Travel Time and Delay Studies

Introduction

A travel time study determines the amount of time required to travel from one point to another on a given route. In conducting such a study, information may also be collected on the locations, durations, and causes of delays. When this is done, the study is known as a travel time and delay study. Data obtained from travel time and delay studies give a good indication of the level of service on the study section. These data also aid the traffic engineer in identifying problem locations, which may require special attention in order to improve the overall flow of traffic on the route.

Applications of Travel Time and Delay Data

- Determination of the efficiency of a route with respect to its ability to carry traffic.
- Identification of locations with relatively high delays and the causes for those delays.
- Performance of before-and-after studies to evaluate the effectiveness of traffic operation improvements.
- Determination of relative efficiency of a route by developing sufficiency ratings or congestion indices.
- Determination of travel times on specific links for use in trip assignment models.
- Compilation of travel time data that may be used in trend studies to evaluate the changes in efficiency and level of service with time.
- Performance of economic studies in the evaluation of traffic operation alternatives that reduce travel time.

Definition of Terms Related to Time and Delay Studies

1. Travel time is the time taken by a vehicle to traverse a given section of a highway.

2. Running time is the time a vehicle is actually in motion while traversing a given section of a highway.

3. Delay is the time lost by a vehicle due to causes beyond the control of the driver.

4. Operational delay is that part of the delay caused by the impedance of other traffic. This impedance can occur either as side friction, where the stream flow is interfered with by other traffic (for example, parking or unparking vehicles), or as internal friction, where the interference is within the traffic stream (for example, reduction in capacity of the highway).

5. Stopped-time delay is that part of the delay during which the vehicle is at rest.
6. Fixed delay is that part of the delay caused by control devices such as traffic signals. This delay occurs regardless of the traffic volume or the impedance that may exist.

7. Travel-time delay is the difference between the actual travel time and the travel time that will be obtained by assuming that a vehicle traverses the study section at an average speed equal to that for an uncongested traffic flow on the section being studied.

Methods for Conducting Travel Time and Delay Studies

- Those using a test vehicle and
- Those not requiring a test vehicle.

Methods Requiring a Test Vehicle

This category involves three possible techniques: floating-car, average-speed, and moving-vehicle techniques.
Floating-Car Technique: In this method, the test car is driven by an observer along the test section so that the test car "floats" with the traffic. The driver of the test vehicle attempts to pass as many vehicles as those that pass his test vehicle. The time taken to traverse the study section is recorded. This is repeated, and the average time is recorded as the travel time. The minimum number of test runs can be determined using an equation below, using values of the *t* distribution rather than the *z* values. The reason is that the sample size for this type of study is usually less than 30, which makes the *t* distribution more appropriate. The equation is:

$$N = \left(\frac{t_\alpha \times \sigma}{d}\right)^2$$

Where
N =sample size (minimum number of test runs).
s = standard deviation (mi/h).
d = limit of acceptable error in the speed estimate (mi/h).
t_α= value of the student's t distribution with (1 - α /2) confidence level and (N - 1) degrees of freedom
α = significance level.

The limit of acceptable error used depends on the purpose of the study. The following limits are commonly used:

- Before-and-after studies: 1.0 to 3.0 mi/h
- Traffic operation, economic evaluations, and trend analyses: 2.0 to 4.0 mi/h
- Highway needs and transportation planning studies: 3.0 to 5.0 mi/h

Average-Speed Technique: This technique involves driving the test car along the length of the test section at a speed that, in the opinion of the driver, is the average speed of the traffic stream. The time required to traverse the test section is noted. The test run is repeated for the minimum number of times, determined from above, and the average time is recorded as the travel time.

In each of these methods, it is first necessary to clearly identify the test section. The way the travel time is usually obtained is that the observer starts a stopwatch at the beginning point of the test section and stops at the end. Additional data also may be obtained by recording the times at which the test vehicle arrives at specific locations which have been identified before the start of the test runs. A second stopwatch also may be used to determine the time that passes each time the vehicle is stopped. The sum of these times for any test run will give the stopped-time delay for that run. Table 1 shows an example of a set of data obtained for such a study.

Table 1 Speed and Delay Information.

Street Name: 29 North *Date: July 7, 1994*
Weather: Clear *Non-peak* *Time: 2:00–3:00 p.m.*

Cross Streets	*Distance (ft)*	*Travel Time (sec)*	*Segment Speed (mi/h)*	*Stop Time (sec)*	*Reason for Stoppage*	*Speed Limit (mi/h)*	*Ideal Travel Time (sec)*	*Segment Delay (sec)*	*Net Speed (mi/h)*
Ivy Road	0	0.0	–	0.0		–	0.0	0.0	–
Massie Road	1584	42.6	25.4	20.1	Signal	40	27.0	15.6	17.2
Arlington Blvd.	1320	27.7	32.5	0.0		40	22.5	5.2	32.5
Wise Street	792	19.7	27.4	8.9	Signal	40	13.5	6.2	18.9
Barracks Road	1320	32.1	28.0	15.4	Signal	40	22.5	9.6	18.9
Angus Road	2244	49.8	30.7	9.2	Signal	40	38.3	11.5	25.9
Hydraulic Road	1584	24.4	44.3	0.0		45	24.0	0.4	44.3
Seminole Court	1584	42.6	25.4	19.5	Signal	45	24.0	18.6	17.4
Greenbrier Drive	1848	41.5	30.4	15.6	Signal	45	28.0	13.5	22.1
Premier Court	1320	37.4	24.1	11.8	Signal	45	20.0	17.4	18.3
Fashion Square I	1584	23.6	45.8	4.9	Signal	45	24.0	−0.4	37.9
Fashion Square II	1056	19.7	36.5	0.0		45	16.0	3.7	36.5
Rio Road	1056	20.2	35.6	14.1	Signal	45	16.0	4.2	21.0
Totals	17292	381.3	30.9	119.5			275.8	105.5	23.5

Alternatively, the driver alone can collect the data by using a laptop computer with internal clock and distance functions. The predetermined locations (control points) are first programmed into the computer. At the start of the run, the driver activates the clock and distance functions; then the driver presses the appropriate computer key for each specified location. The data are then recorded automatically. The causes of delay are then recorded by the driver on a tape recorder.

Moving-Vehicle Technique: In this technique, the observer makes a round trip on a test section like the one shown in Figure 1, where it is assumed that the road runs east to west. The observer starts collecting the relevant data at section X-X, drives the car eastward to section Y-Y, then turns the vehicle around and drives westward to section X-X again.
The following data are collected as the test vehicle makes the round trip:
• The time it takes to travel east from X-X to Y-Y (*Te*), in minutes.
• The time it takes to travel west from Y-Y to X-X (*Tw*), in minutes.
• The number of vehicles traveling west in the opposite lane while the test car is traveling east (*Ne*).

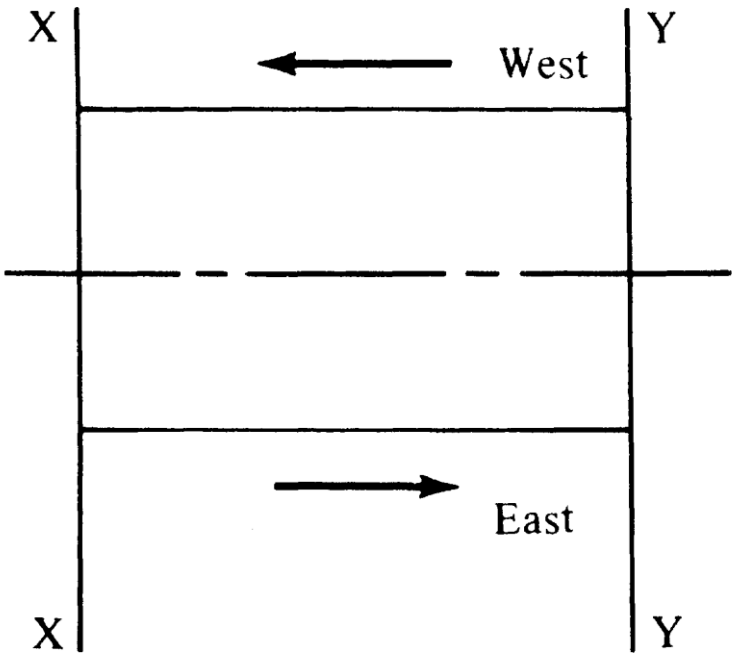

Figure 1 Test Site for Moving-Vehicle Method.

- The number of vehicles that overtake the test car while it is traveling west from Y-Y to X-X, that is, traveling in the westbound direction (O_w).
- The number of vehicles that the test car passes while it is traveling west from Y-Y to X-X, which is, traveling in the westbound direction (P_w).

The volume (V_w) in the westbound direction can then be obtained from the expression:

$$V_w = \frac{(N_e + O_w - P_w)60}{T_e + T_w}$$

Where (Ne - Ow - Pw) is the number of vehicles traveling westward that cross the line X-X during the time (Te-Tw). Note that when the test vehicle starts at X-X, traveling eastward, all vehicles traveling westward should get to X-X before the test vehicle, except those that are passed by the test vehicle when it is traveling westward. Similarly, all vehicles that pass the test vehicle when it is traveling westward will get to X-X before the test vehicle. The test vehicle will also get to X-X before all vehicles it passes while traveling westward. These vehicles have, however, been counted as part of Ne or Ow and therefore, should be subtracted from the sum of Ne and Ow to determine the number of westbound vehicles that cross X-X during the time the test vehicle travels from X-X to Y-Y and back to X-X.

Similarly, the average travel time $\overline{T}_w$ in the westbound direction is obtained from

$$\frac{\overline{T}_w}{60} = \frac{T_w}{60} - \frac{O_w - P_w}{V_w}$$

$$\overline{T}_w = T_w - \frac{60(O_w - P_w)}{V_w}$$

If the test car is traveling at the average speed of all vehicles, it will most likely pass the same number of vehicles as the number of vehicles that overtake it. Since it is probable that the test car will not be traveling at the average speed, the second term of Eq. above corrects for the difference between the number of vehicles that overtake the test car and the number of vehicles that are overtaken by the test car.

Example

The data in Table below were obtained in a travel time study on a section of highway using the moving-vehicle technique. Determine the travel time and volume in each direction at this section of the highway.
Mean time it takes to travel eastward (Te) = 2.85 min
Mean time it takes to travel westbound (Tw) = 3.07 min
Average number of vehicles traveling westward when test vehicle is traveling
Eastward (Ne) = 79.50
Average number of vehicles traveling eastward when test vehicle is traveling
Westward (N_w) = 82.25

Average number of vehicles that overtake test vehicle while it is traveling westward (O_w) = 1.25

Run Direction/ Number	Travel Time (min)	No. of Vehicles Traveling in Opposite Direction	No. of Vehicles That Overtook Test Vehicle	No. of Vehicles Overtaken by Test Vehicle
Eastward				
1	2.75	80	1	1
2	2.55	75	2	1
3	2.85	83	0	3
4	3.00	78	0	1
5	3.05	81	1	1
6	2.70	79	3	2
7	2.82	82	1	1
8	3.08	78	0	2
Average	2.85	79.50	1.00	1.50
Westward				
1	2.95	78	2	0
2	3.15	83	1	1
3	3.20	89	1	1
4	2.83	86	1	0
5	3.30	80	2	1
6	3.00	79	1	2
7	3.22	82	2	1
8	2.91	81	0	1
Average	3.07	82.25	1.25	0.875

Average number of vehicles that overtake test vehicle while it is traveling eastward (O_e) = 1.00
Average number of vehicles the test vehicle passes while traveling westward (P_w) =0.875
Average number of vehicles the test vehicle passes while traveling eastward (P_e) = 1.5

Solution

$$V_w = \frac{(N_e + O_w - P_w)60}{T_e + T_w}$$

$$= \frac{(79.50 + 1.25 - 0.875)60}{2.85 + 3.07} = 809.5 \qquad \text{(or 810 veh/h)}$$

- Similarly, calculate the volume in the eastbound direction.

$$V_e = \frac{(82.25 + 1.00 - 1.50)60}{2.85 + 3.07} = 828.5 \qquad \text{(or 829 veh/h)}$$

- Find the average travel time in the westbound direction.

$$\overline{T}_w = 3.07 - \frac{(1.25 - 0.875)}{810} 60 = 3.0 \text{ min}$$

- Find the average travel time in the eastbound direction.

$$\overline{T}_e = 2.85 - \frac{(1.00 - 1.50)}{829} 60 = 2.9 \text{ min}$$

Methods Not Requiring a Test Vehicle
This category includes the license-plate method and the interview method.

- License-Plate Observations.
- Interviews.
- ITS Advanced Technologies.

Travel Time Data along an Arterial

An Example of the Statistics of Travel Times

Given the cost and logistics of travel-time studies (test cars, drivers, multiple runs, multiple days of study, etc.), there is a natural tendency to keep the number of observations, ***N*,** as small as possible. This case considers a hypothetical arterial on which the true mean running time is 196 seconds over a three-mile section. The standard deviation of the travel time is 15 seconds. The distribution of running times is normal. Note that the discussion is, at this point, limited to *running times*. These do not include stopped delays encountered along the route and are not equivalent to *travel* ***times*,** as will be seen.

Given the normal distribution of travel times, the mean travel time for the section is 196 seconds, and 95% of all travel times would fall within 1.96(15) = 29.4 seconds of this value. Thus, the 95% interval for travel times would be between 196 - 29.4 = 166.6 seconds and 196 + 29.4 = 225.4 seconds. The speeds corresponding to these travel times (including the average) are:

$$S_1 = \frac{3\,\text{mi}}{225.4\,\text{s}} * \frac{3600\,\text{s}}{\text{h}} = 47.9\ \text{mi/h}$$

Table 1: A Sample Travel Time Field Sheet.

Site: Lincoln Highway *Run No.* 3 *Start Location:* Milepost 15.0
Recorder: William McShane *Date:* Aug 10. 2002 *Start Time:* 5:00 PM

Checkpoint	Cum. Dist. Along Route (mi)	Cum. Trav. Time (min:sec)	Per Section: Stopped Delay (s)	Per Section: No. of stops	Per Section: Section Travel Time (min:sec)	Special Notes
MP 16	1.0	1:35	0.0	0	1:35	
MP 17	2.0	3:05	0.0	0	1:30	
MP 18	3.0	5:50	42.6	3	2:45	Stops due to signals at: MP17.2 MP17.5 MP18.0
MP 19	4.0	7:50	46.0	4	2:00	Stops due to signal MP18.5 and double-parked cars.
MP 20	5.0	9:03	0.0	0	1:13	
MP 21	6.0	10:45	6.0	1	1:42	Stop due to School bus.
MP 22	7.0	12:00	0.0	0	1:15	
Section Totals	**7.0**		**88.6**	**8**	**12:00**	

$$S_{av} = \frac{3\text{ mi}}{196\text{s}} * \frac{3600\text{ s}}{\text{h}} = 55.1\text{ mi/h}$$

$$S_2 = \frac{3\text{ mi}}{1666.6\text{ s}} * \frac{3600\text{s}}{\text{h}} = 64.8\text{ mi/h}$$

Note that the average of the two 95% confidence interval limits is (47.9 + 64.8)/2 = 56.4 mi/h, NOT 55.1 mi/h . This discrepancy is due to the fact that the *travel times* are normally distributed and are therefore symmetric. The resulting running speed distribution is skewed. The distribution of speeds, which are inverse to travel times, cannot be normal if the travel times are normal. The 55.1 mi/h value is the appropriate average speed, based on the observed average travel time over the three-mile study section.

So far, this discussion considers only the *running times* of test vehicles through the section. The actual *travel time* results of 20 test-car runs are illustrated in Figure 1.

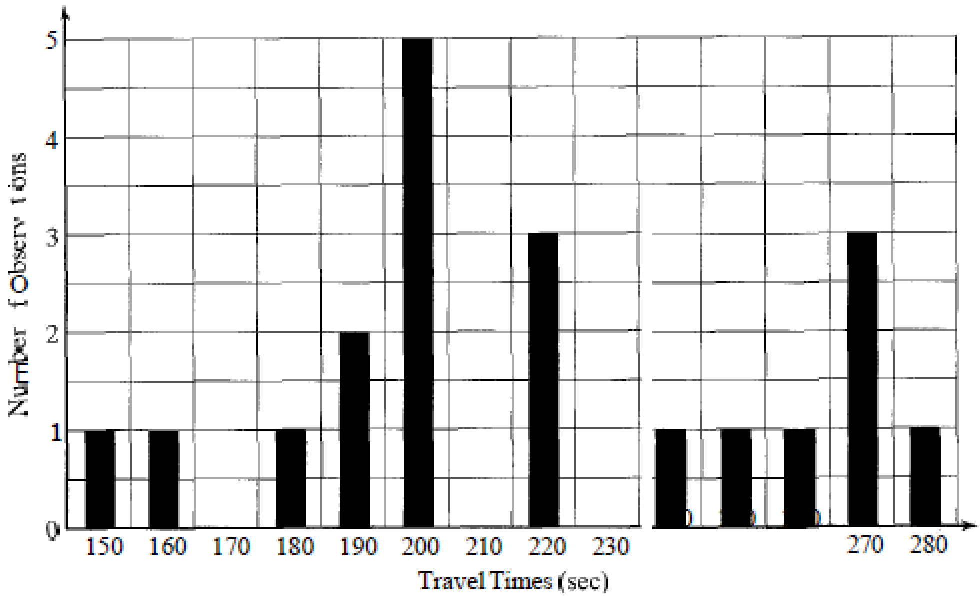

Figure 1. Histogram of Hypothetical Travel Time Data for 20 Runs Over a Three-Mile Section.

This distribution does not look normal. In fact, it is not normal at all, as the total travel time represents the *sum* of running times (which are normally distributed) and stop time delay that follows another distribution entirely.

Specifically, it is postulated that:

No. of Signal Stops	Probability of Occurrence	Duration of stops
0	0.569	0 s
1	0.300	40 s
2	0.131	80 s

The actual mean travel time of the observations in Figure 1 is 218.5 seconds, with a standard deviation of 38.3 seconds. The 95% confidence limits on the average are:

$$218.5 \pm 1.96(38.3/\sqrt{20}) = 218.5 \pm 16.79$$

$$201.71 - 235.29 \text{ s}$$

The speeds associated with these average and limiting travel times are:

$$S_1 = \frac{3\,\text{mi}}{235.29\text{s}} * \frac{3600\text{s}}{h} = 45.9\ \text{mi/h}$$

$$S_{av} = \frac{3\text{mi}}{218.5\text{s}} * \frac{3600\text{s}}{h} - 49.4\ \text{mi/h}$$

$$S_2 = \frac{3\,\text{mi}}{201.71\text{s}} * \frac{3600\text{s}}{h} = 53.5\ \text{mik}$$

Another way of addressing the average travel time is to add the average running time (196 s) to the average delay time,, which is computed from the probabilities noted above as:

$$d_{av} = (0.569 * 0) + (0.300 * 40) + (0.131 * 80) = 22.5\text{s}$$

The average travel time is then expected to be 196.0 +22.5 = 218.5 s, which is the same average obtained from the histogram of measurements.

Travel-Time Displays

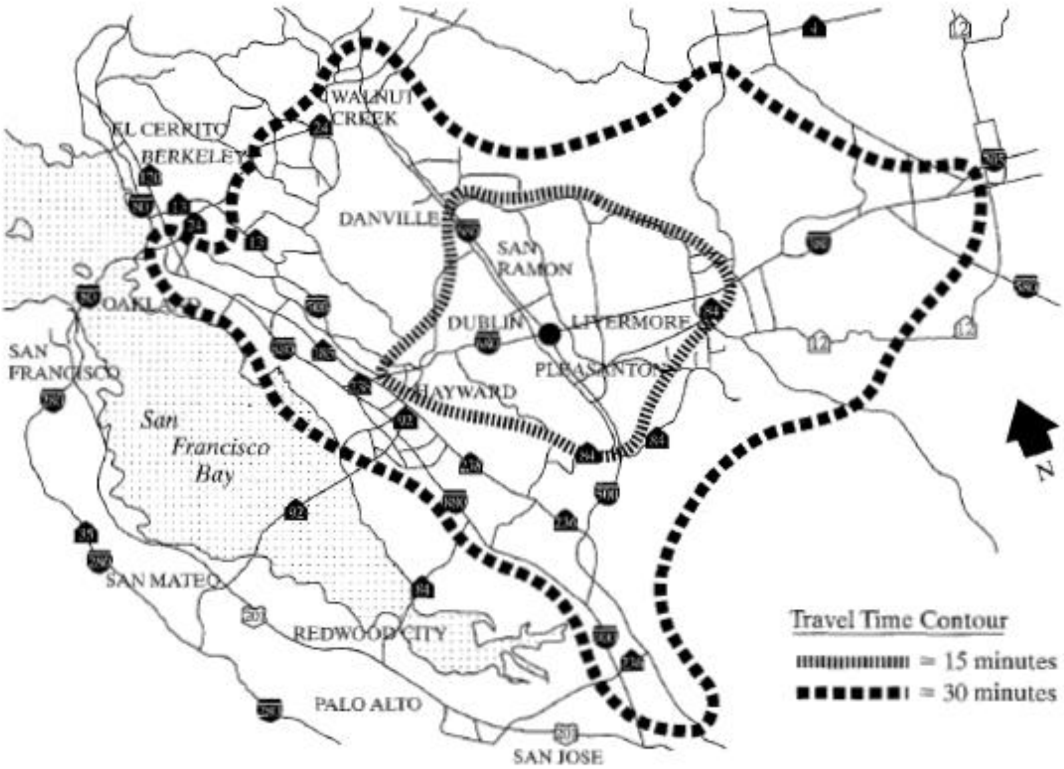

Figure 2. A Travel Time Contour Map (Used with permission of Prentice Hall, Inc., from Pline, J., Editor, *Traffic Engineering Handbook*, 4th Edition, Institute of Transportation Engineers, Washington DC, 1992, pg. 69.)

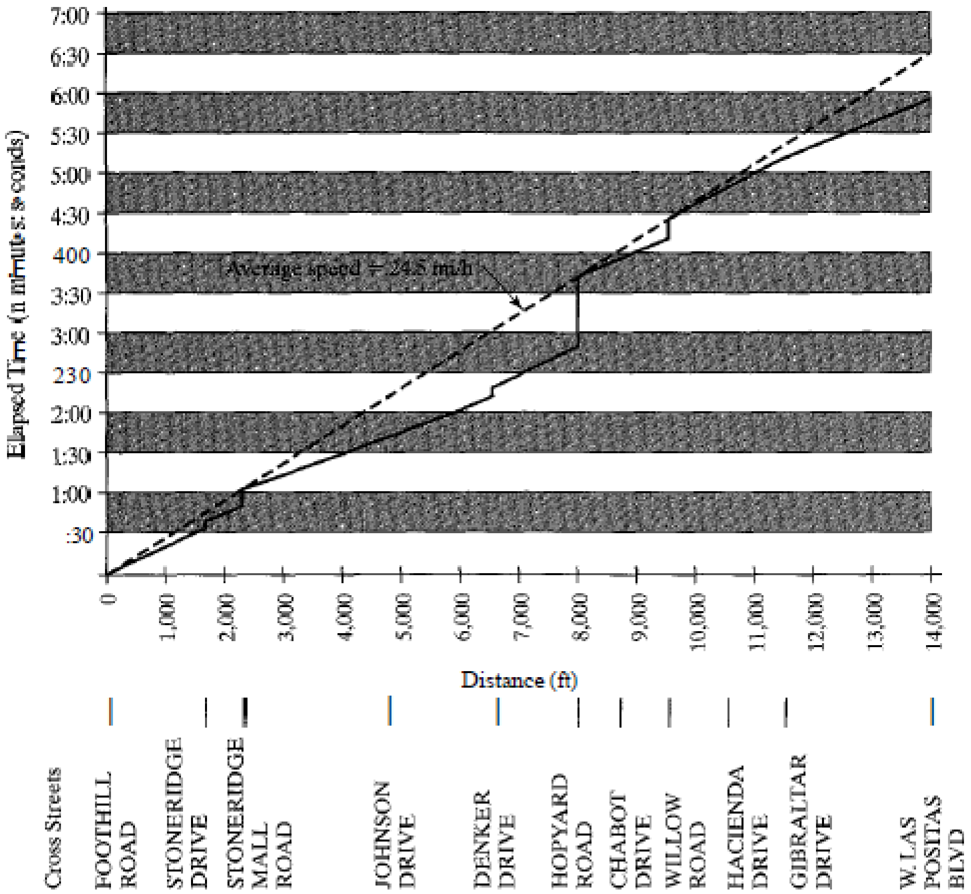

Figure 2. A Plot of Elapsed Time versus Distance (Used with permission of Prentice Hall, Inc., from Pline, J., Editor, *TrafJic Engineering Handbook*, 4th Edition, Institute of Transportation Engineers, Washington DC, 1992.)

INTERSECTION CONTROL DELAY WORKSHEET

General Information		Information	
Analyst	______	Intersection	______
Agency or Company	______	Area Type	☐ CBD ☐ Other
Date Performed	______	Analysis Year	______
Analysis Time Period	______		

Input Initial Parameters			
Number of Lanes, N	______	Total Vehicles Arriving V_T	______
		Stopped Vehicle Count V_{STOP}	______
Survey Count Interval I_s	______	Cycle Length D (s)	______

Input Field Data

Clock Time	Cycle Number	Number of Vehicles in Queue									
		Count Interval									
		1	2	3	4	5	6	7	8	9	10
Total											

Figure 3. Field Sheet for Signalized Intersection Delay Studies (Used with permission of Transportation Research Board, *Highway Capacity Manual*, 4th Edition, Washington DC, pg. 16-173.)