Expect delays on I-25

Prepared by:
Colorado Department of Transportation
in cooperation with
Denver Regional Council of Governments
Denver Regional Integrated
Traveler Information
Display Map Guidelines

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ACRONYMS AND ABBREVIATIONS

AVI.............................................................. Automated Vehicle Identification
AWAM..................................................Anonymous Wireless Address Matching
CADD......................................................Computer Aided Dispatch System
CCTM......................................................City and County Traffic Management
CDOT...................................................Colorado Department of Transportation
COTRIP..................................................Colorado Highway Traveler Information Website
CTMS....................................................Colorado Traffic Management System
DOT..........................................................Department of Transportation
DRCOG.............................................Denver Regional Council of Governments
FHWA..................................................Federal Highway Administration
GIS........................................................Geographic Information Systems
H.............................................................High
ITS.........................................................Intelligent Transportation Systems
L.............................................................Low
MPO........................................................Metropolitan Planning Organization
MOE........................................................Measures of Effectiveness
MSA........................................................Metropolitan Statistical Area
P..............................................................Point
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P2P .................................................................................Point-to-Point

PTI .................................................................................Planning Time Index

PTZ .................................................................................Pan Tilt Zoom

TMC .................................................................................Traffic Messaging Channel

TOD .................................................................................Time of Day

T.T.I .................................................................................Toll Tag Indicator

TTI .................................................................................Travel Time Index

VMS .................................................................................Variable Message Sign

WSDOT .................................................................Washington Department of Transportation

XML .................................................................................Extensible Markup Language
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1. Introduction

1.1 Background and Problem Definition

Over the past few years, significant resources have been invested by State Departments of Transportation in providing real-time travel conditions on Interstates. This information is being provided on the roadway, traveler information websites, and traveler information phone systems. These applications are generally at a mature and advanced state of development. More recently, several local agencies (Cities and Counties) across the United States have begun providing real-time travel condition information on the highway and arterial networks. These applications are at a relatively new stage of development.

With only two local development applications in the Denver Metropolitan Area - the City and County of Denver application and the Douglas County application, it is evident that the data collection, processing and dissemination of road condition information can be accomplished in different ways. The review of few other applications across the United States reveals a similar trend. i.e., there is not much consistency and standardization in how data is being collected, processed and disseminated. Furthermore, it is not clear how the information is intended to be used.

Additionally, there is lack of clarity on the purpose of such applications, and the intended audience. Within the Region, it was not clear if the purpose of such applications is for travelling public or the operators. The problem is further compounded when the arterial condition information needs to be integrated with neighboring jurisdictions and the State DOT. From a travelling public perspective, the traveler information is expected to be consistent, reliable and timely regardless of jurisdictional boundaries.

Additionally, FHWA Rule Title 23 Part 511 Subpart C- Federal Register Volume 75, Number 215, pages 68427-68429, effective December 23, 2010 mandates that state and local agencies provide real-time traveler information systems on Interstates and Routes of Significance.
are specific requirements on implementation date and data quality parameters. This mandate will lead to more implementation across the Denver region, Colorado and the United States.

Therefore, CDOT, DRCOG and local agency stakeholders have decided to undertake this project to proactively address the above concerns and lay a solid foundation that will develop consistent, understandable and meaningful information to the public and operators on arterial road conditions. The project will provide guidelines for display and use of arterial travel conditions. The absence of such guidelines could lead to inconsistency in how data is collected and, processed, displayed, reported and stored.

1.2 Project Goals

The goals of the project are to:

- Investigate how speed and/or travel time data is currently being displayed within Regional stakeholder jurisdictions and rational/basis that was used for displaying it in such manner, and research two to three other large urbanized areas in the continental United States to determine similarities and differences in order to identify best practices.

- Develop inter-agency consensus on the elements such as: protocols, methodologies, data elements and parameters needed in order to have a common map display and database.

- Conduct stakeholder working group meetings and identify specific information obtained during investigation and research and how this pertains to maps and how to display it to achieve a common “look and feel” for these displays on all agency websites.

- Develop a Report that documents all findings and recommends a preferred approach regarding displaying local jurisdiction speeds and/or travel times on local and regional maps.
The overall intent of the project is to provide a reasonable first step toward development of consistent map display, which uses the same data and generates the same information for all local jurisdictions in the DRCOG region. This consistency is imperative to provide the traveling public with understandable and meaningful information regarding local arterial travel times, speeds and road conditions.

1.3 Report Outline

In addition to Section 1 Introduction, this guidelines report contains three other sections as follows:

Section 2 – Existing Applications and Best Practices: Presents the current technologies and practices being used in the Denver area and also in areas outside of the State.

Section 3 – Guidelines for the Denver Region: This section provides guidelines for displaying arterial conditions in the Denver Region.

Section 4 – Conclusions and Next Steps: This section discusses the implications of the guidelines, marketing the usage of the data to other non-traffic departments or agencies and identifies the immediate next steps.

1.4 Guidelines Development Process and Organization

As part of the guidelines development process, the project stakeholders reviewed existing traveler information applications in Colorado and across United States. The detailed review included criteria and technology used, device placement, density, color coding schemes, web display and other relevant information. Based on this in-depth review and evaluation, the stakeholders in the Denver Region identified and agreed upon the following travel condition data parameters, which are listed in priority order.

- Travel time
- Traffic incident information
- Weather related road condition information
- Construction and maintenance operations information
• Traffic video (image and full motion)
• Event information and parking information for events
• Speed
• Queues
• Volume
• Occupancy

Appendix A shows the implementation factors associated with travel data condition parameters and the Regional priority ranking for each travel condition data parameter.

The Guidelines for the Denver Region begin in Section 3 and are organized as shown below:

Section 3.1 - addresses who will use the arterial travel condition information.
Section 3.2 - addresses on which roadways the arterial travel condition information should be provided.
Section 3.3 - identifies how operators need to work together to implement the guidelines.
Section 3.4 - provides guidelines for each travel condition data parameter as follows:
  • Type of device for data collection
  • Placement of the devices
  • Data collection, processing and display
  • Time intervals
  • Measures of Effectiveness (MOE)
  • Usefulness to the operators and others
  • Others that apply
Sections 3.5 –3.9 - provide guidelines regarding the following regional level issues:
  • Data quality
  • Data dissemination
  • Base map
  • Archiving
  • Alarms
- Performance measures report card
- Typical scenario for operator
- Reporting
2. Existing Applications and Best Practices

This section provides a summary on each of the local and out-of-state applications that were examined for the project. The information presented in this section was collected through discussions with the local agency operators and review of existing documentation. The discussion and review covered the following:

- Selection of particular type of detection equipment – to understand if certain types of equipment are well suited for arterial conditions applications
- Data collection device placement – to understand agency operator’s experience regarding the placement of the data collection devices and ability to get accurate information
- Data collection device density – to understand impact of device density on accuracy
- Selection of arterials for implementation – to understand the selection of arterials for implementation
- Overall arterial conditions analysis and display logic – to see how the data is collected, processed and displayed
- Validation – to understand how agencies verified the information
- Data update intervals – to understand acceptable update intervals
- General costs – to understand general costs associated with implementation

2.1 Existing Applications in Colorado

In Colorado, three local jurisdictions are providing arterial travel condition information. The jurisdictions include City and County of Denver, City of Fort Collins and Douglas County.

2.1.1 City and County of Denver

Currently, Denver provides travel condition information on Colfax Avenue and Speer Boulevard. Denver will be expanding the application to Colorado Boulevard by end of 2012. These implementations projects are funded by Denver Regional Council of Governments (DRCOG) through the ITS Pool Project Program. The selection of the corridors was based on available
data collection equipment and proximity to Interstates. The proximity to the Interstates serves as an extension of travel condition information as the COTRIP website has Interstate real-time and travel condition information. The cost for data collection for each arterial segment was around $20,000 and the software configuration for the corridor is around $50,000.

The City intentionally uses different data collection technologies for collecting travel condition information including video detection, radar, etc. This allows the City to evaluate the different technologies. Typically, the data collection device placement captures slightly beyond the normal queue backup of the approach. The detection placement is also dependent on the availability of power and communication. Denver’s algorithm uses “Point” speed and occupancy as the primary measures to report segment conditions. Congestion thresholds are set based on specific arterial segment and what are considered to be its normal operations. Each corridor is divided into segments and each segment is typically from 0.25 mile to one mile. Typically, there are at least two data collection devices in each segment. The signal system server is being used to collect the data from video detection and a software patch was developed to export the data to CDOT’s Colorado Traffic Management System (CTMS) server for processing of data.

For all other data collection devices, the data is directly collected by the CTMS server for processing. The processed data is then posted to the COTRIP website. The refresh rate is two minutes. However, the total time for point data collected in the field, collected by the server, processed and posted on website could be a maximum of six minutes. The travel condition information is available on the COTRIP website and cell phone application. This allows Interstates and arterial condition information to be displayed on the same website and cell phone application. There is a link from the City’s website to the COTRIP site. CDOT uses the Google map base to show travel conditions and the users have the ability to use zoom in/out. The City intends to post the travel condition information on Variable Message Signs (VMS) in the future. The travel conditions on the arterials are shown using the same color coding scheme used to show travel conditions on Interstates as shown in Figure 1. The travel conditions on Interstates are primarily “Point” speed but some segments include “Point to Point” speed data. The legend
for the color coding scheme for travel conditions on arterials is descriptive i.e., moving well, slowing, heavy traffic, very congested and no data. No incident, construction and event information is included with travel condition information on arterials.

For Colorado Boulevard, the City will be using Toll Tag Indicators (TTI) to collect “Point-to-Point” travel time. This will be supplemented with “Point” speed and occupancy data. This corridor will be implemented in late 2012. The City plans to collect travel time information along the corridors on all future implementations.

**Figure 1: Denver Arterial Travel Conditions on COTRIP website**

![Figure 1: Denver Arterial Travel Conditions on COTRIP website](image)

### 2.1.2 City of Fort Collins

The City was displaying arterial travel condition information on all major arterials using a web-based application. The project was funded through the North Front Range Metropolitan Planning Organization, and cost approximately $400,000 to implement the application. The majority of data for the travel condition information was collected by pucks imbedded in the roadway. The primary reason for using the pucks was the lower cost as it allowed for wireless communications. Typically, these data collection devices were placed about 500 feet to 800 feet from the signalized intersection. The City also used video detection for data collection and they were typically closer to the signalized intersection. Segments were about 1 mile long. The data was collected at the server (not signal system server), then processed and posted to the City website.
The City used “Point” volume and occupancy as a measure of congestion. The data was collected in five minute intervals and website was refreshed every five minutes.

The travel condition information was available on the City’s website. Travel condition information available on Interstates was not considered for inclusion. The City used a custom map for the application, which did not have zoom capability. The travel conditions on the arterials followed a three color coding scheme as shown in Figure 2. The legend for the color coding scheme for travel conditions described congestion as low, moderate or high. The City posted known construction and incident information manually. The website showed cameras along the arterials and displayed camera images. Recently, the City decided to temporarily suspend the travel condition application due to staff’s concern that the information may not be reliable. The city continues to post construction and maintenance information on the website. It also allows access to camera images via the website.

**Figure 2: FCtrip Web-based Application used by Fort Collins**

2.1.3 **Douglas County**

Currently, Douglas County has implemented the arterial conditions application for two major arterials; Lincoln Avenue and Quebec Street. The project is being funded by DRCOG through the ITS Pool Project Program. The selection of the corridors was based on available data
collection equipment and proximity to Interstates and Interstates. The cost to implement the application will be available shortly. For data collection, the County primarily uses TTIs and supplements with a radar unit. The County provides travel condition and travel time information along the corridors. The TTIs collects “Point to Point” travel time data and the radar unit collects “Point” speed and occupancy data. The placements of the TTIs were selected based on known travel patterns along the corridors. The data is being collected by the CTMS server, processed and then posted to the COTRIP website. The refresh rate for the website is about two minutes.

The travel condition information is available on the COTRIP website. This would allow Interstates and arterial condition information to be displayed on the same website. There will be a link from the County’s website to the COTRIP site. CDOT uses Google map base to show travel conditions and the users have the ability to use zoom in/out. The County will use VMS to post travel time information to major access points. No incident, construction and event information is included with travel condition information on arterials. Initially, the County planned to display travel time information with color coded text to convey travel condition information as shown in Figure 3. However, the County has decided to use the color coded text for the next phase of the project. At this time, the VMS will only display travel time. For the next phase of the project, Douglas County would like to use Bluetooth technology for detection and expansion to other corridors.
2.2 Existing Applications Outside of Colorado

2.2.1 City of Bellevue, WA:

City of Bellevue provides travel condition information for all major arterials. The project was funded by the City. Most of the signals in Bellevue are actuated and have advanced system detection loops installed between 80 feet to 140 feet from the signal. The City uses occupancy as a measure for representing congestion. Currently, the data is collected every cycle and sent to the signal system server. The server then sends out the data every two minutes to the Geographic Information Systems (GIS) for processing and posting to the website.

The travel condition information is displayed using GIS maps developed by the City as shown in Figure 4. Future developments for the web application include using the Google map base for the background and providing incident and construction information. The City is also planning an iPhone application. It is not clear how the data collection process will work with the City’s two different signal systems – an adaptive signal system for downtown and a new signal system for the remainder of the signals.
Figure 4: City of Bellevue Web-based Application

Washington DOT (WSDOT) provides Interstates traffic condition information within the City of Bellevue as shown in Figure 5. Neither agency’s information is directly displayed on other agency website. However, there is link from WSDOT traffic map to Bellevue Traffic condition map. Additionally, both the agencies display information on different base maps and using different color coding.
2.2.2 City of Seattle, WA:

Seattle provides travel condition information for select State highways. The corridors were implemented by Traffic.com using radars they placed themselves. The City receives data from the vendor, which is processed for posting on the City’s website. The data collection and processing portion of the project was funded by Seattle.

Seattle uses occupancy as a measure for representing congestion and displays it on its website using Bing maps. Future developments for the web application include expansion of the conditions to other major arterials and development of an iPhone application. The City is also planning to implement traffic conditions information using license plate readers and display the information using Variable Message Signs (VMS).
WSDOT also provides traffic conditions for the Interstates within the City of Seattle as shown in Figure 7. Neither agency’s information is directly displayed on other agency website. However, there is link from WSDOT traffic map to Seattle Traffic condition map. Additionally, both the agencies display information on different base maps and using different color coding.
Given some of the above challenges, the Puget Sound Regional MPO (that includes Bellevue and Seattle) is in the processing of developing a Regional standard for representing arterial conditions and traffic conditions. At this time, there are no funds available to implement the regional application.

2.2.3 City of Los Angeles, CA

City of Los Angeles uses a web based application to show traffic conditions on all major arterials as shown in Figure 8. The City uses travel speed to measure congestion. GIS maps are used to display congestion and there are zones within the map for specific regions.
2.2.4 City of Tallahassee, FL:

Tallahassee uses a web based application to show traffic conditions on all major arterials as shown in Figure 9. The City uses travel speed to measure congestion and GIS maps to display congestion.

Figure 9: City of Tallahassee Web-based Application
Apart from the agencies listed above, the cities of Dallas and San Diego were also contacted to discuss any existing arterial conditions applications. It was observed that City of Dallas has an application that has not been developed completely and it display incidents and lane closure information on Bing map. The City of San Diego does not have any web applications for displaying arterial/Interstates conditions maps.

2.2.5 City of Houston, TX

Houston has implemented Bluetooth technology to provide travel time information for the users. Traffic sensors use Anonymous Wireless Address Matching (AWAM) to evaluate speeds and travel times along roadways. Bluetooth readers beside the roadways recognize the Mac address of the each bluetooth device, location and the time of the day the bluetooth device used. These addresses are then matched at the different intersections or points and used to calculate the travel time by central host software and posted on website using XML feeds. Figure 10 shows the concept used in the Bluetooth technology implementation in Houston.

**Figure 10: Bluetooth Concept on the roadside**

*Source: Bluetooth®-Based Travel Time/Speed Measuring Systems Development by Darryl D. Puckett and Michael J. Vickich*
Bluetooth technology was implemented in the west Houston within a 160 square kilometer area bounded by IH-10 on the north, IH-610 on the east, the Westpark Toll way on the south and up to and including SH-6 on the west. Figure 11 shows the implemented arterial network in the west Houston.

**Figure 11: West Houston Arterial Grid for Travel Time Monitoring**

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### 2.3 Arterial Conditions Applications Matrix

Table 1 shows the Arterial Conditions Applications between agencies. Some highlights include:

- Type of Data collection technologies used by agencies is quite varied and included video detection, wavetronix, loops, toll tag, pucks etc.
- Placement of data collection devices varied from back of the queue to 800’ from the intersection.
- The data collection device density was mostly based on segment.
- Refreshing rates are typically around 120 seconds
- Not all of the agencies provide incident, construction and video streaming on the web based application.
- Typically, agencies used 4 -7 colors for representing the arterial conditions.
The base maps used for representing the arterial conditions were either agency developed GIS maps or private providers such as Google or Bing.

The deployment of the application was either network or select corridors. Most of the selected corridors were in close proximity to the Interstates.

All arterial condition information is available through website and/or cell phone application.

No VMS devices are being used to display congestion on arterials. However, two agencies are in the process of using VMS’s for providing arterial condition information.

None of the agencies that were examined provide travel time information on the arterial corridors. However, two agencies are in the process of using travel time data for arterial condition information.

Most agencies expressed their satisfaction with their applications although some sorts of enhancements are being planned. These included iPhone applications, change of base map, additional data collection, etc.
Table 1: Arterial Conditions Application Matrix

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Agency/Source</th>
<th>Denver</th>
<th>Douglas County</th>
<th>Fort Collins</th>
<th>Bellevue</th>
<th>Seattle</th>
<th>Los Angeles</th>
<th>Tallahassee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Collection Technologies</td>
<td></td>
<td>Video, Wavetronix, Canoga Loops and toll tags</td>
<td>Toll tag, Bluetooth</td>
<td>Video and Pucks</td>
<td>Loop detection</td>
<td>Traffic.com, System Detection</td>
<td>Information not available</td>
<td>Information not available</td>
</tr>
<tr>
<td>Data Collection Device Placement</td>
<td></td>
<td>Back of the normal queue</td>
<td>Areas where major travel patterns and queues</td>
<td>500-800’ form signal</td>
<td>140’/300’ from intersection</td>
<td>Unknown</td>
<td>Information not available</td>
<td>Information not available</td>
</tr>
<tr>
<td>Data Collection Device Density</td>
<td></td>
<td>0.25 to 1.0 Mile segment and 2 devices per segment</td>
<td>2 devices per segment</td>
<td>Every 1-mile/one device per segment</td>
<td>Every Signal</td>
<td>One device per segment</td>
<td>Information not available</td>
<td>Information not available</td>
</tr>
<tr>
<td>Data Parameters Considered</td>
<td></td>
<td>Speed and occupancy</td>
<td>Travel Time, speed and occupancy</td>
<td>Volume and occupancy</td>
<td>Occupancy</td>
<td>Occupancy</td>
<td>Speed</td>
<td>Speed</td>
</tr>
<tr>
<td>Refresh Rate</td>
<td></td>
<td>120 Seconds</td>
<td>120 seconds</td>
<td>300 Seconds</td>
<td>120 Seconds</td>
<td>120 seconds</td>
<td>60 Seconds</td>
<td>60 Seconds</td>
</tr>
</tbody>
</table>

**Color Coding**

- **Dark Green**: 81-100% of Speed limit
- **Green/Light Green**: 61-80% of Speed limit
- **Yellow**: 10-20 MPH
- **Red**: 0-10 MPH
- **Blue**: 41-60% of Speed limit
- **Gray**: No Data
- **Black**: Very Congested
- **White**: N/A
- **Pink**: 21-40% of Speed limit
- **Pale Green**: Disabled
- **Base Map**: Google
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Agency/Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Denver</td>
</tr>
<tr>
<td>Arterial Types</td>
<td>Major arterial close to Interstates</td>
</tr>
<tr>
<td>Information Provided</td>
<td>Cotrip</td>
</tr>
<tr>
<td>Additional Information</td>
<td>Construction</td>
</tr>
<tr>
<td></td>
<td>Incidents</td>
</tr>
<tr>
<td></td>
<td>Road Closures</td>
</tr>
<tr>
<td></td>
<td>Camera Image</td>
</tr>
<tr>
<td></td>
<td>Video Streaming</td>
</tr>
</tbody>
</table>
2.4 Private ISPs and Vendors

2.4.1 INRIX

INRIX provides Interstates and major arterial traffic conditions through an application for cell phone users. For operating agencies, it can provide processed data or color coded map of the geographical area. INRIX collects its data from in-vehicle navigation systems, cell phones, probe vehicles, traffic cameras and road sensors. INRIX uses Google Maps to show travel conditions using color coding with four different colors to represent “SLOW” to “FAST” as shown in Figure 12. INRIX can customize the color codes for agencies.

Figure 12: INRIX Traffic Application Map

The INRIX application includes the capability to provide travel time information for user specified origins and destinations. It also provides construction, lane closures, events and incident information, as well as allowing users to report incident/event information. INRIX provides forecast traffic conditions based on historical data and allows users to select their time of travel and provides updates with any incidents or delays. Typically data is updated every two minutes.
Around 750 operating agencies use the travel time data from INRIX which includes Alabama DOT, New Mexico DOT, Virginia DOR, Texas DOT, Texas Transportation Institute, Atlanta Regional Council (MPO), etc. INRIX provides the traveler information for New Mexico DOT on the state developed map. Figure 13 shows the travel conditions for New Mexico.

Figure 13: New Mexico State Travel Conditions Map

2.4.2 Google

Google provides Interstate and major arterial traffic conditions information through the Google Maps web based application and cell phone applications. Google uses data from cell phones and navigation systems. Unlike the web based application, the Google cell phone application does not provide construction and lane closures information at this time. The web based and cell phone applications do not provide incident or event information at this time. Both use color coding to represent travel conditions with four different colors from “SLOW” to “FAST.”

The Google web application provides travel time information for user specified origins and destinations. They provide forecast traffic conditions based on historical data and allow users to select day and time of travel. It is not clear how much time is elapsed between collection of data
from various sources, processed and posted on website or cell phone. Figure 14 shows the Google Traffic web based application.

**Figure 14: Google Travel Conditions Map**

![Google Traffic Conditions Map](image)

### 2.4.3 Bing

Bing provides Interstates and arterial travel condition information through a web based application. They use data from cell phones and navigation systems, and do not provide any incident or event information. It uses color coding with four different colors to represent congestion from “SLOW” to “FAST” as shown in Figure 15. Bing provides travel time information for user specified origins and destinations.
2.4.4 Trafficcast

TrafficCast uses Bluetooth detection devices to provide travel condition information on Interstates and arterials. TrafficCast Bluetooth devices can collect speeds, travel times, etc. DynaFlow is the application developed by TrafficCast to process the data collected from the Bluetooth devices and to represent the travel condition on the map. DynaFlow uses Bing maps to display the information, and uses color coding with three different colors to represent congestion from “CONGESTED” to “FAST” conditions as shown in Figure 16. DynaFlow also provides incident information and uses color coding based on the impact of the incident.

Operating agencies can use the vendor software to process and display the information. Alternatively, the processed data can be provided via XML feed for agencies.
2.4.5 NAVTEQ

NAVTEQ provides Interstates and arterial traffic conditions information through a web based application. Data comes from their own system detectors, some public agencies system detectors, cell phones and navigation systems. NAVTEQ uses color coding to represent travel conditions with three different colors as shown in Figure 17.

NAVTEQ provides travel time information on Interstates and for user specified origins and destinations on arterials. The application provides two maps, Area Traffic Maps and User Traffic Maps. Area Maps show traffic conditions for the entire area, while User Maps show the user’s route choices. Users can set up an account and identify specific route to receive information and notifications. Traffic.com will send alerts through email, phone or text in case of incidents/lane closures/events, and also provides alternate route information to registered users.
2.5 Recommended Best Practice Approaches

Based on the information presented, this Section discusses specific areas that apply to arterial travel conditions implementations that should be considered by the implementing agency, and provide a recommended best practice approach. These best practices will be applied in the development of guidelines.

2.5.1 Arterial Travel Condition Information

Typically, for most state and regional (MPO’s) agencies the primary focus was, and continues to be, to provide real-time traveler information for Interstates. Obviously, the local agencies focus is more on the arterials. Until recently, the technology and technical know-how for providing arterial condition information was at a very nascent stage of development.

Given the current state of the existing and developing applications, it is clear that more and more agencies are striving to provide arterial travel condition information. It is also clear that most of the applications are at a stage where they can no longer be considered test beds or emerging technology projects. Most users and operators report positive feedback regarding their experience with arterial conditions applications. In the near future, with advancement of mobile
applications and technology, it is anticipated that there will be more demand for such applications.

**Best Practice:** Agencies interested in implementing arterial conditions applications should consider the following:

- Consider implementation from a traveler’s (Regional) perspective
- Work and partner with stakeholders in the Region
- Involve and evaluate existing applications by users if possible
- Identify coverage area, information to provide and communications with devices/infrastructure
- Determine cost including deployment, operations and maintenance

### 2.5.2 Planning and Coordination

Typically, the arterial conditions applications are being driven by the local City or County. These agencies invest significant resources in planning, implementing and customizing the application for their needs. However, the lack of planning and coordination at the Regional and State DOT level many times leads to issues including the following:

- Lack of consistency in how the information is displayed to the users. This could be from differences in color coding or terminology related to arterial travel conditions, to fundamental differences in the basis for calculating arterial travel conditions, i.e., use of occupancy, speed, travel time, etc.
- Backward integration at a regional level becomes difficult. The user should not be required to look at several sources of information. It is essential that the information, regardless of jurisdictional boundaries, be available at one location
- There is a risk that without a concerted and coordinated effort, only certain segments of a corridor could get implemented. This problem could be magnified if the corridor crosses multiple agencies. There might be gaps in information which could alienate the user.
Initially, these applications require significant resources to calibrate the application. Also, once the application is calibrated, the system is heavily dependent on detection, i.e., adequate resources need to be devoted to make sure the equipment is operational.

**Best Practice:** Regional and/or state agencies to consider taking on an oversight role to ensure consistency, standardization of any arterial travel condition applications within their jurisdiction. The specifics of what needs to be consistent and standardized should be discussed at a regional and/or state level.

### 2.5.3 Determining Coverage Area for Arterial Travel Condition Implementation

Most arterial travel condition applications are either corridor specific or the complete arterial network. In general, most corridors were selected by operating agencies based on factors such as proximity to Interstates, perceived demand and existing instrumentation.

With implementation across a network, it is important to ensure there are sufficient resources available for data collection, communications, infrastructure, calibration and maintenance. There is also possibility of information overload for the user; including zooming in, or the network being broken into zones for clarity.

**Best Practice:** With implementation on a corridor level, there should be priority scheme for implementation. As users notice and take advantage of the implementation, their expectations for more coverage may increase. Local agencies should consider coordination with other operating agencies if the corridor crosses multiple jurisdictions. Arterials that are close to Interstates or parallel to Interstates are better candidates for implementation as they assist users in making travel decisions.

### 2.5.4 Travel Condition parameters

Most of the arterial condition applications use “Point” data. There are a couple of applications in the development stage that will be using “Point-to-Point” information. “Point” data is collected at one location and the data that is collected is representative of that location. “Point-to-Point”
data is collected between two locations and the data that is collected is representative of what occurs between the two locations.

Most of the devices that can collect “point” data are capable of collecting Volume, Occupancy and Speed. Speed and/or Occupancy are data parameters that are more prevalent. Occupancy appears to be most reliable of the measures whereas volume is the least reliable.

Devices such as Toll tag readers, license plate readers and Bluetooth readers can collect “point to point” data and are capable of collecting travel time.

**Best Practice:** Use “point-to-point” data for arterial travel conditions and use “point” data for validation and supplement the information.

### 2.5.5 Travel Condition Data Collection Technologies

There are several reliable data collection technology options for collecting “point” data including loops, radars, video detection, dopplers, etc. Typically, local agencies have a comfort level for a particular type of technology. The use of different technologies for evaluation can be sound practice. However, for large scale implementations, it might be cumbersome for maintenance staff to be responsible for several types of detection technologies.

There are a few data collection technology options for collecting “point to point” data including Toll tag readers, license plate readers and Bluetooth readers. These options have proven reliable for Interstates travel condition application. The reliability of such technologies for arterials is not proven.

**Best Practice:** For “Point” data, the type of technology used does not matter. However, for large scale implementation, it is better to use one type of technology as it is easier for maintenance. For “Point-to-Point” data, toll tag readers and Bluetooth readers appear as a likely choice.

### 2.5.6 Travel Condition Data Process

Typical data process includes data being collected in the field, sent to server (dedicated for the device or to the signal system); data is extracted and/or processed and lastly posted to
dissemination tool such as website. The process builds in a latency issue i.e., there is time delay between the time data is collected to when it is posted. Several factors such as number and location of data sources, extraction methods-frequency and process, etc can impact latency. Typically, a latency of 2-6 minutes is common. The latency on the private sector applications is not clear.

**Best Practice:** Data collection devices that directly provide information to a server that allows for quicker processing tend to provide more reliable information.

### 2.5.7 Travel Condition Data Validation

Most applications should have built-in validation processes and these can include use of additional source for data collection. In addition, staff validating the data either in the field or observing the application against normal conditions and using available camera coverage to check travel conditions. For private sector applications, it is not clear what validation techniques are used.

**Best Practice:** Using cameras (wherever available) and staff resources to assist in calibration and validation leads to better results.

### 2.5.8 Travel Condition Information Dissemination

Most applications are web based and some also provide mobile applications and traveler information phone systems. Travel conditions can also be provided through VMS signs. A couple of agencies are considering providing arterial travel time information on VMS. None of the agencies are using 511 systems to provide arterial condition information. Some agencies reported using general demographic information in selecting a medium for distributing information.

Web and mobile applications for providing arterial conditions have become the most common medium for public/private agencies applications. They can include live streaming video or pictures of traffic flow, incidents, events and construction information. Most of the private agencies provide their arterial traffic conditions to their users as a web application and a cell
phone application. Cell phone applications can send the information to the users faster and the travelers who are already in the traffic can also access the information and make routing decisions.

VMS signs can be used to provide the arterial conditions, incidents and construction information. VMS signs can be connected to detection systems and can provide travel times along the arterial corridors. Douglas County is the only agency that provides arterial travel time and congestion levels on the VMS.

**Best Practice:** Web and mobile applications are a better way to provide information for users. VMS should be used selectively to supplement web and mobile applications.

### 2.5.9 Users of the Arterial Condition Information

Most of the applications are typically geared towards local travelling public, especially commuters. Several agencies use the application to monitor their arterials. It does not appear the media (TV and Radio) is using the information other than to report events i.e., incidents, lane closures, etc. Also, it does not appear that other internal staff particularly Public Information office is using the information. This is understandable since media and public information office typically focus on exceptions to normal operations i.e., incidents, events, lane closures, signal malfunctions, etc. However, most agencies are providing this information. There are also differences in how these exceptions are depicted on the map i.e., no consistency, etc.

**Best Practice:** Agencies should also focus to provide incident, events, lane closures, etc, information to its users.

### 2.5.10 Technical Development of Application

Quality and Reliability of arterial travel condition information is dependent on several key factors such as

- Placement of the data collection devices – Regardless of “point” or “point-to-point” data, the placement of the devices is absolutely critical. Key considerations are normal queue
lengths, lane utilization and change of travel patterns. Sometimes the focus appears to be on the availability of power and communications.

- Density of the data collectors – segment size, spacing of the detectors is also critical. Key considerations are lane utilization and change of travel patterns
- Proper calibration – The success of the application is dependent on calibration of each individual corridor based on the field data and adjusting the thresholds to accurately reflect specific corridor conditions.
- Proper maintenance – The applications are very dependent on proper working of data collection devices.

**Best Practice:** Proper consideration of the factors and the resources to support calibration and maintenance leads to better results.

### 2.5.11 Base Map

Most website and cell phone applications are using Google or GIS maps. As more travel condition applications are implemented across larger geographical areas, it is important to make easier for the user to quickly access the information. On some applications it is hard to distinguish Interstates and arterials. This may lead users who are not familiar with the area to make improper travel decisions.

**Best Practice:** Regardless of the type of base map, it important to have the following features

- Ability to zoom in/out
- Ability to differentiate Interstates and arterials

### 2.5.12 Archiving Data

Most applications are archiving the data. However, it is not clear how the data is used, the frequency it is used or for what purpose. Private sector applications seem to be doing a better job of using the data for forecasting.

**Best Practice:** Archived data can be useful in understanding traffic patterns and forecasting normal operations.
2.5.13 Use of Private Entities

Most applications use data collected within the agency. Only agency is using private entity. There appears to be lot of uncertainty and concern primarily related to data usage, restrictions, accountability, contracts, etc. However, some of the private sector applications have enormous access to mobile data (cell phone, blue tooth, fleet probe vehicle, in-vehicle navigation systems, etc). The mobile the data sources are expected to increase substantially in the next few years.

**Best Practice:** Private sector entities can be significant resource in implementing the applications. At the least, agencies should consider the innovation techniques being pursued by private sector.

2.5.14 Color Coding and Legend

Most agency applications use 4 to 8 colors to represent traffic conditions on arterials. All most all private sector applications use 4 colors to represent traffic conditions. The legend to describe the traffic conditions is more varied on agency applications. Private sector applications use one word to describe the condition.

**Best Practice:** It is important that agencies within a geographical area to subscribe to one color coding and legend scheme.
3. Guidelines for the Denver Region

The purpose of this section is to clearly define a consistent approach for displaying arterial travel condition information across the Denver Region. The approach reflects input from stakeholders at project workshops and what they determined to be best suited for the Denver Region.

The following describes how Sections 3 and 4 – are organized.

Section 3.1 addresses who will use the arterial travel condition information.
Section 3.2 addresses on which roadways the arterial travel condition information should be provided.
Section 3.3 identifies how operators need to work together to implement the guidelines.
Section 3.4 provides guidelines for each travel condition data parameter as follows:
  - Type of device for data collection
  - Placement of the devices
  - Data collection, processing and display
  - Time intervals
  - Measures of Effectiveness (MOE)
  - Usefulness to the operators and others
  - Others that apply

Sections 3.5 –3.9 provide guidelines regarding the following regional level issues:
  - Data quality
  - Data dissemination
  - Base map
  - Archiving
  - Alarms
  - Performance measures report card
  - Typical scenario for operator
  - Reporting
Section 4 discusses the implications of guidelines on the existing field infrastructure, systems and practices. It also identifies the next steps.

### 3.1 Use of Arterial Travel Condition Information

The primary reason for collecting arterial condition information is so operators are able to better manage the transportation network. There are several inadequacies that hinder the operators’ ability to monitor the roadway network and better utilize the network capacity including:

- Data is only collected on as-needed basis generally during peak periods.
- Data is not real-time.
- Operational problems go undetected and unresolved.
- There is not enough data for incidents, weather, construction and maintenance activities for operators to develop mitigation strategies.

If local agencies do not collect arterial condition information traffic conditions on the roadway network will worsen and resources may not be used properly. There are two other groups in addition to the operators that would benefit from arterial travel condition information: the traveling public and other public agencies and departments.

In 2000, Washington DOT conducted a web based survey for travelers seeking their opinions on arterial traffic condition measures. The following measures rated from highest to lowest benefit:

- Locations of possible incidents
- Level of congestion
- Speed of traffic and travel time
- Camera snapshots and live video of the roadway

By providing the travelling public information they are able to make informed decisions regarding their travel choices and options.

Other public agencies and departments including planning, research, TDM, transit, emergency and public safety, parks, GIS etc. are often not typically aware of the arterial travel condition
information both from a real-time and historical perspective. Arterial travel condition information can be very useful as it relates to their work activities and projects.

3.2 Geographical Coverage for Arterial Travel Conditions

As the Denver Region determines which highways will be implemented with the real-time travel time application, it must now apply provisions from a recently adopted FHWA Rule regarding real-time system management information.

In essence, FHWA Rule Title 23 Part 511 Subpart C- Federal Register Volume 75, Number 215, pages 68427-68429, effective December 23, 2010 states the following:

- Interstate Highways within Metropolitan Statistical Area (MSA) must report traffic and travel conditions (Construction & maintenance, Roadway or lane blocking, Roadway weather observations and travel time or speed information) by November 8, 2014.

- Interstate Highways outside of MSA must report traffic and travel conditions (Construction & maintenance, Roadway or lane blocking and Roadway weather observations) by November 8, 2014. No travel time or speed information is required for Interstate highways outside of MSA.

- Routes of Significance within MSA must report traffic and travel conditions (Construction & maintenance, Roadway or lane blocking, Roadway weather observations and travel time or speed information) by November 8, 2016. Routes of significance are defined as non-Interstate roadways in the MSA that are designated by the State as meriting collection and provision of information related to traffic and travel conditions.

Within Colorado, the Denver-Aurora-Broomfield MSA is identified and consists of the following ten counties: Denver, Arapahoe, Jefferson, Adams, Douglas, Broomfield, Elbert, Park, Clear Creek and Gilpin. Although Boulder County is not included within the MSA, CDOT has determined that Boulder County will be included within this area for real-time purposes. Table 2 provides a summary of the FHWA rule including the data quality parameters prescribed in the rule. In March 2012 CDOT anticipates to begin the process to designate the Routes of
Significance in the Denver Region in collaboration with regional stakeholders. CDOT will also prioritize the routes and develop capital operational and maintenance costs associated with implementation for the Routes of Significance.
Table 2: FHWA Rule on Real Time Traveler Information Systems

<table>
<thead>
<tr>
<th>Traffic and Travel Conditions</th>
<th>Interstate highways outside Metropolitan Statistical Area</th>
<th>Interstate highways within Metropolitan Statistical Area</th>
<th>Metropolitan Statistical Area roadways – Routes of Significance¹</th>
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</thead>
<tbody>
<tr>
<td>Implementation Date</td>
<td>November 8, 2014</td>
<td>November 8, 2014</td>
<td>November 8, 2016</td>
</tr>
<tr>
<td>Traffic and Travel Conditions</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Construction &amp; maintenance activities</td>
<td>Reported within 20 minutes or less from the time of the closure or reopening of roadway².</td>
<td>Reported within 10 minutes or less from the time of the closure or reopening of roadway².</td>
<td>Reported within 10 minutes or less from the time of the closure or reopening of roadway².</td>
</tr>
<tr>
<td>Roadway or lane blocking</td>
<td>Reported within 20 minutes or less from the time the incident is verified.</td>
<td>Reported within 10 minutes or less from the time the incident is verified.</td>
<td>Reported within 10 minutes or less from the time the incident is verified.</td>
</tr>
<tr>
<td>Roadway weather observations</td>
<td>Reported about hazardous driving conditions and roadway or lane closures or blockages because of adverse weather conditions within 20 minutes from the time hazardous conditions, blockage or closure is observed.</td>
<td>Reported about hazardous driving conditions and roadway or lane closures or blockages because of adverse weather conditions within 20 minutes from the time hazardous conditions, blockage or closure is observed.</td>
<td>Reported about hazardous driving conditions and roadway or lane closures or blockages because of adverse weather conditions within 20 minutes from the time hazardous conditions, blockage or closure is observed.</td>
</tr>
<tr>
<td>Travel time or speed information</td>
<td>Not required</td>
<td>Reported on limited access roadways that experience recurring congestion within 10 minutes from the time that the travel time or speed calculation is completed.</td>
<td>Reported on limited access roadways that experience recurring congestion within 10 minutes from the time that the travel time or speed calculation is completed.</td>
</tr>
</tbody>
</table>

**Data Quality Parameters³**

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>Interstate highways outside Metropolitan Statistical Area</th>
<th>Interstate highways within Metropolitan Statistical Area</th>
<th>Metropolitan Statistical Area roadways – Routes of Significance¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shall be 85% accurate at a minimum, or have a maximum error rate of 15%.</td>
<td>Shall be 85% accurate at a minimum, or have a maximum error rate of 15%.</td>
<td>Shall be 85% accurate at a minimum, or have a maximum error rate of 15%.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Availability</th>
<th>Interstate highways outside Metropolitan Statistical Area</th>
<th>Interstate highways within Metropolitan Statistical Area</th>
<th>Metropolitan Statistical Area roadways – Routes of Significance¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shall be 90% available at a minimum.</td>
<td>Shall be 90% available at a minimum.</td>
<td>Shall be 90% available at a minimum.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Timeliness</th>
<th>Interstate highways outside Metropolitan Statistical Area</th>
<th>Interstate highways within Metropolitan Statistical Area</th>
<th>Metropolitan Statistical Area roadways – Routes of Significance¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values must be provided at the time required or specified.</td>
<td>Values must be provided at the time required or specified.</td>
<td>Values must be provided at the time required or specified.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Regional ITS Architecture³</th>
<th>Interstate highways outside Metropolitan Statistical Area</th>
<th>Interstate highways within Metropolitan Statistical Area</th>
<th>Metropolitan Statistical Area roadways – Routes of Significance¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluate Architecture to determine</td>
<td>Evaluate Architecture to determine</td>
<td>Evaluate Architecture to determine</td>
<td>Evaluate Architecture to determine whether</td>
</tr>
</tbody>
</table>
### Denver Regional Integrated Traveler Information Display Map

<table>
<thead>
<tr>
<th>Interstate highways outside Metropolitan Statistical Area</th>
<th>Interstate highways within Metropolitan Statistical Area</th>
<th>Metropolitan Statistical Area roadways – Routes of Significance¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>whether Architecture explicitly addresses real-time highway and transit information needs and methods to meet such needs. Traffic and travel conditions monitoring needs for all Interstate system highways shall be considered. If necessary, Architecture shall be updated and shall feature the components and functionality of the real-time information program.</td>
<td>whether Architecture explicitly addresses real-time highway and transit information needs and methods to meet such needs. Traffic and travel conditions monitoring needs for all Interstate system highways shall be considered. If necessary, Architecture shall be updated and shall feature the components and functionality of the real-time information program.</td>
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</tr>
</tbody>
</table>

¹ The MSA is identified as the Denver-Aurora- Broomfield, and consists of the following ten counties: Denver, Arapahoe, Jefferson, Adams, Douglas, Broomfield, Elbert, Park, Clear Creek and Gilpin. Routes of significance are defined as non-Interstate roadways in the MSA that are designated by the State as meriting collection and provision of information related to traffic and travel conditions. Factors to be considered include: crash rates, environmental events, evacuation/diversion routes, severity and frequency of congestion, and economic activity. All public roadways including arterials, toll facilities and other facilities that apply end user pricing mechanism shall be considered when designating routes of significance. In identifying these routes, States shall apply collaborative practices and procedures.

² Short term or intermittent lane closures of limited duration that are less than the required reporting times are not included as a minimum requirement.

³ State shall develop the methods by which data quality can be ensured. The criteria for defining the validity of traffic and travel conditions made from real-time informant programs shall be established by the State in collaboration with their partners for establishing the programs. State shall receive FHWA concurrence that the selected methods provide reasonable checks of the quality of the information made available by the real-time information program. In requesting FHWA’s concurrence, the State shall demonstrate to FHWA how the selected methods gauge the accuracy and availability of the real-time information and the remedial actions if the information quality falls below the levels described.

⁴ Although no date is provided as to when the Regional ITS Architecture must be updated, if applicable, it is assumed that is it the implementation date. Although the Rule only identifies that traffic and travel conditions shall be considered for all Interstate highways, it is logical to assume that the update would also include MSA Routes of Significance, if applicable.
3.3 Planning and Coordination

To implement the guidelines there needs to be a clear understanding of the agency roles and responsibilities. The implications of these guidelines are discussed later in the report (Section 4.1). These implications can have significant impact on agency resources. This section provides a high-level overview of the roles and responsibilities of Operators, DRCOG and CDOT ITS Branch with the recognition that these roles and responsibilities may change and/or need to defined in greater detail at a later time.

Roles & responsibilities of the Operator

- Implement in accordance with the guidelines (regardless of funding source)
- Complete the System Engineering Analysis (SEA) if federal funds are used for implementation. If no federal funds are used for implementation, SEA is strongly encouraged, although not required.
- Maintain field devices
- Validate field data (configuration, adjustment of thresholds, etc, determine needs and ensure the travel condition information is being reflected accurately)
- Demonstrate to CDOT that the arterial travel condition information meets the guidelines defined in this document

Roles & responsibilities of DRCOG

- Coordinate with operators to promote guidelines and assist with implementation
- Review SEA documentation provided by Operators for implementations that use federal funds administered by DRCOG.

Roles & responsibilities of CDOT ITS Branch

- Maintain COTRIP website and add arterial travel condition information as arterials are implemented provided that the operator demonstrates that the guidelines are being met
- Maintain the CTMS application and the device drivers that CDOT has developed
Maintain CCTM
Support reporting functions through COGNOS
Provide SEA technical assistance and support to Operators for implementations on State Highways

The Guidelines document should be periodically updated by CDOT and the stakeholders in the Denver Region. Given the changes in technology and increased deployment in the near term, it is recommended that the guidelines are updated once a year.

3.4 Travel Condition Data Parameters

The stakeholders in the Denver Region identified and agreed upon the following travel condition data parameters, which are listed in priority order.

- Travel time
- Traffic incident information
- Weather related road condition information
- Construction and maintenance operations information
- Traffic video (image and full motion)
- Event information and parking information for events
- Speed
- Queues
- Volume
- Occupancy

Appendix A shows the travel condition parameters with the associated implementation factors and the Regional priority ranking for each travel condition data parameter.
3.4.1 Travel Time

In the Denver Region travel time is the highest ranked travel condition data parameter used by operators to manage their transportation network.

3.4.1.1 Travel Time Measurement

Point devices measure speed at a particular point on the designated segment. Point devices also can be used to estimate the travel time; however data quality and reliability are less than optimal. Point-to-Point devices are able to measure or calculate the travel times based on when the vehicles are entering and leaving the designated segment.

Guideline(s)

- Point-to-Point devices should only be used to collect travel time.
- Point devices should not be used to determine the travel times. However, Point devices can be used to validate travel speeds along the segment if deemed necessary by the operator.

3.4.1.2 Segment Definition

Private ISPs use Traffic Messaging Channel (TMC) location codes to identify the segments by direction. TMC location codes are applicable to both Interstate Highways and arterials. TMC segmentation is an unofficial standard that has been adopted by mapping companies and private ISPs. Mapping companies make updates to TMC location codes only once a year. Arterial TMC segmentation is not fully developed and there are arterial segments that have one TMC code for both directions.

TMC segment length varies depending on the area, i.e., urban or rural. In urban areas, TMC segment length on Interstate Highways is from on-ramp to on-ramp while on arterials it is from...
major intersection to major intersection. For rural areas the segment length is usually between towns.

**Example of TMC Segmentation on Interstate Highways and Arterials**

- **Interstate Highways** – On I-25 between University Boulevard and Colorado Boulevard the TMC code is 116P04173 in the northbound direction and 116N04172 in the southbound direction. The first digit in the code represents country, the next two digits represent state, P (North or West) and N (South or East) represent directions and the last five digits identify the location ID.

- **Arterials** – On University Boulevard from Evans Avenue to Buchtel Boulevard there is one TMC code for both directions 116N07617.

CDOT and other local operators do not use TMC segmentation in the Denver Region for Interstate Highways or arterials. For the arterials, the current segmentation is based on the following:

- Major intersections
- Major decision points of travel
- Major changes in traffic patterns, i.e., heavy turning traffic

In general, TMC segmentation from major intersection to major intersection is fundamentally sound. However, there needs to be more clarity on what constitutes a major intersection in the Denver Region. DRCOG 2035 Regional Transportation Plan identifies major regional and principal arterials within the Denver Region as shown in Figure 18. Using the DRCOG major regional and principal arterials as a basis, a major intersection can be defined as follows:

- Signalized intersection of two major regional arterials
- Signalized intersection of major regional arterial and a principal arterial
- Signalized intersection of two principal arterials
- Signalized or unsignalized Interstate on and off ramps along the arterial
Figure 18: Major Regional and Principal Arterials within the Denver Region
Additionally, segmentation can be challenging if jurisdictional boundaries exist on a segment between two major intersections as it may require instrumentation in the adjoining jurisdiction.

**Guideline(s)**

- Segment is defined from one major intersection to another major intersection. Figure 18 provides an example of the potential segments on a corridor. However, operators should also exercise engineering judgment based on travel patterns and current operational characteristics in defining the segments. If there is no major change in traffic patterns between two major intersections, the Operator can extend the segment to the next major intersection. If there is a major change in traffic patterns between two major intersections, the Operator can shorten the segment in order to capture the change in travel patterns.

- If a jurisdictional boundary exists between two major intersections and one agency does not have the interest or resources to operate and maintain the P2P device in their jurisdiction, the segment should end at the nearest signal prior to entering the adjoining jurisdictional boundary.

### 3.4.1.3 Sample Size

Regardless of the technology used to collect travel time, the number of good matching samples is critical. In the Denver Region, a sample size of at least three good matching samples every two minutes is considered valid for reporting. This is based on CDOT’s travel time algorithm and experience with Interstate Highways using toll tag technology. However, there is no study or documentation that identifies what constitutes the optimum sample size. In Houston, average sample size of 16 every 15 minutes is being used to report arterial condition data. CDOT uses a standard reporting cycle of two minutes for travel time. A good matching sample is defined as within the acceptable deviation from a typical travel time and comparable to the range of travel times with other samples during the same period.
It should be noted, there is a concern that the sample size that is being used at present in the Denver Region for both Interstate Highways and arterials may not be adequate for arterials due to the differences in operational characteristics and increased accessibility.

Regardless of the type of technology, or use of data from private ISPs, there may be certain times of the day where it is not possible to obtain three good matching samples every two minutes. This could possibly happen during late nights or when there are low numbers of vehicles on the segment. Currently, in the Denver Region, if the good matching sample number drops below three for a two-minute period, no data is reported on the segment for three cycles or six minutes.

**Guideline(s)**

A sample size of at least three good matching samples every two minutes is recommended for the Denver Region regardless of technology or the use of private ISP vendors. However, if it is determined during the validation process that the current sample size of three good matching samples is not adequate, the Denver Region should consider reevaluating the matching sample size for every two minutes. The samples collected should be recent and within the last 12 consecutive months prior to implementation.

If the number of good matching samples falls below three for a two-minute period, the segment should not report any data and the color display for the segment should be gray until the number of good matching samples reaches at least three for a two-minute period.

**3.4.1.4 Placement of the Devices to Measure Travel Time**

The placement of the devices along a segment will impact the ability to meet the data accuracy requirements. Appendix B provides the considerations for placement of devices measuring travel time.
Guideline(s)

P2P devices should be placed at the far-side of the intersection from the signal pole to within 100 feet of the traffic signal. This will allow easy access to power and communications to the device. If any P2P device is installed on the mast arm of a signal, it should be placed on the back side of the mast arm to avoid visual clutter and interference with signal heads. Operators should use engineering judgment to determine proper placement of the device. P2P device placement at mid-block and near-side of the intersection is not recommended.

3.4.1.5 Density of the Devices

Density is the number of devices used to measure the travel time in one single segment. It should be noted that the type of technology used and placement of devices can have an impact on the number of devices. Typically, one device per direction at each end of the segment should be enough to capture accurate travel time provided there are three good matching samples every two minutes.

Guideline(s)

At least two P2P devices should be used for each segment in each direction. It is possible, depending on the placement of the device and technology; one device may cover both directions. If there are not enough matching samples in the segment, the operator should consider.

- Shortening the size of the segment
- Use a different technology

3.4.1.6 Data Collection Timeliness

Within the Denver Region, data are collected from CDOT or the operator owned field device by CTMS every two minutes or less. FHWA Rule (Section 3.2, Table 2) states that travel time should be reported within ten minutes or sooner from the time the travel time calculation is completed. At present, the Denver Region reports travel time on the CoTrip website within two
minutes or less from the time it is calculated. Figure 19 shows the travel time data flow and its potential time intervals.

**Figure 19: Travel Time Data Flow and Potential Time Interval**

Regardless of which agency is processing the data, i.e., CTMS or the vendor software, data from the field device should be collected every two minutes or less. Travel time information should continue to be reported within two minutes or less after processing regardless of the type of technology or if the data are being processed by CTMS or the vendor software.

### 3.4.1.7 Travel Time Data Processing

Depending on the type of technology used for travel time data collection, there are two primary ways to process the data. They are:
• Within the Denver Region, the CTMS software application has been used for generating arterial travel condition information. CTMS has a toll tag software driver for toll tag technology that is being used in the Region to collect travel time information.
• Device vendors have proprietary software and algorithms that can process the data and provide output via XML feed to allow CTMS to post the information on CoTrip.
• Regardless of how the data is processed, data must flow through CTMS in order to be posted on the CoTrip website.

Guideline(s)

The Denver Region should continue using the CTMS application for travel time processing with regard to toll tag technology. If new P2P technologies are considered on arterials, software drivers should be written by the agency implementing the technology. If private ISPs or vendors are used, processed travel time data in a XML feed every two minutes must be provided to CTMS in order to post the information on CoTrip.

3.4.1.8 Travel Time Index (TTI) Processing

Travel Time Index is the ratio of peak period travel time to free-flow travel time.

TTI = Travel Time in minutes / Free-Flow Travel Time in minutes

Example of TTI Calculation

If the free-flow travel time is 15 minutes for a segment and the actual travel time during a two minute interval in the AM peak period is 18 minutes, then the TTI is 1.2 (18/15). This means that the actual travel time is 20% greater than the free-flow travel time.

Free-flow travel time can be obtained using one of the following three methods

• Use distance and the posted speed limit to calculate the free-flow travel time.
• Conduct travel runs during the off-peak period (11AM-1PM).
• Conduct travel runs during the late-night period (10PM-5AM).
Texas Transportation Institute uses late-night period (10PM-5AM) to determine free-flow travel time. In the 2007-2009 CDOT DTD Statewide Travel Time and Analysis Project, the free-flow travel time was based on the off-peak period (11AM-1PM).

**Guideline(s)**

- It is recommended that free-flow travel time obtained by conducting travel runs during late-night period (10PM-5AM), which will be consistent with Texas Transportation Institute’s measurement of free-flow travel time. Also, this will be consistent with other mobility measures Texas Transportation Institute publishes annually for major cities.
- It is recommended that at least six travel delay studies be conducted for each direction. There should not be any travel time studies conducted during construction, bad weather or any other conditions that impact free-flow travel.

### 3.4.1.9 Planning Time Index (PTI) Processing

The PTI is the ratio of the near-worst case travel time to a travel time in free-flow traffic conditions. PTI can be based on a percentile for the reporting period. There is no specific guidance in traffic engineering studies or manuals regarding which percentile should be used to calculate PTI.

Texas Transportation Institute computed PTI using 95th percentile travel time divided by the free-flow travel time. The free-flow travel time used in the calculation of TTI will be useful in calculating the PTI.

\[
\text{PTI} = \frac{95^{\text{th}} \text{ percentile travel time in minutes}}{\text{free-flow travel time in minutes}}.
\]

**Example of PTI Calculation**

If the 95th percentile travel time on a corridor in the identified reporting period is 24 minutes and free-flow travel time is 15 minutes. PTI for this corridor is \(24/15=1.6\).
Guideline(s)

The 95th percentile travel time should be used for PTI calculation in the Denver Region, which will be consistent with the Texas Transportation Institute.

3.4.1.10 Real-Time Travel Time Algorithm and Graphical Display Output

Using CTMS, CDOT provides travel time information on a color coded map on the CoTrip website for both Interstate Highways and arterials. The color codes for Interstate Highways and arterials are similar. However, Interstate Highway color codes are based on speeds, while the color codes for arterials are based on a combination of occupancy and speed. Depending on the arterial segment, a different weightage can be applied to speed and occupancy parameters based on operational characteristics, location, etc. For the recent travel time implementation in Douglas County on Quebec Street and Lincoln Avenue corridors, P2P devices were used. Subsequently, the color codes focused primarily on speed obtained from travel time since no occupancy data were available. As shown in Table 3, the column Existing Legend appears to be a mix of how traffic is flowing or level of congestion as it relates to the arterial color.

<table>
<thead>
<tr>
<th>Color</th>
<th>Existing Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>Moving Well</td>
</tr>
<tr>
<td>Yellow</td>
<td>Slowing</td>
</tr>
<tr>
<td>Red</td>
<td>Heavy Traffic</td>
</tr>
<tr>
<td>Black</td>
<td>Very Congested</td>
</tr>
<tr>
<td>Gray</td>
<td>No Data</td>
</tr>
</tbody>
</table>

The color codes can be based on travel time or speed, TTI (Section 3.4.1.8) or PTI (Section 3.4.1.9). Travel time by itself does not lend well for color coding purposes. For example, a
travel time of 10 minutes does not indicate much about traffic conditions or congestion. Travel time needs to be compared against another condition for it to be more meaningful. Using color codes based on speeds may not be useful. In the Denver Region, speed limits on arterials vary from 30mph to 55mph. A speed of 20mph on a corridor with a speed limit of 35mph may indicate a different level of congestion than on a corridor with a speed limit of 55mph. PTI only considers the 95th percentile travel time instead of current conditions, and therefore is more of a planning measure. TTI compares current travel time to free-flow travel time. TTI provides a more accurate and representative indication of the congestion condition on a corridor regardless of the speed limit. Analysis of three years data collected for the 2007-2009 CDOT DTD Statewide Travel Time and Analysis Project for more than 70 corridors provided a basis for establishing the TTI ranges associated with the arterial color codes. The project provided TTI for morning and evening peak periods by direction.

**Guideline(s)**

The Denver Region should follow the same color codes that currently exist on CoTrip for arterial conditions. However, the color codes for the segment should be based on TTI. Table 4 shows the recommended TTI ranges for each existing color code. In addition, the legend associated with the each of the colors should be changed to reflect a level of congestion. The recommended legend is also included in Table 4.

**Table 4: Color Coding Thresholds and Legends**

<table>
<thead>
<tr>
<th>Color Code</th>
<th>TTI Value</th>
<th>Roadway Congestion Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>&lt;1.2</td>
<td>Light or No Congestion</td>
</tr>
<tr>
<td>Yellow</td>
<td>1.21-1.5</td>
<td>Moderate Congestion</td>
</tr>
<tr>
<td>Red</td>
<td>1.51-1.8</td>
<td>Heavy Congestion</td>
</tr>
<tr>
<td>Black</td>
<td>&gt;1.81</td>
<td>Severe Congestion</td>
</tr>
<tr>
<td>Gray</td>
<td>No data</td>
<td>No data</td>
</tr>
</tbody>
</table>

**3.4.1.11 Real-Time Travel Time Tabular Display**

Presently on the CoTrip website, arterial condition information can be viewed in a tabular format that includes the following:
• Arterial and Direction
• Segment (From & To)
• Travel condition legend and the associated color
• Current travel time

When the segment is selected, a pop-up window for the segment which is shown in Figure 20 displays the following:
• Current speed
• Travel condition legend and the associated color
• Current travel time
• Normal travel time
• Volume
• Occupancy
• Segment Length

Figure 20: Tabular Display of Arterial Corridor information on CoTrip

As more arterials and more segments are added to the CoTrip website, the tabular display may become too cumbersome to use. It is not clear how the travelling public or private ISPs use this information. If the tabular display allowed for “rubber banding” a group of segments to get an aggregated origin/destination travel time, it might be beneficial.
Tabular display for arterial conditions should be made available only for the operators on the CCTM. Also, operators should have the capability to select a segment, which would pop up a window that displays the following information:

- Current travel time
- Current travel speed
- Current Travel Time Index and associated color codes
- Free flow travel time
- Segment limits (From/To)
- Segment length

In addition, operators should have the ability to “rubber band” a group of segments to obtain an aggregate origin and destination current travel times.

### 3.4.1.12 Travel Time Calculation and Validation

In general, the validation process for travel time is dependent on the operator and availability of agency resources. The validation process typically begins after the segments are instrumented with the devices.

**Guideline(s)**

The validation process should begin from the conceptual stage to design through implementation and continue with periodic monitoring.

During the conceptual stage, the validation process should include the following:

- Regardless of the technology used, it should be confirmed that there are at least three good matching samples every two minutes during morning peak hour (7-8AM) and evening peak hour (4:30 to 5:30PM).
- If the matching sample size requirements are not being met, the operator should consider modifying segments, placement of P2P devices and possibly using a different technology.
After the project is implemented, the validation process should include following:

- Compare reported real-time travel time against measured travel time information for the three peak periods. Travel time studies should be conducted during morning peak (7-8AM), Noon peak (12-1PM) and evening peak (4:30 to 5:30PM). It is recommended that at least 4 runs be completed each direction for each period. Typically, deviations in travel time of less than 15% can be considered acceptable.

- If deviations greater than 15% are observed for a particular segment, the process should be repeated the next day for the same period.

- If deviations greater than 15% persist, conduct travel time studies again for the segment and validate the data being reported on the segment.

- Operators should also review a report that shows the number of matching samples every two minutes for a 24 hour period on a weekday and weekend to understand the quality and reliability of data.

- After the initial year, the validation process should include the following:
  - Local agency operators should conduct travel time studies during one of the peak periods and compare it to real-time travel time for the same peak period. This should be done on an annual basis.
  - The operator should confirm that reported/measured travel times did not deviate more than 15 percent.

- The free-flow travel time should be re-collected if the following major changes have occurred along the corridor:
  - Signals added or removed
  - Major lane or geometric changes
3.4.1.13 Accepting Travel Time Data from Private ISPs and Vendors

As mentioned earlier, private ISPs are capable of providing travel time data every two minutes or less on arterial corridors using TMC segmentation. At present, there are a couple of issues with TMC segmentation.

- It is an unofficial standard and TMC segments are only updated once every year.
- Some arterial segments have only one TMC segmentation code for both directions.

Private ISPs are working on providing travel time data for customized segments. Device vendors (Blue Tooth & others) are also willing to provide travel time data to local agencies and are not tied to TMC segmentation. The data collection and processing are done by custom and proprietary software algorithms developed by the vendor.

Guideline(s)

Travel time data from private ISPs are acceptable as long as the following requirements are met:

- Travel time data are provided via XML feed every two minutes.
- Segmentation is clear by direction and meets the requirements of the local agency.
- No restrictions on the use of data for real time or historical purposes.
- Sample size requirements are being met, i.e., minimum of three good matching samples every two minutes.
- Data are measured travel-time data and not speed data that are extrapolated to calculate travel time.

3.4.1.14 Providing Travel Time Data to Private ISPs

As local agencies collect travel time data, it should be made available to private ISPs as they are looking to add more data sources. This will allow the private ISPs to customize and pre-package the information to their individual subscribers or commercial clients.

In discussions with private ISPs, it is evident that data are being purchased from other private vendors such as, cell phone providers, trucking companies, etc. It also appears that data from
public agencies are being provided to private ISPs at no cost. There are a couple of issues that operators should consider

- Data are being provided to a for-profit entity that is reselling the data to its paid subscribers.
- There are additional responsibilities that are being incurred by the operator in terms of maintaining the XML feed, trouble shooting issues, pursuing and monitoring agreements, etc. These responsibilities result in taking time and resources away from normal operations.

Operators may need to consider the possibility of selling the data to private ISPs in order to recover cost associated with collection, processing, storing and dissemination of the data.

Guideline(s)

- Travel time data should be made available to private ISPs. Interested ISPs should poll the data in time intervals no greater than every two minutes. Shorter polling times of less than every two minutes can slow down the available communication channels.
- Agencies should be given the discretion to charge private ISPs for their data.

3.4.1.15 Travel Time Measures of Effectiveness (MOEs) and Reporting

The following MOEs are available

- Travel Time
- Travel Time Index (TTI) – Section 3.4.1.8
- Planning Time Index (PTI) – Section 3.4.1.9
- Congestion Duration

Historical data and reports should be made available through the previous day.
3.4.1.16 **Congestion Duration**

The duration of congestion is a helpful measure for operators to determine how much time the corridor is congested for a specified time period. Congestion occurs when the volume of traffic is greater than the available roadway capacity. CDOT DTD uses V/C (volume divided by capacity) ratio \( \geq 0.85 \) to define congestion. This is based on available historical data and data measures at specific points along the corridor. Although, it is hard to determine if the congestion data were impacted due to traffic incidents, etc. TTI forms a good basis for addressing congestion as it reflects how traffic operates in relation to free-flow conditions.

**Guideline(s)**

- Congestion duration must be determined based on the time period where a segment experiences a TTI of \( \geq 1.2 \).
- Additionally, operators should also consider determining congestion severity by identifying time periods of heavy (TTI between 1.51-1.8) and or severe (TTI \( > 1.81 \)) congestion.

3.4.1.17 **Usefulness of MOEs to Operators**

Typically, travel time studies are manually conducted by operators on an as-needed basis and usually associated with signal retiming efforts. These studies primarily focus on travel time and stopped delay. At present, TTI, PTI and congestion duration are not part of the operator’s tool box.

Operators do not have a baseline for travel time information, which is necessary to perform a comparison with historical data. Operators are not able to determine the impacts on travel time in conjunction with the following conditions:

- During incidents
- During construction or maintenance activity
During weekends
Holidays
During bad weather
During events
Signal malfunctions
Signal retiming
New development or redevelopment

The ability to understand the impacts of these conditions on travel time allows the operators to perform the following actions:

- Examine the restrictions on construction maintenance activity along an arterial. At present, these restrictions are not based on impacts on travel time.
- Determine the needs for weekend timing plans. Currently, most operators use weekday plans on weekends.
- Implement special timing plans with extended yellow and all red intervals for bad weather and events to increase safety.
- Identify the costs of malfunctioning signals to the travelling public and improving the reliability of equipment.
- Determine the benefits of signal retiming efforts.

**Guideline(s)**

- The first year of travel time implementation forms the baseline for all MOEs. This establishes a solid foundation for comparison and trend analysis.
- After the first year, the operator should be able to compare current data in the following ways:
  - Time of Day (TOD) comparisons
  - Day of Week (DOW) comparisons
  - Weekly comparisons
3.4.1.18 Usefulness of MOEs to Others

Operators are focused on real-time information and historical data as it pertains to operations. There are other agencies that are able to use historical travel time MOEs. Potential uses for the historical information include:

- Determining needs for capital improvements along the corridor based on the severity of the problem.
- Creatively using TDM strategies along an arterial and measuring the impacts of these strategies.
- Calibrating planning models.
- Incident management and impacts on alternate routes.
- Impacts of development and land use.

3.4.2 Traffic Incident Information

Traffic incident information is the second highest ranked travel condition data parameter in the Denver Region. It can assist operators in understanding and/or managing the impacts of the incidents. Information about incidents on arterials is also helpful to the travelling public in making travel decisions.

3.4.2.1 Types of Traffic Incidents

An incident is an unexpected occurrence or an event that results in traffic delays and an increase in congestion on the corridor. Incidents can also impede traffic by blocking lane(s) or the roadway. Incidents can be classified by type depending on the level of granularity desired. CDOT’s Courtesy Patrol Program that operates within the Denver Region classifies incidents by
more than 10 different types. This level of granularity may be too much, and therefore may not be useful or necessary for the arterials.

**Guideline(s)**

Incidents on arterials should be classified into the following five types:

- Accident (Primary or Secondary)
- Stalled Vehicle
- Spill load (non HAZMAT)
- HAZMAT Spill
- Other (Vehicle fire, etc)

The NIMS traffic incident classification should be used and they are defined below:

- Minor - traffic incidents with disabled vehicles and minor crashes that result in no lane closure or lane closures of less than 30 minutes.
- Intermediate - traffic incidents that affect travel lanes for 30 minutes to 2 hours and usually require traffic control at the scene to divert road users past the blockage. Full roadway closures may be necessary for short periods during traffic incident clearance to allow incident responders to accomplish their tasks.
- Major – Typically, traffic incidents involving hazardous materials, fatal traffic crashes involving numerous vehicles, and other natural or man-made disasters. These traffic incidents typically involve closing all or part of a roadway facility for a period exceeding 2 hours.

### 3.4.2.2 Traffic Incident Detection

Traffic incidents along the roadways can be detected by the operator in the following ways:

- Incident detection algorithms based on instrumentation using P and/or P2P devices.
- Public Safety receives the incident information from the public and the information is made available to the operator via interface to CSP or local law enforcement Computer
Aided Dispatch System (CADD). In some instances, the operator monitors the public safety radio channels to find out about traffic incidents.

- Depending on the type of incident, operators may receive phone calls from Public Safety or emergency providers requesting support for incidents.
- Observed on the traffic camera by TMC operator.

There may be other sources for incident detection such as maintenance personnel, phone calls to the TMC, etc.

Incident detection algorithms for Interstate Highways are at a more advanced stage of development than for arterials. The operational characteristics of arterials make it difficult to develop a reliable incident detection algorithm. CDOT has an interface into CSP CADD that allows CDOT to know about traffic related incidents. The practice of monitoring Public Safety radio channels may not be the most effective way to find out about incidents.

Traffic cameras are useful for incident detection. The cameras can be Pan Tilt Zoom (PTZ), presence detection cameras at signalized intersections or queue detection cameras at selected locations. All of these cameras require that an operator monitor the camera images to detect an incident.

**Guideline(s)**

- Deployment of an incident detection algorithm for arterials is not recommended at this time.
- Local CTMS client interface to the CSP or local law enforcement CADD system is recommended as this will allow the operator to monitor traffic incidents.
- Operators should use traffic cameras to monitor traffic flow and detect incidents during morning and evening week day peak periods.
3.4.2.3 Traffic Incident Verification

Incident verification is the critical function of a traffic incident management effort. The incident will not be reported to the travelling public on the CoTrip website if it has not been verified. If the incident information is available via the CSP or local law enforcement CADD interface, it can be considered very reliable. However, traffic incident information from other sources should be verified before the incident is reported to the travelling public.

**Guideline(s)**

- Incidents should be verified using traffic cameras before being reported to travelling public via CoTrip website.
- If the incident cannot be verified due to lack of video coverage, the incident should not be reported to the travelling public unless it is confirmed by a reliable source. Acceptable forms of verification include CSP or local law enforcement CADD interface, on-scene public safety personnel, on-scene operators and maintenance personnel.

3.4.2.4 Incident Information Validation

The validation process needs to occur throughout the duration of the incident, i.e., detection, verification, response, reporting and clearance.

Once the incident is verified and reported, the operator should continue to monitor any changes to:

- Roadway or lane closure
- Duration of the incident

If video coverage is not available, the operator is responsible for coordinating with the incident commander to update any changes.
Guideline(s)

- The operator is responsible for updating any changes to the following:
  
  - Roadway or lane closures
  - Duration of the incident
  - Clearance of the incident

3.4.2.5 Traffic Camera Placement

Traffic cameras are one of the primary ways to detect and verify incidents on an arterial. Camera images of an arterial can be available from queue cameras, presence detection and PTZ cameras. The placement of queue presence and queue detection cameras is dictated by other factors since their primary purpose is not to provide camera images. Also, these are fixed cameras, i.e., they do not have PTZ capability and their field of view is calibrated to assist in detection of vehicles and queues. However, cameras with PTZ capability should be considered at critical locations.

Guideline(s)

Cameras with PTZ capability are recommended at major intersections. Major intersection is defined in Section 3.4.1.2 (Segment Definition). To the greatest extent possible, the camera should be placed to allow visibility on both intersecting corridors. However, operators should also exercise judgment based on operational characteristics along the corridor. In some instances, cameras may be required at non-major intersections.

3.4.2.6 Traffic Incident Response and Reporting

Within the Denver Region, CDOT reports incidents on Interstate Highways and other highways; however, incidents that occur on the arterials are not being reported. After the incident is detected and verified, the operator has to make the following decisions:
• Determine the potential duration of the incident - Incident duration includes the time from when the incident is detected to the time when the incidents is cleared. Determining the duration of the incident can be difficult. Incidents are managed on scene by CSP or local law enforcement Personnel. The operator has to rely on visual images and/or obtain potential duration information from the incident commander.

• Implement any mitigation strategies – These include temporarily adjusting signal timing and posting incident information on VMS and CoTrip to alert the travelling public.

**Guideline(s)**

• Operators should consider mitigation strategies only if the potential incident duration is expected to last more than 30 minutes.

• If the incident duration is expected to be more than 30 minutes i.e., intermediate or major incidents, operators should use the local CTMS to report the incident and include location, direction, duration, roadway or lane closure and reporting source.

• Additionally, the operator working with CSP or local law enforcement personnel can implement any temporary changes in signal timing to alleviate the traffic backups in the incident area.

3.4.2.7 Traffic Incident Information Display Output

CDOT provides incident information for Interstate Highways and other highways on the CoTrip website. The symbol for an incident is shown as 🚨. CDOT also uses ✅ to show when the incident is cleared. When the incident symbol 🚨 is selected, it displays text providing information about the incident.

**Guideline(s)**

• The same symbols used on CoTrip regarding incidents should be used for arterials to provide consistency.
When the symbol is selected, it will display the following information:
- Location
- Direction
- Type of Incident
- Roadway or Lane closure
- Potential Duration
- Information Reporting Source

It is also recommended that the cleared incident symbol should be timed to stay on for 10 minutes after the incident has been cleared.

3.4.2.8 Traffic Incident Clearance

Typically, the incident is considered cleared when it is no longer impeding traffic flow on the roadway. When incidents with greater than 30 minutes of duration are cleared, the operator needs to:

- Clear the incident on reporting and if signal timing was temporarily adjusted it should be returned to normal operations.

Guideline(s)

- Operators should confirm that an incident has been cleared before reporting it on CoTrip.
- Operators should confirm return to normal signal operations.

3.4.2.9 Data Timeliness

As per the FHWA Rule, information for incidents pertains to roadway closures or lane blocking on Interstate Highways and on Routes of Significance within the MSA area should be reported within 10 minutes from the time the incident is verified.

Guideline(s)
Denver Region should follow the FHWA Rule regarding reporting incidents that cause roadway closures or lane blocking on arterial corridors within 10 minutes from the time the incident is verified provided that the incident is projected to exceed 30 minutes in duration.

3.4.2.10 Accepting Incident Information from Private ISPs

Private ISPs can provide incident information by collecting the data from many sources, including incidents reported by subscribers. It is not clear how incidents are verified and cleared. Presently, no private ISP has access to CSP or local law enforcement CADD systems.

**Guideline(s)**

- Incident information from private ISPs is acceptable as long as the operator has the ability to verify the incident, as defined in Section 3.4.2.3 (Incident Verification), before any mitigation strategies are implemented.

3.4.2.11 Providing Data to Private ISPs

When incident data are collected for arterials, it should be shared with private ISPs. This will further allow the private ISPs to customize and pre-package the information to their individual subscribers and/or their commercial clients.

**Guideline(s)**

- Incident data should be made available to private ISPs.

3.4.2.12 Incident Information MOEs

The following MOEs that relate to incident information are recommended for the Denver Region:

- Number of incidents over a specified period.
- Type of incidents over a specified period.
- Travel time during incidents.
• Incident duration
• Number of secondary incidents.
• Crash rate (Crashes per million miles travelled) by specified roadway length.

3.4.2.13 Usefulness of MOEs to Operators

At the moment, operators are mostly unaware of incidents that happen on the arterials as incidents are handled by CSP or local law enforcement personnel. Operators do not have a baseline of incident information. With the interface to CSP or local law enforcement CADD systems, operators will be aware of traffic incidents. Also, depending on the availability of cameras, operators will be able to verify the incident and implement mitigation strategies.

Guideline(s)

• The first year of incident information forms the baseline for all MOEs.
• Following the initial year, the MOEs can be expanded to include the operators response to incidents. Case studies should also be selectively performed to understand the benefits of mitigation strategies.

3.4.2.14 Usefulness of MOEs for Others

Operators should share the MOEs with Public Safety and Emergency Management providers. Potential uses for this information may include:

• Traffic incident management plans for specific arterials including agency roles and responsibilities identified in the plans.
• Identification of alternative routes.
• Protocols on handling traffic issues during incidents.
3.4.3 Weather Related Road Condition Information

Weather related road conditions are provided on the CoTrip website for most Interstate Highways, State and US Highways primarily outside of the Denver Region. This information is used by the travelling public during bad weather. It is also used by public and private entities, trucking companies, visitor centers, etc. to assist in their daily operations.

3.4.3.1 Types of Weather Road Condition Information

Weather information can be typically classified into two categories: weather forecasts and weather related road conditions. Weather forecasts are available from a variety of mediums such as television, radio, etc. However, weather related road condition information is more difficult to obtain without instrumentation along the roadway.

Weather related road condition information can be classified in numerous types like blowing snow, snow, icy spots, wet/rain, etc. CDOT uses nine types of weather related road condition information for its highways.

This level of granularity may not be useful or necessary for arterials given the geographic location and terrain within the Denver Region.

Guideline(s)

- Denver Region should provide the following weather related road conditions information:
  - Icy Spots
  - Snow
  - Wet/Rain
  - Poor Visibility/Fog
  - Adverse Conditions
  - No Data (only when no data is available from the device)
• Operators should provide weather related road condition information during adverse conditions, which result in roadway or lane blockage.

• The following weather related road conditions information is not recommended for arterials in the Denver Region:
  o Blowing Snow
  o Dry
  o High Wind

Typically blowing snow and high wind is local to few specific spots in the Region. In addition, providing dry and no data conditions may cause more visual clutter and do not add any value to the information.

3.4.3.2 Segmentation for Weather Related Road Condition Information

Weather related road condition information would be determined and updated based on the corridor segmentation. Most of the time weather related road conditions would be the same on the entire arterial corridor or at least for a few miles of the corridor. If corridor segmentation follows the guidelines for travel time, the weather related road conditions data will be too detailed, which may be confusing for the users.

Guideline(s)

Segmentation to display the weather related road information should follow these guidelines:

• Combine segments to include at least three major intersections or consider minimum segment lengths of five miles.

• If a jurisdictional boundary exists between two major intersections, it is recommended to consider the segment end at the nearest signal prior to entering the adjoining jurisdictional boundary.

3.4.3.3 Detection of Weather Related Road Conditions

Within the Denver Region, the following devices are being used to monitor weather conditions:
• Weather stations and road sensors.
• Traffic Cameras.
• Snow plow vehicles equipped with AVL (some vehicles may also include a camera and/or data input device).
• Fog Visibility Systems.

CDOT uses Maintenance Decision Support System (MDSS), which is tied to various forecasting services, weather stations, sensors, etc. MDSS is capable of collecting surface and pavement condition information from weather stations and providing weather forecasting and roadway treatments based on road condition information. This is an annual paid service to an MDSS vendor based on number of roadway miles covered. Most CDOT weather stations include a fixed camera that can transmit road condition images at periodic intervals. Roadway sensors provide information regarding weather related pavement conditions such as icy spots, snow or rain accumulation, wind, etc. Traffic cameras allow operators to visually monitor pavement and visibility conditions. Also, traffic cameras serve other purposes such as monitoring traffic flow and assisting in incident management. Snow plow vehicles equipped with cameras and/or data input devices provide snap shots of pavement conditions. Also, the snow plow operator can input road conditions if a data input device is available in the vehicle. The fog visibility system includes sensors that detect fog and display warning messages on Variable Message Signs at the approximate location.

Guideline(s)

• Traffic cameras are the best possible devices to obtain weather related road conditions during bad weather. Camera images are also the most popular item accessed on the CoTrip website during bad weather. Traffic cameras are recommended to be used at major intersections. Major intersections are defined in Section 3.4.1.2.

• Weather Stations and road sensor locations can be determined by operators. The implementation of weather station and road sensors should be left to the discretion of the
operator in conjunction with the agency’s needs. If they are installed, the data should be available in CTMS via XML feed.

- Local agencies should decide if they want to implement the MDSS system and/or equip snow plows with AVL capabilities including camera and/or input devices in the vehicle. Operators should consider using the MDSS system instead of implementing a stand alone system. This will increase the benefits through better forecasting, reduced costs and all the data being available on the same system.

3.4.3.4 Road Conditions Graphical Display Output

CDOT provides weather related road conditions for Interstate Highways, State and US highways on the CoTrip website with a color-coded map. The majority of these highways are outside of the Denver Region. The color-coded legend that is used on the CoTrip website is shown in Table 5. CoTrip does not include weather related road condition information for the majority of arterials in the Denver Region.

<table>
<thead>
<tr>
<th>Color Code</th>
<th>Weather Related Road Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark Blue</td>
<td>Blowing Snow</td>
</tr>
<tr>
<td>Light Blue</td>
<td>Icy Spots</td>
</tr>
<tr>
<td>Sky Blue</td>
<td>Snow</td>
</tr>
<tr>
<td>Green</td>
<td>Wet/Rain</td>
</tr>
<tr>
<td>Light green</td>
<td>Dry</td>
</tr>
<tr>
<td>Black</td>
<td>Adverse</td>
</tr>
<tr>
<td>Purple</td>
<td>High Wind</td>
</tr>
<tr>
<td>Light Gray</td>
<td>No Data</td>
</tr>
<tr>
<td>Dark Gray</td>
<td>Poor Visibility/ Fog</td>
</tr>
</tbody>
</table>
Guideline(s)

Color codes should be as shown in the Table 6 for the arterials in the Denver Region. This is consistent with the color codes currently used on CoTrip.

Table 6: Recommended Color Code and Weather Related Road Conditions

<table>
<thead>
<tr>
<th>Color Code</th>
<th>Weather Related Road Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Blue</td>
<td>Icy Spots</td>
</tr>
<tr>
<td>Sky blue</td>
<td>Snow</td>
</tr>
<tr>
<td>Green</td>
<td>Wet/Rain</td>
</tr>
<tr>
<td>Dark Gray</td>
<td>Poor Visibility/ Fog</td>
</tr>
<tr>
<td>Black</td>
<td>Adverse</td>
</tr>
</tbody>
</table>

3.4.3.5 Tabular Display of Weather Related Road Conditions Information

On the CoTrip website weather related road condition information for Interstate Highways, State and US highways can be viewed in a tabular format that includes the following:

- Segment (From & To)
- Road condition

When the segment is selected, a pop-up window for the segment displays the following:

- Segment
- Road Condition
- Length
- Comments
- Updated time

As more arterials and more segments are added to the CoTrip website, the tabular display may become too cumbersome to use. If the tabular display allowed for “rubber banding” a group of segments to get an overall weather related road condition information, it might be beneficial.
Guideline(s)

Tabular display for weather related road conditions should be made available on CoTrip and CCTM for the Denver Region. Also, when the segment is selected a pop up a window should display the following information:

- Segment
- Road condition
- Roadway or lane blockages
- Updated time
- Information Reporting Source

3.4.3.6 Data Timeliness

As per the FHWA Rule, hazardous driving conditions and roadway or lane closures or blockages because of adverse weather conditions on the Interstate Highways and Routes of Significance should be reported within 20 minutes from the time hazardous weather related road conditions, blockages or closures is observed.

Guideline(s)

Denver Region should follow the FHWA Rule and report hazardous driving conditions and roadway or lane closures or blockages within 20 minutes of when they are observed. However, other conditions such as icy spots, snow, wet/rain and poor visibility/fog can be reported within 30 minutes or when conditions change during the morning or afternoon weekday peak periods.

3.4.3.7 Weather Related Road Condition Information Validation

The validation process needs to occur throughout the duration of bad weather conditions, i.e., detection, verification, reporting and clearance.
Once the weather related road condition is verified and reported, the operator should continue to monitor any changes to:

- Roadway or lane closures
- Roadway condition

If video coverage is not available, the operator is responsible for coordinating with maintenance personnel to update any changes.

**Guidelines**

- The operator should update changes to the following information:
  - Roadway or lane closures
  - Road conditions

**3.4.3.8 Weather Related Road Condition MOEs**

As with incidents, operators within the Denver Region do not have a clear understanding of the impacts of weather on arterial operations. As a result, operators are unclear regarding potential mitigation strategies that could be used, such as extended yellow, all red clearance intervals or longer cycle lengths. The following MOEs that relate to weather related road condition information are recommended for the Denver Region:

- Number of adverse conditions observed.
- Travel time during different road conditions particularly during snow conditions.
- Number of observed incidents due to adverse weather conditions.
3.4.3.9 Usefulness of MOEs to Operators

Through use of these MOEs, operators will be able to understand and make informed decisions when weather related road conditions occur. Understanding how travel is impacted during different conditions will allow operators to determine different strategies that may include:

- Adjusting signal timing to reduce accidents.
- Advising alternative routes for traveler.

Guideline(s)

- Operators should study the effect on travel time during the weather related road conditions.
- Operators should consider implementing signal timing changes and determine the impacts from such changes on travel time and safety.

3.4.3.10 Usefulness of MOEs to Others

While operators are focused on real time information and historical data as it pertains to operations, there are other agencies that are able to use these MOEs. Potential uses of the historical information include:

- Evaluation of existing roadway condition and impact due to weather.
- Emergency vehicle routes during bad weather.
- Identification of future roadway capital improvements to improve safety and operations during bad weather.

3.4.4 Construction and Maintenance Operations Information

Typically, construction projects on Interstate Highways, State Highways, US Highways and arterials may take several weeks to complete and some may take a year. In the Denver Region, construction information is one of the second highest ranked travel condition data parameters. Construction can result in roadway changes, i.e., lane closures and detours. Although
construction activity can have significant impacts on roadway traffic conditions, in most instances, operators have minimal to no control over the construction project as the agency project managers work with the construction contractor.

Maintenance operations in the Denver Region involve both planned and emergency operations. Much like roadway construction, maintenance operations can result in lane closures or road blockages causing inconvenience to the travelling public.

Stakeholders agreed that from a travelling public perspective, the distinction between construction and maintenance may not be significantly different. It was also agreed that the travelling public should be informed about both construction and maintenance activities so that they can make informed decisions on their travel. However, there would be distinction drawn between “Planned” and “on-going” activities.

3.4.4.1 Types of Construction and Maintenance Operations

Construction and maintenance operations on an arterial can be classified into several different types. From a travelling public perspective, it is not clear how much difference it would make to know the type of activity on an arterial.

**Guideline(s)**

Construction and maintenance operations within the Denver Region should be classified into one of the five following types:

- Bridge Construction
- Road Construction including above ground and underground utilities (water, sewer and communications)
- Signal Installation/Upgrade
- Paving operations
- Roadway maintenance operations
3.4.4.2 Collection of Construction and Maintenance Operations Information

Collecting information on construction projects and maintenance operations can be done through a variety of methods. This could range from one consolidated clearing house for all construction projects and maintenance operations in the Denver Region to each local agency being responsible to provide construction and maintenance operations information within their jurisdictional boundaries.

**Guideline(s)**

Construction project and maintenance operations information should be provided and updated by the operator within each local agency using local CTMS. The operator is responsible to keep the construction and maintenance operations information current and work closely with the agency project manager, construction contractor or agency maintenance supervisor.

3.4.4.3 Graphical and Tabular Display of Construction and Maintenance Operations Information

CoTrip displays construction and maintenance operations on Interstate Highways and State Highways, US Highways in two ways. The first is by graphically showing a road traffic cone on the map at each construction and maintenance operations location. The tabular display is also available when the road traffic cone is selected. The construction and maintenance operations display is shown in Figure 21.
CDOT includes the following information on each construction project both in graphical and tabular format:

- Roadway
- Direction
- Location and Mile marker
- Hours/Days of construction
- Description of Closures and Detours
- Last Updated, i.e., a date and time stamp
- Expected project completion (month, year)

Figure 22 provides a sample of the type of construction information that is provided when the road traffic cone is selected.
Additionally, CoTrip provides a tabular display of each maintenance operation that includes the location, the time of day operations will occur, and any lane closures, delays, or roadway changes. Figure 23 shows the sample of tabular display of maintenance operations on the CoTrip website.
Typically, this information seems sufficient for construction and maintenance operations on arterials. The one issue that is worth noting is that the current format may not be intuitive to a user and may be cumbersome to read.

**Guideline(s)**

- The cone symbol should be used for graphically displaying construction and maintenance operations for both Interstate Highways and arterials. This avoids any confusion for users.

- Planned construction and maintenance operations should only be reported within 30 days of commencement of the work.

- Only maintenance operations including emergency operations that are expected to be 30 minutes or more in duration should be reported to the travelling public.

- Tabular information should be accessible by clicking on the symbol on the graphical representation.
Construction and maintenance operations information on the arterials should be available on CCTM.

Tabular information for each construction and maintenance operations should include the following information:

- Planned or On-going
- Location and Mile Marker
- Direction
- Road/Lane Closures
- Construction and Maintenance Operations Type
- Hours/Days of Construction
- Completion Date
- Description of Closures and Detours
- Delays
- Update Time/Date Stamp
- Information Reporting Source

3.4.4.4 Data Timeliness

CoTrip updates construction and maintenance operations information as needed. Delay times and roadway or lane closures should be updated more regularly than other more general information. As per the FHWA Rule, the opening or closure of roadways or lanes on Interstate Highways and Routes of Significance due to construction or maintenance activity should be reported within 10 minutes or less from the time of the reopening or closure of the roadway.

Guideline(s)

The following time intervals should be used for updating construction and maintenance operations information:
• Construction and maintenance operations information should be updated on CoTrip within 30 days of the project start date. Earlier updating could result in confusion and later updating could result in travelers not getting the appropriate information.

• Roadway or lane closures should be updated within 10 minutes from the time of the closure or re-opening of the roadway or lanes. This will be consistent with the FHWA Rule.

3.4.4.5 Construction and Maintenance Operations Information Validation

The validation process needs to occur throughout the duration of the construction and maintenance operations. During construction and maintenance operation, the operator should continue to monitor any changes to roadway or lane closures. If video coverage is not available, the operator is responsible for coordinating with the project manager, construction contractor or maintenance supervisor to update any changes.

Guideline(s)

• The operator is responsible for updating the changes to roadway or lane closures throughout the duration of the project and maintenance operation.

3.4.4.6 Construction and Maintenance Operations Information MOEs

Historical operational data about construction and maintenance operations can be useful. By evaluating MOEs, operators will be able to better plan and prepare for such projects.

Guideline(s)

The following MOEs are recommended for the Denver Region:

• Travel time impacts on the arterial due to construction and maintenance operations

• Travel time impacts on other adjacent arterials
3.4.4.7 Usefulness of MOEs for Operators

Operators can use the MOEs to develop a good understanding of impacts on travel times during construction and maintenance operations. Operators can use these MOEs to develop plans to help maintain travel times to acceptable levels within the impacted areas with construction and maintenance operations are being performed. This can be accomplished in the following manners:

- Develop temporary signal timing to accommodate construction and maintenance operations.
- Recommend alternative routes.

*Guideline(s)*

Through the use of historical data and MOEs regarding construction and maintenance operations road condition information, operators can better prepare for construction and maintenance operations projects. This can be accomplished in the following manner:

- Operators should understand how the traveling public makes route decisions by examining travel times.
- Operators can use this information to recommend alternative routes to allow for better utilization of roadway capacity.

3.4.4.8 Usefulness of MOEs for Others

Construction and maintenance operations road condition information can also useful to other agencies. Local agencies can use historical data in determining roadway or lane closures or alternative routes on future construction and maintenance operations projects. Using the information, maintenance operations can perhaps be scheduled during specific time periods so that there is less disruption to traffic and increased safety for maintenance personnel. Also, agencies should consider holding the construction contractor to certain travel time standards during the duration of the project.
3.4.5 Traffic Video

Traffic images are the most popular data item that travelers access on the CoTrip website. Traffic video is either still image or streaming video and is available on CoTrip website. CDOT is completing work on an application (CCTV Application) using its camera command and control software; in conjunction with Google map, that will allow operators to view traffic images across jurisdictional boundaries. In addition, with proper permissions, agencies will be able to control the cameras using the application. Typically, operators are able to control their cameras using specified software and equipment.

Because of extensive video coverage in certain areas, in conjunction with the map scale, CoTrip uses a ‘camera cluster’ symbol. By selecting the symbol, the map is further zoomed in to show camera locations within the cluster.

CoTrip also has camera tours on Interstate Highways. Camera tours present selected camera images of the roadway in pre-set directions.

On Interstate Highways, CDOT uses cameras with PTZ capability. Weather stations typically have fixed cameras. CDOT is in the process of upgrading the weather station cameras to PTZ capability. On arterials, traffic images are available from cameras with PTZ capability, presence detection cameras at signals, weather station cameras and arterial condition cameras.

Typically, PTZ cameras have a range of ¼ to ½ mile view depending on the terrain. Fixed cameras do not have the ability to zoom and have a limited field of view.

It is difficult to determine meaningful MOEs for traffic camera images. The focus of the MOEs should consider the following:

- How much the images are used – This can be tracked on the CoTrip website, CCTM and the new CDOT CCTV Application. Also, it will allow operators to understand the popularity of arterial video images.
• Who is using the cameras – Travelling public is the primary user on CoTrip website. On CCTM and the CDOT Application, it should be easy to track use of cameras to a specific agency or operator.

• How they are used – This is harder to determine and track. Qualitative approaches may need to be developed to determine a better understanding how camera images are used.

Guideline(s)

• As mentioned in Section 3.4.2.5 (Traffic Camera Placement), cameras with PTZ capability are recommended at major intersections.

• Traffic cameras should be installed at locations that will allow multiple uses to serve other travel condition parameters such as:
  o Incidents
  o Construction
  o Weather related road conditions
  o Maintenance operations
  o Traffic information for events
  o Parking information for events

• All traffic video, i.e., PTZ, presence, weather stations, etc. should be made available on CoTrip to the traveling public except cameras that are solely used to collect speed and occupancy and that are directly pointed down at the pavement.

• All traffic video should also be made available on CCTM and the CCTV Application. This can be done via CDOT’s CCTV Application, CTMS, etc.
Operators should work closely with CDOT to determine the best possible approach to have camera images available on CoTrip. The approach will depend on the digital versus analog camera, switches and access control. This also assumes that communications between operating agency and CDOT is existent and available.

- The following MOEs are recommended:
  - Number of web hits for the camera in a specified period of time.
  - Number of unique users accessing the camera image

- The following camera symbols used by CDOT on the CoTrip website should be used on arterials.
  - Still Camera
  - Streaming Camera
  - Camera Tour
  - Camera Cluster

3.4.6 Event Information

Events generate traffic conditions that can cause significant delays to the travelling public, especially if they occur close to the peak periods.

By providing events information, the travelling public is able to make better travel decisions. Operators are mostly aware of events within their jurisdictional boundaries. However, the impacts of events on traffic and travel conditions are not clearly understood or documented. Event information is not displayed on CoTrip website. However, CoTrip uses alerts to provide information regarding specific events.
**Guideline(s)**

- Event information should continue to be made available on the CoTrip website as an alert.

- Operators are responsible for providing the event information via the local CTMS client. Operators should decide if the event is significant enough to report on CoTrip website.

- The event information to be reported on the CoTrip website should include:
  
  - Location of the event
  - Type of the event
  - Road/lane closures
  - Start time and estimated completion time
  - Expected delays
  - Information reporting source

- When the alert is selected it should display the event information.

- The following MOEs are recommended:
  
  - Travel time impacts on arterials due to the event
  - Travel time impacts on adjacent arterials due to the event

- Operators should use the MOEs to recommend alternative routes to allow for better utilization of roadway capacity.
3.4.6.1 Event Information Validation

The validation process needs to occur throughout the duration of the event. The operator should continue to monitor any changes to roadway or lane closures throughout the duration of the event. If video coverage is not available, the operator is responsible for coordinating with the traffic manager to update any changes for the event.

**Guideline(s)**

- The operator is responsible for updating the changes to roadway closures throughout the duration of the project.

3.4.6.2 Parking Information for Events

Parking information for events can be useful and can help alleviate confusion regarding parking for travelers attending the event. Typically, event venues provide parking information on their websites.

Parking lots are mostly operated by private operators. It may be difficult to collect up-to-date parking condition information from these private operators. If the operators decide to provide parking management information for facilities they own, the following guidelines will apply.

**Guideline(s)**

- The operator is responsible for validating the parking availability information for at least one event.

- For public agency operated parking lots and/or garage facilities, operators should consider providing at least the following information.
  - Full
  - Open
• This information should be made available near the parking facility using blankout or Variable Message Signs.

• After implementation of the parking application, the operator should conduct manual parking availability study for at least one event to determine if the reported conditions match the actual conditions.

3.4.7 Speed

In the Denver Region, Speed is one of the third highest ranked travel condition data parameters used by operators to monitor their transportation network.

3.4.7.1 Device Type, Segmentation, Placement and Time Intervals for Data Collection

Speed is similar to the travel time travel condition parameter. It can be collected using P and/or P2P devices. Point devices provide speed at a particular point, which may not reflect the speed for the entire segment. The placement of the P devices can significantly impact the quality of data. Point-to-Point devices are able to derive speed based on when vehicles are entering and leaving the segment.

Guideline(s)

• It is recommended that the travel time travel condition parameter for the segment using P2P device be converted to speed. It should be noted that speed collected from P2P devices includes any stopped delay within the segment, i.e., average travel speed. In addition, segmentation for speed should be between major intersection to major intersection, similar to what was recommended in Section 3.4.1.2 (Segment Definition) for travel time data parameter. The time interval for speed data collection is also what was recommended for travel time data parameter (Sections 3.4.1.6 Time Interval for Data Collection and 3.4.1.7 Time Intervals for Processing and Display).
3.4.7.2 Speed Graphical and Tabular Display Output

CDOT provides a color-coded map on the CoTrip website for both Interstate Highways and arterials. As mentioned in Section 3.4.1.12 (Real Time Travel Time Algorithm and Graphical Display Output), the color codes for Interstate Highways and arterials will remain similar. As discussed previously, the color codes for arterials will be based on TTI and not on speed.

**Guideline(s)**

- There is no need to display segment speed for arterials on CoTrip. In Section 3.4.1.13 (Real-Time Travel Time Tabular Display), it is recommended that tabular display be made available on CCTM for travel time. When the operator selects the segment, it should include the following:
  - Current travel time
  - Free flow travel time
  - Current Travel Time Index and associated color codes
  - Average travel speed
  - Segment limits (From / To)
  - Segment length

3.4.7.3 Accepting Data from Private ISPs

As discussed in Section 3.4.1.20 (Accepting Travel Time Data from Private ISPs and Vendors), private ISPs are capable of providing travel time every two minutes or less on arterial corridors using TMC segmentation. This information can be converted to speed.

**Guideline(s)**

- Segmentation should meet the requirements of the local agency.
- Data should be measured travel time data converted to speed and not based on speed at a particular point on the segment.
3.4.7.4 Speed MOEs and Reporting

The following MOEs can be considered

- Average Travel Speed
- Speed Index = Average Travel Speed/Free flow speed

Historical data and reports should be made available through the previous day.

3.4.7.5 Usefulness of MOEs to Operators

As with other measures, operators do not have a reliable baseline to allow for comparison with historical data.

**Guideline(s)**

- The first year forms the baseline for MOEs. Once this information is available operators can compare travel speeds in many different ways such as
  - TOD
  - DOW
  - Daily
  - Monthly
  - Yearly

3.4.7.6 Usefulness of MOEs to Others

Others agencies are also able to use historical speed MOEs. Potential uses for the speed MOEs information include:

- Determining needs for capital improvements along the corridor based on the severity of the problem.
- Creatively using TDM strategies along an arterial and measuring the impacts of these strategies.
- Calibrating planning models.
3.4.8  Queues

Queues are one of the lower ranked travel condition data parameters operators can use to manage approaches at congested signalized intersections.

3.4.8.1 Queue Presence and Queue Length

Operators are concerned about presence of queues beyond what is considered normal for a given time period. Depending on the operational characteristics of the corridor, the length of queue can vary by lane. The presence of abnormal queues can be a cause for concern for through, left turn or right turn lanes.

In addition, operators are concerned about the length of the queue when it is beyond what is considered normal. The length of queue is generally easier to measure on through lanes as the lanes are mostly continuous. Left-turn and right-turn lanes typically have turn bays with limited lengths.

**Guideline(s)**

- Queue presence and queue length should be collected by lane for through lanes.
- Only queue presence should be collected by lane for left turn and right turn lanes.

3.4.8.2 Device Type to Collect Queue Data

There are several types of point technologies that are able to detect queue presence. The collection of queue length can be complicated. It is probable that almost every available point technology can collect both queue presence and queue length data. However, the level of deployment may vary considerably and is significantly extensive for non-video detection devices.
Guideline(s)

- The type of devices best suited for collecting queue presence and queue length are video detection devices as the level of deployment is minimal and setting up detection zones is easy. Also, video detection has the ability to collect both queue presence and queue length. However, operators can use other technologies as long as the guidelines described in the document can be met.

3.4.8.3 Applicability

At the majority of the signalized intersections and approaches, operators are aware of normal queue backups during peak periods. However, there may be locations that experience significant variations in queues during certain periods. The following signalized intersections are possibly better suited for measuring queue presence and queue length:

- Approaches to major signalized intersections
- Interstate Highway ramp signalized intersections.
  - Detecting queues waiting on the on-ramps to the Interstate Highway.
  - Detecting queues waiting on the off-ramp from Interstate Highway.
- Major signalized intersections at activity centers (major employment centers, shopping centers and event centers).

Guideline(s)

- The applicability of where queue presence and queue length data are useful should be left to the discretion of the operator. The greater the variation of queue over a shorter time period, the better it is suited for such measurements.
3.4.8.4 Placement of Device

Depending on which movement is being considered, i.e., through, left turn or right turn, the placement of data collection device can be critical. Appendix B describes considerations for placement of queue data collection device.

Guideline(s)

• For through lanes, the video detection unit should be placed facing the back of the queue.

• For left-turn and right-turn lanes, the video detection unit can be placed either facing the approaching traffic or facing the back of the traffic.

3.4.8.5 Data Collection Timeliness

Most technologies allow for queue data to be collected in two ways:

• Specified time intervals
• Cycle of the traffic signal

It should be noted that queue length video detection cannot be greater than 300 feet, per video detection unit. If additional length is desired multiple units should be added; however this can result in undesired complexity.

In the Denver Region, cycle lengths typically vary from 80 to 120 seconds depending on the corridor. Also, cycle lengths can change by TOD for the same signal. Given the variations of cycle lengths and potential issues that are tied to reporting, it is best if queue presence and queue length data be tied to specific time intervals. Additionally, queue data tied to the signal cycle will reside in the signal system and it may be harder to move the data to allow for processing.

Guideline(s)

• Queue presence and queue length should be collected every two minutes.
3.4.8.6 Density of the Devices

As discussed previously, the level of deployment is possibly lower by using video detection unit for collection of queue presence and queue length.

**Guideline(s)**

- One video detection unit is needed for each location where queue presence and/or queue length is desired.

3.4.8.7 Time Intervals for Processing and Display

There is no Federal Rule regarding time interval/processing and display of queue presence and queue length data.

**Guideline(s)**

- Queue data should be processed and displayed within two minutes of data collection.

3.4.8.8 Queue Data Processing

Following are the two primary ways for processing data:

- CTMS is being used for generating arterial travel condition information. However, the CTMS is not designed to collect and process queue data. Also, currently CTMS is only equipped to handle queue data from one specific video detection device. This video detection device is being used at the moment to collect speed and occupancy data for arterial conditions in Denver.

- Develop a custom software application that can collect and process the queue data independent of CTMS.
Guideline(s)

- The Denver Region should continue using CTMS for all arterial travel conditions parameters. The implementing agency should be responsible for development of software requirements in CTMS including the development of any new drivers for new detection devices.

Also, the detection zones, regardless of location, need to be setup properly in the following manner:

- 50 feet detection zones that are continuous, i.e., no gaps.
- Detection zones should be numbered consistently.

3.4.8.9 Graphical and Tabular Display Output

At present, no queue data is being displayed on CoTrip or CCTM. Queue presence may be easier to show on a graphical display. It could have the following two colors:

- Green – No queue presence detected on one or more lanes.
- Red – Queue presence detected on one or more lanes.

This could apply to through, left-turn and right-turn lanes. Regardless of the number of lanes, only one symbol should be displayed.

Graphically displaying queue length information by lane may not be effective and may add to visual clutter. Also, Google maps, which is used by CTMS may not be capable of zooming down to the level where lanes are visible.

For tabular display of queue data, it should include the following by lane(s):

- Queue presence
- Queue length in feet

It is expected that only operators will use the queue data information.
Guideline(s)

- Queue data should only be available on CCTM.
- On CCTM there should be a queue data symbol. This queue symbol needs to be developed. By selecting the symbol, the operator will have access to queue presence and/or queue length data by lane as described above.

3.4.8.10 Queue Data Validation

The validation process begins from the conceptual stage to design through implementation and continued with periodic monitoring.

Field survey should determine the following:

- Queue presence benchmark (through, left and right lanes, as applicable)
- Queue lengths (through lanes only)

After the project is implemented, the validation process should include the following:

- Compare reported real-time conditions against field observations during same time period.
- If the queue presence deviations are greater than 15%, the process should be repeated the next day for the same time period.
- If the queue presence deviations are still greater than 15%, it is possible that the volume conditions changed. In which case, the benchmark should be reevaluated and/or timing should be adjusted.
- If the queue length deviations are greater than 50%, the devices may need to be further calibrated.
Guideline(s)

- The operator is responsible for validating if the reported conditions are within the acceptable accuracy requirements.

3.4.8.11 Providing or Accepting Queue Data to Private ISPS

Based on current knowledge, private ISPs do not collect any queue data. There is no known interest in collecting this data from local agencies.

3.4.8.12 Usefulness of MOES to Operators

The following MOEs are recommended:

- Number of queues for a given time period by lane.
- Average queue length for a given time period by lane.

Queue MOEs are helpful for operators in understanding the variations of the queue conditions during different time periods at selected locations. Depending on the location, operators will be able to understand the impact of the following on queues:

- Activity centers
- Incidents on Interstate Highways
- Weather conditions
- Construction or maintenance operations

Guideline(s)

By examining the data, the operator is able to do the following:

- Establish a baseline for a given time period.
When queues are worse than the baseline the operator may choose the following:

- Adjusting the signal timing.
- Develop queue clearance plans for certain conditions.

3.4.9 Volume

Traffic counts at locations along the arterial can be very useful for operators and others. These counts show traffic by lane on an approach. These counts are not turning movement counts at an intersection.

3.4.9.1 Device Type to Collect Volume Data

Volume counts can be collected using P devices along the arterial.

Guideline(s)

- It is recommended to use P devices to count the traffic volumes.

3.4.9.2 Device placement and Density

The placement of the P devices can impact the quality of counts. With most P devices, the detection zone should not have any standing queues on the device.

Depending on the technology, terrain, roadway width and device placement, it may be possible to collect both directions with one device.

Guideline(s)

- Vehicle detection devices that collect volume data should be installed at a sufficient distance from the intersection such that traffic is not in a stop-and-go condition for the approach.
- One device should be sufficient for each approach.
3.4.9.3 Data Collection Timeliness

Most P devices are capable of collecting data in at least one minute intervals. Most operators are accustomed to using 15 minute intervals for volume data.

**Guideline(s)**

- It is recommended to collect the volume data in 15 minute intervals.

3.4.9.4 Time Intervals for Processing and Display

There is no Federal Rule for processing and displaying volume data.

**Guideline(s)**

- It is recommended that the volume data be reported every 15 minutes.

3.4.9.5 Graphical and Tabular Display Output

Currently on CoTrip, when a segment is selected it shows the volume. It should be noted that arterial conditions are using speed and occupancy to report congestion in Denver. Typically, the P devices used to collect speed and occupancy is also capable of collecting volume data. The placement of these devices may not be ideal to report accurate volume data.

**Guideline(s)**

- As the volume data is primarily for operators, it should only be displayed on CCTM.
- If a segment is already collecting other travel condition parameters, such as travel time and speed, the volume by lane should also be displayed when the segment is selected.
- If no travel time or speed is being reported on the segment, there should be a symbol on CCTM and when selected, it should display volume by lane.
3.4.9.6 Volume Data Validation

After implementation, the operator should have a three-day, 24-hour count performed close to the location. This should be compared to the reported data.

If the deviation is greater than 15% for each day, the operator may need to calibrate the point device. It is also possible that the location of the P device may not be ideal.

**Guideline(s)**

- The operator is responsible for validating if the reported volume data is within the acceptable accuracy requirements.

3.4.9.7 Private ISPs

It does not appear there is any significant interest from private ISPs to provide or collect volume data.

3.4.9.8 MOEs and Reporting

The following MOEs are available

- Flow Rate
- V/C Ratio

Historical data and reports should be made available until the previous day.

3.4.9.9 Usefulness of MOEs to Operators

Operators can use the MOEs to monitor corridor operations and retune traffic signals and to understand traffic patterns.
3.4.9.10 Usefulness of MOEs to Others

MOEs can be of great interest to planning and development departments. The MOEs can be used to calibrate planning models.

3.4.10 Occupancy

For arterial condition information in Denver, speed and occupancy travel condition parameters are being used to determine how traffic is flowing. Both these parameters are being collected using point devices.

As mentioned in Section 3.4.1.12 (Real Time Travel Time algorithm and Geographical Display Output), congestion should be based on TTI and not on speed or occupancy or travel time.

Occupancy may be more relevant in implementing traffic responsive plans and more useful to monitor travel conditions on Interstate Highways.

3.5 Data Quality Parameters

There are three parameters that should be considered with regard to data quality:

- Accuracy – The data accurately portrays the actual conditions and has an acceptable error rate.
- Timeliness – The data are being reported within an acceptable time from the time it is collected and disseminated.
- Availability – The data are available for use for the majority of the time.

3.5.1 Accuracy

The FHWA Rule requires real time information program data be 85% accurate at a minimum, or a maximum error rate of 15%. It is important to note that the FHWA Rule applies to travel time or speed, roadway or lane blocking, roadway weather observations and construction and maintenance activities. It does not include other data parameters such as occupancy, volume,
traffic information for events and parking information for events. Depending on the travel condition parameter, one of the other or none may apply. For example, regarding the travel time data parameter, it is easier to ensure a minimum of 85% accurate by conducting travel time studies and comparing it to reported data. However, it may be harder to track and ensure a maximum error rate of 15%. For incidents, it is probably better to focus on a maximum error rate of 15% based on the total number of incidents in a given period.

Within the Denver Region, it appears that available travel condition parameters meet the accuracy standards. However, there is no formal and periodic monitoring process in place to measure and validate accuracy.

**Guideline(s)**

The FHWA Rule for accuracy requirements is recommended as the minimum for the Denver Region. Table 7 below provides specific guidelines for each travel data condition parameter.

**Table 7: Travel Condition Data Parameters and Accuracy Guidelines**

<table>
<thead>
<tr>
<th>Travel Condition Parameter</th>
<th>Accuracy Guidelines</th>
<th>Example</th>
<th>Available Accuracy Validation Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time</td>
<td>85% accurate at a minimum</td>
<td>Accurate travel time = 10 minutes &lt;br&gt;Allowable accuracy = 8.5 minutes or 12.5 minutes</td>
<td>See Section 3.4.1.12 Travel Time Calculation and Validation</td>
</tr>
<tr>
<td>Incidents</td>
<td>Maximum error rate of 15% on reports related to roadway or lane blockages</td>
<td>100 incidents reported with roadway or lane blockages &lt;br&gt;Allowable accuracy = closures reported correctly for 85 incidents</td>
<td>See Section 3.4.2.4 Incident Information Validation</td>
</tr>
<tr>
<td>Weather Related Road Conditions</td>
<td>Maximum error rate of 15% on reports related to roadway or lane</td>
<td>100 adverse weather related conditions reported with roadway or lane blockages &lt;br&gt;Allowable accuracy = closures</td>
<td>See Section 3.4.3.7 Weather Related Road Condition Information Validation</td>
</tr>
<tr>
<td>Travel Condition Parameter</td>
<td>Accuracy Guidelines</td>
<td>Example</td>
<td>Available Accuracy Validation Techniques</td>
</tr>
<tr>
<td>----------------------------</td>
<td>---------------------</td>
<td>---------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td><strong>Construction and Maintenance Operations Information</strong></td>
<td><strong>Maximum error rate of 15 % on reports related to closure and reopening of roadway</strong></td>
<td>100 construction and maintenance operations related roadway closures Allowable accuracy = road closures and reopening correctly reported for 85 reports</td>
<td>See Section 3.4.4.5 Construction and Maintenance Operations Information Validation</td>
</tr>
<tr>
<td>Traffic Video</td>
<td><strong>Does not apply</strong></td>
<td><strong>Does not apply</strong></td>
<td><strong>Does not apply</strong></td>
</tr>
<tr>
<td>Traffic Information for Events</td>
<td><strong>Maximum error rate of 15 % on reports related to closure and reopening of roadway</strong></td>
<td>100 event related roadway closures Allowable accuracy = road closures and reopening correctly reported for 85 events</td>
<td>See Section 3.4.7.1 Event Information Validation</td>
</tr>
<tr>
<td>Parking Information for Events</td>
<td><strong>Maximum error rate of 5 % on parking availability</strong></td>
<td>Actual parking availability 100 events Allowable accuracy is 95 events</td>
<td>See Section 3.4.7.2 Parking Information for Events</td>
</tr>
<tr>
<td>Speed</td>
<td>Same as travel time travel condition parameter</td>
<td>Same as travel time travel condition parameter</td>
<td>Same as travel time travel condition parameter</td>
</tr>
<tr>
<td>Queues</td>
<td><strong>Maximum error rate of 15 % on queue presence</strong></td>
<td>Actual number of queues beyond benchmark= 100 Allowable accuracy is 85 accurate readings of queue presence</td>
<td>See Section 3.4.9.10 Queue Data Validation</td>
</tr>
<tr>
<td></td>
<td><strong>Minimum accuracy of 50% on queue length</strong></td>
<td>Actual queue length =100 feet Allowable accuracy is 50 feet or 150 feet</td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td><strong>Minimum accuracy of 85% on volumes</strong></td>
<td>Actual volume = 1000 vehicles Allowable accuracy is 850 to 1150 vehicles</td>
<td>See Section 3.4.10.6 Volume Data Validation</td>
</tr>
</tbody>
</table>
3.5.2 Availability

The FHWA Rule requires data to be 90% available at a minimum. Within the Denver Region, it appears that available travel condition data parameters meet the availability standards. However, there is no formal and periodic monitoring process in place to measure and validate availability.

**Guideline(s)**

The FHWA Rule for availability requirements is recommended as the minimum for the Denver Region. Table 8 below provides specific guidelines for each data condition parameter.

<table>
<thead>
<tr>
<th>Data Parameter</th>
<th>Availability Guidelines</th>
<th>Example</th>
<th>Availability Validation Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time</td>
<td>90% at a minimum</td>
<td>No data is allowed for a maximum of 14.4 minutes in a day</td>
<td>Possibly use CTMS reporting to determine sample size requirements are being met for 90% of the day</td>
</tr>
<tr>
<td>Incidents</td>
<td>90% at a minimum of the incidents with roadway or lane blockage</td>
<td>No data is reported for 10% of the incidents with roadway or lane blockage</td>
<td>Possibly using Public Safety CADD dispatch interface and/or TMC logs and compare it against the number of incidents reported via CTMS</td>
</tr>
<tr>
<td>Weather Related Road Conditions</td>
<td>90% at a minimum of the weather related road conditions with roadway or lane blockage</td>
<td>No data is reported for 10% of the weather related road conditions or lane blockage</td>
<td>Possibly using MDSS and/or TMC logs and compare it against the number of weather related road conditions reported via CTMS</td>
</tr>
<tr>
<td>Construction and Maintenance Operations Information</td>
<td>90% at a minimum of the construction and maintenance operations activities with roadway or lane blockage</td>
<td>No data is reported for 10% of the construction and maintenance operations activities with roadway or lane blockage</td>
<td>Possibly using TMC logs and compare it against the number of construction and maintenance operations activities reported via CTMS</td>
</tr>
<tr>
<td>Traffic Information for</td>
<td>90% at a minimum of the events with roadway or lane blockage</td>
<td>No data is reported for 10% of the events with</td>
<td>Possibly using TMC logs and compare it against the number of events with</td>
</tr>
<tr>
<td>Data Parameter</td>
<td>Availability Guidelines</td>
<td>Example</td>
<td>Availability Validation Techniques</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------------------</td>
<td>---------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Events</td>
<td></td>
<td>roadway or lane blockage</td>
<td>events reported via CTMS</td>
</tr>
<tr>
<td>Parking Information for Events</td>
<td>90% at a minimum of the events with parking availability information</td>
<td>No data is reported for 10% of the events</td>
<td>Possibly using TMC logs and compare it against the number of parking availability posted on field devices</td>
</tr>
<tr>
<td>Traffic Video</td>
<td>90% at a minimum of the time</td>
<td>Acceptable to not have video images for a maximum of 14.4 minutes in a day</td>
<td>Possibly use CTMS reporting to report downtime</td>
</tr>
<tr>
<td>Speed</td>
<td>Similar to travel time</td>
<td>Similar to travel time</td>
<td>Similar to travel time</td>
</tr>
<tr>
<td>Queues</td>
<td>90% at a minimum of the time</td>
<td>Acceptable to not have queue data for a maximum of 14.4 minutes in a day</td>
<td>Possibly automated reports in CTMS to report downtime.</td>
</tr>
<tr>
<td>Volume</td>
<td>90% at a minimum of the time</td>
<td>Acceptable to not have queue data for a maximum of 14.4 minutes in a day</td>
<td>Possibly automated reports in CTMS to report downtime.</td>
</tr>
<tr>
<td>Occupancy</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

### 3.5.3 Timeliness

The FHWA Rule requires that data values are provided at the time required or specified, which is reporting within 10 or 20 minutes from the time the condition is verified, observed or completed. Within the Denver Region it appears that available travel condition data parameters meet the timelines standards.

**Guideline(s)**

The FHWA rule for timelines requirements is recommended as the minimum for the Denver Region. Table 9 below provides specific guidelines for each data condition parameter.
Table 9: Travel Condition Data Parameters and Timeliness Guidelines

<table>
<thead>
<tr>
<th>Data Parameter</th>
<th>Timeliness Guidelines</th>
<th>Example</th>
<th>Available Timeliness Validation Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time</td>
<td>Reported within 10 minutes from the time that the travel time calculation is completed.</td>
<td>Potential latency of at 4 minutes since data is collected every 2 minutes</td>
<td>Possibly automated reports in CTMS since all P2P data is date/time stamped</td>
</tr>
<tr>
<td>Incidents</td>
<td>Reported within 10 minutes or less from the time that the incident is verified and/or cleared</td>
<td>Potential latency of at 10 minutes</td>
<td>Possibly using Public Safety CADD dispatch interface and/or TMC logs to the time incident is reported on CTMS</td>
</tr>
<tr>
<td>Weather Related Road Conditions</td>
<td>Reported within 20 minutes from the time hazardous conditions, blockage or closure is observed</td>
<td>Potential latency of 20 minutes</td>
<td>Possibly using MDSS and/or TMC logs to the time weather related road condition is reported on CTMS</td>
</tr>
<tr>
<td>Construction and Maintenance Operations Information</td>
<td>Reported within 10 minutes or less from the time of the closure or reopening of the roadway</td>
<td>Potential latency of 10 minutes</td>
<td>Possibly from TMC logs</td>
</tr>
<tr>
<td>Traffic Information for Events</td>
<td>Reported within 10 minutes or less from the time the event is verified</td>
<td>Potential latency of 10 minutes</td>
<td>Possibly from TMC logs</td>
</tr>
<tr>
<td>Parking Information for Events</td>
<td>Reported within 10 minutes or less from the time the event is verified</td>
<td>Potential latency of 10 minutes</td>
<td>Possibly from TMC logs</td>
</tr>
<tr>
<td>Traffic Video</td>
<td>Available almost immediately for streaming video or updated every 2 minutes for still images</td>
<td>Potential latency of 2 minutes</td>
<td>Possibly automated reports from CTMS since video images are date/time stamped</td>
</tr>
<tr>
<td>Speed</td>
<td>Similar to travel time</td>
<td>Similar to travel time</td>
<td>Similar to travel time</td>
</tr>
<tr>
<td>Queues</td>
<td>Reported within 2 minutes or less from the time that the queue presence and/or length calculation is completed.</td>
<td>Potential latency of at 4 minutes since data is collected every 2 minutes</td>
<td>Possibly automated reports in CTMS since all data is date/time stamped</td>
</tr>
<tr>
<td>Volume</td>
<td>Reported within 2 minutes or less from the time that volume data is received.</td>
<td>Potential latency of 17 minutes since data is collected every 15 minutes</td>
<td>Possibly automated reports in CTMS since all data is date/time stamped</td>
</tr>
</tbody>
</table>
## Denver Regional Integrated Traveler Information Display Map Guidelines

### 3.6 Data Dissemination

Within the Denver Region, there are several data dissemination options for the traveling public, operators and others.

#### 3.6.1 CoTrip Website

The CoTrip website provides statewide traveler information primarily for Interstate Highways, State and US highways along with limited coverage on arterials in the Denver Region. The website includes speeds, travel times, construction information, incident notifications, closures, alerts, etc.

**Guideline(s)**

- CoTrip will be the primary online dissemination tool for the traveling public.

- Local agencies can provide traveler information within their jurisdictional boundaries on their agency website displaying the same data shown on CoTrip. In addition, local agencies can include other local relevant information.

- The following travel condition data parameters should be available on CoTrip:
  - Travel time
  - Incident information
  - Weather related road condition information
  - Construction information
3.6.2 511

511 provide similar information to CoTrip through an automated phone system. It is focused on providing traveler information for Interstate Highways, State and US highways.

Guideline(s)

- Arterials that are State and US highways within the Denver Region should be included in 511 for the following travel condition data parameters:
  - Travel time within the available corridor limits but not by each segment in the corridor
  - Incident information
  - Weather related road condition information
  - Construction information
  - Maintenance operations
  - Traffic information for events

- For arterials that are not State or US highways, CDOT should provide the ability to transfer calls to a local 511 system if the travel time information is available on it. Again, travel times will be within the available corridor limits not by each segment in the corridor.
3.6.3 GOV Delivery

GOV Delivery is an e-mail and text system that provides information on events, weather related road condition, construction, and incidents.

Guideline(s)

- Gov Delivery system should be made available for operators that can provide information for incidents, weather related road condition information, construction and events.

- It is recommended all operators and staff should subscribe to this CDOT service.

3.6.4 VMS

VMS provide information on the roadway regarding travel time, incidents, events, and construction information to travelers on the roadway.

Guideline(s)

- The messages posted on VMS should conform to MUTCD.

- VMS messages should be displayed on CoTrip. This is only possible if CDOT has the software drivers for the VMS sign. Any new software drivers will need to be developed by the Operator.

- The following travel condition data parameters should be available on local VMS:
  - Travel time
  - Incident information
  - Weather related road condition information
  - Construction information
3.6.5 **HAR**

HAR is used by Denver to provide mostly event related information.

**Guideline(s)**

- The following travel condition data parameters should be available on local HAR
  - Travel time
  - Incident information
  - Weather related road condition information
  - Construction information
  - Maintenance operations
  - Traffic information for events

3.6.6 **CCTM**

CDOT has developed the CCTM application primarily for the operators. It has additional information such as signals inventory that is not included on the CoTrip website.

**Guideline(s)**

- The following travel condition data parameters should be available on CCTM:
  - Travel time
Incident information

Weather related road condition information

Construction information

Maintenance operations

Traffic video

Traffic information for events

Speed

Queues

Volume

3.6.7 COGNOS

CDOT has procured COGNOS, which is a business intelligence reporting tool license. All data will continue to be archived in the CTMS archive database. The archived data will be moved to COGNOS on a daily basis to allow for reporting. COGNOS is a web based application that can connect to multiple databases across jurisdictional boundaries and can provide a seamless interface to its users.

Although, it is a powerful tool that eliminates cumbersome and expensive software programming and integration, there are issues such as licensing requirements, use of a proprietary tool, roles and responsibilities of different levels of users across agencies that need to be addressed. Licenses are tied to individuals in agencies and not to the agency. The databases can reside at different geographic locations and can be different types of database technology. Configuration and user management may get too unwieldy for CDOT.
Guideline(s)

- Local CTMS data should be tied to COGNOS.
- Standardized reports should be developed that would satisfy a majority of the requirements developed by stakeholders.
- Local jurisdiction should pay for COGNOS license(s) to support the local application.

3.6.8 CCTV Application on Google

CDOT has developed an application with (CCTV Application) using its camera command and control software, in conjunction with Google map, that will allow Authorized operators to view and control cameras across jurisdictional boundaries.

Guideline(s)

- Local agency traffic cameras should be included on the CDOT CCTV Application.

Table 10 displays the dissemination options used for each travel condition data parameter. COGNOS is not included in the table as it a reporting tool. The CCTV Application will be made available through CCTM.
### Table 10: Data Dissemination Options

<table>
<thead>
<tr>
<th>Travel Condition Data Parameters</th>
<th>CoTrip</th>
<th>511</th>
<th>Gov Delivery</th>
<th>VMS</th>
<th>HAR</th>
<th>CCTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time Graphical Display for Arterials</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Travel Time Tabular Display for Arterials</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Travel Time for Arterials on the Roadway (Enroute)</td>
<td>No ¹</td>
<td>Yes ²</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Incident Information</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Weather Related Road Condition Information</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes ³</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Construction and Maintenance Operations Information</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes ³</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Traffic Video</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Traffic Information for Events</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes ³</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Parking Information for Events</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
### Denver Regional Integrated Traveler Information Display Map Guidelines

<table>
<thead>
<tr>
<th>Travel Condition Data Parameters</th>
<th>CoTrip</th>
<th>511</th>
<th>Gov Delivery</th>
<th>VMS</th>
<th>HAR</th>
<th>CCTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Queues</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Volume</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Occupancy</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Notes:

1. Available via mobile devices with internet service
2. Selected State and US highways only and interface to local 511
3. Adverse weather conditions on State and US highways
3.7 Base Map for Displaying Arterial Travel Condition Information

CoTrip uses 2011 Google Maps for displaying traveler information for both Interstates and arterials. CDOT pays a licensing fee, which is based on a maximum number of page views. On CoTrip, there is no easy way to clearly distinguish Interstate Highways and arterials on the Google map. Also, color coding for traffic conditions is overlaid on the top of the existing route label symbols. This may create confusion for the travelling public who are not familiar with the area. CDOT is working with Google to resolve the issue; however, it is not clear when the issue will be resolved.

**Guideline(s)**

- CoTrip should continue to use Google maps for providing traveler information for Interstate Highways and arterials.

- As more arterial travel condition information is made available, CDOT should provide users with the option to select layers for Interstate Highways, arterials, and/or all other roadways to view the traveler information.

3.8 Base Map for Displaying Arterial Travel Condition Information for Local Agencies

Operators may desire to display arterial travel condition information within their jurisdictional boundaries. There are numerous base map options available, such as; BING, GIS, etc. The other option for an operator to consider is to use CDOT’s Google base map. This would require CDOT to add the operator agency domain information to its current license with Google. This option has a cost implication to CDOT if the increased web usage results in the maximum number of page views being exceeded.
Guideline(s)

- Operators are free to choose their base map as long as the information that populates on the map is available through CTMS. However, it is preferred that Google base map be used by operators. Operators can include other information pertinent to their agency to customize their site. However, all information generated via CTMS must be consistent with what is being displayed on CoTrip. Users should be provided a link to access CoTrip for statewide information. Also, it is desirable that the base map have zooming capabilities.

- If an Operator chooses to use the Google base map, the agency should coordinate with CDOT to determine the cost implications to share the map.

3.9 Transmission and Archiving Data

Data from Operators needs to be sent to CDOT so that CoTrip can be updated with the latest information. Also, CDOT is storing existing data for arterials within CTMS. This is not a long term solution. MOEs derived from historical data can be a powerful tool for operators and others.

3.9.1 Transmitting Data to CDOT

Data can be transmitted to CDOT in a couple of different ways, CTMS or XML feed. Operators can use CTMS client at their location to transmit data and configure/manage their own field devices. Currently, CDOT does not have a formal policy on criteria for CTMS deployment. In discussions with CDOT IT Staff, it was suggested that direct connection on CDOT private network would be strongly preferred to enable deployment of CTMS. In the event no direct connection to the CDOT private network is available, Operators can enable direct communication to field devices so that CTMS can collect the information directly from the field. The drawback of this configuration is that the Operator is not able to configure/manage their field devices. Additionally, it will require CDOT resources to perform these functions. CDOT is also considering changing CTMS architecture from Client/Server-based to web-based in the near
future. It should be noted that the CTMS option is only available for operators and not private ISPs or vendors.

Currently, CDOT makes its data available to interested agencies via XML. The data schema for speed, travel time, road conditions, alerts, still video image, message signs and weather stations are available on the CoTrip website. CDOT also receives speed data via XML feed from a vendor. Although, there are no barriers for CDOT to receive data from multiple sources, a schema would need to be developed for CDOT to receive data for each travel condition data parameter.

**Guideline(s)**

The specific schemas for CDOT to receive data for each travel condition data parameter should be addressed by the stakeholders in the Region.

### 3.9.2 Data Storage

CDOT has been allowing local agencies to store arterial data on the CTMS database located at the CDOT CTMC in Golden. However, as more corridors are implemented, it will require additional CDOT resources to properly store and maintain the data.

Although the CTMS software should be used within the Region to process travel time, the Region and CDOT should begin to consider alternatives for storage and retrieval of travel time data. The alternatives could include:

- CDOT stores all arterial data. Operators would reimburse CDOT based on the data stored and use of resources.
- Data are stored at each operator location using a CTMS client.
- All arterial data are stored at one operator location.

Figure 25 shows a proposed high level architecture for one of the potential alternatives. Each operating agency providing travel time will have CTMS software client at their location, which
will be interconnected with the CTMS at CDOT CTMC. This will allow each agency to add/remove P2P devices and store the data at their location. The display of travel time information will still occur on CoTrip. This alternative requires an Oracle license at each operator location as CTMS is Oracle based. Also, there may be a need for Oracle support from agency staff in performing normal database functions.

**Figure 24: Proposed High Level Architecture**

Guideline(s)

The specific alternative(s) of how arterial data are stored at a separate location(s) should be addressed by the stakeholders in the Region.

3.9.3 Data Archival

In the Denver Region, local agencies tend to store the data indefinitely. This tends to take up additional storage space on the local systems. Given that storage costs have dropped considerably, this may not be a major concern at this time. Nevertheless, as more corridors are added and more data are collected in the future, this issue will become more critical. More importantly, access to this data is crucial.
Guideline(s)

- Each local agency should be responsible for storing data generated from travel condition data parameters within the local CTMS archive database.
- Data should be stored based on the recommended intervals as shown in Table 11 for five years.

**Table 11: Time Intervals for the current data storage**

<table>
<thead>
<tr>
<th>Travel Condition Data Parameter</th>
<th>Time Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time</td>
<td>Every Two Minutes</td>
</tr>
<tr>
<td>Incident Information</td>
<td>Each Incident</td>
</tr>
<tr>
<td>Weather Related Condition</td>
<td>Each Occurrence</td>
</tr>
<tr>
<td>Construction Information</td>
<td>Each Project</td>
</tr>
<tr>
<td>Maintenance Operations</td>
<td>Each Occurrence</td>
</tr>
<tr>
<td>Traffic Video</td>
<td>Not Archived</td>
</tr>
<tr>
<td>Traffic Information for Events</td>
<td>Each Event</td>
</tr>
<tr>
<td>Speed</td>
<td>Every Two Minutes</td>
</tr>
<tr>
<td>Queue</td>
<td>Every Two Minutes</td>
</tr>
<tr>
<td>Volume</td>
<td>Every 15 Minutes</td>
</tr>
<tr>
<td>Occupancy</td>
<td>None</td>
</tr>
</tbody>
</table>

- Data that are more than five years old will be aggregated into daily values and stored for additional five more years. The storage format shown in Table 12 below.
### Table 12: Storage Format of Older Data

<table>
<thead>
<tr>
<th>Travel Condition Data Parameter</th>
<th>Archived Data Consolidation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time</td>
<td>Average daily travel time by segment by direction</td>
<td>At two minutes interval, 720 records in a day per direction will be averaged and consolidated into one record.</td>
</tr>
<tr>
<td>Queue</td>
<td>Queue presence will aggregated for the day and reported as a number. Average length of queue per day per lane by direction</td>
<td>Queue presence will be aggregated for the day for the traffic movement. Queue length will be averaged for the times there was a queue and reported for the day</td>
</tr>
<tr>
<td>Volume</td>
<td>Total daily traffic volume by segment by direction.</td>
<td>At 15 minute peak intervals, 96 records in a day per direction and these will be aggregated into one record.</td>
</tr>
<tr>
<td>Speed</td>
<td>Average daily speed by direction by segment.</td>
<td>At two minute interval, 720 records in a day per direction will be aggregated into one record.</td>
</tr>
<tr>
<td>Weather, Construction, Maintenance Operations and Traffic Information for Events</td>
<td>Data will be deleted</td>
<td>These are individual instances and possibly have no value beyond five years.</td>
</tr>
</tbody>
</table>

### 3.10 Alarms

The purpose of the alarms is to alert the operator regarding current conditions without having to constantly monitor the CTMS, CCTM and traffic cameras. It allows the operator to better utilize the limited resources. The following are key considerations:

- Defining the thresholds that can trigger the alarm.

- Once the alarm is generated, it is important to capture any action related to the alarm. In some instances, the operator may not be required to perform any action or there is no action possible.

**Guideline(s)**

- The operator should be able to set the acceptable thresholds.

- If the event alarm is generated on CTMS, the operator should have the option to perform the following:
• "Close" the alarm without action performed.
• "Close" the alarm with action performed.

- For travel time, the alarm should be generated if the travel time exceeds the threshold percentage limit for three consecutive cycles, i.e., six minutes. The operator should be allowed to set the threshold limits.

- For incidents, weather related road conditions, planned construction, maintenance operations, and events an alarm should be generated at operator defined intervals on all active operations to alert the operator to update the information. If no operator defined intervals are specified, the alarm should pop up on CTMS two hours from the last update of the operation in case the operation is still open.

- Alarm for speed is similar to alarm for travel time. The acceptable threshold percentages are based on baseline data. In the event the speed drops below the threshold percentage, an alarm is generated on CTMS.

- Queue presence alarm should be generated if the presence of queue is detected over three consecutive cycles or six minutes. The operator should be given the ability to select the number of acceptable cycles before an alarm is generated.

- Volume alarm should be generated if the volume exceeds the acceptable threshold percentage for the location.

- No alarms for occupancy.

- Parking availability alarm should be generated if the parking availability drops below the acceptable threshold percentage. The operator should have the ability to set the threshold for alarms. If no operator threshold is available, an alarm will be generated when the parking availability reduces to 10 percent.
3.11 Performance Measures Report Card

There are several ways to approach developing a report card for performance measures and the following are key considerations:

- Users of the report card
- Frequency of the report card
- Functionality – graphical, tabular, grading, dashboards, etc.
- Availability

**Guideline(s)**

- The initial focus of the report card should be for use by the operator.
- The report card should focus on previous day. If operators desire to see older data, there should be an option to increase the duration for reporting.
- The report card should be available on CCTM and/or sent to the operator via email each morning at 7:00 AM.
- The report card should be summary of all travel condition parameters on one-page at a minimum and it should include for each parameter:
  - Average travel time for each corridor morning (7-8 am), noon (noon-1 pm) and evening (5-6 pm) peak periods.
  - Individual number of incidents, construction, maintenance operations and events.
  - Number of alarms generated for travel condition data parameters.
  - Number of alarms responded by the operator.
3.12 Typical Day Scenario for an Operator

Operators typically have responsibilities that often go beyond traffic operations. In an ideal scenario, the operator’s typical day would include the following:

- Every morning at 8 am, there will be a performance measures report card that captures the summary for the previous day. If the operator desires more detail, the report card should preferably be interactive to allow access to more detailed information.

In addition, the operator will be alerted to any alarms based on thresholds throughout the day.

Typically, most operators work normal business hours (8 am to 5 pm). Operators should be provided with the option to have certain type of alarms generate a text message to operator cellular phone or pager.

3.13 Reporting

Reports can be very useful to the operators and others. There are several considerations for reporting:

- Age of the data to be considered.
- Use of standard reports.
- Ease of use.
- Functionality – graphical, tabular, comparison, etc.

**Guideline(s)**

- At a minimum, reports should be available to include the previous day’s data and up to 5 years.
• Standard report formats should be developed in COGNOS. This will eliminate any potential user errors and make it easy for use for operators and others.

• Reports should allow for both graphical and/or tabular use whenever possible.

• Reports should allow for comparison between the following:
  
  o Time periods

  o Locations
4 Conclusions and Next Steps

4.1 Implications of the Guidelines

The guidelines have significant impact on existing systems, technical processes, practices and operations. This section presents potential issues for consideration but does not identify solutions, which may be technical, institutional, policy level, etc.

4.1.1 Commitment and Resources

There are significant implications to resources when implementing one or more travel condition parameters in order to properly meet the guidelines, especially the data quality parameters.

The resource commitments may extend beyond the normal business hours and place additional burdens on the operators, who are already strapped for time pursuing their own duties.

One key thing to realize is that these travel condition data parameters are mainly designed for the operator. The operator is definitely more equipped quickly with the information. It also places responsibility on the operator to take appropriate action when necessary. Operators should consider the benefit versus costs, the value of the information and resources required before considering implementation. Several key considerations are:

- Type of expertise required.
- Potential actions that result from having the information.
- Costs to monitor maintain and replace infrastructure including network related equipment.
- Multiple use for other travel condition data parameters and/or use to other agencies or departments.
As the extent of implementation grows geographically and functionally, agencies may need to consider a Regional TMC to ease the workload and share responsibilities.

4.1.2 Field Infrastructure

The City and County of Denver uses P devices that collect speed and occupancy to report congested conditions on the Speer Boulevard and Colfax Avenue corridors. Colorado Boulevard is currently being instrumented with P and P2P devices.

Based on the Guidelines, these corridors would need to be instrumented with P2P devices in order to report congestion levels. This may require significant additional funding.

4.1.3 CTMS

- The arterial congestion algorithm would need to be updated to use only travel time data from P2P devices.

- The travel time algorithm is designed for toll tag technology. Any new P2P technology would require new drivers to be written to support processing in CTMS.

- All arterial data would reside with the local operator(s) and a local CTMS is envisioned that resides in each agency. This is a major disadvantage from the existing CTMS Architecture, and therefore needs a more in-depth analysis, evaluation and recommendation.

- Segmentation is different for travel time and weather related road conditions data parameters.

- Changes to include alarms and timers to alert the operator to update or clear a travel condition data parameter.

- Changes to include alarms for certain travel condition data parameter to generate alarms to the operator if the baseline conditions are exceeded.
• Changes to include baseline data to allow for future comparisons.

4.1.4 CoTrip

• CoTrip uses Google base map and its licensing is based on the number page views. As more arterial information is added, it will increase the number of page views for CoTrip resulting in potentially more cost for CDOT.

• Displaying information on layers is an extensive effort.

• If the labeling of the highways so that they are not overlaid by color codes is not resolved by Google, it may require significant effort from CDOT.

• All of the information may cause slower download speeds for the CoTrip website which may require CDOT to invest in higher processing capabilities.

4.1.5 CCTM

• There is increased responsibility on CDOT to setup and maintain access to operators and other authorized users.

• It is not clear how CCTM fits into the regional vision beyond traveler information.

• It is not clear if CCTM would replace the executive desktop and/or CTMS in the near future.

• There are intricate technical linkages between CoTrip, CCTM and CTMS where changes in one can cause a ripple effect in other systems.
4.1.6 **COGNOS**

- CDOT anticipates that data from CTMS archive database will be updated in COGNOS every day. Operators eventually might desire updates every 4 hours, which is currently the limit on CTMS before the data are archived.

- Agencies need to procure licenses under CDOT’s umbrella license. Licenses are issued to individuals at agencies. This will increase CDOT efforts to maintain administrative functions.

4.1.7 **Marketing of Travel Condition Data Parameters**

Travel condition data parameters are useful to other departments or public agencies. These include:

- Planning Departments
- TDM
- Maintenance
- Parks
- Streets
- GIS
- Emergency
- Public Safety
- Boards, Council and Management

Operators recognize the need to market the availability of the data to these entities. Furthermore, these entities should be engaged in discussions on how the data can be useful for their needs. It is
critical that operators have support from these other agencies to further active management and monitoring of roadway network.

Travel condition data parameter are also useful for private “for profit” entities. Operators should consider selling the data to such entities.

Data quality is a very significant factor when marketing the data to others. Higher quality means more demand.

4.2 Next Steps

1. CDOT and the stakeholders in the Denver Region to initiate a study in 2012 that will designate the Routes of Significance in accordance with the FHWA Rule regarding real time system management information, and prioritize the routes, develop costs associated with implementation and responsibility for implementation. This study will also identify detailed segmentation for the designated routes of significance.

2. There is a need to modify the existing CTMS to accommodate the changes to the color coding based on TTI. It is not clear how this change will be funded. This change should not affect Douglas County field infrastructure as P2P devices are being used for travel time. However, the field infrastructure on Speer and Colfax corridors needs to be updated with P2P devices. As an interim step, the color coding methodology used on these two corridors will remain unchanged until the field infrastructure is upgraded. It is not clear how the upgrades will be funded.

3. CoTrip modifications for consideration include rubber banding of multiple segments to report overall data, ability to close tabular display to increase display area and dynamic window sizing.

4. After the color coding is implemented using TTI, there needs to be a study that examines if the TTI thresholds are valid or need to be revised. It should be noted that the TTI thresholds
apply for the Denver Region and should not be customized by segments or operating agencies.

5. There needs to be a study that provides a long term solution for data sharing, data storage, archiving and reporting. This architecture has to be developed by CDOT, DRCOG and Operators in the Region. The study should take into account the needs of other Stakeholders such as planning departments, law enforcement and public safety, Public Works and other agencies. In conjunction with the study, the data schemas for CDOT to receive data from operators should be developed.

6. As more corridors are implemented per the guidelines, there is a need for configuration management that includes a process to update the guidelines document and a schedule that triggers the timing of the updates. CDOT will take the lead in maintaining and updating the guidelines document at least once a year initially. Potential technical issues that need to be addressed in the next update include defining COGNOS licensing requirements for other agencies and users, use of buffer index, measure showing the additional travel time due to congestion and reexamining the measures for travel time tabular display.

7. There needs to be further discussion regarding the feasibility of including traveler information for transit and other modes of travel within the Denver Region in the Guidelines.
Appendix A - Prioritization Process for Travel Condition Data Parameters

The following implementation factors were considered for the prioritizing the travel condition data parameters:

- **Data Collection Device Type** – This refers to the type of device that is used to collect the data, i.e., Point (P), Point-to-Point (P2P) device, or System Software (S).
- **Overall Quality** – This refers to the quality of data with the type of device used within the travel condition data parameter. Overall quality is qualitatively rated as High (H), Medium (M) or Low (L) based on the device type. However, quality is also a function of device placement and density.
- **Typical Cost** – Identifies the general capital costs, i.e., device cost only per location pertaining to the specific technologies. It does not include costs for installation, power, communication, operations and maintenance. In addition, it does not include any system integration costs.
- **Density of Devices** – Identifies the density of deployment required, which can be High (H), Medium (M) and Low (L).
- **Output** – Identifies the potential measures derived from the data parameter that can be presented to users.
- **Usefulness of Information** – Identifies the usefulness of the information to operators, the travelling public and Information Service Providers (ISPs). These conditions were identified regarding usefulness:
  1. Not useful, i.e., user has no use for the travel condition data parameter and associated output at any given time.
  2. Somewhat useful, i.e., user may have use for the travel condition data parameter and associated output sometimes.
  3. Very useful, i.e., user uses the travel condition data parameter during and associated output most times.
- **Regional Ranking** – Identifies the regional ranking base on stakeholder input. The ranking is for informational purposes only and provides relative importance of the parameters in the region.
Table A-1 shows a summary of travel condition data parameters with each implementation factor and a priority ranking of the travel condition data parameters as identified by the Regional stakeholders.
## Table A-1: Travel Condition Data Parameters, Implementation Factors and Regional Ranking

<table>
<thead>
<tr>
<th>Travel Condition Data Parameters</th>
<th>Data Collection Device Type</th>
<th>Overall Quality</th>
<th>Typical Cost</th>
<th>Density of Devices</th>
<th>Implementation Factors</th>
<th>Usefulness of Information</th>
<th>Regional Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time</td>
<td>P2P</td>
<td>H</td>
<td>$5K-$15K</td>
<td>L</td>
<td>• Raw travel time or travel time converted to speed&lt;br&gt; • Travel Time Index&lt;br&gt; • Planning Time Index&lt;br&gt; • Congestion Duration</td>
<td>Very useful&lt;br&gt; Very useful&lt;br&gt; Very useful</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>L</td>
<td>$5K</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic Incident Information</td>
<td>S¹</td>
<td>H</td>
<td>Unknown</td>
<td>None</td>
<td>• Location&lt;br&gt; • Direction&lt;br&gt; • Type of Incident&lt;br&gt; • Roadway or lane closure. &lt;br&gt; • Possible duration of clearance&lt;br&gt; • Delay</td>
<td>Very useful&lt;br&gt; Very useful&lt;br&gt; Very useful</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>P2P</td>
<td>M</td>
<td>$5K-$15K</td>
<td>L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>M</td>
<td>$5K</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Denver Regional Integrated Traveler Information Display Map

<table>
<thead>
<tr>
<th>Travel Condition Data Parameters</th>
<th>Implementation Factors</th>
<th>Usefulness of Information</th>
<th>Regional Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data Collection Device Type</td>
<td>Overall Quality</td>
<td>Typical Cost</td>
</tr>
</tbody>
</table>
| Weather Related Road Condition Information | P2P ² | H | >$3K | L | - Image  
- Location  
- Direction  
- Road condition type  
- Roadway or Lane Closure | Very useful | Very useful | Very useful | 2 |
|                                  | P | H | >$5K | H | - Location  
- Direction  
- Type of construction  
- Roadway or lane closure  
- Possible duration  
- Delay | Very useful | Very useful | Very useful | 2 |
<p>| Construction and Maintenance Operations Information | P ³ | H | &gt;$5K | H | | Very useful | Very useful | Very useful | 2 |</p>
<table>
<thead>
<tr>
<th>Travel Condition Data Parameters</th>
<th>Implementation Factors</th>
<th>Usefulness of Information</th>
<th>Regional Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Operators</td>
<td>Traveling Public</td>
</tr>
<tr>
<td><strong>Data Collection Device Type</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Overall Quality</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Typical Cost</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Density of Devices</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Usefulness of Information</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Regional Ranking</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Image</strong></td>
<td>Very useful</td>
<td>Very useful</td>
<td>Very useful</td>
</tr>
<tr>
<td><strong>Video</strong></td>
<td>Very useful</td>
<td>Very useful</td>
<td>Very useful</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Very useful</td>
<td>Very useful</td>
<td>Very useful</td>
</tr>
<tr>
<td><strong>Direction</strong></td>
<td>Very useful</td>
<td>Very useful</td>
<td>Very useful</td>
</tr>
<tr>
<td><strong>Type of event</strong></td>
<td>Very useful</td>
<td>Very useful</td>
<td>Very useful</td>
</tr>
<tr>
<td><strong>Possible duration</strong></td>
<td>Very useful</td>
<td>Very useful</td>
<td>Very useful</td>
</tr>
<tr>
<td><strong>Delay</strong></td>
<td>Very useful</td>
<td>Very useful</td>
<td>Very useful</td>
</tr>
<tr>
<td><strong>Raw speed</strong></td>
<td>Very useful</td>
<td>Somewhat useful</td>
<td>Somewhat useful</td>
</tr>
<tr>
<td><strong>Congestion duration</strong></td>
<td>Very useful</td>
<td>Somewhat useful</td>
<td>Somewhat useful</td>
</tr>
<tr>
<td><strong>Queue presence</strong></td>
<td>Very useful</td>
<td>Not useful</td>
<td>Not useful</td>
</tr>
<tr>
<td><strong>Queue length</strong></td>
<td>Very useful</td>
<td>Not useful</td>
<td>Not useful</td>
</tr>
<tr>
<td><strong>Raw volume</strong></td>
<td>Very useful</td>
<td>Not useful</td>
<td>Not useful</td>
</tr>
<tr>
<td><strong>Relate it to congestion</strong></td>
<td>Very useful</td>
<td>Not useful</td>
<td>Not useful</td>
</tr>
<tr>
<td><strong>Relate it to congestion</strong></td>
<td>Very useful</td>
<td>Not useful</td>
<td>Not useful</td>
</tr>
<tr>
<td>Travel Condition Data Parameters</td>
<td>Implementation Factors</td>
<td>Usefulness of Information</td>
<td>Regional Ranking</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------------------------</td>
<td>---------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Parking Information for Events</td>
<td>Data Collection Device Type</td>
<td>Overall Quality</td>
<td>Typical Cost</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>H</td>
<td>&gt;$5K</td>
</tr>
</tbody>
</table>

**Notes:**

1 Interface to public safety computer aided dispatch system (CADD)
2 Snow plow vehicle equipped with camera that can provide still image
3 Video
B.1: Considerations for placement of devices to measure travel time

Point-to-Point devices that measure travel time can be placed at various locations along the segment, i.e., mid-block, near-side or far-side of the major intersection. Figure B-1 shows the potential placement configurations and how it impacts segmentation. Factors such as number of devices, costs, availability of power and communications, device access to maintenance personnel, ability to maintain the device, terrain, roadway aesthetics, etc. tend to play a significant role in the placement of devices. This can lead to inconsistency in how devices are placed.

**Figure B-1: Potential Device Placements**

Option 1 - P2P device at the far-side of intersection for both directions
Option 2 – P2P devices at the near-side of intersection for both directions

![Diagram showing Option 2 with P2P devices at the near-side of intersection for both directions.]

Legend:
- □ P2P Device

Option 3 – P2P device at far-side on one direction and near-side on the other direction

![Diagram showing Option 3 with P2P devices at the far-side and near-side, respectively.]

Legend:
- □ P2P Device
Appendix B – Implementation Considerations

Option 4 – P2P device at mid-block for both directions

Because data are being reported from P2P devices, and provided there are no gaps in geographical coverage, the placement of devices is not critical. However, if the devices are placed mid-block, it would be contrary to the recommended segmentation guidelines defined earlier. Also, these P2P technologies collect data every second in the field. The P2P device is placed on the near-side, it will continuously collect data for the same vehicle until it clears the detection range. This creates additional data sets that can increase data storage size but it does not impact the processing of the data. Therefore, for sake of consistency and standardization, it is better to adopt a device guidelines placement configuration as recommended in 3.4.1.4.

B.2: Considerations for placement of devices to measure queues

As discussed earlier, video detection devices are best suited for collecting queue presence and queue length. Typically, most video detection units have a range of 300 feet.

For the collection of queue presence and queue length, the operator needs to establish a queue presence benchmark based on their knowledge of operations. Once the benchmark is established, the following configuration approaches are available:

1. Place the video detection unit facing the approaching traffic
2. Place the video detection unit facing the back of traffic

Figure B-2 shows the placement configuration for both approaches.
As discussed in Section 3.4.9.1, queue presence was recommended for left turn and right turn lanes. For these movements, the placement of video detection unit is not as critical since queue length is not being collected. Therefore, for sake of consistency and standardization, it is better to adopt a device guidelines placement configuration as recommended in 3.4.9.4.
Figure B-3: Placement for Turning Lanes

Legend

- Video detection camera
## Appendix C – Denver Region Integrated Traveler Information Display Map Guidelines Summary Matrix

<table>
<thead>
<tr>
<th>Travel Condition Data Parameter</th>
<th>Guidelines</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.4.1 Travel Time</strong></td>
<td><strong>Travel Time Measurement</strong></td>
<td>3.4.1.1</td>
</tr>
<tr>
<td></td>
<td>Travel times should only be collected using P2P devices.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Point devices should not be used to determine the travel times. However, Point devices can be used to validate travel speeds along the segment if deemed necessary by the operator.</td>
<td></td>
</tr>
<tr>
<td><strong>Segment Definition</strong></td>
<td>The Denver Region segment is defined from one major intersection to another major intersection.</td>
<td>3.4.1.2</td>
</tr>
<tr>
<td></td>
<td>If a jurisdictional boundary exists between two major intersections and one agency does not have the interest or resources to operate and maintain the P2P device in their jurisdiction, the segment should end at the nearest signal prior to entering the adjoining jurisdictional boundary.</td>
<td></td>
</tr>
<tr>
<td><strong>Sample Size</strong></td>
<td>A sample size of at least three good matching samples every two minutes is recommended for the Denver Region.</td>
<td>3.4.1.3</td>
</tr>
<tr>
<td><strong>Placement of the Devices to Measure Travel Time</strong></td>
<td>P2P devices are recommended to be placed at the far side of the intersection from the signal pole to within 100 feet of the traffic signal. P2P devices placement at mid-block and near-side of the intersection is not recommended.</td>
<td>3.4.1.4</td>
</tr>
<tr>
<td><strong>Density of the Devices</strong></td>
<td>At least two P2P devices should be used for each segment in each direction.</td>
<td>3.4.1.5</td>
</tr>
<tr>
<td><strong>Data Collection Timeliness</strong></td>
<td>Regardless of who is processing the data, i.e., CTMS or the vendor software, data from the field device should be collected every two minutes or less.</td>
<td>3.4.1.6</td>
</tr>
<tr>
<td><strong>Travel Time Data Processing</strong></td>
<td>The Denver Region should continue using the CTMS application for travel time processing with regard to toll tag technology. If new P2P technologies are considered on arterials, software drivers should be written by the agency implementing the technology. If device vendors are used, vendor should be required to provide processed travel time data in a XML feed to CTMS every two minutes.</td>
<td>3.4.1.7</td>
</tr>
<tr>
<td><strong>Travel Time Index (TTI) Processing</strong></td>
<td>Free-flow travel time should be calculated by conducting travel runs during late-night period (10PM-5AM). TTI = travel time in minutes / free-flow travel time in minutes.</td>
<td>3.4.1.8</td>
</tr>
</tbody>
</table>
### Appendix C – Denver Region Integrated Traveler Information Display Map Guidelines Summary Matrix

| **Planning Time Index (PTI) Processing** | 95th percentile speed should be used for PTI calculation in the Denver Region. PTI = 95\textsuperscript{th} percentile travel time in minutes / free-flow travel time in minutes | 3.4.1.9 |
| **Real-Time Travel Time Algorithm and Graphical Display Output** | Denver Region should follow the same color codes that exist right now on CoTrip for arterial conditions. However, the color codes for the segment should be based on TTI. | 3.4.1.10 |
| **Real-Time Travel Time Tabular Display** | Tabular display for arterial conditions should be made available only for the operators on the CCTM. Also, operators should have the capability to select a segment, which would pop up a window that displays the following information:  
- Current travel time  
- Current travel speed  
- Current Travel Time Index and associated color codes  
- Free flow travel time  
- Segment limits (From/To)  
- Segment length  
In addition, operators should have the ability to “rubber band” a group of segments to obtain an aggregate origin and destination current travel times. | 3.4.1.11 |
| **Travel Time Calculation and Validation** | The validation process should begin from the conceptual stage to design through implementation and continue with periodic monitoring. | 3.4.1.12 |
| **Accepting Travel Time Data from Private ISPs and Vendors** | Travel time data from private ISPs are acceptable as long as the following requirements are met:  
- Travel time data are provided via XML feed every two minutes.  
- Segmentation is clear by direction and meets the requirements of the local agency.  
- No restrictions on the use of data for real time or historical purposes. | 3.4.1.13 |
### Appendix C – Denver Region Integrated Traveler Information Display Map Guidelines Summary Matrix

| Providing Travel Time Data to Private ISPs | Sample size requirements are being met, i.e., minimum of three good matching samples every two minutes.  
Data are measured travel time data and not speed data that are extrapolated to calculate travel time. |
| Travel Time Measures of Effectiveness (MOEs) and Reporting | Travel time data be made available to private ISPs. Interested ISPs should poll the data in time intervals of two minutes or more. Shorter polling times of less than two minutes can slow down the available communication channels. Agencies be given the discretion charge private ISPs for their data. |
| Congestion Duration | Congestion duration should be determined based on the time period where a segment experiences a TTI of ≥ 1.2.  
Additionally, operators should also consider determining congestion severity by identifying time periods of heavy (TTI between 1.5-1.8) and or severe (TTI > 1.81) congestion. |
| Usefulness of MOEs to Operators | The first year of travel time implementation forms the baseline for all MOEs.  
After the first year, the operator should be able to compare current data in the following ways:  
- Time of Day comparisons  
- Day of week comparisons  
- Weekly comparisons  
- Monthly comparisons  
- Yearly comparisons |

---

3.4.1.14

3.4.1.15

3.4.1.16

3.4.1.17
### 3.4.2 Traffic Incident Information

<table>
<thead>
<tr>
<th>Types of Traffic Incidents</th>
<th>Incidents on arterials should be classified into the following five types:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Accident</td>
</tr>
<tr>
<td></td>
<td>• Stalled Vehicle</td>
</tr>
<tr>
<td></td>
<td>• Spill load (non HAZMAT)</td>
</tr>
<tr>
<td></td>
<td>• HAZMAT Spill</td>
</tr>
<tr>
<td></td>
<td>• Other (Vehicle fire, etc)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Traffic Incident Detection</th>
<th>Local CTMS client interface to the local law enforcement CADD system is recommended as this will allow the operator to monitor traffic incidents.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operators should use traffic cameras to monitor traffic flow and detect incidents during morning and evening peaks during week days</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Traffic Incident Verification</th>
<th>Incidents should be verified using traffic cameras before it is reported to travelling public via CoTrip website.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>If the incident cannot be verified due to lack of video coverage, the incident should not be reported to traveling public unless it is confirmed by a reliable source.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Incident Information Validation</th>
<th>The operator is responsible for updating any changes to the following:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Roadway or lane closures</td>
</tr>
<tr>
<td></td>
<td>• Duration of the incident</td>
</tr>
<tr>
<td></td>
<td>• Clearance of the incident</td>
</tr>
</tbody>
</table>

| Traffic Camera Placement | Cameras with PTZ capability are recommended at major intersections. |

<table>
<thead>
<tr>
<th>Traffic Incident Response and Reporting</th>
<th>Operators should consider mitigation strategies only if the potential incident duration is expected to last more than 30 minutes.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>If the incident duration is expected to be more than 30 minutes, operators will use the local CTMS to report the incident and include location, direction, duration, roadway or lane closure</td>
</tr>
</tbody>
</table>
## Appendix C – Denver Region Integrated Traveler Information Display Map Guidelines Summary Matrix

| Traffic Incident Information Display Output | and information reporting source.  
Additionally, the operator working with CSP or local law enforcement personnel can implement any temporary changes in signal timings to alleviate the traffic backups in the incident area. |
| Traffic Incident Clearance | Operators should confirm that an incident has been cleared before reporting it on CTMS. Operators should confirm return to normal signal operations. |
| Data Timeliness | Denver Region should follow the FHWA Rule regarding reporting incidents that cause roadway closures or lane blocking on arterial corridors within 10 minutes from the time the incident is verified provided that the incident is projected to exceed 30 minutes in duration. |
| Accepting Incident Information from Private ISPs | Incident information from private ISPs is acceptable as long as the operator has the ability to verify the incident, as defined in Section 3.4.2.3 (Incident Verification), before any mitigation strategies are implemented. |
| Providing Data to Private ISPs | Incident data should be made available to private ISPs. |
| Incident information MOEs | The following MOEs that relate to incident information are recommended for the Denver Region:  
  - Number of incidents over a specified period. |
### Appendix C – Denver Region Integrated Traveler Information
Display Map Guidelines Summary Matrix

<table>
<thead>
<tr>
<th>Usefulness of MOEs to operators</th>
<th>The first year of incident information forms the baseline for all MOEs. Following the initial year, the MOEs can be expanded to include the operator’s response to incidents. Case studies should also be selectively performed to understand the benefits of mitigation strategies.</th>
</tr>
</thead>
</table>

#### 3.4.3 Weather Related Road Condition Information

<table>
<thead>
<tr>
<th>Types of Weather Road Condition Information</th>
<th>Denver Region should provide the following weather related road conditions information:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Icy Spots</td>
</tr>
<tr>
<td></td>
<td>• Snow</td>
</tr>
<tr>
<td></td>
<td>• Wet/Rain</td>
</tr>
<tr>
<td></td>
<td>• Poor Visibility/Fog</td>
</tr>
<tr>
<td></td>
<td>• Adverse Conditions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Segmentation for Weather Related Road Condition Information</th>
<th>Segmentation to display the weather related road information should follow these guidelines:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Combine at least three major intersections to major intersections or consider minimum segment length of five miles.</td>
</tr>
<tr>
<td></td>
<td>• If a jurisdictional boundary exists between two major intersections, it is recommended to consider the segment end at the nearest signal prior to entering the adjoining jurisdictional boundary.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Detection of Weather Related Road Conditions</th>
<th>Traffic cameras are recommended to be used at major intersections. The implementation of weather station and road sensors should be left to the discretion of the operator in conjunction with the agency’s needs. If they are installed, the data should be available in CTMS.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local agencies are recommended to decide if they want to implement the MDSS system and/or equip snow plows with AVL capabilities including camera and/or input devices data. If implemented, information should be made available to CTMS for display on the CoTrip</td>
</tr>
</tbody>
</table>
## Appendix C – Denver Region Integrated Traveler Information Display Map Guidelines Summary Matrix

| Road Conditions Graphical Display Output | Use the same color codes as CoTrip to display road conditions graphical output for the arterials in the Denver Region | 3.4.3.4 |
| Tabular Display of Weather Related Road Conditions Information | Tabular display for weather related road conditions should be made available on CoTrip and CCTM. Also, when the segment is selected, it would pop up a window that displays the following information:  
  - Segment  
  - Road condition  
  - Roadway or lane blockages  
  - Updated time  
  - Information reporting source | 3.4.3.5 |
| Data Timeliness | Denver Region should follow the FHWA rule and report hazardous driving conditions and roadway or lane closures or blockages within 20 minutes of when they are observed. However, other conditions such as icy spots, snow, wet/rain and poor visibility/fog can be reported within 30 minutes or when conditions change during the morning or afternoon peak periods on weekday. | 3.4.3.6 |
| Weather Related Road Condition Information Validation | The operator is responsible to update the changes to the following information:  
  - Roadway or lane closures  
  - Road conditions | 3.4.3.7 |
| Weather Related Road Condition MOES | The following MOEs that relate to weather related road condition information are recommended for the Denver Region:  
  - Number of adverse conditions observed.  
  - Travel time during different road conditions particularly during snow conditions.  
  - Number of observed incidents due to adverse weather conditions. | 3.4.3.8 |
### Appendix C – Denver Region Integrated Traveler Information Display Map Guidelines Summary Matrix

<table>
<thead>
<tr>
<th>Usefulness of MOEs to Operators</th>
<th>Operators should study the effects of travel time over the weather related road conditions. Operators should consider implementing signal timing changes and determine the impacts of the changes on travel time and safety.</th>
<th>3.4.3.9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.4.4 Construction and Maintenance Operations Information</strong></td>
<td>Construction and maintenance operations within the Denver Region should be classified into one of the five following types:</td>
<td>3.4.4.1</td>
</tr>
<tr>
<td>• Bridge Construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Road Construction including above ground and underground utilities (water, sewer and communications)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Signal Installation/Upgrade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Paving operations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Roadway maintenance operations</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Types of Construction and Maintenance Operations</strong></td>
<td>Construction project and maintenance operations information should be provided and updated by the operator within each local agency using local CTMS. The operator is responsible to keep the construction and maintenance operations information current and work closely with the agency project manager, construction contractor or agency maintenance supervisor.</td>
<td>3.4.4.2</td>
</tr>
<tr>
<td><strong>Collection of Construction and Maintenance Operations Information</strong></td>
<td>Cone symbol should be used for graphically displaying construction conditions for both Interstate Highways and arterials. This avoids any confusion for users. Planned Construction and maintenance operations should only be reported within 30 days of commencement of work Only maintenance operations including emergency operations that are expected to be 30 minutes or more in duration should be reported to the travelling public. Tabular information should be accessible by clicking on the symbol on the graphical</td>
<td>3.4.4.3</td>
</tr>
</tbody>
</table>
Tabular information for each construction and maintenance operation should include the following additional information:

- Planned or On-going
- Location
- Direction
- Road/Lane Closures
- Construction and Maintenance operations Type
- Hours/Days of construction
- Completion Date
- Description of Closures and Detours
- Delays
- Update time/date Stamp
- Information Reporting Source

The following time intervals should be used for updating construction and maintenance operations information:

- Construction and maintenance operations information should be updated on CoTrip within 30 days of the project start date. Earlier updating could result in confusion and later updating could result in travelers not getting the appropriate information.

- Roadway or lane closures should be updated within 10 minutes from the time of the closure or re-opening of the roadway or lanes. This will be consistent with the FHWA Rule.

The operator is responsible for updating the changes to roadway closures throughout the duration of the project and maintenance operation.
### Appendix C – Denver Region Integrated Traveler Information
Display Map Guidelines Summary Matrix

<table>
<thead>
<tr>
<th>Construction and Maintenance Operations Information MOEs</th>
<th>The following MOEs are recommended for the Denver Region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Travel time impacts on arterial due to construction and maintenance operation</td>
</tr>
<tr>
<td></td>
<td>• Travel time impacts on other adjacent arterial</td>
</tr>
<tr>
<td>Usefulness of MOEs for Operators</td>
<td>• Operators should understand how the traveling public changes route decisions by examining travel times.</td>
</tr>
<tr>
<td></td>
<td>• Operators can use this information to recommend alternative routes to allow for better utilization of roadway capacity.</td>
</tr>
<tr>
<td>3.4.5 Traffic Video</td>
<td>Traffic cameras should be installed at locations that will allow multiple uses to serve other travel condition parameters such as:</td>
</tr>
<tr>
<td></td>
<td>o Incidents</td>
</tr>
<tr>
<td></td>
<td>o Construction</td>
</tr>
<tr>
<td></td>
<td>o Weather related road conditions</td>
</tr>
<tr>
<td></td>
<td>o Maintenance operations</td>
</tr>
<tr>
<td></td>
<td>o Traffic information for events</td>
</tr>
<tr>
<td></td>
<td>o Parking information for events</td>
</tr>
<tr>
<td></td>
<td>All traffic video, i.e., PTZ, presence, weather stations, etc. should be made available on CoTrip to the traveling public except cameras that are solely used to collect speed and occupancy and that are directly pointed down at the pavement.</td>
</tr>
<tr>
<td></td>
<td>All traffic video should also be made available on CCTM and the CCTV Application. This can be done via CDOT’s CCTV Application, CTMS, etc.</td>
</tr>
<tr>
<td></td>
<td>Operators should work closely with CDOT to determine the best possible approach to have camera images available on CoTrip.</td>
</tr>
<tr>
<td>3.4.6 Event Information</td>
<td></td>
</tr>
</tbody>
</table>
### Event Information Validation

The operator is responsible for updating the changes to roadway closures throughout the duration of the project.

<table>
<thead>
<tr>
<th>Parking Information for Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>- The operator is responsible for validating the parking availability information for at least one event.</td>
</tr>
<tr>
<td>- For public agency operated parking lots and/or garage facilities, operators should consider providing at least the following information.</td>
</tr>
<tr>
<td>- Full</td>
</tr>
<tr>
<td>- Open</td>
</tr>
<tr>
<td>- This information should be made available near the parking facility using blankout or Variable Message Signs.</td>
</tr>
<tr>
<td>- After implementation of the parking application, the operator should conduct manual parking availability study for at least one event to determine if the reported conditions match the actual conditions.</td>
</tr>
</tbody>
</table>

### 3.4.7 Speed

<table>
<thead>
<tr>
<th>Device Type, Segmentation, Placement and Time Intervals for Data Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is recommended that the travel time travel condition parameter for the segment using P2P device be converted to speed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Speed Graphical and Tabular Display Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>The tabular display used for travel time be made available on CCTM. When the operator selects the segment, it should include the following:</td>
</tr>
<tr>
<td>- Current travel time</td>
</tr>
<tr>
<td>- Free flow travel time</td>
</tr>
</tbody>
</table>
### Appendix C – Denver Region Integrated Traveler Information Display Map Guidelines Summary Matrix

<table>
<thead>
<tr>
<th><strong>Accepting Data from Private ISPs</strong></th>
<th><strong>Usefulness of MOEs to operators</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Segmentation should meet the requirements of the local agency.</td>
<td>The first year forms the baseline for MOEs. Once this information is available operators can compare travel speeds in many different ways such as</td>
</tr>
</tbody>
</table>
| Data should be travel time data and not based on speed at a particular point on the segment. | • Time of day  
• Day of week  
• Daily  
• Monthly  
• Yearly |

### 3.4.8 Queues

<table>
<thead>
<tr>
<th><strong>Queue Presence and Queue Length</strong></th>
<th><strong>Device Type to Collect Queue Data</strong></th>
</tr>
</thead>
</table>
| Queue presence and queue length should be measured by lane for through lanes  
Only queue presence should be considered for left turn and right turn lanes. | The type of devices best suited for collecting queue presence and queue length are video detection devices as the level of deployment is minimal and setting up detection zones is easy.  
Also, video detection has the ability to collect both queue presence and queue length. |

<table>
<thead>
<tr>
<th><strong>Applicability</strong></th>
<th><strong>Placement of Device</strong></th>
</tr>
</thead>
</table>
| The applicability of where queue presence and queue length data are useful should be left to the discretion of the operator. | For through lanes, the video detection unit should be placed facing the back of the queue.  
For left-turn and right-turn lanes, the video detection unit can be placed either facing the approaching traffic or facing the back of the traffic. |

<table>
<thead>
<tr>
<th><strong>Data Collection Timeliness</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Queue presence and queue length should be collected every two minutes.</td>
<td></td>
</tr>
</tbody>
</table>

3.4.7.3  
3.4.7.5  
3.4.8.1  
3.4.8.2  
3.4.8.3  
3.4.8.4  
3.4.8.5
<table>
<thead>
<tr>
<th>Density of the Devices</th>
<th>One video detection unit is needed for each location where queue presence and/or queue length is desired.</th>
<th>3.4.8.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Interval for Processing and Display</td>
<td>Queue data should be processed and displayed within two minutes of data collection.</td>
<td>3.4.8.7</td>
</tr>
</tbody>
</table>
| Queue Data Processing | The Denver Region should continue using CTMS application for all arterial travel conditions parameters. The implementing agency should be responsible for development of software requirements in CTMS including the development of any new drivers for new detection devices. Also, the detection zones, regardless of location, need to be setup properly in the following manner:  
  - 50 feet detection zones that are continuous, i.e., no gaps  
  - Detection zones should be numbered consistently | 3.4.8.8 |
| Graphical and Tabular Display Output | Queue data should only be available on CCTM  
On CCTM there should be a queue data symbol. This queue symbol needs to be developed. By selecting the symbol, the operator will have access to queue presence and/or queue length data by lane as described above. The reporting section details the format of the queue data report. | 3.4.8.9 |
| Queue Data Validation | The operator is responsible for validating if the reported conditions are within the acceptable accuracy requirements. | 3.4.8.10 |
| Usefulness of MOEs to Operators | By examining the data, the operator is able to do the following:  
  - Establish a baseline for a given time period  
When queues are worse than the baseline then operator may choose the following:  
  - Adjusting the signal timing  
  - Develop queue clearance plans for certain conditions | 3.4.8.12 |

### 3.4.9 Volume

| Device Type to | It is recommended to use P devices to count the traffic volumes. | 3.4.9.1 |
### Appendix C – Denver Region Integrated Traveler Information
**Display Map Guidelines Summary Matrix**

<table>
<thead>
<tr>
<th>Collect Volume Data</th>
<th>Device Placement and Density</th>
<th>Data Collection Timeliness</th>
<th>Time Intervals for Processing and Display</th>
<th>Graphical and Tabular Display Output</th>
<th>Volume Data Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vehicle detection devices that collect volume data will be installed at a sufficient distance from the intersection such that traffic is not in a stop-and-go condition for the approach. Typically one device should be sufficient for each approach.</td>
<td>Collect the volume data in 15 minute intervals.</td>
<td>Volume data be reported every 15 minutes.</td>
<td>As the volume data is primarily for operations, it should only be displayed on CCTM. If a segment is already collecting other travel condition parameters, such as travel time and speed, the volume should also be displayed when the segment is selected. If there is no travel time or speed is being reported on the segment, there should be a symbol on CCTM. When this symbol is selected, it should display volume by lane.</td>
<td>The operator is responsible for validating if the reported volume data is within the acceptable accuracy requirements.</td>
</tr>
</tbody>
</table>

#### 3.5 Data Quality Parameters

<table>
<thead>
<tr>
<th>3.5.1 Accuracy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time</td>
<td>85% accurate at a minimum</td>
</tr>
<tr>
<td>Incidents</td>
<td>Maximum error rate of 15 % on reports related to roadway or lane blockages</td>
</tr>
<tr>
<td>Weather Related Road Conditions</td>
<td>Maximum error rate of 15 % on reports related to roadway or lane blockages during adverse weather conditions</td>
</tr>
<tr>
<td>Construction and Maintenance Operations Information</td>
<td>Maximum error rate of 15 % on reports related to closure and reopening of roadway or lane</td>
</tr>
<tr>
<td>Traffic Video</td>
<td>Does not apply</td>
</tr>
<tr>
<td>Traffic Information for Events</td>
<td>Maximum error rate of 15 % on reports related to closure and reopening of roadway or lane</td>
</tr>
</tbody>
</table>
### Appendix C – Denver Region Integrated Traveler Information

#### Display Map Guidelines Summary Matrix

<table>
<thead>
<tr>
<th><strong>Parking Information for Events</strong></th>
<th>Maximum error rate of 5% on parking availability</th>
<th>3.5.1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Speed</strong></td>
<td>Same as travel time travel condition parameter</td>
<td>3.5.1</td>
</tr>
<tr>
<td><strong>Queues</strong></td>
<td>Maximum error rate of 15% on queue presence and Minimum accuracy of 50% on queue length</td>
<td>3.5.1</td>
</tr>
<tr>
<td><strong>Volume</strong></td>
<td>Minimum accuracy of 85% on volumes</td>
<td>3.5.1</td>
</tr>
<tr>
<td><strong>Occupancy</strong></td>
<td>None</td>
<td>3.5.1</td>
</tr>
<tr>
<td><strong>3.5.2 Availability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Travel Time</strong></td>
<td>90% at a minimum</td>
<td>3.5.2</td>
</tr>
<tr>
<td><strong>Incidents</strong></td>
<td>90% at a minimum of the incidents with roadway or lane blockage</td>
<td>3.5.2</td>
</tr>
<tr>
<td><strong>Weather Related Road Conditions</strong></td>
<td>90% at a minimum of the weather related road conditions with roadway or lane blockage</td>
<td>3.5.2</td>
</tr>
<tr>
<td><strong>Construction and Maintenance Operations Information</strong></td>
<td>90% at a minimum of the construction activities with roadway or lane blockage</td>
<td>3.5.2</td>
</tr>
<tr>
<td><strong>Traffic Video</strong></td>
<td>90% at a minimum of the time</td>
<td>3.5.2</td>
</tr>
<tr>
<td><strong>Traffic Information for Events</strong></td>
<td>90% at a minimum of the events with roadway or lane blockage</td>
<td>3.5.2</td>
</tr>
<tr>
<td><strong>Parking Information for Events</strong></td>
<td>90% at a minimum of the events with parking availability information</td>
<td>3.5.2</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>Similar to travel time</td>
<td>3.5.2</td>
</tr>
<tr>
<td><strong>Queues</strong></td>
<td>90% at a minimum of the time</td>
<td>3.5.2</td>
</tr>
<tr>
<td><strong>Volume</strong></td>
<td>90% at a minimum of the time</td>
<td>3.5.2</td>
</tr>
<tr>
<td><strong>Occupancy</strong></td>
<td>None</td>
<td>3.5.2</td>
</tr>
<tr>
<td><strong>3.5.3 Timeliness</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Travel Time</strong></td>
<td>Reported within 10 minutes from the time that the travel time calculation is completed.</td>
<td>3.5.3</td>
</tr>
</tbody>
</table>
## Appendix C – Denver Region Integrated Traveler Information
### Display Map Guidelines Summary Matrix

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidents</td>
<td>Reported within 10 minutes or less from the time that the incident is verified and/or cleared</td>
<td>3.5.3</td>
</tr>
<tr>
<td>Weather Related Road Conditions</td>
<td>Reported within 20 minutes from the time hazardous conditions, blockage or closure is observed</td>
<td>3.5.3</td>
</tr>
<tr>
<td>Construction and Maintenance Operations</td>
<td>Reported within 10 minutes or less from the time of the closure or reopening of the roadway</td>
<td>3.5.3</td>
</tr>
<tr>
<td>Traffic Information for Events</td>
<td>Reported within 10 minutes or less from the time the event is verified</td>
<td>3.5.3</td>
</tr>
<tr>
<td>Parking Information for Events</td>
<td>Reported within 10 minutes or less from the time the event is verified</td>
<td>3.5.3</td>
</tr>
<tr>
<td>Traffic Video</td>
<td>Available almost immediately for streaming video or updated every 2 minutes for still images</td>
<td>3.5.3</td>
</tr>
<tr>
<td>Speed</td>
<td>Similar to travel time</td>
<td>3.5.3</td>
</tr>
<tr>
<td>Queues</td>
<td>Reported within 2 minutes or less from the time that the queue presence and/or length calculation is completed</td>
<td>3.5.3</td>
</tr>
<tr>
<td>Volume</td>
<td>Reported within 2 minutes or less from the time that the queue presence and/or length calculation is completed</td>
<td>3.5.3</td>
</tr>
<tr>
<td>Occupancy</td>
<td>None</td>
<td>3.5.3</td>
</tr>
</tbody>
</table>

### 3.6 Data Dissemination

CoTrip will be the primary online dissemination tool for the traveling public.

Local agencies can provide traveler information within their jurisdictional boundaries on their agency website displaying the same data shown on CoTrip.

The following travel condition data parameters should be available on CoTrip:

- Travel time
- Incident information
- Weather related road condition information
- Construction information
- Maintenance operations
- Traffic video
### Appendix C – Denver Region Integrated Traveler Information Display Map Guidelines Summary Matrix

| 511 | Arterials that are State and US highways within the Denver Region should be included in 511 for the following travel condition data parameters: |
|     | - Travel time within the available corridor limits but not by each segment in the corridor  
|     | - Incident information  
|     | - Weather related road condition information  
|     | - Construction information  
|     | - Maintenance operations  
|     | - Traffic information for events  
|     | For arterials that are not State or US highways, CDOT should provide the ability to transfer calls to local 511 system if the travel time information is available on it. Again, travel times will be within the available corridor limits not by each segment in the corridor. |
| GOV Delivery | Gov Delivery system should be made available for operators that can provide information for incidents, weather related road condition information, construction and events. |
| VMS | The following travel condition data parameters should be available on local VMS |
|     | - Travel time  
|     | - Incident information  
|     | - Weather related road condition information  
|     | - Construction information  
|     | - Maintenance operations  
|     | - Traffic information for events  
|     | - Parking information for events |
| HAR | The following travel condition data parameters should be available on local HAR |
|     | - Travel time  
|     | - Incident information |
### Appendix C – Denver Region Integrated Traveler Information
Display Map Guidelines Summary Matrix

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CCTM</strong></td>
<td>The following travel condition data parameters should be available on CCTM</td>
<td>3.6.6</td>
</tr>
<tr>
<td></td>
<td>• Travel time</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Incident information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Weather related road condition information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Construction information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Maintenance operations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Traffic video</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Traffic information for events</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Speed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Queues</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Volume</td>
<td></td>
</tr>
<tr>
<td><strong>COGNOS</strong></td>
<td>Local CTMS data should be COGNOS.</td>
<td>3.6.7</td>
</tr>
<tr>
<td></td>
<td>Standardized reports should be developed that would satisfy a majority of the requirements developed by stakeholders</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local jurisdiction should pay for COGNOS license(s) to support the local application</td>
<td></td>
</tr>
<tr>
<td><strong>CCTV Application on Google</strong></td>
<td>Local agency traffic cameras should be included on the CDOTs CCTV Application.</td>
<td>3.6.8</td>
</tr>
<tr>
<td><strong>3.7 Base Map For Displaying the Arterial Condition Information</strong></td>
<td>CoTrip should continue to use Google maps for providing traveler information for Interstate Highways and arterials.</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>As more arterial travel condition information is made available, CDOT should provide users with the option to select layers for interstate highways, arterials, and/or all other roadways to view the traveler information.</td>
<td></td>
</tr>
</tbody>
</table>
### Appendix C – Denver Region Integrated Traveler Information Display Map Guidelines Summary Matrix

| 3.8 Base Map for Displaying Arterial Travel Condition Information for Local Agencies | Local agencies are free to choose the base map as long as the information that populates on the map is available through CTMS. Agencies can include other information pertinent to their agency to customize their site. However, all information generated via CTMS must be consistent with what is being displayed on CoTrip. Users should be provided a link to access CoTrip for statewide information. Also, it is desirable that the base map have zooming capabilities.
If an agency chooses to use the Google base map, the agency should coordinate with CDOT to determine the cost implications to share the map. | 3.8 |
|---|---|---|
| 3.9 Transmitting and Archiving Data | Each local agency should be responsible for storing data generated from travel condition data should be stored based on the recommended intervals for five years parameters within the local CTMS archive database.
Data that is more than 5 years old should be aggregated into daily values and stored for five additional years. | 3.9 |
| 3.10 Alarms | The operator should be able to set the acceptable thresholds. | 3.10 |
| 3.11 Performance Measures Report Card | The report card should focus on previous day. If operators desire to see older data, there should be an option to increase the duration for reporting.
The report card should be available on CCTM and/or sent to the operator via email each morning at 7:00 AM. | 3.11 |

NOTE: Refer to the main document for background and details. Some guidelines are not included in this Summary Matrix due to document size constraints.