USING PRIVATE SECTOR TRAVEL TIME DATA FOR PROJECT-LEVEL WORK ZONE MOBILITY PERFORMANCE MEASUREMENT

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The Federal Highway Administration (FHWA) has been encouraging states to better monitor and track work zone operational performance. The use of mobility performance measures will enable agencies to better assess the contribution of work zones to network congestion, identify specific projects that are in need of remedial action, and potentially assess penalties to contractors creating excessive impacts. A major challenge in implementing work zone mobility performance measures has been the availability of traffic condition data. States have become increasingly interested in using travel time data from private sector vendors to generate this information since this data set offers the ability to obtain condition information over a wide area without deploying any sensor infrastructure.

This paper summarizes lessons learned about using private sector data to develop project-level work zone mobility performance measures based on experiences in Virginia. A series of case studies are used to show considerations in using private sector data to develop delay and queue length performance measures at four sites. Issues related to the spatial and temporal granularity of the data are discussed, as well as the ability of the data to reflect performance at urban and rural sites. The experience and insights shown in this paper can help guide agencies to better construct new mobility performance measurement programs using this data source.
INTRODUCTION

The Federal Highway Administration (FHWA) has been encouraging states to better monitor and track work zone impacts by creating performance measurement programs that cover a broad range of exposure, safety, and mobility effects (1). The accurate and consistent tracking of work zone mobility impacts has been particularly challenging, however, as states develop performance measurement programs. Consistent and accurate mobility data would allow state departments of transportation (DOTs) to better assess the overall contribution of work zones to network congestion, identify specific projects that are in need of remedial action, and potentially assess penalties to contractors creating excessive delays. This data could also be useful when evaluating contractor requests to work outside pre-defined allowable work hours.

A major challenge in implementing work zone mobility performance measures has been the availability of traffic condition data. Outside of major urban areas, traditional point detector systems like inductive loops or side fire radar are often located at wide spacings. This makes it unlikely that existing sensors would be available to provide data on many operational metrics used by DOTs. In urban areas, traditional sensor coverage is denser, but sensors are often taken off line during construction. Installing new, temporary sensors specifically to monitor work zone mobility is an option, but it is often only cost effective for long-term, major projects. Even then, construction activities could require that sensors be relocated several times during the course of the project, resulting in additional expenses to the DOT.

One option that may overcome traditional point sensor limitations is the use of private sector travel time data generated from probe vehicles. Many states have begun utilizing travel time and speed data that has been purchased from private sector companies like INRIX, TomTom, and NAVTEQ for performance measurement and real-time traveler information. For example, the Texas A&M Transportation Institute Urban Mobility Report (2) currently uses INRIX data to quantify congestion in U.S. cities, and the Virginia DOT and Maryland State Highway Administration use INRIX data to provide real-time traveler information on overhead variable message signs (3,4). Private sector companies typically create their travel time estimates using global positioning system (GPS) data obtained from commercial fleet management systems and private vehicles using navigation or traveler information smart phone applications. This location data is then processed to estimate travel times on roadways. Several studies have shown that this data is generally accurate on freeways, and can be used for real-time traveler information and freeway performance measurement (5,6).

Private sector data has been used to generate work zone project-level performance measures in several states. One recent study developed work zone travel time reliability measures for 15 projects in Virginia (7). The Ohio DOT has also developed a systematic program to track mobility performance measures on a project-level basis using private sector data from INRIX. Figure 1 shows an example of performance measures generated for one project in Ohio (8). The performance measure shown is the number of hours operating under 25 mph. Monthly performance is shown and contrasted to preconstruction performance and speeds observed during the prior calendar year.

As DOTs begin to use private sector data to assess work zone mobility, it is extremely important that they have a clear understanding of the capabilities and limitations of this data source. This paper discusses lessons learned from the development of work zone mobility performance measures in Virginia using private sector data, with the goal of identifying key
decisions that DOTs must make before mainstreaming private sector data into their work zone mobility program.

![Figure 1: Example of work zone performance measures from Ohio DOT (8).](image)

**OBJECTIVES AND SCOPE**

The Virginia DOT has purchased statewide real-time access to private sector travel time and speed data, and has used this information to investigate potential project-level work zone performance measures. The paper discusses several key lessons learned from this investigation, and illustrates some of the capabilities and limitations of this data set using a series of case studies.

The objective of this paper is to identify critical issues in the use of private sector data streams for work zone mobility performance measurement. The ability of the private sector data to produce commonly used work zone performance measures is illustrated using data from INRIX for a sample of Virginia work zones. Although the data was provided by INRIX, the lessons learned from this investigation should apply across other private sector providers as well. Some specific issues that were assessed included:

- What performance measures can be calculated reliably using the private sector data?
- What is the impact of the temporal level of aggregation on the performance measures?
- How does the spatial granularity of the private sector data impact performance measures?

The focus of this paper is on project-level performance measures, although many of the findings can be aggregated upward to be applicable to programmatic performance measures. The accuracy of the data has been previously established in other research (5, 6), so that is not
discussed in detail in this paper. Prior work in Virginia validated the data quality of the INRIX estimates by comparing them to Bluetooth reidentification travel time estimates on 615 directional miles of freeway between June 2011 and June 2013 (9). Those results showed that INRIX data summarized in 5-minute intervals had a mean bias of +0.45 mph and a mean absolute error of 4.7 mph relative to the Bluetooth data, which was within the error tolerances specified by Virginia DOT. These evaluations covered both recurring and non-recurring congestion. As a result, this paper does not present further detailed analysis of the quality of the data. Rather, the focus of this paper is on how the data is summarized and manipulated to develop performance measures.

WORK ZONE MOBILITY PERFORMANCE MEASURES

First, work zone mobility performance measures used by DOTs were reviewed to identify the most common potential application areas for private sector data. A recent domestic scan report (10) summarized common work zone mobility performance measures used by DOTs. Table 1 provides a brief summary of the findings of that report. Delay and queue length were the most common performance measures in use by DOTs, although other unlisted measures (such as travel time reliability metrics (7)), are also possible. It is unclear from the literature, however, whether performance measures were selected because they could be easily measured or because they best represent work zone mobility.

<table>
<thead>
<tr>
<th>Agency</th>
<th>Performance Measure</th>
<th>Performance Threshold</th>
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<tbody>
<tr>
<td>California DOT</td>
<td>Delay</td>
<td>0 to 20 minute delay depending on location and complexity of project</td>
</tr>
<tr>
<td>Florida DOT</td>
<td>Queue length</td>
<td>2 mile maximum queue on interstates or highways with speed &gt; 55 mph</td>
</tr>
<tr>
<td>Indiana DOT</td>
<td>Queue length</td>
<td>Queues cannot be present for &gt; 6 continuous hours, or for more than 12 hours/day. Queues &gt; 1.5 miles are not permitted, and queues between 0.5 and 1.5 miles have are limited to between 2 and 4 hours, depending on length</td>
</tr>
<tr>
<td>Maryland DOT</td>
<td>Queue length</td>
<td>Freeways: queues &gt; 2 miles are not acceptable, queues &lt; 1 mile are permitted, and queues between 1 and 1.5 miles are limited to 2 hours Delays &lt; 15 minutes on arterials LOS requirements are set separately for signalized and unsignalized intersections, depending on initial LOS</td>
</tr>
<tr>
<td>Michigan DOT</td>
<td>Delay Volume/Capacity (V/C) Ratio Level of Service (LOS)</td>
<td>Delays &lt; 10 minutes V/C &lt; 0.8 Drop in LOS &lt; 2 levels, no LOS worse than D</td>
</tr>
<tr>
<td>Missouri DOT</td>
<td>Delay</td>
<td>Delays &gt; 15 minutes are considered excessive</td>
</tr>
<tr>
<td>New Hampshire DOT</td>
<td>Delay</td>
<td>Delays &gt; 10 minutes undesirable</td>
</tr>
<tr>
<td>New Jersey DOT</td>
<td>Delay</td>
<td>Delays &lt; 15 minutes</td>
</tr>
<tr>
<td>Ohio DOT</td>
<td>Queue Length</td>
<td>Queues &gt; 1.5 miles are not acceptable</td>
</tr>
<tr>
<td>Oregon DOT</td>
<td>Delay</td>
<td>Delays &lt; 10% of the peak travel time</td>
</tr>
<tr>
<td>Pennsylvania DOT</td>
<td>Delay</td>
<td>Delays between 15 - 30 minutes limited to 2 consecutive hours</td>
</tr>
<tr>
<td>Wisconsin DOT</td>
<td>Delay</td>
<td>Maximum of 15 minutes of added delays between major city nodes</td>
</tr>
</tbody>
</table>
Given the popularity of delay and queue length measures, this paper focuses on the ability of private sector data to produce these two metrics. Issues with applying private sector data to the calculation of each of these two performance measures are discussed below.

**Using Private Sector Data to Calculate Delay Metrics**

Delay is a measure of the additional time incurred by travelers as a result of the work zone. Delay can be summarized in several ways, including:

- Average delay per vehicle
- Average delay per person
- Total vehicle-hours of delay
- Total person-hours of delay

While private sector data directly provides the speed or travel time information required to determine average vehicle delay values, additional information is required to determine other metrics. The total vehicle-hours of delay measure requires that consistent traffic volume data be available. The per person measures also require that data on vehicle occupancy be available.

In order to calculate all of these delay metrics, the analyst must have at least two pieces of information:

- Data on travel time or speed in the work zone
- A benchmark travel time or speed for comparison purposes

These values are compared to determine whether the work zone has created a negative mobility impact. As a result, the selection of the benchmark travel time/speed is a critical part of the calculation of delay. Common benchmarks for delay and their advantages/disadvantages are shown in Table 2. The different benchmarks have tradeoffs in terms of ease of calculation/collection versus their ability to separate work zone impacts from background conditions.

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
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<tbody>
<tr>
<td>Posted speed limit</td>
<td>Easily defined and understood, often readily available in DOT databases, provides constant benchmark for site</td>
<td>Posted speed limit may not be realistically attained during higher volume periods of the day, especially on arterial routes; may cause delay attributed to the work zone to appear higher than it should be</td>
</tr>
<tr>
<td>Free flow speed</td>
<td>Theoretical upper maximum of travel speed, easily understood, provided by some private sector companies, provides constant benchmark for site.</td>
<td>Much of the daytime period will be determined to have delay even if there are no readily apparent operational issues; delay attributed to work zone may appear higher than reality</td>
</tr>
<tr>
<td>Historic average speed</td>
<td>Allows for separation of work zone impacts from pre-construction recurring congestion</td>
<td>Benchmark varies by time of day, data availability could be problematic (although it is provided by some companies)</td>
</tr>
</tbody>
</table>
Overall, the private sector data can certainly serve as a viable data source for delay measures. Generally speaking, private sector data lends itself most directly to measuring delay in terms of average delay per vehicle. Often accurate volume data from point detectors is not available at work zones, limiting the ability of a DOT to determine total delay. Depending on the vendor selected, each of the benchmarks listed in Table 2 may be available, so the DOT would need to determine which measure would be most widely accepted by the agency. Performance measures involving total delay or per person measures can be partially fed by the private sector data stream, but would require fusion with other data streams to create the final measure.

Using Private Sector Data to Measure Queue Length

While private sector data directly reports travel times and speeds, queue lengths are not measured directly. When using private sector data to develop this measure, queued traffic is typically identified based on when the reported travel speeds drop below a predefined threshold. Thus, selection of this threshold will have a direct impact on the estimated length and duration of queues. For example, one study in North Carolina defined a queue as being present from when traffic is either stopped or slowed more than 25 mph below the posted speed limit until it has reached average speed of 45 mph or more (11). If a DOT used different thresholds, then obviously the estimated queue length and duration would change.

Another concern when using private sector data to assess queue length relates to the way in which speed/travel time data is reported by the vendor. Many vendors report travel times and speeds using Traffic Message Channel (TMC) links. TMCs were defined by mapping companies as a consistent way to report traveler information on digital mapping devices (12). TMCs have been typically defined as homogeneous segments between major interchanges or intersections. If a queue is defined as when a TMC falls below a certain speed threshold, this will cause the entire TMC to be categorized as either queued or not queued. The interaction of the TMC length and the speed threshold plays an important role when using private sector data to estimate queue length. TMC lengths can vary considerably depending on roadway functional class and setting. Urban TMCs are often very short, allowing more precision in the estimation of queue lengths. In rural areas, however, TMCs can be much longer, which can obscure the impact of the work zone in a local area. This can be particularly problematic in work zones since project boundaries or impacts may not align well with the TMCs. One prior study of 15 work zones found that, on average, an additional 1.8 miles of non-work zone roadway was included in the TMCs that contained the work zone (7). To illustrate the impact of this spatial mismatch, consider an 8-mile long TMC that has a 2-mile work zone in the middle of it. In this case, the private sector data may never detect any localized queueing at the work zone since impacts would be “washed out” by the conditions on the other 6 miles of the TMC.

CASE STUDY METHODOLOGY

Four case studies from Virginia are presented to illustrate the abilities, limitations, and key tradeoffs that must be made when using private sector data to develop project-level delay and queue length estimates. The Regional Integrated Transportation Information System (RITIS) developed by the University of Maryland was used to acquire real-time private sector data for
four work zone sites in Virginia with a range of traffic and site characteristics. Information from
the Virginia Department of Transportation was used to identify study locations, define the time
periods when the work zone was active, as well as specific work zone activities that were
occurring.

While all four case studies occurred on the interstate system, each had diverse traits that
could pose a challenge when using private sector data. The four case studies evaluated were:

1. I-81 Northbound, Milepost (MP) 191-200: This site involved a lane closure in a rural,
mountainous area of the state. This site is used to illustrate whether performance
measures could be generated under lower volume conditions during overnight hours in
rural areas.

2. I-95 Southbound, MP 74-84: This site was located in an urban downtown area with
densely spaced interchanges, but construction occurred overnight, when private sector
data is often more limited.

3. I-95 Southbound, MP 158-161: This case study examined a one-day project occurring
during overnight hours in a suburban area, and served to illustrate whether short-term
work zone impacts could be captured accurately.

4. I-81 Southbound, MP 118-140, and US Route 460/11: This case study involved a full
freeway closure in a rural area, and a subsequent detour onto a parallel arterial route. It
serves to illustrate whether impacts due to the work zone could be captured on
surrounding facilities.

In all four cases, field observations noted that queuing and congestion were present during the
work activities. Case studies 1, 2, and 4 present a snapshot of data from a single day within a
long term work zone, while case study 3 shows an example of analysis from a short term work
zone. Performance measures for long term work zones could be aggregated using these daily
analyses, but are not illustrated in this paper.

Data Collection and Performance Measure Calculation

First, information on the spatial extent and duration of the work zones were collected for each
site from VDOT project logs. Specific information acquired included the location of the work
zone (route mileposts) and direction of travel, time when work zone was active, nature of the
work zone, and traffic volumes. Dates and times when lane closures or detours were present
were also noted. Since the focus of this paper is on project level performance measures, data for
one day in which congestion was present at each site is reviewed to illustrate some tradeoffs and
issues that must be confronted by DOTs when calculating performance measures using private
sector data.

Next, speed and travel time data were acquired based on the project information. The
two metrics selected for investigation were average delay per vehicle and queue length. Data
was downloaded using the RITIS Massive Raw Data Downloader based on each site’s location
and the time when work zone impacts were observed. For the purposes of the work zone impact
analysis, it is important to download data that extends farther than the work zone limits in order
to capture any impacts that may extend past the advance warning area. For example, if the work
zone limits were from MP 50-60, data was initially queried for at least from MP 45-65 to ensure
that the full extent of congestion and queuing was collected. Data were then aggregated using
both 1-hour and 5-minute intervals to compare and contrast the impacts of temporal aggregation
on the resulting performance measures. These time intervals were selected to illustrate a range
of values of aggregation, one very disaggregate and one very aggregate. Intermediate levels of
time aggregation would produce results that vary between these values.

The procedure for performance measure calculation was as follows:

1. First, the maximum spatial extent of the queuing and congestion was determined.
   Historic speeds at the site when no work zone was present were provided by the private
   sector provider as a reference point to compare against real-time data while the work
   zone was active. For each TMC and each time interval, the historic average speed was
   compared to the real-time speed when the work zone was present. If real-time speeds
   were less than 90 percent of what was observed historically on that TMC at that time of
day, it was assumed that the TMC was impacted by the work zone. The 90 percent
   threshold was set to try to eliminate periods where minor fluctuations in speed were due
to random variation unrelated to the work zone effects, but still try to capture the work
   zone impacts as fully as possible. To be conservative, if a TMC is determined to be
   affected by the work zone at any given interval, that TMC was retained throughout the
   analysis. Any TMCs that never dropped below this threshold were assumed to not be
   impacted by the work zone and were removed from further analysis.

2. Next, the TMCs were examined to determine whether traffic was queued. RITIS uses a
   threshold of 60 percent of the historic average speed to determine bottleneck locations
   (13), and this was adopted as the threshold for determining queued traffic. If a TMC
   speed drops below 60 percent of the historic average speed, it was marked as queued.
The sum of the lengths of the TMCs falling below this threshold during each time
   interval was summed to determine the queue length. The duration when any link was
   marked as queued was used to determine the overall queue duration at the work zone.
The use of the historic data threshold allows for the separation of work zone impacts
   from pre-existing congestion at the site.

3. To determine the delay caused by the work zone, the sum of the historic travel times
   across contiguous impacted TMCs was subtracted from the observed travel time during
   work zone operations on those same TMCs. This provides a measure of the average
delay per vehicle.

The performance measures were then compared across sites to help illustrate variations in the
quality of performance measures that could be generated from private sector data.
CASE STUDY RESULTS

Case Study 1: I-81 Northbound, MP 191 – 200

The first case study occurred on I-81 Northbound from MP 195 to 197 in Rockbridge County, VA. The right lane of a two lane directional segment was closed as part of ongoing work on a truck climbing lane project. The section was located in a rural area and had a grade of approximately +2.9 percent. The 2012 directional annual average daily traffic (AADT) was approximately 20,000 veh/day. This work zone project began in February 2009 and had an estimated completion date in late 2013, but this case study focuses on data from 6/19/12.

Although the work zone was only present from MP 195 to 197, the private sector data revealed traffic impacts that extended from MP 191 to 200. A key consideration at this site is that heavy vehicles composed approximately 50 percent of the traffic stream during these hours. Since the work zone was on an uphill grade, the high truck volumes caused traffic capacity to be substantially lower than would be observed on flat, level terrain. Furthermore, the trucks often drove side-by-side until they reached the taper to deter queue jumping, which further reduced capacity and increased queuing.

Figure 2a shows the average delay experienced between MP 191 and 200 between 7:00 PM and 11:30 PM on 6/19/12 using both 1-hour and 5-minute aggregation intervals. Figure 2a shows that there is a marked difference in the performance measures calculated depending on the aggregation interval used. Using a 1-hour interval serves to dampen variation in the data at this site. The maximum delay using the 1-hour interval was 20.56 minutes, while it was 31.52 minutes using the 5-minute summary interval. This difference could create significant impacts, depending on how the performance measures are being used at the project level. If they are being used to assess penalties to contractors or determine compliance with work zone performance measures, an hourly aggregation interval would be less likely to detect sub-hourly intervals where the contractor exceeds allowable thresholds. Thus, while an hourly aggregation interval may reduce analytical workload for the development of monthly or annual programmatic work zone performance measures, they may be very conservative if they are being used to assess real-time contractor compliance with operational targets.

Figure 2b shows the queue length that was estimated at this site using the private sector data. The queuing diagram exhibits far less variation than the delay figure due to the influence of the TMC size. In this case, the 9.3 mile analysis length was composed of only 4 TMCs which ranged in length from 0.58 and 5.04 miles. Since each of these four TMCs were either identified as queued or not queued based on the speed threshold noted earlier, this produced a queuing figure that resembles a step function with very sudden changes. In this case, long TMCs (like the 5.04 mile section) create impediments to using private sector data for queuing performance measures in rural areas. These issues are not present in the delay calculations at this site, however. This indicates that queue measures should be viewed with caution in rural areas due to the influence of average TMC size on the queue length estimates.
FIGURE 2  (a) Average delay and (b) Queue length for case study 1 on 6/19/12 between 7 PM and 11:30 PM.
Case Study 2: I-95 Southbound, MP 74 - 84

The second case study involved closure of 2 out of 3 southbound lanes on I-95 in downtown Richmond, VA on Sunday through Thursday evenings (9/30/2012 – 10/5/2012) from 8:00 PM to 6:00 AM. I-95 was reduced to one travel lane in each direction between the Lombardy Street Bridge (MP 77) and Laburnum Avenue (MP 79). Although drivers were advised to follow posted detour routes, significant congestion was still observed on I-95. The 2012 AADT of this location was approximately 65,000 veh/day. Based on the private sector data, it was found that the work zone impacts extended from MP 74 to 84.

Figures 3a and 3b show the results of the delay and queue performance measure calculations at this site on 9/30/12 between 8 PM and Midnight. Figure 3a shows the delay performance measure calculations for the site for the 1-hour and 5-minute aggregation intervals. In this case, there are smaller differences between the two aggregation intervals than in case study 1, but the hourly aggregation interval still serves to dampen the impact of the work zone peaks. It also fails to capture the onset and dissipation of congestion at the site as accurately since the start/end of congestion both happened approximately midway through the hour.

Figure 3b shows the queuing profile for the site, and serves as a contrast to case study 1. The total analysis length of this site was similar to case study 1 (9.3 miles for case study 1 vs. 9.6 miles for case study 2), but many more TMCs were present for case study 2. A total of 4 TMCs were available for case study 1 vs. 17 TMCs for case study 2. The 17 TMCs for case study 2 ranged in length from 0.08 to 1.89 miles. The shorter mean TMC length for case study 2 is representative of what is often seen in urban areas where TMCs have been created based on complex, closely spaced interchanges. This granularity in turns permits much more accurate estimates of queue length to be developed in comparison to more rural cases with longer TMCs. The 5-minute aggregation interval still reflects changing queues more rapidly, as well as the sub-hourly variation, but differences between 1-hour and 5-minute results are generally not as large as in case study 1.
FIGURE 3  (a) Average delay and  (b) Queue length for case study 2 on 9/30/12 between 8 PM and 12:00 AM.
Case Study 3: I-95 Southbound, MP 158-161

The third case study examined a short-term work zone on I-95 SB in the suburbs of Washington, D.C. At 9:00 PM on 2/17/2012, VDOT removed a 30 foot tall cantilevered sign structure located on southbound I-95 at the interchange with the Prince William Parkway in Woodbridge. The 2012 directional AADT of this section of road was approximately 80,000 veh/day. Two of three lanes were closed, but motorists could avoid delays by using the parallel high occupancy vehicle (HOV) lanes. The private sector data showed that the area impacted by the work zone extended for approximately 3.5 miles from MP 158 to 161.

This case study served to examine whether performance measures could be determined for a one-time, short term work zone that occurred during overnight hours. Real-time data was available for this site, and measured impacts were corroborated by field observations. Figure 4a shows the delay measurements at the site. Generally speaking, this site showed greater consistency between the 5-minute and 1-hour aggregation intervals than other case studies. In general, the 5-minute results were within ± 5 minute of the 1-hour averages. Once again, the 5-minute intervals showed more variability in results.

Figure 4b shows the queues experienced at the site. Since this was an urban area, once again TMC sizes were relatively short. The 3.56 mile analysis length was composed of 5 TMCs with lengths between 0.36 and 1.42 miles. Similar to the delay calculations, the results were relatively similar between the 5-minute and 1-hour aggregation intervals. The small average TMC length allowed for reasonably detailed queue length estimates to be generated as well. Estimated queue length durations were longer for the 1-hour aggregation interval, however, since the onset and dissipation of congestion were not captured to as great of a temporal resolution.
FIGURE 4 (a) Average delay and (b) Queue length for case study 3 on 2/17/12 between 9:00 PM and 3:00 AM.
Case Study 4: I-81 Southbound, MP 118 – 140, and US 11/460

The final case study involved construction of a new truck climbing lane on I-81 SB between Salem, VA and Christiansburg, VA. This project began in 2010 and has an estimated completion in late 2013. The work was located on an existing two lane directional segment with a +3.7 percent grade sustained for 2.2 miles and a 2012 directional AADT of 25,000 veh/day. On July 18, 2012, a full interstate closure was conducted due to blasting operations on I-81. Traffic was detoured onto US 11/460 at I-81 exit 132 and back onto I-81 at exit 118. The detour route had a 2012 AADT (without detour traffic) of approximately 18,000 for both directions of travel combined. The detour route was a four lane divided arterial.

On the day studied, the detour was implemented between 10:30 AM and 1:00 PM. A right lane closure was also in place on westbound Route 11/460 during the detour. The private sector data showed work zone impacts extended for approximately 8 miles from MP 132 to 140 on I-81, as well as throughout the length of the detour route. This case study serves to illustrate how the private sector data can be used to assess system-wide impacts of work zones on parallel facilities, as well as issues related to the use of the data on arterial roads.

Figures 5a and 5b show the delay and queuing impacts that occurred on I-81 as a result of the freeway closure. The section of road monitored was 16.8 miles long, and consisted of 6 TMCs. The TMCs ranged in length from 0.17 to 8.64 miles. Figure 5a shows that using a 1-hour aggregation interval masks many sub-hourly variations, sometimes causing an under-reporting of delay by almost 15 minutes/veh. The onset and dissipation of congestion is also not captured adequately. Figure 5b shows the estimated queue that was determined. The maximum queue is significantly lower using the 1-hour interval, and the duration of queuing is also underestimated by approximately 1 hour. In this case, the TMC located closest to the diversion point was 4.42 miles long. As a result, the initial queue quickly changed from 0 to 4.42 miles. The relatively coarse spatial granularity on the section of rural interstate makes the queuing estimates less reliable than what was seen in case studies 2 and 3.

Figures 6a and 6b show conditions along the arterial detour route during the freeway closure. The detour route was 10.73 miles long, and composed of just 2 TMCs which were 4.35 and 6.38 miles long. Figure 5a shows the delay that was experienced on the detour route. The figure shows that the hourly aggregation significantly deviates from the 5-minute aggregation during the onset and dissipation of congestion. When the data in Figure 6a is combined with the data from Figure 5a, it should be possible to determine a combined user delay impact for the entire work zone. Figure 6b shows the estimated queue from the private sector data. Given that only 2 TMCs were available over the entire 10.73 mile detour route, the estimated queues are very coarse and cannot be assumed to reliably show the spatial extents of queuing. There is also a significant difference in the estimated queue duration of about 1 hour between the 1-hour and 5-minute aggregation intervals. Again, use of the hourly data causes the averages to be much lower than when shorter durations are used.
FIGURE 5. (a) Average delay and (b) Queue length for I-81 case study 4 on 7/18/12 between 10 AM and 2 PM.
FIGURE 6. (a) Average delay and (b) Queue length for US 11/460 case study 4 on 7/18/12 between 10 AM and 2 PM.
While this case study shows that it is possible to generate system-wide estimates of work zone mobility impacts, it also shows some of the difficulties than can arise as a result of long aggregation intervals and large TMC lengths. The hourly data significantly underestimated the duration of queuing on both the mainline and arterial route, and the large TMC lengths on these rural sections also made estimates of queue length inherently imprecise. These queue length measures would not appear to be suitable for project level performance measurement, particularly if contractor performance would be subject to penalties or remedial actions.

LESSONS LEARNED

This research attempted to define specific lessons learned that would impact how a DOT sets up a work zone mobility performance measurement program using private sector travel time and speed data. Major findings from the cases studies are discussed below.

Applicability to Different Performance Measures

Private sector travel time data were used to determine two commonly used work zone performance measures: delay and queue length. Delay could generally be calculated easily from the data sets that were used. Historic average speeds were available for pre-construction conditions which allowed calculation relative to that baseline measure. Alternatively, posted speed limits or other thresholds could be easily used.

Queue length was a more problematic measure for the private sector data. First, a speed threshold had to be set below which traffic on the link was determined to be queued. Thus, the amount of queuing determined will be sensitive to the threshold value selected by the DOT. A more significant issue is the influence of TMC granularity on the determination of queue length and queue duration. The case studies in this paper serve to illustrate the large variability in TMC size that can be present in rural vs. urban facilities. The rural facilities of case studies 1 and 4 had mean TMC lengths of between 2.3 and 5.4 miles, while the urban/suburban work zones of case studies 2 and 3 had average TMC lengths of 0.56 and 0.71 miles. Thus, using private sector data to define queue lengths should be viewed cautiously, especially in rural areas. This concern is heightened for project-level performance measures where there could be project cost implications if queues are not measured correctly.

Spatial Aggregation Impacts

The spatial granularity at which the data is reported should be closely considered when defining a work zone performance measurement program. TMCs are typically defined based on the locations of intersections or interchanges. Since work zones may occur at the midpoint of TMCs, long TMCs could mask the impact of the work zone by including a significant amount of non-work zone travel data. Given the differences in rural and urban TMC lengths, it currently appears that urban sites could be most effectively monitored using the private sector data. Analysts should closely examine the TMC sizes before proceeding with performance measure calculations, especially in rural locations. If the spatial aggregation intervals are too large, the agency may need to install temporary point detectors to adequately monitor conditions at a work zone.
Temporal Aggregation Impacts

Another issue that could impact performance measure outputs is the level of temporal aggregation. This is especially important for project-level assessments that could be used to ask contractors to make changes to the traffic control plans or to assess performance penalties. As the time over which performance measures are created increases, the severity of congestion tends to be masked. For example, if the DOT is interested in the amount of time delay exceeds 15 minutes at a work zone, the a 1-hour aggregation interval will result in fewer violations than if the performance measures are calculated every 5 minutes. Thus, the DOT should carefully consider and specify the time over which any performance measures are aggregated.

FUTURE DIRECTIONS FOR PRIVATE SECTOR DATA

It should be emphasized that the findings of this research represent current conditions as of the writing of this paper. Private sector companies are continually refining their methodologies and attempting to improve their sample sizes. Future developments may allow for dynamic segmentation of TMCs or other improvements that could remove some of the current limitations of using private sector data in rural areas.

Likewise, DOTs will need to have a computerized system that can perform project monitoring automatically if private sector data is to be mainstreamed into work zone performance measurement. In this paper, the RITIS software developed by the University of Maryland was used. Several vendors are making software modifications that can fuse together DOT work zone records with probe vehicle records to generate performance measure figures and charts in an automated manner. Provision of these tools will help enhance and expand the use of this data stream for mobility measurement in work zones.

REFERENCES


