Report No. CDOT-2012-6
Final Report

ADAPTIVE SIGNAL TIMING COMPARISON BETWEEN THE INSYNC AND QUICTRAC ADAPTIVE SIGNAL SYSTEMS INSTALLED IN COLORADO

July 2012

COLORADO DEPARTMENT OF TRANSPORTATION
DTD APPLIED RESEARCH AND INNOVATION BRANCH

The contents of this report reflect the views of the author(s), who is(are) responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Colorado Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CDOT-2012-6		

4. Title and Subtitle	5. Report Date
ADAPTIVE SIGNAL TIMING COMPARISON BETWEEN THE INSYNC AND QUICTRAC ADAPTIVE SIGNAL SYSTEMS INSTALLED IN COLORADO	July 2012
	6. Performing Organization Code
7. Author(s) David Sprague	8. Performing Organization Report No. CDOT-2012-6
9. Performing Organization Name and Address ATKINS 4601 DTC Blvd, Suite 700 Denver, CO 80237	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. 92.12
12. Sponsoring Agency Name and Address Colorado Department of Transportation - Research 4201 E. Arkansas Ave. Denver, CO 80222	13. Type of Report and Period Covered
	14. Sponsoring Agency Code

15. Supplementary Notes
Prepared in cooperation with the US Department of Transportation, Federal Highway Administration

16. Abstract
The FHWA's Every Day Counts (EDC) initiative identifies adaptive signal control as a tool for local agencies to deploy innovation. In an effort to achieve the goals of the EDC initiative, the traffic sections of the Colorado Department of Transportation (CDOT), in Region 2 and 4 and the City of Greeley implemented adaptive traffic signal control systems on 10th Street (US 34 Business) in Greeley and US 24 in Woodland Park. This new technology uses real-time data collected by system detectors to optimize signal timing for each intersection in the corridor. The use of real-time data means that signal timing along the corridor changes to accommodate the traffic patterns at any given time of the day.

There are many different adaptive traffic signal control systems of which two, InSync and QuicTrac, were selected for implementation in Colorado. The InSync adaptive signal control system, produced and supplied by Rhythm Engineering, was installed in Greeley on 10th Street and the QuicTrac adaptive signal control system, produced and supplied by McCain, Inc., was installed on US 24 in Woodland Park. The evaluation of the performance of these systems on their distinct corridors was documented in separate reports and provided to the agencies and stakeholders. This report focuses on a more direct comparison between the two systems including costs for installation, maintenance, and expected benefits on a per intersection basis. The study is not intended to recommend a preferred system, but present the results for each system and provide data allowing decision makers to make an informed decision when selecting an adaptive system.

Implementation
Proper application of adaptive signal control can reduce congestion, smooth flows, improve travel times, maximize the benefits of signal timing, and potentially reduce crashes.

17. Keywords	18. Distribution Statement
adaptive signal control technology, travel time, congestion, traffic signal timing, EDC	No restrictions. This document is available to the public through the National Technical Information Service www.ntis.gov or CDOT's Research Report website http://www.coloradodot.info/programs/research/pdfs

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	23	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Adaptive Signal Timing

Comparison between the InSync and QuicTrac Adaptive Signal Systems Installed in Colorado

Colorado Department of Transportation Region 4 and Region 2 in cooperation with the City of Greeley and CDOT DTD

July 2012

ATKINS

Table of contents

Tables

Figures

Executive summary

The U.S. Department of Transportation, Federal Highway Administration (FHWA) has created the Every Day Counts (EDC) Initiative, which is "designed to identify and deploy innovation aimed at shortening project delivery, enhancing the safety of our roadways, and protecting the environment" (http://www.fhwa.dot.gov/everydaycounts/index.cfm). The initiative is broken down into two main areas: (1) accelerating technology and innovation deployment and (2) shortening project delivery.

Within the first area (accelerating technology and innovation deployment), FHWA has identified adaptive signal control as a tool that can help local agencies achieve the goals of the EDC program. It is important to remember that "EDC is not about inventing the next big thing. It's about taking effective, proven and market-ready technologies and getting them into widespread use. By advancing 21st century solutions, we can improve safety, reduce congestion and keep America moving competitively" (http://www.fhwa.dot.gov/everydaycounts/technology/).

In an effort to achieve the goals of the EDC initiative, the traffic sections of the Colorado Department of Transportation (CDOT), in Region 2 and 4 and the City of Greeley implemented adaptive traffic signal control systems on 10th Street (US 34 Business) in Greeley and United States Highway (US) 24 in Woodland Park. This innovative new technology uses real-time data collected by system detectors to optimize signal timing for each intersection in the corridor. The use of real-time data means that signal timing along the corridor changes to accommodate the traffic patterns at any given time of the day. Proper application of adaptive signal control will reduce congestion, smooth flows, improve travel times, maximize the benefits of signal timing, and potentially reduce crashes, which delay the need for more costly improvements such as adding capacity to the corridor.

There are many different adaptive traffic signal control systems of which two, InSync and QuicTrac, were selected for implementation in Colorado. The InSync adaptive signal control system, produced and supplied by Rhythm Engineering, was installed in Greeley on 10th Street and the QuicTrac adaptive signal control system, produced and supplied by McCain, Inc., was installed on US 24 in Woodland Park. The evaluation of the performance of these systems on their distinct corridors was documented in separate reports and provided to the agencies and stakeholders. This report will focus on a more direct comparison between the two systems including costs for installation, maintenance, and expected benefits on a per intersection basis. The study is not intended to recommend a preferred system, but present the results for each system and provide data allowing decision makers to make an informed decision when selecting an adaptive system.

The implementation of new traffic signal systems could have an impact to the overall safety of the corridor through an increase or decrease in the number of accidents that occur at the signalized locations. In theory, the improved progression for the mainline approaches to the intersections should help reduce the frequency some accident types, primarily rear end. With more responsiveness to side street demand the theory would also apply to these approaches as well. CDOT traffic safety engineers will be conducting a multi-year crash study on the corridor over the next 3-5 years and even longer into the future to compare accident rates to the before implementation conditions. The scope to complete such an analysis is beyond the current project, but during the brief period of time that both systems have been operational, staff from the stakeholders have not noticed or been made aware of an increase in accidents along the corridors.

Table 1 presents a summary of the benefits of the two systems based on the evaluation of their installations on Colorado highways.

Table 1. Comparison Summary – System Benefits

Category	InSync System		QuicTrac System	
	Actual Project	Minimal Project*	Actual Project	Minimal Project*
Number of Intersections	11		8	
Daily cost saving (corridor)	$3,789		$2,567	
Annual cost saving (corridor)	$1.326 million		$898,500	
Install costs (corridor)	$905,500	$375,000	$176,300	$162,400
Daily cost saving (per intersection)	$344		$321	
Annual cost saving (per intersection)	$120,500		$112,300	
Install costs (per intersection)	$82,300	$34,000	$22,000	$20,300
Benefit to cost ratio	1.58	3.79	5.64	6.10
10-year projected savings	$4.2 million	$4.7 million	$2.8 million	$2.8 million
20-year projected savings	$9.2 million	$9.7 million	$5.7 million	$5.7 million
AADT (CDOT data near middle of corridor)	26,500 vehicles		22,500 vehicles	
Daily cost saving per user	$0.14		$0.11	
Annual cost saving per user (assume 350 day use of road)	$49.00		$38.50	

*Minimal project assumes the corridor has the necessary equipment to provide a truly "plug and play" system

Table 2 presents a comparison of the installation and operational requirements of the two systems.

Table 2. Comparison Summary - System Requirements

Category	InSync System	QuicTrac System
Controller Types Compatibility	Any	170E or 2070
Operating System Compatibility	Any	QuicNet
Unique Controller Firmware Required	No	Yes
Communication System Needed	Yes, any type between all intersections	Yes, any type between intersections and QuicNet
Detection Type Requirements	Any (stop bar detection only)	Any (midblock or existing advanced detection on mainline)
Centralized CPU to communication to other local controller required	No	Yes
Possibility to increase space in cabinets to accommodate devices	Yes	No
All intersections operate on same cycle length	No	Yes
Fixed phasing pattern	No	No (can vary by adaptive plan)

1. Introduction

The U.S. Department of Transportation, Federal Highway Administration (FHWA) has created the Every Day Counts (EDC) Initiative, which is "designed to identify and deploy innovation aimed at shortening project delivery, enhancing the safety of our roadways, and protecting the environment" (http://www.fhwa.dot.gov/everydaycounts/index.cfm). The initiative is broken down into two main areas: (1) accelerating technology and innovation deployment and (2) shortening project delivery.

Within the first area (accelerating technology and innovation deployment), FHWA has identified adaptive signal control as a tool that can help local agencies achieve the goals of the EDC program. It is important to remember that "EDC is not about inventing the next big thing. It's about taking effective, proven and market-ready technologies and getting them into widespread use. By advancing 21st century solutions, we can improve safety, reduce congestion and keep America moving competitively" (http://www.fhwa.dot.gov/everydaycounts/technology/). The objectives of the EDC Initiative are:

- Implementing a signal control system that will better and continuously adjust to traffic conditions. A successful implementation should reduce the number of travelling public complaints received by the operating agency. A system that is operating correctly will reduce driver frustration, which in turn will reduce the number of signal timing complaints.

- Improving operations to reduce wasted costs in the form of travel time, driver delay, fuel consumption, and the cost for staff to maintain and retime the signals. As drivers stop at traffic signals, they experience delay in their trips, which translates to wasted fuel, lost productivity, and a possibility of increased labor costs for businesses. More efficient traffic signal operations will reduce these costs, resulting in a positive cost benefit for the project that will pay for itself in a shorter period of time.

- Making system-wide improvements for all roadway users including those that are approaching the primary roadway from side streets as well as those driving along the main roadway. To completely quantify the benefits of a signal system, the impacts to drivers on the side street approaches to the mainline must be included in the analysis. A system that makes significant improvements to the driving experience on the main roadway should not simply offset that benefit by shifting delay and congestion to the side streets.

- Reducing the level of emissions produced by vehicles in an effort to produce a greener environment for the community as a whole. If vehicles are experiencing shorter trip times and fewer stops, the vehicles will produce lower pollution levels. Lower vehicle emissions/pollution levels benefit the entire community as the air is cleaner for those that live/work, walk, play, or ride in the vicinity of the roadway.

In an effort to achieve the goals of the EDC initiative, the traffic sections of the Colorado Department of Transportation (CDOT), in Region 2 and 4 and the City of Greeley implemented adaptive traffic signal control systems on 10th Street (US 34 Business) in Greeley and United States Highway (US) 24 in Woodland Park. This innovative new technology uses real-time data collected by system detectors to optimize signal timing for each intersection in the corridor. The use of real-time data means that signal timing along the corridor changes to accommodate the traffic patterns at any given time of the day. Proper application of adaptive signal control will reduce congestion, smooth flows, improve travel times, maximize the benefits of signal timing, and potentially reduce crashes, which delay the need for more costly improvements such as adding capacity to the corridor.

There are many different adaptive traffic signal control systems and two distinct systems were selected for implementation in Colorado. The InSync adaptive signal control system, produced and supplied by Rhythm Engineering, was installed in Greeley on 10th Street and the QuicTrac adaptive signal control system, produced and supplied by McCain, Inc., was installed on US 24 in Woodland Park. The evaluation of the performance of these systems on their distinct corridors was documented in separate reports for the involved agencies. This report will focus on a more direct comparison between the two systems including costs for installation, maintenance, and expected benefits on a per intersection basis. The study is not intended to recommend a preferred system, but present the results for each system and provide data allowing decision makers to make an informed decision when selecting an adaptive system.

1.1. Project Areas

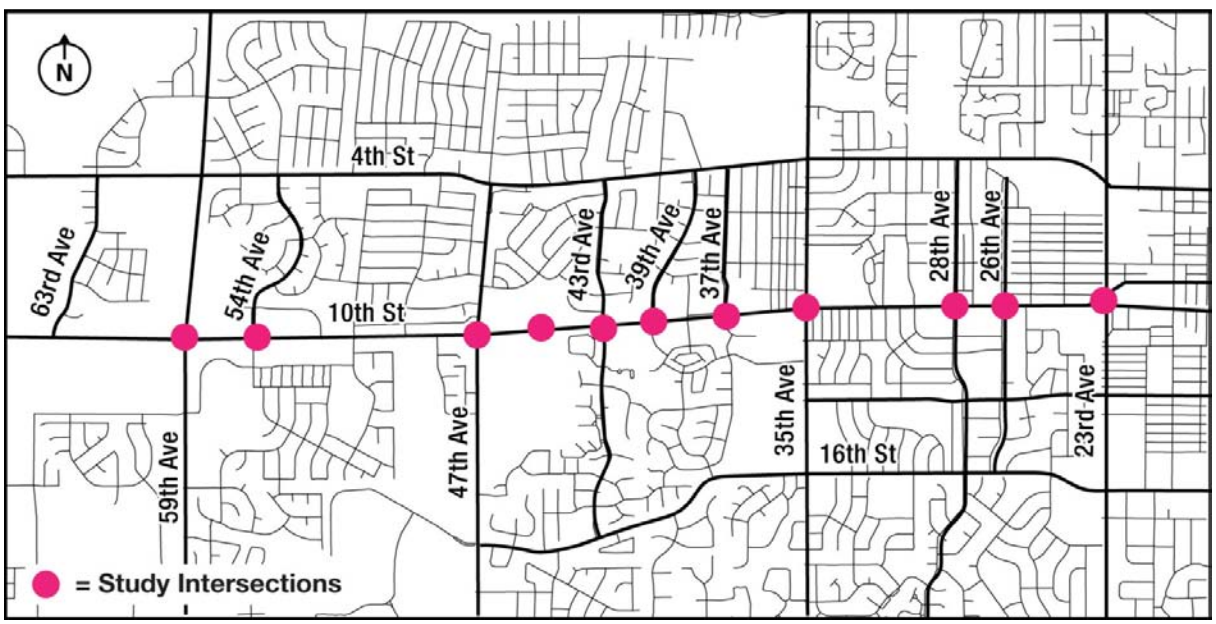
1.1.1. InSync

The 10th Street corridor within Greeley services commuting traffic traveling the entire length of the corridor, as well as people traveling to destinations along this stretch of 10th Street. The traffic patterns on 10th Street include visitors, shift changes, local university traffic that can result in some irregular flows due to events and other activities, and school traffic during student drop-off and pick-up times. In addition, several of the side street approaches have heavy demands throughout the day; thus, the corridor is a good candidate for using adaptive signal timing to adjust to the travel patterns on 10th Street and the approaching roadways.

The corridor has changing traffic flows during holidays, special events, and during the times when school children are being dropped-off and picked-up. According to CDOT data, typical annual average daily traffic on 10th Street is approximately 28,000 vehicles per day west of 35th Avenue and approximately 25,000 vehicles per day east of 35th Avenue. The study corridor, as shown in Figure 1, is approximately 4 miles long and includes the following 11 signalized intersections:

- 23rd Avenue
- 26th Avenue
- 28th Avenue
- 35th Avenue
- 37th Avenue
- 39th Avenue
- 43rd Avenue
- 45th Avenue
- 47th Avenue
- 54th Avenue
- 59th Avenue

Figure 1. Project Area



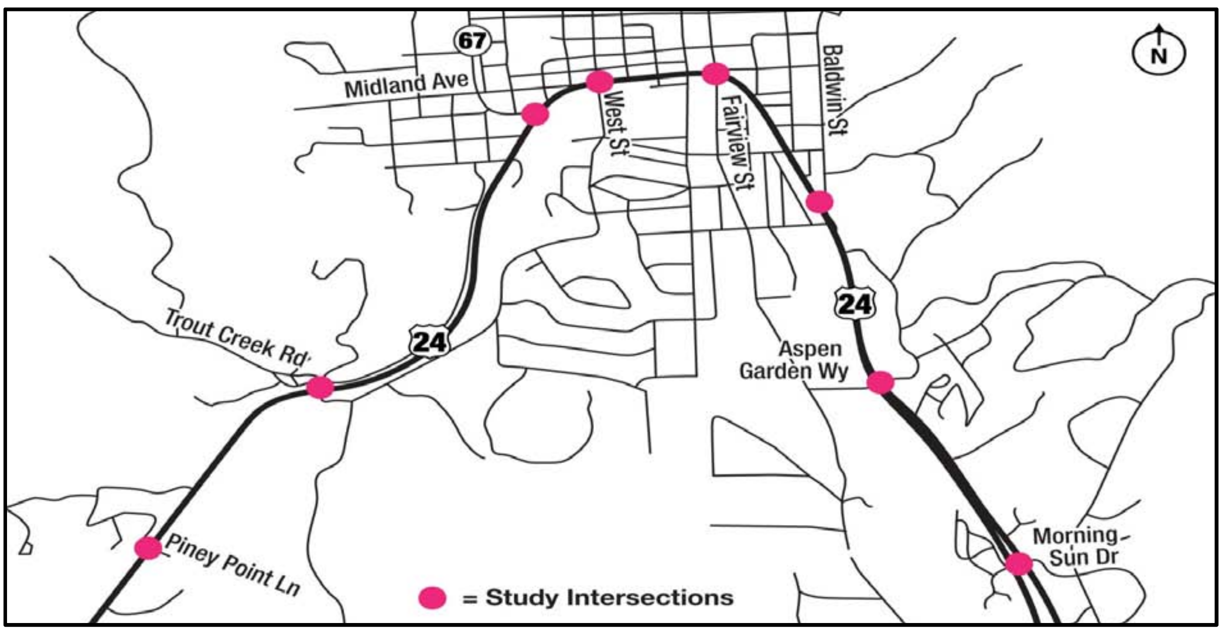
1.1.2. QuicTrac

The US 24 corridor within Woodland Park primarily serves local traffic, including commuters working in Colorado Springs, during the week and visitors/mountain recreational travelers on the weekends. The traffic patterns for US 24 can vary rapidly and unpredictably on the weekend due to the nature of recreational travelers and weather conditions that may cause travelers to change when they begin and terminate their recreational activities. Thus, the current application of time-of-day based signal coordination plan were identified as inadequately adjusting to the travel patterns of the visitors that come to and pass through the area on US 24 and State Highway (SH) 67.

The corridor tends to have unpredictable flows during holidays, special events, and during the early fall season when the aspen leaves are changing colors. According to CDOT data, typical annual average daily traffic on US 24 is approximately 19,000 vehicles per day west of SH 67 and approximately 26,000 vehicles per day east of SH 67. The study corridor, as shown in Figure 2, is approximately 3.65 miles long and includes the following eight signalized intersections:

- Piney Point Lane
- Trout Creek Road/County Road (CR) 25
- SH 67
- West Street
- Fairview Street
- Baldwin Street
- Aspen Gardens Way/Paradise Valley Drive
- Morning Sun Drive

Figure 2. Project Area along US 24 within Woodland Park



1.2. Existing Traffic Signal Timing Conditions

Before implementing the InSync and QuicTrac adaptive signal timing systems, all of the traffic signals within the study areas were using time-based coordination plans. Prior to the installation of the adaptive control systems, the coordinated signal timing plans on both corridors were retimed within the last 5-6 years.

2. Adaptive Signal Timing System

A traditional signal timing project typically involves developing time-of-day plans in an effort to improve signal timing along a corridor. An adaptive signal system uses real-time traffic data to develop signal timing plans that respond to the traffic needs at any given time. This chapter will provide basic details about the InSync and QuicTrac adaptive systems used for these projects including the installation and maintenance of the system.

2.1. System Background

2.1.1. InSync

InSync is a real-time traffic adaptive system that plugs into existing signal cabinet hardware. The system connects through an Ethernet system that allows remote viewing and traffic data retrieval. InSync collects detector data to learn traffic conditions along a corridor by time of day and day of the week at each intersection. These data are used to anticipate the demand that a corridor will have, while also using real-time data to adjust the signal timing to actual demand.

The basic flow of data and InSync performance is as follows:

1. Detectors (video) collect speed and volume data and send this to the local InSync processor.

2. The local InSync processor communicates the current conditions and demands to all of the other intersection processors.

3. The processors work together to build a set of offsets along 10th Street to ensure progression of the mainline traffic.

4. The individual intersections serve all vehicle and pedestrian movements as determined by the local processor. The phase sequence is determined by the processor to allow for progression of the mainline traffic based on information regarding when the traffic was released from adjacent intersections, prevailing speeds, and distance between intersections.

5. Intersections are not required to operate on a consistent cycle length or even on the same cycle length between intersections. The intersections do not have to operate phasing in the same order, but the phasing is optimized based on current demand and the time available to ensure the mainline progression band is not interrupted.

Prior to system installation, the maintaining agency provides phasing and sequencing preferences that are programmed into the system, which can prevent phasing sequences they would like to avoid. The system takes these data, combined with the detector data, and adjusts the timing to real-time conditions. InSync is able to truncate, extend, or cancel phases based on demand and redistribute the green time to phases with higher demand.

The operating agency can remotely view the corridor by viewing live video feed from system detectors (information technology [IT] based cameras). The system does store historic basic data like vehicle counts, cycle length, split time, and phasing into a database. If a detector stops working, the system will refer to the stored data to develop signal timing based on historic trends by time of day so the system can continue to operate until the detector is fixed. If the system fails due to a power outage or other event, the system can rely on historic data to continue to function as an adaptive system or can revert back to time-of-day coordination plans that reside within each of the local controllers until the system is back up and running normally.

2.1.2. QuicTrac

McCain's QuicTrac adaptive control is a real-time traffic adaptive system that is part of the McCain QuicNet operating central software. Just like other adaptive control systems, all of the intersections that are intended to be part of the corridor must have communication with each other. It operates in a Windows based environment and is currently compatible with both 170 and 2010 controllers. The ability to work additional controllers is expected to occur in the near future. The system can operate with almost all existing detection types as long as the system can gather speed information along the corridor, usually at midblock locations between each intersection controlled by a traffic signal. The adaptive control of the signals can be controlled by a time-of-day schedule or a more advanced traffic responsive approach to managing traffic flows on the corridor.

The basic flow of data and QuicTrac performance is as follows:

1. Detectors collect speed data and send this to the local intersection controllers.
2. The local controllers running an appropriate version of firmware to collect the data from the detectors and send it to QuicTrac, which is a module of QuicNet.
3. QuicTrac computes the optimal cycle length based on traffic patterns, speeds, desired direction of travel, and other data points. The cycle length adjustments are limited to 7-second changes in one direction or the other if the system is operating in the time of day mode. If the system is using the traffic responsive mode then the adjustments to the cycle lengths can be larger.
4. QuicTrac then sends the preferred cycle length time back to the individual controllers.
5. Local controllers take the cycle length and determine an optimal offset based on prevailing speeds measures on the corridor and a optimal split pattern based on vehicle demand volumes most recently experienced on a particular approach.

The operating agency can remotely view the corridor, using a digital subscriber line (DSL), to view the operations of the signals through the QuicNet operating system or can use an Ethernet connection to view live video feed from system detectors (information technology [IT] based cameras).

The system does store basic data like vehicle counts, occupancy data from the detector zones, and offsets/splits/cycles into a Sequel (SQL) database. If a detector stops working, the system can be told to refer to the stored data to develop historic trends based on time of day so the system can continue to operate until the detector is fixed. The detector will revert back to default parameters if it is not told to look at historic stored data. If the system fails due to a power outage or other event then the system will revert back to the existing time of day based coordination plans that reside within each of the local controllers.

The system can be configured to report certain typical MOEs such as throughput, average speeds, amount of green time, and other commonly used information from signal systems. More complex MOEs are not programmed into the system yet, but could be in the future. The QuicTrac system does require that all traffic signals operate on a single cycle length, but each individual signal can optimize its own offset and split times to maximize operations. This approach can be viewed as being a form of dynamic-coordination because the signals all operate on a single cycle length.

2.2. Unique Issues Related to the Installation of Systems

2.2.1. InSync

During the system selection process completed by Region 4 staff prior to this study, the following factors were considered before staff made a final choice of adaptive control system:

1. The intersections along the corridor were not in communication with each other, but communication capabilities could be added to the corridor in the form of wireless communication.
2. The corridor had good video detection on all approaches.
3. The new system must work with the existing 170 controllers.
4. The City of Greeley has planned to install a fiber optic system in the future and the new system needs to be compatible with the future communication upgrade.
5. The City of Greeley has a traffic operations center and the new system would have to be able to communicate information and video feedback to this location.

Based on these factors, Region 4 staff selected the Rhythm Engineering InSync adaptive control system for use on 10th Street in Greeley. InSync is a “plug-and-play” system that is compatible with all traffic signal controllers including the 170 controllers on 10th Street. The InSync processor is installed into the signal cabinet and communicates to the existing signal controller. An Ethernet cable connects the InSync processor to the detector cameras, which can then send live video feedback to Greeley’s traffic operations center via the Internet. InSync allows the intersections to communicate with one another via Ethernet, which can be wireless in the interim and will be compatible with Greeley’s fiber optic cable in the future.

To install InSync along this corridor, the following infrastructure improvements were necessary to accommodate the system:

- Installed larger signal controller cabinets to accommodate the InSync processor at five intersections.
- Upgraded communications along the corridor to include a wireless radio network that allowed communication between all intersections and transmission of data from the corridor back to the Greeley traffic operations center.
- Installed InSync digital video detection system at all intersection approaches.
- Installed conduit and pull boxes as needed to accommodate additional cables and repeaters.
- Upgraded traffic operations center to accommodate communication to InSync.

Once these improvements were made, the InSync system was installed and deployed. During the installation process, Rhythm Engineering provided on-site installation training for CDOT and City of Greeley staff. In addition, a field engineer was also present during the turn-on of the adaptive system. Fine-tuning of the system was completed after the system was turned on to ensure that it was working as desired.

2.2.2. QuicTrac

During the system selection process completed by Region 2 staff prior to this study, the following factors were considered before staff made a final choice of adaptive control system:

1. All signals already had fiber optic connections for communication between each of the signalized intersection within the study area.
2. There was no video detection for the mainline movements on the corridor, but all other movements including all side street movements and mainline left turn phases were using video detection.
3. Must work with the existing 170 controllers.

4. Corridor had existing flashing yellow left-turn arrows and flashing yellow beacons for advanced warning signs that needed to be maintained.
5. System had a central processing unit (CPU) acting as a master controller for the corridor already in place.

Based on these factors, Region 2 staff selected the McCain QuicTrac adaptive control system for use in Woodland Park because it was the most compatible with the existing field equipment and required the least amount of updating or installation of additional system components.

To make the system operational, the following changes were installed along the US 24 corridor:

- The QuicNet central operating system was installed on the existing CPU because there was no direct connection between the corridor and a regional traffic operations center or office.
- The McCain 233 MC1 local controller firmware was installed at each interaction.
- The QuicNet software was installed and configured in accordance with Region 2 staff specifications.
- Microwave vehicle presence sensors/detectors were installed along the corridor to gather speed and volume data on the approach to each intersection.

Working together, staff from McCain and CDOT Region 2 installed the system in November of 2011. The team encountered some issues with the existing basic timing parameters, which caused a delay in the system activation. These issues were resolved in early 2012 and McCain then installed the fixed timing parameters (yellow time, red time, walk time, do not walk time, etc.) into the new adaptive control system and central operating system. CDOT R2 staff provided input regarding the time of day schedule for when the system was to operate in adaptive control versus free mode or flashing mode as well as the maximum allowable cycle lengths during the different time of day periods.

Region 2 staff worked with McCain, Inc. to implement the appropriate timing parameters to provide the maximum benefit to the motorists using US 24. The adaptive system was set up with the following timing parameters for US 24 for the eight the study intersections:

- Weekday – Enters into an eastbound adaptive plan at 5:30 a.m., transitions to a midday plan (balanced eastbound and westbound) at 9:00 a.m., transitions to a westbound adaptive plan at 2:30 p.m., goes to free operations at 10:00 p.m., and then enters flash mode at 11:00 p.m.
- Weekend – Enters into a westbound adaptive plan at 6:00 a.m. on Saturday, transitions to a midday plan at 9:00 a.m., remains in the midday plan until it goes to free operations at 10:00 p.m., and finally enters flash mode at 11:00 p.m.
- Sunday – Enters into a midday plan at 6:00 a.m., transitions to an eastbound plan at 2:30 p.m., goes to free operations at 10:00 p.m., and finally enters flash mode at 11:00 p.m.
- The maximum adaptive cycle length for any plan is set to 120 seconds and the minimum adaptive cycle length is 90 seconds.

2.3. Maintenance

Once the systems are operating, maintenance of the actual system is expected to require minimal effort from Region 2, Region 4, and Greeley staff. The most significant issue will be to ensure the controllers maintain continuous communication with each other. The ability of the adaptive system to operate effectively depends on this communication at all times; therefore staff will need to ensure the communication equipment is functioning properly and respond to any system alerts in a timely manner. The second most important maintenance issue will be to ensure that all system detectors remain operational and functional. Again, the system relies on the ability to collect real-time volume and speed data from the system detectors to make decisions regarding the optimal operating conditions. Staff will need to ensure that detectors are maintained and continue to operate at all times to ensure that the adaptive signal timing continues to perform at its peak.

Finally, staff will also need to continue to monitor and maintain the remainder of the signal system similar to how it was being done before the implementation of adaptive signal control. This includes ensuring that traffic signal bulbs are replaced when necessary and the basic timing parameters, such as yellow, all red, walk, don't walk, minimum cycle, and maximum cycle times, are updated when necessary.

2.3.1. InSync Warranty

The InSync system includes a two-year hardware and software warranty and Rhythm Engineering will also provide technical support, as needed, for two years.

2.3.2. QuicTrac Warranty

CDOT Region 2 traffic staff is in negotiation with McCain Inc. regarding the warranty period and technical support hours that will be provided by McCain over the next few years.

3. Evaluation

The corridor operations were evaluated for both before and after conditions. This chapter will provide a brief summary of the results of the corridor evaluations including the following MOEs:

- Travel time
- Fuel consumption and emissions
- Intersection delay and level of service (LOS)
- Average number of stops
- Corridor surveys
- Benefit cost

3.1. Travel Time Studies

Table 3 shows the results of the before and after travel time runs for the two corridors for both weekday and weekend traffic conditions. The percentages represent the combined improvement for travel times for a total of six runs through the corridor in each direction of travel during six time periods for a weekday and one time period for the weekends. Both InSync and QuicTrac are adaptive traffic signal systems that attempt to respond to the traffic conditions at each intersection along the corridor with an emphasis on progressing traffic on the mainline as best possible. The results of the travel time studies show that both systems have accomplished the goal of improving traffic operations on the highways by lowering travel times, reducing delay, and increasing travel speeds.

It should be noted the after travel times were completed during time periods when traffic volumes on the corridors were very similar to the before travel time volumes except for US 24 on the weekend. Volumes on US 24 during the after travel time studies were about 30% lower in the weekend after study analysis time period. This may explain why the US 24 weekend improvements are much higher compared to the other time periods evaluated. It is likely that even with an increase in traffic volumes on the weekend (closer to the levels of peak aspen viewing season) that the system would still result in a positive impact to corridor operations.

Table 3. Travel Time Study Results

MOE Benefit (Percentage Change)*				
Study Period	**Corridor**	**Travel Time**	**Stopped Delay**	**Average Speed**
Overall Weekday	10th Street	9%	13%	11%
	US 24	6%	15%	7%
Overall Weekend	10th Street	11%	37%	13%
	US 24	19%	54%	22%

**Percentage change is computed by comparing the after study MOE to the before study MOE. A positive percentage change represents an improvement in that MOE.*

3.2. Fuel Consumption and Emissions

The results of the travel time studies showed that the implementation of the adaptive traffic signal control systems improved the overall operations for vehicles on the highways. As delay and travel time are reduced on a corridor, fuel consumption and emissions are also expected to decrease. The travel time data were used to calculate overall benefits to fuel consumption and emissions, as shown in Table 4, for each corridor by analysis period. Overall weekday and weekend fuel consumption decreased and vehicle related emissions were lowered. By reducing fuel consumption on the corridor, the implementation of the adaptive systems has achieved the goal of lowering costs to the roadway users. In addition, lower vehicle emissions further helps the projects achieve the goals of the EDC initiative by improving the air quality for the general public along the roadway and creating a greener environment.

Table 4. Fuel and Emissions Results

MOE Benefit (Percentage Change)*						
Study Period	**Corridor**	**Fuel Consumption**	**Pollutant Emissions**			
			Carbon Monoxide	**Hydro-Carbons**	**Nitrogen Oxides**	**Carbon Dioxide**
Overall Weekday	10th Street	3%	4%	9%	4%	3%
	US 24	2%	2%	0%	1%	2%
Overall Weekend	10th Street	4%	4%	13%	5%	4%
	US 24	7%	7%	17%	10%	7%

**Percentage change is computed by comparing the after study MOE to the before study MOE. A positive percentage change represents an improvement in that MOE.*

3.3. Delay and Level of Service

For a signal timing project with fixed cycle lengths during specific periods of the day, traffic simulation software can be used to estimate side-street delay at study intersections. Because the adaptive traffic signal systems are constantly changing cycle lengths to react to real-time travel demand, the *Highway Capacity Manual* (Transportation Research Board, 2000) method for field measurement of intersection control delay was used to calculate intersection control delay and LOS. Video recordings were conducted at four intersections on each corridor, as identified by agency staff, to capture the before and after conditions during the morning, midday, and evening weekday peaks. The before and after intersection delay and LOS for the intersections on 10th Street and US 24 are shown in Table 5.

Table 5. Weekday Overall Intersection Delay and LOS*

Corridor	**Intersection**	**Morning Peak**				**Midday**				**Evening Peak**			
		Before		**After**		**Before**		**After**		**Before**		**After**	
		Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS
10th Street	35th Avenue	22	C	22	C	29	C	31	C	42	D	23	C
	45th Avenue	6	A	5	A	16	B	11	B	17	B	13	B
	47th Avenue	13	B	18	B	21	C	23	C	28	C	28	C
	59th Avenue	17	B	12	B	21	C	15	B	31	C	23	C
US 24	Morning Sun Drive	6	A	4	A	15	B	15	B	14	B	12	B
	Aspen Gardens Way	10	B	7	A	14	B	9	A	15	B	17	B
	Baldwin Street	4	A	5	A	4	A	5	A	6	A	7	A
	SH 67	10	B	14	B	15	B	17	B	22	C	21	B

**Delay refers to control delay and is reported in seconds per vehicle. LOS is based on definitions from the latest Highway Capacity Manual.*

The weekday LOS analysis indicates all of the intersections continued to operate at the same overall LOS or experienced a slight reduction in delay compared to before the adaptive system was installed. None of the intersections experienced an overall degradation in LOS due to the adaptive system installation.

Although not shown in the table, after implementing adaptive control, some of the side street approaches on both corridors experienced mixed results with some approaches improving by a small amount, others had significant improvements, and other intersections experienced significant degradation in side street approach delay.

3.4. Average Number of Stops

Comparing the number of stops per trip through the corridors indicates that the implementation of the adaptive signal systems resulted in overall fewer stops during the weekday and weekend time periods, as shown in Table 6. The results indicate a significant improvement for travellers on the highways and are consistent with the results of the travel time analysis, which indicates fewer stops and shorter trips through the study area.

Table 6. Average number of stops on 10th Street

MOE Benefit (Percentage Change)*		
Study Period	**Corridor**	**Number of Stops**
Overall Weekday	10th Street	37%
	US 24	8%
Overall Weekend	10th Street	52%
	US 24	50%

**Percentage change is computed by comparing the after study MOE to the before study MOE. A positive percentage change represents an improvement in that MOE.*

3.5. As-Built Project Benefit Cost

A benefit cost analysis was completed to determine how long each system would take to pay for itself, as well as the benefits that would be realized in the future for CDOT R2, CDOT R4, the City of Greeley, but more importantly the general public and roadway users. The following factors were used to calculate the benefit cost:

- Travel time
- Fuel consumption
- Side-street delay
- Design and engineering cost
- Adaptive system cost
- Detection/communication upgrade cost
- Construction/installation cost
- Staff time spent for design, installation, and training
- Expected annual maintenance

To calculate the cost savings in terms of reduced travel time and fuel consumption, the total travel time (vehicle-hours) was multiplied by the value of time and vehicle occupancy values for the area and the fuel consumption savings were multiplied by the average per gallon fuel cost for the area. The value of time for both corridors was obtained from research performed by FHWA and input from the CDOT Division of Transportation Development (DTD) staff and was found to be $15.00 per person per hour. CDOT DTD staff indicated a recent study for the area identified the average vehicle occupancy for both of the highways is 1.3 people per vehicle. Average fuel costs of $3.65 per gallon in the Greeley area and $3.50 in the Woodland Park area were identified based on Internet research.

Annual costs/benefits were computed based upon a 350 day year (250 weekdays and 100 weekend days) to best capture the majority of typical traffic volume days, where the remaining days of the year are considered non-typical travel days (holidays, events, weather, etc.) and are omitted from the computation. Table 7 and Table 8 show that the systems result in significant annual savings to both corridors with 10th Street experiencing a predicted user saving of more than $1.326 million dollars and US 24 users experiencing a savings of almost $900,000 per year.

Table 7. 10th Street Annual Benefit (combined weekday and weekend)

Measure of Effectiveness	Daily Benefit*	Daily Benefit*	Annual Benefit (millions)*
Travel Time (veh*hrs)	207	$4,034	$1.412
Fuel Consumption (gal)	122	$445	$0.156
Side-street delay (veh*hrs)	*-41*	*-$805*	*-$0.282*
Annual Maintenance (estimated to be a 1163 hours saving per year at $35 per hour)		$115	$0.0407
	TOTAL	**$3,789**	**$1.326**

**Benefits and costs are computed by comparing the after study MOE to the before study MOE. A positive change represents an improvement (savings for users) and a negative change represents degradation in that MOE (added costs to users).*

Table 8. US 24 Annual Benefit (combined weekday and weekend)

Measure of Effectiveness	Daily Benefit*	Daily Cost*	Annual Cost (millions)*
Travel Time (veh*hrs)	191	$3,730	$1.305
Fuel Consumption (gal)	149	$522	$0.183
Side-street delay	*-87*	*-$1,698*	*-$0.594*
Annual Maintenance (estimated by staff to be a 130 hours saving per year at $35 per hour)		$12.86	$0.0045
	TOTAL	**$2,567**	**$0.898**

**Benefits and costs are computed by comparing the after study MOE to the before study MOE to compute a change. A positive change represents an improvement (savings for users) and a negative change represents degradation in that MOE (added costs to users).*

The next step in determining a benefit cost ratio is to determine the actual costs that the agencies had to spend to install the new systems. Based on information provided by each agency, the costs associated with the installation of the systems are shown in Table 9 and Table 10. Implementing the InSync adaptive control system on 10th Street cost approximately $905,500, while the QuicTrac system cost Region 2 about $176,300.

Based on the benefits (Table 7 and Table 8), and cost to install the new system (Table 9 and Table 10), Region 4 and the City of Greeley can expect to experience a benefit to cost ratio of 1.55 the first year that the InSync system is in operation. This means that for every dollar Region 4 and the City spent installing the system, it will result in a saving of $1.55. Implementation of the QuicTrac system will result in a benefit to cost ratio of 5.64 to Region 2 or a saving of $5.64 for every dollar spent to install the system. In addition, Region 4 and the City will recover their original investment in approximately 244 days, or a about 8 months, while Region 2 recovered its initial investment within the first 67 days after the system was installed and made operational.

Table 9. Cost to Implement InSync Adaptive Control on 10th Street

Item	Cost
Misc. Construction (sidewalk, potholing, erosion, etc.)	$34,750
Bored Conduit	$6,600
Pull Boxes	$7,100
Wiring	$35,510
InSync System and Components	$416,319
Install Controller Cabinets	$10,125
Telemetry (communication system)	$38,178
Construction equipment and control	$101,418
Engineering	$250,000
Annual Maintenance Costs (estimate)	$5,500
TOTAL	**$905,500**

Table 10. Cost to Implement QuicTrac Adaptive Control on US 24

Item	Cost
QuicNet Pro Central System	$30,750
10 - Local Controller Firmware	$36,000
Training	$3,000
Central/Local Software Install and Configuration	$3,300
Misc. Install Costs	$1,800
Support from McCain	$8,500
Controller, HC11	$13,120
16 - Microwave Presence Detectors	$66,550
Misc. Cables/Tape/DSL Line/Computer	$1,580
CDOT Labor to Install (160 hours at $37.50 per hour)	$6,000
Annual Maintenance Costs	$4,500
TOTAL	**$176,300**

Additional analysis was completed to compare how much would have spent maintaining and retiming the existing signal systems compared to how much the agencies are expected to spend maintaining the new systems. One main assumption for maintaining the existing systems is the need to retime the signals every five years or approximately four times in the next 20 years. These retiming projects would result in benefits to the corridors due to savings in travel times and fuel consumption. The assumption was that the 10th Street corridor would experience a benefit of about $800,000 per year if the existing signals are retimed and the US 24 corridor would benefit approximately $500,000 per year for retiming the signals.

Based on the additional analysis, Region 4 and the City of Greeley will save approximately $8.9 million over the first 20 years with the InSync system managing the traffic operations on the 10th Street corridor. At the same time, Region 2 will save about $5.8 million over the first 20 years with the QuicTrac system managing the traffic operations on the US 24 corridor.

3.6. Minimal Project Benefit Cost

Both of the systems installed required the agencies to spend additional funds to upgrade the existing signal system equipment in order to accommodate the new system equipment or operational needs. On 10th Street, several of the existing controller cabinets were not large enough to accommodate the new equipment and some of the intersections were in need of new conduit to accommodate the wiring of new video detection cameras and their associated repeater devices. Thus, it was necessary for Region 4 and the City of Greeley to spend funds on engineering and construction management and oversight to provide an engineering design package for the construction of the improvements. A large portion (49%) of the cost of the InSync system was associated with the engineering, construction, and construction management ($440,000). In addition, another 4% or about $40,000 was spent to install a communication system on the 10th Street corridor in order to ensure the controllers at each intersection could communicate with each other. It is possible that a corridor could have the InSync system installed without the need to spend funds on any improvements, which in the case of the Greeley project would have saved almost $500,000 on the total $905,000 spent to install the system, or more than 55% of the actual project costs.

In Region 2, approximately 7% of the system installation costs, or about $13,100, was spent on the purchase of new controllers to make sure the controllers had the ability to run the firmware necessary to operate the QuicTrac system. Again, it is possible that this expense would not be necessary on another corridor, which would have reduced the overall cost of the project.

Additional analysis was completed to evaluate the benefit to cost ratio that the systems would have if upgrades to the corridor were not required to install the systems. Based on the number of intersections on the 10th Street corridor, the InSync system cost Region 4 and the City approximately $82,300 per intersection. However, on a corridor that does not require upgrades, much of the costs associated with the installation of the InSync system could be saved. Assuming a reasonable labor effort by CDOT and City of Greeley staff ($10,000) the InSync system could be installed for about $34,000 per intersection, which would include digital video detection cameras, technical support, and all hardware to connect the InSync system into the existing controllers. This saves $48,300 per intersection compared to what was actually spent on the corridor. Based on a cost of $34,000 per intersection, CDOT Region 4 and the City of Greeley would have experienced a benefit to cost ratio of 3.79 or they would have saved $3.79 for every $1 spent installing the system. The system would have paid for itself in about 100 days and would have saved the agencies more than $9.6 million over the first 20 years of operation, or almost 26 times their initial investment amount.

Based on the number of intersections on the US 24 corridor, the QuicTrac system cost Region 2 approximately $22,000 per intersection. However, if the upgrades to the controllers were not needed, assuming a reasonable labor effort by CDOT staff ($5,000), the system could be installed for about $20,300 per intersection. This would have saved $1,700 per intersection compared to what was actually spent on the corridor. Based on a cost of $20,300 per intersection, CDOT Region 2 would have experienced a benefit to cost ratio of 6.10 or they would have saved $6.10 for every $1 spent installing the system. The system would have paid for itself in about 60 days and would have saved the agencies more than $5.7 million over the first 20 years it is in operation or 36 times their initial investment.

4. Conclusion

The purpose of this document was to summarize the results of the evaluation conducted regarding the implementation of two different adaptive traffic signal control systems in Colorado. The InSync system (by Rhythm Engineering) on 10th Street (US 34 Business) in Greeley and the QuicTrac (by McCain Inc.) on US 24 in Woodland Park. The intent of this report is not to make a recommendation for a specific system, but to report a comparison of the two systems, the requirements for installation and operations, and the benefits obtained from each system to allow decision makers and others interested in this innovative technology to make informed decision regarding the installation of such a system on other highways and roadways within their jurisdictions.

The implementation of new traffic signal systems could have an impact to the overall safety of the corridor through an increase or decrease in the number of accidents that occur at the signalized locations. In theory, the improved progression for the mainline approaches to the intersections should help reduce the frequency some accident types, primarily rear end. With more responsiveness to side street demand the theory would also apply to these approaches as well. CDOT traffic safety engineers will be conducting a multi-year crash study on the corridor over the next 3-5 years and even longer into the future to compare accident rates to the before implementation conditions. The scope to complete such an analysis is beyond the current project, but during the brief period of time that both systems have been operational, staff from the stakeholders have not noticed or been made aware of an increase in accidents along the corridors.

Table 11 presents a summary of the benefits of the two systems based on the recently completed evaluation of their installations on Colorado highways.

Table 11. Comparison Summary - System Benefits

Category	InSync System		QuicTrac System	
	Actual Project	Minimal Project	Actual Project	Minimal Project
Number of Intersections	11		8	
Daily cost saving (corridor)	$3,789		$2,567	
Annual cost saving (corridor)	$1.326 million		$898,500	
Install costs (corridor)	$905,500	$375,000	$176,300	$162,400
Daily cost saving (per intersection)	$344		$321	
Annual cost saving (per intersection)	$120,500		$112,300	
Install costs (per intersection)	$82,300	$34,000	$22,000	$20,300
Benefit to cost ratio	1.58	3.79	5.64	6.10
10-year projected savings	$4.2 million	$4.7 million	$2.8 million	$2.8 million
20-year projected savings	$9.2 million	$9.7 million	$5.7 million	$5.7 million
AADT (CDOT data near middle of corridor)	26,500 vehicles		22,500 vehicles	
Daily cost saving per user	$0.14		$0.11	
Annual cost saving per user (assume 350 day use of road)	$49.00		$38.50	

Table 12 presents a comparison of the installation and operational requirements of the two systems.

Table 12. Comparison Summary - System Requirements

Category	InSync System	QuicTrac System
Controller Type	Any	Any
Operating System	Any	QuicNet
Controller Firmware	No	Yes
Communication System Needed	Yes	Yes
Detection Requirements	Video (all approaches)	Any (midblock on mainline)
Master Controller Needed	No	Yes
Additional space in cabinets	Yes	No
Fixed cycle length at all intersections	No	Yes
Fixed phasing pattern	No	Yes

David Sprague and Jamie Archambeau
Atkins North America - Denver
4601 DTC Boulevard, Suite 700
Denver, CO 80237

Email: david.sprague@atkinsglobal.com jamie.archambeau@atkinsglobal.com
Telephone: 303.221.7275
Direct telephone: 720.475.7028 (David) and 720.475.70xx (Jamie)
Fax: 303.221.7276

© Atkins Ltd except where stated otherwise.

The Atkins logo, 'Carbon Critical Design' and the strapline 'Plan Design Enable' are trademarks of Atkins Ltd.