure out how to help us, that would be great. If nothing else it's a fun project to talk about. I guess from my perspective, anything you can do, that's fun to have that insight. And from my perspective if there's something else that we can do for you, I'd be glad to talk to you as long as you want about this stuff, do you have specific questions...

LFR: [truncated] ... We had some angry residents that are trying to stop the City from closing a couple of really nasty grade crossings. And they're going to us and saying Emergency Services has to have these, and we took the position a long time ago that it's no big deal to us, because we can't go that way anyway. We don't rely on that, we can't count on getting through there, there's just so much traffic there. We're talking in particular about the 2nd & J St.... it's a mess if you've ever seen it. There's bunches of tracks, there's three little street, two of them are dirt or gravel, and we don't even count on going through there.

LFR: When the Harris Overpass closed, that was really an issue. But I would say 50%, 60% of the time we couldn't use either one of those anyhow, because they were blocked.

LFR: Our tactic now is that we dispatch units from both sides, and whoever gets there first does, and whoever doesn't they call them off. But we have not had as far as I can recall...we've been doing that now since 2001 or so. I can't recall any citizen calling and complaining that a fire truck was delayed because of a train. I would have thought that if they were unhappy, they would have called us. I don't know of our guys ever reporting that a dispatch was messed up because of a train. We just kind of accommodated the fact that, you know, it's like if the bridge is out, you go the other way. We're not helicopters; we have to drive on the street, so you go the other route-

[various anecdotal stories truncated]

Accuracy verification:

Ryan,

I have made a few edits (see red) with the track change function. good luck with your project.

John Huff
Assistant Fire Chief
Lincoln Fire & Rescue

From: **Richard J. Furasek**
Sent: Mon 5/17/10 10:57 AM
To: 'Ryan Haas'

Ryan, Chief Huff has made some adjustments. I reviewed your information and see that it reflects our comments to you during our meeting. If you need any more information, feel free to call me at [phone number]. Good luck with the thesis.

**APPENDIX D Lincoln Public Schools Custodial and Transportation Services
Discussion Transcript**

April 28, 2009
1:30 PM

Attendees:

Bill McCoy, *Director of Operations – LPS Custodial and Transportation Services*
Fred Craigie, *Assistant Supervisor for Transportation Services – LPS Custodial and Transportation Services*
Ryan Haas
Dr. Jones

RH: Do you have access to any data from crossings, either historical or real-time? Is there currently anything you're using?

BM: Currently not. Not that I'm aware of. I think Fred Craigie would give the same answer. I'm not aware of any information that we're presently using, regarding any of the crossings. As a transportation department, we try to avoid – whenever possible we try to avoid crossing railroad crossings. I think most people – transportation providers – would tell you the same thing, that we try to avoid that scenario whenever possible.

[Fred Craigie enters]

BM: Fred, to your knowledge, have we ever used any statistical data from railroads or information available about railroad crossings in terms of any of our operational processes that you're aware of? What I was explaining to them is that generally people - transportation providers – try to avoid railroad crossings whenever possible, in terms of our route structure. In fact, we use a routing system right now that if we instruct it to, we could designate a railroad crossing as a no-travel zone. The only problem with that is that if we do it in some instances, it may add significant time to a route or what have you.

FC: I think the only time we've been in contact – what was it, last fall with the City, or last spring...but the City, they talked about closing [the crossing at] 35th & Adams. And that's the only time we've been in contact with anybody, other than Operation Lifesaver over the years, that I can remember.

RH: If there was a way to deliver data – operational data – from any given railroad crossing to you guys, what types of data would you guys find...

BM: Well certainly the frequency of use would be of some value, just from a planning standpoint. We have a set of tracks down the road here on Park Blvd., and probably at the height of the season, Fred, I don't know...

FC: They're running about 85, 88 trains a day through here, and...since we've got the Van Dorn bridge now, it really doesn't affect us. When you pull out the gate, if you see a train, go the other way. So we have a definite alternate route.

BM: I guess to answer your question, I suppose that would be something that would be of some value, to be able to know what the frequency of the crossing is, what the use of a particular crossing would be. I don't know if beyond that if there's a whole lot of other data that would be of value to us. Fred's been in the industry for about 20 years, and so he's had a lot of opportunity to see a lot of different scenarios.

FC: I've seen a lot of crossings go away.

DJ: Would it be of any use to have information be able to be sent to the bus driver, saying "okay, there's going to be a train, so today you're going to take an alternate route, or for this run, you're going to take an alternate route"?

FC: Not really. What I teach the drivers is, if you have a crossing, any time is train time, [inaudible]. And they need to think about an alternate route, and if there is a train, and generally most trains aren't there more than 3 to 5 minutes in a worst case, until they run into where occasionally when they'll stop on a crossing. But that's few and far between anymore, they try not to do that, I haven't seen that – years ago, 15-20 years ago they used to stop down here for half a day sometimes, and that was atrocious. But that just doesn't happen anymore, I think the railroad, they keep the wheels rolling anymore. So, I'm not sure.

BM: I guess in response to that too, Libby, would be that there would be the assumption that we would have certain technology available on the bus that would enable that communication to take place, whether it would be through a GPS tracking system or something of that nature.

DJ: There's actually a program out in transportation right now called Intellidrive, and the concept of it is, and they've been working on a proof of concept for this whole system for about 5 years, is that you're able to have vehicles talk to other vehicles, vehicles talk to the roadside, and by that I mean the traffic signal controller. With this network of communications that's out there, you could send a message to a bus driver before they even get to a grade crossing.

BM: What device is used to send the message with then?

DJ: It's basically a wireless network. The car manufacturers want this intellidrive stuff to happen faster, and they're driving it so, well they're not in very good shape right now, but, it's been the car manufacturers worldwide trying to drive this – getting information into cars. So there's a lot of safety stuff that goes on with it, too. There's the micro level, so a car is talking to another car and says "okay I just slammed on my brakes," and tells your car to slow down, so before you as a driver even know – recognize that you need to slam on your brakes, the car is already braking for you. So there's the micro level but

there's also the macro level, where you could be sending these messages through the system, and if you've got a bus driver on Adams heading toward that grade crossing, they could predict that, okay, a train is going to be there roughly the same time, just avoid that and take an alternative route for that particular instant. So that's probably 10 years out from now...

BM: Well I do know in a school transportation, or the school bus industry, there's a lot of strides being made in technology with some of the on-board computers that they've got primarily now for diagnostics and some of the other applications. We use a pretty intuitive routing software system with which if we invested a little bit more money, we could – by purchasing the GPS system, there are a lot of different things we could do with that, that we're presently not able to. But I don't think anything in it would enable the capabilities that you're talking about, it would be more so just tracking where the bus is at, plotting it on a map, or even going so far as tracking when the stop arm is extended or when the door opens, or in some cases, and OPS is in fact doing this right now, they're looking at a GPS system which I believe will track student movement, when kids get on and off the bus. But there's cost associated with all those programs, and unfortunately for many school districts they're strapped financially to be able to afford those additional technologies. But certainly there would be some value in that I think. Again, I think of the crossings in the City that we use on a regular basis, probably that 35th & Adams would probably be one of the most traveled, would that be safe to say, Fred? Other than that, maybe the one on 70th?

FC: Well, as long as we're going to Abbott Sports Complex, we run 70th St. a lot, and Norwood Park, we're running that one a lot. Next year we'll have Morley going and I don't know what it will take – I think a lot of the buses are going to be using 70th St. again, and several may use 84th St. to bypass the main line. The other one we run into is we cross the one south of Highway 2 a lot, but that's – an out of service line technically.

DJ: And that changed with the contract, who's hauling coal. So that could change again and it could be off of the Adams crossing and back onto that one.

FC: We have a lot of buses cross – I suppose if we had a bus count, more cross Highway 2 than we do up there because the day we did that survey, I think we only had 11 buses cross through that crossing in a day, which is pretty minimal. But I think a lot of them choose not to use that, they go up to 48th St. and come around or, because it tends to be a bottleneck in there when you've got a train on the tracks. They have a tendency to avoid that. And I don't know if we checked 33rd at the time – that's just a couple blocks away. Again we just don't have a lot of busing up that way, compared to south.

RH: A couple of the different things we're looking at is, two different kinds of data, both real-time data and historical data, once we archive different things. What would be of interest to you, you mentioned train frequency, we could derive average train event duration and delay and things like that, but it's sounding like that is becoming less and less of interest to you, is that?...

FC: I don't know that it would be of...

RH: ...as more of the crossings close, it's just...

FC: Yeah, yeah.

RH: Another thing, and I'm not sure how easily it would be archived, but one of the areas of focus of my project is looking at human factors-related data. From the City's perspective they would maybe be interested in driver violations, things like driving around the arms. From you guys' perspective, would there be any interest in having access to data, as far as driver compliance, stopping far enough ahead of time, opening the door, that kind of thing.

BM: As far as our school bus drivers are concerned? It's a very critical piece of the training that Mr. Craigie does in terms of training a school bus driver, in terms of railroad crossings and appropriate stopping and notification and when the lights are flashing and what have you. But would it be of value to know if we have drivers that are – if they are or they aren't? The public is usually not very bashful about letting us know when a school bus is obeying the traffic limits or laws. So we usually get a lot of feedback from people to let us know when a driver's not doing what they should be doing.

EJ: So in general, is that information useful to you guys?

BM: Oh, absolutely. Every time we get feedback like that we use it as an opportunity to emphasize a particular piece of our operation, and yeah, we want – it would be helpful to have that feedback, just to know whether we have a driver out there who's not doing what they're supposed to be doing. And sometimes the bus can be doing everything exactly right, the driver's not violating any laws, and they'll still call. There's something about a bus traveling down a residential street, a patron will call in and say they've seen the bus traveling at a high rate of speed. Well, how fast was it going? "I don't know, but it was awful fast." I've heard Fred say many times, you get a big yellow bus out there traveling down the road, the perception is that it's going faster than it actually is. But yeah, I think there would be some benefit in that.

RH: Maybe to clarify, this isn't saying that that would be immediately available or even available, if ever, but from an abstract level...the other thing you mentioned, or you had mentioned that sometimes you get complaints even though the driver does everything properly. If we had archived video at crossings, would there be then some interest in protecting yourselves from liabilities, if say, someone complained or if there was an incident or that kind of thing, that you'd have access to that video...

BM: Absolutely.

FC: Absolutely.

EJ: The railroads have found video extremely helpful with their in-cab video that they've put, for dealing with grade crossing...

BM: Well we had an example of that a couple of years ago on that South 14th Street crossing. We had a situation where, well, the design doesn't lend itself very well there anyway, how close the crossing is to the intersection. But we had the incident a few years ago where the bus actually went through the intersection and the cross arm came down without notification, and struck the top of the bus if I remember correctly, did it not Fred?

FC: I think so.

BM: And there were no lights flashing according to passer-bys or patrons who were in the area. Now if there would have been video of that, that would have been very critical, because we ended up terminating a driver based on what was reported to us. And the driver was very adamant that that's not what happened. But those sometimes are very difficult things to argue, particularly when you have a patron who says that the school bus went through the red – there was no train on the track...there was a train a ways down the line. The bus was empty, but there were no lights flashing, the arm dropped on top of the bus as the driver was going through the crossing. So having some video of that would have been helpful.

FC: I want to say there was a story in *School Bus Fleet* last month about, the railroad said the bus driver violated a crossing while a train was coming, they said they drove around the arms. This particular school district must have had an abundance of money, and they had a GPS system that did all that – documented all the stop and break and lights, and their GPS system said “Yes, the driver did stop.” And the railroad said they didn't, but they backed off. So, if you have video in that kind of situation it does pay.

RH: Would historical accident-related data at crossings be – is that something that's of any interest to you, not specifically school buses, but in general if there's an accident rate or some way to gauge the hazard level at a particular crossing, is that something that you take into account for route selection or is it – do you treat every crossing similarly?

BM: I think we would probably – Fred may have a different take on it but I guess we treat every...generally we would try to avoid crossings altogether, if we could. But if we had the data tell us that maybe one crossing was more hazardous than another, yeah, that would be of value. I mean, we look at certain intersections in the city as being fairly dangerous, and as I'd said earlier, we have the capability in our routing system to identify those as no-travel zones. We probably don't use that feature of the software as much as we probably could...yeah, there would be some value in that, I think. To try to weight it in terms of how valuable it would be in relationship to some of the other things, I'm not sure, but...

RH: Going back real quick to having access to real-time data, is that an area that you have ever looked at in the past in earnest? Or is it just something that's kind of...

BM: You're talking about GPS?

RH: Yeah, that kind of – some kind of dissemination system.

BM: We have looked at it pretty substantially; in fact I've done some preliminary budgeting for it. We've had some vendors come in and make presentations to us. So yeah, we've looked at it, we've not went so far as to put out an RFP or anything of that nature, but just from the standpoint of – if we had the money and we could do it, would I rank it as high as having video cameras on buses? Probably not, we'd probably put video cameras on buses before we install GPS tracking. But, quite honestly, if were to put GPS on buses, I would do it more for a personal need, and that would be to improve our efficiency, because many of the software programs now allow you to download real-time data back into your routing software system, and then basically what you have is just a virtual consistent updated route plan. Because the way the routing system works now and how most vendors' works is that it projects how long it's going to take to drive the route based on assumptions. For example, if the average travel time is 25 miles per hour in residential areas, it's going to plot the speed at which the bus gets to Stops 1, 2, 3, and 4 based on those criteria. And with the GPS system, you can take and download on a daily basis what the driver actually did back into the routing system and have more real-time information. And in doing such, I think we would improve our efficiencies quite substantially in some areas, because there's still a human element that's involved in routing, even with the best computer programs, and you have to rely a lot on what the driver tells you, and sometimes that's not always necessarily the most accurate.

RH: You had mentioned – so, GPS aside, you seemed to indicate that there are some locations – at least one location where there is a decision for the driver of the bus to make, looking ahead to the tracks, is there a train there or not, and if there is to go one way and if not to go ahead and proceed through the crossing. If the City had advance warning signs that say “Train will be at the tracks at such-and-such time,” would you feel that that would help your drivers make better decisions?

BM: Your thoughts, Fred?

RH: Because it kind of takes the guess work out of will a train be there or not.

FC: Probably. A good example is coming back on Van Dorn to turn on Park Blvd., once you make the turn you're pretty well committed, unless you can see the train through the trees sometimes, and guess. But...

BM: Yeah, and the other dilemma the school bus driver has is that backing up a bus is really not an option in most instances.

FC: Once you get stopped by a train you're there for the duration.

BM: Whereas a small vehicle may have the luxury of being able to turn around, you just can't do that in a school bus. So yeah, I can see a benefit to that. And Fred's illustration is a good example of it, because I've had that happen to me many times. If you knew that

the train was going to be on that track before you ever turn the corner, you would definitely go the other way. And certainly bus drivers would benefit from that I believe.

RH: That kind of covers all our bases. If we go back and look through, if I have any follow-up questions, can I drop you a line.

BM: Feel free to do so, or shoot me an email. We can try to answer via email. Like I said, I've only been associated with transportation for a little over seven years now. Mr. Craigie's been involved a lot longer, and he's our Level 1, Level 2 trainer, so he works with bus drivers every day in terms of just teaching them the ropes. Fred's driven a bus for quite a few years, so a lot of these things that you're talking about he's experienced at one point in time or another.

[non-pertinent exchange]

Accuracy verification:

Re: Ryan Haas - UNL Thesis Discussion

From: **Fred C. Craigie**
Sent: Tue 6/15/10 1:35 PM
To: Ryan Haas

Ryan,

I believe your documentation is very accurate as to our conversation on grade crossing situations with school buses.

Re: Ryan Haas - UNL Thesis Discussion

From: **Bill McCoy**
Sent: Fri 6/18/10 12:14 PM
To: Ryan Haas

Information appears accurate and reflective of our conversation.

Thanks

**APPENDIX E City of Lincoln and Lancaster County Railroad Transportation
Safety District Discussion Transcript**

July 2, 2008
8:30 AM

Attendees:

Roger Figard, *City Engineer, City of Lincoln; Executive Director, City of Lincoln and
Lancaster County Railroad Transportation Safety District*

Ryan Haas

Dr. Jones

RF: I'm actually now a technical committee member for the MUTCD, and the technical committee I'm on is RR Grade Crossings, so Chapters 8 and 10 of the Manual. We were in Mobile, AL, for a meeting down there so I'm still starting to learn a whole new group of things about RRs and preemption.

Take a minute or two and back up and when you say "test bed," maybe give me the executive summary again of kind of the project, the goal, so that I better understand exactly what you're trying to do or wanting to do and that I think will help me with –

DJ: Sure, well let me take this because Ryan's on this specific project and I'm the one who's supposed to understand the whole thing and keep it all on track. What we originally were funded by FRA through an earmark for the UN-L on rail research, was to look at better ways to do traffic signal preemption for RRs. Larry Rilett had done some work down at TA&M on this, using detection equipment that's off the RR ROW, so that you don't have to deal with the track structure and the (?) that they use and all the control, because there's a limited amount you can go back from a grade crossing with that signal structure that they use. Also, trying to get the RR to cooperate with other entities can be a challenge...down there they were just using Doppler radar because they had a single track that they had to worry about. What's interesting about a multiple track is that when you get into that, radar doesn't work anymore. What radar does and what we've collected data is that it gets confused of which train it's looking at, and it'll actually bounce back and forth between the two trains – they're going different speeds, you can pick that out – but if they're close to the same speed, you don't know. And you also don't know which direction they're necessarily going either. So, we've supplemented that with video detection, and video detection works pretty well, except for it's a really noisy signal. So you can fluctuate by a couple- three - MPH and it bounces, and especially when the train first comes through it really bounces all over the place. So we've taken the approach of combining both of them. Radar gives you a really good signal, but it can be fluctuating between two trains. But you can pick out those highs and lows and then combine. But even that data's pretty noisy. When you combine that with video and all of a sudden you get a really good estimate of speed. Which means you can put that quite a bit of distance back from the grade crossing so instead of getting 20 seconds notice that the train's coming through and having to operate the signals now you

can give it a full cycle's notice and be able to operate the signal – so you give a full cycle notice of “here's how to start”; then, additionally, you still get that 20 second notice from the RR to verify and make sure you're in the right part of the signal. And so the test bed, what we've done is we've – working with you guys and you've been a great partner on this, we couldn't be where we are right now – we're putting, as soon as cabinets get in, video and radar on the Big T aimed down at the railroad there. We've already got a camera installed. Dave Bernt's been a great help debugging communication. He's a great resource. And understanding what we need to do to work within your system without stepping on any toes or causing you guys any problems. So we've got a video camera that we're getting a feed back right now of the grade crossing at 35th & Adams. The other side we're looking at 44th Street, but there's some issues there of getting the camera up high enough, and figuring out – so that one, in terms of being able to set up more than just a University experiment where we're doing preemption offline and doing it post-processing, and being able to show how it would implement with the City – we may not be able to do that without spending quite a bit more money to put in a pole and communication. But that's the general idea behind where we first started. And to have a system where you'd be able to collect this data, and you'd be able to look at different preemption algorithms, collect data, do simulation, go back and see if your prediction is actually – do the prediction, have that done at the University, and then just show on a screen “here's our prediction, and here's where the train is”... have a live shot and here's (inaudible). Just instead of trying to implement in the field, because it can take a while to have everybody get comfortable and make sure the safety is okay. So that was the initial...then as we got into this, one of the things that happened was FRA shifted us from their track/rail/control people over to human factors. ... Now we've got human factors people looking at safety issues and then that video that we took that showed people going the wrong way out there and all that raised question about “well, it looks like we've got a lot of other issues that might be complicating understanding what's going on with safety and how the grade crossing operates and how it interacts with the signal. And it brings up a whole human factors area – what are drivers doing and what are they perceiving? How do they just interact with a basic grade crossing? Understanding the different types of warning signs and control signs you can put up. The idea of putting up stop signs – that's a big thing right now.

RF: Yes, every crossing that doesn't have active gates and lights will either have a yield or stop sign within a certain period of time.

DJ: I've certainly read literature where people suggested it should be a regular traffic signal; drivers will obey a red light without a regular traffic signal without a gate better than they will with flashing (lights) and gate arms. So there are all these issues that are coming up, and FRA looking at this as “hey, we're getting a lot of data back from this, how could we supplement what we're doing right now for basic signal preemption?” Maybe with some extra cameras, aiming them differently; enhanced data collection, so you actually are capturing details on signal timings and what's – just really getting some detailed stuff. Not only getting the video – what are drivers doing – but you're getting what was going on with the traffic signal and the common time stamp for all of that. So you really start having this extremely rich data set that's difficult to collect otherwise.

But we don't know – we just have a camera out there right now recording video. And if we want we can probably ask you guys if we could hook up our system to collect reds and greens. So that's the background and it overlaps with your quiet zone as well. So that has certainly some interest from FRA as well, since they know it overlaps. And it's one of the more interesting grade crossings, certainly, in the city of Lincoln right now. And it looks like it'll be there for at least another 10 years probably. So with that background, the student who's...

RH: First of all I guess I just wanted to touch base to see if there's anything other than basic preemption data that you guys are using as far as at railroad crossings. Is there anything beyond just basic traffic signal preemption that is available to you guys or is that where you stand right now as far as...

RF: I think that's all that's there. Scott's been talking about – Scott Opfer – has been talking about, at our regular signalized traffic intersections, our equipment is capable of gathering much more data, but we've not – we're too busy operating every day to get into what are some of the other things we (inaudible). But at grade crossings I'm sure there's nothing else.

RH: I guess that leads into, are there things that you have thought about, sources of information or data that would improve safety or efficiency at the crossings? Are there things that...

RF: ...there is a ton of data I think I'd like to be able to have. I'd like to know obviously number of trains. I'd like to know actual crossing closed time. I'd like to know the time frequency between trains. At the time that the train is there, I'd not only like to know the delay time for the traffic, but I'd like to be able to perhaps quantify the number of vehicles that are delayed in each of those circumstances. With the video, I'd like to be able to quantify the poor behavior as the train approaches – (drivers) going around, jumping over the curbs, and after we get quiet zones in some of those other locations, it would be nice to be able to quantify, are people actually going to go ahead and jump over the curb and go around the gates and the lights – that behavior.

DJ: When's the quiet zone supposed to go into operation?

RF: Well, we are trying to finish the review of (inaudible) plans right now and get the bid out. So yet still this summer. My problem, what's going on in the corridor, is getting an agreement with the railroad for the wayside horn equipment there at 35th & Adams. Just like you said, getting an agreement – they want to shed themselves of more liability at that crossing and give more to the City. But still this summer, I hope before cold weather's here we'll have that (inaudible). I kind of got off track...

DJ: You were talking about driver behavior.

RF: I think that over the last year and a half in serving with the committee that I'm hearing from railroads, I'm hearing from FRA, that 90-plus percent of the incidents at the

grade crossings are a choice-caused issue, which is just driver behavior. And I think just to be able to see that and quantify that I think then helps all of us as decision-makers to come up with, “okay, so if that’s a conscious decision, how in the world are we going to deal with that?” That perhaps reinforces, then, to my way of thinking now we’re probably getting into analysis, but it would reinforce for me – if that...why the behavior and what would we have to change in the field to affect that behavior to change, to come back and behave properly? Is it – and then that gets back to how long are people...is there a time frame someone will sit there and behave correctly? Or at what point in time does somebody get frustrated and say “I’m not going to do this any longer” and they either try to turn around or they go around the gates and lights. And having some sense of what’s tolerable for the public might help us in our decision-making...what measures are we going to have to take? Some of these crossings, we may be able to tell folks exactly when the train is going to be there, we know exactly what’s going to happen, we know how long they’re going to be there, but there isn’t any way to shorten that short of closing the crossing, grade separations, coming up with other techniques for somebody to go somewhere else. Maybe the idea of knowing when to alert somebody that that crossing is going to be closed so that they can go somewhere else because you know that timeframe (at which) they’re going to get frustrated sitting there and do something else.

DJ: Especially at that crossing, trains are not always going through, they’ll keep slowing down or they’ll stop and the gates – they’ll be coming into town and you’ll see the gates come down and then the train stops and then they go back up because the train is stopped. And I think understanding what the train is doing and how people react...

RF: I think some of that wait time and some of those kinds of things could be data that we could try then to use just as we analyze congestion and other issues on some of the corridors. Antelope Valley was a big thing, we talked a lot about how many trains were going to be there and how many minutes out of the day people actually were sitting at a crossing and I think a lot of this kind of data helped them to project – exactly – delay time, cost factors, and justification for additional improvement. It seems to me like it’s silly – we put up all the warning devices...let’s just use 44th Street as an example – there isn’t a lot of traffic there – but why spend a ton of money when the majority of the day the crossing is closed and you can’t get through anyway...and understanding that data can help us (inaudible). Whether the video can – you talked about gates down/gates up, (inaudible) green time – collecting all of that data to be able to have that analyzed and look at it along with what else is happening out there I assume would be beneficial. Those would be the main things, I think, to start with.

DJ: What about – one of the things that’s been interesting that we’ve seen was when you look at what the railroads are doing with their in-cab data collection, video – it’s not just video, they’re capturing everything, including – they’ve got a mic, not in the cab, they’re not listening to what the engineer is saying, right?

RF: Some are and some aren’t – depends on...

DJ: Depends on the union.

RF: Yeah.

RH: And then they found even when they did put those in, the train would come back in and they had been removed by the crew.

DJ: They are getting the audio signal of when the horn was sounded, engine – when the train started braking. And I got to thinking that'd be – how well does the quiet zone work?

RF: Well actually now that you mention it, that would be another thing...we get a ton of complaints about, “well, the train horn was too loud, too loud, too soon, and they weren't doing the right long/short in the timing.” If the railroad would allow us to have – are you suggesting, I don't know how...would our equipment out there be able to actually have a mic and we actually get to the point where we could pick up train horns?

DJ: Well that's what I was thinking when Ryan and I were talking about this is, gee that'd be kind of interesting to maybe ask some of the people who do acoustics at the University, “where would we put – what kind of mics would we put up? Where would we put them up? How does this data come in? Would we get this data?”

RF: Well I think it would be interesting. I've been working too long – it's difficult to remember how much fun it was to gather data and analyze it and then see whether it means anything. We just get a ton of complaints all the time from people saying “well, they're not blowing that horn the way they're supposed to – they start too soon, and they go way past where they need to go.” So if we had the ability with video and then with audio to pick up in relationship to the position of the train and the speed of the train...when did the horn start, how long was it, what was the cycle. And being able to put that in real time with position, you could do a couple things. We could take that back to the railroad and say, “here's what your rules say and your folks are supposed to blow the horn this way; here's what's really happening out in the field.” If they're doing it correctly but the citizens are saying “oh no, they're violating the horn whistle rule,” you could say “no, here's the data,” and clearly we could show the train – where it is, position, the 15 or 20 seconds ahead of the crossing, the whistle blew, here was the duration. I don't know whether you could actually get to the place to where you could (inaudible)...it might be nice to ask the audio folks and acoustic folks if the equipment is sophisticated enough to actually be able to pick up the decibel levels.

DJ: That's something I start thinking about with...

RF: Because there is minimums and maximums now in the Horn Rule, so if it would be capable of catching that, yeah, that would be...

DJ: Plus I always get the – listen to enough people tell me they've waited 5 minutes at the traffic signal, I don't think they (actually) waited five minutes at the signal. There's

this perception versus reality on the public's part and when you get frustrated all of a sudden things go out of whack with what's actually happening.

RF: What do you – we're going to have a camera on the Big T...

DJ: Camera and radar at the Big T right now, and we've got – we had funds to put up two cameras; there's one camera out there right now, and it's just a daylight camera. We've ordered – and we actually have them all in – day/night cameras. Because that was a problem we saw right away with the regular traffic detection cameras is they don't work on trains at night. So all our cameras that we'll have out except for one will be day/night cameras, but every location we put – will have day/night cameras. I think we're going to leave the regular traffic camera up. Again, just to – if the question comes up "why do you need a day/night camera?", here's why.

RF: Let's talk a little about pedestrians and collecting data. I think that I'm growing more and more concerned about the pedestrians – maybe more so than cars. The majority of the incidents with trains now according to railroads over the last two years is trespass pedestrian issues. Trying to figure out pedestrian behavior and what is reasonable to ask a pedestrian to travel to an approved type of crossing. My fear is if we close 44th Street, what are we going to do for pedestrians? It's one thing to tell cars "you're going to go around" and they have to go around, but have we solved the safety issue here –

DJ: Yeah, you think about what people are willing to walk to catch a bus – a block, half a block.

RF: Last week I was in Oklahoma City (inaudible) and there's a movie theater on one side of an arterial street and obviously there isn't enough parking, there's continued shopping on the other side of the street and there's tons of parking and the doors for the movie theater are exactly in the middle of the block. Every time I went and came people were running across the arterial street, unwilling to go that 100 to 150 feet to a traffic signal. So, how are you going to get someone to walk a quarter of a mile or a half a mile from a grade crossing?

DJ: I think the whole idea here is – trying to plan out if we were going to expand this grade crossing test bed, what would we want to look at?

RF: Well the pedestrian issue with the University –

DJ: Trying to keep the students from cutting the fence.

RF: Yeah. Now my understanding is the University cameras where the police actually caught a couple of folks has – I don't know that we've had any more fence cutting issues. I would like to be able to try to collect that data to use as a diagnostic tool, but we need another crossing between 10th Street and the new Big T at 16th or 17th, with 14th Street closed. So overall that would be information to try to determine just what kind – in an

urban area – what kind of frequency of maximum distance can you expect pedestrians to go (inaudible) and then you'd need to have facilities to go (inaudible).

DJ: Is Antelope Valley set up to have pedestrians going across the Big T?

RF: Not specifically because everything is set up, if you're over on the north side, you can go underneath and there's a series of trails and bridges that take you across the creek, under the railroad tracks back into the University so we've got that covered. I was at the MidStates Highway Rail Grade Crossing Safety Conference, it was in Grapevine Texas, and the cameras in the locomotives continue to be very beneficial to them. Some of the engineers don't want their voices recorded. A couple of folks said that they thought that if the public or the juries actually heard the responses of the engineer saying, "oh, get out of the way!" (or) "oh no there isn't anything we can do!", it added a human component in these liability cases. My understanding is that the cameras in trains have really reduced their litigation (inaudible). So that maybe is the other thing is can this information be reliable enough where we can actually use it in – bring it into a court situation?

DJ: We certainly have no chain of custody, which makes it almost completely useless.

RF: Would the video equipment be good enough that when we observe poor behavior that we might actually be able to determine ownership – license plate information to be able to get to the point where when we have legislation we could ticket people?

DJ: We have not set up the cameras that way right now but you certainly could.

RH: Yeah, that technology exists. In other jurisdictions where it is legal they have – similar to red-light running cameras they set up equipment to –

RF: I believe in the next session with Ernie (Chambers) gone, there will be a move within the State Legislature to allow legislation – to try to get that enabled with legislation. I think eventually that's where we'll need to be, because there isn't enough manpower to put (?) enforcement.

DJ: Red light running is pretty bad.

RF: I have a horrible thought, too, I've been back and forth over three times in the last (inaudible) and I drive about 80, and I'm thinking "you know, this red-light running technology could be adapted to the interstates, it could get to the point where you couldn't speed anywhere without somebody watching you.

DJ: Yeah, they do this in Europe, instead of having aircraft like the State Patrol uses sometimes, they'll just have license plate matching through a work zone. And they'll look at how long it took you to get through that work zone, and if it took you too short of a time, you just got a ticket. So instead of enforcing it at a point, speed, they enforce it over this length. So that's certainly out there.

RF: Do you have other questions that might spur my thinking?

RH: A couple of things. Briefly, I just wanted to touch on human factors-related data, and you had mentioned pedestrians – collecting data to determine... what kind of data are you talking about? Are you talking about actually surveying pedestrians to see about their willingness, or to see if there have been studies to see how far pedestrians are willing to walk?

RF: Maybe some of both, but maybe the data would be observed by observing the pedestrians there and seeing what they do, trying to draw our own conclusion on what their own tolerance for wait time and travel might be.

RH: Okay. Because there is a lot of other human factors-related areas, or at least things that contribute to driver behavior, are difficult or impossible to measure automatically. You would need to conduct surveys for that kind of thing. The driver behavior is the big thing that you can collect in automated fashion, so I just wanted to touch on that. You had mentioned briefly a system which could distribute information to drivers or emergency crews or whatever the user may be as far as train arrival times, departure times, that kind of thing. Is that something that you've thought of that there would be some interest in maybe setting up some kind of system with variable message signs or web distribution, that kind of 511 type...

RF: [person's name] is about ready to strangle me. He's been wanting to do more of this for a long time, and I think with the increasing number of trains proposed along that Cornhusker corridor, I think that there may well need to be – there could be some advantage in some variable message signs that as people are driving up and down Cornhusker, or maybe 33rd, or maybe 70th Street – with 44th we're not quite as concerned – that we'd be able to predict when 33rd's going to be closed, when 70th's going to be closed and tell somebody to go use 27th Street or to use the underpass at 48th Street. I think those are some things that could reduce some congestion, and that might end some frustration. [person's name] and I had talked at one point about trying to do something along the Old Cheney corridor south of town so that when 14th & Highway 2 or 27th & Highway 2, some of those crossings were going to be blocked then we have some advance warning to offer. Then they quit hauling quite so much coal down to the power plant down there and the frequency of trains really dropped off so I think the interest there kind of faded. But if BNSF started having to serve all that coal and we start running a number of trains again that would be another location. I think some of those early advance warning driver kinds of directives may have to serve as the interim between now and someday being able to provide grade separations. The goal at 33rd and 70th Street one day will be to have those separated.

DJ: Yeah, we actually looked at putting our equipment up at 33rd as well, but there's no infrastructure out there for us to mount the camera on – power pole, communications there, that was too expensive for what we've been budgeted –

RF: Is it too late if suddenly somebody else had some wherewithal to get you some pole, and power, and equipment?

DJ: It's not too late. You know that's actually our problem at 44th as well is on the south side of the railroad. The north side, we've got a signal there but the power lines are low enough that the signal pole doesn't go up very high and so detect both tracks, we're going to have to have a camera on either side, where at the Big T we're aiming down and we're able to get both tracks with one camera.

RF: Is there anything that would preclude – if we had permission and we had the right safety – of putting the equipment on the power pole?

DJ: No, there's nothing that would...

RF: Okay, Dan [last name] is the chief engineer at [?] and I have an outstanding relationship and he and I get together periodically, and I have absolutely no concerns in discussing with him the potential of mounting some equipment...

DJ: Yeah, we actually purchase some extra equipment just in case we found a way to put something extra up at 44th, but that doesn't mean we couldn't put something up at 33rd as well.

RF: It seems to me like it would be nice to look at as much of the corridor all the way from 10th Street clear east of 70th Street. Maybe it's not all at once, maybe it's a test reach that builds and grows and we can equipment, and over time you may be done but there would be students after you...

DJ: Well I think that was FRA's thought on this is instead of just putting more stuff out just to get more detailed information specific to preemption and signal operations, let's focus on the broader issue. So in a way they're paying us to do all their legwork to write another proposal, is really what I look at this as. So if understanding the – if it takes to understand what's going at this grade crossing and to understand the broader issues, if it takes a broader test bed where maybe you cover the whole quiet zone.

RF: That's kind of what I'm thinking.

DJ: And then extend it to cover the University issues with pedestrians, cover the quiet zone, cover grade crossings which are likely to be there for a while.

RF: You know, one of the things going back to acoustics and sound for a minute...a lot of people, I believe, don't understand that the quiet zone doesn't mean there aren't going to be horns. And being able to pick up the sound, somebody could call and say "well horns were blowing, that's supposed to be a quiet zone." To be able to detect why the horn blew...routine crossing horns aren't supposed to sound. But any time somebody is working or there's trespassing or poor behavior, they're going to sound. Picking that up to be able to say "here was the instance and here's some video that shows what was going

on” could be valuable and certainly would be interesting. When you were talking about preemption, one of the concerns that my technical committee member has is – Rick Campbell, I don’t know if you know who he is – he’s concerned that we really don’t have redundancy and fail-safe equipment connection between the rail equipment and preemption where you have a traffic signal in close proximity and you need it reacting, we’re going to be working on that more in the upcoming year. But when you’re talking about preemption, you’re really just talking about the train situation interacting with the traffic signal and us being able to understand and predict when that’s going to happen, not whether or not there is redundancy in signal and safety connection between them?

DJ: Right, we were really looking at it from how you operate the signal. You often can catch pedestrians out in the middle of the street, and all of a sudden they’re out there and they’re in conflict with a green, that’s a classic example that people use on signal preemption algorithms that exist today.

RF: Well that clearly is one of the things that we discussed in Mobile, and there was huge arguments within the committee how you figure that preemption time and the concern is then you do end up with somebody trapped.

DJ: It really comes down to you don’t – that the 20 seconds just isn’t enough when you’re dealing with even a 60 second cycle length. You could really be in the wrong place in the cycle and you just – 10 seconds into a pedestrian crossing the street and they’re out in the middle...five seconds they’re out in the middle. You have to be able to clear the traffic off the tracks...that pedestrian’s just going to be at risk. If you had a longer lead time, if you had a cycle length, you probably could operate things a lot smarter and not cause that problem to pedestrians. In addition to that, if you’ve got coordination you might be able to instead of completely destroying coordination along the main line that’s going to go back to green once the crossing’s closed, you might be able to manage that coordination a little bit better as well and not screw up your coordination in the process of this. And that’s the one thing that really hasn’t been looked at is the broader effects of this, and then the...well, you get it on Cornhusker with the queuing of people wanting to go on Adams, that queue during rush hour can spill back onto the main line. And you’ve now got a hazard located quite a ways from the grade crossing and it’s still a grade crossing issue. And how do you – just managing all that traffic, if you just got longer time, that was really our purpose. But the fail-safe issue, and how do you wire this so that you actually are getting that signal, how do you know you’re actually getting that signal?

RF: Well, I’m really interested then as you gather data and look at those situations to see if you really are getting the lead time you need, I’ll have to admit that there were some of the arguments that the committee was having that I wasn’t sure that I fully understood...but boy, you could get a railroad guy arguing with a DOT guy, and they have very different opinions on how those traffic signals and preemption ought to be set up, and to sit down and the argument that the manual is not real clear on how you actually determine what that preemption time needs to be, so gathering any data that you

can gather can help actually – help us analyze what is occurring or not occurring would help.

RH: One thing I just wanted to check on, I noticed that some of the future projects on the RTSD website – are those just mainly infrastructure/grade separation kind of projects or is anything in there possibly information-related or data-related?

RF: Right today, they're almost all directed just towards hard infrastructure. That doesn't mean that if you had some ideas and some thoughts that I would be open – if you've got some projects, something that you need some help, I'm willing to present to the board that we ought to work with the University and collect this data or we ought to put up some ITS components that can help in that area. We've not done much of that to date. The jump into quiet zone really is the first kind of departure from just crossing material, grade separation. I'm open to that if you've got some ideas.

RH: What kind of factors – or how do you decide where your biggest area of need is when you go to address these projects? How do you decide one location over another, what factors go into that? Is it primarily safety? Is it accident history? What kind of factors do you look at?

RF: Well for the grade separations themselves the number one criteria is just using exposure rates, which is the number of trains times the number of the ADT, and working with the Department of Roads I think they're saying anything over 50,000 is the threshold number then they are suggesting are eligible for [SIDE A ENDS]

[SIDE B BEGINS]

RF: ...so safety would be a component, but the number one right today for grade crossings is that exposure. If we had more data...

DJ: Is that a Department of Roads threshold or –

RF: Yeah, we got that from Roads.

DJ: Do they get that from the Feds or somebody?

RF: I have no idea, Ellis Tompkins...

DJ: I was going to say, that's a question for us to ask – Ellis is on our list of people to talk to.

RF: If we had more data gathered, and where we could truly see where we've got a safety issue...the primary responsibility of the RTSD is to reduce conflicts and to improve safety between trains and pedestrians and vehicles. So if we truly can demonstrate a safety problem, then I would be more than comfortable trying to direct project resources in that direction.

RH: Just jumping around here a little bit, but I just wanted to...so I'm hearing from you that you could see potential use for both real-time data as far as from an operational standpoint, and then also archived – when you take that data and archive it from a broader standpoint –

RF: Yes.

DJ: I think the last thing that both of us are interested in is – we certainly have Ellis down as somebody to talk to. We are going to talk with Nebraska Trucking Association to talk about their perspective about trucks going over grade crossings. And we're going to try to get in touch with somebody at Lincoln Public Schools about school buses and their concerns of what they'd like to know about grade crossings. Is there somebody else in the City [name]

RF: Well, [name] –actually I'd like you to have you guys talk to Scott Opfer, in Traffic Operations. He'd have connectivity both just with concerns of traffic on the crossing, but also preemption interconnect there. Maybe Parks and Trails, you've got the same pedestrian trail issue at a number of these crossings.

DJ: Is there somebody there that you could think of?

RF: I'm going to say Glenn Shorney.

DJ: Also, EMS...if the fire truck or the ambulance gets stuck by a grade crossing – if you could get information to them, “hey there's a train coming, don't go the direct route”
–

RF: Go the other route. That's a good one, too. Niles Ford is the new Fire Chief, I think I would start there. And specifically we might be asking him, are there particular places around town where they struggle more than others because of a train and not knowing which way to dispatch. I know we've got a place down here on South Salt Creek where if they have a call down there they dispatch from two different stations simultaneously, and if there's a train in the way and they can't get through one way or the other the other truck always gets there. But there's a situation, because they don't know they dispatch two vehicles every time per call.

DJ: The thing that's good about the Adams crossing is there are alternatives that are fairly close and it's not too much of a diversion out of their way.

RF: But that clearly would be – is there eventually if we have better ITS, better electronic communication across the whole organization, would EMS actually want data being fed into their command center so that it's not the driver going down Cornhusker that sees it, when they get ready to dispatch they know where those trains and some of those are –

DJ: That was one of the issues that Larry did down at Texas A&M with just the radar information they were getting...they put a camera out because, and not to do video detection, because EMS didn't trust the University accurate information. They wanted to see that train to verify the prediction that was coming through. But they found it really useful to have that – I would suspect that they probably got comfortable with “hey this is actually giving us reasonable predictions and is accurate almost all of the time.” So, it's nice to have that verification of video that the train is actually coming. So I can see where there might be a similar type of feed.

RF: Well, and if you ask that question of EMS, what about Police or the Sheriff, asking them as well?

DJ: Yeah. Actually, talking about ITS, the vehicle infrastructure integration, you could almost put that message inside the car.

RF: Almost boggles your mind, the potential in upcoming...

DJ: And I've thought that's certainly an opportunity to go after some other pools of funding from the federal government is to say, “we've got this test bed, and we now want to add a VII component,” where you put this on the school buses that run through that grade crossing, and give them some kind of signal inside of the school bus, “hey there's a train coming, so just stop and back up.” That's like everybody's worst nightmare is have a school bus hit by a train.

RF: Absolutely. If you think about the crashes at grade crossings in relationship to just traffic crashes...40,000 people killed last year in traffic crashes, and I think there was only 400 people killed in at-grade crossings. Are you guys thinking about other kinds of things to try to improve overall safety just for the traveling public? I mean 40,000 people killed, and you don't hear a single outcry it seems to me like – you hear about the bad trains, you hear about how many soldiers get killed in Iraq...

RH: Plane crashes?

RF: Yeah. Somewhere along the line it seems to me like we need to try to be able to zero in on what is the predominant cause of this 40,000? Is it behavior? And I've been thinking a lot about that of late because of the cell phone issues and all the talk about, okay, we're going to – it'll be against the law to hold your cell phone, but it'll be okay if you have hands-free...

DJ: It's just as bad...

RF: ...and I'm one of the worst violators, but I also believe if we're really going to make a difference, we just have to pay attention when we're driving which we can be distracted with a phone or watching a video, or...I'm amazed at times driving down the Interstate and somebody's on the phone, and I've seen people with a book laid right across the steering wheel, reading...

DJ: Yeah, well I watched a guy work on a computer while he was driving. It's always interesting when you drive across the state of Nebraska, after I got an SUV where you're sitting up a little higher and you can see into other peoples' cars and all of a sudden you're like, "oh my gosh, that guy is reading," he's got stuff laid out on the passenger seat, he's got his laptop obviously rigged up so he can do this on a regular basis, to sit there and work as he's driving down the road. I was like, "man, I'm getting around this guy and I don't care if I get a speeding ticket, I'm going to get around this guy."

RF: I'll visit with Scott and some folks here also about some other poles or some equipment. I'll talk to [Dan Putins?] at LES, you're saying specifically there at 33rd?

DJ: 33rd would be really nice, because it actually gives us another point where we can predict and verify what's going on with the grade crossings.

RF: We've got a ton of those. Do you have another card so I could give one to Dan? Are you a full time employee?

RH: Mm-hm.

[end]

Accuracy verification:

FW: Ryan Haas - UNL Thesis Discussion

From:

Roger A. Figard

Sent: Fri 6/11/10 3:34 PM

To: 'Ryan Haas'

2 attachments | [Download all attachments](#) (149.0 KB)
[Appendix ...doc](#) (74.5 KB), [Appendix ...doc](#) (74.5 KB)

Ryan,

I have reviewed the information in the attachments you sent me and I am satisfied that they accurately reflect my comments and answers to your questions and interview from last year.

Congratulations on all your hard work and best wishes in your future endeavors.

APPENDIX F Nebraska Trucking Association Discussion Transcript

May 26, 2009

2:00 PM

Attendees:

Larry Johnson, *President, Nebraska Trucking Association; Member of Board of Directors, Operation Lifesaver*

Tom Micek, *Regional Manager, Burlington Northern Railway Company; Member of Board of Directors, Operation Lifesaver*

Ryan Haas

Dr. Jones

[truncated]

NTA: We were just talking about that...50 percent increase in commercial truck accidents with trains...on BNSF, since January, compared to last year. The storage areas between our tracks and where the existing highway is, when they built these ethanol plants...when a truck is exiting the plant, and they're using the type of crossing we want, which is active warning devices –gates and lights – when they pull up to the stop sign on the highway, they're required to stop looking for traffic in both directions, five or six feet of their vehicle is still hanging out over the crossing. When you have our train crew...when you're motoring along and you see this truck out there, there's a lot of things that go through your mind real quick. Should I put that train in emergency? Is this guy going to get off? Is he going to hear me when I blow the whistle? Does he see me? There's all kinds of things that go through your mind in these very few seconds. That's a concern from the railroad's perspective.

And there may be technology now that could warn this guy earlier, so he wouldn't be hanging out there.

[truncated]

DJ: What kind of information from a trucking perspective would you like to have regarding what's going on at a grade crossing? What information do trucking firms use to make decisions on how they route trucks, that's related to grade crossings?

NTA: You know, that's the part that creates problems for us, is that it comes down to a driver choice in most cases. It's his experience, it's his choice, and sometimes I think that's where we enter complacency, and we get hit...

Some guy uses the same crossing all the time probably doesn't see a train, and...those types of things that get people in trouble. One of the last ones I was involved in that was a fatality, was a guy who used the same crossing a dozen times a day. (The crossing was) wide, wide open, there wasn't a tree within ten miles. And he drove his pickup right into

the side of a locomotive. And the first thing you think is, was it a suicide? But it wasn't, he just used the same crossing, and there were skid marks on the gravel where he tried to stop. He just didn't see a train a lot, but the infrequency (contributed)...

[truncated]

RH: Would there be interest in, if there was a way to deliver information to the truck drivers, saying "okay, in four minutes there's going to be a train at this crossing you're heading towards, you might want to select an alternate route." Is that something there would be interested in, if there was a way to do that?

NTA: If it were affordable...let's say we've got the UPS, FedEx, kind of deliveries...somebody that's in a confined space or territory. They may use a route more often than not, but it's driven by maybe they have more packages on this side of the track taking them longer on this given day than it would on the other. Then we go up to furniture delivery, or garbage trucks...that would be somebody that follows a route that would be pretty consistent...

DJ: They probably couldn't deviate from their route very easily because they have to stop at every address.

NTA: Yeah, yeah, that's right. So who would be able to...let's go to that next level. Pegler-Sisco, Pegler Sisco probably could, but they've already loaded their trucks (in order) by stop.

DJ: So they're unloading it by stop.

NTA: Yeah. Um, less than truckload, your Conways, Yellow Freight, those kind of guys...basically the same thing. I'd have to move all this other stuff in order to be able to get to his in a deviation, so I might as well wait (at a crossing).

Um, truckload...truckload would be let's say in town, in that area. Truckload guy is bringing raw materials to Goodyear. Chances are he'd never put himself in that position at 35th, he'd (bypass to 48th). Let's take it away from there, let's go to grain – ethanol. If he's delivering in, he's got an appointment...I'm thinking of around Axtell and in that area. He's not going to be in that big of a hurry because chances are they're going to make him wait anyway (once he arrives at the destination).

[truncated]

NTA: As GPS becomes more affordable, if there's something that you could add to GPS (to make HRGCs safer), I could see value to that but (not if it were too expensive).

[truncated]

NTA: ...if it's Pegler-Sisco, UPS, FedEx, that route's different every day, unlike the garbage trucks where that's pretty much set in stone...

So from a cost justification, we know that any time, whether it's life, or property, or environmental, there's justification for prevention...

DJ: There's some type of balance there.

NTA: Yeah.

[truncated]

RH: Would there be an application (similar to red-light running cameras) that maybe truck carriers would be interested in, where they could know if their drivers are committing violations at crossings? Not only that, but for liability issues, if there happens to be an incident, would that kind of data be of interest?

NTA: Yeah, there would be. In fact...they have all this in-cab technology. We were just talking about that application in terms of changing driver behavior...

[truncated]

DJ: If you wanted to have more information collected at a grade crossing, from a trucking perspective...what would you want that maybe you currently don't have?

NTA: I could see value in – at a crossing – in knowing number of trucks, the type of trucks.

[truncated]

Accuracy verification:

Re: Ryan Haas - UNL Thesis Discussion

From:

Larry Johnson

Sent: Mon 6/14/10 8:18 PM

To: Ryan Haas

Ryan. Sorry for the additional delay. I have read the document and have determined it to be accurate. Thx! It was nice to work with you. Larry

APPENDIX G Nebraska Department of Roads
June 16, 2010
1:00 PM

Attendees:

Ellis Tompkins, *Division Manager, Rail & Public Transportation Division*
Abe Anshasi, *Public Transportation Engineer*
Ryan Haas
Dr. Rilett

[Truncated]

RH: I guess, first off, are there any data that you guys use either at the Adams St. crossing or at crossings in general, any information that you currently have available to you ... have access to or are currently using?

ET: Well we have basic inventory information about every public crossing in the state. The basics ... the type of warning devices at the crossing, whether it be passive or active, and then if it's active, what type of active warning devices. We have basic information in the inventory about the crossing – does it have the crossing type in there, Abe?

AA: Type?

ET: Whether it's concrete or asphalt or whatever?

AA: Yes, it does.

ET: Okay. It has the crossing width. It has the pavement, the type of roadway, whether it's gravel or hard surfaced. And of course we have traffic information, traffic counts, train counts.

AA: The number of tracks. And if it's main line tracks or industry tracks, it will have that information.

ET: There's – and I wouldn't say that this is the most accurate part – but it does have whether there's advance warning signs or stop signs or that kind of thing at a particular location, too. But since we don't have the funding to be able to go out and do any kind of a regular inventory, that some of that's probably not in the greatest shape from an inventory standpoint. We do keep up a pretty good relationship with the railroads with respect to the critical things: the train counts, the type of warning devices, and of course traffic counts. Traffic counts on a lot of the rural county roads especially are not an actual count, they are a count based on our traffic analysis folks' best guess as to what's there based on their experience. If we are dealing with a county with respect to some crossing or crossings, or if we hear of some situation, maybe a new plant or housing area or something like that, then we would ask the county to go out and do a traffic count.

And we even provide them a counter if they don't have one. And then we do have an accurate count in the inventory to use for an analysis if we're going to make some decisions about whether to put in some active warning devices or not. That's about it as far as the inventory, isn't it, Abe?

AA: Yeah, it will show the condition of it also, as far as if it's good or average.

ET: We have all of that information, like I said, we have that on all of the crossings, so if there's something that you want there we can certainly provide that to you pretty darn easy.

RH: Okay. Does Department of Roads operate any traffic signals that are adjacent to a crossing where there's interconnect?

ET: Yes, yes we do.

RH: So you've got preemption information there?

ET: Right across the street is one of them right here on 14th Street, we have one. We have others, but I don't – I don't know if you could think of any others off the top of your head, I'm not sure that I could. But I know there are others.

AA: Well ... I know Dr. Rilett works with traffic engineering folks, traffic engineering folks with the cities also set up the timing of the signals and such. And I know along Cornhusker (Highway) there are some ones that will stop you from turning left when there's a train going by. They'll have "Do not turn left" signs. So I know those are interconnected. As far as locations statewide, I don't know if we have that information.

ET: I'm going to have to ask [name] if we have that information in the inventory, I'm not sure that we do.

AA: I would guess "no."

ET: I know we do have a few around the state, not a lot, but a few.

RH: I noticed on your website, under the rail section it talked about railroad crossing complaints. What kind of complaints do you get?

ET: I would say that probably the biggest complaint that we get has to do with the crossing surface, wouldn't you, Abe?

AA: Yes.

ET: Somebody calls and complains about a rough crossing. If someone calls and complains about there being a lack of an active warning device, for instance, then we would refer them to their local public agency, whether it be the city or county depending

on what kind of a location it is, because we don't deal with citizens on that kind of thing, we deal with the public agency. And in most cases there's going to be some financial responsibility from them if we do something, so we want the county or city to be involved, so that they're aware that if they want to put in active warning devices there it might cost them some bucks. So we just tell citizens to talk to your county board or your city council. Most of the complaints that we get have to do with rough crossings or blocked crossings, where the railroad has for various reasons has left a train parked in one place too long.

AA: And also those complaints seem to come from county crossings or city/village type crossings. The ones on the highway we seem to keep up pretty good with our highway maintenance program. But a lot of these city ones and village and county ones, sometimes there's a misunderstanding, the approaches can be rough but that's actually the responsibility of that local agency to take care of the approaches.

ET: And the ones with the blockages, in most cases, you can find a big elevator that's close to the crossing that's being blocked, and it probably has to do with some kind of switching movements or something that's involved with the elevator. Not always, but I'd say the majority of them have something to do with an elevator, don't you think, Abe?

AA: Yes, especially during harvest, when they're loading up trains.

ET: The trains are getting longer all the time and that's causing a problem. We have so many county roads that are on a one mile grid system, and coal trains are becoming longer than a mile. So they stop behind one of their block signals and they can be blocking two crossings in a particular segment. And even though the railroads will stand in front of the transportation committee and tell everybody in the world that they're very cognizant of that, "we don't block crossings," they do block crossings. Train crews are, in my opinion, are notoriously not worried about that, they just don't care. And if you talk to some big-shot with the railroad, yeah, they do care, but... I think that the other thing that everybody has to understand and I tried to tell our management more than once, that the one thing you have to understand about the railroads is that they have one thing that they're concerned about, and that's moving trains. And everything else is secondary. And they've gotten a lot better in the last 10 years or so with public relations and dealing with some of those kinds of issues. But they are still only worried about moving trains and seeing how fast they can move trains. We've gotten them to work a lot better with our district offices with respect to crossing maintenance. They come in and they're going to close a particular crossing for three days in order to do some crossing maintenance. In the '80s, they'd just do it, they didn't talk to anybody. And all of a sudden I'd get a phone call, and the district engineer is madder than a hornet because they've closed the crossing at so-and-so. Now we've finally gotten rules and regulations about that and they do a pretty good job of working with our district staff to set up signage and detours and stuff when they're going to do that. But if they have an emergency, if they have a derailment or something like that, then that's a little more understandable. But then they just start doing things because the main thing they care about is getting the track back opened up to get their coal trains going again. Because

when they have a coal train sitting in Nebraska when it's supposed to be at a power plant in Arkansas, they're losing big bucks for every hour that that train's not there, behind schedule. And from what I've understood, *big* bucks. And then their products have changed a lot in the last number of years as well. Such a tremendous amount of their trains now have to do with the containers coming off at Long Beach from the west, from China and Thailand and so on. And everything goes to Chicago. Everything in the world must go to Chicago before it goes somewhere else. And we're in between the west coast and Chicago for BN and UP both. So everything goes through us. And a lot of those kind of loads have strict time schedules on them. So they're very cognizant of trying to get those to Chicago and out at certain times. I'm certain that Wal-Mart and places like that have some pretty strict rules on they have to work. I'm not privy to any of that, but I'm...I'll tell you a little story that kind of relates to this. I was supposed to pick up one of the Burlington people in McCook one night, this is years ago. Well he was coming in on the Amtrak train from Denver to McCook and he was supposed to be there at 11:00 at night. And I was there to pick him up and he didn't come and he didn't come. Finally the Amtrak came rolling in at about midnight. And I asked him what happened, and he said "well, we got pushed off on the siding." And I said "what do you mean, you're telling me Amtrak doesn't have priority?" And he said "absolutely not. They had one of those hot-shot produce trains that was on its way to Chicago, and they have priority over everything." And Amtrak got shoved off on the siding because this train was coming up from behind. So that's just the way their priorities are.

RH: Do you guys track incidents? Do you keep track of, maybe if one crossing has had more crashes than another?

ET: Yes, we have crossing accident information. And when we get information on that, we have it by the DOT number, which is the national Department of Transportation number. Every crossing has a DOT number, both public and private. And our traffic safety people keep it by DOT number.

RH: So I guess, what kinds of information could you identify that you don't currently have access to but that you would like to see, either at the Adams Street crossing specifically, or at crossings in general?

ET: I don't know, off the top of my head I can't think of anything right at the moment, Ryan.

RH: Okay.

AA: If there's something we need, we usually will get one of our maintenance people to go out if it's a remote location, or we'll look at it ourselves, or we'll ask the railroad to provide information.

DR: Could you briefly describe the types of...is it traffic volumes that you're talking about? Trains per day?

AA: If there was something we needed, you mean?

DR: Yeah. You said you went out and got stuff you needed, can you give some examples?

AA: We have, for example, if we're replacing a crossing, we have the crossing surface, width...but we would go out to re-measure it for widening a road. Or, for example, some of them have signals but the inventory wouldn't have that information, as far as where the signals are in relationship to the edge of the roadway. And that's something we might need. If you're widening the roadway two feet or something, that makes a difference where the signals are at. So something like that, we would have to get a more accurate measurement.

ET: Those are the kind of things that are associated with doing some kind of a project. I think on a typical day-to-day basis, I really can't think of anything that we don't already have in our inventory. Certainly at times we would like to have a little more up-to-date traffic, or train counts especially, than what we get. The train counts...the information that goes into the national inventory is split into two areas: there's information that is provided by the railroads, and information that's provided by the states. Now, we only provide information that has to do with the roadway-type information. The train kind of information, train counts, number of tracks, type of warning devices, all of that stuff, they're supplied to the national inventory by the railroad. And there has been an ongoing debate over the national inventory for 25 years, and how information gets into the national inventory. The folks at the Department of Transportation all blame it on the states that we don't provide them information up-to-the-date. And we blame it on them because we say we've supplied the information to them and they don't get it into the national inventory fast enough. And an awful lot of it has been a lack of coordination between the states and the Department of Transportation on the programs, the type of computer programs in order to be able to make this stuff easily put into the inventory and up-to-date. But what happens is that the railroads, well for one thing they don't necessarily supply the information to DOT as often as we would like. But then once they supply it, sometimes it can take months and months and months before it actually gets into the national inventory and is usable. So we pretty much keep our own inventory, and we work with the two railroads to try to keep our train information reasonably accurate. So that's what we use, as far as when we're doing assessments for safety projects, we use our inventory information. If we're actually looking at a particular location and trying to decide whether to put in an active warning device or not, of course we'd be working with Roads, so we'd have an accurate count at that location, so we'd know what it is right now. But even those, they vary day-to-day.

DR: You can see, two years ago rail traffic was significantly higher than now because of the economy. So just as a follow-up, on the train counts, do you get that yearly?

ET: Yeah.

DR: Basically the railroad companies, both of them give it to you?

ET: Yeah. But like in the UP's triple-main line corridor between North Platte and Gibbon, a couple years ago they were running 140 or 145 trains a day. Now they're down to 120 or so, or a little less. They keep saying that if the economy comes back, it'll go back up, and I'm sure that's true. They claim that there was going to be 200 trains a day in that corridor at some point in time. I think the economy has put a little slowdown on that.

DR: But they're still going to quadruple tracks throughout there, right? Adding to their capacity...

ET: They'll have four main line tracks through there 10 years from now. I would be awfully surprised if they don't. It's the heaviest freight corridor in the world.

RH: So, would it be fair to say that most of the information that you need, you're already being supplied with, as far as the characteristics of the crossing? But not necessarily the – it's maybe outside of what you're concerned with, as far as day-to-day characteristics, or operational –

ET: Right, yeah.

RH: Well is there anything else, any other information or data needs that you can think of?

ET: I can't think of anything right now, Ryan. If we think of something, I'll be sure to get a hold of Larry and let you know.

DR: Just out of curiosity, would the folks in the traffic side [of NDOR], would they be interested in operational things on the trains. Or is that a level of detail that goes beyond them?

ET: No, I don't think so.

AA: I don't think so.

DR: And my guess is it's pretty much what you're saying, it's a project-based, as-needed basis, right? If they're doing a traffic signal, they'll go out and get that data and use that with [inaudible]. They don't need it necessarily every day to...

AA: Exactly.

DR: That's sort of a...a fair statement.

AA: Yeah.

RH: If you have anything else you think of, go ahead and get in contact with us.

ET: We'd be glad to. If there's anything we can do to help you out, feel free to call, we'd be glad to do that.

[truncated]

Accuracy verification:

RE: Ryan Haas - UNL Thesis Discussion

From: **Tompkins, Ellis**
Sent: Mon 6/21/10 7:49 AM
To: Ryan Haas

Looks fine to me Ryan.

RE: Ryan Haas - UNL Thesis Discussion

From: **Anshasi, Abe**
Sent: Fri 6/25/10 9:17 AM
To: Ryan Haas

Ryan,

They appear to be accurate.

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