430 IACC Building – Fargo, ND 58105
Tel 701-231-8058 – Fax 701-231-1945
www.atacenter.org - www.ugpti.org

Moorhead Area Integrated Train Detection and Traffic Control System

Phase II-A Evaluation Report

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Prepared for:
Minnesota Department of Transportation

Prepared by:
Advanced Traffic Analysis Center
Upper Great Plains Transportation Institute
North Dakota State University
Fargo, North Dakota

EXECUTIVE SUMMARY

This report summarizes the results of the evaluation of Phase-IIA of the *Moorhead Area Integrated Train Detection and Traffic Control System*. This project was conceived in 1998 in response to the problems associated with frequent train movements in the Moorhead area. The area experiences over 70 trains per day, including unit trains which simultaneously block several Highway Rail Intersections (HRIs). The majority of these trains (about 50) are carried by the main Burlington Northern and Santa Fe (BNSF) line. Given the limited number of grade-separated HRIs, traffic operations, especially in the north-south direction are greatly impeded by the trains.

The main concept of the project is to use non-intrusive detection technology to detect trains, estimate train lengths, and adjust traffic control plans to accommodate resulting traffic patterns. Future phases of the project include potentially sharing train information with law enforcement and emergency dispatch, as well as the driving public.

The evaluation of this project was initiated by the Minnesota Department of Transportation (MnDOT), the lead agency on this project. The main goals of the evaluation were to document experiences from this project, examine how project objectives were met, and to share information generated from the evaluation with other agencies. The Advanced Traffic Analysis Center (ATAC) of North Dakota State University was selected as the independent evaluator for the project.

An Evaluation Plan was developed based on federal guidelines for ITS project self-evaluation process. An evaluation team consisting of relevant agencies and organizations guided the development of the evaluation plan and assisted the evaluator in collecting information and data about the system. The main component of the evaluation plan was to conduct field comparisons (before/after) of system operations and measure impacts on traffic operations. The two main areas targeted in the evaluation included impact on traffic delays at two major intersections and the accuracy of the train detection system.

The evaluation method used in this project is some what unique since it uses field data. In contrast, traffic simulation has been widely used for estimating system impacts. Further, field data collection methods had to recognize the randomness of train activity in the area. Therefore, travel time studies were not viable due to the difficulty in predicting when trains will arrive at affected HRIs. As a result, video surveillance at two intersections was the primary method of collecting field data. The video provided the evaluator with traffic data (for estimating counts and measuring delay) and train event for evaluating the detection system accuracy.

The data analysis suggests mixed results for the system’s impacts on traffic operations. Field traffic delay measurements for the before and after cases were inconclusive, i.e., several approaches experienced a reduction in traffic delay during specific peak periods while others showed an increase. However, these results may be largely influenced by limitations in the existing traffic signal hardware and related limitations to timing plans.

Specifically, there were some issues related to bringing signal controllers back in synchronization after a train event. The accuracy of the detection system also showed mixed results. There were numerous technical difficulties related to the detector, which had to be replaced twice before the system was brought on line.

It should be noted that the project overall had significant improvements to traffic operations in the area. Five intersections were added to the existing coordinated system. In addition, traffic signal timing plans were updated to reflect current traffic conditions. Another major benefit of the project is improved east-west traffic operations by implementing train-present traffic signal timing plans.

Finally, the time-frame for collecting the field data was constrained by the start of a major construction project that will replace the Main Avenue bridge, which connects the downtown areas in Fargo and Moorhead. There were several lane closures prior to the official closure of the bridge in mid June which had an impact on traffic patterns in the downtown area. As a result, the data collection was limited to less than two weeks. It also reduced the ability of the system design team to monitor timing plans and make adjustments accordingly.

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1.0 INTRODUCTION

Highway-Rail Intersections (HRIs) continue to receive public attention largely due to perceived safety issues and the impacts on traffic operations. High profile traffic crashes, such as the school bus brash in Illinois a few years ago, serve as reminders of potential safety hazards at HRI. However, in reality, traffic fatalities resulting from crashes at HRIs make up only a small portion of the total annual fatalities caused by traffic crashes.

Traffic operations in areas which experience frequent train movements may be greatly impacted, depending on the locations of rail lines. Many communities, especially in the Midwest, were established along rail lines and developed around them. Heavy agricultural and coal movements result in unit trains that can be a mile long. The City of Moorhead is a good example of how a major rail line bisects the downtown area in an east-west direction which greatly impedes north-south traffic flow. Several key intersections with close proximity to the busy rail line experience traffic congestion and blockage for several minutes while a train clears the area. It is estimated that a total of 70 trains go through the area every day, with about 50 trains on the main Burlington Northen and Santa Fe (BNSF) line.

Due to funding limitations, grade separation of surface street traffic and train traffic at affected HRIs is not feasible. Therefore, operational enhancements may be the only effective way of providing relief to safety and traffic operations problems at HRIs. Intelligent Transportation Systems (ITS) which have been applied in similar situations carry the promise of providing cost-effective solutions to HRI problems.

The Minnesota Department of Transportation (MnDOT) started studying the impacts of trains in the Moorhead area and exploring potential ITS solutions. These efforts began with a scoping study that looked at motorists attitudes and willingness to use information. A proof-of-concept was the next step to determine how available traffic detection technologies could be used. A prototype system was installed in May of 2003, and is known as Phase IIA, which has the following functional areas: detect trains, communicate train arrivals to traffic signal controller, and implement traffic-present signal timing plans. In turn, these areas make up the main components of the project evaluation.

The evaluation effort was initiated by the MnDOT, who is the lead agency on this project, in an effort to document experiences from this project and share information generated from the evaluation with other agencies. The Advanced Traffic Analysis Center (ATAC) of North Dakota State University conducted the evaluation in cooperation with other project partners, especially SRF Consulting Group, Inc. and the City of Moorhead.

The ATAC conducted some related work in the Fargo-Moorhead area that included a survey on HRI issues in the downtown area as well some traffic simulation analysis of affected intersection in Fargo. The ATAC has a video traffic data collection system which uses the Autoscope 2004 system and two cameras mounted on a 42-foot telescoping mast. The system was used for completing most of the data collection for the project evaluation, which is described in more detail under the Evaluation Plan chapter.

The following sections of this chapter describe the project goals and objectives. Chapter 2 describes the evaluation plan. Chapter 3 presents the evaluation results. Finally, Chapter 4 provides conclusions and discussions of the evaluation.

1.1. Project Background

The downtown area of the City of Moorhead is bisected by a major BNSF Railroad line which carries about 50 trains per day. Long trains, combined with closely-spaced intersections, result in blocking several at-grade highway rail intersections (HRIs) which impedes traffic operations in the downtown area. It is estimated that these crossings are blocked an average of four minutes per train, with some trains as long as 7 minutes.

Although local motorists have developed strategies to avoid potential train delays, there are a few grade-separated HRIs that could provide alternative routes to the blocked HRIs. Additionally, changes in train schedules make it difficult to predict when at-grade HRIs will be blocked at various times of the day. Often trains block these HRIs during the busiest periods when traffic on the surrounding roads is at its highest levels.

The impacts of train movements are potentially more severe for emergency vehicle operations and transit vehicles with fixed routes that cross the railroad. Given the limited number of alternative routes and the unpredictability of train movements, ITS technologies were sought to provide some solutions to the train problems in Moorhead.

The Moorhead Area Integrated Train Detection and Traffic Control System has been deployed in several phases, with more phases planned in the future. Project phases include:

Phase- I: Deploy demonstration test site consisting of a video-based train detector, wireless communication infrastructure, and host-end system.

Phase IIA: Expand system to include multiple detection sites. Interface with signal systems to implement alternative timing plans.

Phase-IIB: Graphical User Interface (GUI) to provide emergency dispatchers with real time information.

Phase-III: Expand system to include additional detection sites as warranted and deploy Variable Message Signs (VMS) for motorist information.

1.2. Project Goals and Objectives

This evaluation plan focuses on Phase II-A of this project, which has the following goals:

1. Improve safety
2. Reduce travel time
3. Develop, implement, and test a system that may be beneficial for many cities

Figure 1 shows a graphical illustration of the project area.

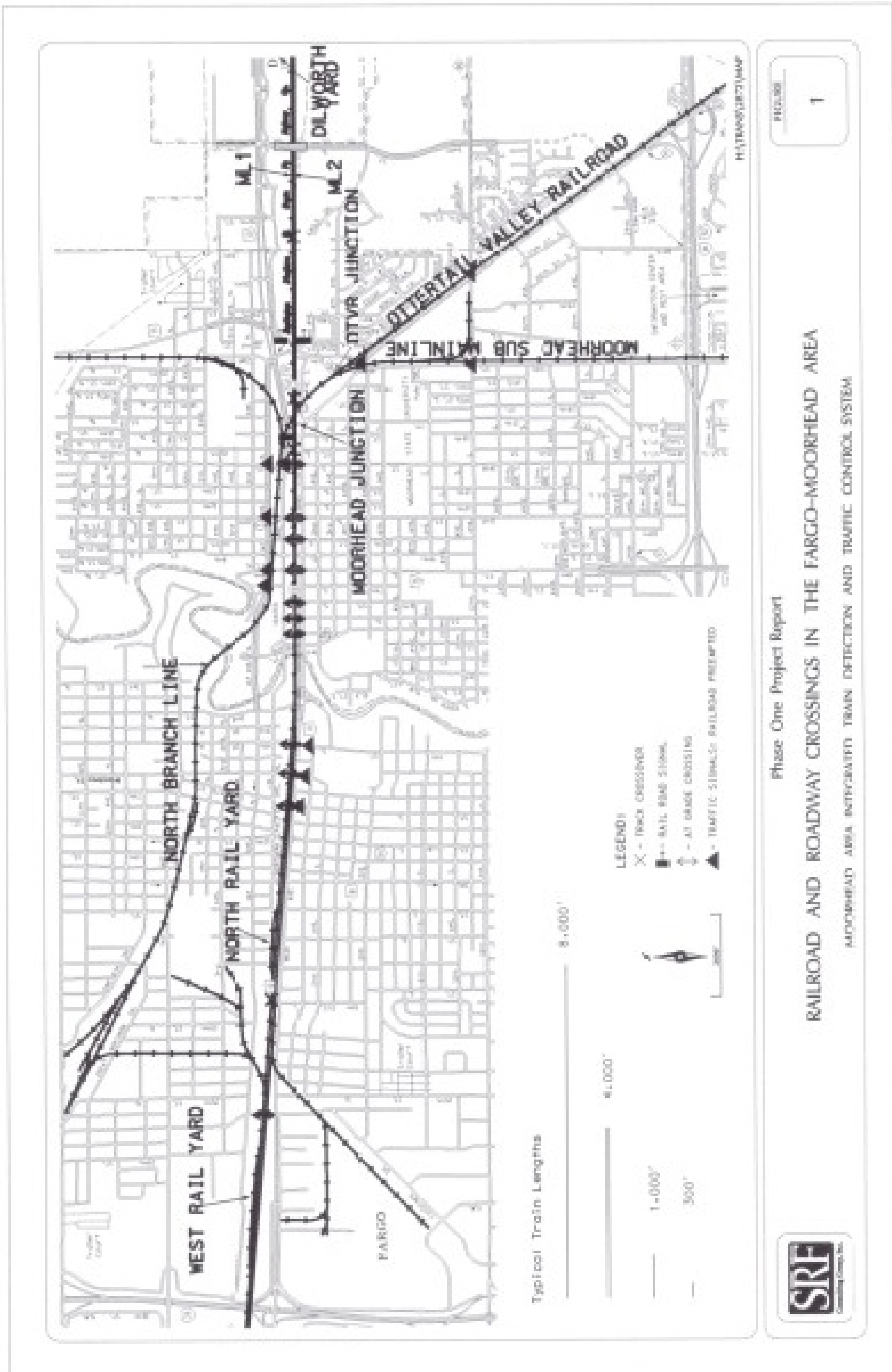

Figure 1 Project Map (source: MNDOT)

2.0 EVALUATION PLAN

This chapter describes the plan developed for evaluating the Moorhead Area Train Detection and Traffic Control System. The evaluation plan development was guided by an evaluation team which included various project partners. The process was based on federal ITS evaluation guidelines for conducting project self evaluation. The process largely aims at measuring how the project goals and objectives are achieved and documenting lessons learned in the deployment to benefit other agencies.

The following sections outline the details of the evaluation plan. They describe the evaluation strategy and discuss the specific test plans for conducting the evaluation.

2.1 Evaluation Team

The Evaluation Team for this project consisted of representatives from relevant agencies with roles in the project. The role of the Evaluation Team is to guide and assist the project evaluator (ATAC) throughout the evaluation period from developing an evaluation plan, collecting the data, and documenting the results. Below is a listing of representatives on the Evaluation Team:

Farideh Amiri, MnDOT, OTE/ITS (and Daryl J. Taavola, MnDOT)
Rashmi Brewer, MnDOT, OFRW
Bob Bright, F-M COG
Janelle Fowlds, District 4, MnDOT
Clair Hanson, City of Moorhead
James Kranig, MnDOT, OTE/ITS
Rick Lane, City of Fargo
Jim McCarthy, FHWA Minnesota Division
Erik Minge, SRF Consulting Group, Inc.
Ayman Smadi, NDSU-ATAC
Tom Sopp, City of Moorhead
Roger Sowder, MnDOT
Bob Zimmerman, City of Moorhead

2.2 Evaluation Strategy

The overall strategy for conducting this evaluation is to develop an evaluation framework which addresses the goals and objectives of this project in the context of the ITS goal areas identified in the National ITS Program. There are several key factors that can influence the design of this evaluation, and more specifically the Test Plans developed for the major evaluation areas. The evaluation strategy must recognize the priorities of individual evaluation areas, as agreed upon by the evaluation team. The availability of data will also influence the designs of the various test plans. Finally, there are limited resources to conduct the evaluation which will influence how these resources are allocated to the various activities.

2.2.1 ITS Goal Areas

ITS goal areas have traditionally included the following goals which may have measured outcomes (in addition to project-specific goal areas as appropriate):

1 Traveler safety
2. Traveler mobility
3. Transportation system operational efficiency
4. Productivity of transportation providers
5. Conservation of energy and protection of the environment

After discussions with the Evaluation Team members it was concluded that the most relevant ITS Goal Areas for this phase of the Moorhead project are goals 1 through 3. Additional evaluation goals specific to the project are identified in Section 2.2.2 below.

2.2.2 Evaluation Areas

Evaluation Team members ranked possible evaluation areas for the project relating to five main areas. The ranking scale included three possible scores: 1 for most important, 2 for average importance, and 3 for not important. Given the limited resources for this evaluation, only those areas which received a ranking equal to or less than 2 are considered. Below are the different evaluation areas and the scores they received (averaged for 12 members on the Evaluation Team). Below each area are notes about the possibility of measuring its outcomes in quantitative terms.[1]

1. Meeting project goals and objectives
   a. Reduce delay (**1.1**)
      i. May be quantified
   b. Improve safety (**1.9**)
      i. Hard to quantify since there are few numbers of auto-train crashes during a given time period (i.e., year)
   c. Transferability (**2.3**)
      i. Hard to quantify, however, information can be included in Lessons Learned

2. System Performance
   a. Reliability (**1.2**)
      i. May be quantified.
   b. Technology works (**1.5**)
      i. Hard to quantify but information can be part of Lessons Learned
   c. Detection system accuracy (**1.5**)
      i. May be quantified.
   d. Traffic signal control plans (**1.9**)
      i. May be quantified (part of 1.a. traffic delay above)

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[1]The use of the term "system" refers to various components or hardware that support the operations of the Moorhead Area Integrated Train Detection and Control System and include the detection system and the communications system.

e. Communications (**1.8**)
    i. May be quantified as part of system reliability (reported problems). Also specific issues can be addressed in the Lessons Learned

3. System functionality
    a. User interface (**2.1**)
        i. Hard to quantify. Interviews with users can be included in the Lessons Learned.
    b. Interface with traffic signal controller (**1.2**)
        i. Hard to quantify, but relevant information can be included in the Lessons Learned

4. System Costs
    a. Initial and operating costs (**1.8**)
        i. May be quantified.
    b. Personnel/staff requirements (**1.7**)
        i. May be quantified

5. Institutional arrangement
    a. Public-Public (**1.8**)
        i. Hard to quantify but may be documented in the Lessons Learned
    b. Public-Private (**2.3**)
        i. Hard to quantify but may be documented in the Lessons Learned

2.2.3 Evaluation Goals and Objectives

The goals and objectives for the evaluation were developed to cover the evaluation areas which were identified by the Evaluation Team to rank in the most important or average important categories (average score less than or equal to 2). These areas were then matched to the ITS goal areas. Areas receiving lower ranking may still be examined, however, they will not necessarily be evaluated using detailed test plans. Below are the project evaluation goals and objectives:

1. Estimate impacts on the transportation system
    a. Estimate traffic delay savings due to the system
        i. Measures:
            (1) Intersection traffic delay

2. Assess the performance of the system
    a. Evaluate system reliability
        i. Measures:
            (1) Percentage of time system is fully operational
            (2) Number of reported problems in one or more components
    b. Evaluate the accuracy of the detection system
        i. Measures:
            (1) Percentage of trains detected vs. trains observed
            (2) Percentage difference in train lengths detected vs. observed

c. Evaluate the effectiveness of the user interface
    i. Measures:
        (1) Qualitative interviews with users/system operators

3. Quantify system costs
    a. Document the system's initial costs
        i. Measures:
            (1) Cost of equipment
            (2) Initial cost of set up and other services

    b. Document the system's operating costs
        i. Measures:
            (1) Communication costs
            (2) Equipment maintenance/replacement costs
            (3) Labor costs for maintenance and update

4. Document institutional arrangements/issues
    a. Identify success stories
    b. Identify possible institutional issues/problems

5. Write an Evaluation Report
    a. Description of the Evaluation Plan
    b. Results of Test Plans
    c. Lessons Learned
    d. Recommendations

2.3 Evaluation Test Plans

This section summarizes specific test plans that were developed for accomplishing the evaluation goals. The test plans pertain to areas that may be quantified and require data collection, including: traffic delays and detection system accuracy.

2.3.1 Test Plan 1 Traffic Impacts

This test plan was developed to address the system impacts on traffic operations in the area. Specifically, the test plan addresses the following evaluation goal:

Goal: assess transportation system impacts (attributed to the project implementation)
Objective 1: estimate traffic delay savings due to improved signal timing
Measure: approach and intersection traffic delay

2.3.1.1 Methodology

The main approach to assessing the impacts of the system on traffic delay was to conduct a before-and-after study of selected intersections. Field data were collected for two intersections using ATAC's video traffic data collection system (TDCS).

As mentioned earlier, Phase II-A of the project which is covered by this evaluation includes two main initiatives as follows:

1. Add five intersections to existing coordinated traffic signal system, update signal timing plans to current traffic patterns, and develop a “train present” plan to facilitate traffic movements when trains are blocking affected HRIs.

2. Install a train detection system to determine the existence of trains and their length in order to trigger the “train present” signal plan.

The base-line conditions for this test plan (the before case) refers to the existing conditions with the updated traffic signal timing plans. The “after” case refers to the conditions with the updated timing plans and the train detection system supporting a “train present” timing plan.

Since the number of trains (and their length) is not expected to change due to this project, it is assumed that the net change in traffic delay for a time period may be attributed to the enhancements of the signal operations through the “train present” plan. This period must be long enough to allow for experiencing a representative number of trains. Therefore, the initial proposal for the test plan called for collecting data for the three peak periods (AM, Midday, and PM) during a 12-hour period.

2.3.1.2 Selection of Intersections

The intersections that experience the highest volumes of traffic in the study area are located along the US 75 route through Moorhead, which corresponds to a section on 8th Street. The two signalized intersections on this section are 8th Street with Main Avenue and Center Avenue. In fact, during the early planning for this project, the consultant team had identified the intersection of 8th Street and Center Avenue as the location which will see the majority of saving in traffic delay. A discussion with the Evaluation Team during a kick-off meeting for the evaluation supported this conclusion. Two more intersections were also identified as potential data collection sites, the intersections of 11th Street with Main Avenue and Center Avenue.

During the initial design of this test plan, the project evaluator began to estimate the level of resources required to cover the four intersections of 8th Street and 11th Street with Main Avenue and Center Avenue. After conducting a site survey, it was evident that the intersections of 8th Street with Main Avenue and Center Avenue were the busiest. It was further determined that due to building locations along these intersections it would be impossible to capture more than two intersection approaches in a single set up of the ATAC’s TDCS. Therefore, the project evaluator proposed to collect data for only the two intersections of 8th Street with Main Avenue and Center Avenue. Figure 2 shows the two intersections in more details and illustrates the video surveillance locations..

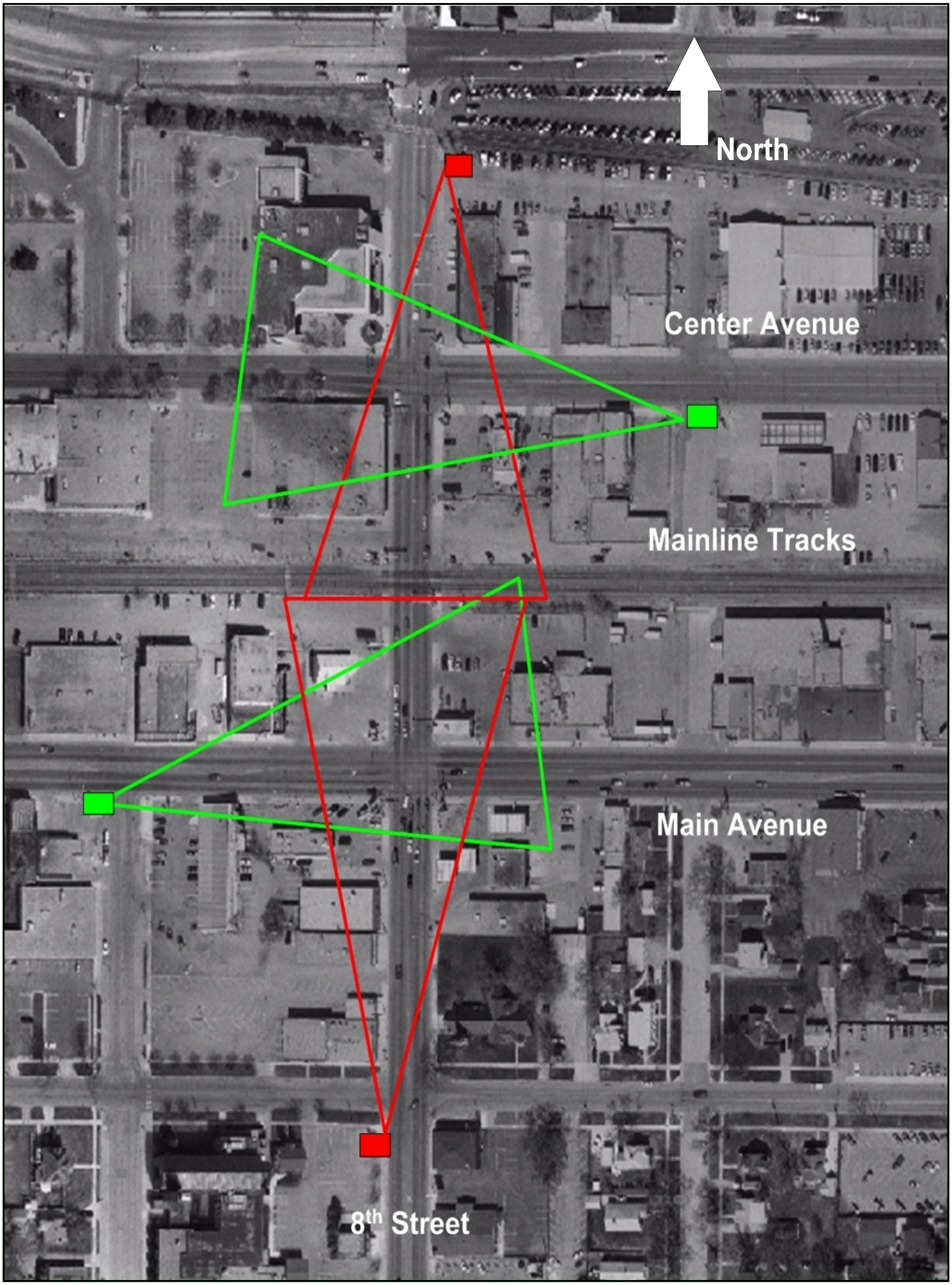

Figure 2 Locations of Traffic Data Collection using the ATAC's TDCS (video surveillance)

2.3.1.3 Data collection design

Traffic delay measurements are often used in traffic engineering studies, especially those studies that aim at evaluating the impacts of geometric or operational improvements on traffic flow. The reduction in delay is often used to measure the benefits of operational or geometric improvements.

Traffic delay can be classified into several types, however, stopped delay is the most common delay used. Stopped delay refers to the time a vehicle is held up at an intersection due to the traffic signal operations. Measuring this delay in the field requires direct observations of an intersection approach and recording the number of vehicles stopped during a short time interval. This interval can generally be 15 seconds or less to accurately capture delays experienced at signalized intersections. The observers record the number of vehicles stopped for each interval then multiply it by the duration of the interval. After the study period is completed the delay calculated for each interval is totaled then divided by the number of vehicles observed[2].

In order to measure delay in the field, several observers must watch each approach. Given the difficulty of arranging for multiple survey teams to observe each approach, an alternative method is to use video surveillance in the field then analyze the video later in the lab, using JAMAR counters. The ATAC Traffic Data Collection System (TDCS) was used for collecting these data. The TDCS has two traffic detection cameras that may be raised on a telescopic mast in a mobile unit which allows for complete coverage of intersection approaches under study.

Due to the geometry of the intersection studied, only two approaches at each intersection could accurately be observed in order to capture queue buildups. Therefore, each intersection had to be observed for two days (12 hours each day) in order to capture all four approaches. The east/west movements were captured on one day while the north/south movements were captured on the second day. In order to ensure consistency in traffic patterns (and normalize traffic delay calculations) for the same intersection on two different days, traffic counts for the two days were compared and the difference estimated. Traffic counts had to be within 10% for the two days to reflect average traffic volume for the intersection. There was one case where a third observation had to be made since the traffic counts were off by more than 10%. The third attempt resulted in an acceptable range (i.e., under 10% difference).

The data collection was conducted for a 12-hour period to incorporate the three peak periods using a two hour block for each period (a total of 6 hours). The approaches were taped for 12 hours, from 7:00 AM to 7:00 PM. During the observation, the video camera angle also allowed for observing train movements as they approach and clear the rail line within the vicinity of the two intersections. The train data are later used to examine the accuracy of the train detection system. Table 1 shows the locations and dates for data collection at the two intersections.

[2] Institute of Transportation Engineers, Manual of Transportation Engineering Studies, 2000

Table 1 Intersection Data Collection Dates

	8^{th} Street/Main Avenue		8^{th} Street/Center Avenue	
	N/S approaches	E/W approaches	N/S approaches	E/W approaches
Before	01/29/03	02/26/03	01/30/03	01/28/03
After	06/03	06/03	06/03	06/03

2.3.2 Test Plan 2 Detection System Accuracy

This test plan was developed to measure the detection system accuracy. The feasibility of this test plan is influenced by how train detection data are stored. The detection system screens trains and transmits train arrival data when the train length is estimated to be 110 seconds or longer. The goal to be measured and the associated objectives are as follows:

Goal: Assess the performance of the system
Objective: Evaluate the accuracy of the detection system
Measure: Percentage of trains detected accurately

2.3.2.1 Methodology

The main approach to assessing the accuracy of the detection system consisted of manually collecting train data for a selected period and comparing these data to logs from the detection systems. Data for this test plan were collected during the intersection surveillance in the "After" period (i.e., after the system was operational), a total of four 12-hour periods. Video footage from intersection surveillance was analyzed by a two-person team to identify the times when a train entered an intersection/cleared an intersection. Instances when two trains went through the intersection during the same time or when a train was stopped at the intersection were also recorded in the analysis.

3.0 EVALUATION RESULTS

This chapter summarizes the results of the data analysis conducted as part of the evaluation. The main focus of this chapter is on reporting traffic delays and detection system accuracy.

3.1. Traffic Delays

This section discusses the results of the traffic data analysis at the two intersections included in the evaluation, i.e., 8th Street with Center Avenue and Main Avenue. The results are based on conducting stopped delay measurement from video surveillance data collected at the two intersections. The data collection was for two 12-hour periods for each intersection to capture the east-west and north-south movements independently. Traffic counts on the two days had to be within 10%. Therefore, two additional data collection periods were added to make up for days when the difference was 11% and 12%. The acceptable data collection days had traffic levels that varied by less than 2% on average. Figure 3 shows an example of traffic count comparisons for the two data collection days in the before case.

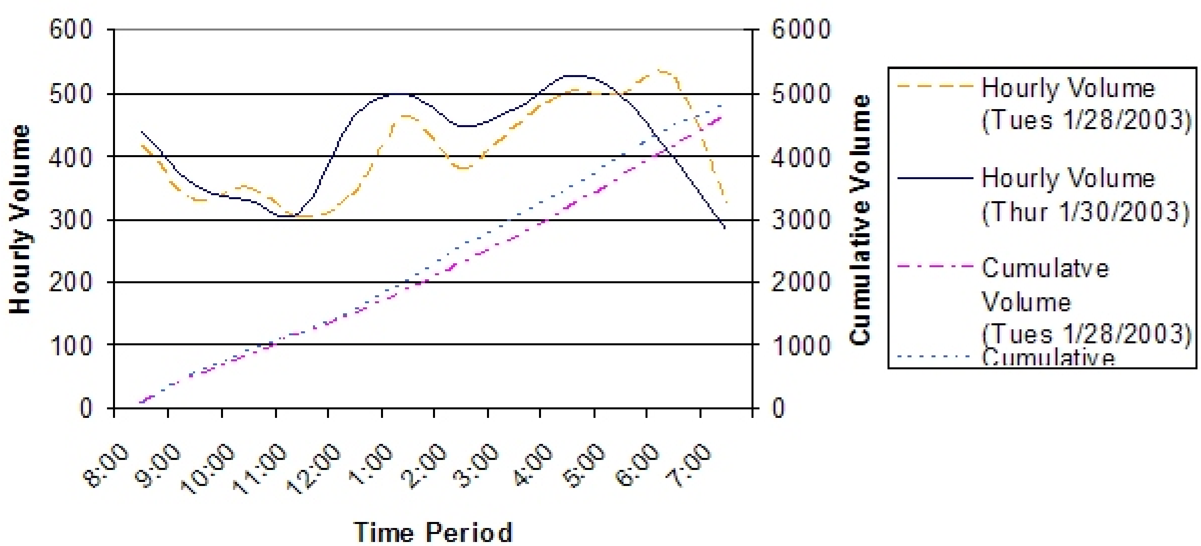

Figure 3 Example of Traffic Counts Comparisons for "Before" Conditions

The data analysis was based on a 15-minute interval for conducting the counts (by movement and classified into auto and truck). The delay estimation was based on a 5-second interval. During each interval observed, stopped vehicles were counted and assigned a 5-second delay. The total delay was estimated as 5 seconds multiplied by the number of vehicles counted. The average delay was obtained by dividing the total delay by the number of vehicles observed in the intersection. It should be noted that the delay measurement was conducted for each movement independently.

The following tables summarize the results of the traffic delay analysis. Each table shows the before and after traffic data for a single approach by movement type. The data are summarized for three peak periods and averaged for daily values. The sequence of the table is to show before and after data, followed by a summary of the difference for each approach.

3.1.1 Center Avenue and 8th Street

Table 2 below shows the data analysis summary for Center Avenue and 8th Street eastbound approach. The approach has two possible movements: left turn and a through/right. The delay values are expressed in seconds per vehicle (sec/veh).

Table 2 Eastbound Approach Before and After Data (Center/8th St)

Movement	Before				After			
	Left		Through/Right		Left		Through/Right	
Period	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles
Daily	9.6	461	7.5	6006	11.6	469	8.9	5798
AM Peak	11.9	22	7.7	174	19.0	23	13.1	221
Mid Peak	12.1	50	13.1	790	13.9	42	8.3	569
PM Peak	8.0	50	13.9	911	9.8	56	11.4	932

Table 3 summarizes the differences in delay for three peaks as well as a daily average. Positive values in the table indicate traffic delay went up in the after case, while negative values indicate a reduction in delay (i.e., an improvement). The percentages are calculated using the difference between before and after divided by the before values.

Table 3 Eastbound Approach Traffic Delay Comparison (Center/8th St)

Movement	Left				Through/Right			
Period	Sec/Veh	% Sec/Veh	Veh	%Veh	Sec/Veh	% Sev/Veh	Veh	%Veh
Daily	2.0	21%	8	2%	1.4	18%	-208	-3%
AM Peak	7.1	60%	1	5%	5.4	70%	47	27%
Mid Peak	1.8	15%	-8	-16%	-4.8	-37%	-221	-28%
PM Peak	1.8	23%	6	12%	-2.5	-18%	21	2%

Traffic delay in the after case increased for left turning traffic across all peak periods. The through/right traffic however, experienced a reduction in delay during the midday and afternoon peak periods. However, the through/right movement saw a daily increase in delay of about 18%. Traffic volumes in the after case were slightly higher for the left turn and slightly lower than the before case for the through/right movement.

Table 4 shows the data analysis summary for Center Avenue and 8th Street westbound approach. The approach has two possible movements: left turn and a through/right. The delay values are expressed in seconds per vehicle (sec/veh).

Table 4 Westbound Approach Before and After Data (Center/8th St)

Movement	Before				After			
	Left		Through/Right		Left		Through/Right	
Period	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles
Daily	20.7	1170	7.9	2427	22.1	1437	8.1	2914
AM Peak	12.1	65	8.5	279	28.2	92	7.6	297
Mid Peak	30.8	126	11.3	246	25.4	140	9.7	278
PM Peak	36.5	120	10.9	210	29.7	165	9.7	266

Table 5 summarizes the differences in delay for three peaks as well as a daily average. Positive values in the table indicate traffic delay went up in the after case, while negative values indicate a reduction in delay (i.e., an improvement). The percentages are calculated using the difference between before and after divided by the before values.

Table 5 Westbound Approach Traffic Delay Comparison (Center/8th St)

Movement	Left				Through/Right			
Period	Sec/Veh	% Sec/Veh	Veh	%Veh	Sec/Veh	% Sev/Veh	Veh	% Veh
Daily	1.4	7%	267	23%	0.2	3%	487	20%
AM Peak	16.1	133%	27	42%	-0.8	-10%	18	6%
Mid Peak	-5.4	-18%	14	11%	-1.7	-15%	32	13%
PM Peak	-6.8	-19%	45	38%	-1.2	-11%	56	27%

Traffic in the westbound approach of Center Avenue and 8th Street generally experienced less delays during the peak periods. However, the overall daily average increased slightly. It should be noted that the traffic volumes observed in the after case were higher than the before case. The overall daily change for that approach was an increase of 267 (23%) for the left turn movement and 487 vehicles (20%) for the through/right movement.

Table 6 shows the data analysis summary for Center Avenue and 8th Street northbound approach. The approach has two possible movements: left turn and a through/right. The delay values are expressed in seconds per vehicle (sec/veh).

Table 6 Northbound Approach Before and After Data (Center/8th St)

Movement	Before				After			
	Left		Through/Right		Left		Through/Right	
Period	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles
Daily	27.2	886	24.7	4140	26.5	1137	26.8	5189
AM Peak	25.3	83	20.3	379	23.6	109	21.6	434
Mid Peak	31.5	109	28.5	392	23.1	128	21.8	506
PM Peak	21.1	66	24.0	434	27.1	82	21.0	432

Table 7 summarizes the differences in delay for three peaks as well as a daily average. Positive values in the table indicate traffic delay went up in the after case, while negative values indicate a reduction in delay (i.e., an improvement). The percentages are calculated using the difference between before and after divided by the before values.

Table 7 Northbound Approach Traffic Delay Comparison (Center/8th St)

Movement	Left				Through/Right			
Period	Sec/Veh	% Sec/Veh	Veh	% Veh	Sec/Veh	% Sec/Veh	Veh	% Veh
Daily	-0.8	-3%	251	28%	2.1	9%	1049	25%
AM Peak	-1.7	-7%	26	31%	1.4	7%	55	15%
Mid Peak	-8.4	-27%	19	17%	-6.7	-24%	114	29%
PM Peak	6.0	29%	16	24%	-2.9	-12%	-2	0%

The left turn movement on the northbound approach of Center Avenue and 8th Street experienced a slight reduction in average daily delay. However, the average daily delay for the through/right movement increased by 9%. The traffic on the approach was significantly higher for all movements, averaging a 28% increase for left turn movement and 25% for the through/right movement. It should be noted that with the new system in place, more traffic was moved through the north approach while the impacts on the delay were minor.

Table 8 shows the data analysis summary for Center Avenue and 8th Street southbound approach. The approach has two possible movements: left turn and a through/right. The delay values are expressed in seconds per vehicle (sec/veh).

Table 8 Southbound Approach Before and After Data (Center/8th St)

Movement	Before				After			
	Left		Through/Right		Left		Through/Right	
Period	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles
Daily	14.8	69	22.7	2013	23.7	100	26.0	2649
AM Peak	10.0	1	16.1	162	7.5	2	21.4	162
Mid Peak	25.6	11	27.3	200	35.6	9	28.3	247
PM Peak	16.8	9	18.1	221	26.7	16	55.1	311

Table 9 summarizes the differences in delay for three peaks as well as a daily average. Positive values in the table indicate traffic delay went up in the after case, while negative values indicate a reduction in delay (i.e., an improvement). The percentages are calculated using the difference between before and after divided by the before values.

Table 9 Southbound Approach Traffic Delay Comparison (Center/8th St)

Movement	Left				Through/Right			
Period	Sec/Veh	% Sec/Veh	Veh	% Veh	Sec/Veh	% Sec/Veh	Veh	% Veh
Daily	9.0	61%	31	45%	3.3	15%	636	32%
AM Peak	-2.5	-25%	1	100%	5.3	33%	0	0%
Mid Peak	10.0	39%	-2	-18%	1.0	4%	47	24%
PM Peak	9.9	59%	7	78%	37.0	205%	90	41%

The southbound approach similarly experienced increased traffic for all movements. Traffic delay for the left turn movement increased except for the AM peak period. The through/right movement experienced an increase in average daily delay of 15%.

3.1.2 Main Avenue and 8th Street

Table 10 below shows the data analysis summary for Main Avenue and 8th Street eastbound approach. The approach has two possible movements: left turn and a through/right. The delay values are expressed in seconds per vehicle (sec/veh).

Table 10 Eastbound Approach Before and After Data (Main/8th St)

Movement	Before				After			
	Left		Through/Right		Left		Through/Right	
Period	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles
Daily	20.4	1045	16.8	7554	19.9	1139	12.6	6671
AM Peak	24.0	40	11.3	455	23.8	49	10.3	314
Mid Peak	20.1	94	18.9	662	31.1	123	14.5	647
PM Peak	25.7	135	26.3	909	25.4	141	18.8	798

Table 11 summarizes the differences in delay for three peaks as well as a daily average. Positive values in the table indicate traffic delay went up in the after case, while negative values indicate a reduction in delay (i.e., an improvement). The percentages are calculated using the difference between before and after divided by the before values.

Table 11 Eastbound Traffic Delay Comparison (Main/8th St)

Movement	Left				Through/Right			
Period	Sec/Veh	% Sec/Veh	Veh	% Veh	Sec/Veh	% Sec/Veh	Veh	% Veh
Daily	-0.5	-3%	94	9%	-4.2	-25%	-883	-12%
AM Peak	-0.2	-1%	9	23%	-1.0	-9%	-141	-31%
Mid Peak	11.0	55%	29	31%	-4.4	-23%	-15	-2%
PM Peak	-0.3	-1%	6	4%	-7.5	-28%	-111	-12%

Eastbound traffic experienced an overall reduction in delay for all movements (except for left turns during midday peak period). The daily traffic on this approach was down from the before case.

Table 12 below shows the data analysis summary for Main Avenue and 8th Street westbound approach. The approach has two possible movements: left turn and a through/right. The delay values are expressed in seconds per vehicle (sec/veh).

Table 12 Westbound Approach Before and After Data (Main/8th St)

	Before				After			
Movement	Left		Through/Right		Left		Through/Right	
Period	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles
Daily	32.1	1075	18.0	4247	38.2	1109	16.8	3802
AM Peak	28.3	93	15.3	408	26.2	82	14.8	366
Mid Peak	30.9	97	16.5	397	34.0	115	18.6	383
PM Peak	43.0	121	17.3	419	63.8	120	19.0	321

Table 13 summarizes the differences in delay for three peaks as well as a daily average. Positive values in the table indicate traffic delay went up in the after case, while negative values indicate a reduction in delay (i.e., an improvement). The percentages are calculated using the difference between before and after divided by the before values.

Table 13 Westbound Traffic Delay Comparison (Main/8th St)

Movement	Left				Through/Right			
Period	Sec/Veh	% Sec/Veh	Veh	%Veh	Sec/Veh	% Sec/Veh	Veh	% Veh
Daily	6.1	19%	34	3%	-1.2	-7%	-445	-10%
AM Peak	-2.1	-7%	-11	-12%	-0.6	-4%	-42	-10%
Mid Peak	3.1	10%	18	19%	2.1	13%	-14	-4%
PM Peak	20.9	49%	-1	-1%	1.6	10%	-98	-23%

The average delay for the left turn movement increased by 19% while the through/right movement experienced a 75% reduction in delay. Traffic volume for the through/right movement decreased by about 10%.

Table 14 below shows the data analysis summary for Main Avenue and 8th Street northbound approach. The approach has two possible movements: left turn and a through/right. The delay values are expressed in seconds per vehicle (sec/veh).

Table 14 Northbound Approach Before and After Data (Main/8th St)

Movement	Before				After			
	Left		Through/Right		Left		Through/Right	
Period	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles
Daily	20.8	2474	13.9	4574	30.2	1555	17.5	4237
AM Peak	19.1	217	13.5	440	---	---	---	---
Mid Peak	22.9	224	11.9	423	31.4	201	16.2	509
PM Peak	27.8	246	13.6	474	23.0	166	13.8	544

Table 15 summarizes the differences in delay for three peaks as well as a daily average. Positive values in the table indicate traffic delay went up in the after case, while negative values indicate a reduction in delay (i.e., an improvement). The percentages are calculated using the difference between before and after divided by the before values.

Table 15 Northbound Traffic Delay Comparison (Main/8th St)

Movement	Left				Through/Right			
Period	Sec/Veh	%	Veh	% Veh	Sec/Veh	%	Veh	% Veh
Daily	9.4	45%	-919	-37%	3.6	26%	-337	-7%
AM Peak	NA	NA	NA	NA	NA	NA	NA	NA
Mid Peak	8.5	37%	-23	-10%	4.2	36%	86	20%
PM Peak	-4.9	-17%	-80	-33%	0.2	1%	70	15%

Similar to the north-south approaches at Center Avenue and 8th Street, this approach experienced an increase in average delay for all movements. Additionally, the traffic volume was lower than the before case.

Table 16 shows the data analysis summary for Main Avenue and 8th Street southbound approach. The approach has two possible movements: left turn and a through/right. The delay values are expressed in seconds per vehicle (sec/veh).

Table 16 Southbound Approach Before and After Data (Main/8th St)

Movement	Before				After			
	Left		Through/Right		Left		Through/Right	
Period	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles	Sec/Veh	Vehicles
Daily	25.3	296	19.7	3580	30.7	320	28.4	3648
AM Peak	16.5	14	17.8	258	---	---	---	---
Mid Peak	30.8	29	18.3	377	35.6	31	31.8	452
PM Peak	24.4	36	21.7	459	22.4	44	21.0	575

Table 17 summarizes the differences in delay for three peaks as well as a daily average. Positive values in the table indicate traffic delay went up in the after case, while negative values indicate a reduction in delay (i.e., an improvement). The percentages are calculated using the difference between before and after divided by the before values.

Table 17 Southbound Traffic Delay Comparison (Main/8th St)

	Left				Through/Right			
	Sec/Veh	% Sec/Veh	Veh	% Veh	Sec/Veh	% Sec/Veh	Veh	% Veh
Daily	5.4	21%	24	8%	8.8	45%	68	2%
AM Peak	NA	NA	NA	NA	NA	NA	NA	NA
Mid Peak	4.8	16%	2	7%	13.5	74%	75	20%
PM Peak	-2.0	-8%	8	22%	-0.7	-3%	116	25%

Once again, the southbound approach mostly experienced an increase in delay for various movements. The only exception is the afternoon peak period which saw a reduction in delay for both left turn and through/right movements.

3.1.3 Discussion of Traffic Delay Results

The traffic delay data analysis indicate mixed results at best. In general, traffic delay at the two intersections included in the evaluation increased for various movements. However, there are several potential contributing factors that can help explain these results, as discussed below.

3.1.3.1 Traffic signal controller hardware[3]

The current signal controllers (Traconex) in the project are outdated. The main issue with these controllers was their inability to maintain coordination (i.e., get back in synchronization) after a different plan was activated. Re-synchronizing traffic signal controllers is a common challenge for traffic operations staff, i.e., emergency vehicle preemption. However, the relatively high frequency of trains in this project amplify any controller inefficiencies, potentially resulting in significant additional delay to traffic in the area. The approach to solving the Traconex controller sync problem was to dwell for 1 second during the train-present plan and 25 seconds for the background plan. Newer traffic signal controllers would offer more options to solve this problem.

3.1.3.2 Traffic signal timing plans

The corridor operates on a short (75-seconds) cycle. Therefore, approaches with heavy traffic are not always provided with adequate splits to clear the queues. This is especially critical during the peak periods that also experience trains. A longer cycle may also facilitate regaining coordination by the controller with less delay. Finally, a north-south-train-present plan should be re-evaluated. The north-south approaches experienced significant delay. Extended field observation of the timing plans may assist in revealing some of these problems.

3.1.3.3 Changes in traffic patterns

Due to several technical difficulties (mainly equipment malfunction), the time frame for collecting the after data was severely delayed. The before data was collected in January of 2003 with the expectation that the system would go online within a couple of months (i.e., March-April). However, the system was not fully operational until the first week of June. By that time, traffic patterns in the area may have changed due to several possible reasons, including:

1. Lane closures in the area to prepare for the Main Avenue bridge removal and reconstruction project. Main Avenue carried the majority of traffic between downtown areas of Fargo and Moorhead. There had been a strong public outreach campaign to alert area motorists to the project and advise them to take alternative routes.

2. Many area schools were either done with the spring semester or were in final exam periods. That period usually experiences less activity by area students, and therefore, may have had an impact on traffic levels.

3.1.3.4 Limitations in data collection

The data collection was limited due to the intensive resources required in observing each intersection. Other methods, such as travel time studies were difficult to implement given the unpredictability of train arrivals in the area.

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[3] SRF contributed most of the technical information on traffic signal operations

3.2. Train Detection Data

The evaluation of the train detection accuracy was straight forward. The same video surveillance data collected at Center Avenue/8th Street and Main Avenue /8th Street were used to identify train arrival and departure events. Therefore, train activity data from the field observation were considered to be true values (TDCS). There were two sources of information about the train detection system activity: a SQL database at the City of Moorhead (SQL) and data from the local master traffic signal controller in the field (Controller).

It should be noted that only trains 110 seconds or longer were captured by the system. Therefore, trains shorter than 110 seconds were dropped from TDCS data as well. Also, there were some issues in retrieving data from the SQL and Conroller. Not all of the four days when field data are available were usable due to data loss from the logging system.

Table 18 shows a summary of the number of trains recorded by the three systems, over three days of data collection. The percentages for Controller and SQL represent the number of times train events did not match train data as observed in the filed (TDCS). There were no train event data available through Controller for the first day. SQL train event data aligns reasonably well with the TDCS data for days 1 and 2. However, train data for day 3 show a great deviation from observed train activity. A more detailed description of train detection data is provided in Figure 4.

Table 18 Train Detection System Performance

	TDCS	Controller	%	SQL	%
Day 1	18	NA	NA	16	-11%
Day 2	15	12	-20%	12	-20%
Day 3	19	9	-53%	8	-58%

3.2.1 Discussion of Train Detection System Performance

The train event data used for evaluating the accuracy of the detection system limited the availability of interval data. Events were logged by the system only when trains met the 110 seconds threshold. Further, there were limited data for examining system diagnostics (when the system malfunctioned).

It should be noted that there were several technical problems regarding the performance of the detection system. The microwave radar sensor used to detect trains had to be replaced twice. Many of the initial field problems were attributed to site factors (i.e., aiming the sensor to accurately pick up trains). MnDOT and its project consultant SRF worked vigorously to make the sensor work. However, there may have been less than adequate support from the sensor vendor, largely due to distance and the fact that this was a small project relative to its business.

Train Event Data

	Time	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45
06/04/03	TDCS		1		1				1			1	1		1			1	1	1					
	Controller	No Data Available																							
	SQL		1						1	2			1	1			2		1						
06/05/03	TDCS	1											1							1			1	1	
	Controller																				1		1		1
	SQL																		1				1	1	
06/12/03	TDCS		2				1					1				1	1			1				1	2
	Controller							1					1								1			1	
	SQL						1*									1				1			1		

	Time	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45	16:00	16:15	16:30	16:45	17:00	17:15	17:30	17:45	18:00	18:15	18:30
06/04/03	TDCS			1		1				1			1	1			1		1		1			1
	Controller	No Data Available																						
	SQL			2	1							2									1			1
06/05/03	TDCS		1	1								1			1	2		2		1			1	
	Controller			2								1					1	2	1		1		1	
	SQL		1	1								1				1	2	1		1		1		
06/12/03	TDCS				1				1	1		1				1		1		2			1	
	Controller				1			1				1	1											1
	SQL			1			1									2							1	

*Constant track call for several time periods

Figure 4 Train Event Data

3.3. Cost Data

This section illustrates some of the various costs for designing and developing the system. The reported numbers are estimates provided by the project consultant, SRF Consulting Group. The costs are broken down by type of service or equipment. Table 19 shows aggregate cost summaries for the project. A more detailed break down of the costs in provided in Appendix A. It should be noted that these costs include engineering services for updating traffic signal timing and developing signal coordination plans.

Table 19 Project Cost Summary

Cost Item	Amount ($)
Main consultant fees (design and project management)	$159,573
Main consultant database and system support equipment	$8,465
Train detection sensor (MnDOT)	$13,654
Electric work	$24,500
Communication equipment	$17,000
Communication services (labor)	$18,500
TOTAL	**$241,692**

3.4. User Feedback

This evaluation did not have a formal method (i.e., survey instrument) to gauge the satisfaction or perception of various project partners with the system. Therefore, the evaluation team relied on voluntary feedback from members of the Evaluation Team. There largely is a perceived (and real) need for the system in Moorhead given the impacts of trains on traffic operations and safety. Therefore, there is tremendous optimism for this project to provide the groundwork for alternatives that would alleviate those problems.

Moorhead city officials indicated there was more positive feedback from the public about the system and very few complaints. The main issue they identified was the limitations of the current traffic signal controllers and perhaps accommodating north-south traffic.

During the project there has been some key staff changes including the Moorhead Public Works Director, who was involved in the project since inception, and the MnDOT project manager. However, the project team worked around potential problems and tried to address them as they arose.

4.0 CONCLUSIONS

The Moorhead Area Train Detection and Traffic Control System demonstrated the feasibility of using ITS to alleviate traffic operations and safety problems at HRIs. The project provides valuable information for agencies which may have similar situations and are interested in ITS applications to HRIs. The project also demonstrates the value of partnerships between local and state agencies as well as private companies. This project was only made possible as a result of great efforts from MnDOT, SRF Consulting Group, City of Moorhead, and other technical service contractors. The one player perhaps missing from this team was the railroad.

The results of the quantified system performance measures indicate room for improvement. Traffic delays increased after the system became operational, however, that is largely due to limitations in traffic signal hardware. In fact, even with the limitations in re-synching traffic signal controllers, reductions in traffic delay were observed on several approaches. This indicates the potential of the system in greatly improving traffic operations once it is fine tuned.

The detection sensor had somewhat limited success. There were several problems initially in attempting to use a video detection sensor. Similarly, the microwave based sensor had technical problems and had to be replaced twice. Although the system tested satisfactorily prior to installation, there may have been some site issues that caused detection problems once it was installed in the field.

The evaluation process was restricted by delays in getting the detection system to work, which pushed the data collection dates to pre-scheduled major construction activity in the area and end of school year in area schools and colleges. Additionally, the resources required to conduct a field evaluation were very intensive, and although a longer evaluation period would have been helpful, the cost of the evaluation would have been infeasible. On the positive side, field validation is generally superior to using less resource-intensive methods, such as traffic simulation.

It is expected that the operations of the Moorhead system will be re-visited after the Main Avenue bridge construction is complete. At that time, traffic patterns in the area should be evaluated to explore needed changes to traffic signal timing and coordination plans. The two most critical areas related to signal timing are controller re-sync and accommodating north-south traffic. Additionally, traffic signal preemption should be considered at the busiest intersection within the corridor.

APPENDIX A
DETAILED COST DATA

This appendix provides detailed cost data for various project activities. The information is solely based on estimates provided by SRF Consulting Group, the main consultant on this project.

Summary:

SRF Costs (Design, PM, S/W)	$ 159,573
SRF (Equipment)	$ 8,465
MnDOT equipment (train sensor)	$ 13,654
Moorhead Electric	$ 24,500
EDC (Equipment)	$ 17,000
EDC (Labor)	$ 18,500
TOTAL	**$ 241,692**

EDC is Electronic Design Company which provided communication equipment and local support

Detailed Costs:

(A) SRF Labor Costs = $154,908*

1. Deploy System = $14,375
2. Integrate System Hardware = $36,181
3. System Software = $50,197
4. Develop Timing Plans = $38,997
5. System Testing and Training = $15,158

*Note: design costs include labor costs for system development and deployment. Preliminary engineering costs are not included.

(B) SRF (Direct Expense) $ 4,665
(travel expenses)

(C) SRF (Equipment) $ 8,465

SRF Equipment	Unit	Qty	Total
Relay Board	$139.00	2	$278.00
MS SQL s/w	$1,300.00	1	$1,300.00
Shorthand Modem	$77.00	2	$354.00
TV/VCR	$181.04	1	$181.04
DB Server PC	$3,854.20	1	$3,854.20
Comm Server PC	$2,497.39	1	$2,497.39

(D) MN-DOT Equipment (train sensor) $ 13,654

Speed sensor costs	$1,750.00	2	$3,854.20
Presence sensor costs	$4,900.00	2	$9,800.00

(E) Moorhead Electric $ 24,500

(F) EDC (Equipment) $ 17,000

Qty	Manufacturer	Part No.	Description	Unit Price	Extd Price
1	ENCOM	4510P	Model 4510 Pole Mounted Transmitter	$3,000.00	$3,000.00
1	ENCOM	4610P	Model 4610 Shelf Rack Mounted Receivers	$3,000.00	$3,000.00
3	Microwave Data Systems	MDS P70	P-70 Universal Package Mounted	$1,428.00	$4,284.00
1	Microwave Data Systems	MDS 97-3661A43	10.0 dB Tagi Antenna Directional 890-960 MHz 200 watts	$291.84	$291.84
3	Microwave Data Systems	MDS 9810	Transceiver 902-928 MHz	$1,125.00	$3,375.00
3	Microwave Data Systems	MDS Option 1	Option Network Diagnostic	$91.80	$275.40
3	Microwave Data Systems	MDS 03-3960A01	Enclosure Heater, 120VAC	$202.50	$607.50
3	Microwave Data Systems	MDS 97-1678A15	Lighting Protectors	$73.20	$219.60
1	EDC Solutions	Misc. Mounting Hardware	Misc. Mounting Hardware	$240.00	$240.00
1	EDC Solutions	RETURN FEE Restock Fee MDS Radios	Return Fee for Equip. as stated	$456.42	$456.42
1	EDC Solutions	RETURN FEE Restock Fee MDS Radios	as stated	$625.00	$625.00
1	EDC Solutions	RETURN FEE Restock Fee MDS Radios	as stated	$625.00	$625.00

(G) EDC (Labor) $ 18,500