Final Report

MOTORIZED TRAFFIC DATA (SHORT DURATION COUNT) SITE SELECTION STUDY AND STRATEGIC PLAN DEVELOPMENT PROJECT

by

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16. ABSTRACT:

This report describes the recommended business process that the Colorado Department of Transportation's (CDOT) Traffic Analysis Unit (TAU) can use to organize its short duration count program. The report also describes the business activities that need to occur and provides details on each of those activities. Included in those details are recommendations for actions and decisions the TAU should take, as well as specific issues that should be considered.

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RECOMMENDED COLORADO DOT SHORT COUNT BUSINESS PROCESS

INTRODUCTION

This report describes the recommended business process that the Colorado Department of Transportation's (CDOT) Traffic Analysis Unit (TAU) can use to organize its short duration count program. The report also describes the business activities that need to occur and provides details on each of those activities. Included in those details are recommendations for actions and decisions the TAU should take, as well as specific issues that should be considered.

Figure 1 illustrates the recommended short count business process. The figure shows the specific sequence of activities that should be undertaken annually to identify where short counts should be taken to meet the needs of CDOT. These activities are described in detail in the following section of this report.

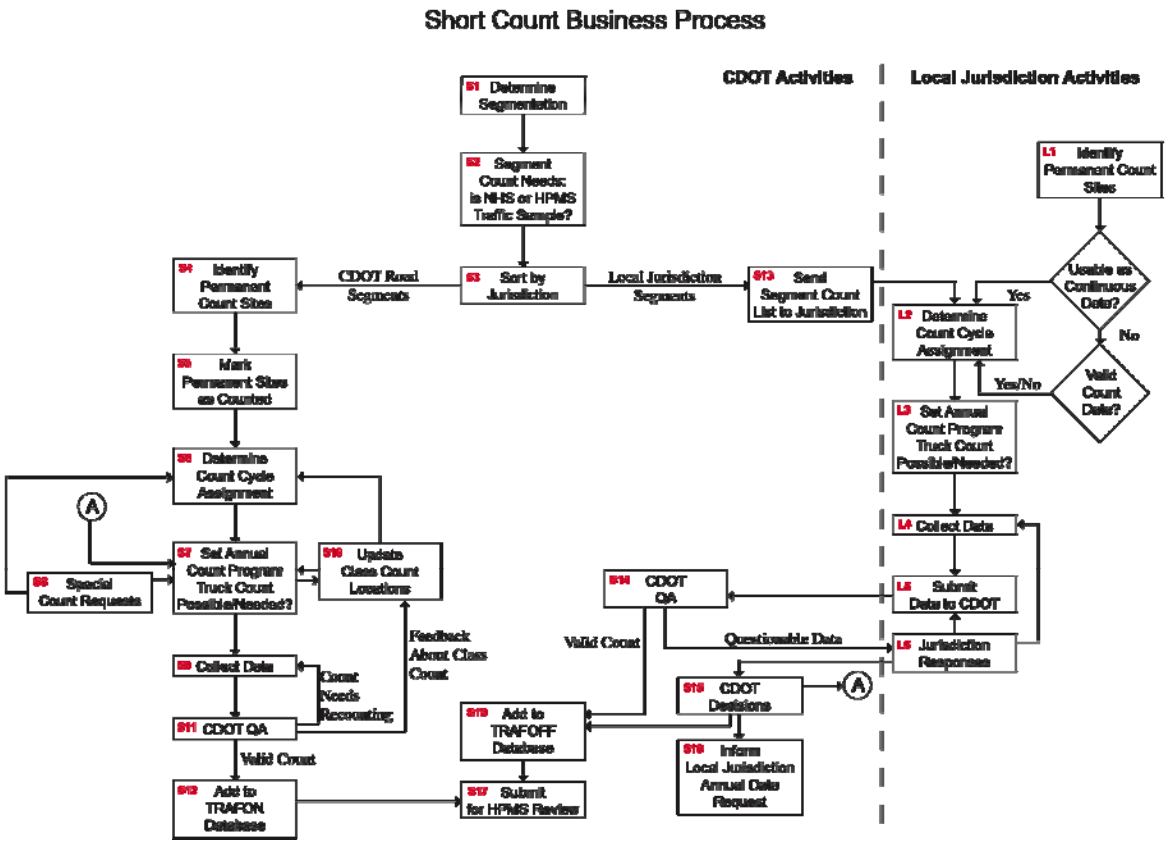

Figure 1: Short Duration Count Business Process

In addition to the structured tasks illustrated in Figure 1, the TAU must perform a set of secondary activities at irregular intervals during the year to support the collection of short count data. These additional steps are discussed in the third section of this report and include working with local jurisdictions to improve data sharing, updating the traffic segmentation used to collect and report traffic data, and updating records that describe which roads are operated by which jurisdiction and where vehicle classification counts can and can not be successfully collected. These steps are not on the critical path associated with identifying, collecting, and posting short duration count data each year, but their performance is very important .

Note that this document primarily describes the activities required of the CDOT TAU. It describes the activities of other jurisdictions and divisions of CDOT only to the extent that those activities affect the activities of CDOT TAU staff. As a result, the business process activities shown in Figure 1 are also separated into two parts, those that the CDOT TAU must perform (indicated with an "S") and those that Colorado's local jurisdictions must perform (indicated with an "L.")

This report also includes in its appendices, two working papers developed as part of this project. These cover the data needs of CDOT, the constraints placed on the short count data collection program and the project's recommendations for the design of the CDOT TAU short duration count program.

BUSINESS PROCESS FOR CDOT SHORT COUNTS

The business process illustrated in Figure 1 and discussed below assumes that CDOT will aggregate and submit the traffic data required to meet the federally mandated Highway Performance Monitoring System (HPMS) requirements. However, the actual collection of traffic data will be the responsibility of the agency that owns and operates each given section of road that is included in the Colorado state HPMS submittal. Thus, unless a jurisdiction specifically contracts with CDOT for the collection of those data or CDOT chooses to collect data off the state system for its own purposes, all data for each segment of roadway[1] in the state will be collected by the agency that owns and operates that road segment or that agency's contractors. CDOT will be responsible for collecting data on state routes operated by CDOT.

S1) Determine Segmentation

Roadway segmentation is key to both the HPMS and the method used to deliver traffic data to users. Traffic volume estimates collected at specific points on a road are assumed to be valid for longer stretches of roadway, or segments, where a segment may extend for some distance up- and downstream from the physical collection location. The main reporting process for CDOT depends on roadway segments that are developed to support the HPMS and that also meet the general needs of CDOTs users.

Consequently, the first task required in the short duration count program is to ensure that the segmentation being used is correct. The appropriate starting point is the existing traffic segmentation found in the TRAFFON and TRAFFOFF databases that the TAU uses for collection and submittal of HPMS data. The current segmentation meets user needs and should

[1] For this report, it was assumed that the traffic data being discussed are collected only on road segments that are not functionally classified as either "rural minor collectors" or "local" facilities.

be changed only when traffic conditions change. Table 1 provides guidance[2] on the size of volume differences that are acceptable within a defined roadway segment. Segments should be split only when changes in average daily traffic within a segment exceed these values.

Table 1: Recommended Criteria for Separating Traffic Segments

AADT Classification Groups	Criteria (Volume Change of)
Under 500	1,000 Vehicles
500 - 1,999	
2,000 - 4,999	2,000 Vehicles
5,000 - 9,999	
10,000 - 19,999	5,000 Vehicles
20,000 - 34,999	
35,000 - 54,999	
55,000 - 84,999	10% change in Volume
85,000 - 124,999	
125,000 - 174,999	
175,000 - 249,999	
250,000 and more	

Because the current segmentation meets the vast majority of CDOT needs, it is not necessary for segmentation to be widely reviewed on an annual basis. Rather, segments should be reviewed when

- Large amounts of land development occur in specific geographic areas (then examine roads likely to carry traffic to/from that development)
- New road capacity is being built or removed from service[3]. Travel patterns change as a result of the capacity changes. (examine road segments potentially affected by those roadway changes)
- Data being collected for special study purposes (such as traffic signal timing optimization) indicate that road volumes within a previously defined segment are not homogenous given the bounds described in Table 1.

S2) Segment Count Needs: Determine Whether the Traffic Sample is for NHS or HPMS

Traffic volume estimates need to be reported for each traffic segment defined in the previous business process. However, the frequency with which counts should be taken on those segments varies. Put simply, traffic segments that are part of the National Highway System (NHS) or that have been selected as Traffic Sample Sections for the Colorado HPMS submittal must be counted a minimum of once every three years. All other roadway segments defined in the previous step, including all freeway ramps, must be counted a minimum of every six years.

[2] Note that the 2012 version of the FHWA Traffic Monitoring Guide uses a slightly different table, but this table and the TMG table are very similar. The new TMG table can be found in Appendix E.

[3] For example, a road might be closed when funding is not available to repair/replace an old bridge that has reached its ultimate life.

In Business Process S2, the TAU should determine which roadway segments must be counted every three years and which must be counted every six years and then place the appropriate designator in the database for each roadway segment.

As a result of MAP-21[4] and HPMS reporting requirements, the State of Colorado is responsible for submitting traffic volumes for all functionally classified roads in the state, not just roads operated by CDOT. As a result, this segmentation task must be performed for all functionally classified roads, not just the on-system roads that CDOT maintains and operates.

The results of this task allow the CDOT TAU to track which road segments must be counted within each time interval. This allows the TAU to both schedule counts on CDOT roadways and work with local jurisdictions to ensure that the other data needed for statewide Vehicle Miles Traveled (VMT) estimation are available for the HPMS.

Note that when counts are not taken on a roadway segment in a given year, traffic volumes on those segments are estimated by factoring the previously collected data to account for growth. This task, while important, is not part of the short duration count business process.

S3) Sort the Information by Jurisdiction

Because each jurisdiction is responsible for collecting data on its road system, the TAU must provide each of those jurisdictions with information on where counts are needed and how often they are required.

In Business Task S3, the TAU should sort the information developed in the two previous tasks by jurisdiction, so that CDOT can send to each jurisdiction a list of the roadway segments for which data are required and the required frequency of those counts.

At this time, exactly which counts will be taken in which year is not yet known. CDOT will need to work with the local jurisdictions to determine when those counts will be taken. (See the section "Next Steps for Facilitating the Collection of Local Jurisdiction Traffic Data" presented later in this report for a more complete description of the required interactions with local agencies.)

S4) Identify Permanent Count Sites (CDOT Activity)

In Business Process S4, the TAU staff needs to identify the locations of CDOT permanent equipment that are actively collecting traffic volume and/or vehicle classification data. The availability of data from permanent devices, assuming the data are valid and complete,[5] removes the need for the TAU to perform a short duration count on that roadway segment, although the TAU may wish to perform at least one short count at various ATRs to confirm the operation of those devices.

These permanent devices can be operated by the TAU, the ITS Branch of CDOT, or one of the CDOT Regional offices. Currently, the TAU and Region 6 operate the majority of these devices, but this may change over time if more active traffic management activities are

[4] MAP-21 is the federal highway authorizing legislation passed in July 2012. Its full title is the Moving Ahead for Progress in the 21st Century Act (P.L. 112-141).

[5] The data at a site need to cover an entire roadway or desired ramp. It is not helpful for a permanent device to only cover one lane of a four-lane facility. For ramp counts, the data available need to cover an entire on- or off-ramp but do not need to count the mainline traffic at that location.

implemented across the state. Permanent devices may be placed to collect traffic data for general Departmental use, or they may be placed to provide data for very specific traffic management purposes.

A variety of data collection technologies may be used at these locations. The technology (e.g., loops, radar, digital processing of video images, etc.) is not important, although it is important that where possible and cost effective, the equipment collects both vehicle classification and volume data.[6] The most important aspects of any continuous count device are that the equipment counts traffic reliably and that the traffic count data are accessible to the TAU. The TAU may have to work with the group operating the equipment to determine its accuracy and provide assistance that helps improve the performance of the device as part of that review. Similarly, if new equipment is required at a site, the TAU staff should be able to provide useful technical assistance in selecting, installing, and calibrating it.

While having access to the continuous data stream from these devices is the preferred outcome, it is not necessary for the TAU to have access to this level of data. Traffic data from non-TAU controlled devices can be collected on a short duration basis at locations where technical difficulties make getting access to the full data stream impractical or too costly. In these cases, the TAU needs to

1) Make a note in its segmentation database that a permanent device can provide short duration data at the location
2) Work with the owner of the device to identify when short duration counts can best be obtained from the location
3) Send reminder requests for those data at appropriate times in the year, and
3) Obtain and process the 48-hour counts for the specified periods.

To support this activity, the TAU will need to work with the equipment owners to select and publish file formats and data transfer protocols to minimize the time and effort required by both groups to create and transfer these data sets.

Not all permanent sites will provide good data. Inaccurate data can result from a lack of maintenance funding, but can also result from limitations in the equipment selected for that operational task. For example, during meetings associated with this project, individuals familiar with the T-Rex project indicated that some of the video-based detector systems purchased and installed as part of that project had high error rates during specific periods of specific months because of the equipment's inability to operate during times of intense sun glare. If this type of condition is known, then the 48 hours selected by the agency operating the camera-based detector should be collected during months when glare is not an issue. Alternatively, if the errors are from failed sensors, counts can be rescheduled for periods after those sensors have been repaired, or the site can be treated as if no permanent device exists.

One place where permanent detectors may provide significant assistance to the TAU is on freeway ramps. A significant number of ramps contain detection as part of CDOT's ramp metering efforts. In many cases, two data collection locations exist on a single ramp; one detector location exists at the stop bar for the ramp meter, and another is located well up the

[6] It is acceptable for these devices to collect length-based vehicle class data, as those data meet the HPMS reporting requirements.

ramp to serve as a queue detector. The TAU should work closely with the CDOT Region operating those devices to select whichever location counts ramp volumes more accurately.[7]

S5) Mark the CDOT Permanent Sites as Counted

Once the CDOT-operated permanent devices have been investigated, for each roadway segment containing a permanent device the TAU staff should indicate whether that device

- Provides continuous data
- Can provide short duration data
- Can provide data that meet federal reporting requirements.

These designations should be revisited each year as equipment is added, taken out of service, repaired, or are currently not operating effectively.

Segments designated with either of the first two abilities listed above can be removed from the list of sites where short count data need to be obtained. When making that notation, the TAU should also ensure that it has access to the continuous data from that site or has a plan to obtain short count data from the operators of those devices.

S6) Determine Count Cycle Assignments

Business Process S6 involves designating the years in which on-system traffic segments (maintained in the TRAFFON database file) should be counted.

Segments identified in the Business Process S4 that contain permanent traffic data collection devices that provide continuous data should be marked as having data collected every year. (This is a continuation of Business Process S5.) These segments do not need routine traffic counts.

The remainder of the traffic segments need to be counted either once or twice during each six-year count interval. The information obtained in Business Process S2 will have defined for each segment whether one or two counts are needed in the six-year cycle. Therefore, the only step remaining is to determine which segments should be counted in which years.

Since a count cycle already exists for the vast majority of Colorado's state road system, and the data users are generally satisfied with the data those counts provide, no specific changes are recommended. However, if the count program needs to be revised, the following should be considered in determining when to take specific counts.

- Counts taken close together geographically reduce the travel time required by crews to set counting equipment. Therefore grouping counts will reduce costs.
- Counting traffic segments on contiguous road segments of the same road on the same day allows for both a level of quality assurance (it can capture unusual weather effects) and limits some of the effects of day-to-day variability in traffic from Annual Average Daily Traffic (AADT) estimates for those roads.
- Maintaining some geographic stratification of counts is good in that it allows growth captured in any one year to be spread across the state.

[7] For example, it has been shown that in some cases, loop detectors placed near the arterial end of a ramp as queue detectors can undercount badly. This occurs because vehicles turning onto the ramp do not maintain good lane discipline, and as a result, many are not observed by the detector.

- Conducting a roughly equal number of counts in any given year helps the traffic counting program maintain consistent funding needs.

Taking these basic concepts into account, the recommended approach is to start by segregating the counties into three sets by county, approximately balancing the counties so that the number of counts required in each group of counties is roughly equal. Note that locations on the NHS or that are HPMS Sample sites will need to be counted twice in that time period. Also remember that ramp counts need to be included once in the county totals.

A simple method that can be used to allocate counts per year is as follows:

- Compute the number of counts required in a six-year period within each county (that is, two counts per segment for all NHS and HPMS traffic samples not counted with permanent devices and one count per year for all other traffic segments not counted by permanent devices).
- Sort the counties, high to low, by the total number of counts required.
- Allocate one entire county's counts to one of three count years.
- Place the county with the highest number of counts in Year 1, the second highest in Year 2, the third highest in Year 3, then wind back and forth through the columns so that the county with the fourth highest number of counts is also in Year 3, the fifth is in Year 2, and the sixth is in Year 1. Continue to wind through the assignment column. Toward the end of the list of counties, allocate counties to roughly balance the number of counts in each year.

Table 2 on the next page shows an example of what this allocation will look like. Note that Table 2 is only an example, as it is based on the current segmentation of roads in the TRAFFON file and accounts for the NHS designation of specific segments, but it does not account for which non-NHS segments are part of the HPMS Traffic sample, does not account for the need to count freeway ramps, and does not account for permanent count locations.

Once this basic table has been developed, the TAU should examine the geographic distribution of counts by year. The allocation of counties to the three-year count cycle in this manner is an easy way to balance the number of counts required each year, but it does not account for the geographic diversity of those counties. After looking at the geographic distribution of counties, the TAU may wish to swap counties between count years to provide more efficient count distribution. For example, in Table 2, Dolores and San Juan counties might be moved to Year 2 to be replaced in Year 1 by Kiowa County. In this manner, more of the southwest corner of the state will be covered in one year.

Lastly, specific counts or sets of counts may also be transferred from one count year to another to improve either the efficiency of the count program or the value of the resulting counts. This is particularly true for ramp counts on freeways in the central portion of the state. There are good technical and cost reasons to count consecutive ramps on a roadway on the same day, as such counts allow the Department to better understand the access/egress patterns along that road under constant demand conditions. (That is, if two counts are both taken on the same day, their differences in volume are due to geographic changes in demand for access to the road, rather than to variation in total demand on the corridor. This may be the case if two counts from different days are compared.)

Table 2: Example Distribution of Counts by Year by County

Year 1		Year 2		Year 3	
County	Number of Counts	County	Number of Counts	County	Number of Counts
Jefferson	385	Denver	325	Weld	290
Larimer	245	Adams	263	Boulder	273
El Paso	232	Pueblo	222	Mesa	205
Otero	127	Douglas	128	Arapahoe	203
Morgan	114	Montezuma	103	La Plata	102
Moffat	85	Logan	88	Montrose	90
Garfield	83	Prowers	81	Fremont	74
Grand	65	Yuma	71	Alamosa	73
Summit	62	Las Animas	61	Rio Grande	60
Chaffee	55	Delta	56	Kit Carson	58
Eagle	55	Huerfano	55	Lincoln	53
Broomfield	45	Clear Creek	47	Gunnison	48
Routt	44	Washington	43	Conejos	42
Teller	39	Baca	40	Park	41
Cheyenne	37	Saguache	37	Phillips	36
Pitkin	31	Sedgwick	33	Bent	35
Ouray	28	Archuleta	27	Costilla	27
Lake	23	Custer	23	Elbert	27
Dolores	16	Rio Blanco	23	Jackson	20
San Juan	5	Kiowa	21	Crowley	15
		San Miguel	16	Gilpin	10
		Mineral	10		
		Hinsdale	7		
Total	1776		1780		1782

Finally, note that the count cycle described in Table 2 is a three-year count cycle. This three-year cycle must be converted to a six-year count cycle. To do that, use the output from Business Process S2 to indicate which traffic segments should be counted every three years. For example, in Table 2, all Jefferson County NHS road segments would be counted in Year 1 and Year 4. One half of the remaining traffic segments and ramps should then be allocated to one or the other of those two years. So one-half of the Jefferson County ramps and non-NHS road segments would be counted in Year 1 and the other half of those road segments would be counted in Year 4. (Note that if it made better sense from a count allocation perspective, all of the ramps could be counted in Year 1 and all of the non-NHS road segments could be counted in Year 4.)

To track these count assignments, the TAU should maintain a simple database of the TRAFFON roadway segments plus the ramp count locations. Associated with each roadway segment should be the year in which the short count for that segment should be taken. This same database should indicate whether that road segment is instead covered by a permanent counter, and whether that counter provides continuous data to the TAU or the TAU must request that the device owner supply short duration count data. (Note that this latter task replaces the need to pay a contractor to collect a short duration count using portable equipment, but that activity should take place on the same three-year or six-year count cycle used by other nearby short duration counts.) It is also a good idea to have a comment field in this database so that notes about specific road segments can be included to help track unusual conditions, events, and issues associated with specific road segments.

By incorporating additional fields, this same database can be used to determine whether vehicle classification counts should be collected for specific road segments, whether specific counts have been performed as intended, and whether additional counts have been collected for other CDOT purposes, potentially eliminating the need for some routinely performed short counts.

S7) Set the Annual Count Program (Classification Count Possible/Needed)

This business process is directly related to Task A3 in the CDOT TAU business process described by Cambridge Systematics in the report, "*Traffic Analysis Business Process and Integrated Software Recommendations Report*" (June 30, 2008).

In Business Process S7, the TAU sets the actual traffic count schedule for the year before sending that schedule to its contractor. The TAU needs four sets of inputs to set the schedule. These inputs are as follows:

- The routine traffic counting needs described in the output from Business Process S6,
- Special request traffic counts made by groups within CDOT and outside agencies (see Business Process S8),
- Decisions by CDOT management that result in the TAU being tasked with collecting data on off-system locations (see Business Process S15),
- Information from the short count data collection contractor that describes its ability or inability to collect specific types of traffic data at previously defined data collection locations (see Business Process S10).

Combining the short duration counts needed to meet HPMS and routine CDOT needs (S6), the special request counts (S8), and the off-system counts selected by CDOT management (S15) results in an initial list of short counts that should be scheduled for this year.

The next step is, the TAU staff needs to determine whether any of these three sources of count requests duplicate each other. That is, has one request already been met by an existing short count or other data collection effort? An additional question the TAU staff need to answer is the following: can one of the requests be met by one of the other counts required? For example, if a Regional office requests a series of traffic counts along a state route as part of a corridor planning study, one or more of those counts might take the place of one or more of the routine HPMS counts resulting from Business Process S6. Removing these duplicates can reduce the total cost of the short count data collection effort.

The next task within this business process is for the TAU staff to determine whether each short duration traffic count must be performed as a 48-hour volume count, a 48-hour vehicle classification count, or some other type of count (e.g., a 24-hour count because equipment is unlikely to function correctly for longer than 24 hours). The intent is to conduct vehicle classification counts on all of the NHS and HPMS Traffic Sample road sections and collect whatever data are requested by users for other data collection efforts.

However, some of these roadway sections may not be conducive to the collection of vehicle classification data. For example, traffic may not operate at a constant speed at the location where data are collected and therefore vehicle classifiers may not work accurately. In other cases, it may not be physically possible within budgetary constraints to place a vehicle classifier on a road segment due to the size of the roadway (e.g., a multi-lane freeway may not allow classification with the equipment available).

Feedback from the short count data collection contractor is needed to understand these limits on the ability of the TAU to request a classification count. When such limits do occur, the TAU staff needs to consider the following options:

1) Moving the count to a slightly different location on that roadway section
2) Requesting the use of different types of equipment and perhaps different types of vehicle classification data (for example, to meet the needs of the HPMS, CDOT can use vehicle length classifiers instead of axle classifiers, which may allow classification of additional sites)
3) Working with CDOT Regional offices to determine whether other types of equipment can be installed (e.g., magnetometers) the next time those roadway lanes are closed for construction or maintenance,
4) Simply making a note (for reference later when working with data requesters and/or FHWA reviewers) indicating why vehicle classification counts are not possible.

The TAU staff needs to note the recommended outcome in the TRAFFON database that tracks count related activities and adjust the count request submitted to the data collection contractor accordingly.

S8) Identify Special Count Requests

This business process is Task A4 in the CDOT TAU business process described by Cambridge Systematics in the report, "*Traffic Analysis Business Process and Integrated Software Recommendations Report*" (June 30, 2008). In this task, the TAU accepts requests for traffic data collection that are not met by the routine data collection efforts identified in business process S6.

After determining that existing data can not meet these needs, the TAU staff needs to work with the data requesters to ensure that those data collection needs are correctly identified and that funding is available, and then add those count requests to the list of counts and count locations that is provided to the short count data collection contractor. (The required data are used as one of the inputs to Business Process S7.)

S9) Collect the Data

In Business Process S9, the TAU provides the list of data collection sites required this year to its selected data collection contractor. The contractor then collects these data and returns the data to the TAU, which then performs quality assurance testing (S11). This business process is Task A6 in the CDOT TAU business process described by Cambridge Systematics in the report, *"Traffic Analysis Business Process and Integrated Software Recommendations Report"* (June 30, 2008).

As part of this process, the TAU needs to communicate effectively with the data collection contractor about the actual data collection sites and the need to move those sites within the traffic segment. Ideally, data collection takes place at the same location every time. However, there are instances when a data collection site needs to be moved within a traffic section. For example, these might include the following:

- The current site does not allow the collection of vehicle class data, and a move within the segment will allow that collection
- Physical changes within the traffic segment (e.g., a new roadway alignment, the removal or moving of existing street lighting to which equipment was previously attached) make it necessary to move the site
- Changes in the type of equipment being used means that a different location will provide more accurate data collection.

The TAU currently obtains summary information from the contractor about instances when local conditions limit traffic data collection. This information transfer may need to be improved to better help the TAU understand when it is in its interest to move existing data collection sites. Such improvement would involve the transmission of modest details when the contractor recommends moving a site. One specific piece of desirable information is the ability of the contractor to collect vehicle classification data within a road segment. This insight should then be passed to the TAU for use in Business Process S10.

S10) Update Class Count Locations

The HPMS data collection guidelines now request 48-hour vehicle classification counts, rather than just 48-hour volume counts. This is because of an increasing need for truck volume information for a variety of studies. In Business Process S10, the TAU should use the feedback from the contractor from Business Process S9 to make modifications to future requests for data on NHS and HPMS traffic roadway segments. These changes are specifically intended either to allow the collection of vehicle classification data (by moving the data collection site to a location more conducive to vehicle class data collection), or to make note of the inability to collect data on that roadway segment and the reasons why.

The output from this business process should influence the design of the annual count program (S7) and should be recorded in the database that tracks information on traffic segment count locations (S6).

S11) Conduct CDOT Quality Assurance Procedures (QA)

This business process consists of Tasks B9 through B20 in the CDOT TAU business process described by Cambridge Systematics in the report, "*Traffic Analysis Business Process and Integrated Software Recommendations Report"* (June 30, 2008). The intent of these tasks is to ensure that the short count data collected by the CDOT contractor are valid. Invalid counts are returned to the contractor to be recounted (S9). The Quality Assurance (QA) process may also produce information that should be considered in the selection of count locations (S10), which in turn may change whether a vehicle classification count can be taken on a road segment.

Short duration count data that successfully pass the quality assurance checks are then passed to the TRAFFON database at the conclusion of year-end processing.

S12) Add Statistics to the TRAFFON Database

This business process consists of Tasks D7 through D9 plus D12 in the CDOT TAU business process described by Cambridge Systematics in the report, "*Traffic Analysis Business Process and Integrated Software Recommendations Report"* (June 30, 2008). It consists of converting the short count data from the short duration counts that pass the QA tests into estimates of annual average daily traffic, and then computing the statistics required for the annual HPMS submittal.

These statistics are then stored in the TRAFFON database, which is supplied to the CDOT HPMS division for final review and inclusion in the CDOT annual HPMS submittal (S17).

S13) Send the Segment Count List to the Jurisdiction

This business process is the TAU task needed to start coordination with local jurisdictions. It involves taking the sorted list of traffic road segments for off-system traffic segments that comes from Business Process S3 and delivering the appropriate lists of road sections to the individual agencies that own and operate those roadways.

This list defines the extent (beginning and ending point) of each road segment, and the minimum count frequency with which data should be collected on each of those segments. As with on-system road segments, this is once every three years for NHS and HPMS Traffic Sample sections and once every six years for all other traffic segments.

The first time the TAU performs this business process it will need to include with the transmittal the following additional information:

- A request that each jurisdiction provide these data in the time frame requested (including both the year in which each traffic segment will be counted, and the time of year when those data will be submitted to CDOT)
- A request that each jurisdiction develop and submit a traffic counting plan indicating when each segment will be counted and whether that count will include a vehicle classification count (so that CDOT can manage the HPMS submittal)
- A request that each jurisdiction review the segmentation of its roadways, and
- Directions for helping each jurisdiction submit those data.

These additional items are required to help the local agencies understand what is required of them. While CDOT has previously requested data from local jurisdictions, the increased requirements from USDOT associated with both MAP-21 and the latest revisions to the HPMS means that CDOT must rely more heavily on local jurisdictions to collect data on the roads they own and operate. However, local jurisdictions may not be counting at the required frequency. Consequently, the TAU must work with the local jurisdictions wherever possible to reduce the time and effort needed to submit these data.

As with the CDOT TAU, once a count cycle has been established by each local jurisdiction, it needs only to annually review and update the data associated with that data collection plan. Consequently, in subsequent years the TAU should transmit to the local jurisdictions a report that includes the following:

- Definitions of the off-system traffic segments that exist in that jurisdiction
- Descriptions of where and when counts have been previously taken within those traffic segments over the last six years
- The traffic segments that based on the jurisdiction's previous submittals to CDOT are due to be counted this year
- The locations that are overdue for counts (i.e., that were missed in previous years.)

It is important that this communication occur when the local jurisdictions can effectively plan to obtain the required counts. It is recommended that the Traffic Data Committee[8] help identify the appropriate timing for this formal report.

L1) Identify Permanent Count Sites

Business Process L1 is analogous to Business Process S4. The primary difference is that it must be performed by each jurisdiction. In this step the jurisdictions need to determine where they already have traffic data collection capabilities because they operate existing data collection sensors, and whether those existing sensors provide accurate traffic counts that can be used to meet the HPMS submittal requirements.

Where permanent counters exist, they can provide either continuous data or short duration count data. These capabilities are described below:

Useable as Continuous Data

Many local jurisdictions operate permanently installed traffic detectors. For example, most jurisdictions operate traffic signal systems that use traffic detection as an input to actuated, semi-actuated, and other adaptive traffic signal timing plans. Many traffic signal systems can be configured to collect and store these data if engineers designate specific detectors as system detectors. Where these detectors are properly located (often mid-block) they provide excellent traffic count data. In other cases, where high quality detectors are used, even stop bar loops at intersections can provide excellent traffic counts and, in some cases, vehicle classification data. In other cases, particularly in larger jurisdictions, the agency may operate permanent detectors similar to those used by CDOT for similar purposes. That is, they may collect data for seasonal

[8] The Traffic Data Committee is a working group of individuals that represent agencies from around the state that collect and share traffic data. The committee meets routinely to discuss data collection topics of mutual interest.

and day-of-week trends in order to use that information for planning, engineering, and traveler information purposes.

In this business process, local jurisdictions need to review their existing traffic sensors and determine where these sensors can supply traffic data that meet the quality requirements of the HPMS, as well as how these data can be transferred to CDOT.

These data can be provided to CDOT as

- A continuous data stream (that is, that CDOT can directly download from a site, just as it does with its own continuous counters)
- A full year of data, submitted as a file transfer at the end of the year (or on some scheduled basis)
- 48 (or more) consecutive hours of data from a permanent site, but submitted as a short count. (This approach might be used where data collection is possible from existing detectors, but where the local jurisdiction does not routinely use that capability. In this case, the agency would set up a special data collection effort from those detectors and transfer the resulting data to CDOT.)

Agencies should only transfer continuous data streams, or cull years of data, to CDOT when they are actively using those data and are confident of the performance of their sensor systems.

Valid Count Data?

In all cases, the local agency should check to ensure that the data it is supplying to CDOT are valid. This check is specifically required in this business process for cases in which permanent devices are being used to supply short duration counts. This is because it is easy for the performance of data collection sensors to degrade over time, and if an agency does not routinely review the accuracy of those data, there is a high likelihood that the data are not accurate. Therefore, if permanent sensors are used in short duration count mode, the local agencies should additionally review those data before transmitting them to CDOT.

L2) Determine Count Cycle Assignments

As with Business Process S6, this business process determines the specific years in which each local agency will collect traffic count data on its road segments. Each local agency follows the same process as described in S6. Starting from the list of count requirements provided by CDOT as an outcome of S13, the local agency can determine which road segments are already covered by permanent detectors, the outcome of L1. The remaining road segments need to be counted with portable counters. This business process allocates those counts to specific years in the three and six-year count cycles. Note that some jurisdictions may not need to conduct a large number of counts and, as a result, may choose to do all of their counting in specific years, rather than spreading those counts evenly across all years.

Note that each jurisdiction is responsible for counts on its road segments and therefore may structure its count program to meet its own needs. The only constraint is that it must supply reliable, accurate data suitable for the Colorado HPMS submittal.

L3) Set the Annual Count Program (Classification Count Possible/Needed)

Using the outcome of its individual counting plan from Business Process L2, each jurisdiction then develops a specific annual count program. As part of this plan, it should identify required vehicle classification data and arrange to collect them.

L4) Collect the Data

In this business process, to the jurisdiction collects the data identified in its annual counting program, as defined in Business Process L3.

L5) Submit the Data to CDOT

Data collected by each jurisdiction are delivered to CDOT in Business Process L5. It is important that the TAU work with the local jurisdictions to make this data delivery process as easy as possible for both the local jurisdictions and the TAU. (See "Improve Data Entry/Sharing for Local Jurisdictions," below.)

S14) Conduct CDOT QA

In this business process, the CDOT TAU accepts the traffic data submitted by the local jurisdictions and performs quality assurance tests on those data. It is assumed that data may be provided by the local jurisdictions in three different formats: already annualized summary HPMS statistics, raw short duration count data, or continuous count records. Each of these types of data submittals will require slightly different QA tests.

Some local jurisdictions may decide to provide CDOT with only the summary traffic statistics required for HPMS reporting. When this occurs, the TAU will need to perform two separate types of QA tests:

- A process review
- A comparison of the submitted data with previous traffic estimates for those roadway sections.

The process review is similar to the FHWA Division Office's periodic review of the CDOT HPMS traffic counting process. In the review, the TAU staff need to ensure that the counts are correctly taken, that the appropriate factors are being applied to those counts (i.e., day of week, month of year, axle corrections—if an axle counter is used), and that the summary factors are being computed correctly. This ensures that the local jurisdiction's AADT estimate takes into account the time variable nature of traffic and the types of traffic counting devices being used.

The comparison check examines the new traffic statistics for each segment in light of previous traffic estimates for those road segments. When large discrepancies are noticed, the TAU needs to discuss those segments with the local agency for two reasons:

- To confirm that the new count is accurate, and
- If the count submittal was not an error, to obtain an explanation for why the count changed so significantly.

On the basis of the local jurisdiction responses to these QA comments (Business Process L6), CDOT either accepts the data or requests the location be recounted.

Local agencies may also provide data to CDOT in the form of raw, short duration counts. These can be either hourly volume counts or hourly vehicle classification counts. They may also involve other time reporting intervals, as long as those intervals are acceptable to both agencies. When this type of data is submitted, the TAU staff can enter these counts into TRADAS and pass the data through the same quality assurance process used by the TAU for contractor collected data. (See Business Process A6 in the Cambridge Systematics report, "*Traffic Analysis Business Process and Integrated Software Recommendations Report,"* June 30, 2008.) To do this, the TAU will need to create a count location within TRADAS. The advantages to this include the ability to access the TRADAS capabilities and the ability for CDOT to share these data with users over the Internet via the AVID software system. As with the summary data submittal, questions raised as a result of the QA review should be passed to the local jurisdiction through Business Process L6; as a result the TAU should either receive a satisfactory explanation for the unusual data or ask the jurisdiction to recount that location.

A local agency may also provide CDOT access to the raw, continuous count data from a permanent traffic monitoring device. In this instance, the TAU will be responsible for performing the same business processes it currently uses for its own continuous count stations. These are described in business processes A, B, C, and D in the Cambridge Systematics report and include a variety of both quality assurance tests and data summarization tasks. As with the summary data submittal, questions raised as a result of the QA review should be passed to the local jurisdiction through Business Process L6; as a result the TAU should either receive a satisfactory explanation for the unusual data or ask the jurisdiction to count that location with a short duration count (if the permanent counter is not functioning correctly). The TAU may also identify dates when the data are valid (if the counter worked for some period that year but then failed), extract a minimum of 48 hours of valid data from the continuous data already available, and then treat those data as if they were from a short duration count.

The final task required in the business process is that the TAU should track the data submitted by each local jurisdiction against the count cycle assignment and annual count programs for each jurisdiction that are outcomes of business processes L2 and L3. In this way, the TAU can track the data being submitted against the data expected for each year. The QA process should help the TAU identify and report back to the local jurisdiction where new traffic counts were expected but not submitted. The lack of an expected traffic count during any year may not be a significant problem, as the use of three and six-year cycles means that data can be collected in other years to make up for missing data. However, the QA process is a good opportunity to confirm the schedule for collecting those data and allows communication between CDOT and the local agencies to ensure that all required data are collected in the appropriate timeframe.

Data that pass the S14 QA process are input to update the TRAFFOFF database the TAU uses to track volumes on off-system roadway segments for which travel is reported through the HPMS (Business Process S16).

L6) The Jurisdictions Respond

In Business Process L6, the individual local jurisdictions respond to the TAU's quality assurance review of the submitted HPMS data. Each local jurisdiction may respond in one of four ways:

- Acknowledge that a problem with the submitted data exists and recount that location (Business Process L4) if the data collected were invalid
- Acknowledge that a problem with the submitted data exists and resubmit the data (Business Process L5) if the problem was a transmittal error (e.g., the wrong data were inadvertently submitted to CDOT as part of the first submittal)
- Explain to CDOT why the submitted data are, in fact, correct (Business Process S15) (For example, the site shows a large increase in volume due to changes in land development along that road)
- Acknowledge that a problem with the submitted data exists while also notifying CDOT that the jurisdiction is not able to provide valid data for that site for this HPMS submission (Business Process S15).

In the first two scenarios, CDOT will need to reprocess the resubmitted data through the S14 QA business process once the local jurisdiction has submitted revised data.

S15) CDOT Makes Decisions

In response to the latter two scenarios in Business Process L6, CDOT management will need to decide what to do about the lack of resubmitted data from the local jurisdiction. These decisions are made in Business Process S15.

If the originally submitted data are said to be valid, the TAU must decide whether those data should be provided as the valid estimate of traffic conditions in the HPMS or additional work should be performed to develop those estimates. For example, construction may be occurring on roads leading to the segment being monitored. This would make the count valid for the current conditions, but the traffic estimate might not be appropriate for future HPMS submittals when the construction was no longer present. (This is an important consideration, especially for locations where counts are taken only once every six years.) Some professional judgment is needed in responding to local jurisdiction explanations, and good notes should be taken so that the decision can be reviewed as part of the next year's data collection, as well as the next time data are collected at that site.

If the TAU is not satisfied with the local jurisdiction response to the CDOT QA process, or the local jurisdiction acknowledges that it is not able to supply valid data for the HPMS traffic segments, then CDOT management will need to help decide how to respond. Among the choices the Department has are the following:

- Use CDOT resources to collect or help collect those data (e.g., using CDOT funds to pay for off-system counts or providing technical expertise that helps those counts be taken)
- Accept the lack of data, growth factor the previously available data, and develop the appropriate messages if asked to respond to this lack of data by FHWA
- Use communications at higher levels of agency management to convince the local jurisdiction to redirect local resources to the traffic counting program so that these counts are collected in the next year's count cycle.

In all cases, when the QA process identifies issues, it is important that CDOT maintain good records of the issues identified, the decisions made, and the implications of those decisions for future year count programs. These notes allow the TAU to track whether missing counts that

are intended to be made up during the next year are in fact made up and can be used to illustrate to FHWA how CDOT is making a good faith effort to obtain and submit the required traffic data.

S16) Add to the TRAFFOFF Database

In Business Process S16, all off-system data that pass the TAU quality assurance process should be stored in the TRAFFOFF file used to track off-system traffic data. This process includes the calculation of AADT estimates and other traffic statistics required for submission as part of the HPMS. In some cases, the local jurisdictions will provide these statistics as part of their data submittal to CDOT. In other cases, the TAU will need to compute these statistics by following the same procedures the Department uses for on-system short counts.

S17) Submit the Data for HPMS Review

Once all traffic data have been obtained and stored in both the TRAFFON and TRAFFOFF databases, the traffic data are then uploaded to the HPMS group within CDOT for review within the HPMS submittal process. The HPMS review may identify some data issues that the TAU and/or local jurisdiction personnel need to review. Ideally, as a result of its own QA process, the TAU will have answers for all questions the HPMS review generates. It is recommended that the TAU work with the HPMS group to identify the HPMS review steps and add those steps to its own QA process. This should allow the HPMS upload to proceed more quickly, as the TAU will have already investigated and fixed (or otherwise noted) any issues identified by the HPMS review process.

S18) Inform Local Jurisdictions about the Annual Data Request

The final business process included in the processing of short counts is the need to pass along the results of the CDOT decision making in Business Process S15 to the local jurisdictions. This includes updating the list of road segments that CDOT expects local jurisdictions to count in the next year, as well as informing them of the support that CDOT will provide (if any) to help with that data collection and submittal process.

The tasks that CDOT needs to undertake that will support local jurisdictions are briefly described in the following report section.

PERIODIC (ANNUAL) PROCESSES

This section describes specific activities that support the short duration count program.

Examine TRAFFON to Refine Segmentation

The traffic data collection plan and the mechanism used to report traffic statistics within CDOT are dependent on the definition of roadway segments. A roadway segment is intended to be homogeneous with respect to traffic. That is, traffic volumes are assumed to be effectively constant (in engineering terms) throughout the length of the traffic segment. Because traffic patterns change over time as land uses change and as the road network changes, it is important that CDOT periodically update the roadway segmentation used for the state roadway system (i.e., on-system counts).

The difficulty with examining traffic segmentation is that, ideally, segmentation decisions are based on actual traffic count data available from multiple points along each traffic segment.

Unfortunately, the CDOT traffic count program uses the segment definitions to limit the number of locations routinely counted on a segment to just one location. As a result, it often occurs that not enough data are available to routinely examine all on-system road segments to determine whether segmentation should change.

Consequently, to improve the Department's ability to determine whether segmentation should change, we recommend that CDOT capture all project-related special count traffic data collected for any CDOT affiliated project and enter those data into TRADAS. Those data will then form the basis for an analysis of traffic segmentation for any roadway on which these types of project-specific data are collected. Thus, when a CDOT project has collected detailed traffic data on multiple road segments included within a single traffic segment, those multiple data points can be used to determine whether one or more current traffic segments need to be divided into multiple segments, or where two current segments can be combined.

Whenever the TAU obtains and enters traffic data for multiple locations within a defined road segment, it should informally review the existing roadway segmentation. This includes determining both where existing segments need to be divided because traffic volumes are not consistent within the segment, and whether existing pairs of traffic segments can be combined because traffic volumes on adjacent segments are similar.

Table 3 contains suggested rules for determining when road segments should or should not be combined into a single traffic segment, given differences in AADT from one available traffic count to the next. This table is taken from the soon to be published 2013 update to the FHWA Traffic Monitoring Guide (TMG).

Table 3: Graduated Scale for Defining Traffic Count Segments from the 2013 TMG

Beginning Segment AADT	Adjoining Segment AADT Within
100,000 or more	+ 10%
50,000 – 99,999	+ 20%
10,000 – 49,999	+ 30%
5,000 – 9,999	+ 40%
1,000 – 4,999	+ 50%
Less than 1,000	+ 100%

An alternative to the set of criteria shown in Table 3 is shown in Table 4. Rather than using percentage changes in traffic volume, for roads with volumes below 55,000 AADT, this table uses criteria based on absolute differences in volume along the road segment.

The project team also suggests adopting criteria for segmentation that involve truck volumes. However, until more resources are available to test the sensitivity of various key engineering analyses to differences in truck volumes, only one additional rule is currently recommended. The initial recommendation is to split a road into two segments if there is a difference of 1,000 trucks per day in the volume of trucks on those two proposed segments.

Table 4: Absolute Vehicle Volume Differential for Defining Traffic Count Segments

AADT Classification Groups	Criteria (Volume Change of)
Under 500	1,000 Vehicles
500 - 1,999	
2,000 - 4,999	2,000 Vehicles
5,000 - 9,999	
10,000 - 19,999	5,000 Vehicles
20,000 - 34,999	
35,000 - 54,999	
55,000 - 84,999	10% change in Volume
85,000 - 124,999	
125,000 - 174,999	
175,000 - 249,999	
250,000 and more	

Examine TRAFFOFF to Refine Segmentation

It is also recommended that all local jurisdictions periodically perform this same segmentation review on the roads they operate and for which they are collecting traffic data.

When submitting HPMS data, jurisdictions should also describe changes needed in traffic segmentation on those roads. Local agencies already provide an annual update of HPMS segments[9] to CDOT as part of the annual HPMS data submittal. However, the current HPMS submittal from the local agencies details only changes in the roadway infrastructure and geometry. This recommendation extends that local responsibility to include the segmentation used for collecting traffic volumes on those roads.

For these off-system traffic counts, local jurisdictions can likely more effectively perform this segmentation review than CDOT. This is because CDOT does not have day-to-day experience with changes in traffic patterns on those roads whereas the local agencies have to deal with ongoing changes in land use and roadway infrastructure. For example, local agencies should be actively reviewing traffic impact studies associated with new development and should therefore be recommending changes in segmentation that are required to account for those changes in road use patterns. (Note that the local jurisdictions will also be responsible for changing their data collection plans to address the needs of the new segmentation.)

[9] Note that one "traffic segment" within HPMS may consist of multiple "HPMS segments." This is because HPMS segments are primarily designed to describe roadway infrastructure. They describe the location and condition of bridges, the number of lanes, and the type and condition of pavement present. Thus, multiple HPMS segments may exist within one traffic segment. Each HPMS segment within that stretch of roadway may consist of different pavement types (asphalt versus Portland cement) while traffic remains constant—meaning that only one HPMS traffic segment is needed.

Work with Local Jurisdictions

The short count data collection plan described in this report relies on local jurisdictions to collect and share traffic data on the roadways they own and operate. This plan makes sense in that the agencies that control and operate the roadways should already be collecting the data necessary to describe the use of those roads, and therefore, sharing those data should be the lowest cost option for meeting federal reporting requirements. However, this requires a change from the current level of interaction between CDOT and many, but not all, local jurisdictions.

The TAU has already created good communication channels with local jurisdictions through the Traffic Data Committee, but communication should continue to expand and improve. The communications described in business processes S13, S14, S18, and L5, and L6 will require a number of additional formal communications between the agencies. It is important that CDOT support those communications channels with additional technical and institutional support on an ad hoc basis. The TAU staff have a great deal of institutional knowledge about counting traffic, and making that knowledge available to the local jurisdictions will likely increase the quality of the local jurisdiction data supplied to CDOT, as well as reduce the cost of collecting those data.

Improve Annual Data Entry/Sharing for Local Jurisdictions

Because CDOT will rely on local jurisdictions for data collection, it is important that CDOT make the transfer of data from the local jurisdictions as easy, efficient, and beneficial to all parties as possible. This is particularly important because data sharing requires time and energy on the part of both the local jurisdictions and CDOT staff, and all roadway agencies are heavily constrained in terms of staff and resources.

Several factors currently hinder effective data sharing from local agencies for the purposes of the CDOT HPMS submittal. One is that if agencies can easily retrieve and submit their data to CDOT, they do so. However, these activities may occur only when agency staff has the time to perform them. As a result, the data submittals are often not in sync with the needs of the TAU's traffic counting program, especially as they relate to the HPMS submittal timeline. Another issue is that if the local agencies do not have an easily manipulated traffic data archive, the effort to transmit data to CDOT can be sufficiently arduous that they simply cannot respond to the CDOT request. A third issue is that the data supplied by local agencies come to CDOT in a variety of formats and with varying levels of quality. This makes accepting and using those data more time consuming then necessary for CDOT.

As a result, it is recommended that CDOT develop an easy to use, low cost, electronic data transfer mechanism that all local agencies can use to provide their traffic data to CDOT.

This data transfer mechanism should be designed in consultation with the Traffic Data Committee members. In Business Process L5, three different types of data submittals are described, and it is expected that these three types of data transmittals will meet the needs of both the CDOT and the local agencies. However, it is important that CDOT staff work with the Traffic Data Committee members to understand their needs, as they may have data transmittal needs that are not covered by the mechanisms proposed in L5 and ideas that may be more efficient for both the agencies and CDOT. At the very least the L5 data transmittal may have to include a variety of data record formats (e.g., CSV files, Excel files, fixed field ASCII files, and database files), and understanding what formats are best can only be determined by working closely with the local agencies.

If local agencies routinely work with private contractors to collect data, it may be possible for those contractors to upload copies of the data directly to CDOT as part of their data collection activities for the local jurisdictions. This would relieve local agency staff of the data transfer task, saving time and money. However, it would also require CDOT to build a process that allowed identification and uploading of unexpected data to CDOT. Consequently, additional work is needed at CDOT to determine how best to accommodate the receipt, storage, and QA testing of those data.

In addition, it is recommended that CDOT publish the local agency data on-line with a map interface so that all state traffic data users can gain easy access to the data submitted to CDOT once the agency has accepted those data. The current AVID system that CDOT is developing and deploying is an excellent example of such a system, and its extension to all state agencies should be considered. If the TAU posts all data supplied by local agencies on the Web via AVID, it would provide an excellent incentive for those agencies to supply CDOT with the traffic data needed by all users. Providing ready access to the data supplied by the local jurisdictions through one single data sharing effort will reduce the staff time required at the local agency level to respond to requests for traffic data. (That is, if a local agency uploaded all of its traffic data to CDOT, and CDOT posted those data on a readily available website, all citizens could access those data without having to request them from local agency staff, freeing those staff to work on other activities.) Similarly, having access to that website would allow neighboring jurisdictions to review the traffic volumes on roads leading into their own arterials. Thus, a single archive that served CDOT's statewide needs would also serve local needs.

CDOT should work with, and look for support from, the regional metropolitan planning organizations (MPOs) when it expands its current on-line traffic data sharing systems. MPOs have a similar need for collecting traffic data from local agencies and sharing them, because they need those data to support their ongoing planning and modeling efforts. It may even be worthwhile for the larger MPOs to consider purchasing TRADAS licenses to allow them, or the agencies that work with them, to store all of their traffic data in TRADAS and have access to TRADAS capabilities. This would not only provide benefits to the agencies, it would eliminate the need to physically transfer data to CDOT, thus reducing staff tasks for both agencies.

Adjust the HPMS Traffic Sample Selection As Required

The 2010 HPMS Field Manual describes a number of reasons why the HPMS Traffic Panel sample may need to change over time. Reasons include, but are not limited to, changes in the functional classification assigned to specific roads, changes in rural and urban designations, and the construction of new roads. In MAP-21 Congress changed the designation of the National Highway System and thus the counts required for the HPMS.

Consequently, the TAU should work with the CDOT HPMS group to annually review the HPMS traffic sample and make changes to that sample as required. Those changes then need to be reflected in the base traffic segment counting program (Business Process S2), and those changes then cascade through the rest of the business processes described in this report.

Record Roadway Jurisdiction Changes

In most states, some roads shift ownership over time. That is, for a variety of reasons, the state takes over ownership and operation of a road from a local jurisdiction, or cedes ownership and operation of a state route to a local jurisdiction. The TAU must be aware of these changes in

ownership because they shift the traffic counting requirement to the new owner of the affected roads. These changes need to be reflected in Business Process S3, which should then result in changes to both agencies' traffic counting programs.

Update Locations at Which Trucks Are Counted

One of the major changes that occurred with the 2010 update to the HPMS Field Manual was an increased emphasis on counting and reporting truck volumes in the HPMS. This supports an increasing emphasis, both nationally and in many states, on understanding, effectively planning for, and operating roadways with improved knowledge of truck movements. For the state of Colorado, the 2010 HPMS revisions mean that many traffic volume counts need to be replaced by vehicle classification counts. Unfortunately, performing vehicle classification counts is not as easy as counting traffic volumes. There are many road segments on which current technology allows accurate volume counting, but not accurate truck or vehicle classification counting.

Business Process S10 requires the TAU to work with its data collection contractor to understand where vehicle classification counts can be taken on state routes and where those counts are not practical. Local agencies also need to perform this task, and the TAU may be able to provide valuable assistance to those agencies as they prepare to perform these classification counts. It is important that CDOT stay abreast of changing vehicle counting technology to understand where it may be cost-effectively used to conduct vehicle classification counts. It then needs to share this knowledge with the local jurisdictions.

No specific business process task has been defined for the TAU to provide this support to local jurisdictions. However, this is another area where the local agencies will benefit greatly from improved outreach from the TAU. For example, a good starting point might be to include a presentation on the use of current vehicle classifiers ,what technology they use, what it costs to use them, the traffic conditions under which those devices work well or do not work well as a topic for upcoming Traffic Data Committee meetings.

The TAU staff could then provide assistance as needed to individual agencies that are collecting traffic data and need to collect truck volumes with vehicle classifiers.

NEXT STEPS FOR FACILITATING THE COLLECTION OF LOCAL JURISDICTION TRAFFIC DATA

To successfully implement the above business processes, the following steps are recommended:

- Begin an outreach program to the local jurisdictions.
- Work with the CDOT LTAP program and the CDOT Regional offices to support that outreach program.
- Identify and work with select partner organizations to develop improved procedures and systems for sharing existing traffic data collected by local jurisdictions.
- Make improvements to AVID and other CDOT software to increase the capabilities to meet the traffic data sharing needs of both CDOT and the local jurisdictions.
- Pilot test and refine those improvements with initial partners.
- Work with CDOT management to gain support for data sharing at the local level.

Each of these steps is described in more detail below.

Because CDOT needs to obtain traffic data from the local jurisdictions routinely and in a timely manner, it is imperative that these data requests be presented to the local jurisdictions now. A start to that effort took place as part of the December 2012 Traffic Data Committee meeting. However, much more outreach is needed.

A good starting place is to work with the CDOT LTAP[10] office. LTAP was present at the December Traffic Data Committee meeting and expressed a strong interest in helping with this process. One early step would be to write an article for the LTAP newsletter. (This letter should support, but not take the place of, direct communications with each jurisdiction explaining what is needed and why.) A second step would be to schedule training classes for the local jurisdictions on the use of AVID. At these classes CDOT should also describe how local agencies can/should submit data to CDOT and have those data become accessible through the AVID interface. (This assumes that the TAU and local partners agree that AVID is the appropriate mechanism for sharing data, and that CDOT has completed the work needed to accept local agency data by the time these classes are offered.)

In addition to the LTAP outreach program, it is recommended that the TAU staff reach out to the state MPOs and to the CDOT Regional offices to describe the Department's traffic counting needs and obtain their assistance in working with the local jurisdictions. The MPOs in particular should have considerable interest in an efficient, multi-agency, data sharing system and may be able and willing to provide support for improved data sharing, especially if that data sharing system also helps meet their needs for regional traffic data.

Next, the TAU should identify a limited number of partner agencies with which to refine, test, and initially deploy the data sharing systems described in this report. This includes gaining insight into how best to exchange data with local jurisdictions. Two agencies, the City of Denver and the North Front Range MPO, expressed interest in participating in the development of these data sharing capabilities at the December Traffic Data Committee meeting. The TAU staff may also know of other agencies that would be good early partners. Having four to five early partners should make this effort small enough to be nimble in its development but also diverse enough in its composition to ensure that the majority of issues with multi-agency data sharing are identified and resolved in this initial development and deployment effort. Early partners need to have a strong interest in data sharing and be able to supply at least some staff time to work with CDOT staff in developing and testing the necessary data transfer protocols.

Once a working group of partner agencies has been established, the group needs to explore how it can expand the current CDOT capabilities to meet the need for statewide traffic data sharing of at least summary statistics. For example, it may be possible to provide the MPOs with access to CDOT software (e.g., TRADAS), under existing MPO funding, and have the MPOs enter data directly to TRADAS, which can then be uploaded to AVID for sharing by CDOT.

Alternatively, it may work better (or be less expensive) for the TAU to maintain control of all data entry through TRADAS, but that process might be improved by allowing local jurisdictions to use a Web application to locate/create data stations on a map that CDOT could then "enter" into TRADAS by simply reviewing and accepting those remotely entered locations.

[10] Local Technical Assistance Program

(For example, the Web application might geocode and name the station, but not actually enter the data into CDOT's database. Instead, the data entered would be sent to CDOT, which would review those entries before accepting them into the CDOT data systems, allowing the short count data associated with each of those locations to be processed by CDOT.)

Finally, the TAU should continue to press for support from CDOT management. Having support for data sharing from local agency management will significantly improve the shift to greater data sharing and overall lower data collection costs for Colorado transportation agencies. The best way to obtain this local agency upper management support is for CDOT management to approach local agency management and promote these plans. It was suggested at the December Traffic Data Committee meeting that working with groups such as the Colorado Municipal League, and stressing both the cost savings and the improved availability of public data from this plan, would be a good way of promoting local agency participation.

It is also crucial that CDOT management be prepared for the possibility that local jurisdictions will not actively participate in the proposed data sharing model. If this occurs, CDOT will lack data that need to be submitted as part of the HPMS and will have to decide whether to pay for that data collection out of CDOT resources or simply not submit data requested by USDOT.

APPENDIX A: ACRONYMS

AADT – Average annual daily traffic

AADTT – Average annual daily truck traffic

AASHTO – American Association of State Highway and Transportation Officials

CDOT – Colorado Department of Transportation

CU – Combination trucks (trucks consisting of more than one physical unit)

D – Directional split

ESAL – Equivalent standard axle load

FHWA – Federal Highway Administration

HPMS – Highway Performance Monitoring System

K – Design hour factor

MEPDG – Mechanistic-Empirical Pavement Design Guide

MPO – Metropolitan planning organization

NHS – National Highway System

RMC – Rural minor collector (a specific functional classification of roads)

STIP – Statewide Transportation Improvement Plan

SU – Single unit truck

TAU –Traffic Analysis Unit (Colorado Department of Transportation)

TMG –Traffic Monitoring Guide (Federal Highway Administration)

TPR – Transportation Planning Region

TRADAS – A software system used by CDOT that stores, manipulates, and reports traffic statistics

TRB –Transportation Research Board (National Academy of Sciences)

USDOT – United States Department of Transportation

v/c – the ratio of roadway volume divided by roadway capacity

VHT – Vehicle hours of travel

VMT – Vehicle miles traveled

APPENDIX B

MOTORIZED, SHORT DURATION, TRAFFIC COUNT SITE SELECTION

DATA NEEDS AND CONSTRAINTS

This is the initial, interim report for a Colorado Department of Transportation (CDOT) project that is examining the design and implementation of the CDOT short duration traffic count program. This report describes the basic needs that users have for the traffic data that CDOT collects. It also describes the roles played by both the CDOT short duration count program, operated by the Traffic Analysis Unit (TAU), and the continuous count program in meeting those needs. Finally, it describes known limitations and constraints that must be considered in designing the short count program. This report does not address the emerging CDOT non-motorized counting program.

The first section of this report provides a basic description of the geographic and temporal variability of traffic data, as well as how user requirements can be affected by the need (or not) for information about that variability. The section then briefly describes the basic design of the CDOT traffic data collection program and how that program design is intended to meet the needs of users.

The next section of this document describes more specific needs of traffic data users that were determined from both meetings held with CDOT staff and a review of the literature (see Appendix C).

Finally, the report describes various constraints that must be accounted for in the design of CDOT's short count data collection program.

INTRODUCTION TO CDOT TRAFFIC COUNTS

As recommended by the FHWA Traffic Monitoring Guide, the Colorado DOT traffic count program consists of a variety of "nested" traffic monitoring activities. The monitoring activities consist of both short duration and continuous counts, and these collect data on traffic volume, vehicle classification, vehicle weight, and vehicle speed. In general, when truck weight data are collected, the data collected also provides information on total volume and total volume by vehicle classification. When classification counts are conducted, data on total volume are also available. This "nesting" of count data reduces the total number of "volume counts" that must be performed, as every weight data collection effort or classification count also gathers volume data.

Traffic data are collected at a variety of locations, at various levels of temporal and geographic aggregation. The majority of data collected by CDOT are obtained on the state highway system ("on-system" counts), although the Department does collect a significant number of counts off the state operated roadway system ("off-system" counts) to meet the reporting requirements of the Highway Performance Monitoring System (HPMS).

Spatial (Geographic) Variation in Traffic Volumes

Traffic volumes vary with geographic location. Traffic volumes can increase or decrease whenever travelers have an opportunity to exit/enter a roadway. Therefore, traffic volumes vary longitudinally along a roadway. The extent of that variation on any given road is a function of the volume on the roadway and the size of traffic generators that connect to that roadway (e.g., intersecting roads and adjacent land-use activities connected to the roadway by driveways).

To make traffic data collection and use manageable, traffic data collected at a specific point on a given roadway are assumed to represent traffic on a stretch or "segment" of roadway, where that segment extends for some distance up- and downstream from that physical data collection location. The distance from the actual count location at which this assumption remains valid is a function of how traffic attributes change along that roadway. The valid distance is also a function of how significant volume change along that stretch of road is, in relation both to that road and to the analysis that relies on the data. (That is, a 1,000-car change in volume is not significant on a freeway carrying 200,000 cars, but may well be significant to a road that carries only 5,000 cars.)

A count taken between two consecutive interchanges on a limited access roadway (e.g., an Interstate) can be used as an accurate measure of vehicle volume between those two interchanges. In this case, one can safely assume that the data collected at a specific point will accurately represent the whole segment, regardless of the physical distance between the two interchanges, as no opportunity exists for traffic volumes to change anywhere along that stretch of highway. No matter where that count is taken within that stretch of road, total traffic volume on that roadway should be the same. (While traffic may change lanes at points along that stretch of roadway, the total facility volume should be constant.)

On the other hand, if the road segment is an urban arterial located between two major intersections, the assumption that traffic volumes do not change significantly over the course of that road segment may not be valid—especially if there are many driveways and/or minor intersections along the stretch of roadway between the major intersections. Under these conditions, large numbers of vehicles—relative to the total arterial volume—may enter or exit the roadway at points between the two major intersections, causing traffic volumes at one end of the roadway section to be very different than those at the other end.

The use of roadway segments makes it possible for a limited number of traffic counts to represent traffic throughout the state. If a segment is well designed (that is, where traffic volumes are reasonably uniform throughout the segment), then a single traffic measurement will meet the data needs for that entire roadway segment. However, if a road segment is not reasonably homogenous, then a single count may provide an inaccurate measure of traffic for the segment as a whole.

For roadways that are not limited access facilities, traffic volume will vary along the length of each defined segment as discussed above. Whether that variation affects the validity of any specific traffic count is a function of both the variability of traffic and the accuracy requirements of the specific use planned for that traffic measurement. Some

uses of traffic data are relatively insensitive to traffic variability. For example in pavement design, a simple rule of thumb is that a doubling of the number of trucks generally requires one extra inch of pavement material. Therefore, only very large errors in truck traffic counts affect the outcome of pavement depth analyses. Other analyses that rely on traffic data, such as traffic signal timing analyses, are much more sensitive to data errors. As a result, they may require additional counts along the length of a defined roadway segment. Therefore, the definition of roadway segments and the variability of traffic volumes and other characteristics within the defined roadway segments are key issues for the design and use of CDOT's traffic count program. These topics are dealt with later in this document.

CDOT has defined approximately 3,300 distinct, on-system roadway segments that are assumed to have consistent traffic volumes throughout their length. A minimum of one count is then performed on each of these segments during the course of a traffic counting cycle (annually, every 3 years, or 6 every years, depending on the road segment) so that recent traffic count data are available for each of these roadway segments.

Temporal Variation in Traffic Characteristics

Traffic volume also varies temporally, both by time of day and over longer periods, as traffic exhibits day-of-week and seasonal or monthly patterns. Having data that describe these variations are important for some but not all analyses. For example, many analyses (such as pavement design with the traditional AASHTO methodology) require only an estimate of average traffic conditions over the course of the day—average annual daily traffic (AADT) and an estimate of the percentage of trucks in that traffic. Other analyses (including the new pavement design system in the Mechanistic-Empirical Design Guide) require more detailed traffic data, including time of day traffic estimates by type of vehicle.

Some analyses, such as the development of new traffic signal timing plans, require very detailed time of day volume data, as well as data on weekday versus weekend differences in those time of day patterns, to create signal timing patterns that are appropriate for the different traffic volumes that motorists experience throughout the week. Similarly, capacity analyses require an understanding not only of time of day patterns, but also of those hourly patterns during the times of the year when roadway usage is highest.

Short duration counts can provide detailed time of day data. Short duration count time of day measurements meet the needs of many studies, for example most operational analyses. Unfortunately, short count data do not meet the needs of analytical tasks that require data on annual conditions or that require statistics—such as the 30^{th} or 100^{th} highest hour—that can only be collected from continuously operating counters.

Similarly, although short duration counts provide a measure of the traffic volume when the count was taken, they cannot be used directly to estimate AADT. For estimating AADT, the data from the short duration counts must be adjusted to account for the days of week and month of the year when the counts were taken. These adjustment factors can only be computed from data collected at continuous count locations.

Consequently, the short count program must be supplemented by data collected with the continuous count program in order to meet the need for annualized statistics.

The Current CDOT Count Program

To cost effectively meet the spatial and temporal traffic data needs of the Department and the public, CDOT operates a traffic data collection program that consists of approximately 110 continuous count sites and a large number of short duration counts. The basic roles of these two programs in meeting the needs of CDOT's traffic data customers are described below.

Intent of the Continuous Count Program

The CDOT continuous count program has been designed to determine time of day, day of week, and seasonal changes in traffic patterns on roadways in the state. While the basic travel patterns are well known, modest changes in these patterns occur over time. (For example, the amount and timing of snowfall will affect overall winter travel patterns in a given year—which changes the adjustment factors that should be applied to a short count taken in May to estimate the average annual volume.) Similarly, increases in congestion can cause changes in time-of-day travel as more motorists leave earlier or later to avoid slowdowns. (The term for this phenomenon is "peak spreading.") This flattens the time of day pattern and decreases the percentage of travel occurring in the peak hour at congested locations. Similarly, heavy congestion actually decreases the functional capacity of the roadway, further reducing the traffic volume in the peak period.

The primary role of the continuous count program is to track these trends so that the appropriate adjustments can be made to short duration counts. Because of the costs of buying, installing, operating, and maintaining continuous counters, CDOT operates approximately 110 continuous count stations (not including continuous counters used primarily to collect data for traffic management systems such as traffic signals or freeway ramp metering). Therefore, the continuous count program supplies only a small portion of the geographically widespread data required to describe Colorado's roads.

Intent of the Short Duration Count Program

The short duration count program is specifically designed to supplement the geographic coverage of the continuous count program (by providing a limited amount of data at a large number of locations).

The TAU has developed a short duration count schedule and contracts with a private company to collect these data. Short duration counts are generally conducted for 24 to 48 hours. The 24-hour counts generally occur where it is difficult to keep traffic counting equipment operating effectively for longer than 24 hours (i.e., in urban areas). The 48-hour count duration, recommended by FHWA, is designed to provide data that will identify unusual variations in traffic volume, both to assist with quality assurance and to limit the effects of day-to-day variation in traffic volumes on the AADT estimates produced from those short duration counts.

The short duration of each traffic count allows the contractor to limit the number of data collection devices required but still collect data at a large number of sites. This

includes collecting data both on state routes (the primary role of the CDOT counting program) and off the state roadway system when those off-system data are needed to support CDOT activities and are not available from the jurisdictions that control those roadways.

Over the past 30 years, technology improvements have allowed automated, short duration traffic counting to collect data on types of vehicles as well as the total volume.[11] Vehicles are classified either on the basis of their total body length (length-based classification) or according to a 13-category classification table developed by FHWA.[12] Among other attributes, "classification counts" allow the identification of how many trucks, of different categories, are using the roads being monitored. Because truck use is an important statistic for many analyses, the short duration count program collects traffic volume by vehicle class whenever possible.

CDOT TRAFFIC DATA USER NEEDS

A wide variety of clients, both internal and external to CDOT, use the traffic data collected and published by CDOT. Table B-1 summarizes common uses of traffic data and the general traffic data attributes necessary for those studies. A more detailed discussion of specific users, their data needs, and how those needs are best met is presented later in this document.

Highway Performance Monitoring System (HPMS) Requirements

The HPMS is a national-level information system that includes data on the extent, condition, performance, use, and operating characteristics of the nation's highways. The HPMS contains information about the administration and extent of system for all public roads, while information on other characteristics is represented in the HPMS as a mix of universal[13] and sample[14] data for arterial and collector functional systems. More limited information on travel and paved roadway miles is included in summary form for the lowest functional systems. Among its many very important applications is its use by USDOT to calculate vehicle miles traveled (VMT) for each state; those VMT statistics are then used as key inputs to the formula that computes each state's federal gas tax allocation.

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[11] The collection of vehicle classification data is not a ality.lways possible at some roadway locations because of limitations in the data collection equipment's functionality.

[12] The 13-category FHWA classification scheme can be found in the Traffic Monitoring Guide.

[13] For some variables for which data are submitted in the HPMS, detailed data must be collected for all roadway segments in the state except those road segments which have been functionally classified as being "local" or as a "rural minor collector." When data is required for all of these non-local roadways the data is referred to as being collected for the "Full Extent" or as a "universe" data item.

[14] For some variables in the HPMS, a state must collect detailed data on only a sample of their universe of non-local road segments. These are referred to as "sample" data. Detailed traffic data is only required for a sample of the state's HPMS segments.

Table B-1: Example Uses of Traffic Data

User	Type of Data Required	Temporal Stratification Needed	Geographic Stratification Needed	Example Analyses and Data
Planning and Freight Planning (CDOT / MPO / TPR)	Volume Classification	Time of day Day of week Annual & annual changes Forecasts	Corridor Region	VMT trend analysis (AADT on all HPMS (CDOT) road segments) VHT calculations at the corridor level (AADT by hour on CDOT segments) Truck route designations (Truck volumes by CDOT segment) Forecast corridor needs (Forecast volumes from current CDOT segment volumes)
Operations (CDOT)	Volume Classification Speeds (travel times, delays)	Time of day Day of week Short term forecasts	Specific locations Corridors	Traffic signal timing (Traffic volume by hour by segment weekday/weekend to determine the number of timing plans. Then by 15 minute interval for each signalized intersection for each plan interval, turning movements.) Ramp metering or incident response activity Traffic volume by hour (or by 5-min) by segment Volume to capacity (v/c) and delay calculations
Design (CDOT or Design Build)	Volume Classification Weight	Annual Hourly Forecasts	Specific locations	Geometric design (AADT—current and forecast—for all segments included in the study area / corridor. AADTT[15] for those same segments. 15-minute or hourly design volumes for signal/stop sign warrants and design..

[15] AADTT = Average Annual Daily Truck Traffic

Pavements (CDOT)	Volume Classification Weight	Annual Hourly Forecasts	Specific locations	Pavement design and maintenance AADT, AADTT, axle load spectra, hourly distribution of trucks, monthly variation in truck volumes Construction traffic management Hourly volumes by day-of-week by segment (to determine when construction activities can occur, and the design construction traffic management plans.)
CDOT HPMS	Volume Classification	Annual	Specific locations	HPMS submittal AADT, K factor, D factor, AADTT for Single Units (SU), AADTT for combination units (CU)), Truck percentage in the peak hour (by SU and CU) Note: CDOT roadway segments are a superset of HPMS segments
Environmental Review	Volume Classification	Annual Hourly	Corridor Region	Air, water, noise, operational impacts AADT, AADTT, by roadway segment. Volumes by hour by segment.
Private Citizens, Developers, etc	Volume (Class?)	Annual Hourly Forecasts	Specific locations	Development review AADT, hourly volume, (AADTT if a truck related activity is being investigated e.g., a truck stop.)
Safety Office	Volume Classification Speed	Time of day Annual Forecasts	Specific locations	Safety analysis AADT, AADTT, hourly volumes by segment, site specific (sub-segment level) AADT, vehicle speeds at specific locations
Bridge (CDOT)	Volume Classification Oversize Vehicles	Annual Hourly Forecasts	Specific locations	Bridge design and bridge maintenance (AADT by segment, AADTT by segment, maximum observed/expected truck loads and configurations, traffic volumes on bridges crossing state routes, hourly volumes for construction traffic planning)

Because the HPMS VMT calculation has such significant funding impacts, the USDOT has given states very specific instructions on how to define and count their roadway system to ensure that the state VMT estimates accurately represent travel. As a result, CDOT must perform a prescribed set of traffic data collection and data processing steps. This process was recently updated as part of an ongoing national reassessment and updating of the HPMS. The latest HPMS traffic count requirements are described in the *HPMS Field Manual*, September 2010.[16]

The HPMS requires states to divide their road systems into segments. Each segment should have essentially homogenous traffic volumes and characteristics. Those segments are then stratified by traffic volume and assigned to specific volume group. These volume groups are shown in Table B-2. A panel sample of segments is then chosen from each volume group for each functional class of roadway. Traffic counts must then be taken on those segments once every three years. (A minimum of one third of the sample locations must be counted each year.)

Table B-2: HPMS Volume Groups

Volume Group	Lower Volume Bound	Upper Volume Bound
1		500
2	500	1,999
3	2,000	4,999
4	5,000	9,999
5	10,000	19,999
6	20,000	34,999
7	35,000	54,999
8	55,000	84,999
9	85,000	124,999
10	125,000	174,999
11	175,000	249,999
12	250,000	

The 2010 HPMS Field Manual also requires that all road segments in the state that are

- part of the National Highway System (NHS)
- classified as being Interstates or Principal Arterials or
- part of the HPMS sample

be counted once every three years at a minimum. (In years when these sections are not counted, the traffic data submitted as part of the HPMS should be factored to account for growth.) CDOT is responsible for meeting these data collection requirements even for roads that are not on the state highway system. CDOT may obtain these count data from the agency that operates an off-state system road, as long as those counts are collected to the same quality standards as CDOT collected data.

[16] http://www.fhwa.dot.gov/policyinformation/hpms/fieldmanual/

In addition, the HPMS Field Manual requires that all roadway sections in the state that are not functionally classified as rural minor collectors (RMC) or local roads be counted at least once every six years. This data collection requirement encompasses all roads in Colorado, even those that CDOT does not operate, and includes ramps to and from Interstate highways and other freeways and expressways.

These last new requirements pose a significant issue for CDOT, for two reasons:

1) It requires that CDOT collect data on a large number of road segments operated and maintained by other jurisdictions and
2) It requires that CDOT set up mechanisms to identify when off-state system road segments need to be modified (that is when one segment needs to be split into two or more segments).

If the work must be performed by CDOT staff (or under contract to CDOT), this will require a substantial increase in the number of traffic counts routinely taken by CDOT.

Ideally, both these tasks should be undertaken by the jurisdictions that operate these roadways. While CDOT currently collects traffic data updates from those agencies, these updates have not been a significant point of emphasis for the Department. When a local jurisdiction has not provided the updates, the consequences have simply been that the volume group assignments for the jurisdiction's roadways did not change. This in turn meant that the VMT estimates for those roads changed only slightly, depending on changes in statewide volume estimates for those groups, rather than on measured volume changes on the jurisdiction's off-system roads. Under the new HPMS requirements, CDOT will now be held responsible for failure to perform this important update task in the VMT estimation process, because that update, or the lack thereof, contributes to the accuracy of the overall statewide VMT estimate used to calculate federal funding for the state

All required HPMS counts are intended to be based on 48 hours of data. However, a count of less than 48 hours may be used if the state can demonstrate no loss in statistical reliability of the data submitted to FHWA. We assume that this exception means that 24-hour counts are acceptable under the following circumstances:

- when equipment occasionally fails part-way through a planned 48-hour count but when at least 24 hours of data are still valid
- where traffic volumes are particularly stable
- at a limited number of locations where location factors make collecting more than 24 hours of data difficult.

In addition to the basic 48 hours of traffic volume data, the current HPMS traffic data submittal process also requires the provision of truck volume data. Four different truck volume statistics are required:

- average annual daily single unit truck volume
- average annual daily combination trucks volume
- the percentage of single unit trucks in the peak hour
- the percentage of combination trucks in the peak hour.

Whereas the AADT statistics are reported for all HPMS segments, including ramps (subject to the counting requirements described above),[17] the AADTT statistics (truck volumes) for both single unit and combination unit trucks are required only for the HPMS traffic sample sections, which now include all of the NHS and Interstate highway segments. This is true for all functional classes of road.

The need to supply these truck statistics means that whenever possible, the 48-hour traffic count on the HPMS roadway segment should be a vehicle classification count. Where this is not possible because of limitations in equipment performance or capability, data collected up- or downstream from that HPMS sample section should be used to estimate the truck volumes on the HPMS sample section.

Colorado DOT Roadway Segments

CDOT already maintains a roadway database that divides the state highway system into road segments that have homogenous traffic volumes. There are roughly 3,300 currently defined on-system traffic segments. These traffic segments are equal to, or are supersets of, the HPMS road segments used for reporting to FHWA. (CDOT roadway segments defined for traffic data collection purposes may be divided into separate HPMS reporting segments for purposes other than changes in traffic characteristics.)

General rules of thumb for the creation of CDOT roadway segments are as follows:

- A segment boundary exists at each intersection between two state highways or between a state highway and a major arterial.
- A segment boundary is created whenever a 10 percent difference in AADT occurs.
- A segment boundary is created on limited access facilities whenever an interchange occurs.

Most needs for traffic data from state highways appear to be met by the traffic data statistics that are collected and maintained for the approximately 3,300 roadway segments, as long as the data on those segments are valid measures of current traffic within the segment. (That is, the defined segment actually has homogeneous traffic, and a valid traffic count has been taken recently enough that the traffic volumes collected still represent current traffic conditions.)

Consequently, key tasks for the CDOT will be to ensure that

- accurate traffic statistics are available for each roadway segment, and
- each segment continues to contain homogenous traffic characteristics.

Historically, not all CDOT road segments have been routinely counted. Unfortunately, without routinely scheduled counts, data needed for analyses on those segments can be out of date. While age alone does not make a traffic count invalid, as the time between counts increases, the potential for significant changes in roadway use also increases. This is the basic thinking behind the HPMS requirement for a three-year count cycle for HPMS samples (which are directly used in computing the VMT estimates used in federal gas tax apportionment) and a six-year count cycle for all other roadway segments (which are used primarily to determine the expansion factors applied in the statewide VMT calculation process). Unless major changes

[17] When not counted during a given reporting year, AADT values are estimated by factoring counts taken in previous years to account for growth in traffic volume.

occur in activity levels on land from which trips to a given road segment originate, for most analyses a three-year count cycle should be frequent enough to limit the size of errors caused by factoring growth for data from uncounted locations to acceptable levels.

The number of counts required annually to collect data on the approximately 3,300 CDOT traffic segments is well within the scope of the current CDOT traffic data collection effort. Therefore, continuation of the counting program at the current level of effort should allow CDOT to meet its basic traffic counting needs.

What is not clear is whether the current CDOT program can effectively identify when changes in the roadway segmentation should occur. If only one count is taken on a road segment each year, and traffic is able to vary along that road segment (i.e., there are intersections or driveways within the defined traffic segment), there must be a process to periodically determine whether traffic patterns have changed enough along that road segment that traffic is no longer homogeneous and the segment should be divided.

Roadway Segments Located Off the State System

A significant change in the HPMS traffic data collection requirements (adopted as part of the HPMS reassessment effort) is that all road segments included on the U.S. Federal Aid Highway system[18] must now be counted, at a minimum, every three years. This applies whether those road segments are located on the Colorado state highway system or are locally owned and operated facilities. In addition, all roads in the state that are not functionally classified as local roads or rural minor collectors must be counted once every six years.

As noted in the HPMS section above, this creates a traffic counting need for CDOT that is also an unfunded mandate.[19] Consequently, as part of its responsibilities for the HPMS, CDOT must address the issue of the availability of valid off-system counts for both HPMS sample sections and non-sample sections. The agency has several basic options in this regard:

- It can count those segments itself.
- It can request the jurisdictions that own and operate those roads to perform and report these counts.
- It can work with the jurisdictions that own and operate those roads to collect the data required (that is, CDOT would collect a limited number of the counts, while the jurisdictions would supply the remainder).

Since this change in HPMS requirements, CDOT's Traffic Analysis Unit (TAU) has been requesting supplemental budgets to ensure that all required HPMS sample counts have been performed. Where valid data could be obtained from jurisdictions, those data have been used, reducing the need for CDOT to perform supplemental counts. In addition, the TAU has collected some additional off-system counts as needed to meet specific CDOT needs. However,

[18] In 23 CFR 470A, the "federal aid highway system" is defined as all Interstate highways and the National Highway System. Conversely, "federal aid highways" is defined as "highways on the Federal-aid highway systems and all other public roads not classified as local roads or rural minor collectors."

[19] It can be argued that SPR funding provided by USDOT to CDOT can be used to pay for these tasks. On the other hand, no increase in SPR funding occurred when the increase in required traffic counting was adopted.

there are a very large number of off-system HPMS sections for which CDOT does not have recent count data.

In addition to the basic need for counts to be collected on a six-year cycle for all traffic segments in the state (that are not RMC or local roads), there is a need—as with the state highway network—to determine whether the defined off-system roadway segmentation is correct or should be adjusted to account for changing traffic patterns. (That is, are the defined off-system roadway segments no longer sufficiently homogeneous because of changing traffic patterns?)

The importance of this task to CDOT is lower than it is for the on-system segmentation. This is because the on-system segmentation affects the quality of the traffic counts used by CDOT staff for specific analyses. The off-system segment definitions only affects the accuracy of the HPMS expansion factors, and the impact of a limited number of errors in the segment definitions that are aggregated into those expansion factors is not likely to be large enough to be observable in the statewide VMT estimates. Nevertheless, this task still must be performed periodically.

CDOT Traffic User Needs By Analysis Group

This section discusses CDOT management's traffic data needs, as described in interviews conducted for this study. Staff from the following groups that routinely work with CDOT traffic data were interviewed:

- HPMS
- Mobility and Operations
- Safety
- Planning
- Infrastructure (pavement and bridge).

The needs expressed by the four latter groups are discussed below. The HPMS needs are discussed in the previous section.

Mobility and Operations

The Mobility group at CDOT studies 71 designated congested corridors. The staff in the mobility section are generally satisfied with the roadway data currently available. Their most important analytical needs for traffic data are to support the estimation of system-wide delays, the analysis of where and when congestion occurs, and initial studies examining ways to mitigate that congestion.

To meet those needs, the staff use the traffic data from the CDOT roadway segments to compute volume to capacity (v/c) ratios and delay estimates. These include time of day volumes, as well as the traditional traffic statistics used in capacity analysis (AADT, K and D factors). They are currently working with privately collected vehicle probe data to determine whether those data will support better locating and estimation of delay. However, even if the private sector data help identify congestion locations more effectively than the traditional v/c computations, the traffic statistics available at the roadway segment level will still be needed to estimate the use of each congested roadway segment. It is possible that the private sector data may indicate the locations of congestion in some portions of a current traffic roadway segment but not other portions. Such a result may require the collection of traffic data at more than one

location within that segment to more effectively understand the performance of that roadway. That kind of need for data should be met through the request of a "special study."

The Mobility group's data needs are further supported by the continuous count program. Of particular importance is the need for seasonal data on weekend travel in parts of the state affected by seasonal recreational volumes. Because short duration counts are taken exclusively during weekdays, the short counts that cover most traffic segment volumes do not include direct measurement of weekend volumes. The short counts may also not be taken during the highest volume months of the year. Because the mobility program needs data on the size and timing of peak movements, it relies on the traffic patterns described by the continuous count program to understand when peak volumes occur and the relative size of the weekend/weekday traffic volume relationship.

This use of data from both the short duration and continuous count programs does not currently require a change in the CDOT data collection process, but it may warrant some additional conversation between the Traffic Analysis Unit and the Mobility Unit to provide the Mobility Unit staff with the best possible data for their analyses. It is possible that counts at some locations might be more useful for mobility analyses if they were taken on key weekends in the year. Whether the benefit from this site-specific collection of very high volume traffic conditions would warrant the added cost of weekend data collection is the primary topic to be discussed between the TAU and the Mobility Unit. At the informational meetings held for this project, the Mobility staff indicated that they were currently satisfied with the use of continuous count data for estimating these peak weekend flows.

The other area of potential future changes in data needs is the use of truck volume data. Truck volume data for single and combination trucks are already collected for the on-system road segments. More detailed truck volume statistics (e.g., volumes by the 13 FHWA classifications) are stored in the TRADAS database and can be accessed through TRADAS. Therefore, it does not appear that this growing need will require a change in the current data collection plan. However, in the future, roadway segments may need to be defined at least partly on the basis of truck use, and Mobility Unit staff—and potentially other users—may need easy access (similar to current Internet access via the TRAFFON file) to the more detailed truck data, such as detailed hourly count summaries by the 13 vehicle classes, contained in TRADAS. Because of this increasing interest in truck volumes the TAU has requested additional review of the truck counting effort which will be done as part of this study.

Safety

The Safety staff are responsible for analyses involving the identification of hazardous locations, the causes of crashes at those locations, the predicted effects of geometric and operational changes at those locations, and the monitoring of actual changes as a result of CDOT activities. The group relies primarily on the segment-based data collected by the Traffic Analysis Unit for the AADT and other detailed traffic statistics required for these analyses.

The primary traffic data need identified in interviews that is not currently met by the CDOT segment-based data involves cross-streets at intersections, especially when the cross-street is not a state highway. (Ideally, crash analyses at intersections use detailed turning movement data, as well as through-volumes on all intersecting roads. However, these data are not collected as part of the regular short count data collection program.) Data on detailed

intersection movements needs to be collected on a "special study" basis as part of detailed safety analyses of crash hot spots.

In addition, some concern was expressed about the availability of detailed traffic data on roads with designated wildlife zones. Lower night speed limits were requested for these 100 miles of roads, with double fines slated for violators ticketed for speeding. The visibility of this program means that the Safety group is especially concerned about the accuracy of traffic volumes used to determine crash rates on those facilities before and after implementation of the speed restrictions.

Not mentioned by the Safety staff was a need for motorcycle volume data. Motorcycle data are a current emphasis area within FHWA. They are available from vehicle classification counts, but AADT estimates for motorcycles that are based on weekday vehicle classification data and traditional factoring techniques may underestimate motorcycle VMT on roads used by large motorcycle groups, or that experience large increases in seasonal, weekend, recreational motorcycle travel. Traditional, volume-based, seasonal factoring is unlikely to correctly account for large weekend motorcycle volume increases on these roads. Capturing the motorcycle VMT associated with these large recreational movements may require performing weekend vehicle classification counts that are specifically intended to capture motorcycle travel. While it is not clear that CDOT's Safety Unit will indeed need these data, the TAU should discuss the need for motorcycle volumes at least annually with the Safety Unit in order to understand whether "special short counts" are needed to more accurately estimate motorcycle travel.

Planning

The Planning staff are primarily involved in the development of the long-range state transportation plan, as well as tracking key statewide statistics such as VMT, VMT/capita, VHT, and VHT/capita. More detailed project planning, design, and environmental work is performed at the regional level and in the Transportation Planning Regions (TPR). The state transportation plan is based on 350 defined "corridors." Work at the corridor level is well served by the traffic data currently available at the roadway segment level, as well as by even higher aggregations of those data.

When regions perform more detailed corridor or project planning work and require more detailed data than the CDOT road segment data, they collect the data through their own project consulting contracts or by requesting special counts from the TAU and using their own project funds. Planning staff needs can be anticipated by examining the State Transportation Improvement Plan (STIP).

Bridge and Pavement Groups

The headquarters staff responsible for bridges and pavements indicated that the roadway data currently available from the CDOT roadway segments, combined with other data available through the TAU (primarily equivalent single axle load or ESAL estimates), generally meet their needs. The use of ESALs may well be supplanted at some point in the future by load spectra[20] as

[20] A load spectrum is defined as the number of axles of specific weights being applied to a roadway. For example, daily load spectra might include 12 single axles weighing between 10,000 and 10,999 pounds, 15 single axels weighing between 11,000 and 11,999 pounds, 9 axles weighing between 12,000 and 12,999 pounds, etc.)

CDOT moves from ESAL-based pavement design (the AASHTO procedure used at the end of the previous century) to mechanistic-empirical pavement design. The Mechanistic-Empirical Design Guide (MEPDG) is the new design process being developed and deployed with AASHTO support to address limitations in the traditional ESAL-based procedures.

In the past, the Bridge staff have funded some of their own off-system counts. According to the CDOT staff interviewed for this report, those data were required for a submittal to FHWA but were not otherwise used by the Bridge staff. (These counts collected traffic volumes on the bridges that cross above state highways, and where the roads using those bridges are not owned or operated by the CDOT.

Both the new MEPDG procedures and the ESAL procedures use inputs of average annual daily truck traffic. These estimates are currently available at the roadway segment level. The quality of the classification data at the segment level is a function of the ability of CDOT to collect truck data. For the most part, the TAU collects classification data when possible as part of its short duration count program. No special consideration appears to be given to the collection of truck volume data for the Pavement and Bridge groups, although they may make such requests as part of specific project design efforts.

Other CDOT Short Duration Count Traffic Data Needs (Special Needs Counts)

The Traffic Analysis Unit does perform "special needs" counts. That is, when the data available at the traffic segment level does not meet the needs of significant projects, specific counts designed to meet detailed project needs may be performed by the TAU at the request of the CDOT group performing the project or other entities such as MPOs. For example, additional funding was provided to the TAU so that it could conduct counts at railroad grade crossings as part of a study of rail crossing exposure.

In the past few years, the TAU has also requested additional funding to expand its count program to collect "special counts" (that is, counts that had not been regularly performed in recent years) to meet the new HPMS six-year count cycle requirements for traffic volume data on both ramps and off-system locations. More traditional "special count" efforts may include counts for specific mobility, safety or design projects.

Other "special counts" performed by the TAU include the following:

- scheduled "recounts," which are used to help determine the validity of traffic volume data collected by contractors when those data are significantly different than expected but pass other quality assurance tests
- counts designed to clarify whether specific CDOT road segment definitions should change (and where those new segment boundaries should be placed).

Notably, CDOT staff indicated that not all "special counts" taken for CDOT projects are managed by the TAU. Some counts are taken by consultants working on projects for CDOT, and those counts are not always submitted to the TAU for inclusion in the TRADAS database.

Summary of Short Duration Count Needs

The majority of CDOT traffic data client needs can be met by the current CDOT on-system roadway segmentation system, as long as

- count data available on that system are up-to-date and

- the segments remain homogeneous with respect to traffic volumes.

Consequently, the primary design criteria for the TAU short count program should be to maintain the quality of data on these segments. Most of these segments are already counted on the three-year cycle required to meet HPMS reporting, with a small proportion being counted annually, and the remainder counted on the six-year cycle. The count schedule should be updated to reflect these basic count needs.

In addition to these base counts, the TAU should plan on routinely performing some additional on-system counts on state roads to investigate where the roadway segmentation that underlies the on-system count program may need to be revised. These additional count locations should be identified through a review of

- collected traffic data to identify locations with significant, observed volume changes
- the locations where development is occurring in the state
- the locations of major road projects that may indicate potential traffic volume changes.

Specific recommendations for identifying these sites will be presented in the next report for this project as part of an update of the TAU business process.

Another important task is to meet the off-system count requirements imposed by the HPMS reassessment. These requirements are real, have benefit to the state, and will ensure the quality and accuracy of HPMS reporting by CDOT. However, these counts also have a much lower direct utility to CDOT and its primary traffic data clients. Directly counting these segments also will require a considerable expansion of the CDOT short duration count program—with a commensurate increase in the cost of the program. Because these counts are on roads not operated or maintained by CDOT, we suggest that CDOT explore ways to delegate the collection of these data to avoid directly performing the counts. Only where counts can not be obtained through other means should they be performed directly by CDOT and the TAU. This topic will be covered in the next report for this project, which will discuss initial recommendations for the TAU.

Three additional data needs, identified through the literature review (see the Bibliography in Appendix C) and discussions with CDOT staff, directly pertain to the TAU business function. These needs include the following:

- ramp counts to be provided on a six-year cycle
- continued improvement in the availability of vehicle classification data within the CDOT roadway segmentation
- potential changes to roadway segmentation to account for changes in truck traffic, even if the current segmentation is acceptable for total traffic volume.

CDOT staff participating in the project interviews made little mention of truck volume data. However, the literature indicates that more and more operational, planning, and structural analyses specifically require the inclusion of high quality truck volume data. Therefore, we expect that the TAU will see additional requests for high quality, detailed truck volume data that it will need to supply through the short duration count program.

Finally, the TAU should continue to be aware of the “special count needs” of the rest of the Department. In particular, this relates to the need for “project specific” counts that are intended to meet the design and operational analysis needs of the regions and other Department

offices . It is not clear that the TAU must directly collect these data, but the TAU should capture any data that are collected for these purposes—regardless of what entity collects them—as they can provide an excellent source for several of the traffic data needs described above. For example, multiple, detailed traffic counts taken within a segment by a CDOT Regional Office for project design purposes could also be used to review current roadway segmentation, without the need for additional TAU-funded traffic counts. These counts would not have to be full 48-hour counts. They would simply need to provide enough detail to allow TAU staff to understand whether current the roadway segmentation needed to be modified.

IDENTIFIED CONSTRAINTS

A number of constraints were identified as part of the data collection effort for this report. The most obvious constraint is the limited funding available for traffic data collection. To date, the TAU has been able to obtain supplemental funding to expand its traditional count program to meet the increased data collection responsibilities due to the HPMS reassessment. It is unclear if such support can be sustained indefinitely. However, given that gas tax revenue streams are declining for all roadway agencies, it is clear that the cost of the traffic data collection program is a key constraint.

A second major constraint observed in the initial needs assessment is the fact that the majority of the Department's "unmet needs" are for data from off-system locations. These include both off-system HPMS sample sections and all other HPMS sections not classified as either rural minor collectors or local roads. As with on-system counts, off-system counts require both that valid traffic counts occur on each homogenous road segment every six years and that the roadway segments remain homogenous or be updated. Because CDOT does not operate or maintain the off-system roads, the need for off-system data creates significant administrative, logistical, and financial questions and constraints. (Can CDOT routinely perform counts on off-system roads? If counts are performed by the "owning" jurisdiction, how are the data submitted to CDOT and will they pass CDOT's quality assurance tests? Who is responsible for updating the off-system roadway network, when will that occur, and how will those updates affect the count program of both CDOT and participating jurisdictions?) Finding ways to effectively collect the required off-system data, while at the same time limiting the cost to CDOT, is likely to be the key problem faced by the TAU as they respond to these new HPMS requirements.

Another constraint relates to roads in recreational areas, which experience capacity problems during periods other than the traditional urban commute periods. Depending on the area, peak demand occurs during specific months and during specific periods when large numbers of visitors are arriving or departing from the area. These time periods are frequently on Friday, Saturday, or Sunday, with the timing of the peak movements highly dependent on conditions unique to each area. Understanding these peak traffic movements so that key policy decisions about what roadway improvements could/should be made requires traffic data. However, the cost of weekend data collection is a major constraint, especially given the fact that recreational movements can be affected by events such as weather that can not be accounted for in scheduling traffic counts.

One final constraint relates to the growing need for vehicle classification data. While vehicle classification data were not mentioned frequently in the CDOT interviews as a significant need, at the national level there is a growing interest in, and use of, vehicle

classification data. Truck volumes are important inputs for many of the operational, planning, and design tools being developed by USDOT, AASHTO, and the TRB. Freight movements are important for economic and policy studies in the state and its regions, as well as for safety and operational analyses. Consequently, we conclude that the TAU will see an increasing interest in, and requests for, truck data. Constraints stem from the fact that classification data are difficult to collect on many road segments, and the collection of classification data is generally more expensive than the collection of simple traffic volume data.

APPENDIX C: BIBLIOGRAPHY

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APPENDIX D

RECOMMENDATIONS FOR THE COLORADO DEPARTMENT OF TRANSPORTATION'S SHORT DURATION COUNTING PROGRAM

INTRODUCTION

This interim report summarizes of the short duration count requirements of the Colorado Department of Transportation (CDOT). It describes the short duration counts needed to meet those requirements, and it describes the business processes necessary to maintain the short duration count program over the long term. Finally, Appendix E describes draft analytical procedures that CDOT should perform annually to identify changes to the short duration count program. These procedures will be formalized after the CDOT Traffic Analysis Unit (TAU) staff have reviewed the report.

REQUIRED SHORT DURATION COUNTS

A previous working paper[21] for this project described in more detail the uses for traffic data obtained through CDOT, which determine the traffic data collection requirements that CDOT TAU must address through a combination of its short duration count and permanent counter programs. The section below summarizes the material in that document.

CDOT traffic data needs can be initially divided into two groups: 1) data on state highways owned and operated by CDOT ("on-system" counts) needed for a variety of analytical purposes and 2) basic car and truck volume statistics for roads that are not owned, operated, or controlled by CDOT ("off-system" counts) but that are required for submission to and use by the federal Highway Performance Monitoring System (HPMS). These two categories of necessary data are presented below.

On-System Count Requirements

CDOT is responsible for collecting, summarizing, and making available the traffic data needed for the engineering, planning, and operation of CDOT-maintained roads. To meet these needs, CDOT maintains a roadway database that divides the state highway system into road segments that have homogenous traffic volumes ("traffic segments"). The database currently contains approximately 3,300 currently defined on-system traffic segments.

The data readily available at the traffic segment level include average annual daily traffic (AADT), AADT for single-unit trucks and combination trucks, design hour volume (DHV), and directional distribution (DD). More detailed data that underlie these statistics are also available through the TAU. Counts are currently performed on each traffic segment either a) annually, b) on a three-year cycle, or c) on a six-year cycle.

[21] Interim Report: Motorized, Short Duration, Traffic Count Site Selection Data Needs and Constraints

Some sites are counted annually because of their importance or because they are the location of permanently installed, continuous counting equipment. Many sites are counted on a three-year cycle in large part because federal HPMS reporting requirements require three years as the minimum count cycle for the following types of roadways:

- road segments that are on the National Highway System (NHS)
- roads that are classified as being Interstates or Principal Arterials
- road segments that are part of the HPMS traffic volume sample.

A three-year cycle is appropriate for most short duration counts. Because the day-to-day variation in traffic volume is high relative to the size of growth, AADT estimates made from short duration traffic counts on an annual count cycle are unlikely to capture changes—or may exaggerate them—at the individual location level until multiple years have passed, allowing the growth to reveal a more general trend. This makes annual counts an inefficient use of resources for most—but not all—locations. However, three years of steady but unspectacular growth will generally be captured by counts taken on a three-year cycle. Therefore, the three-year count cycle not only meets the HPMS requirements, it supplies most users with data of sufficient accuracy for their needs.

For the remaining CDOT-maintained roads, a six-year count cycle is appropriate. This is a suitable cycle for roads where traffic volumes do not change rapidly (e.g., for many small rural roads in Eastern Colorado), as well as for lower volume roads where engineering decisions are not affected by modest changes in traffic volume levels. For example, a change from 5,000 AADT to 7,000 AADT, while large in percentage terms, is unlikely to require changes in the number of lanes or the depth of pavement.

It is important to note that the six-year HPMS count cycle also includes traffic counts on all ramps to and from Interstate highways and other freeways and expressways. While CDOT has recently completed a special data collection effort to obtain these data, this task should be incorporated into the routine CDOT short duration count data collection program.

The review of the uses for CDOT traffic data revealed only two significant limitations in the use of traffic segments. The first is that a limited number of CDOT activities (e.g., those involving traffic management and operations) require more detailed traffic data than those provided by a single count within a traffic segment that may extend for several miles and include multiple intersections. The second is that unless the traffic segment is on a limited access highway and its endpoints are the only points of access, the traffic volumes on that segment will not be purely homogeneous, and some additional data collection will be needed over time to either confirm the definition of an existing "homogeneous" traffic segment or define how the current traffic segmentation should change.

Projects that require more detailed data for specific project purposes should arrange with the TAU to collect the additional data. Alternatively, the project team can collect those data themselves, but any traffic data they collect should be provided to the TAU so that they can be used for other CDOT analyses and activities. For example, the development of new signal timing plans on arterials requires detailed volume data for each intersection approach. The arterial signal timing project should arrange for additional traffic counts. The data from those counts should be provided to the TAU for

inclusion in the TAU TRADAS data archive. In return, the TAU can provide not only quality assurance reviews of those data to the group collecting and using them but also make those data available to all other CDOT data users. Finally, those data can also be used to review existing traffic segmentation.

In addition to traffic volume data, the CDOT traffic segments also provide data on the trucks using the roadway. This means that the definition of "homogeneous traffic" must be extended to truck traffic as well as total volume. It also means that, whenever possible, the TAU should use counting equipment that can collect truck volumes—at a minimum to classify single-unit trucks, combination trucks, and all other vehicles (i.e., collect truck volumes by simple length categories). However, more detailed vehicle classification data are preferable to this minimum classification system, as more detailed, axle-based truck classifications are useful for many detailed engineering analyses.

Off-System Count Requirements

Previous work in Colorado divided the off-system road network into roughly 25,000 road segments for HPMS reporting. These segments have been further aggregated into just under 8,100 homogeneous traffic segments. CDOT is responsible to USDOT for reporting traffic data on these off-system traffic segments for use in the HPMS. The traffic reporting requirements for these segments are the same as those for on-system counts. That is, counts must be performed at least once every three years on all road segments that are either

- on the National Highway System (NHS)
- classified as being Interstates or Principal Arterials or
- part of the HPMS traffic volume sample.

In addition, the 2010 update to the *HPMS Field Manual* states that all road segments in the state, except those that are functionally classified as rural minor collectors or as local roads, should receive traffic counts at a minimum of every six years to confirm the integrity of their assignment to the HPMS volume categories. This requirement was added to ensure the accuracy of the expansion factors for converting the HPMS sample count data into the estimates of statewide VMT on which allocations of federal gas tax are based.

This revision of the HPMS traffic counting requirements poses several difficulties for CDOT. The first is that CDOT does not control or operate the off-system roadways and therefore has no reason other than federal reporting to collect traffic data on those road segments. The second is that the local jurisdictions that do collect traffic data on those roads do not routinely report those counts to CDOT. Although several jurisdictions have arranged to submit available traffic count data to CDOT since the creation of the statewide Traffic Data Committee, there is no formal mechanism or process for doing so, nor do most of Colorado's jurisdictions send traffic data to CDOT. However, if CDOT were to collect the data on those roads, it would have to substantially expand its current CDOT traffic counting program. Such an expansion would still require considerable coordination with local agencies because CDOT does not operate those roads.

These issues notwithstanding, CDOT is responsible—in USDOT's view—for collecting and reporting these off-system counts within the HPMS.

Maintenance of the Traffic Segmentation

For both on-system and off-system counts, CDOT must have a process that ensures the accuracy of the traffic segmentation. For most roads, traffic segments (that is contiguous sections of roadway with "homogeneous traffic") are unlikely to change from year to year. However, changes in levels of land-use activities and the construction of new roads will change travel patterns within road segments. These changes may result in the need to split one current traffic segment into more than one segment or to combine two or more traffic segments.

Therefore, periodically updating the traffic segments is important both to maintain the integrity and accuracy of the HPMS reporting (and consequent VMT computations) and because the on-system traffic segmentation is the primary organizational mechanism by which CDOT traffic data clients receive traffic volume data for state routes. If the traffic segmentation is out of date, the supplied traffic data may be inaccurate—resulting in poor engineering and planning decisions.

SUMMARY RECOMMENDATIONS

On the basis of the requirements for traffic data described above, we make the following recommendations for the TAU's short duration count program:

1) The TAU should count the on-system traffic segments at the current three-year and six-year cycles defined by the *HPMS Field Manual.*
2) The TAU should routinely count freeway ramps on a six-year cycle, with all ramps within a specific corridor[22] counted on the same day whenever possible. (Different directions can be counted on different days if that allows for more cost-efficient data collection. Similarly, different corridors can be counted on different days.)
3) The primary source of off-system counts should be the jurisdictions that operate those roadways.
4) The TAU should set up a formal process for obtaining those off-system counts.
5) As part of that formal process the TAU should develop an annual review and notification business process that identifies, for each local jurisdiction, the counts that are needed. The TAU should notify jurisdictions of upcoming program counts at least two years before the off-system count section will be delinquent in terms of the HPMS requirements. When responding to these communications, local agencies should both supply data and describe where off-system segmentation should be changed to reflect actual travel within each jurisdiction.

[22] Note that the term "corridor" is used loosely in this recommendation, where each corridor is intended to collect data on related travel movements. For example, a "corridor" may consist of ramps from downtown Denver to the suburbs but not extend out that roadway to the ramps in the surrounding rural area. It is recognized that this desired approach may not be possible on all facilities because of the practical limitations associated with the number of counters that can be placed.

6) CDOT management should take significant steps to support the TAU in gaining compliance from the local jurisdictions in sharing their traffic data.
7) Where necessary, in a limited number of locations, the TAU should be prepared to collect traffic data on off-system HPMS sample sections. (The TAU should not collect data on off-system traffic segments that are not HPMS sample sections.)
8) The TAU should periodically conduct a formal review of the on-system traffic segmentation.
9) The TAU should make sure—with the help of CDOT management—that it receives electronic copies of all traffic data collected for CDOT purposes so that they can be entered into TRADAS, made available to other CDOT traffic data clients, and used by the TAU to revise current traffic segmentation. This includes all traffic data collected by CDOT or consultants working for CDOT should be entered into TRADAS so that they can be used for all CDOT analyses.

Each of these recommendations is discussed in more detail below.

DISCUSSION OF RECOMMENDATIONS

This section provides more details on the summary recommendations above.

1. The TAU Should Continue Current Cycles for On-System Traffic Segment Counts

This recommendation essentially affirms much of the TAU's current practice for collecting short duration counts on state highways. While this study has not reviewed the permanent count program, the basic size of that effort (approximately 110 locations) is reasonable. Those locations should continue to be used to replace the need for short duration counts on those traffic segments.

The only real change recommended for adoption by the TAU is that changes to the federal requirements for HPMS slightly increase the number of road sections that should be counted on a three-year cycle rather than a six-year cycle as the number of road segments assigned to the National Highway System has increased as a result of recent Congressional actions.

2. The TAU Should Routinely Count Freeway Ramps

A more substantial change in the number of traffic counts performed each year will occur as a result of the need to collect volumes on roughly 1,800 ramps across the state. Those counts should be taken on a six-year cycle. We recommend that a subset of those counts (roughly 300) be performed each year, rather than performing them as a "special" effort once every six years. We further recommend that—if possible—all ramps within a specific corridor serving traffic moving in a given direction be counted on the same day. Different directions can be counted on different days if that would allow for more cost-efficient data collection. Note that the term "corridor" is used loosely in this recommendation, as each "corridor" is intended to encompass data collected on related

travel movements. For example, the recommendation would be that all eastbound ramps on I-70 coming from the west of the city and traveling toward central Denver should be counted on the same day, as that would make it possible to understand the relative size of movements on and off the freeway for each specific corridor. The westbound ramps for that corridor might then be counted during the next "counter set." This "corridor counting" philosophy should also be applied in rural areas. Although this approach is desired, it may not be possible on all facilities because of the practical limitations associated with the number of counters that the TAU can have placed during a specific "counter set." When such limitations occur, the TAU staff should consult with the CDOT staff responsible for operating that roadway (and most likely to use those ramp data for operational purposes) to determine the best start and end points for count collection during a specific counter set.

Where CDOT is metering ramps and reliable traffic count data can be obtained from the ramp metering system, those counts should be used to limit the number of additional short duration counts that must be performed.

3. Off-System Counts Should Come from Jurisdictions Operating Those Roadways

The TAU should avoid routinely performing traffic counts on off-system locations, including HPMS sample segments. Instead, those data should be obtained from the local agencies that own and operate the off-system road network. Currently, the TAU performs counts on a significant proportion of the HPMS sample sections, which are found on roads that are not owned and operated by CDOT. This has been necessary because jurisdictions have not routinely supplied CDOT with traffic data collected for their own engineering, planning, and operational purposes.

In addition to the HPMS sample sections that CDOT is currently collecting, the latest HPMS reporting requirements state that all roads in the state that are not functionally classified as local roads or rural minor collectors must be counted at least once every six years in order to maintain accurate HPMS sample expansion factors. The state highway agency is responsible to USDOT for this task.

There are three options for collecting traffic data on all non-local and non-rural minor collectors in the state:

1) CDOT itself collects all of the required data.
2) CDOT does not collect data on all off-system road segments; instead, it requests those data from the local agencies, but it does not receive a significant proportion of the requested data. This would leave the CDOT vulnerable to reaction from USDOT when the data required to support its statewide VMT estimate (and subsequent federal gas tax share calculation) were not supplied.
3) CDOT provides a combination of incentives and disincentives to local agencies to encourage them to supply data to CDOT in a manner that benefits both the local agencies and CDOT, resulting in the collection of the vast majority of data required for the HPMS submittal.

All of these alternatives involve some combination of risk and/or expense to CDOT, with the majority of the unknown risk being USDOT's reaction to a lack of data to support the

HPMS expansion factors CDOT uses. It is possible that USDOT would take no action if CDOT was unable to obtain those data, either because of lack of money or lack of cooperation from local agencies, as no specific consequence for such failure has been described in the federal regulations. However, given that the potential consequences could be significant, the project team recommends that CDOT adopt the third option. We believe that this option has the correct outcome at the lowest life cycle cost, as well as has the least associated risk , although it does require some CDOT investment of both money and political capital.

The project team does not believe that CDOT should collect the required off-system data. Such a data collection effort would essentially double the current short duration count program. Given that as an agency CDOT has relatively minor needs for those data, this would not be a good allocation of CDOT resources. Instead, it will be much more cost effective for the state if the agencies that own and operate those roads (and in most cases are already collecting traffic data on them) supply the data. Furthermore, since local agencies already provide GIS data on all off-system traffic segments to CDOT, it makes sense that they also provide the HPMS traffic data for those same off-system roads. This should free up some CDOT funds for the collection of ramp counts.

While the TAU currently requests copies of traffic data collected by local agencies, the response to these requests has been inconsistent at best. Even when data are provided to CDOT, they are often not sent in a timely manner. Consequently, to meet the timing of the HPMS submittal, the TAU currently performs counts on off-system HPMS sample sections each year. If a jurisdictions submits acceptable local data in a timely manner, then the TAU cancels the count request for the locations. When data are not received in a timely manner, the TAU funded data collection effort is often a (necessary) duplication of effort.

Better coordination and data sharing between CDOT and the local jurisdictions will reduce this duplication of effort, allowing the funds to be used for other traffic counts that can benefit both CDOT and the local jurisdictions. (For example those funds could be used to pay for the ramp counts—which should also be useful in signal timing analyses at intersections where the ramps terminate at local arterials.)

The difficulty with this obvious cost saving solution is that data sharing requires time and energy on the part of the local jurisdictions, which are often heavily constrained in terms of staff and resources. In addition, there is little incentive—other than professional courtesy and interagency goodwill—for local agencies to allocate staff resources to this task. Finally, there are no significant consequences to a local agency that fails to share data.

Several factors hinder data sharing from local agencies. One is that if agencies can easily retrieve and submit their data to CDOT, they do so. However, these activities occur when agency staff have the time to perform them. As a result, the data submittals are often not “in sync” with the needs of the TAU’s traffic counting program, especially as they relate to the HPMS submittal timeline. Another is that if the local agencies do not have an easily manipulated traffic data archive, the effort to transmit data to CDOT can be sufficiently arduous that they simply cannot respond to the CDOT request. A third is

that the data supplied by local agencies come to CDOT in a variety of formats and with varying levels of quality. This makes accepting and using those data more time consuming then necessary for CDOT.

Because of these factors, we recommend that CDOT develop a formal data submission process (see the next section below). As part of that formal process, CDOT and the state should develop a package of incentives and disincentives aimed at both encouraging local jurisdictions to share data and reducing the time and resources required to share those data.

4. CDOT Needs a Formal Process for Obtaining Local Jurisdiction Counts

To increase the ease and efficiency with which local traffic data are obtained and shared, CDOT needs to develop and implement a more formal and efficient mechanism for obtaining those data. This process would include both formal sets of communication between CDOT and the local agencies, and simple, automated mechanisms for transferring the data. The project team also believes that CDOT should supply agencies with both incentives to share data and disincentives for failing to supply data the state needs to ensure that it obtains its fair share of federal gas taxes.

We recommend that this formal system have the following attributes:

- A formal business process that includes communications from CDOT to the agencies describing the HPMS needs for traffic data for each agency's roads, with those communications timed so that both CDOT and the agencies can effectively schedule their traffic counting activities
- A formal method of communication from the local agencies to CDOT that not only supplies necessary traffic count data but that also describes changes in traffic patterns that require changes to CDOT's off-system road segmentation
- An easy to use, low cost, electronic data transfer mechanism for supplying traffic data to CDOT
- A user-friendly system that allows all state traffic data users to access the submitted data once CDOT has accepted them.

The first three of these attributes are necessary to make the data sharing functional. The fourth is important so that local agencies can double check the data they have submitted. The project team believes that the fourth bullet is a key incentive for ensuring that local agencies actively participate in the data sharing effort, since it will give cities easy access to traffic volume data from roads in surrounding jurisdictions. This will both help each jurisdiction meet its own data needs and provide local peer pressure for jurisdictions to participate in the data sharing project (e.g., "I need data on Main Street on your city's side of the city border, why haven't you posted it on the CDOT website?").

More discussion with the state's Traffic Data Committee is needed to determine both the appropriate technical procedures for sharing data and the appropriate set of incentives and disincentives likely to achieve and maintain local agency participation.

However, the project team believes that supplying the local agencies with access to all state traffic count data through a single, easy to use, Web-accessible interface is a good starting point for discussing incentives for participation. Furthermore, the existing CDOT software capabilities are a good place to start this discussion. For example,

CDOT might consider giving local agencies access to CDOT's TRADAS and AVID traffic data systems. This would allow those jurisdictions to take advantage of the data processing capabilities CDOT already uses to provide map-based access to its data, without having to develop those systems themselves. At the same time, it would provide CDOT with direct access to local jurisdiction data. This would ensure that data collected by one agency could be shared by all users, reducing the need for duplicative data collection among all agencies. Private vendors that collect data under contract to local agencies could also adopt the existing CDOT data submission process, as they are already capable of transmitting data to CDOT.

The primary limitation of this recommendation is that it is unclear what this capability would cost. For example, both AVID and TRADAS—while already built—would need extended support, for which no cost has yet been determined. In addition, although there may be easier ways to perform this task, AVID does provide an excellent example of functionality that would benefit local jurisdictions, thus giving them considerable incentive to participate in a CDOT data sharing effort, and TRADAS contains all of the underlying technical capabilities that help ensure the validity of the collected traffic data.

5. The TAU Should Provide an Annual Review and Notification to Local Jurisdictions

To facilitate the activities of the local agencies and to ensure that all agencies work from identical data sets, we recommend that each year the TAU provide each local jurisdiction with a report that does the following;

- defines the off-system traffic segments that exist in that jurisdiction
- describes where and when counts have been previously taken within those traffic segments over the last six years
- highlights count locations (traffic segments) that have not been counted for at least four years—along with a request that those traffic segments be counted in the next two years
- highlights count locations that have not been counted for at least five years and that are identified as requiring counts in the coming year
- highlights count locations that are overdue (six years or more).

This formal process assumes that CDOT tracks the submission of traffic count data from each jurisdiction and updates its own off-system count database. That database should then serve as the basis for this formal communication.

It is important that this communication take place at a time when the local jurisdictions can effectively plan to obtain the required counts. We suggest that the Traffic Data Committee help identify the appropriate timing for this formal report.

If possible, each local agency should respond to this request with indications of when specific counts will be obtained. (For example, the local jurisdiction might acknowledge that a count is indeed four years old and explain when that location is scheduled to be counted next.)

Ideally, this submittal would be available to an agency in several formats, including a simple Excel-style data table and an on-line GIS map indicating the locations of specific traffic segments and the locations and ages of counts. (Those traffic segments might be color coded to indicate the age of the count or the number of years until the next count must be submitted.)

A second response that should come from each local jurisdiction would include any changes in traffic segmentation that it believes should occur because of either growth in the area or changes in the roadway infrastructure. One problem with the off-system traffic segmentation is that CDOT does not have day-to-day experience with changing traffic patterns on those roads. It is therefore difficult for CDOT to determine when traffic segmentation should change to reflect non-homogeneous traffic volumes. The local agencies should have this knowledge and therefore should be in charge of making those changes. (They would also then be responsible for collecting the traffic data needed to justify the new segmentation.)

Local agencies already provide an annual update of HPMS segments to CDOT as part of the annual HPMS data submittal. However, the current HPMS submittal from the local agencies details only changes in the roadway infrastructure. This recommendation extends that local responsibility to include the traffic volumes on those roads.

6. CDOT Management Support Is Needed to Obtain Local Jurisdiction Traffic Data

Many local jurisdictions are severely resource constrained and therefore have not participated in the existing data sharing efforts CDOT encourages through the state Traffic Data Committee. Further encouragement from CDOT's TAU staff to participate in this effort and improved mechanisms for data handling are unlikely to result in high levels of local agency compliance without some additional upper management support for the data sharing effort from within each local jurisdiction.

Consequently, we recommend that CDOT upper management work with state and local elected officials to convince upper management of local transportation agencies to help change priorities so that the modest resources needed to share traffic data are allocated to this task.

While the intent is to make the data sharing process as much of a win/win situation as possible for all agencies and jurisdictions, in agencies where resources are severely constrained, some "direction from above" may be necessary for priorities to be changed. Consequently, CDOT management is requested to promote the data sharing activities—and the benefits of those activities—with local jurisdictions. If politically possible, CDOT management should also develop a set of consequences for agencies that do not participate in the data sharing effort, in order to pass along the consequences the CDOT itself faces.

Finally, CDOT management support is needed to fund the software enhancements required both to minimize the effort of agencies that provide data to CDOT and to supply value to those agencies when they share their data.

7. Where Necessary, the TAU Should Collect Some Off-System Data

There are likely to be times when local agencies are unable to collect data required for the HPMS. For example, the agency may not have the technical ability to collect the data, or it may not be able to overcome resource constraints in the given timeframe. Consequently, the TAU may need to step in and collect off-system data that would not otherwise be collected—an activity it currently performs. Until participation significantly increases in the data sharing process, this may be especially necessary for HPMS sample sections that the TAU has counted in recent years.

While this report's recommendation is to "get the TAU out of the business of collecting other jurisdictions' traffic data," considerable goodwill might be gained if the TAU (or other groups within CDOT) could provide at least some traffic counting assistance to local jurisdictions. This assistance could be in the form of the TAU performing a limited number of counts. Or the TAU could notify a local agency that other CDOT groups were taking counts for special project purposes, in locations that could substitute for its traffic counts. This extra level of coordination would be one of the benefits of working collaboratively to share data.

However, the size of this counting effort should be—and remain—small. These count activities should be seen as "one time" activities undertaken as part of a cooperative effort to meet federal requirements. Counts at specific locations or for specific agencies should not become a routine CDOT activity—unless the funds for those counts are provided by the local agency.

8. The TAU Should Periodically Review the On-System Traffic Segmentation

One of the limitations of the current traffic data collection system is that it assumes that the traffic segmentation is correct, i.e., that a count performed at one location within a traffic segment will provide a valid traffic estimate for elsewhere on that traffic segment. This does hold true for most traffic studies—so long as the traffic segment is indeed homogeneous.

Unfortunately, traffic patterns can change over time, so segments that once had homogeneous traffic may no longer do so. Therefore, the TAU should periodically review the segmentation assigned to on-system roads. (The off-system road segmentation should be designated by the local agencies that own and operate those roads.) Traffic segmentation should be reviewed every three years, on the same schedule as the HPMS sample segments.

The difficulty with examining traffic segmentation is that the CDOT traffic count program routinely counts only one location within a traffic segment on a recurring basis. Therefore few data are available to help examine whether traffic volumes have changed significantly within a defined traffic segment.

To improve the ability to make these determinations, we recommend that CDOT capture all project-related "special count" traffic data and enter those data into TRADAS. Those data would then form the basis for an analysis of traffic segmentation. Thus, when a CDOT project has collected detailed traffic data on multiple road segments included within a single traffic segment, those multiple data points can be used to determine whether the current traffic segment needs to be divided into multiple segments.

While reviewing traffic segments, the TAU should also determine whether existing pairs of traffic segments can be combined. Appendix E of this report includes suggested rules for determining when road segments should or should not be combined into a single traffic segment.

9. All Traffic Data Collected for CDOT Purposes Should Be Entered into TRADAS

The discussions the project team had with CDOT staff for this project indicated that sometimes groups within CDOT request additional traffic data collection in order to gain detailed information not available from the recurring short duration count cycle program. When these "special counts" are requested through the TAU, the collected data are entered into the TRADAS traffic database and are available for all future users. However, at other times data collected for CDOT analytical purposes are not requested through the TAU. For example, a consultant working for CDOT may hire a private contractor to collect traffic data for design purposes. It is not clear whether all of those data are currently entered into the TRADAS database.

As noted in the previous discussion, these detailed project counts are the primary tool CDOT uses to check the current traffic segmentation. They also provide an excellent resource for other CDOT analyses. Consequently, these data need to be captured within the existing TAU data processes.

To ensure their capture, the TAU must be aware of the "special count needs" of the rest of the Department, particularly "project-specific" counts conducted to meet the design and operational analysis needs of the regions and other CDOT offices. The TAU does not need to directly collect these data, but it does need to capture any resulting data—regardless of where they are collected.

We also recommend that the CDOT adopt the policy that a copy of all traffic data collected with state or federal transportation funds be given to the TAU for inclusion in the statewide traffic database. This will ensure that these data are quality checked and available to others.

APPENDIX E: TRAFFIC SEGMENTATION DISCUSSION

This appendix makes recommendations about when to combine specific HPMS road segments into one or more "traffic segments."

The Traffic Monitoring Guide (TMG) is currently being revised. The language on segmentation in the draft revision of the TMG is as follows:

"The primary objective is to count enough locations on a roadway so that the traffic volume estimate available for a given highway segment accurately portrays the traffic volume on that segment. … A rule of thumb that has been used in the past to define these traffic count segments is that traffic volume in each roadway segment be within 10 percent. An alternative approach would be to define limits by using a graduated scale such as the one shown in the following Table."

Table E1. Graduated Scale for Defining Traffic Count Segments

Beginning Segment AADT	Adjoining Segment AADT Within
100,000 or more	+ 10%
50,000 – 99,999	+ 20%
10,000 – 49,999	+ 30%
5,000 – 9,999	+ 40%
1,000 – 4,999	+ 50%
Less than 1,000	+ 100%

The character of the road systems and the volumes carried have a major impact on the definition of segments. For roads where access is controlled (such as the Interstate system), a simple definition of segments between interchanges is appropriate. For lower-volume systems, clear traffic volume breaks are not always apparent and other rules of thumb (such as major intersections) must be applied. Rural and urban characteristics also require different handling. For the lowest volume roads, the 10 percent rule of thumb may be too narrow. Careful definition of roadway segments can significantly reduce the number of counts needed to cover all highways within an agency's jurisdiction, while still providing the accurate volume data required for planning and engineering purposes.

The project team reviewed the TMG discussion and conducted additional analysis on the potential impacts on traffic volume errors that result from inaccuracies in the assumption of homogeneous traffic conditions. Unfortunately, these impacts change from analysis to analysis, and many of the effects occur at boundary conditions. In other words, a minor change in volume may not matter, unless that modest change results in the need for an additional lane to meet capacity requirements. Further complicating this analysis is the fact that capacity is a function of not just AADT but also peaking and directional factors and the desired level of service. This makes it difficult to use a specific analysis or set of analyses to arbitrarily define the variation that should be allowed within a given traffic segment. Consequently, the review concentrated on the specific errors that would affect the statewide VMT calculations.

The resulting recommendation is a table that is not significantly different than the new draft TMG table. Table E2 uses an absolute vehicle volume differential for road segments below 55,000 vehicles and the 10 percent value for higher volume roadways. Like the TMG table, Table E2 allows for fairly large percentage differences in traffic volume within sub-segments of defined low volume traffic segments. But even these relatively large percentage changes in volume—on low volume road segments—have very little impact on the statewide VMT estimate. Consequently, the value obtained from a "better estimate" is minor relative to the cost of counting more frequently.

Table E2. Absolute Vehicle Volume Differential for Defining Traffic Count Segments

AADT Classification Groups	Criteria (Volume Change of)
Under 500	1,000 Vehicles
500 - 1,999	
2,000 - 4,999	2,000 Vehicles
5,000 - 9,999	
10,000 - 19,999	5,000 Vehicles
20,000 - 34,999	
35,000 - 54,999	
55,000 - 84,999	10% change in Volume
85,000 - 124,999	
125,000 - 174,999	
175,000 - 249,999	
250,000 and more	

The project team also suggests adopting a criterion for segmentation that involves truck volumes. The recommended segmentation split is a difference in 1,000 trucks on an average annual daily basis.