Chapter 7 Presentation Script

Welcome to the Manual on Uniform Traffic Studies, also called MUTS, computer-based training! This training module will cover Chapter 7 - Intersection Delay Study.

This training contains audio, so please adjust your speakers accordingly. An alternate version is available on the resources page. To begin, select the start button or press Shift + N on your keyboard.

During this training module, we will refer to one form in excel format stored on the MUTS online library through the F-D-O-T's Traffic Engineering and Operations Office website. Before continuing the training, consider scanning the Q-R code using your phone camera. It will direct you to the online library shown in this slide. The link to the form is also provided in the resources page to this training. Please open Form number 750-020-07 as we will refer to it later in the module.

We will begin the training by describing the purpose of intersection delay studies.

Intersection delay studies measure the performance of intersections with respect to vehicular movement. These studies capture the experience of drivers as they pass through an intersection or use an intersection to turn onto another route. As a primary metric of intersection performance, delay studies are critical for several traffic engineering studies, including the ones shown on the right sidebar of this slide.

To inform this wide variety of studies, the delay measure can be categorized into various types.

The first type is time in queue delay, which is the time it takes a motorist to join the back of a queue, advance through it, and clear the intersection on the other end.

Control delay is the time difference between what a motorist experiences with the intersection and what the motorist would experience in an uncontrolled condition, without the intersection.

Geometric delay reflects the slowdowns experienced as motorists reduce their speed to navigate geometric features, such as curves.

Two other types of delay are described in the MUTS, which are aggregations of the three types discussed earlier.

Travel Time Delay is computed for segments, which can include one or more intersections. It is the time difference between what a motorist experiences traveling through the segment versus what the motorist would experience if the segment had no intersections and the motorist could simply continue traveling at its approach speed. Refer to Chapter 13 of the MUTS for additional guidance on Travel Time Delay Studies.

The Extra Travel Time Delay measure is a recent addition to the toolbox. It was included in the Highway Capacity Manual or HCM 6th Edition to better capture the delay associated with navigating alternative intersection designs, where motorists often have to travel out-of-direction followed by a U-turn to complete a movement.

This slide summarizes how the different types of delay relate to each other.

The time spent in queue plus the time it takes to decelerate and accelerate at an intersection constitute the control delay. In turn, when you add control delay to the geometric delay associated with traversing a segment with one or more intersections, you get the travel time delay. Finally, the new Extra Travel Time Delay adds the extra distance travel time associated with out-of-direction travel.

Now that we have an understanding of the purpose of intersection delay studies and the types of delay that can be measured, we will turn to the equipment you may use to conduct them.

Before we talk about measuring delay, it is important to talk about resources for gathering other data points that are often an input to intersection delay studies.

Intersection turning movement counts, also known as TMCs, are often required to conduct a delay study and to compute overall intersection delay. These counts may be collected through manual or automated means. MUTS Chapter 4 – Turning Movement Counts covers the available methods and procedures to collect TMCs. Refer to Chapter 4 for additional guidance on TMCs.

Secondly, intersection delay studies often rely on a comparison to free-flow approach speeds. MUTS Chapter 12 – Vehicle Spot Speed Study provides detailed information on the equipment, personnel, and procedures needed to obtain these speeds.

This slide focuses on the equipment that is often used to measure control delay, which you may recall is the time spent in the queue plus acceleration and deceleration delay. For additional reference, MUTS Table 7-1 contains a summary of commonly used equipment for intersection delay studies.

There are several tools that can aid during manual data collection and input. The most basic of tools is simple tally sheets, using forms such as the ones discussed in this chapter. We will describe those in more detail in later slides.

Another solution is electronic count boards, which can keep track of time while aiding in data entry. As mentioned earlier, cameras may also be used to enable post-processing of counts away from the count site. The cameras can be mounted to poles or on drones. Mobile devices such as laptops, tablets, and phones may be loaded with software that can help keep track of time, aid in data entry, and summarize the data for delivery.

To capture travel time delay, which is computed from point A to point B, different equipment is needed. Test vehicles (also known as floating cars) can be used with either manual timekeeping and recording or **with** assistance from GPS devices. Additional guidance on test vehicles is included in later slides. Refer to MUTS Chapter 13 – Travel Time and Delay Study for additional information on equipment and personnel needs for data collection.

There are also ways to estimate travel time delay with minimal field labor. A computer model can be built to simulate the performance of the intersection. Another way that has become commonplace in recent years is **the** use of probe data from cell phones or connected vehicles. We will share guidance on the use of probe data towards the end of this training.

Before we get into procedures and analyses of the data, it's important to cover the personnel and training requirements associated with intersection delay studies.

The number of observers needed will vary with the specifics of the study and the location, but is primarily based on the equipment being used, the duration of the counting period, the level of traffic, and the number of lanes being observed.

It's good practice to plan for breaks of 10-15 minutes every two hours, and 30-45 minutes every four hours for data collection periods longer than 8 hours.

When measuring delay on the field, it is recommended that the observers stand at about the midpoint of the maximum queue expected on the right sidewalk or shoulder, at a point where they have a clear view of the lanes being observed.

In general, a single observer can record queued vehicles for up to two lanes if the queues are under 25 vehicles per lane. A single observer could also record long queues on a single lane if they use an audio signal to mark the end of the count interval. The audio signal should also be used on two lanes if the queues are approaching 25 vehicles per lane. In other situations, two observers are usually required.

If drones are being used for the data collection, it is critical to prepare ahead of time as the Federal Aviation Administration regulates the operation of drones. Regulations include altitude restrictions or complete bans on flying drones. All data collection should be researched in advance to comply with these regulations. Refer to MUTS Chapter 4 – Turning Movement Counts for additional guidance on the use of drones for intersection data collection.

This next section covers the form in this chapter, which can be used to measure control delay in the field.

The basic process of measuring control delay involves repeatedly counting queued vehicles on an intersection approach every 10 to 20 seconds. The choice of count interval is up to the practitioner and should consider cycle length and signal actuation. At a signalized intersection, the signal's cycle length should not be divisible by the count interval. In other words, if the signal cycle is 90 seconds, the analyst should not pick 10 or 15 seconds as the count interval, but rather pick 14 or 20 seconds. This reduces bias associated with queues building up in a cyclical pattern.

This field-based approach is generally applicable when queues are up to 25 vehicles per lane but could be extended with more observers or video cameras.

The form included in this chapter can be helpful when performing these counts. As with other MUTS forms, the heading of the form should be filled out completely. Some general information such as date, time, intersection name, and area type could be filled out in advance of the field review.

Also, record the number of lanes, free-flow speed, cycle length, and the selected count interval as described in the previous slide. MUTS Chapter 12 - Vehicle Spot Speed Study provides guidance on collecting the free-flow approach speed.

The middle portion of the form is where the observer will record the queue counts based on field observations. A queued vehicle is considered as any vehicle traveling less than 3 miles per hour or two-three vehicle lengths from the vehicle that is queued in front of it.

Preferably, begin the counts at the start of a red phase when there are no remaining vehicles from the previous cycle. By starting the data collection before congestion builds up, it will be easier to find such a time.

For each survey count interval, record the number of vehicles in the queue. A vehicle must be counted more than once if it is stopped during more than one sampling interval. That is, a particular vehicle will continue to be counted in all intervals during which it remains stopped on the intersection approach.

Also record the approach volume, broken down by whether the vehicles stopped or did not stop. Vehicles stopping multiple times should only be counted once under the approach volume columns. This vehicle count is conducted for the entire study period.

There are three equations included in the bottom part of the chapter form, which are covered in MUTS Section 7.4. The first equation discussed in the MUTS summarizes the two components of control delay, which are time in queue delay and acceleration and deceleration delay. We will now show how to compute these two components using the other two equations.

The next equation discussed in the MUTS covers the acceleration and deceleration delay, which is calculated as the product of the fraction of vehicles stopping times a delay correction factor.

The fraction of vehicles stopping is equal to the number of vehicles stopping divided by the total number of vehicles. This is computed for each approach across the entire study period.

As an example, in this filled form the number of vehicles stopping was 223. The total number of vehicles on the approach was 530. Therefore, the fraction of vehicles stopping is 0.42.

Let's take a look at the second term in the equation or C-F.

The second term in the equation (C-F) is an empirical correction factor that can be looked up from MUTS Table 7-3, **which** is also included on the form itself.

To look up the C-F, you need to know two pieces of information: the first one is the number of vehicles stopping per lane per cycle, which can be obtained using the equation shown here. It is calculated using the number of vehicles stopping divided by the product of the number of cycles and the number of lanes. All these inputs are highlighted for our example form. In this example, there are 13.9 vehicles stopping per lane per cycle.

The second piece of information you need is the approach speed, also referred to as the free-flow speed in the form or shown in the green box here on our example. In this case, the approach speed is 45 miles per hour.

So, for this example, we can conclude that our C-F is +4.

Finally, taking the fraction of vehicles stopping from the previous slide (0.42) and the C-F, we obtain an acceleration/deceleration delay of 1.68 seconds per vehicle.

The final equation in this section is for time in queue delay. It multiplies an empirical factor (0.9) times the ratio of queued vehicles to all vehicles, and times the count interval in seconds.

On our example form, you will find the survey count interval here, the sum of all vehicles in queue here, and the total number of vehicles here. Once you plug in the values into the equation, we obtain a time in queue delay of 10.27 seconds.

Now that we have both the acceleration/deceleration delay and the time-in-queue delay, we can go back to the first equation and compute the total control delay for our example.

As we saw, the time-in-queue delay was 10.27 seconds. The acceleration/deceleration delay was 1.68 seconds. Adding those together results in a control delay of 11.95 or approximately 12 seconds.

If the analyst is using the Excel version of the form, this and other equations are automatically computed as the data is recorded electronically.

We will now cover the procedures for measuring travel time delay: manual test vehicle, **GPS**-assisted test vehicle, and **probe** data. Probe data may be obtained using Bluetooth or Wi-Fi readers or be purchased from commercial vendors that aggregate GPS and cell phone location data, such as INRIX, HERE, StreetLight Data, and others.

The test vehicle method also known as floating car is widely used on arterial streets. It requires a minimum one-mile route length and could be performed with three different techniques: average car, where the driver aims to keep to the average speed in the corridor; floating car, where the driver passes as many vehicles as pass the test car; and maximum car, where the driver drives at the speed limit unless impeded by traffic or safety considerations. Much more detail on the test vehicle method is available in MUTS Chapter 13 - Travel Time and Delay Study, refer to this chapter for additional guidance on the test vehicle method.

Recent advances in technology and wider availability of data are enabling the use of probe data to calculate intersection- and segment-level delays. However, because of typically low sample sizes, an extended data collection period is needed.

The duration of the data collection period for probe data will depend on the answer to four key questions:

How many motorists use the approach, intersection, or segment that you are studying?

What percentage of motorists are included in the sample you are collecting? This will vary depending on the specific technology being used and is usually available from the data or equipment vendor.

What is the inherent variability in what is being measured? If a roadway is typically at or near a fixed speed, then it follows that you don't need as many samples to confirm that.

Finally, how accurate does the estimate need to be? A planning study may require less precision than a traffic operations study.

For purposes of the MUTS Table 7-4 included in this chapter, these four questions are interpreted as the traffic volume or A-A-D-T, the capture rate, the speed range, and the confidence interval and permitted error. For the last one, MUTS Table 7-4 assumes a 95% confidence interval and a 1 mile per hour permitted error, which is in line with operational-level studies.

Out of those four items, the speed range is the one that the analyst may need to compute beforehand using readily available data, such as a spot speed study or a sample dataset. The speed range is defined as the difference between the maximum speed and the minimum speed observed during the study period.

If the maximum or minimum speeds are outliers and not representative of travel in the corridor, the analyst may select the 90^{th} and 10^{th} percentile instead.

An example of a spot speed study distribution is included on the right side of this slide. In this example, the maximum speed is 55 miles per hour and the minimum speed is 25 miles per hour, leading to a speed range of 30 miles per hour. Neither the maximum or the minimum speeds are outliers in this example, but if they were, the speed range would use the 90th and 10th percentiles shown in the distribution (47 and 29 miles per hour).

Here is a subset of MUTS Table 7-4, which shows the minimum number of weeks of probe data that must be collected for segment delays and for intersection delays, which are shown in parentheses. The user must first select the speed range closest to the one experienced in the facility.

Then, the user must look up the appropriate capture rate. This will vary depending on the source of the probe data and is generally available from the vendor.

Finally, the user must look up the segment A-A-D-T or the lower of the two A-A-D-Ts of intersecting roads at an intersection.

Regardless of which method is used to collect data, the travel time delay can be computed by **comparing** the travel time through the intersection against the unimpeded travel time. If probe data is being used, **unimpeded** travel time may be obtained by analyzing low-traffic hours, such as late night or early morning.

Note that probe data is usually summarized by short segments, often called traffic message channels. To compute travel time for a corridor, travel times for all traffic message channels in the corridor must be summed for each time period collected. In this example, **there** are three traffic message channels: a, b, and c. Together, they cover the study corridor **from** node number 1 to node number 2.

To obtain travel times for the study corridor, the individual traffic message channel travel times must be added. For example, for the first time period, the corridor travel time is 6 + 4 + 3 equal 13 minutes. Note that the second time period has missing data for one of the traffic messages channels, so we cannot compute a corridor travel time for that time period.

Let's now look at key takeaways from this chapter and how to access the forms.

Intersection delay is a primary performance measure used in a wide variety of traffic studies.

There are different types of delay and different methods of collecting it, either on the field or at the office using simulation and data.

Field collection for control delay can be suitable for intersections with queues up to 25 vehicles per lane but could be extended with additional observers and equipment.

The form included in this chapter and shown in this slide can help collect and analyze field-collected data. It can be accessed by clicking the link on this slide or by scanning the Q-R code with a cellphone camera.

Finally, probe data offers a convenient way of computing intersection and segment delays but requires weeks or months of data due to lower sample sizes. Guidance is included in this chapter to aid with collecting and computing travel time from probe data.

This concludes the Manual on Uniform Traffic Studies computer based training, Chapter 7 - Intersection Delay Study.

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You will now be directed to a 10-question quiz to test your knowledge and understanding on the material presented in this computer-based training. A passing grade of 70% is required to obtain the Certificate of Completion for the training. If a grade below 70% is obtained, the trainees are required to re-take the full training until a passing grade of 70% or higher is obtained. If you do not pass the quiz, please return to the Index page by selecting the Index button below and re-take this training. To continue to the next chapter of this training please select the “NEXT” button below this CBT. On the next slide, please enter your first and last name before continuing to the quiz. Thank you for your time and attention.

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