Denver Regional Council of Governments

Traffic Signal System Improvement Program

2013 Update

DRCOG

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Traffic Signal System Improvement Program

2013 Update

Adopted September 18, 2013

DENVER REGIONAL COUNCIL OF GOVERNMENTS
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EXECUTIVE SUMMARY

Background

The Denver Regional Council of Governments (DRCOG) administers the federally-funded "pool" project titled *Regional Traffic Signal System Improvement Program,* or TSSIP. The purpose of TSSIP is to implement cost-effective traffic signal timing and coordination improvements that reduce travel time and harmful auto emissions within the DRCOG Transportation Management Area (TMA). There are now more than 3,800 traffic signals maintained and operated by 38 different agencies within the TMA.

The TSSIP was originally adopted in 1994 and has been updated in 1996, 1999, 2003, 2007, and 2010 corresponding with funding authorized in the Transportation Improvement Programs (TIP). Since the last update, the program has assisted 24 operating agencies in these efforts and completed 34 capital improvement projects. The program conducted retiming and coordination for all of these capital projects, and also completed 17 timing and coordination projects not related to capital projects. These projects improved operations for more than 770 traffic signals throughout the region and reduced daily delay by nearly 21,000 vehicle-hours per day, fuel consumption by more than 10,000 gallons per day, air pollution emissions (mainly carbon monoxide) by more than 7,600 pounds per day, and greenhouse gas emissions by more than 203,000 pounds per day.

Implementation Plan

This TSSIP update examines progress, assesses results, and updates the program of capital improvements for fiscal years 2014-2019. It recognizes recent changes to the regional traffic signal system made by local jurisdictions and Colorado Department of Transportation (CDOT). To further improve the operations of the regional traffic signal system, the TSSIP will continue to pursue the following activities.

Capital Improvements to Signal Systems

This TSSIP update has programmed the capital improvements to:

a. Upgrade and replace insufficient/unreliable communications for seven corridors/ areas (230 signals);
b. Expand the system control to key signals not on system for five corridors (28 signals);
c. Improve the signal system efficiency, control, and the ability to monitor system operations performance in five jurisdictions; and,
d. Pilot advanced functions such as traffic adaptive control, and advanced functions to support transit, bicycles, and pedestrians.

Table E-1 shows the location of the capital projects of the implementation plan and the year(s) those projects are proposed for implementation.

System Engineering and Design

The TSSIP funds system studies and design activities required for the capital projects identified, as well as coordination with regional transportation management and intelligent transportation system (ITS) planning efforts.

Special Projects

The TSSIP will implement several special projects: a regional CMAQ benefits; implementation of performance monitoring infrastructure along selected corridors; systems engineering analysis studies for multiple candidate projects proposed for traffic-adaptive control; and evaluation of these special projects.

In addition, funds are reserved for implementation of improvements that support multimodal operations (potential projects include transit signal priority, bicycle detection, corridor speed monitoring and control).

Contingency and Miscellaneous Equipment Purchases

These funds ensure that projects can proceed to construction if actual costs exceed the conceptual estimates developed for this update. Once it is certain that identified construction projects can progress, remaining contingency funds are used for miscellaneous traffic signal equipment purchases. To a limited extent this provides a way to address evolving needs in response to growth and development, funds critical needs that had to be deferred to stay within the budget, and allows capital projects from later years of the program to be advanced. These funds are also available to satisfy requests from operating agencies procuring new signal systems for operating assistance funding for a limited period of time.

Timing and Coordination

This fundamental part of the program anticipates continued development of new time-of-day (TOD) schedule-based timing plans on a recurring basis in a three- to five-year cycle or as needed for major corridors and for all capital projects implemented (including miscellaneous signal equipment purchases). Some additional funds will be targeted for selectively developing TOD plans that address weekend traffic patterns. The program will also develop and implement timing plans for traffic-responsive control (TRC) as requested. In addition, pilot implementations of traffic-adaptive control (TAC) will be evaluated for implementation.

Benefits and Result Documentation

Determining and documenting the benefits and effectiveness of currently ongoing and programmed projects is critical to this program update. Because the TSSIP is funded with federal Congestion Mitigation/Air Quality (CMAQ) funds, the benefits of every project must be measured and reported. The program's primary documentable benefits

Table E-1
Signal System Capital Improvement Projects

Project/Description/Location		FY14	FY15	FY16	FY17	FY18	FY19
Insufficient or Unreliable System Communication							
Broomfield	Sheridan Blvd: 1st Ave - Dillon Rd						X
CDOT Region 1	University Blvd (SH 177): Arapahoe Rd - Hampden Ave (US 285)	X					
	Federal Blvd (SH 88): Bellewood Dr -Hampden Ave (US 285)			X			
Denver	Colorado Blvd: 1st Ave - 50th Ave Speer Blvd: Elitches - 13th Ave		X				
	Central Business District (CBD) Ph 1					X	
	Central Business District (CBD) Ph 2			X	X		
	DTC Blvd: Tamara St - Union Ave	X					
Key Signals Not on System							
Arapahoe County	Jordan Rd: Broncos Pkwy - Otero Ave Broncos Pkwy & Cherokee Trail	X					
Brighton	Bridge St: Main St - 27th Ave	X					
	Bromley Ln: Fulton St - Judicial Center Dr 27th Ave: 136th Ave - Bridge St		X				
CDOT Region 1	Belleview Ave (SH 88): Holly St - Quebec St		X				
Centennial	Arapahoe Rd: Chapparal Rd - Himalaya Way		X				
Advanced Functionalities and Special Projects							
Arapahoe County	Next generation system replacement/upgrade	X					
Brighton	Traffic signal system procurement	X					
Centennial**	City-wide performance monitoring system					X	
DRCOG	Regional CMAQ Benefits Study	X					
Jefferson County	Next generation system replacement/upgrade and compatible controller and communications upgrades. McIntyre St: 60th Ave - 44th Ave CR 73: Buffalo Park Rd - Kitty Dr Bowles Ave: Coal Mine Ave - Grant Ranch Kipling Pkwy: Progress Ave - Remmington Ave Ken Caryl Ave: Shaffer Pkwy - Depew St	X					
Thornton	Next generation system replacement/upgrade and compatible controller and communications upgrades. Washington St: 160th Ave - SH-7 SH-7: 160th Ave - York St Washington St: 83rd Dr - 102nd Ave Thornton Pkwy: Pecos St - York St 144th Ave: Lincoln St - Washington St Colorado Blvd: 88th Ave - 144th Ave Thornton Pkwy & Welby Rd 136th Ave: High St - Washington St 104th Ave: York St - McKay Rd 88th Ave: Pecos St - Dahlia St 84th Ave: Huron St - Grant St Huron St: 84th Ave - Fire Station #2 120th Ave: I-25 - Quebec St Washington St: 121st Ave - 134th Ave Washington St: 120th Ave - 124th Ave Colorado Blvd: 115th Ave - 120th Ave	X	X	X	X	X	
Contingency/Misc. Equipment**		X	X	X	X	X	X
Reserve (Multimodal Operations and Other Pilot Projects)**				X	X		X
Reserve (Traffic-adaptive control)**							X
Estimated Expenditure (2013 constant)		**$3,047,000**	**$2,418,000**	**$2,464,000**	**$2,247,000**	**$2,289,000**	**$2,203,100**
Estimated Expenditure (YOE)*		**$3,047,000**	**$2,491,000**	**$2,613,000**	**$2,456,000**	**$2,576,000**	**$2,554,000**

* A 3% inflation rate is assumed for each year after FY14.
** All or portions of these project will require local match.

result from the retiming of major arterials. Drivers, passengers, truckers, service vehicles, bicyclists and pedestrians all reap the benefits of improved signal timing and coordination. Fewer stops and less delay saves time, money, and reduces air pollution for everyone. Based on past efforts, travel times on individual corridors are expected to be reduced by five to 15 percent after a retiming project. TRC projects implemented in the region have produced travel time benefits of two to four percent. Transit signal priority (TSP) projects have provided marginal benefits.

I. INTRODUCTION

Background

The Denver Regional Council of Governments (DRCOG) administers the federally-funded "pool" project, *Regional Traffic Signal System Improvement Program* (TSSIP). It is identified in the Transportation Improvement Program (TIP) as Project ID # 1997-045. This project is directed by the *Traffic Signal System Improvement Program* (TSSIP) adopted by the DRCOG Board of Directors.

The purpose of TSSIP is **to implement cost-effective traffic signal timing and coordination improvements** that **reduce travel time and harmful auto emissions** within the DRCOG Transportation Management Area (TMA, see Figure 1). This program was originally adopted in 1994 and has been updated in six times corresponding with funding authorized in the following TIPs.

TSSIP	Corresponding TIP
1994 Original	1993-1995 and 1995-2000
1996 Update	1997-2002 and 1999-2004
1999 Update	1999-2004 and 2001-2006
2003 Update	2003-2008 and 2005-2010
2007 Update	2007-2012 and 2008-2013
2010 Update	2008-2013 and 2012-2017

This TSSIP update examines progress, assesses results, and updates the program of capital improvements for fiscal years 2014 – 2019. It recognizes recent changes to the regional traffic signal system made by local jurisdictions and the Colorado Department of Transportation (CDOT). In addition, the program was reassessed regarding implementation of multimodal operations support, performance monitoring, and signal coordination reliability.

The regional TSSIP partners and stakeholders have distinct roles and responsibilities with regard to the TSSIP. Each operating agency is responsible for operating and maintaining the traffic signals and system within their jurisdiction. The program can be used to secure capital improvements that are expected to improve signal timing coordination. The capital projects do not include signal or intersection construction elements (i.e. poles, mast arm, signal heads, stop bar detection, signing or striping). DRCOG provides technical staff support to assist in the development and fine-tuning of signal timing plans. The local agencies implement and maintain the signal timing plans and DRCOG and the local agencies work together to fine-tune the implementation. DRCOG is responsible for conducting an evaluation of the projects' benefits for the region.

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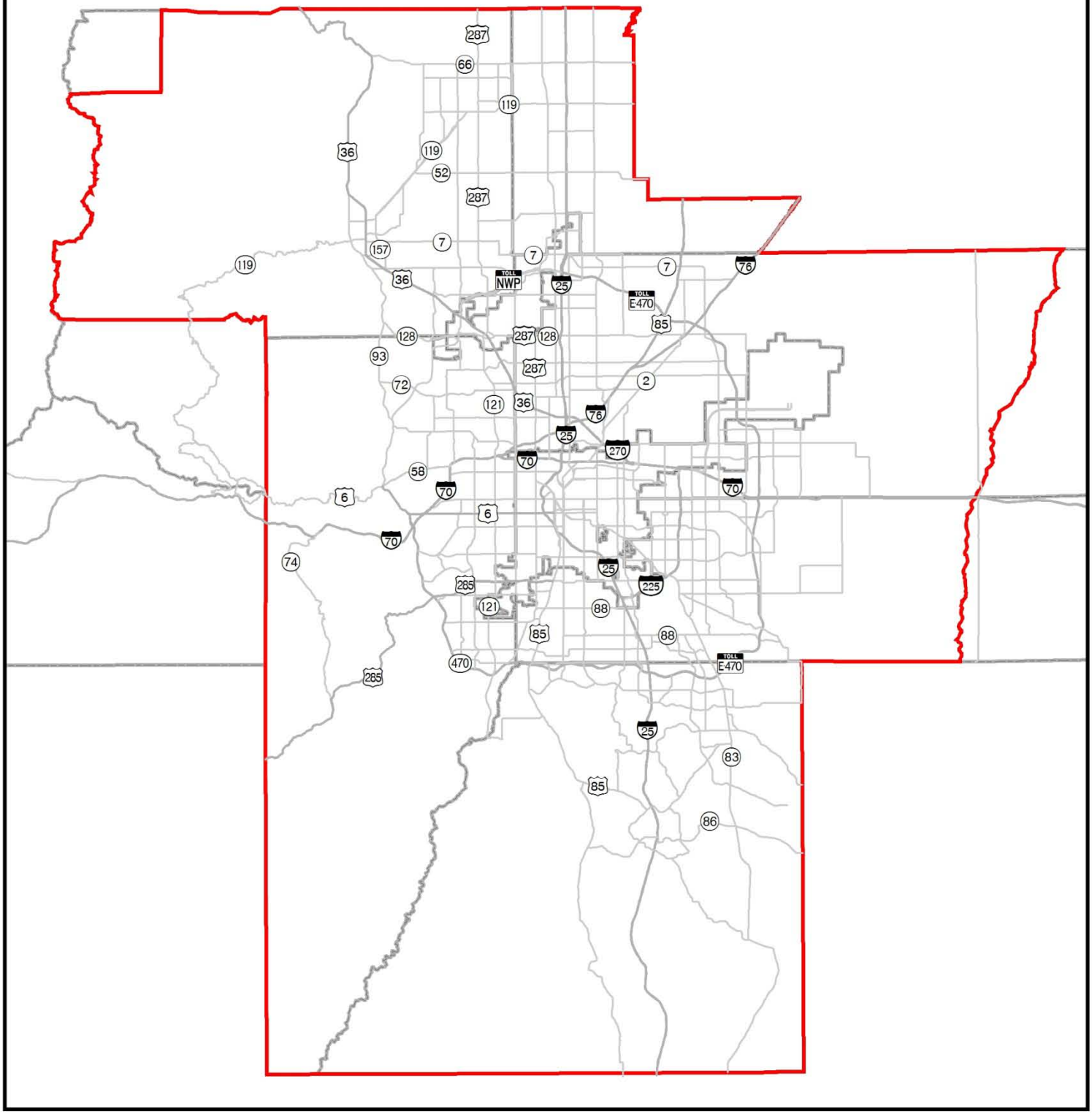
Figure 1
Transportation Management Area



LEGEND

- Transportation Management Area
- DRCOG County Boundaries

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Miles

Source: DRCOG
Projection: Colorado State Plane, NAD 83
PJ 06/13

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Program Progress

Since the last update (2010), the program has continued to assist stakeholders in implementing new traffic signal control systems; extending and/or upgrading system communications to enhance traffic signal operations at **key signals**[1]; and implementation and evaluation of pilot studies.

Since the 2010 update, the program has assisted 24 operating agencies in these efforts and completed 34 capital improvement projects. The program conducted retiming and coordination for all of these capital projects, and also completed 17 timing and coordination projects not related to capital projects. These projects improved operations for more than 860 traffic signals throughout the region and reduced, in total, daily delay by about 23,000 vehicle hours, daily fuel consumption by more than 11,000 gallons, daily air pollution emissions (mainly carbon monoxide) by more than 7,700 pounds, and daily greenhouse gas emissions by more than 110 tons, as shown in Table 1. The corresponding project locations are illustrated in Figure 3.

Several capital improvement projects (system equipment and communications upgrades) are nearing completion:

- Arapahoe Road communications system upgrade from Colorado Boulevard to Parker Road (Centennial and CDOT)
- Easter Avenue and Broncos Parkway from Havana Street to Peoria Street (Centennial and Arapahoe County)
- Dry Creek Road from Holly Street to Arapahoe Road (Centennial)
- Buckley Road from Arapahoe Road to Smoky Hill Road (Centennial)
- Smoky Hill Road from Tower Road to Gibraltar Street (Centennial)

Several other more advanced capital improvement projects and studies were either completed or made significant progress since the last update.

Advanced Traffic Signal System Procurement

Denver, Littleton, CDOT Region 6, and Englewood were each allocated funds to procure an advanced-function traffic signal system. Denver volunteered to lead a procurement process for the benefit of the region. Denver, assisted by the other project partners and other interested regional partners, developed a request for proposal to allow any operating agencies in the region to procure off Denver's bid. The intent was to identify a traffic signal system that met the requirements of the bid with pricing advantageous to all regional partners. The system selection is in its final stages.

[1] Key signals are those located on the 2035 Metro Vision Regional Transportation Plan major regional arterials and principal arterials AND in the Denver CBD core (area bounded by I-70, I-25, and Colorado Boulevard (see Figure 2).

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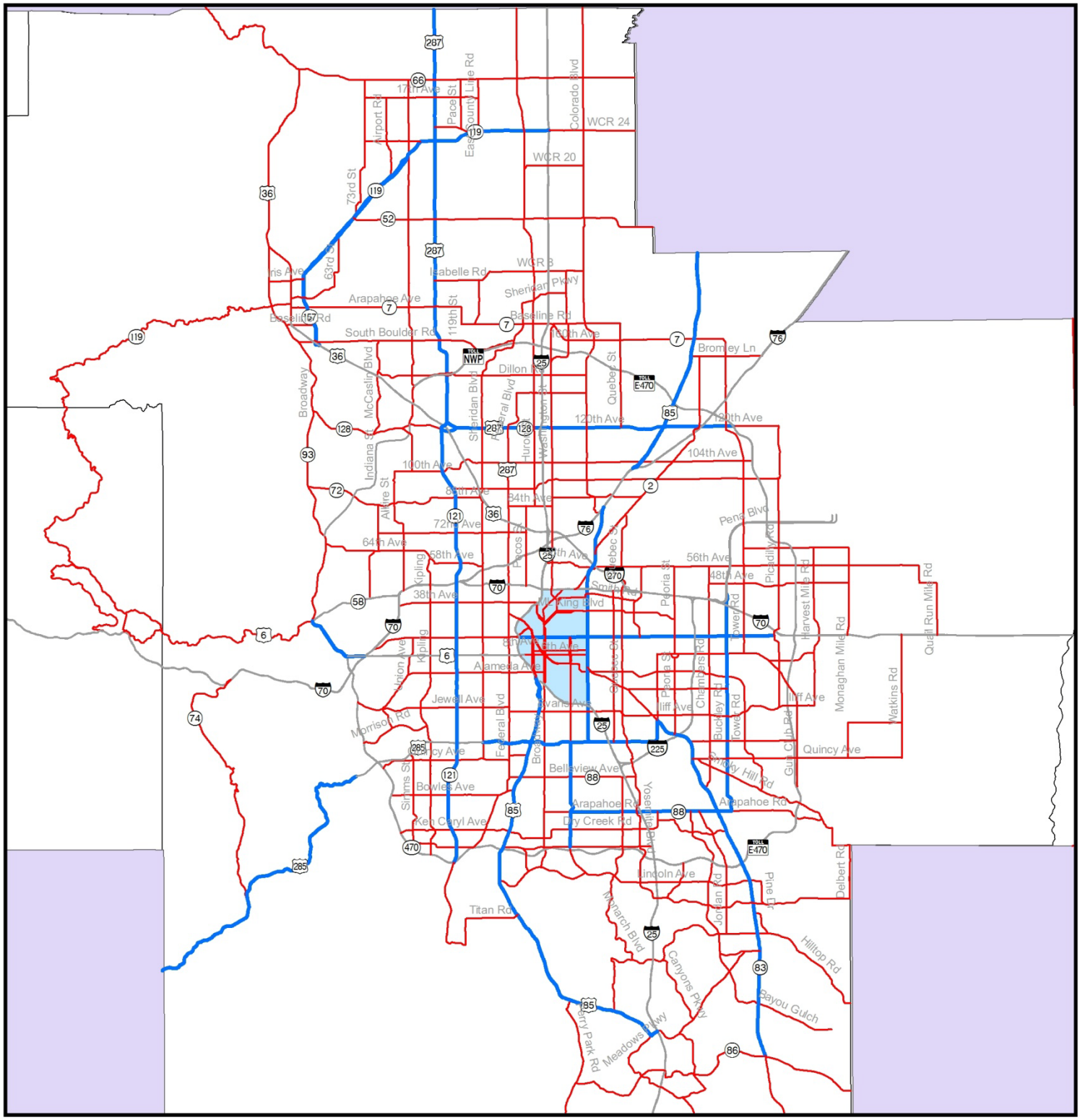
Figure 2
2035 RTP Transportation Management Area
Major Regional and Principal Arterial Roads



LEGEND

- Major Regional Arterials
- Principal Arterial
- Freeways/Tollways
- CBD/Core Area
- Area Outside Region

N

0 5 10

Miles

Source: DRCOG
Projection: Colorado State Plane, NAD 83
PJ 06/13

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Table 1
Traffic Operations Improvement Summary

	Year Completed	Project Limits	Number of Signals	Average Daily Traffic	Benefits				
					Corridor Travel Time Reduction (veh-hrs/day)	Fuel Consumption Reduction (Gal/day)	Air Pollutant Emission Reduction (lbs/day)	Greenhouse Gas Emission Reduction (lbs/day)	User Savings ($/day)
Capital Project									
Lower Core	2010	Logan Street: Louisiana Avenue to 1st Avenue Downing Street: Louisiana Avenue to Alameda Avenue	22	15,000	114	51	146	*	$2,400
Washington Street	2010	83rd Drive to 98th Avenue	10	30,000	124	49	117	*	$2,650
North Washington Street	2010	Pennsylvania Street to 136th Avenue	7	17,000	63	60	110	*	$1,110
Monaco Parkway	2010	1st Avenue to 35th Avenue	30	45,000	251	172	370	*	$5,450
SH 93 / US 6	2010	US 40 to Golden Gate Canyon Rd	13	36,000	414	138	461	*	$8,600
Thornton Parkway	2010	Pecos Street to York Street	12	32,500	354	211	1,276	*	$7,600
University Boulevard	2010	Hampden Avenue to Dad Clark Drive	22	31,500	167	119	1,886	*	$3,750
Alameda Avenue	2010	Colorado Boulevard to Havana Street	12	31,000	498	202	627	*	$10,450
South Broadway	2010	Belleview Avenue to Iliff Avenue	17	30,000	86	31	87	*	$1,800
Dry Creek Road	2010	Clarkson Street to Yosemite Street	18	20,000	127	66	129	*	$2,700
Hampden Avenue/Havana Street	2011	Colorado Boulevard to Parker Road	27	60,000	1,146	594	143	12,334	$24,900
72nd Avenue	2011	Indiana Street to Lamar Street	27	15,000	388	205	54	4,234	$8,450
Sheridan Boulevard	2011	52nd Avenue to 72nd Avenue	11	51,600	395	209	54	4,350	$8,600
Broadway (Boulder)	2011	University Avenue to Greenbriar Boulevard	23	30,000	322	179	46	3,680	$7,000
Baseline Road (Boulder)	2011	17th Street to 30th Street	7	27,700	99	69	18	1,412	$2,200
Colfax Avenue	2011	Welch Street to Kendall Street	14	28,000	478	250	63	5,206	$10,400
Easter Avenue/Broncos Parkway	2011	Havana Street to Jordan Road	11	16,800	170	88	24	1,820	$3,700
Central Colfax Avenue	2011	Sheridan Boulevard to I-25	11	38,000	215	162	38	3,333	$5,100
Belleview Avenue	2012	Lowell Boulevard to Pirate's Cove Entrance	8	42,000	213	103	24	2,161	$4,800
Kipling Parkway	2012	Alameda Avenue to Belleview Avenue	17	49,000	843	441	111	9,199	$19,250
Jewell Avenue	2012	Alameda Parkway to Sheridan Boulevard	14	19,000	260	119	31	2,508	$5,900
Santa Fe Drive (North)	2012	Mississippi Avenue to Mineral Avenue	19	79,000	1,931	1,003	233	20,840	$44,000
Mississippi Avenue	2012	Zuni Street to Santa Fe Drive	8	21,000	130	68	15	1,412	$2,950
Yale Avenue	2012	Colorado Boulevard to Quebec Street	9	24,500	147	78	18	1,589	$3,300
28th Street	2012	Colorado Avenue to Jay Road	39	33,000	383	207	50	4,263	$8,750
Arapahoe Avenue	2012	Folsom Street to 65th Street	12	36,500	531	266	65	5,521	$12,050
Foothills Parkway	2012	Baseline Road to Valmont Road	10	45,000	231	125	28	2,614	$5,250
Smoky Hill Road	2012	Buckley Road to Liverpool Street/Picadilly Street	14	33,000	Weekday				
					148	76	18	1,578	$3,350
					Weekend				
					64	33	9	667	$1,450
Hampden Avenue	2012	Inca Street to University Boulevard	11	55,500	1,132	581	138	12,064	$25,750
Alameda Avenue	2013	Sheridan Boulevard to Marion Parkway	29	35,000	671	406	99	8,451	$15,850
University Boulevard	2013	Alameda Avenue to Hampden Avenue	19	36,000	643	401	88	8,287	$15,150
Arapahoe Road	2013	University Boulevard to Waco Street	29	82,000	1,056	547	132	11,352	$24,550
US-85	2013	Bromley Lane to 104th Avenue	9	39,000	290	130	30	2,710	$6,550
84th Avenue/ Huron Street	2013	Huron Street to Washington Street 84th Avenue to Conifer Road	12	30,000 19,000	240	75	18	1,542	$5,400
120th Avenue	2013	Nickel Street to Holly Street	30	55,500	1,097	590	151	12,201	$25,600
Wadsworth Boulevard	2013	64th Avenue to 108th Avenue	34	55,000	532	250	63	5,214	$12,300
Parker Road	2013	Chambers Road to Cottonwood Drive	12	69,000	886	447	99	9,278	$20,550
		Subtotal	**629**		**16,775**	**8,768**	**7,060**	**159,153**	**$378,160**
Timing/Coordination Project									
Ward Road	2011	44th Avenue to 64th Avenue	8	42,000	373	175	38	3,666	$8,100
64th Avenue	2011	Quaker Street to Yank Way	9	28,000	99	46	14	962	$2,150
North Sheridan Boulevard	2011	Sheridan Boulevard: 120th Avenue to 72nd Avenue 88th Avenue: Lamar Drive to Sheridan Avenue	27	50,000	1,021	513	135	10,635	$22,150
92nd Avenue	2011	Pierce Street to Lowell Boulevard	9	30,000	198	91	22	1,861	$4,300
North Colorado Boulevard	2011	88th Avenue to 136th Avenue	22	25,000	250	121	30	2,518	$5,450
Colorado Boulevard	2011	Alameda Avenue to 48th Avenue	25	60,000	614	324	89	6,688	$13,300
Vasquez Boulevard	2011	56th Avenue to 77th Avenue	9	39,000	323	159	39	3,308	$7,050
104th Avenue	2011	Federal Boulevard to Colorado Boulevard	21	47,000	139	65	16	1,364	$3,000
Washington Street	2011	102nd Avenue to 120th Avenue	10	45,000	388	200	52	4,149	$8,450
88th Avenue	2011	Huron Street to Dahlia Street	13	22,000	373	184	47	3,775	$8,050
Santa Fe Drive (South)	2012	County Line Road to West Highlands Ranch Parkway	6	50,000	437	224	50	4,677	$9,950
Bowles Avenue	2012	Santa Fe Drive to Grant Ranch Boulevard	7	35,000	106	51	16	1,061	$2,350
Flatiron Mall Area	2012	Flatiron Mall Area	24	17,000	408	217	57	4,481	$9,300
136th Avenue	2012	Huron Street to Holly Street	14	22,000	128	64	13	1,339	$2,900
Smoky Hill Road	2012	Aurora Parkway to Riveria Way/Saddle Rock Trail	7	34,000	Weekday				
					76	40	10	830	$1,750
					Weekend				
					57	26	6	538	$1,300
Sheridan Boulevard	2013	Aspen Creek Drive to 118th Avenue	9	21,000	502	266	67	5,541	$11,750
North Huron Street	2013	128th Avenue to 104th Avenue	12	21,000	309	157	35	3,267	$7,200
		Subtotal	**232**		**5,744**	**2,897**	**730**	**60,122**	**$127,200**
		Grand Total	**861**		**22,519**	**11,665**	**7,790**	**219,275**	**$505,360**

* The calculation methods were revised in 2011: greenhouse gas emissions estimates are calculated and the criteria air pollutant emissions have been updated with current models.

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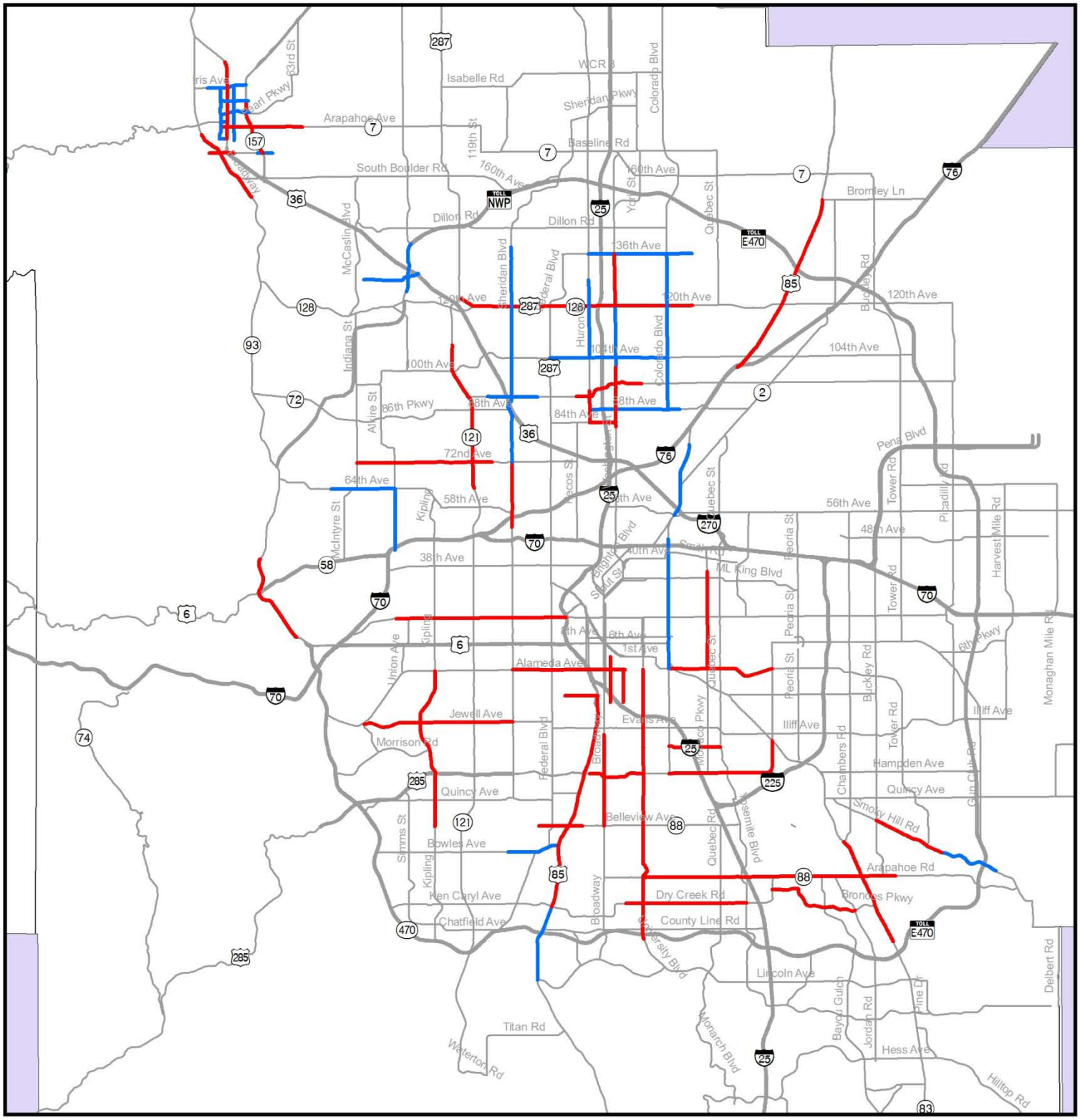
Figure 3
TSSIP Projects Completed
2010 - Present



LEGEND

- Capital Improvement
- Timing/Coordination
- Area Outside Region

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Miles

Source: DRCOG
Projection: Colorado State Plane, NAD 83
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Performance Measures Pilot

DRCOG continues to work with CDOT, Englewood, and other stakeholders regarding the pilot implementation of a performance measures application on Hampden Avenue from Federal Boulevard to University Boulevard. Since the last TSSIP update the pilot implementation design and construction is complete. The system integration and final testing will be completed this year.

Transit Signal Priority Pilots

Two pilot implementations and evaluations are complete and operational and the third is completing software development. The first project was completed with local funds on State Highway 7 by Boulder County in partnership with the City of Boulder and CDOT. This project was successful, but the evaluation illustrated that there were minimal CMAQ benefits. The second pilot project was implemented by Denver in collaboration with RTD on Colorado Boulevard. The results of this pilot implementation illustrated that TSP is technically feasible, but due to technical limitations, Denver is facing challenges to effectively monitoring system performance, which limit CMAQ benefits measurement. Denver continues to tweak the system implementation and will continue to determine system benefits. Finally, Boulder and Via Mobility Services (formerly Special Transit) are continuing to implement another pilot TSP project. This implementation is unique in that Boulder and Via Mobility Services are overseeing software development to be completed this year.

Center-to-Center Demonstration

DRCOG, Denver, Littleton, Englewood, and CDOT completed a demonstration project involving center-to-center communications between traffic signal systems at neighboring agencies. The purpose of the demonstration project was to control the group of signals operated and maintained by several agencies on Santa Fe Drive in response to changes in traffic volume, generally due to a diversion from the freeway. As a result of the demonstration project, it was determined that it was technically feasible to conduct cooperative multi-agency signal operations. The results also highlighted that this cooperation required significant trust and partnership from the neighboring jurisdictions, requiring good planning and ongoing coordination and cooperation during operations.

CMAQ Benefits of Uninterruptible Power Supplies and Ethernet Conversion

Since the last TSSIP update, DRCOG conducted a study of the benefits of Ethernet conversion and the implementation of Uninterruptible Power Supplies (UPS). Ethernet is a common communications protocol whose use is increasing in the transportation operations arena. UPS both condition the power for the controllers and maintain signal operations during power interruptions. Both of these functions help the signal system provide more reliable operations. The results of the study illustrated that UPS provide CMAQ benefits by preventing an additional 72 hours of delay per power interruption per controller. The study did not yield the same results for Ethernet conversion. Although it is generally accepted that Ethernet communications are more robust and can offer

greater bandwidth than serial communications, the study illustrated only marginal CMAQ benefits for Ethernet over serial. As a result of the study, Ethernet conversion projects alone will not be considered for funding. Projects that either illustrate the communications reliability issues or include Ethernet conversion as a component of a project offering advanced capabilities will continue to be considered for funding.

Bicycle Detection

Funds were allocated to Denver through the Miscellaneous Equipment Purchase Program for pilot implementations of bicycle detection. Denver currently configures signal operations at select intersections such that bicyclists are presented the pedestrian signal phase without having to dismount and press the pedestrian call button. This has the effect of calling up the pedestrian phase for every cycle whether a bicyclist (or pedestrian) is present or not. It is anticipated that bicycle detection will allow more efficient operations while continuing to accommodate the bicyclists. DRCOG will lead the benefits evaluation for these pilot implementations.

Regional Concept of Transportation Operations

Since the last update, the DRCOG Board adopted the Regional Concept of Transportation Operations (RCTO), which describes the collaborative plan to improve regional operations performance across the region over the next five years. The focus of this RCTO is to **improve regional traveler reliability**, which involves both leveraging existing systems and success of ongoing regional transportation operations initiatives and newly focusing on **reducing the impact of traffic incidents.**

The RCTO is a management tool that provides guidance to the TSSIP. It presents a unified direction for transportation systems management and operations based on a holistic view of the whole region based on operations objectives and performance measures that can be used in the transportation planning process. In addition, the RCTO clarifies the roles and responsibilities of the partners in the collaborative effort.

Program Update Process

The Regional Transportation Operations (RTO) work group with representation from traffic signal operating agencies, the Colorado Department of Transportation (CDOT), RTD and FHWA assisted in the TSSIP update effort. The work group was extensively involved in the update process, including verifying current conditions, and identifying critical needs and updating the purpose and evaluation of the TSSIP. Several stakeholder meetings were held between July 2012 and June 2013.

II. REGIONAL TRAFFIC SIGNAL MANAGEMENT AND OPERATIONS PLAN

Recognizing a national need to improve traffic signal management and operations, the FHWA published a guide for achieving a basic service model for traffic signal management and operations.[2] The guide, following a systems engineering analysis approach, describes the development of an operational and management environment based on simply stated and defensible operational objectives that consider the capabilities and capacity of the operating agency. Locally, the Town of Castle Rock recognized the value of the guide and prepared its own traffic signal operations and management plan in 2010.

The original 1994 TSSIP was also created following a systems engineering approach. The existing TSSIP goals, objectives and strategies are restated and clarified here within the context of FHWA's basic service model. As the TSSIP has a regional perspective, the traffic signal management and operations planning here provides a framework for the operating agencies in the region and encourages each of the operating agencies to create its own traffic signal management and operations plan, building from the framework described below.

Regional Goals and Objectives

The following are the currently revised goal and objectives for the TSSIP:

Goal:	The region's traffic signals systems will operate in a safe manner making most efficient use of arterial street capacity
Objective 1:	Minimize arterial traveler stops
Objective 2:	Minimize traveler stop time at intersections
Objective 3:	Maximize traffic signal system equipment reliability

The RTO work group took the opportunity of this update to ensure that all travelers (auto/transit passengers, pedestrians, and bicyclists) are considered in the goals and objectives.

Regional Operations and Management Strategies

The basic service model focuses on the development of strategies for four areas: operations, maintenance, design and public communications. The strategies laid out here are general and provide the basics for regional and interjurisdictional signal operations. As each agency is responsible for the operations and maintenance of its own traffic signal system, they are encouraged to prepare their own traffic signal management and operations plans building from the core strategies listed here.

[2] *Improving Traffic Signal Management and Operations: A Basic Service Model*, December 2009, FHWA‐HOP‐09‐055

Operations

Operations Strategy #1: Address signal coordination timing on a corridor-by-corridor basis without regard to jurisdictional boundaries. This will be achieved by operating agencies working together and synchronizing with the Universal Coordinated Time (WWV time) broadcast by the National Institute of Standards and Technology (NIST) in Boulder.

Operations Strategy #2: On a three- to five-year basis, optimize cycle lengths, splits, and offsets of coordination timing plans that:

- Minimize main street stops and travel time delays for all travelers.
- Minimize queue lengths and cycle failures.
- Provide adequate (as determined by operating agency) crossing time for pedestrians and bicyclists.
- Manage vehicle queue lengths to minimize their effect on the overall corridor during congested periods.

Operations Strategy #3: For weekday operations, provide three time-of-day (TOD) coordination timing plans. TOD coordination timing plans are developed based on historical information to address typical traffic conditions typically for the morning peak (e.g. 6 to 9 a.m.) and afternoon peak (3 – 7 p.m.) periods along with a mid-day/off-peak period covering the time in between. For weekend operations and other special coordination timing plans will be evaluated and implemented where needs are demonstrated.

Operations Strategy #4: The operating agencies will monitor and manage the traffic signal systems to ensure reliable, coordinated operations for key signals. This includes ensuring that the implemented signal timing plans are performing as expected.

Operations Strategy #5: Implement advanced function signal timing where needs and engineering analysis demonstrate a technical- and cost-effectiveness. Options include:

- Traffic-responsive control (TRC) timing plans are based on historical information, but the signal system, based on detected traffic conditions, implements the appropriate timing plan. This control strategy helps address circumstances where traffic patterns vary (i.e. special events, incidents, and day-to-day variability).
- Traffic-adaptive control (TAC) is a complex control strategy where timing plans are developed and implemented by the signal system in real time based on actual traffic conditions detected in the field. Through its *Every Day Counts* initiative the FHWA is promoting the use of TAC.
- Transit signal priority (TSP) is a system involving communications between transit vehicles and the traffic signal controllers that adjust traffic signal phasing on an intersection-by-intersection basis in order to promote the flow of transit vehicles.

- As a component of incident management, special traffic signal timing coordination plans are prepared for use in response to incidents. Generally, this occurs on routes identified for diversion from another facility.

Maintenance

Maintenance Strategy #1: Where warranted, implement and maintain a traffic signal system with the following base-level traffic signal control requirements:

- Provide automatic synchronization to Universal Coordinated Time to minimize clock drift.
- Provide reliable upload/download of timing/coordination parameters.
- Provide for back-up time-based coordination (TBC) operation.
- Provide remote access to system databases.
- Provide real-time and reliable monitoring of signal system and intersection operations.
- Provide error detection and automatic reporting.
- Provide uninterruptible power at critical intersections where power reliability is poor.

Maintenance Strategy #2: Provide controllers that are compatible with the traffic signal system and provide functionality that supports the other maintenance and support strategies.

Maintenance Strategy #3: Where warranted, implement and maintain a traffic signal system with the following advanced-level traffic signal control requirements:

- Provide greater error detection and automated reporting with a focus on the reliability of coordinated operations.
- Provide operating agencies the capability to share system monitoring, traffic monitoring, and system operations/control.

Maintenance Strategy #4: Operating agencies will maintain the field infrastructure under their control in working order to support other operations and maintenance strategies.

Design

Design Strategy #1: Operating agencies will use communications design practices that will support center-to-center communications that directly support shared traffic monitoring and operations. Each operating agency is individually responsible for the design of intersection control in their jurisdiction, but the TSSIP does fund much of the design of signal interconnect projects.

Public Communications

Public Communications Strategy #1: When an operating agency receives public comments regarding a traffic signal, the operating agency will acknowledge that the public comment is being addressed by the appropriate agency; otherwise, it will provide direct contact information for the responsible agency.

Public Communications Strategy #2: When discussing signal coordination timing plans on principal arterials and major regional arterials with the public, the operating agency will highlight that the signal timing coordination plans are developed in partnership with the operating agency, its neighboring jurisdictions, and DRCOG.

Public Communications Strategy #3: DRCOG will conduct an evaluation of each signal coordination timing plan implemented in the region and summarize the results in a report made available to the public as well as the decision-makers and operators directly impacted by the improvements. For each project, DRCOG will also calculate the Arterial Progression Index (API), a measure of the corridor's travel time considering the number and duration of stops.

III. SYSTEM INVENTORY

State of the Current System

A survey questionnaire was sent to each operating agency asking for updated information regarding signal system inventory and traffic signal operations. The information received was reviewed by DRCOG staff and compiled into five tables presented in this chapter to illustrate the current condition of operations in the region.

There are now more than 3,800 traffic signals (about a two percent increase from the 2010 update) maintained and operated by 37 different jurisdictions within the Denver TMA. Nearly 2,800 of these signals (a negligible change from 2010 update) are considered key signals. In addition, more than 2,400 key signals are currently connected to a traffic signal control system (a negligible change from 2010 update). Table 2 summarizes the traffic signal inventory in the region. Table 3 summarizes the types of controllers and the various traffic signal control systems that are being used in the region by each operating agency.

All traffic signal systems in operation meet the six base-level system requirements as per the traffic signal management and operations plan in the previous chapter. With the exception of Brighton, all agencies that have key signals and more than 20 signals to operate have a traffic signal control system. The only operating agencies in the region currently without a system are: Castle Pines, Erie, Federal Heights, Firestone, Frederick, Golden, and Sheridan. A number of other regional partner jurisdictions currently do not have any signals within the Denver TMA, including Weld County, Dacono, Fort Lupton, Hudson, Lochbuie, and Mead.

Table 2
Traffic Signal Inventory within the Transportation Management Area

Operating Agency	2010 Totals	2013		
		Number of Signals	Number of Key Signals	Number of Key Signals on System[5]
Adams County	51	50	27	21
Arapahoe County	31	34	23	11
Boulder County	19	19	10	0
Douglas County	101	103	69	65
Jefferson County	108	110	60	52
Arvada	101	104	43	31
Aurora	323	328	244	239
Boulder	144	148	93	90
Brighton[3]	10	31	22	7
Broomfield	72	74	27	13
Castle Pines	7	7	7	0
Castle Rock	27	30	15	14
Centennial	70	75	60	29
Commerce City	26	34	21	14
Denver[2]	1289	1291	1030	920
Englewood	60	61	30	30
Erie	2	4	4	0
Federal Heights	4	3	2	0
Firestone	8	8	8	0
Frederick	2	2	2	0
Golden	17	17	0	0
Greenwood Village	38	47	16	16
Lafayette	13	13	7	6
Lakewood	199	205	114	108
Littleton	69	70	47	46
Lone Tree	40	43	31	30
Longmont	86	89	64	64
Louisville	18	19	15	14
Northglenn	38	38	31	31
Parker	75	77	60	57
Sheridan	2	2	1	0
Superior	10	10	4	4
Thornton	139	144	106	93
Westminster	109	110	77	74
Wheat Ridge	39	39	13	10
CDOT R1[3,4]	59	369	319	278
CDOT R4	48	53	49	48
CDOT R6[4]	318	-	-	-
	3772	**3861**	**2751**	**2415**
		2% increase from 2010	*negligible change from 2010*	*negligible change from 2010*

(1) Includes four Edgewater signals.
(2) Includes Glendale signals.
(3) Brighton assumed ownership of 21 signals on two highways abandoned by CDOT.
(4) CDOT R1 and R6 have combined into one region.
(5) 88% of key signals are on system.

Table 3
Controller Types and Signal Systems

Operating Agency[6]	Controller Type	Signal System Type
Adams County	NEMA[1]	Econolite Aries
Arapahoe County	NEMA	Econolite Aries
Boulder County	NEMA and 170[2]	Econolite Aries[3]
Douglas County	2070[2]	Naztec ATMS.now
Jefferson County	170	Econolite Translink 32
Arvada	NEMA	Econolite Centracs
Aurora	NEMA	Siemens Tactics v 2.0
Boulder	170 and 2070	Econolite Centracs
Brighton	NEMA and 170	No system
Broomfield	2070	Siemens Tactics v 2.0
Castle Pines	170 and 2070	No system
Castle Rock	170	Econolite Translink 32
Centennial	NEMA	Econolite Centracs
Commerce City	NEMA	Eagle Actra
Denver	NEMA	Econolite Icons
Englewood	NEMA	Econolite Icons
Erie	NEMA	No system
Federal Heights	170	No system
Firestone	170	TrafficView23
Golden	170	No system
Greenwood Village	NEMA	Econolite Centracs
Lafayette	NEMA	Eagle Marc NX
Lakewood	NEMA	Transcore TransSuite
Littleton	NEMA	Econolite Icons
Lone Tree	2070	Naztec ATMS.now
Longmont	NEMA	Econolite Centracs
Louisville	NEMA	Econolite Aries
Northglenn	NEMA	Econolite Aries
Parker	170	Econolite Translink 32
Sheridan	NEMA	No system
Superior	170	Econolite Translink 32
Thornton	170	Econolite Pyramids
Westminster	NEMA	Econolite Centracs
Wheat Ridge	NEMA	Econolite Aries
CDOT R1[4]	170	Econolite Pyramids and Translink 32
CDOT R4[5]	170	Econolite Translink 32

(1) National Electrical Manufacturer's Association (NEMA) developed and maintained signal controller standards.
(2) Model 170 signal controller standard. These controllers are approaching obsolescence. Model 2070 is a standard for controllers that provides advanced functions and is designed as a replacement for Model 170 controllers.
(3) Currently not in operation.
(4) CDOT R1 and R6 are combined into one region.
(5) Operate and maintain other traffic signal control systems outside of the region.
(6) The following jurisdictions have neither traffic signals nor traffic signal system in the region: Weld County, Dacono, Fort Lupton, Frederick, Hudson, Lochbuie, and Mead.

Communication Systems

A reliable communications network is an important component of a complete traffic control system, as it provides the connection between field equipment and the traffic signal control system. Lacking such communications, a traffic control system is less functional and sometimes less reliable. The communication element of a traffic signal control system provides for the movement of data from the local intersections to the point of control (be it a central computer, a master controller, or the responsible engineer or technician) and the movement of commands from the point of control to the local intersections.

System communications used by the operating agencies across the region are: fiber-optic networks, radio networks, leased phone line services and agency-owned copper wire. Within individual systems, signal communications is mostly achieved through a combination of spread-spectrum radio and fiber-optic networks. CDOT Region 1 is also utilizing an obsolete licensed frequency packet radio system that CDOT is phasing out. Some agencies have implemented or are implementing Ethernet-based communication (both by fiber and by radio) for traffic signal system control, but a significant amount of serial communications continues to exist in the region. Ethernet communications is seen as more robust and efficient communications protocol that can be supported by existing IT staff.

Table 4 identifies the communications media currently used in the region.

Table 4
System Communications Media

Operating Agency	Communications Media
Adams County	Agency owned hardwire and cell phone
Arapahoe County	Agency owned hardwire, spread spectrum radio, fiber and leased telephone network
Boulder County	None for NEMA (system not in operation), some spread spectrum radio
Douglas County	Agency owned fiber and Ethernet radio
Jefferson County	Agency owned spread spectrum radio and leased telephone network
Weld County	None
Arvada	Agency owned spread spectrum radio, fiber and hardware
Aurora	Leased telephone network, agency owned hardwire and spread spectrum radio (both serial and Ethernet)
Boulder	Agency owned spread spectrum radio and leased telephone network
Brighton	None
Broomfield	Agency owned fiber, spread spectrum radio and some packet radio
Castle Pines	None
Castle Rock	Agency owned fiber, spread spectrum radio and hardwire
Centennial	Agency owned fiber, hardwire, spread spectrum radio, and leased telephone network
Commerce City	Agency owned fiber, spread spectrum radio
Dacono	None
Denver	Agency owned fiber, spread spectrum radio and hardwire
Englewood	Agency owned fiber, spread spectrum radio and hardwire
Erie	None
Federal Heights	None
Firestone	Encom Commpak Wireless Broadband Units
Fort Lupton	None
Frederick	None
Golden	None
Greenwood Village	Agency owned fiber and radio
Hudson	None
Lafayette	Agency owned spread spectrum radio
Lakewood	Agency owned fiber and spread spectrum radio
Littleton	Agency owned fiber and spread spectrum radio
Lochbuie	None
Lone Tree	Agency owned fiber and Ethernet radio
Longmont	Citywide WiFi
Louisville	Agency owned fiber
Mead	None
Northglenn	Leased telephone network
Parker	Agency owned fiber and spread spectrum radio
Sheridan	None
Superior	Agency owned fiber and spread spectrum radio
Thornton	Agency owned fiber and spread spectrum radio
Westminster	Agency owned fiber, hardwire and spread spectrum radio
Wheat Ridge	Agency owned fiber, hardwire and leased telephone network; exploring radio communications
CDOT R1(1)	Agency owned fiber, hardwire, spread spectrum radio, and packet radio
CDOT R4	Agency owned spread spectrum radio

(1) CDOT R1 and R6 are combined into one region.

Detection

Detection refers to the component of the traffic signal system used to:

- Inform signal controllers at local intersections of the presence of vehicles, pedestrians, or bicycles that need to be served; and,
- Measure and monitor traffic, either for information purposes or for advanced system control strategies.

There is a wide variety of technologies available in the marketplace that is used by the operating agencies. Predominantly, a combination of inductive loops and video detectors are used, but other non-invasive technologies using radar and infrared video are also in use. Many of the detectors are used for individual signalized intersection operations (outside of the purview of the TSSIP). Some of these detectors are also being used for traffic counting or system detection purposes. The system detection is largely used for traffic-responsive control, and in some cases it is also used for system performance monitoring and traveler information. System detection is also critical in traffic-adaptive control operations.

Signal Coordination

Coordination is the process of making signals work together, as opposed to operating independently. Signal timing coordination plans are prepared for groups of traffic signals to reduce delays for travelers as they progress through the roadway network.

Most traffic signal coordination in the region is accomplished through the use of a traffic signal system with backup time-based coordination (TBC). A **traffic signal system** links traffic signals together with a communications network and various signal control functions are governed by a master controller or a central computer, which are synchronized with WWV time. **TBC** relies on synchronizing time clocks installed with or within the controllers at individual intersections and controllers that have stored the current signal timing plans. Table 5 summarizes the coordination methods used by each jurisdiction and the number of signals included.

Through the TSSIP, DRCOG staff facilitate coordination of traffic signals across jurisdictional boundaries, with an objective of retiming signals on major roadways every three to five years when possible. Operating agencies also devote resources to partner with DRCOG staff and/or consultants for corridor retiming projects.

In general, during weekdays, most corridors are coordinated using three TOD timing plans (morning peak, afternoon peak and all other times). Several agencies now use two plans for the non-peak period, a timing plan for the few hours during lunch time and another one (with a shorter cycle length) to cover the low-volume off-peak periods. On weekends, many agencies still use afternoon peak or all other times plans. Over the last few years, DRCOG timing projects have also provided specific weekend plans. This practice will continue where feasible and applicable.

System Control Strategies

Time-of-day (TOD) control is the predominant type of control strategy currently used in the region. TOD involves preparing and maintaining timing plans developed based on historical information to address typical traffic conditions during several different periods of the day (i.e. morning peak, mid-day/off-peak, and evening peak periods).

Traffic-responsive control (TRC) is utilized by a handful of operating agencies on a select number of corridors. TRC involves preparing timing plans developed "off-line" based on historical information that the signal system selects and implements based on detected traffic conditions. This control strategy helps address variable traffic patterns caused by special events, incidents, and unpredictable day-to-day variability.

Traffic-adaptive control (TAC) is a complex control strategy where signal coordination timing plans are developed and implemented in real time, based on actual traffic conditions detected in the field. TAC is not yet implemented in the region, but the RTO work group has indicated interest in pilot implementations of TAC.

Table 5
Coordination Methods

Operating Agency	Coordinated Signals		Uncoordinated Signals[1]	TOTALS
	SYSTEM	TBC		
Adams County	24	0	26	**50**
Arapahoe County	15	9	10	**34**
Boulder County	0	7	12	**19**
Douglas County	71	4	28	**103**
Jefferson County	65	1	44	**110**
Arvada	43	10	51	**104**
Aurora	275	0	53	**328**
Boulder	132	2	14	**148**
Brighton	0	11	20	**31**
Broomfield	31	22	21	**74**
Castle Pines North	0	6	1	**7**
Castle Rock	23	0	7	**30**
Centennial	39	20	15	**74**
Commerce City	20	0	14	**34**
Denver	987	259	45	**1291**
Englewood	48	0	13	**61**
Erie	0	0	4	**4**
Federal Heights	0	2	1	**3**
Firestone	0	0	8	**8**
Frederick	0	0	2	**2**
Golden	0	13	4	**17**
Greenwood Village	26	0	21	**47**
Lafayette	6	0	7	**13**
Lakewood	136	7	62	**205**
Littleton	62	0	8	**70**
Lone Tree	37	0	6	**43**
Longmont	62	0	27	**89**
Louisville	14	0	5	**19**
Northglenn	33	0	5	**38**
Parker	59	0	18	**77**
Sheridan	0	0	2	**2**
Superior	5	5	0	**10**
Thornton	87	26	31	**144**
Westminster	82	10	18	**110**
Wheat Ridge	20	0	19	**39**
CDOT R1[2]	310	13	46	**369**
CDOT R4	33	0	20	**53**
	2736	**433**	**692**	**3861**

(1) Several uncoordinated fire signals are the in system
(2) CDOT R1 and R6 are combined into one region.

Legend

System - Traffic signals monitored and synchronized by a traffic signal control system or master controller.
TBC - Traffic signals, synchronized to WWV time, controlled by timing plans residing in the controller.
Uncoordinated Signals - Traffic signals that are not coordinated with any other signals.

Additional Highlights

The following highlights drawn from the survey questionnaires reflect the current state of the operating agencies. Table 6 provides a snapshot of these operations.

- Sixteen operating agencies (a small increase over the last update) reported having some type of real-time data collection. The data is used for traffic-responsive control, volume monitoring, signal timing analysis, performance monitoring, and public information purposes.
- Most operating agencies with signal systems have functional capabilities beyond base-level control (i.e., traffic-responsive control and transit signal priority) available in the traffic signal system. However, many of these systems would need upgrades in system licensing and the deployment of traffic or transit detection to make these advanced functions operational.
- Interest in implementing transit signal priority (TSP) remains relatively low. The operating agencies are considering the results of the pilot implementations and are waiting to see the direction RTD will take in technology and strategy selections. RTD completed a feasibility study to implement TSP at ramp signals along the US 36 corridor, which identified existing technology on the transit vehicles to communicate with the traffic signals. Another RTD transit priority study is currently underway on Colfax Avenue in Denver.
- Four agencies—Denver, Northglenn, CDOT Region 6 and Englewood—have traffic-responsive control (TRC) in operation (in the Coors Field area for ballgame traffic; on 104th Avenue near I-25; 88th Avenue near I-76; and, along Hampden Avenue near Santa Fe Boulevard). About half of the operating agencies (17) report that they continue to consider the implementation of TRC where appropriate.
- More than half of the agencies (21) reported interest in having inter-agency communication mostly at the data sharing level. Data sharing and sharing of system control was evaluated as a demonstration project on Santa Fe Drive. The demonstration project illustrated that the technology and practical knowledge are available to support data sharing and even shared control; however, the interjurisdictional procedures and agreements to conduct shared operations are key to successful operations. CDOT ITS Branch also supports the City and County Traffic Management (CCTM) Desktop, which is a secured web page displaying the Colorado Transportation Management System (CTMS) operational information where regional operations data is shared with operating agencies.
- About one half of the operating agencies (20) reported having only one engineer for traffic signal operations. These engineers are also usually responsible for other transportation engineering services. Signal operations in the smaller agencies are usually the responsibility of the city engineer or public works director.

- Mid-sized and large agencies tend to have technician staff and contract services to support operations. Small agencies tend to use contractors to support operations.
- More than half of the operating agencies (29) reported some staff assignment to "real-time" monitoring of the signal system and transportation operations. Mainly, this is part-time attention from engineers, but some agencies have dedicated operations staff. Small agencies tend to use contracted services to monitor and maintain operations. The period of coverage is daily with a focus on weekday peak periods. It is rare that weekends and special events are staffed. For the most part, the comments related to the real-time monitoring responses suggest that monitoring is on an exception basis.
- About two-thirds of the agencies reported that the traffic operations center is either the engineer's office or they have no operations center. Only four operating agencies (Douglas County, Denver, Lakewood, and Commerce City) have a dedicated traffic operations center. Many agencies have expressed a desire to establish a dedicated traffic operations center. The RCTO also suggests that established traffic operations centers could assist in monitoring several neighboring agencies.

Table 6
Snapshot of Operating Agencies

Number of signals	Number of Jurisdictions	Real Time Data Collection: Use real time data collection	Real Time Data Collection: For what purpose?	Types of Detection	How many have signal system?	Signal system meets base-level functionality	Advanced functional capabilities in signal system	Interested in implementing TRC?	Interested in implementing TSP?	Interested in inter-agency communication?	Interested in center-2-center communication?	Who monitors the signals in real time?
<30	19	2	Traffic volume trends and speed monitoring	Video (9) Loop (7)	5	5	TRC (5)	1		3	0	Contractor (2)
30-100	17	9	TRC, congestion benchmark, traffic studies, volume counts, speed monitoring, weather.	Video (14) Loop (13) Microwave (4) MicroLoop (1)	16	16	TRC (16) TSP (1) Video Monitoring (1)	9	1	12	7	Contractor (3) Staff (9)
101-250	7	4	TRC, traffic studies, volume counts.	Video (7) Loop (6) Microwave (1) Magnetometer (1)	7	7	TRC (7) TSP (1) Video Monitoring (3)	4	2	4	5	Contractor (1) Staff (5)
>250	3	1	TRC, traffic studies, volume counts, traveler information.	Video (3) Loop (3) Microwave (2)	3	3	TRC (3) TSP (1) Video Monitoring (3)	3	2	2	3	Staff (3)

Number of signals	Traffic Operations Center: Dedicated operations center/room	Traffic Operations Center: Shared room with other functions	Traffic Operations Center: Engineer's office	Who operated and who maintains signals?: Operations	Who operated and who maintains signals?: Maintenance	Engineers and time spent working with signals: Number of Engineers	Engineers and time spent working with signals: % time spent working with signals	Range of signals to engineers ratio	Technicians and time spent working with signals: Number of Technicians	Technicians and time spent working with signals: % time spent working with signals	Special Events Timing Plans	Time required to respond to and complete a timing change
<30	1	1	1	Contractor (7) Combination (3)	Contractor (8) Combination (2)	0 ER (11) 1 ER (4) 2 ER (2)	5 to 40% 5%	8 to 1 - 19 to 1	1 Tech (1) 3 Tech (1)	10% 20%		1 to 2 days (5) 2 to 4 weeks (4)
30-100	4	2	8	Staff (12) Combination (2)	Staff (1) Contractor (3) Combination (10)	1 ER (11) 2 ER (2) 3 ER (1)	5 to 50% 15 to 30% 20%	21 to 1 - 77 to 1	1 Tech (4) 2 Tech (2) 3 or more (3)	5 to 100% 10 to 90% 10 to 100%	Events (3) Holidays (6)	1 to 5 days (10) 2 to 4 weeks (2) Varies (2)
101-250	3		2	Staff (6) Combination (1)	Staff (2) Contractor (2) Combination (3)	1 ER (5) 2 ER (1) 3 ER (1)	10 to 90% n/a 100%	34 to 1 - 148 to 1	4 Tech (1) 5 Tech (1) 6 Tech (1) 17 Tech (1)	80 % 100% 25 to 50% 30%	Events (1) Holidays (2) IMP (1)	1 to 5 days (5 1 to 2 weeks (1) Varies (1)
>250	1		2	Staff (3)	Staff (3)	2 ER (2) 12 ER (1)	30 to 50% 50%	108 to 1 - 164 to 1	8 Tech (1) 12 Tech (1) 42 Tech (1)	45% 25 to 80% 50%	Events (3) Flea Market (1) Holidays (1)	1 to 5 days (2) Varies (1)

Snapshot based on questionnaires received and selected clarification interviews.

III. NEEDS ASSESSMENT

Overview

This part of the update process was performed to determine the short-term needs in the region. Five stakeholder meetings were held between September 2012 and June 2013 where stakeholders reported and assessed their signal system improvements needs. The specific needs were expressed through a call for projects that was analyzed by DRCOG staff and the RTO work group to identify specific areas for capital improvements.

Several new needs arose from the stakeholder meetings, including:

- conversion from serial to Ethernet communications is needed to improve real-time monitoring and error detection/reporting;
- additional planning and evaluation support is required for traffic-adaptive control, flashing yellow arrow operations, bicycle detection, and other advanced functions;
- several agencies note that both controllers and signal systems are approaching obsolescence.

The eligibility of projects was modified in the call for projects to account for these new needs.

Call for Projects

Ten jurisdictions (Arapahoe County, Arvada, Aurora, Brighton, City and County of Broomfield, CDOT Region 1, Centennial, City and County Denver, Jefferson County, and Thornton) submitted applications for various system/communications improvements. Some projects were not eligible, and some projects were not selected for funding. The total funding request in this TSSIP update is estimated at approximately $14.6 million. This section summarizes the results of the call for projects.

Arapahoe County.....*Traffic signal system replacement/upgrade*

This project requests funding to replace the existing traffic signal system. The main goal/justification of the project is to provide advanced system capabilities including effectively support center-to-center functionality (i.e., regional signal control, cross-jurisdictional incident management, and regional traffic data sharing/warehousing) not available in Arapahoe County's current system. This change also supports Arapahoe County's goal to convert all traffic signal communications to Ethernet.

The traffic signal system selected through the bid led by Denver may be procured as soon as Denver's negotiations are complete. If this option is not exercised, a system selection study and competitive procurement will be required for this project.

Arapahoe County ..... *Extend the reach of system control*

This project requests funding to extend system communications to three signals on Jordan Road from Broncos Parkway to Otero Way and one signal at Broncos Parkway and Cherokee Trail. The main goal/justification of the project is to connect this signal to Arapahoe County's signal system and provide a base-level system control capability and coordination reliability.

A design or PS&E (plans, specifications and estimate) package will be required for this project.

City of Aurora..... *Special project: time-of-day flashing yellow arrow implementation*

This project requests funding to implement time-of-day flashing yellow arrow operations at:

- Four intersection on Airport Boulevard/Buckley Road from Colfax Avenue to Quincy Avenue; and,
- Five intersections on Chambers Road from Colfax Avenue to Hampden Avenue.

The purpose of the project is to establish pilot locations to be evaluated for the benefit of the TSSIP. This project involves the installation of a number of new signal heads and retrofitting cabinets to support the flashing yellow operations.

A design or PS&E package is not required for this project. This project requested signal heads, which is not normally eligible under the TSSIP. As such, the RTO work group did not support this project and it was removed from consideration for funding.

City of Brighton (1) ..... *Provide a traffic signal system*

This project requests funding to provide a traffic signal system where one currently does not exist. The main goal/justification is to provide City of Brighton staff the ability to monitor and manage the traffic signals in their jurisdiction. To align with the goals and objectives of the RCTO, the traffic signal system will include advanced system capabilities to effectively support center-to-center functionality (i.e., regional signal control, cross-jurisdictional incident management, and regional traffic data sharing/warehousing).

The traffic signal system selected through the bid led by Denver may be procured as soon as Denver's negotiations are complete. If this option is not exercised, a system selection study and competitive procurement will be required for this project.

City of Brighton (2) ..... *Extend the reach of system control*

This project requests funding to extend system communications to the 21 key signals under Brighton's jurisdiction, including:

- Bridge Street from Main Street to 27th Avenue.
- Bromley Lane from Fulton Street to Judicial Center Drive.
- 27th Avenue from 136th Avenue to Bridge Street.

The main goal/justification of the project is to connect these signals to Brighton's signal system and providing both base-level and advanced system control capability and coordination reliability.

A design or PS&E package will be required for each subproject. This project will also include a communications needs analysis and design.

City and County of Broomfield (1) ..... *Replace/upgrade unreliable communications*

This project requests funding to replace the existing spread spectrum radio communications along Sheridan Boulevard from 1st Avenue to Dillon Road. The main goal/justification is to replace unreliable communications due to foliage along this roadway periodically interrupting communications.

A design or PS&E package will be required for this project.

City and County of Broomfield (2) ..... *Replace/upgrade unreliable communications*

This project requests funding to replace the existing spread spectrum radio communications along Midway Boulevard from Garden Center to Center Street. The main goal/justification is to replace unreliable communications. TRC operations along this corridor are sensitive to the unreliable communications.

A design or PS&E package will be required for this project. This corridor is a Minor Arterial and the annual daily traffic volumes do not exceed the thresholds. This project was removed from consideration for funding.

CDOT Region 1 (1)..... *Replace/upgrade unreliable communications*

This project requests funding to replace/upgrade existing unreliable radio communication with fiber-optic communications on three key corridors for a total of 11 signal locations:

- University Blvd. [SH 177] from Arapahoe Road to Hampden Avenue.
- Federal Blvd. [SH 88] from Bellewood Drive to Hampden Avenue.
- Belleview Avenue [SH 88] from Holly Street to Quebec Street (which currently lacks any communications).

The main goal/justification is to both eliminate excessive communication drops due to interference and improve reliability of signal timing operations.

A design or PS&E package will be required for each of the corridor sub-projects.

CDOT Region 1 (2)..... *Replace/upgrade unreliable communications*

This project requests funding to replace/upgrade existing unreliable radio communication with fiber-optic communications on two corridors for 7 signal locations:

- Broadway (SH 53) from I-25 to 70th Avenue.
- Morrison Road (SH 8) from C-470 to Maple Street.

The main goal/justification is to both eliminate excessive communication drops due to interference and improve reliability of signal timing operations.

A design or PS&E package will be required for each of the corridor sub-projects. Broadway is a Minor Arterial and the annual daily traffic volumes do not exceed the thresholds. Morrison Road is a Collector and is not eligible for funding. Both projects were removed from consideration for funding.

City of Centennial (1) .....*Extend the reach of system control*

This project requests funding to extend system control to Arapahoe Road from Chapparal Road to Himalaya Way for a total of thee traffic signals. The main goal/justification is to provide a base-level system control capability and coordination reliability.

A design or PS&E package will be required for this project.

City of Centennial (2)..... *Corridor performance monitoring*

This project will implement a performance monitoring system that is aligned with the RCTO and CDOT's *Regional Integrated Traveler Information Display Guidelines*. The main goal/justification is to collect performance measures data that will allow operators to take action to improve coordination reliability. Secondarily, this information will be useful as traveler information.

A systems engineering analysis and a design or PS&E package will be required for this project.

City and County of Denver (1) ..... *Replace/upgrade unreliable communications*

This project will update/upgrade signalized intersection equipment to Ethernet communications and will install uninterruptable power supplies (UPS) on Speer Boulevard, Colorado Boulevard, the CBD core area, and the DTC area for a total of 251 signal locations. The main goal/justification of the project is to re-attain timing and coordination reliability. Denver has documented issues with signals that are on system drifting from the universal coordinated time, which often leads to the signal going into transition, leaving the signal uncoordinated.

A design or PS&E package will be needed for each sub-project.

Jefferson County (1).....*Replace/upgrade central control signal system*

This project will replace/upgrade Jefferson County's central control signal system. The main goal/justification of the project is to provide advanced system capabilities including effectively support center-to-center functionality (i.e., regional signal control, cross-jurisdictional incident management, and regional traffic data sharing/warehousing) not available in Jefferson County's current system.

This project also includes implementation of controllers and communications equipment upgrades compatible with the system that provide functions beyond base level signal control. The key corridors in this project are:

- McIntyre Street: 60th Avenue - 44th Avenue
- CR 73: Buffalo Park Road - Kitty Drive
- Bowles Avenue: Coal Mine Avenue - Grant Ranch
- Kipling Parkway: Progress Avenue - Remington Avenue
- Ken Caryl Avenue: Shaffer Parkway - Depew Street

A design or PS&E package will be needed for each sub-project.

The traffic signal system selected through the bid led by Denver may be procured as soon as Denver's negotiations are complete. If this option is not exercised, a system selection study and competitive procurement will be required for this project.

City of Thornton (1) .....*Replace/upgrade central control signal system*

This project will replace/upgrade Thornton's central control signal system. The main goal/justification of the project is to provide advanced system capabilities including effectively support center-to-center functionality (i.e., regional signal control, cross-jurisdictional incident management, and regional traffic data sharing/warehousing) not available in Thornton's current system.

This project also includes: the implementation of controllers and communications equipment upgrades that are compatible with the system and provide functions beyond base level signal control; and upgrades of communications that will allow more efficient allocation of fiber to allow growth and expansion in the signal system network among other benefits. The key corridors in the project are:

- Washington Street: 160th Avenue - SH-7
- SH-7: 160th Avenue - York Street
- Washington Street: 83rd Drive – 102nd Avenue
- Thornton Parkway: Pecos Street - York Street
- 144th Avenue: Lincoln Street - Washington Street
- Colorado Boulevard: 88th Avenue - 144th Avenue

- Thornton Parkway & Welby Road
- 136th Avenue: High Street - Washington Street
- 104th Avenue: York Street - McKay Road
- 88th Avenue: Pecos Street - Dahlia Street
- 84th Avenue: Huron Street - Grant Street
- Huron Street: 84th Avenue - Fire Station #2
- 120th Avenue: I-25 - Quebec Street
- Washington Street: 121st Avenue - 134th Avenue
- Washington Street: 120th Avenue - 124th Avenue
- Colorado Boulevard: 115th Avenue - 120th Avenue

A design or PS&E package will be needed for each sub-project.

The traffic signal system selected through the bid led by Denver may be procured as soon as Denver's negotiations are complete. If this option is not exercised, a system selection study and competitive procurement will be required for this project.

Special Project (1) ..... *Regional CMAQ Benefits Study*

In this TSSIP update, operating agencies recommended that the region needs a consistent means to evaluate the CMAQ benefits related to advanced function projects that cannot be evaluated by the program's existing process of collecting before and after travel run data and calculating the benefits.

DRCOG staff, with the regional jurisdictions as partners, will lead a study that will develop both a matrix to assist in the estimation of advanced function project benefits prior to implementation and a process to measure/evaluate the direct CMAQ benefits of the project after implementation.

Special Project (2) ..... *Pilot traffic-adaptive control implementations*

Three jurisdictions requested funds for equipment and implementation support involving traffic-adaptive control operations:

- CDOT Region 1 requested funds for traffic-adaptive control at I-76 and 88th Avenue to address unpredictable traffic volumes at the signals in this area due to the Mile High Flea Market. It is possible that coordination may also be required with Thornton signals near to the area.
- Denver requested funds for traffic-adaptive control in the Denver Technology Center between Belleview Avenue and I-225. This request also includes the implementation of monitoring equipment including system detectors and closed-circuit television (CCTV) cameras. The nature of operations in this

area also requires multi-agency participation and coordination with CDOT and Greenwood Village.

- Centennial requested funds for traffic-adaptive control at and around the I-25/Arapahoe Road interchange. This request also includes the implementation of monitoring equipment including system detectors and CCTV cameras. The nature of operations in this area also requires multi-agency participation and coordination with CDOT and Greenwood Village.

The FHWA requires that projects that involve traffic-adaptive control must follow the systems engineering process in the development, design, implementation and evaluation of this project. In particular, the FHWA recommends the use of *Model Systems Engineering Documents for Adaptive Signal Control Technology (ASCT) Systems* to guide the systems engineering analysis.

DRCOG will lead the systems engineering analysis effort in partnership with the project sponsors and stakeholders. It is recognized that implementation of traffic-adaptive control may not be the final results of the systems engineering analysis. As such, a reserve of funds is established to fund between one and three pilot traffic-adaptive implementations that DRCOG will subsequently evaluate.

Special Project (3) .....*Multimodal Operations Support and Other Pilot Implementations*

Two projects were submitted that request funds that either provide multimodal operations support or identify pilot projects. In particular, Denver submitted a project requesting funds to implement bicycle detection and select signals across its jurisdiction. Denver also submitted a project requesting funds to implement interactive speed signs along key corridors with the intent of controlling the speed to fall within the progression green band.

For the former, Denver and DRCOG are already partnered on a bicycle detection implementation and evaluation. The program will await the results of that evaluation before consideration further investment. For the latter, the RTO work group expressed interest in the project, but felt that the project development was not yet sufficiently complete to allow a successful pilot implementation.

As such, a reserve for these projects will be maintained and will be open for the RTO work group will establish a process for identifying and selecting multimodal and other novel projects (e.g. center-to-center applications) for either pilot implementation or expansion as the program progresses.

Timing and Coordination on Key Corridors

The ultimate goal of this program is to use the traffic signal control systems to provide optimal timing and coordination to reduce stops and delays, corridor travel time, fuel consumption, criteria air pollutant emissions, and greenhouse gas emissions. On average,

the program aims to retime approximately 250 signals each year. Experience continues to show signal timing and corridor coordination should be updated (or at least reevaluated) on key corridors on a three- to five-year cycle. While some jurisdictions have this capability, there remains a need for the program to assist others that do not, especially for corridors that cross jurisdictional boundaries.

Traditionally, weekday timing and coordination plans for morning peak, afternoon peak, and off-peak periods are developed. In more heavily traveled corridors, the program has been developing a weekday plan for noon-peak. The trend of using additional weekday plans is expected to continue. Weekend timing and coordination improvements are also identified as a critical need for many corridors. However, it is noted that development of weekend plans adds cost and generally achieves fewer benefits.

Summary of Critical Needs

Table 7 summarizes needs identified by the workgroup and the estimated cost required to fully implement those needs.

Table 7
Summary of Critical Needs

I. INSUFFICIENT/UNRELIABLE COMMUNICATIONS

Seven corridors or projects with about 230 signals.

II. KEY SIGNALS NOT ON A SYSTEM

Five corridors/areas or projects with about 28 signals.

III. IMPROVEMENTS FOR HIGHER EFFICIENCY BEYOND BASE-LEVEL SIGNAL CONTROL

1. Upgrade to traffic signal control system with advanced functions for Arapahoe County, Brighton, Jefferson County, Thornton.
2. Implement IP/Ethernet technology for more efficient system communication for Thornton.
3. Implement controllers compatible with advanced function systems for Thornton and Jefferson County.

IV. SPECIAL PROJECTS

1. Implement pilot advanced function traffic management equipment and modules including traffic-adaptive control.
2. Implement advanced function traffic management equipment and modules to benefit transit, bicycles and pedestrians.
3. Complete a CMAQ benefits study that establishes base benefits estimates and the benefits evaluation processes for advanced function operations strategies and deployments in this region.
4. Implement system and operations performance monitoring system and equipment for Centennial.

V. TRAFFIC SIGNAL TIMING PLANS FOR MORE CORRIDORS AND SITUATIONS

Costs for Capital/Special Projects:

Funding requested: $14.6 million
Funding available: $13.2 million

IV. IMPLEMENTATION

Overview

This section presents an implementation program/schedule that identifies the best mix of projects to continue improving the regional signal control system and provides the most benefits to the region within available resources. Sufficient funding is not available to fully address the needs identified by the operating agencies over the next six years.

Funds Available

The implementation plan was developed based on a level of funding consistent with current program allocations, and extended to 2019, as shown in Table 8. Fiscal years 2014 and 2015 have an approved allocation of $3.7 million each in the *2012-2017 Transportation Improvement Program* (TIP) *Policy*. Available program savings of about $700,000 have been added to fiscal year 2014. Fiscal years 2016 through 2019 are projected at the same annual level as previous fiscal years, assuming that the DRCOG Board continues to support this program at that level of funding.

Table 8
Funding for Implementation Program ($1,000)

	Fiscal Year[1]						
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
Regional Traffic Signal System Improvement Program*	$4,440	$3,700	$3,700[2]	$3,700[2]	$3,700[2]	$3,700[2]	$22,940

[1] In "year-of-expenditure" dollars.
[2] Funding level assumptions. Funding levels to be set in upcoming TIP Policy definition.

About $2.2 million of the annual expenditure will be directed towards the capital needs identified in the previous chapter (total of about $13.2 million to address the $14.6 million need).

Prioritization and Implementation Rationale

The implementation program was developed by prioritizing projects and activities based on regional consideration and general consensus from the stakeholders and DRCOG:

- The criticality of the need (higher priority was assigned to corridors/projects addressing key signals not on system, insufficient communications, and/or obsolete systems)
- The capability of the project to advances the RCTO goals and objectives
- Cost effectiveness (lower priority was assigned to improvements with a high cost per signal)

- The importance of the corridor (priority based on roadway classifications)
- Strategic communications links
- Local priorities and synergies among projects

In general, providing base-level signal control is considered higher priority than advanced capabilities because it expands or improves system control and maximizes documentable benefits. However, the stakeholders felt it was important for the program to continue to pursue advanced functionalities identified in the needs assessment process, such as multimodal operations, effective measuring and reporting of system performance, and coordinated corridor management and operations.

Implementation Program Elements

The implementation program consists of four categories of activities:

- Capital improvements and special projects
- Contingency and miscellaneous equipment purchases
- Signal timing and coordination
- System engineering and design

The funding breakdown for these activities, for the typical annual total of $3.7 million, is about $2.2 million for capital improvements; about $300,000 for contingency and miscellaneous equipment purchases; about $1.0 million for signal timing and coordination; and about $200,000 for system engineering and design.

Capital Program

The capital program would replace insufficient or unreliable communication on key corridors, extend the reach of existing systems to key signals not on system, and provide higher efficiency systems and equipment in support of desirable regional ITS applications.

Table 9 presents the corridors/projects identified to implement the above actions and the year(s) these projects will be pursued. The schedule for implementation was determined based on the following principles:

- Generally try to fund higher priority projects first
- Break some larger projects at relevant breakpoints if needed
- Fund Denver projects somewhat uniformly over the years
- Avoid conflicts with known/planned roadway construction
- Recognize jurisdictional capabilities for implementation
- Consider project synergy and project capabilities that advance the RCTO goals and objectives

Table 9
Signal System Capital Improvement Projects

Project/Description/Location		FY14	FY15	FY16	FY17	FY18	FY19
Insufficient or Unreliable System Communication							
Broomfield	Sheridan Blvd: 1st Ave - Dillon Rd						X
CDOT Region 1	University Blvd (SH 177): Arapahoe Rd - Hampden Ave (US 285)	X					
	Federal Blvd (SH 88): Bellewood Dr -Hampden Ave (US 285)			X			
Denver	Colorado Blvd: 1st Ave - 50th Ave Speer Blvd: Elitches - 13th Ave		X				
	Central Business District (CBD) Ph 1					X	
	Central Business District (CBD) Ph 2			X	X		
	DTC Blvd: Tamara St - Union Ave	X					
Key Signals Not on System							
Arapahoe County	Jordan Rd: Broncos Pkwy - Otero Ave Broncos Pkwy & Cherokee Trail	X					
Brighton	Bridge St: Main St - 27th Ave	X					
	Bromley Ln: Fulton St - Judicial Center Dr 27th Ave: 136th Ave - Bridge St		X				
CDOT Region 1	Belleview Ave (SH 88): Holly St - Quebec St		X				
Centennial	Arapahoe Rd: Chapparal Rd - Himalaya Way		X				
Advanced Functionalities and Special Projects							
Arapahoe County	Next generation system replacement/upgrade	X					
Brighton	Traffic signal system procurement	X					
Centennial**	City-wide performance monitoring system					X	
DRCOG	Regional CMAQ Benefits Study	X					
Jefferson County	Next generation system replacement/upgrade and compatible controller and communications upgrades. McIntyre St: 60th Ave - 44th Ave CR 73: Buffalo Park Rd - Kitty Dr Bowles Ave: Coal Mine Ave - Grant Ranch Kipling Pkwy: Progress Ave - Remmington Ave Ken Caryl Ave: Shaffer Pkwy - Depew St	X					
Thornton	Next generation system replacement/upgrade and compatible controller and communications upgrades. Washington St: 160th Ave - SH-7 SH-7: 160th Ave - York St Washington St: 83rd Dr - 102nd Ave Thornton Pkwy: Pecos St - York St 144th Ave: Lincoln St - Washington St Colorado Blvd: 88th Ave - 144th Ave Thornton Pkwy & Welby Rd 136th Ave: High St - Washington St 104th Ave: York St - McKay Rd 88th Ave: Pecos St - Dahlia St 84th Ave: Huron St - Grant St Huron St: 84th Ave - Fire Station #2 120th Ave: I-25 - Quebec St Washington St: 121st Ave - 134th Ave Washington St: 120th Ave - 124th Ave Colorado Blvd: 115th Ave - 120th Ave	X	X	X	X	X	
Contingency/Misc. Equipment**		X	X	X	X	X	X
Reserve (Multimodal Operations and Other Pilot Projects)**				X	X		X
Reserve (Traffic-adaptive control)**							X
Estimated Expenditure (2013 constant)		**$3,047,000**	**$2,418,000**	**$2,464,000**	**$2,247,000**	**$2,289,000**	**$2,203,100**
Estimated Expenditure (YOE)*		**$3,047,000**	**$2,491,000**	**$2,613,000**	**$2,456,000**	**$2,576,000**	**$2,554,000**

* A 3% inflation rate is assumed for each year after FY14.
** All or portions of these project will require local match.

System Engineering and Design

Systems and operation plans must be prepared to implement the capital improvements in the TSSIP. The system and operation plans will address the following issues:

- Conditions of existing system/operation
- Relevant hardware/software improvements
- Communications media
- Implementation details
- System operation and roles and responsibilities
- Operation protocols

The recommendations of the system plan are implemented either through equipment purchases with installation by local forces, or through a formal design process leading to bids and construction. As necessary, design activities are funded through this category within the program. The program will also fund coordination of regional transportation management and operations tasks when feasible and applicable for traffic signal system improvement.

Contingency and Miscellaneous Equipment Purchases

A contingency and miscellaneous equipment category is included as it was in the original TSSIP and the previous updates. These funds ensure that projects can proceed to construction if actual costs exceed the conceptual estimates developed for this update. Once it is certain that identified construction projects can progress, remaining contingency funds are used for miscellaneous traffic signal equipment purchases. To a limited extent this allows capital projects from later years of the program to be advanced, funds critical needs that had to be deferred to stay within the budget, and provides a way to address evolving needs in response to growth and development. The stakeholders suggested the category be funded at about $300,000.

In this update, additional funds have been included in the contingency category to be available as operating assistance for the operating agencies that implement a new traffic signal control system. The operating assistance is intended to be in the form of extended service/support from the system vendor, which will assist operating agencies with their transition to the new system. The operating agencies may apply for operating assistance funding as part of the miscellaneous equipment purchase program.

Signal Timing and Coordination Studies

This fundamental program element anticipates continued development of new TOD timing plans on a recurring basis in a three- to five-year cycle for major corridors and for all capital projects implemented (including miscellaneous signal equipment purchases). In addition, some funds will be targeted for selectively developing TOD plans that address weekend traffic patterns and other advanced function strategies. Development and evaluation of timing plans for advanced function strategies will be directed by the DRCOG study that will both define the

evaluation processes for determining CMAQ benefits and the baseline estimates of CMAQ benefits for each project type.

DRCOG Traffic Operations Program Responsibilities

DRCOG's Traffic Operations Program (TOP) will be responsible for managing and implementing the TSSIP, with each activity pursued in partnership with the operating agency(s).

- The TOP will prepare system and operation plans in advance of design for capital improvement projects and will fund for the construction design. Once the new or upgraded systems are brought on-line, new timing and coordination plans will be developed and implemented cooperatively with the project sponsor and other stakeholders.

- The TOP will conduct data collection and analysis, develop coordination plans, and assist with the implementation, field verification and fine-tuning of coordination plans. The TOP will conduct an effectiveness evaluation and document results, plus assist with ongoing validation as requested by the operating agencies. The TOP will also pursue the recurring corridor-timing program, and will develop more timing plans for more situations including weekend traffic and potentially traffic-adaptive implementations.

- The TOP will conduct a study to define the processes and methods to determine CMAQ benefits for advanced function strategies.

- For the funds reserved for traffic-adaptive operations and other advanced functions, the TOP will lead the project stakeholders in the systems engineering analysis effort and will coordinate with the RTO work group to determine specifically how the reserved funds will be allocated.

It is important for operating agencies to develop and sustain programs that allow achievement of their own goals, with assistance and support from the TSSIP. TSSIP funds are not sufficient for DRCOG to honor all possible requests.

Benefits and Program Effectiveness

Determining and documenting the benefits and effectiveness of currently ongoing and programmed projects is critical to this program update. Because the TSSIP is funded with federal Congestion Mitigation/Air Quality funds, the benefits of every project must be measured and reported. The program's primary documentable benefits result from the regular retiming of major arterials. Making capital improvements provides an enhanced platform to implement this retiming and helps maintain reliable coordination. Drivers, passengers, truckers, service vehicles, bicyclists and pedestrians all benefit from improved signal timing and coordination. In addition, direct support for alternate travel modes in signal operations is also expected to positively impact the use of those alternate modes. Fewer stops and less delay saves time, money, and reduces air pollution for everyone. Based on the past efforts, travel times on

individual corridors are expected to be reduced on average by between five and fifteen percent. Each year, the program is expected to reduce around 10,000 vehicle hours of travel (VHT) per day, approximately 1,000 pounds of criteria pollutant emissions per day, and approximately 38 tons of greenhouse gas emissions per day.

Two forms of advanced signal operations have been implemented and evaluated in the region: TRC and TSP. TRC projects generated about two to four percent more benefits above the associated TOD plans optimization. For TSP projects, simulation results from the regional TSP study suggest similar benefits can be expected from TSP implementation. However, field results have yet to replicate those benefits – improvements in the systems capability to monitor performance are required.

BOARD RESOLUTION

DENVER REGIONAL COUNCIL OF GOVERNMENTS

STATE OF COLORADO

BOARD OF DIRECTORS RESOLUTION NO. 11, 2013

A RESOLUTION ADOPTING THE *TRAFFIC SIGNAL SYSTEM IMPROVEMENT PROGRAM 2013 UPDATE.*

WHEREAS, the Denver Regional Council of Governments conducts a traffic operations program to assist local governments and the state in improving the efficiency of traffic signals in the region; and

WHEREAS, the efficient operation of traffic signals assists in relieving congestion, conserving energy, and reducing air pollutant emissions; and

WHEREAS, the Traffic Signal System Improvement Program was prepared by the Denver Regional Council of Governments in cooperation with local governments and the Colorado Department of Transportation and describes needed improvements of the region's traffic signal system and identified an implementation program to pursue these improvements; and

WHEREAS, the Board of Directors Resolution No. 3, 1994 approved and Resolutions No. 12, 1996, No. 24, 1999, No. 11, 2003, No.14, 2007, No. 17, 2010, updated the Traffic Signal System Improvement Program to provide guidance for implementation and the work activities of the traffic operations program from 1993 through 2016; and

WHEREAS, the Denver Regional Council of Governments, in cooperation with local governments, the Colorado Department of Transportation and the Regional Transportation District, has prepared another update of the Traffic Signal System Improvement Program extending the implementation program to fiscal years 2014-2019; and

WHEREAS, the Regional Transportation Committee of the Denver Regional Council of Governments has recommended approval of the *Traffic Signal System Improvement Program 2010 Update.*

NOW, THEREFORE, BE IT RESOLVED that the Denver Regional Council of Governments hereby approves the *Traffic Signal System Improvement Program 2013 Update* to provide guidance for the implementation of cost-effective traffic signal system, timing and coordination improvements over fiscal years 2014-2019 and for the work activities of the traffic operations program.

RESOLVED, PASSED AND ADOPTED this 18th day of September, 2013 at Denver, Colorado.

Jack Hilbert, Vice Chair
Board of Directors
Denver Regional Council of Governments

ATTEST:

Jennifer Schaufele, Executive Director

Mobility

DRCOG

DENVER REGIONAL COUNCIL OF GOVERNMENTS

We make life better!

Traffic Signal System Improvement Program

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