# WORKING PAPER 13

# SUMMARY OF OPERATIONAL DATA

**NCHRP 3-65**
**Applying Roundabouts in the United States**

**Report prepared by**
**Michael Kyte, University of Idaho**
**Michael Dixon, University of Idaho**

**Data Collection Team**
**George List, Rensselaer Polytechnic Institute**
**Aimee Flannery, George Mason University**
**Michael Dixon, University of Idaho**
**Michael Kyte, University of Idaho**

**Field Data Collection Team**
**Phil Rust, University of Idaho**
**Stacy Eisenman, Rensselaer Polytechnic Institute**
**Yuri Mereszczak, University of Idaho**
**William Johnson, George Mason University**
**Hyunwoo Cho, Rensselaer Polytechnic Institute**
**Angie Martin, George Mason University**
**Alix Demers, Rensselaer Polytechnic Institute**
**Rebecca Brown, Rensselaer Polytechnic Institute**

**Data Extraction Team**
**Audra Sherman**
**Julie Busby**
**Yuri Mereszczak**
**Phil Rust**
**Christina Hemberry**
**Gary Haderlie**
**Brent Orton**
**Chittemma Potlapati**
**JoeAnn Brazell**

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## Section 1. Introduction and Overview

The purpose of this working paper is to present a summary of the operations data that have been extracted from the DVDs recorded during summer 2003. It is hoped that the data presented and summarized here will provide a useful introduction to the scope and variation of the data that are now available for use by the modeling team and others. No firm conclusions are suggested based on this initial review of the data, only general (and hopefully informative) trends.

Time segments were identified in which there was persistent queuing on a roundabout approach. The time segments with some degree of persistent queuing include nine one-lane sites and four two-lane sites. The one-lane sites include fifteen unique approaches and a total video time of 15:53:16. The two-lane sites include nine unique approaches and a total video time of 18:30:18. A complete list of these time periods are included in Appendix A of this working paper.

Following are some of the highlights of the data sets that were produced based on the 34 hours of traffic operations:

**Table 1. Data set highlights**

| Parameter | One-lane sites | Two-lane sites |
|---|---|---|
| Number of one-minute data points | | |
| • Total | 884 | 923 |
| • Number in which proportion time queued exceeded 0.90 | 344 | 135 (left lane)<br>218 (right lane) |
| Maximum one minute measurements | | |
| • Entry flow, veh/min | 24 | 19 |
| • Conflicting flow, veh/min | 18 | 48 |
| • Mean delay, sec/veh | 47.1 | 121.7 |
| Mean proportion time queued | 0.78 | 0.55 (left lane)<br>0.65 (right lane) |
| Gap sequences | | |
| • Total | 10,785 | 13,530 |
| • Number involving an accepted gap | 8,282 | 5,295 |
| • Number involving a rejected lag followed by an accepted gap | 1,318 | 1,067 |
| • Number involving a rejected lag, followed by one or more rejected gaps, followed by an accepted gap | 1,151 | 7,168 |
| Turning movement proportions, means for sites | | |
| • Left turns | 0.28 | 0.23 |
| • Through movements | 0.46 | 0.22 |
| • Right turns | 0.31 | 0.11 |
| Travel time through roundabout (sec) | | |
| • Left turns | 10.8 | 11.8 |
| • Through movements | 6.6 | 7.4 |
| • Right turns | 3.1 | 2.7 |
| • U-turns | 16.2 | 18.8 |

The remainder of the working paper includes six sections and an appendix. Section 2 of the working paper defines the data that were extracted and the method of extraction or computation for the data.

Section 3 describes the method that was used to identify periods of persistent queuing. The parameter that was used for this purpose was the proportion of time that a queue existed for the approach under study during each one minute time interval.

Section 4 presents a summary of the flow rate and delay data that were extracted, including major trends that were identified. The flow rate data include the entry flow for the approach under study, the circulating or conflicting flow on the roundabout that passes this approach, and the flow that exits the roundabout at the exit immediately upstream of the entry point. Delay, also summarized for each one minute period, is the difference between the actual travel time and the free flow travel time from a point upstream of the yield line to the yield line.

Section 5 presents the gap data that were extracted. Some of the issues with respect to the computation of the critical gap are also presented.

Section 6 presents a summary of the turning movement data gathered from 30 minute samples for each of the roundabout sites. Included in this data set are the proportion for each origin-destination movement and the mean travel time for each movement.

Section 7 presents an overview of the formats in which the data sets are summarized on the CD-ROM that accompanies this working paper.

The appendices include additional information on the data sets presented in this working paper.

## Section 2. Data Extraction and Definitions

The purpose of this section is to list and define the data that were extracted from the DVDs recorded in the field. Data were extracted by observing selected portions of the DVD and recording keystrokes when events of interest occurred. These "events of interest" are summarized below in Table 2 and illustrated in Figure 1:

**Table 2. Events of interest**

| Event | Keystroke | Description |
|---|---|---|
| Entry time | 2 | The entry of a vehicle into the roundabout from the approach. The time was recorded when the vehicle crossed the yield line; the lane placement of the vehicle (either left lane or right lane) was recorded for two lane roundabouts. The vehicle type was also recorded. |
| First-in-queue time | 1 | The arrival of a vehicle into the server or first in line position on the approach. The time was recorded when the vehicle was about to enter the roundabout (if it did not stop) or the time that it stopped at or near the yield line waiting to enter the roundabout. |
| Upstream time | z | The passage of a vehicle past a point upstream of the entry point that defines the beginning of the travel time trap. |
| Conflict time | s | The passage of a vehicle through the conflict point on the roundabout, a point that is adjacent to the point of entry for a minor street vehicle. |
| Exit time | a | The exiting of a vehicle from the roundabout. |
| Entry/exit times | n/a | The entry of the vehicle into the roundabout and the exiting of the vehicle from the roundabout were recorded to capture origin-destination pairs or turning movements. |

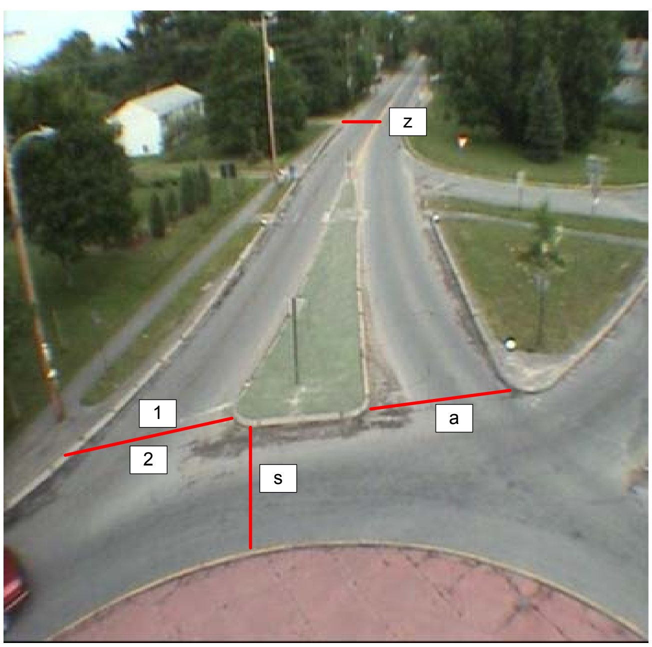



**Figure 1. Location of events of interest at roundabout approach, ME01-E**

The raw event data were processed to compute a variety of secondary data. These data include:

- Flow rates, or the number of vehicles passing by a given point during a specified time interval. Flow rates were computed for entry flows, circulating or conflicting flows, and exit flows.
- Delays, or the time spent traveling from the “z” line to the yield line (the “2” event) on a given approach that is in excess of the free flow time for this same route. The free flow time was measured for each approach, considering a sample of vehicles moving unobstructed from the “z” line to the “2” line. The actual travel time for each vehicle was computed for this same pair of events. The difference between these two travel times is the delay for a given vehicle.
- Turning movement proportions, or the proportion of vehicles entering from one approach and traveling to each of the possible exit points on the roundabout.
- Gaps, including gaps that were accepted or rejected by vehicles on the minor approach. Consideration must still be given to how gap events are defined, particularly the effect of exiting vehicles and, for multi-lane roundabouts, the position of vehicles on the circulating roadway on the behavior of entering vehicles.
- Service times, or the time difference for a minor approach vehicle between the “1” event and the “2” event. This is the time that a vehicle spends in the server.
- Move up times, or the time difference between the entry of one vehicle into the roundabout (the “2” event) and the arrival of the following vehicle at the first in queue position (the “1” event).
- Travel times on the roundabout from each entry point to each exit point.
- Proportion of time that a queue exists on the approach for each minute.

One minute summaries have been prepared for the following data:

- Entry flow
- Conflicting flow
- Exit flow
- Average delay
- Proportion time queued

Gap data have been computed for each entering vehicle:

- The size of the accepted or rejected lag, defined as the time from the arrival of the minor vehicle at the server (“1” event) to the arrival of the next conflicting vehicle (“s” event).
- The size of all gaps that are rejected by the minor vehicle, defined as the time between subsequent vehicles on the circulating roadway (“s” events).
- The size of the gap that is accepted by the minor vehicle, defined as the time between the two consecutive conflicting vehicles on the circulating roadway (“s” events).

## Section 3. Identifying Capacity Conditions

One of the most important tasks in the preparation of the operations data base is to determine periods during which queuing on a minor approach is persistent. It is during these time periods that the maximum rate of flow, or capacity flow, can be measured.

The first step in identifying these time periods was the initial review of all of the directional DVDs that were recorded during the field data collection. Here, an observer noted the beginning and ending time periods during which at least one vehicle was present in the server or entry point to the roundabout. These time periods were then assembled to form the periods for data extraction. Since many of these periods were of short duration, the accumulated time periods for data extraction included a mix of both queued and non-queued conditions.

Once the data extraction was completed, a more numerically precise method was needed to identify time periods during which persistent queuing was present. During a period of persistent queuing, the server is not occupied 100 percent of the time. When a vehicle in the server enters the intersection, some time will elapse before the next vehicle in line moves up to occupy the server. This time interval is called the "move up time". When a queue exists, the move-up time will approach some minimum value.

To determine the characteristics of the move up time parameter, the data from one single lane site, the north approach from the site WA04, were analyzed. For this site, a total of 3,260 move-up time measurements was available. Figure 2 shows a frequency distribution for those data using 0.25 second bins, while Table 3 shows the key statistics for these data. For this approach, the mean value was 3.50 seconds, while the median value was 2.79 seconds.

**Table 3. Move up time data, WA04-N**

| Statistic | Value |
|---|---|
| Mean | 3.50 |
| Standard Error | 0.05 |
| Median | 2.79 |
| Mode | 2.13 |
| Standard Deviation | 2.76 |
| Range | 32.62 |
| Minimum | 0.85 |
| Maximum | 33.47 |
| Count | 3260 |

During low volume periods when queues may last only a short time (often for only two or three vehicles) and do not persist, move up times lie on the right side of Figure 2. However, during a continuous queue, we expect to see values on the left side of the distribution, between one and four seconds. The mean of the distribution tends to overestimate the move up time, since the higher values, measured during low volume periods, are included in the total sample. The median, here 2.79 seconds, is probably a better estimator of the move up time.

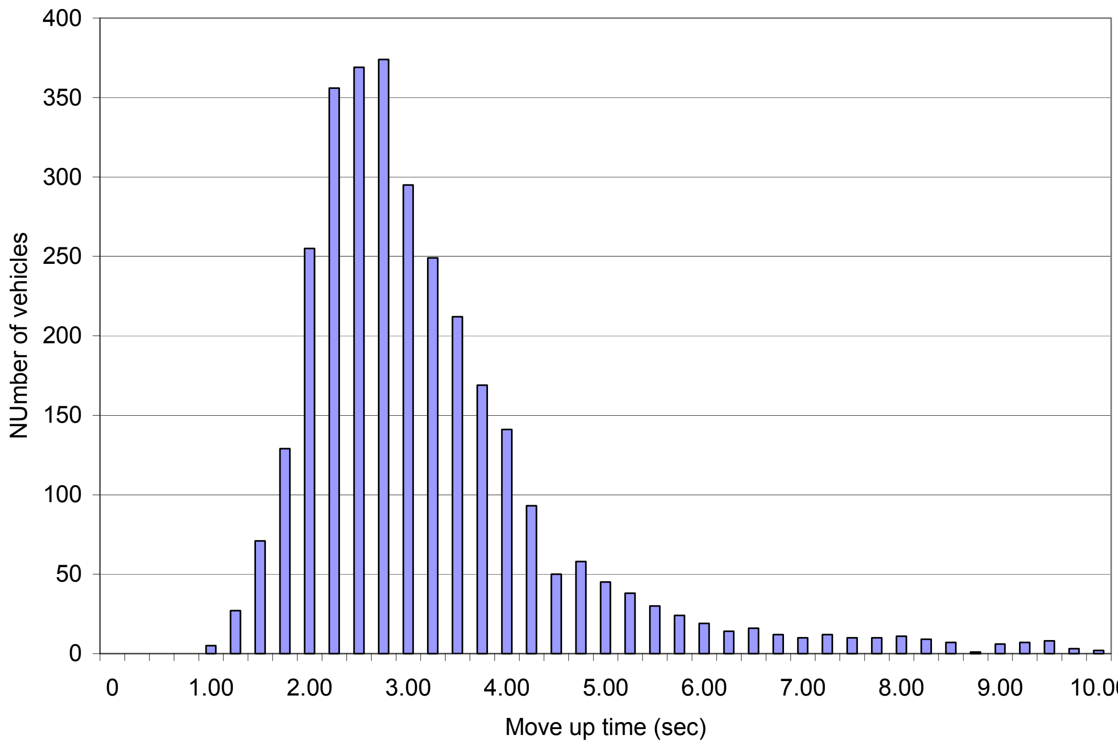



**Figure 2. Move up time frequency distribution, WA04-N**

But why should we include consider values of the move up time larger than the mean or median, even up to four seconds, in the identification of time periods in which queues persist? To answer this question, we must draw on our observations of driver behavior at the entrance to a roundabout. While a queue is present, drivers often "move up" at a slow speed, gauging their arrival at the yield line to coincide with an available gap in the conflicting traffic stream. Since they can enter without stopping, drivers do not have to "rush" to the yield line as they might do at a two-way stop-controlled intersection.

The parameter "proportion time queued" is used as a measure of the queue persistence for a given time period. It is computed as the sum, for a given minute, of the service times for each vehicle that enters the roundabout and the product of the number of vehicles entering the roundabout during a given minute and the average move up time.

To determine the usefulness of the proportion time queued parameter in identifying periods of persistent queuing, several plots were prepared. One useful comparison is to plot the sum of the conflicting and entry flow during a given minute against the proportion of time that a queue exists during that same minute. This sum represents the maximum number of vehicles that can pass through the conflict point, including both vehicles entering the roundabout as well as those already on the roundabout. We would expect that for higher values of this sum, the proportion of time that a queue exists would be high. Conversely, for lower values of this sum, the proportion of time that a queue exists would be low. Figure 3 bears out this expectation. When the proportion of time queued exceeds 0.90, the sum of the entry and conflicting flow rates ranges from 13 to 23 vehicles per minute. By contrast, when the proportion time queued is less than 0.70, the range is 6 to 17 vehicles per minute.

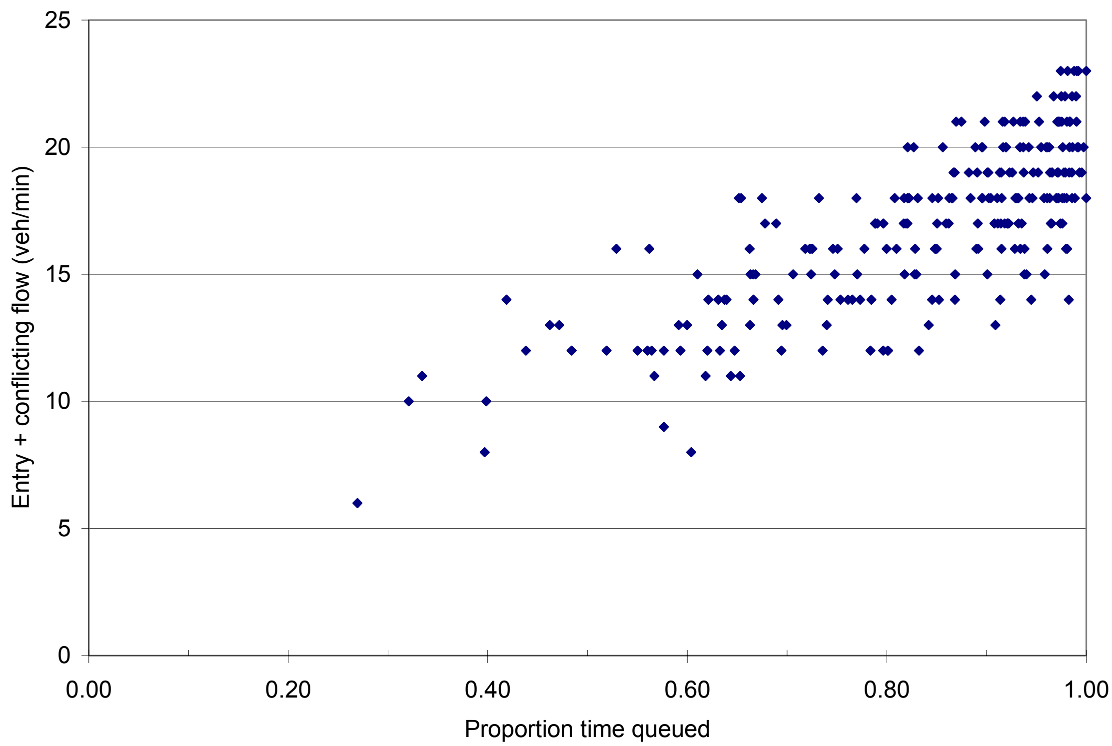



**Figure 3. One-minute entry + conflicting flow vs proportion time queued (3.25 sec move up time), WA04N**

Another perspective is a plot of the entry flow rate vs. the conflicting flow rate. During capacity conditions (periods of persistent queuing), we would expect to see the classic line of decreasing entry (capacity ) flow with increasing conflicting flow. Data points taken during persistent queuing should lie along this line; data points taken when queuing is less intensive would tend to lie below this line. Figure 4 bears out this expectation. For time periods during which a queue was present for ninety percent of the time or more, the data lie approximately along this line. However, for time periods during which a queue was present less than 70 percent of the time, the data lie predominately below this line. The patterns in this chart support the claim that this parameter, proportion time queued, is a useful one in identifying periods of persistent queuing.

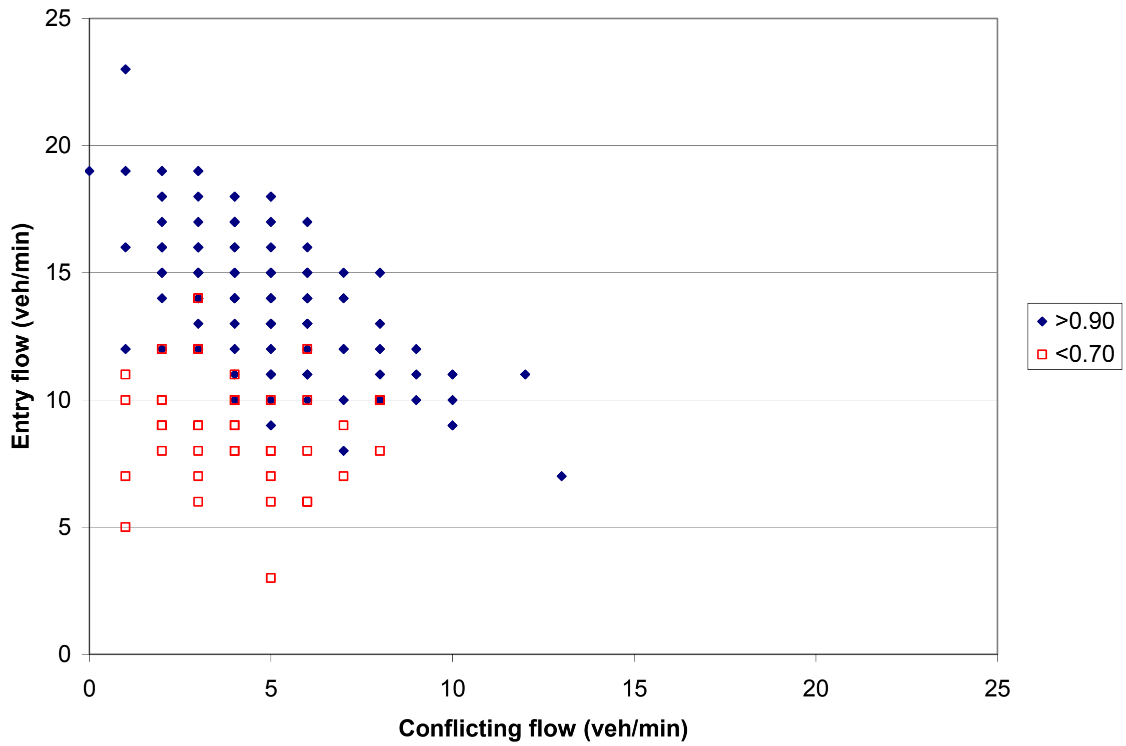



**Figure 4. One-minute entry flow vs conflicting flow, WA04 (3.25 sec move up time), showing two "proportion time queued" ranges (greater than 0.90 and less than 0.70)**

While more precise models will be developed to quantify the factors that affect delay, we expect that both entry flow and conflicting flow combine to effect delay. For example, the larger the conflicting flow rate, the longer the time vehicles must wait to enter the roundabout. And, the larger the entry flow rate, the longer the time a vehicle must move through the queue to enter the roundabout. We would therefore expect that delay is an increasing function of the sum of the entry and conflicting flow rates. Figure 5 bears out this expectation. As before, we can partition the data according to the proportion of time that a queue exists during a given minute. Figure 5 shows two such partitions, one when the proportion of time that a queue exists is greater than 0.90 and the other when this proportion is less than 0.70. Considering both partitions together, delay increases as the sum of entry plus conflicting flow rates increase.

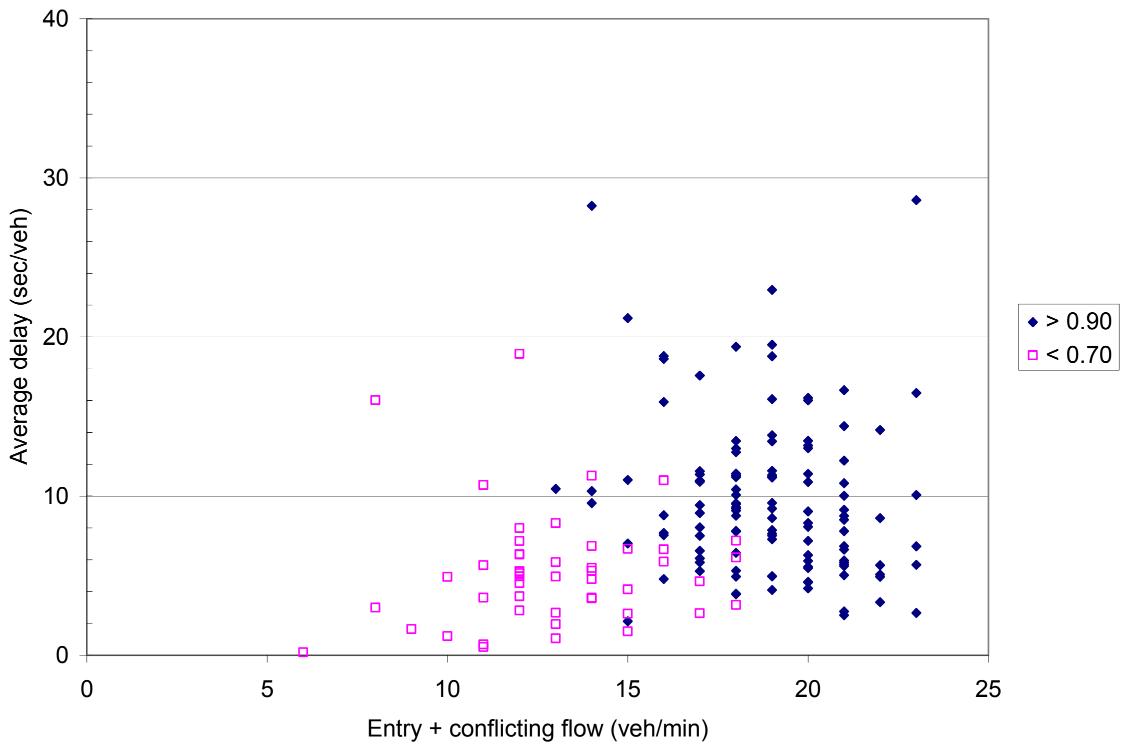



**Figure 5. One minute delay vs conflicting plus entry flow, WA04-N, showing two ranges of "proportion time queued" (greater than 0.90 and less than 0.70)**

Queuing is a highly variable phenomena and the persistence of queuing at a given site will vary over time as the demand changes both during the day and throughout a peak period. What sort of temporal variation should we expect in the proportion time queued parameter? Figure 6 shows a plot of this parameter vs. time for WA04-N1 during a four hour time period. The periods of persistent queuing are shown on the upper portion of the chart, when the proportion of time queued is above 0.80 or 0.90. However, there are numerous periods during which the level of queuing is much lower, below 0.70. Of the 248 1-minute time periods for this approach (including time periods not shown in Figure 6), 121 time periods have a queue present at least 90 percent of the time.

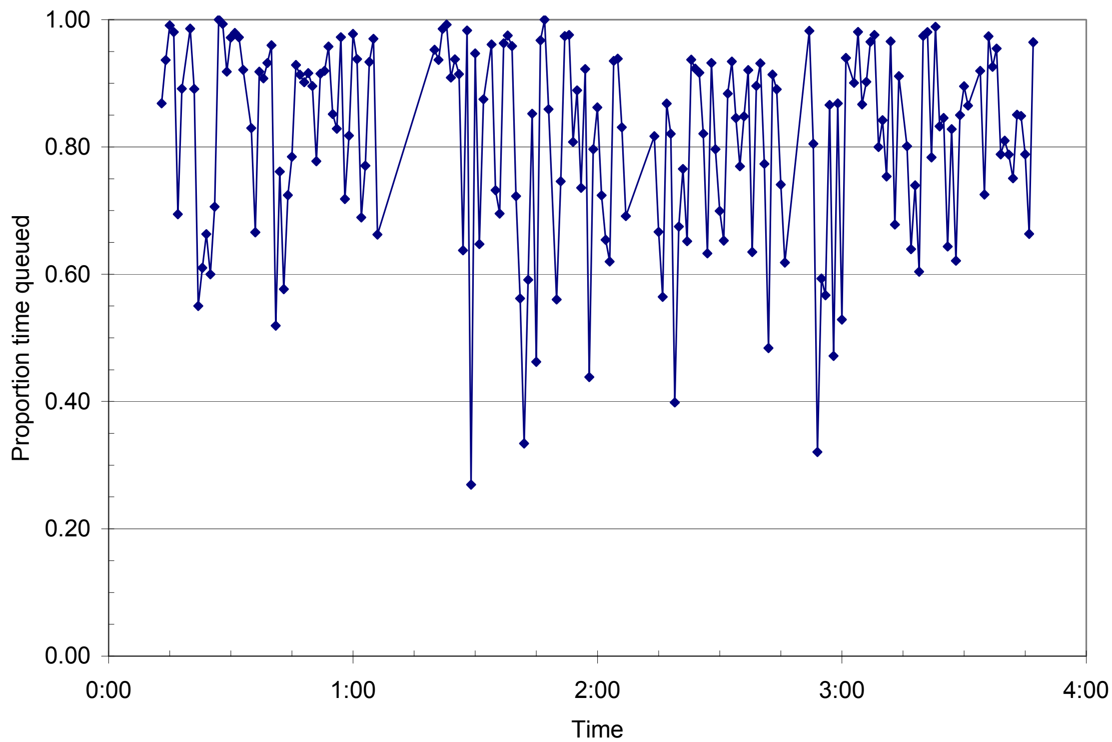



**Figure 6. Proportion time queued vs time, WA04-N1**

While this parameter (proportion time queued) provides important information, it should be noted that there are some problems in using this parameter, particularly when the level of persistent queuing is not high and/or varies significantly from one time period to the next. Figure 7 shows an example of this case, using data from MD07-E1. Of the 130 one-minute data points in this data set, the proportion time queued for 41 of the one-minute time periods (or 32 percent of the total) is less than 0.70, while 21 of the time periods have values less than 0.40.

Consider the three data points for the periods 1:20, 1:21, and 1:22, shown with large red circles in Figure 7. For these three data points, the proportion time queued varies from 0.92, to 0.00, to 0.95. These data are based on the move up times shown in Table 4. Even though the time interval 1:21 shows a zero value for proportion time queued, this is actually a drastic underestimation of the parameter value. In fact, it should be noted that part of the time during which the server is empty should be attributed to the previous minute. This apparent large variation in the parameter is an artifact of the process of summarizing the data into one-minute time periods. The conclusion should be drawn that when there is wide variation in the proportion time queued, care should be taken in the use of this parameter as an indicator of the persistence of queuing.

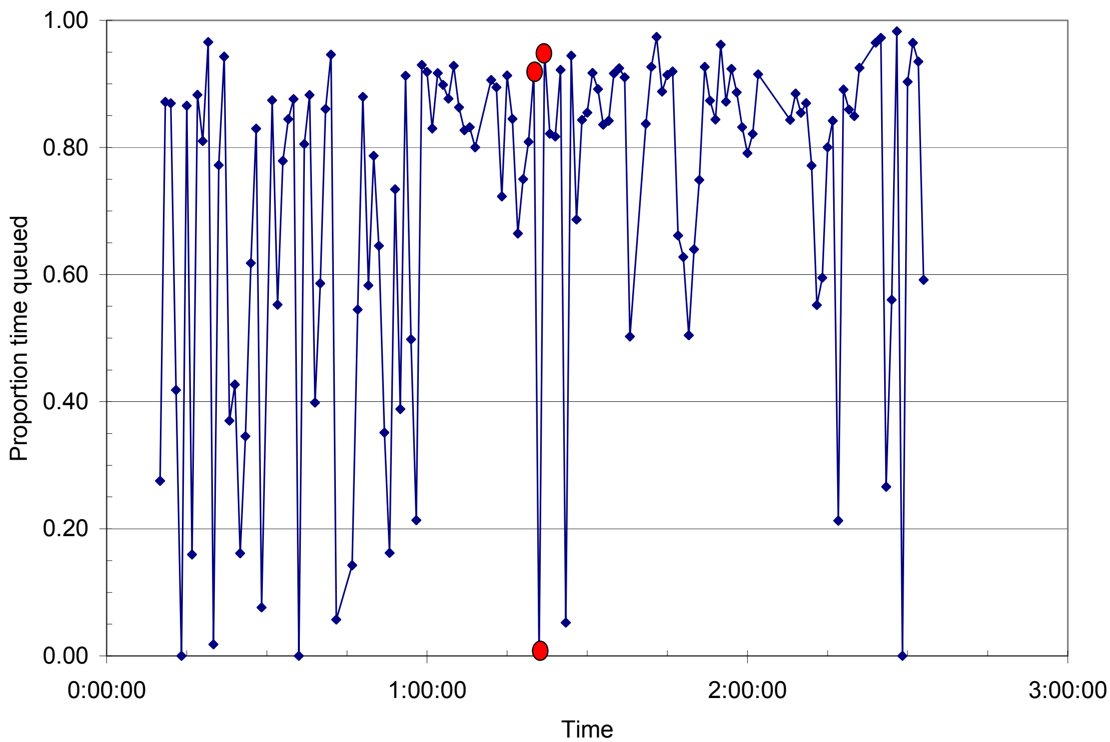



**Figure 7. Proportion time queued vs. time, MD07-E1**

**Table 4. Computation of proportion time queued**

| First in Queue Time (h:m:s.x) | Entry Time (h:m:s.x) | Move up Time (sec) | Time that no queue is present (sec) | Time Interval (h:m:s) | Time that no queue is present (sec) | Time that queue is present (sec) | Proportion time queued |
|---|---|---|---|---|---|---|---|
| 1:20:01.8 | 1:20:01.9 | 6.7 | 3.4 | 1:20:00 | 5.0 | 55.0 | 0.92 |
| 1:20:04.2 | 1:20:04.3 | 2.3 | 0.0 | | | | |
| 1:20:08.3 | 1:20:12.1 | 3.9 | 0.7 | | | | |
| 1:20:16.2 | 1:20:16.3 | 4.1 | 0.8 | | | | |
| 1:20:19.3 | 1:20:19.4 | 3.0 | 0.0 | | | | |
| 1:20:22.6 | 1:20:22.7 | 3.2 | 0.0 | | | | |
| 1:21:22.5 | 1:21:22.7 | 59.8 | 56.5 | 1:21:00 | 63.3 | 0.0 | 0.00 |
| 1:21:24.9 | 1:21:25.0 | 2.3 | 0.0 | | | | |
| 1:21:28.7 | 1:21:28.8 | 3.7 | 0.5 | | | | |
| 1:21:31.2 | 1:21:31.3 | 2.4 | 0.0 | | | | |
| 1:21:35.9 | 1:21:36.0 | 4.6 | 1.4 | | | | |
| 1:21:41.0 | 1:21:42.8 | 5.0 | 1.7 | | | | |
| 1:21:45.6 | 1:21:45.8 | 2.9 | 0.0 | | | | |
| 1:21:49.8 | 1:21:49.9 | 4.0 | 0.8 | | | | |
| 1:21:54.3 | 1:21:54.4 | 4.4 | 1.2 | | | | |
| 1:21:59.0 | 1:21:59.1 | 4.6 | 1.3 | | | | |
| 1:22:04.9 | 1:22:05.0 | 5.8 | 2.6 | 1:22:00 | 3.0 | 57.0 | 0.95 |
| 1:22:07.9 | 1:22:08.1 | 2.9 | 0.0 | | | | |
| 1:22:10.6 | 1:22:16.5 | 2.6 | 0.0 | | | | |
| 1:22:19.4 | 1:22:19.6 | 2.9 | 0.0 | | | | |
| 1:22:23.2 | 1:22:26.1 | 3.7 | 0.4 | | | | |
| 1:22:28.3 | 1:22:37.2 | 2.2 | 0.0 | | | | |
| 1:22:40.4 | 1:22:52.8 | 3.2 | 0.0 | | | | |
| 1:22:55.4 | 1:22:57.5 | 2.6 | 0.0 | | | | |

## Section 4. Flow Rate and Delay Data

The purpose of this section is to present a summary of the flow rate and delay data that were extracted for the one-lane and two-lane sites. The data have been summarized into one-minute bins.

### *4.1 One lane site data*

Table 5 includes data ranges for the fifteen one-lane approaches, including

- the number of one minute time periods for each approach,
- the minimum and maximum flow rates for entry and conflicting flows,
- the minimum, maximum, and average delay values,
- the minimum, maximum, and mean values of proportion time queued, and
- the mean and median values for the move-up time.

This data base includes 884 one-minute time intervals. The maximum entry flow rate is 24 vehicles per minute, while the maximum conflicting flow rate is 18 vehicles per minute. The one-minute average delay ranges from zero to 47.1 seconds per vehicle, while the means range from 4.9 seconds per vehicle at the site/approach MD06-N to 18.9 seconds per vehicle at the site/approach WA01-N. The mean proportion time queued ranges from 0.60 at the site/approach WA01-N to 0.96 at site/approach WA07-S.

**Table 5. Parameter summary for one-lane sites, one-minute data**

| Site | Number of time periods | Entry flow (veh/min) | | Conflicting flow (veh/min) | | Delay (sec/veh) | | | Percent time queued | | | Move up time | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Mean | Minimum | Maximum | Mean | Mean | Median |
| MD06-N | 51 | 2 | 24 | 0 | 5 | 0.3 | 16.0 | 4.9 | 0.12 | 1.00 | 0.75 | 3.7 | 2.7 |
| MD06-S | 13 | 3 | 10 | 5 | 15 | 5.4 | 35.7 | 18.4 | 0.01 | 1.00 | 0.68 | 6.5 | 3.5 |
| MD07-E | 130 | 2 | 20 | 0 | 11 | 0.0 | 44.7 | 12.7 | 0.00 | 0.98 | 0.71 | 4.4 | 3.1 |
| ME01-E | 72 | 5 | 18 | 1 | 13 | 0.2 | 42.3 | 13.5 | 0.27 | 1.00 | 0.85 | 3.5 | 3.1 |
| ME01-N | 19 | 2 | 9 | 5 | 15 | 3.0 | 38.0 | 14.2 | 0.00 | 1.00 | 0.60 | 7.7 | 3.3 |
| OR01-S | 71 | 2 | 15 | 0 | 15 | 0.4 | 44.1 | 11.0 | 0.02 | 1.00 | 0.74 | 4.6 | 2.8 |
| WA01-N | 15 | 2 | 10 | 3 | 16 | 1.1 | 47.1 | 18.9 | 0.21 | 1.00 | 0.68 | 6.4 | 3.1 |
| WA01-W | 24 | 3 | 11 | 3 | 18 | 2.9 | 43.5 | 13.5 | 0.13 | 1.00 | 0.76 | 4.6 | 2.8 |
| WA03-E | 19 | 5 | 16 | 1 | 7 | 1.7 | 14.3 | 5.2 | 0.37 | 0.92 | 0.65 | 5.0 | 3.8 |
| WA03-S | 129 | 2 | 16 | 0 | 12 | 0.3 | 25.8 | 8.2 | 0.18 | 1.00 | 0.77 | 4.3 | 3.2 |
| WA04-E | 31 | 6 | 22 | 0 | 14 | 2.3 | 18.9 | 8.8 | 0.41 | 1.00 | 0.90 | 3.1 | 2.5 |
| WA04-N | 248 | 3 | 23 | 0 | 13 | 0.2 | 28.6 | 8.1 | 0.27 | 1.00 | 0.83 | 3.5 | 2.8 |
| WA04-S | 23 | 5 | 16 | 3 | 13 | 0.6 | 32.4 | 10.0 | 0.00 | 1.00 | 0.74 | 4.5 | 3.2 |
| WA05-W | 32 | 8 | 21 | 0 | 6 | 1.3 | 15.1 | 5.9 | 0.54 | 1.00 | 0.87 | 3.1 | 2.7 |
| WA07-S | 7 | 11 | 18 | 3 | 7 | 4.8 | 13.2 | 7.5 | 0.92 | 1.00 | 0.96 | 2.7 | 2.4 |

### 4.1.1 Entry flow/conflicting flow data

One item of interest to the research team is the range of entry flow/conflicting flow combinations in the data sets that were extracted. To help answer this question, several tables and charts were assembled showing the range of flow rate and delay data.

Figure 8 shows the number of observations of entry flow rates and conflicting flow rates for the range of vehicle per minute bins from zero to 25. The mean entry flow rate for all observations is 11.1 vehicles per minute, while the mean conflicting flow rate is 5.3 vehicles per minute.

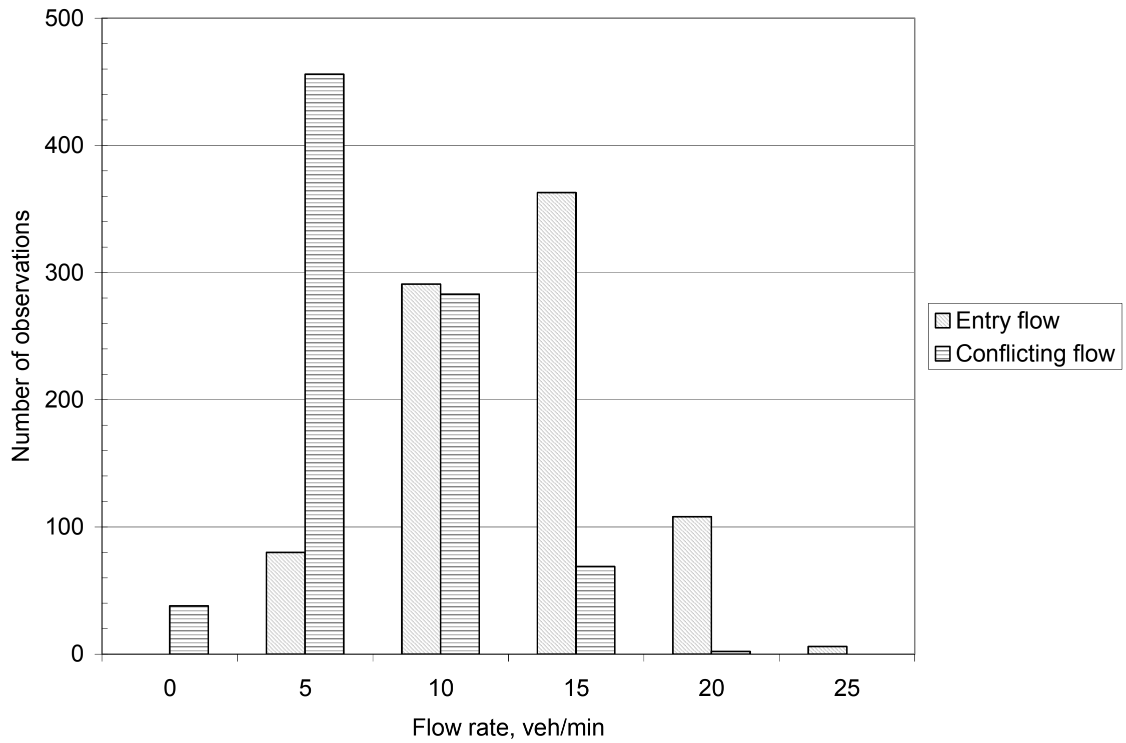



**Figure 8. Number of one-minute observations, entry flow rates and conflicting flow rates, one-lane sites**

Figure 9 shows a plot of the number of one-minute observations for each entry flow rate/conflicting flow rate pair. One of the important items to note about the flow distribution shown in this figure is that most of the flow rate ranges of interest are included in the data base. The majority of data points are in the ranges of entry flow rates from 6 to 18 vehicle per minute and conflicting flow rates from 1 to 10 vehicles per minute.

| Entry flow (veh/min) \ Conflicting flow (veh/min) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | 2 | 1 | 2 | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | 3 | 3 | 2 | 4 | | | | | | | | | | | | | | | | | | | | | | |
| 18 | 5 | 4 | 9 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | |
| 17 | 2 | 3 | 7 | 7 | 7 | 1 | 2 | | | | | | | | | | | | | | | | | | | |
| 16 | 2 | 5 | 6 | 10 | 5 | 4 | 1 | | | 1 | | | | | | | | | | | | | | | | |
| 15 | 2 | 6 | 9 | 15 | 6 | 7 | 4 | 4 | 2 | 1 | 1 | | | | | | | | | | | | | | | |
| 14 | 4 | 8 | 6 | 20 | 17 | 9 | 8 | 5 | 2 | | | | | | | | | | | | | | | | | |
| 13 | 1 | 3 | 9 | 10 | 7 | 16 | 13 | 2 | 3 | | 1 | 1 | | | | | | | | | | | | | | |
| 12 | 3 | 3 | 5 | 9 | 16 | 12 | 16 | 8 | 7 | 3 | | | | | | | | | | | | | | | | |
| 11 | 4 | 5 | 6 | 7 | 6 | 11 | 12 | 5 | 7 | 9 | 3 | 2 | 2 | | | | | | | | | | | | | |
| 10 | 1 | 3 | 5 | 8 | 8 | 8 | 7 | 9 | 11 | 6 | 7 | 3 | | | | | | | | | | | | | | |
| 9 | 1 | 4 | 5 | 5 | 9 | 5 | 6 | 7 | 6 | 4 | 6 | 2 | 4 | | | | | | | | | | | | | |
| 8 | 2 | 1 | 4 | 4 | 7 | 5 | 9 | 8 | 5 | 3 | 4 | 1 | 2 | 2 | 4 | 2 | | | | | | | | | | |
| 7 | 1 | 1 | 2 | 4 | | 7 | 2 | 8 | 2 | 3 | 5 | 1 | 4 | 2 | 1 | 2 | | | | | | | | | | |
| 6 | 1 | 5 | 1 | 2 | 2 | 6 | 8 | 2 | 4 | 1 | 3 | 1 | 3 | | 3 | | 1 | | | | | | | | | |
| 5 | | 2 | | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 5 | 2 | 2 | 2 | 2 | 2 | | | 1 | | | | | | | |
| 4 | 1 | | | | 1 | 2 | 1 | 5 | 2 | 2 | 1 | 5 | 1 | 2 | | | | | | | | | | | | |
| 3 | | | 3 | 3 | | 2 | 1 | 1 | | 1 | | 1 | 1 | | 2 | 2 | | | | | | | | | | |
| 2 | 1 | 2 | 2 | 1 | 1 | 1 | | | | | 1 | | 2 | | | 1 | | | | | | | | | | |
| 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Figure 9. Entry flow vs conflicting flow, number of observations for each entry flow/conflicting flow cell, one-lane sites**

Figure 10 shows a plot of the entry flow rates vs. the conflicting flow rates for one lane sites, for those time periods during which the proportion time queued exceeds 0.90.  As noted in section 3 for the site WA04, the plot of entry vs. conflicting flows does follow the expected form of the standard capacity line (entry flows decrease as conflicting flows increase).

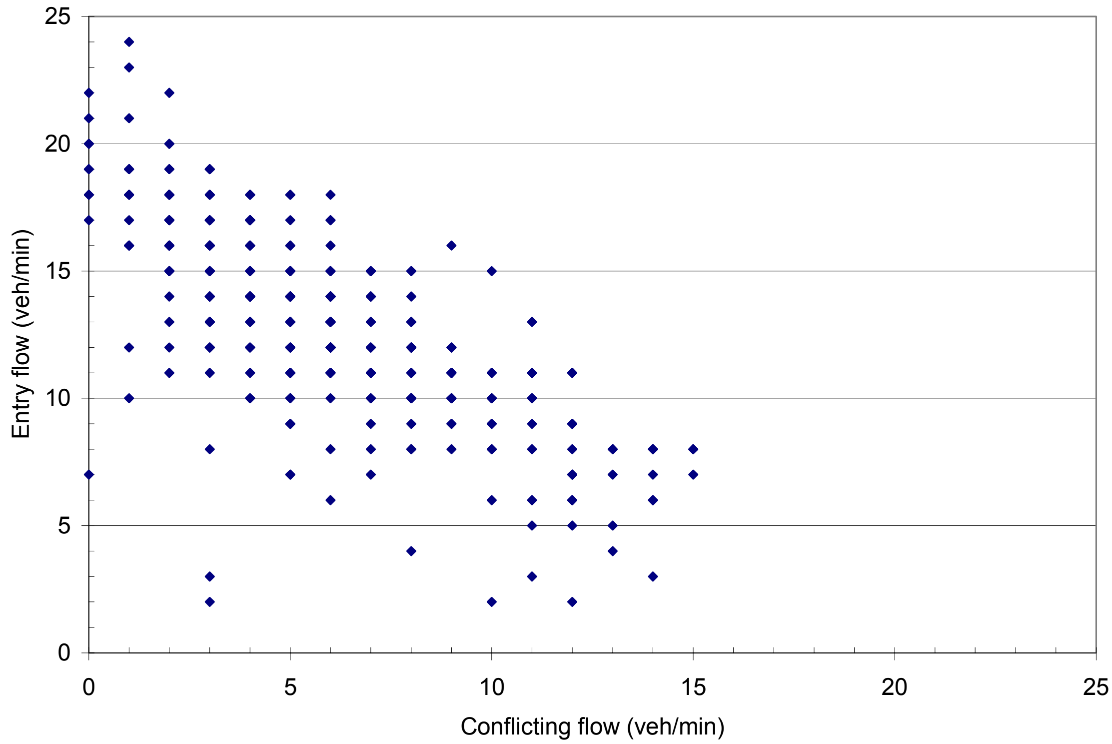



**Figure 10. Entry flow vs. conflicting flow, one minute data, one lane sites,  proportion time queued > 0.90**

By contrast, Figure 11 shows a plot of entry flow vs. conflicting flow for those time periods that the proportion time queued is less than 0.70. Here, the points lie below the standard capacity line.

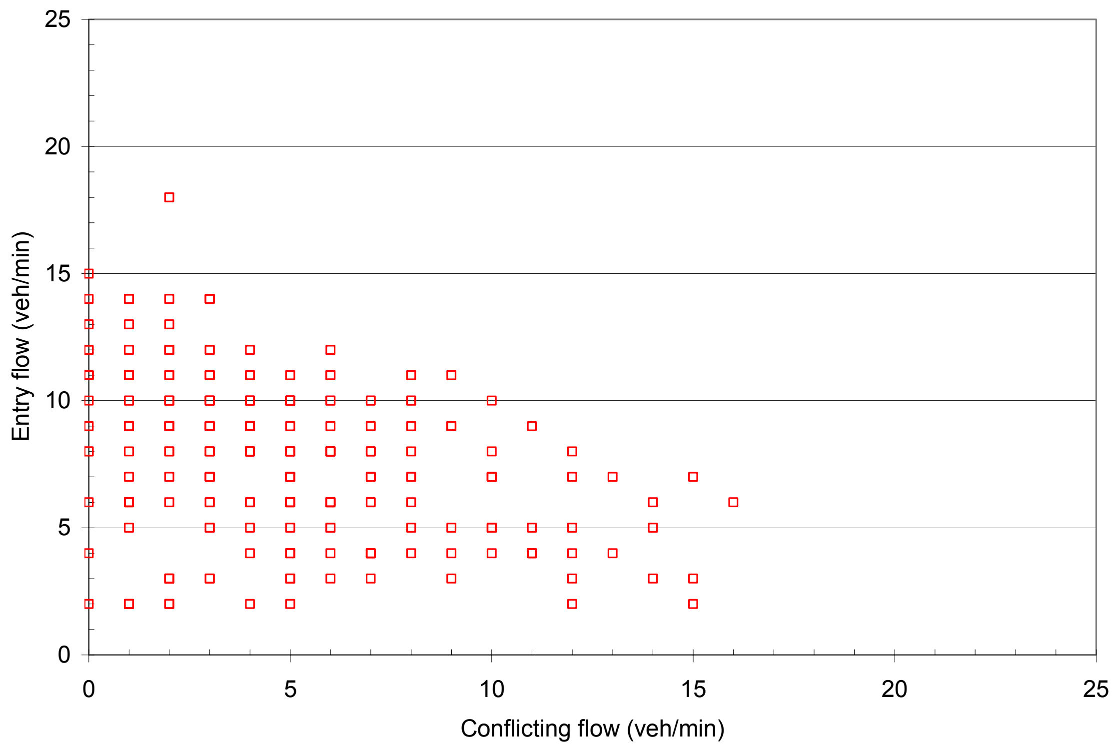



**Figure 11. Entry flow vs. conflicting flow, one minute data, one lane sites, proportion time queued < 0.70**

### *4.1.2 Delay data ranges*

Figure 12 shows the distribution of delay observations for all one lane sites, using five second bins from zero seconds to 50 seconds. The mean delay is 9.9 seconds. Most of the delay measurements are less than 15 seconds per vehicle.

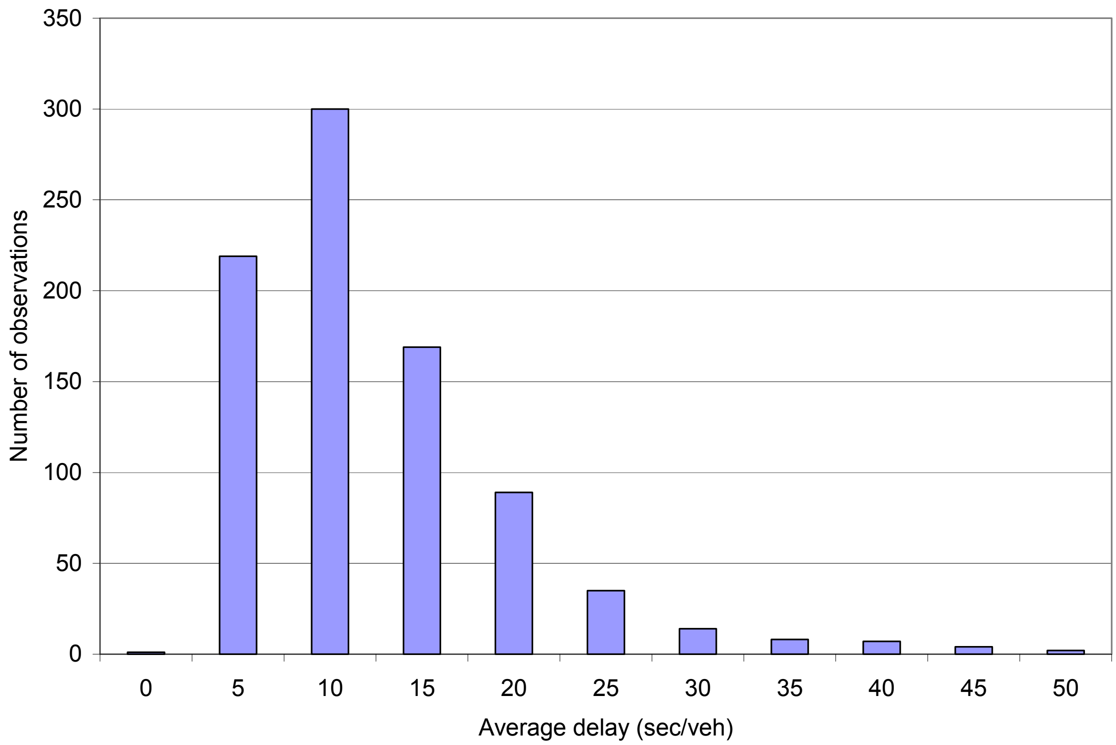



**Figure 12. Number of one-minute observations, average delay, one-lane sites**

Figure 13 shows a plot of the mean delay for each entry flow/conflicting flow pair. As expected, delays increase as the combination of entry and conflicting flows increase.

| | Conflicting flow (veh/min) | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Entry flow (veh/min)** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** |
| **25** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **24** | | 2.8 | | | | | | | | | | | | | | | | | | | | | | | | |
| **23** | | 2.6 | | | | | | | | | | | | | | | | | | | | | | | | |
| **22** | 3.9 | | 6.9 | | | | | | | | | | | | | | | | | | | | | | | |
| **21** | 5.0 | 5.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| **20** | 4.1 | 11.7 | 5.1 | | | | | | | | | | | | | | | | | | | | | | | |
| **19** | 4.1 | 4.4 | 2.6 | 7.7 | | | | | | | | | | | | | | | | | | | | | | |
| **18** | 6.5 | 5.3 | 6.0 | 5.7 | 6.0 | 6.3 | 11.9 | | | | | | | | | | | | | | | | | | | |
| **17** | 4.1 | 4.3 | 13.1 | 9.1 | 9.1 | 5.1 | 8.6 | | | | | | | | | | | | | | | | | | | |
| **16** | 4.3 | 6.4 | 9.2 | 9.0 | 7.4 | 9.5 | 10.0 | | | 7.3 | | | | | | | | | | | | | | | | |
| **15** | 9.9 | 8.5 | 6.5 | 8.7 | 8.8 | 9.2 | 8.3 | 11.9 | 15.4 | 12.5 | 10.2 | | | | | | | | | | | | | | | |
| **14** | 5.4 | 7.5 | 14.7 | 8.0 | 9.9 | 8.5 | 10.6 | 8.7 | 9.9 | | | | | | | | | | | | | | | | | |
| **13** | 1.0 | 10.4 | 15.1 | 8.3 | 10.6 | 12.3 | 11.0 | 7.5 | 12.9 | | 9.5 | 6.5 | | | | | | | | | | | | | | |
| **12** | 5.6 | 11.5 | 7.2 | 6.8 | 9.3 | 10.7 | 10.9 | 12.5 | 11.1 | 17.4 | | | | | | | | | | | | | | | | |
| **11** | 5.2 | 4.7 | 8.7 | 6.6 | 7.4 | 16.6 | 14.1 | 9.9 | 10.6 | 13.0 | 16.7 | 18.2 | 25.2 | | | | | | | | | | | | | |
| **10** | 4.9 | 6.3 | 9.2 | 6.1 | 10.9 | 9.2 | 10.9 | 12.9 | 14.9 | 13.8 | 14.7 | 19.0 | | | | | | | | | | | | | | |
| **9** | 1.7 | 4.0 | 4.5 | 4.4 | 7.3 | 9.6 | 7.9 | 8.3 | 13.2 | 12.0 | 18.6 | 7.8 | 21.5 | | | | | | | | | | | | | |
| **8** | 2.6 | 3.6 | 6.2 | 10.6 | 7.5 | 3.8 | 4.2 | 8.4 | 14.6 | 11.6 | 16.1 | 31.8 | 12.6 | 30.2 | 19.2 | 18.4 | | | | | | | | | | |
| **7** | 18.7 | 3.0 | 10.3 | 5.3 | | 10.4 | 8.7 | 9.2 | 5.7 | 12.5 | 10.2 | 7.8 | 21.0 | 10.3 | 44.1 | 20.9 | | | | | | | | | | |
| **6** | 0.6 | 6.1 | 0.8 | 6.7 | 3.2 | 5.5 | 5.6 | 5.3 | 8.6 | 21.0 | 6.1 | 43.5 | 21.5 | | 18.3 | | 25.9 | | | | | | | | | |
| **5** | | 6.9 | | 5.7 | 2.1 | 2.2 | 9.3 | 4.9 | 3.8 | 4.9 | 11.7 | 20.2 | 15.6 | 19.1 | 25.2 | 29.2 | | | 20.6 | | | | | | | |
| **4** | 3.6 | | | | 4.1 | 5.8 | 3.8 | 5.9 | 14.5 | 5.2 | 6.6 | 11.2 | 38.0 | 26.3 | | | | | | | | | | | | |
| **3** | | | 1.2 | 2.3 | | 11.6 | 2.8 | 1.2 | | 15.0 | | 6.8 | 4.6 | | 21.5 | 14.0 | | | | | | | | | | |
| **2** | 1.9 | 0.9 | 1.6 | 5.8 | 1.4 | 0.3 | | | | | 3.0 | | 5.6 | | | 3.5 | | | | | | | | | | |
| **1** | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Figure 13. Entry flow vs conflicting flow, one minute data, delay for one-lane sites**

Figure 14 shows a plot of average delay vs. entry plus conflicting flow, for the one lane sites, using the one-minute data. Two data ranges are shown, those time periods for which the proportion time queued exceeds 0.90 and those for which the parameter is less than 0.70. As expected, delay increases as the sum of the entry plus conflicting flows increase.

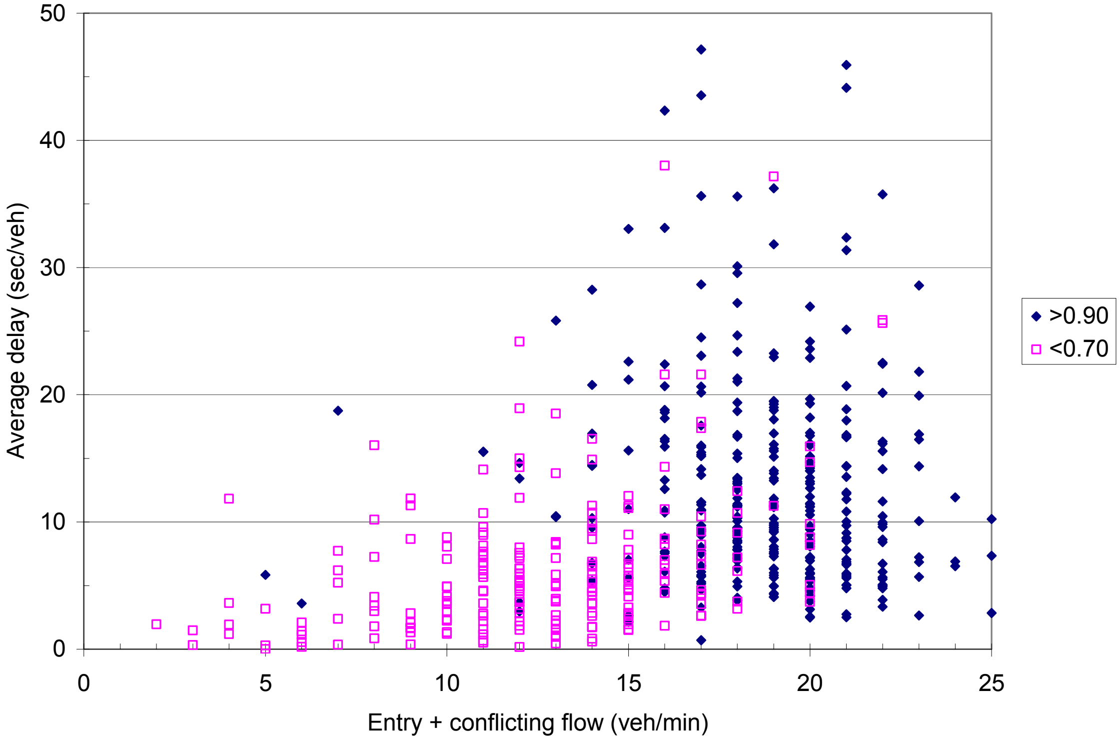



**Figure 14. Average delay vs. entry plus conflicting flow, one minute data, one lane sites**

### 4.1.3 Range of proportion time queued data

Figure 15 shows the frequency distribution for the parameter proportion time queued for the one-minute data for the one-lane sites. Of the 848 one-minute data points included in the sample, 344 (or 41 percent) exceed 0.90. Another 185 data points exceed 0.80. In total, 529 data points (or 62 percent) exceed 0.80. The mean proportion time queued for the sample is 0.78.

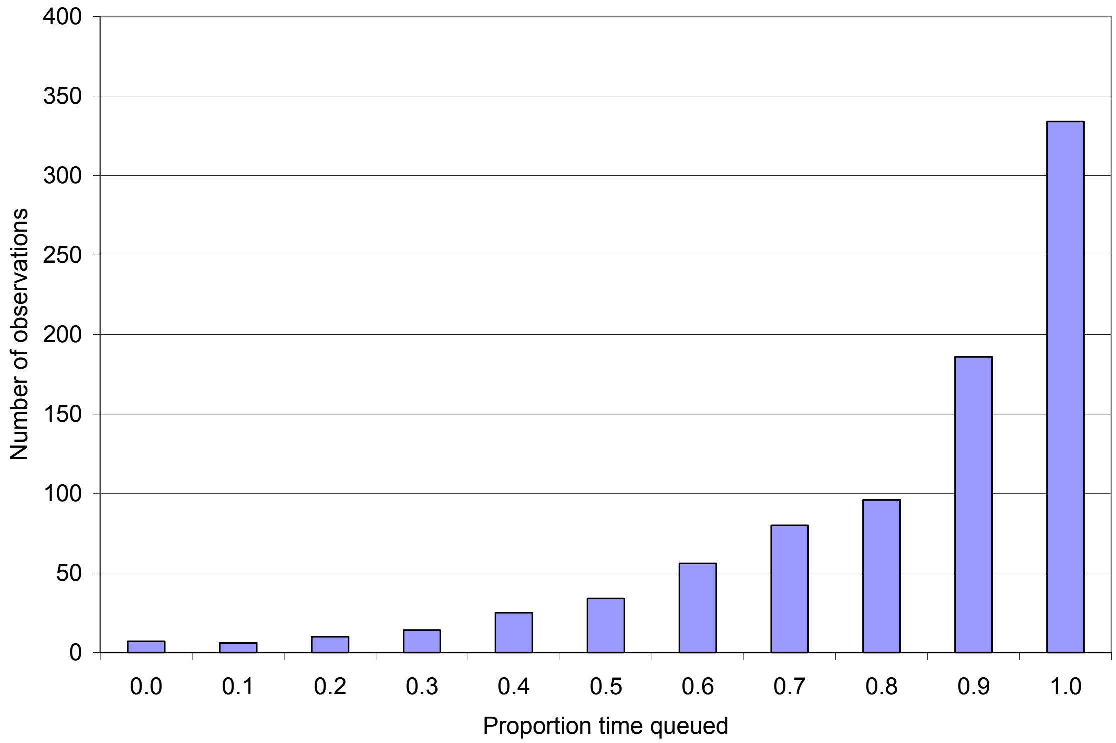



**Figure 15. Number of one-minute observations, proportion time queued**

Figure 16 shows a plot of entry plus conflicting flow vs. the proportion time queued for the one-lane sites. As expected, the larger the sum of the entry and conflicting flow rates, the higher the value of proportion time queued. When the proportion time queued exceeds 0.80, the sum of the entry and conflicting flow rates exceed 12 vehicles per minute.

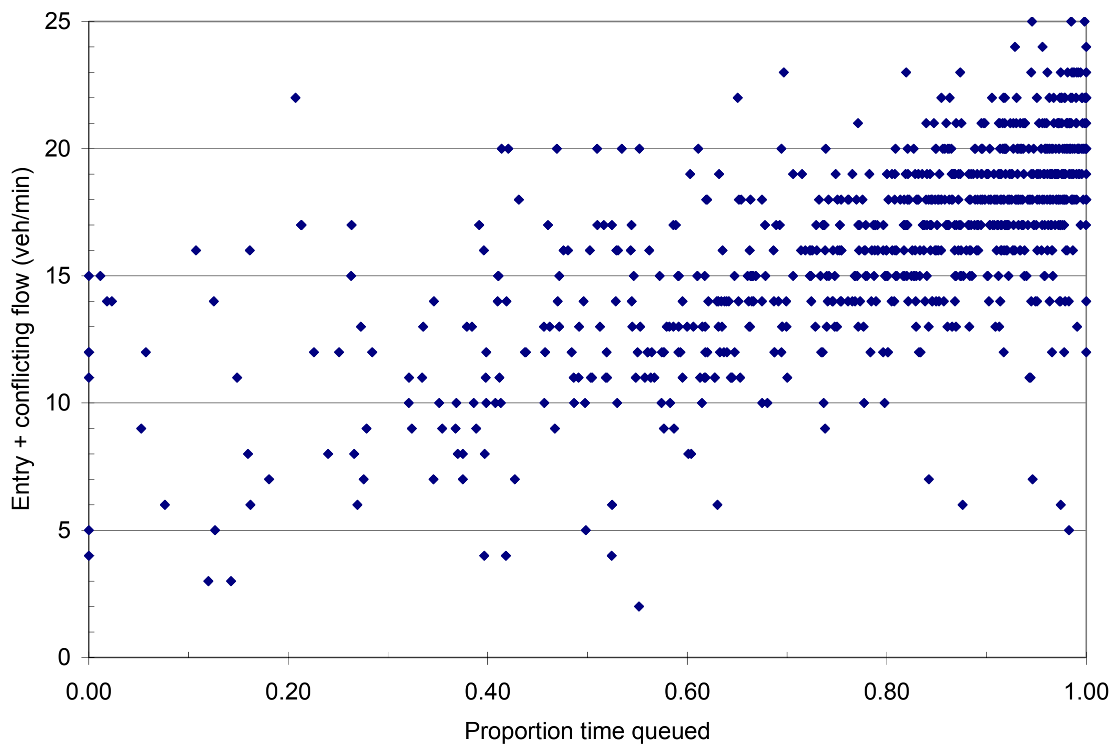



**Figure 16. Entry + conflicting flow vs proportion time queued, one minute data, one lane sites**

For another perspective, Figure 17 shows the mean proportion time queued for each entry flow rate/conflicting flow rate pair. Again, as expected, the proportion time queued is highest for the higher entry/conflicting flow rate pairs.

| | Conflicting flow (veh/min) | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Entry flow (veh/min) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | 0.55 | 0.13 | 0.21 | 0.98 | 0.08 | 0.18 | | | | | 1.00 | | 0.50 | | | 0.39 | | | | | | | | | | |
| 3 | | | 0.21 | 0.55 | | 0.49 | 0.59 | 0.15 | | 0.64 | | 1.00 | 0.26 | | 0.62 | 0.59 | | | | | | | | | | |
| 4 | 0.40 | | | | 0.27 | 0.32 | 0.41 | 0.37 | 0.49 | 0.54 | 0.13 | 0.50 | 0.69 | 0.54 | | | | | | | | | | | | |
| 5 | | 0.57 | | 0.24 | 0.37 | 0.57 | 0.47 | 0.83 | 0.38 | 0.60 | 0.53 | 0.69 | 0.71 | 0.87 | 0.71 | 0.81 | | | 0.70 | | | | | | | |
| 6 | 0.63 | 0.45 | 0.37 | 0.31 | 0.39 | 0.54 | 0.57 | 0.43 | 0.69 | 0.82 | 0.84 | 0.94 | 0.92 | | 0.79 | | 0.65 | | | | | | | | | |
| 7 | 0.95 | 0.40 | 0.60 | 0.48 | | 0.59 | 0.80 | 0.74 | 0.50 | 0.76 | 0.60 | 0.86 | 0.85 | 0.69 | 0.98 | 0.59 | | | | | | | | | | |
| 8 | 0.42 | 0.46 | 0.62 | 0.63 | 0.58 | 0.60 | 0.70 | 0.71 | 0.80 | 0.87 | 0.85 | 0.95 | 0.74 | 0.98 | 0.97 | 0.97 | | | | | | | | | | |
| 9 | 0.39 | 0.63 | 0.57 | 0.58 | 0.62 | 0.84 | 0.77 | 0.76 | 0.81 | 0.77 | 0.84 | 0.72 | 0.95 | | | | | | | | | | | | | |
| 10 | 0.53 | 0.71 | 0.56 | 0.67 | 0.74 | 0.77 | 0.70 | 0.75 | 0.87 | 0.94 | 0.86 | 0.90 | | | | | | | | | | | | | | |
| 11 | 0.62 | 0.46 | 0.75 | 0.73 | 0.79 | 0.86 | 0.80 | 0.89 | 0.83 | 0.88 | 0.90 | 0.97 | 0.99 | | | | | | | | | | | | | |
| 12 | 0.66 | 0.80 | 0.61 | 0.82 | 0.81 | 0.87 | 0.89 | 0.90 | 0.95 | 0.97 | | | | | | | | | | | | | | | | |
| 13 | 0.66 | 0.77 | 0.80 | 0.86 | 0.87 | 0.92 | 0.92 | 0.99 | 0.98 | | 0.82 | 0.96 | | | | | | | | | | | | | | |
| 14 | 0.74 | 0.79 | 0.81 | 0.83 | 0.90 | 0.91 | 0.96 | 0.93 | 0.93 | | | | | | | | | | | | | | | | | |
| 15 | 0.66 | 0.82 | 0.92 | 0.89 | 0.91 | 0.94 | 0.96 | 0.97 | 0.96 | 0.87 | 0.95 | | | | | | | | | | | | | | | |
| 16 | 0.83 | 0.89 | 0.92 | 0.91 | 0.92 | 0.90 | 0.97 | | | 0.99 | | | | | | | | | | | | | | | | |
| 17 | 0.89 | 0.87 | 0.93 | 0.93 | 0.95 | 0.97 | 0.99 | | | | | | | | | | | | | | | | | | | |
| 18 | 0.90 | 0.93 | 0.91 | 0.94 | 0.98 | 0.99 | 0.93 | | | | | | | | | | | | | | | | | | | |
| 19 | 0.93 | 0.98 | 0.95 | 0.96 | | | | | | | | | | | | | | | | | | | | | | |
| 20 | 0.96 | 0.89 | 0.99 | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | 0.98 | 0.98 | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | 1.00 | | 1.00 | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | 0.99 | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Figure 17. Proportion time queued, one minute data, one lane sites**

### 4.2 Two-lane sites

Table 6 and Table 7 include data ranges for both the left lane and right lane for the two-lane approach sites, including

- the number of one minute time periods for each approach,
- the minimum and maximum flow rates for entry and conflicting flows,
- the minimum, maximum, and average delay values,
- the minimum, maximum, and mean values of percent time queued, and
- the mean and median values for the move-up time.

This data base includes 923 one-minute time intervals. The maximum entry flow rate is 19 vehicles per minute, while the maximum conflicting flow rate is 48 vehicles per minute. The one-minute average delay ranges from zero to 121.7 seconds per vehicle, while the means range from 5.1 seconds per vehicle at the site/approach VT03-S to 121.7 seconds per vehicle at the site/approach MD05-SW-NW. The mean proportion time queued ranges from 0.36 to 0.73 for the left lane data and from 0.45 to 0.83 for the right lane data.

**Table 6. Parameter summary for two-lane sites, left lane, one minute data**

| Site | Number of time periods | Entry flow (veh/min) | | Conflicting flow (veh/min) | | Delay (sec/veh) | | | Proportion time queued | | | Move up time | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Mean | Minimum | Maximum | Mean | Mean | Median |
| MD04-E | 347 | 0 | 19 | 0 | 48 | 0.0 | 55.5 | 10.7 | 0.00 | 1.00 | 0.73 | 4.7 | 3.1 |
| MD05-SW/NW | 123 | | | 1 | 42 | | | | | | | | |
| MD05-SW-W | 21 | 0 | 5 | 14 | 28 | 0.3 | 40.5 | 19.9 | 0.00 | 1.00 | 0.42 | 26.1 | 10.3 |
| MI01-E | 10 | | | 3 | 13 | | | | | | | | |
| VT03-W | 275 | 0 | 9 | 3 | 23 | | 101.1 | 6.8 | 0.00 | 1.00 | 0.36 | 17.0 | 7.2 |
| VT03-E | 57 | 0 | 10 | 8 | 23 | 0.2 | 45.1 | 14.0 | 0.00 | 1.00 | 0.49 | 10.8 | 3.9 |
| VT03-S | 75 | 0 | 10 | 3 | 17 | | 30.7 | 5.1 | 0.00 | 1.00 | 0.38 | 12.7 | 6.1 |

**Table 7. Parameter summary for two-lane sites, right lane, one-minute data**

| Site | Number of time periods | Entry flow (veh/min) | | Conflicting flow (veh/min) | | Delay (sec/veh) | | | Proportion time queued | | | Move up time | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Mean | Minimum | Maximum | Mean | Mean | Median |
| MD04-E | 347 | 0 | 14 | 0 | 48 | 0.0 | 42.0 | 6.7 | 0.00 | 1.00 | 0.49 | 8.5 | 4.1 |
| MD05-SW/NW | 123 | 0 | 16 | 1 | 42 | 0.0 | 121.7 | 32.7 | 0.00 | 1.00 | 0.79 | 5.0 | 2.8 |
| MD05-SW-W | 21 | 0 | 5 | 14 | 28 | 0.0 | 36.6 | 13.1 | 0.00 | 1.00 | 0.45 | 16.5 | 7.8 |
| MI01-E | 10 | 4 | 12 | 3 | 13 | 1.5 | 47.0 | 18.4 | 0.39 | 1.00 | 0.83 | 4.1 | 2.8 |
| VT03-W | 275 | 2 | 19 | 3 | 23 | 0.3 | 80.9 | 9.8 | 0.22 | 1.00 | 0.76 | 4.4 | 3.3 |
| VT03-E | 57 | 1 | 11 | 8 | 23 | 1.1 | 44.9 | 14.0 | 0.00 | 0.98 | 0.54 | 7.9 | 4.5 |
| VT03-S | 75 | 3 | 18 | 3 | 17 | 1.5 | 20.6 | 8.6 | 0.41 | 1.00 | 0.82 | 3.6 | 2.7 |

### *4.2.1 Entry flow/conflicting flow data*

Table 8 shows the number of observations of entry flow rates and conflicting flow rate for a range of vehicle per minute bins. The mean entry flow rate for all observations is 6.3 vehicles per minute, while the mean conflicting flow rate is 11.4 vehicles per minute.

**Table 8. Number of one-minute observations, entry flow and conflicting flow, two-lane sites**

| Flow rate (veh/min) | Number of observations | | |
|---|---|---|---|
| | Entry flow | | Conflicting flow |
| | Left lane | Right lane | |
| 5 | 434 | 350 | 148 |
| 10 | 257 | 368 | 324 |
| 15 | 74 | 174 | 269 |
| 20 | 7 | 13 | 78 |
| 25 | 0 | 0 | 21 |
| 30 | 0 | 0 | 29 |
| 35 | 0 | 0 | 19 |
| 40 | 0 | 0 | 11 |
| 45 | 0 | 0 | 4 |
| 50 | 0 | 0 | 2 |
| 55 | 0 | 0 | 0 |
| 60 | 0 | 0 | 0 |

Figure 18 and Figure 19 show the number of observations for each entry flow rate/conflicting flow rate combination for the left-lane and right-lane data.

| Entry flow, LL (veh/min) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 2 | | | | | 1 | 3 | 4 | 3 | 4 | 2 | 2 | 1 | | 4 | 2 | 1 | | 1 | 1 | 1 | | 1 | | | | 1 | | 2 | | | | | |
| 1 | 1 | 1 | | 2 | 3 | 2 | 4 | 7 | 9 | 8 | 4 | 7 | 9 | 1 | 7 | 4 | 4 | 2 | 1 | 1 | | 1 | | 1 | | | | 2 | | | | | | |
| 2 | | | | 1 | 1 | 1 | 6 | 6 | 6 | 8 | 7 | 12 | 13 | 4 | 6 | 3 | 1 | 2 | | 2 | 3 | 1 | 2 | 1 | | | | 1 | 1 | | | | | |
| 3 | | 1 | | 2 | 3 | 3 | 7 | 5 | 9 | 3 | 7 | 5 | 13 | 8 | 7 | 6 | 3 | 1 | 3 | 1 | | 1 | | 1 | | | | | | | | | | |
| 4 | 2 | | 1 | | 1 | 4 | 3 | 5 | 5 | 8 | 9 | 3 | 3 | 8 | 5 | 1 | 3 | 3 | | 2 | 3 | 1 | | | | | | | 1 | | | | | |
| 5 | | 1 | 1 | 1 | 3 | 4 | 2 | 5 | 4 | 5 | 7 | 7 | 5 | 2 | 6 | 4 | 3 | 3 | 1 | 1 | | | | 1 | | | | | | 1 | | | 1 | |
| 6 | | | 1 | 1 | 5 | 1 | | 1 | 5 | 5 | 5 | 6 | 7 | 3 | 2 | 4 | 2 | 2 | 2 | | | | | 1 | | | | | 1 | | | | 1 | |
| 7 | | | 2 | 3 | 3 | 2 | 4 | 4 | 13 | 4 | 5 | 7 | 2 | 4 | 2 | | 2 | 1 | | | | | | | | | | | | | | | | |
| 8 | | | | 3 | 3 | 7 | 1 | 5 | 5 | 2 | 1 | 2 | 3 | | 5 | 5 | 1 | 1 | | | | | | | | | | | 1 | | 1 | | | |
| 9 | 2 | 2 | 1 | 1 | 1 | 4 | 2 | 5 | 3 | 3 | 5 | 7 | 5 | 1 | 1 | | | 2 | | | | | | | | | | | | | | | | |
| 10 | 2 | 1 | 6 | 3 | 4 | 3 | 7 | | 6 | 6 | 1 | 4 | 1 | 2 | | | | | | | | | | | | | | 1 | | | | | | |
| 11 | | | | 3 | 1 | | 6 | 5 | 2 | | 1 | 2 | | | | | | | | | | | | | | | | | | | | | | |
| 12 | 1 | | 2 | 4 | | 2 | 3 | 1 | 3 | 1 | 3 | | | | | | | | | | | | | | | | | | | | | 1 | | |
| 13 | 2 | 1 | 2 | | 1 | 5 | | 2 | | 2 | | | 1 | | 1 | | | | | | | | | | | | | | | | | | | |
| 14 | | | 1 | 1 | 2 | | 2 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | | | | | 1 | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | | | | | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Figure 18. Left lane entry flow vs. conflicting flow, number of observations for each entry flow/conflicting flow cell, two lane sites**

| Entry Flow, RL (veh/min) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | 1 | | | | | 1 | | | 1 | | | | | 1 | | 1 | | | | | 1 | | | | | | 2 | | | | | 1 | | 1 | |
| 1 | 3 | | | 3 | | | 1 | | 2 | | 2 | 2 | 2 | 1 | 1 | | 1 | 1 | | | | | | | | | | 2 | 3 | | | 1 | 1 | | 1 | | |
| 2 | | | 2 | 1 | 1 | 2 | 1 | 2 | 4 | 1 | 1 | 3 | | 2 | 2 | 1 | 1 | | 2 | 2 | 2 | 3 | | 3 | | | | 1 | 1 | 2 | 1 | 1 | | | | 1 | |
| 3 | 1 | 1 | 2 | 3 | 3 | 4 | 8 | 4 | 7 | 7 | 1 | 2 | 5 | 2 | 2 | 5 | 1 | 2 | 3 | 3 | | 1 | 1 | | 1 | | | | | 1 | 2 | 4 | 3 | 2 | | | 1 |
| 4 | 1 | | 1 | 1 | 1 | 9 | 1 | 5 | 7 | 5 | 4 | 8 | 7 | 5 | 5 | 5 | 2 | 3 | 5 | 1 | 1 | 1 | 2 | | | 1 | 1 | | | 1 | 2 | | | 1 | 1 | | |
| 5 | 3 | 1 | 2 | 1 | 6 | 2 | 3 | 8 | 7 | 8 | 2 | 7 | 6 | 8 | 5 | 2 | 1 | 2 | 1 | 3 | 3 | | 1 | 1 | | | 1 | 2 | 1 | 2 | 2 | | | | | | 1 |
| 6 | 1 | 3 | | 3 | 3 | 7 | 6 | 8 | 6 | 6 | 2 | 3 | 7 | 1 | 6 | 3 | 2 | 3 | 1 | 1 | 1 | | | 1 | 1 | | | | | 1 | | | | | | 1 | |
| 7 | | | 5 | 3 | 4 | 3 | 6 | 3 | 7 | 8 | 7 | 9 | 9 | | 6 | 3 | 2 | 3 | 1 | 2 | 1 | 1 | | | 1 | | | | | | | | | | | | |
| 8 | 1 | 1 | 3 | 3 | 5 | 2 | 2 | 7 | 5 | 2 | 4 | 12 | 10 | 6 | 7 | 2 | 5 | 2 | | 3 | 1 | 1 | | | | | | 1 | | | | | | | | | |
| 9 | | | | 1 | 4 | 2 | 4 | 4 | 10 | 7 | 7 | 5 | 4 | 3 | 8 | 2 | 1 | 1 | | | 1 | | | | | | | | | | | | | | | | |
| 10 | | | | 2 | 3 | 2 | 2 | 1 | 9 | 4 | 4 | 5 | 8 | 4 | 3 | 2 | 3 | 1 | | | | | | | | | | | | | | | | | | | |
| 11 | 1 | 1 | 1 | 1 | 3 | | 3 | 7 | 6 | 4 | 6 | 5 | 4 | 2 | 4 | 3 | 1 | | | | | | | | | | | | | | | | | | | | |
| 12 | | | | 1 | 1 | 1 | 5 | 1 | 3 | 3 | 12 | 8 | 3 | 1 | 5 | 2 | 1 | | | | | | | | | | | | | | | | | | | | |
| 13 | 1 | | | 1 | 1 | 4 | 5 | 6 | 4 | 8 | 4 | 1 | 4 | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | 1 | 1 | | | 1 | 4 | 3 | 2 | 2 | 3 | 1 | 3 | 2 | 2 | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | | 1 | | | 2 | | 1 | 1 | 2 | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | | | | 2 | | 1 | 3 | 1 | 1 | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | | | | | | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Figure 19. Right lane entry flow vs. conflicting flow, number of observations for each entry flow/conflicting flow cell, two lane sites**

Figure 20 and Figure 21 show plots of the entry flow rates vs. the conflicting flow rates for two-lane sites, for those time periods during which the proportion time queued exceeds 0.90. As expected, most of the data points follow the form of the standard capacity line.

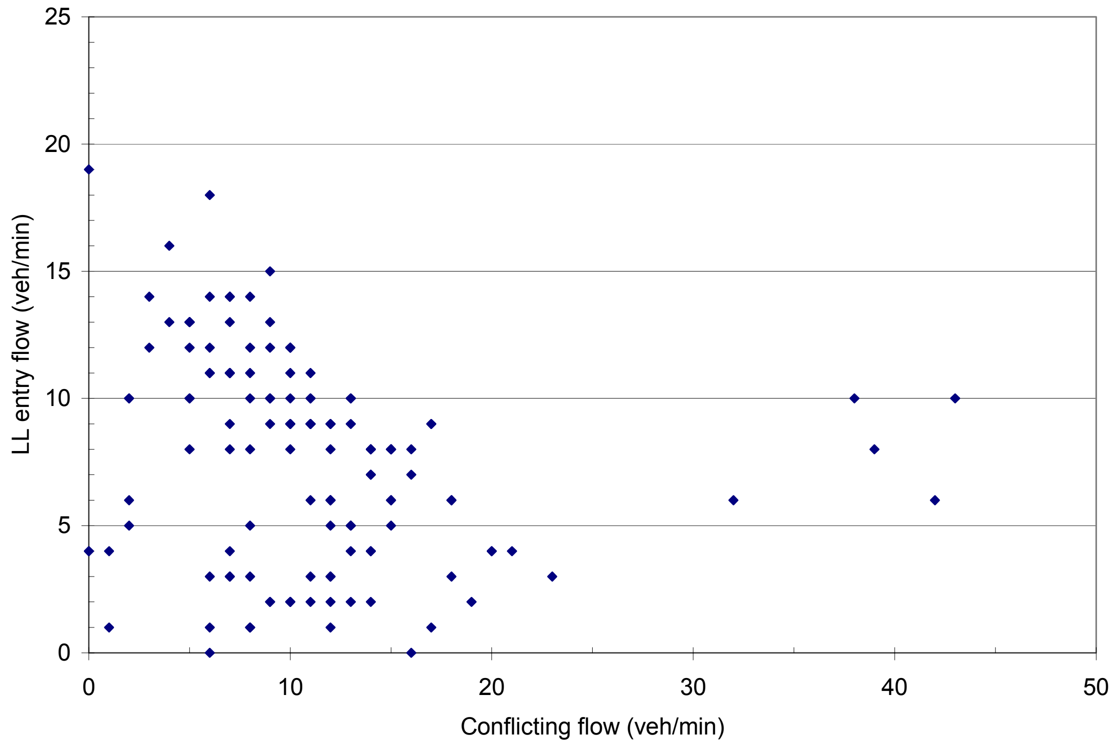



**Figure 20. Left lane entry flow vs. conflicting flow, one minute data, two lane sites, proportion time queued > 0.90**

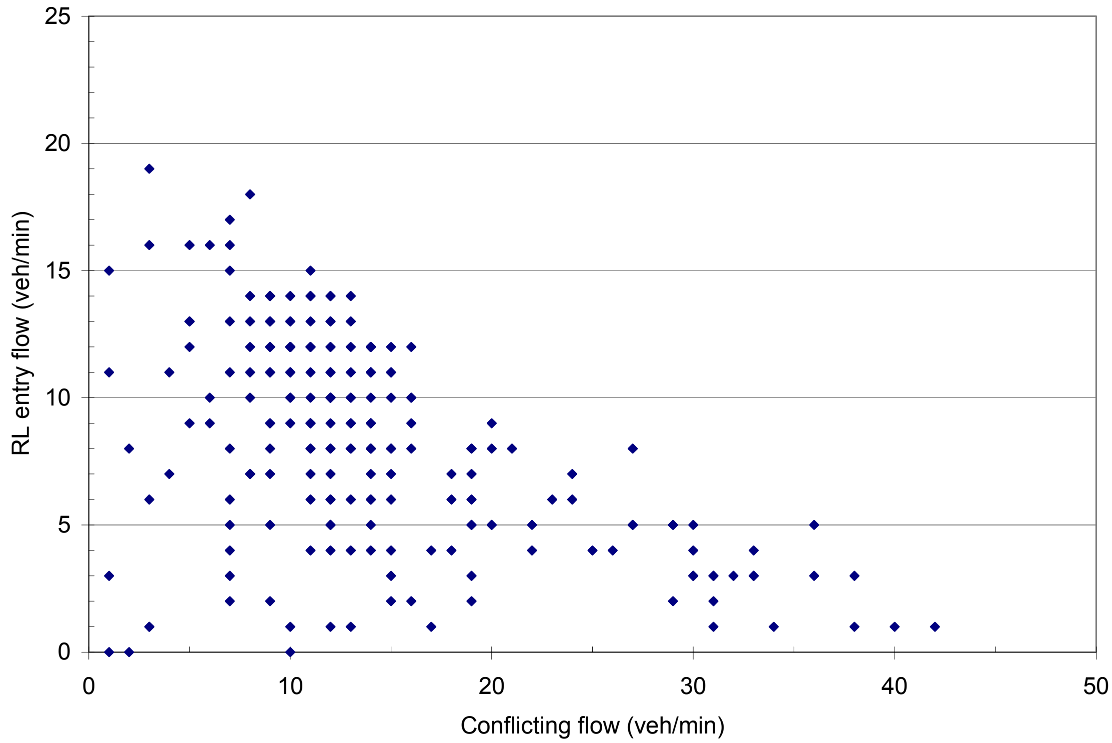



**Figure 21. Right lane entry flow vs. conflicting flow, one minute data, two lane sites, proportion time queued > 0.90**

### *4.2.2 Delay data ranges*

Figure 22 shows the distribution of delay observations for all two-lane sites, using five second bins from zero seconds to 95 seconds. The mean delay is 10.7 seconds per vehicle. Most of the delay measurements are less than 20 seconds per vehicle.

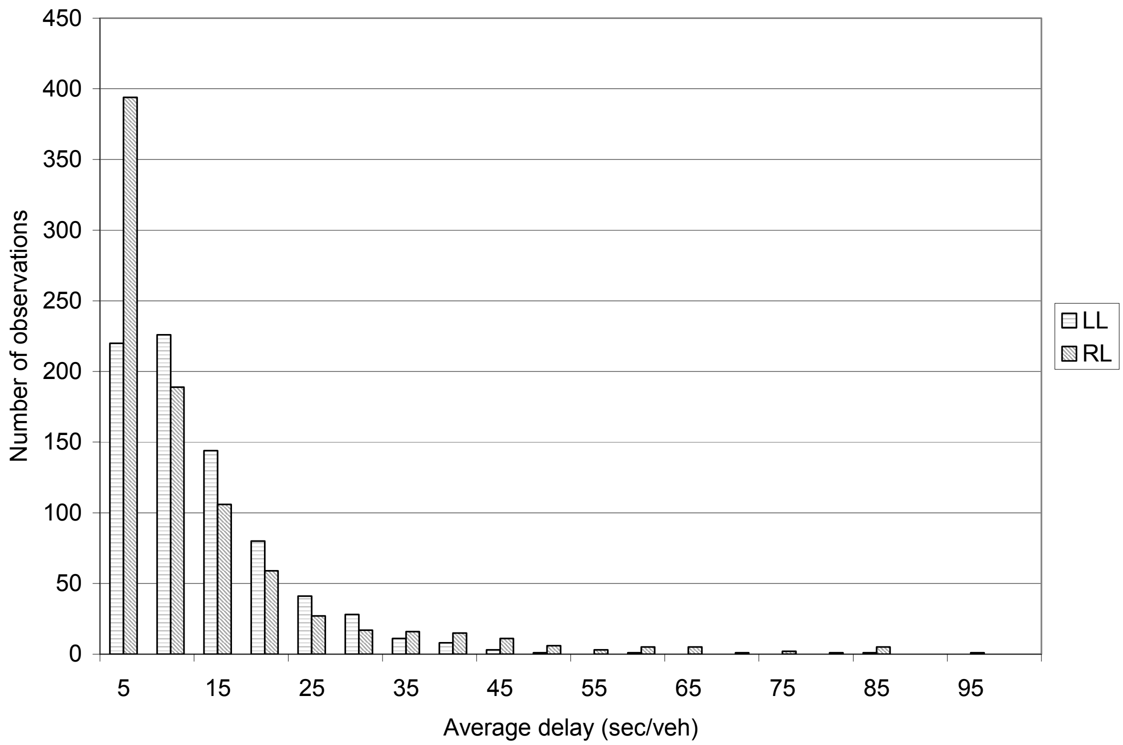



**Figure 22. Number of one-minute observations, average delay, two-lane sites**

Figure 23 and Figure 24 show plots of the mean delay for each entry flow/conflicting flow pair.  As expected, delays increase as the combination of entry and conflicting flows increase.

Conflicting flow, veh/min (columns 0–25)

| Entry flow, LL, veh/min | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | | | | | 1.8 | 2.7 | 4.7 | 3.7 | 4.7 | 7.8 | 2.8 | 4.5 | | 11.9 | 5.0 | 10.4 | | 26.3 | | 28.6 | | | | | |
| 1 | 0.3 | 12.6 | | 3.3 | 5.1 | 3.2 | 5.7 | 4.5 | 6.6 | 7.7 | 9.5 | 6.2 | 11.3 | 11.6 | 10.0 | 13.2 | 11.5 | 11.4 | 13.8 | 24.4 | | 15.6 | | 14.3 | | |
| 2 | | | | 1.7 | 17.7 | 7.8 | 6.4 | 7.4 | 7.8 | 6.6 | 7.6 | 7.3 | 7.7 | 9.9 | 13.4 | 11.5 | 7.7 | 17.8 | | 13.5 | 15.7 | 0.3 | 26.5 | 14.2 | | |
| 3 | | 0.4 | | 4.5 | 2.0 | 8.2 | 3.4 | 24.4 | 6.2 | 11.0 | 8.6 | 6.8 | 12.6 | 12.5 | 11.6 | 14.4 | 15.2 | 3.7 | 26.0 | 20.8 | | 19.3 | | 17.8 | | |
| 4 | 2.4 | | 13.6 | | 6.6 | 5.5 | 3.7 | 6.3 | 7.5 | 10.1 | 7.8 | 12.1 | 9.5 | 9.2 | 19.8 | 14.9 | 7.8 | 17.8 | | 18.0 | 40.2 | 10.2 | | | | |
| 5 | | 5.7 | 23.8 | 1.5 | 8.4 | 5.0 | 0.4 | 6.6 | 11.7 | 7.6 | 8.8 | 14.8 | 4.9 | 22.5 | 16.0 | 18.5 | 19.5 | 17.5 | 30.8 | 28.2 | | | | 33.5 | | |
| 6 | | | 14.1 | 0.2 | 2.6 | 2.3 | | 10.5 | 5.4 | 11.3 | 11.9 | 7.3 | 16.8 | 12.3 | 10.8 | 12.4 | 6.7 | 16.0 | 18.6 | | | | | 2.4 | | |
| 7 | | | 0.2 | 2.8 | 4.7 | 2.4 | 8.4 | 4.4 | 7.4 | 11.1 | 7.7 | 6.6 | 13.9 | 12.4 | 21.8 | | 23.4 | 5.2 | | | | | | | | |
| 8 | | | | 4.3 | 2.6 | 7.8 | 9.0 | 7.6 | 10.0 | 8.0 | 16.2 | 11.2 | 10.1 | | 21.6 | 25.0 | 40.0 | 13.4 | | | | | | | | |
| 9 | 0.3 | 1.6 | 1.0 | 5.5 | 4.1 | 6.3 | 3.6 | 4.7 | 5.0 | 12.9 | 15.9 | 21.1 | 17.6 | 9.2 | 3.0 | | | 23.8 | | | | | | | | |
| 10 | 1.1 | 1.0 | 7.0 | 3.7 | 5.0 | 9.2 | 6.0 | | 10.7 | 15.7 | 27.8 | 10.0 | 12.0 | 16.2 | | | | | | | | | | | | |
| 11 | | | | 2.5 | 5.1 | | 18.4 | 15.1 | 20.6 | | 21.4 | 25.3 | | | | | | | | | | | | | | |
| 12 | 14.1 | | 3.2 | 6.8 | | 12.1 | 8.5 | 10.1 | 16.2 | 18.7 | 21.1 | | | | | | | | | | | | | | | |
| 13 | 3.5 | 8.5 | 9.5 | | 11.9 | 16.6 | | 6.8 | | 14.1 | | | 1.2 | | 4.9 | | | | | | | | | | | |
| 14 | | | 2.2 | 27.0 | 8.4 | | 16.1 | 7.2 | 27.1 | | | | | | | | | | | | | | | | | |
| 15 | | | | | 12.4 | | | | 16.7 | 15.0 | | | | | | | | | | | | | | | | |
| 16 | | | | | 15.8 | 3.8 | | | | | | | | | | | | | | | | | | | | |
| 17 | | | | 6.5 | 3.4 | | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | 15.8 | | | | | | | | | | | | | | | | | | | |
| 19 | 19.9 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | | |

Conflicting flow, veh/min (columns 26–50)

| Entry flow, LL, veh/min | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | | 21.9 | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | 13.3 | 38.8 | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | 35.7 | | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | 9.1 | | | 6.2 | | | 6.0 | | | | | | | | | | | | | | | |
| 6 | | | 5.9 | | | | 15.5 | | | | | | | | | | 43.6 | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | 6.3 | | 3.9 | | | | | | | | | 47.2 | | | | | | | | | | | |
| 9 | | | | | | | | | 3.6 | | | 5.2 | | | | | | | | | | | | | |
| 10 | | 4.8 | | | | | | | | | | | 29.8 | | | | | 26.4 | | | | | | | |
| 11 | | | | | | | | | | | | | | | | | | | | | | | 4.5 | | |
| 12 | | | | | | 10.9 | | | | | | | | | | | | | | 14.4 | | | 24.4 | | |
| 13 | | | | | | | | | | | | 4.7 | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | |

**Figure 23. Left lane entry flow vs. conflicting flow, one minute data, left lane delay for two-lane sites**

Conflicting flow, veh/min (columns 0–25)

| Entry flow, RL, veh/min | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | 3.3 | | | 19.2 | | | | | | | 6.1 | | | | | | | | |
| 1 | 0.5 | | | 2.4 | | | 6.3 | | 2.8 | | 24.4 | 3.6 | 6.8 | 1.5 | 22.1 | | 5.8 | 14.5 | | | | | | | | |
| 2 | | | 8.2 | 0.0 | 4.9 | 3.9 | 17.0 | 7.1 | 2.0 | 12.6 | 3.4 | 1.1 | | 9.8 | 2.4 | 13.7 | 23.2 | | 17.5 | 1.3 | 17.4 | 10.7 | | 5.5 | | |
| 3 | 2.0 | 13.8 | 0.0 | 0.3 | 2.0 | 1.6 | 3.0 | 4.5 | 7.3 | 8.3 | | 3.2 | 6.9 | 8.9 | 10.6 | 6.2 | 5.4 | 11.5 | 16.1 | 21.4 | | 4.0 | 45.1 | | 43.7 | |
| 4 | | | 3.6 | 0.7 | 1.2 | 4.4 | 10.4 | 24.4 | 6.0 | 4.8 | 4.3 | 4.3 | 7.9 | 15.8 | 12.0 | 13.6 | 11.9 | 22.0 | 19.8 | 3.2 | 10.0 | 27.7 | 16.9 | | | 27.9 |
| 5 | 0.6 | 0.4 | 0.8 | 3.8 | 3.4 | 1.6 | 2.1 | 11.0 | 7.6 | 10.4 | 5.5 | 9.0 | 11.1 | 6.6 | 16.3 | 11.6 | 12.3 | 8.0 | 21.0 | 20.0 | 59.6 | | 81.2 | 4.2 | | |
| 6 | 0.6 | 1.8 | | 3.0 | 1.2 | 3.9 | 6.7 | 9.9 | 5.6 | 5.5 | 5.8 | 4.4 | 16.0 | 14.0 | 11.1 | 31.1 | 2.4 | 17.0 | 63.1 | 32.4 | | | | 12.8 | 73.5 | |
| 7 | | | 1.7 | 3.2 | 6.0 | 6.1 | 5.7 | 6.5 | 22.8 | 11.1 | 11.5 | 12.3 | 9.7 | | 12.7 | 15.4 | 14.9 | 3.6 | 12.7 | 72.6 | 15.6 | 19.4 | | | 112.4 | |
| 8 | 14.9 | 2.2 | 8.7 | 5.7 | 3.5 | 3.5 | 2.8 | 4.0 | 6.0 | 10.4 | 7.3 | 10.9 | 9.7 | 11.1 | 20.6 | 5.3 | 14.9 | 22.5 | | 24.6 | 92.3 | 24.2 | | | | |
| 9 | | | | 7.4 | 3.7 | 16.5 | 8.0 | 3.3 | 11.2 | 7.5 | 4.9 | 12.0 | 12.4 | 7.1 | 17.4 | 5.3 | 8.1 | 22.3 | | | 6.7 | | | | | |
| 10 | | | | 1.6 | 11.0 | 4.4 | 5.8 | 9.2 | 4.3 | 9.4 | 9.7 | 16.9 | 7.8 | 36.0 | 13.6 | 4.4 | 8.4 | 3.0 | | | | | | | | |
| 11 | 0.8 | 37.9 | 10.5 | 1.2 | 7.4 | | 5.4 | 10.5 | 9.7 | 6.0 | 9.3 | 4.8 | 14.6 | 8.5 | 4.7 | 6.7 | 7.2 | | | | | | | | | |
| 12 | | | | 6.6 | 4.3 | 16.5 | 4.5 | | 2.0 | 5.2 | 5.3 | 4.1 | 11.2 | 5.3 | 7.5 | 22.2 | | | | | | | | | | |
| 13 | 1.3 | | | 4.3 | 1.4 | 2.4 | 4.7 | 12.4 | 2.2 | 6.2 | 4.9 | 19.3 | 1.8 | 3.8 | | | | | | | | | | | | |
| 14 | 11.6 | 1.2 | | | 0.5 | 5.9 | 2.8 | 0.6 | 6.2 | 2.5 | 3.8 | 3.8 | 5.0 | 3.7 | | | | | | | | | | | | |
| 15 | | 11.2 | | | 1.9 | | 2.6 | 7.8 | 10.4 | 4.1 | | 10.9 | | | | | | | | | | | | | | |
| 16 | | | | 1.4 | | 12.7 | 7.0 | 4.8 | 4.6 | | | | | 7.7 | | | | | | | | | | | | |
| 17 | | | | | | 1.2 | | 0.2 | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | 0.0 | | | | | | | | | | | | | | | | | |
| 19 | | | | 2.2 | | | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | | |

Conflicting flow, veh/min (columns 26–50)

| Entry flow, RL, veh/min | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | | 3.2 | 14.4 | | | 71.3 | 4.5 | | 52.2 | | | 5.0 | 17.0 | | 22.2 | | 84.2 | | | | | | | | |
| 2 | | 34.7 | 20.1 | 35.5 | 61.6 | 43.4 | | | | 12.1 | | | | | | | | | | | | | | | |
| 3 | | | | 37.5 | 27.4 | 29.2 | 25.3 | 62.4 | | | 56.6 | | 30.0 | | | | | | | | | | | | |
| 4 | 36.6 | | | 22.2 | 41.7 | | | 46.7 | 1.9 | | | 1.8 | 3.1 | | | | | | | | | | | | |
| 5 | 12.2 | 39.5 | 10.1 | 37.9 | 44.6 | | | | | | 52.2 | 12.2 | | | | | | | | | | | | | |
| 6 | | | | 17.0 | | | | | | 12.8 | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | 17.9 | | | | | | | | | | | |
| 8 | | 54.4 | | | | | | | | | | | | | | | | 5.8 | | | | | 8.6 | | |
| 9 | | | | | | | | | | | | | | | | | 8.1 | | | 7.6 | | | | | |
| 10 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | | | | | | | 13.3 | | |
| 13 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | |

**Figure 24. Right lane entry flow vs. conflicting flow, one minute data, right lane delay for two-lane sites**

Figure 25 and Figure 26 show plots of left-lane and right-lane average delay vs. entry plus conflicting flow, for the two lane sites, using the one-minute data. Two data ranges are shown, those time periods for which the proportion time queued exceeds 0.90 and those for which the parameter is less than 0.70. As expected, delay increases as the sum of the entry plus conflicting flows increase.

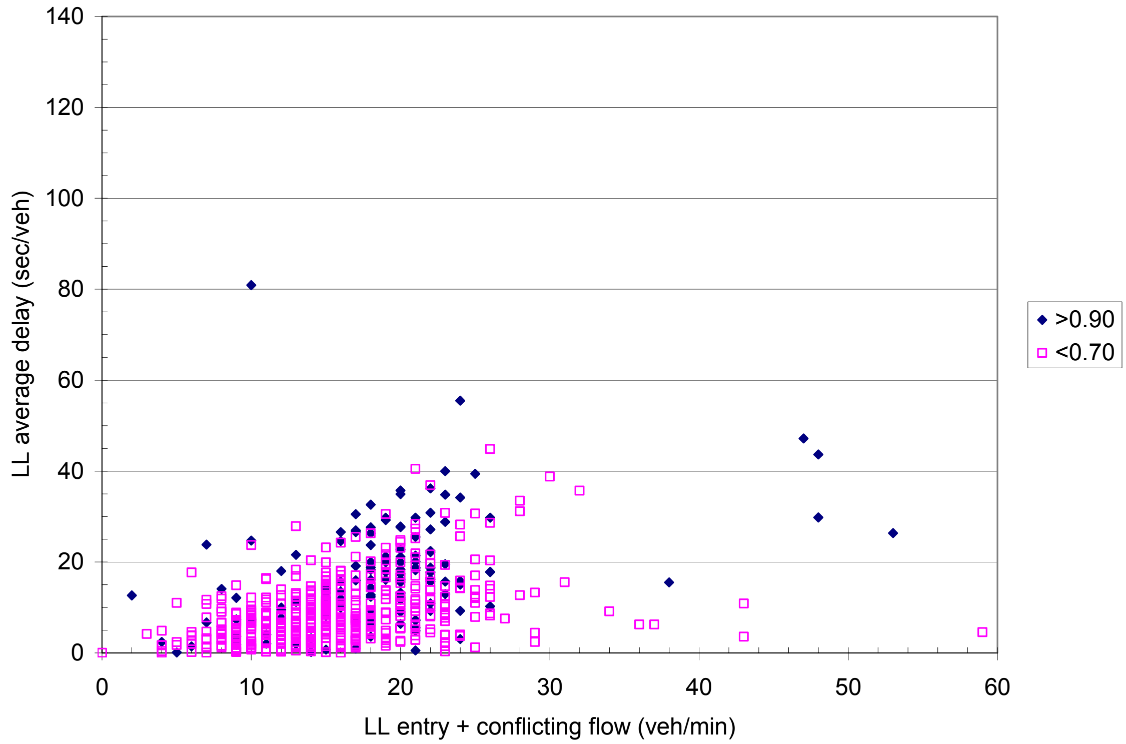



**Figure 25. Average left lane delay vs. left lane entry plus conflicting flow, one minute data, two lane sites**

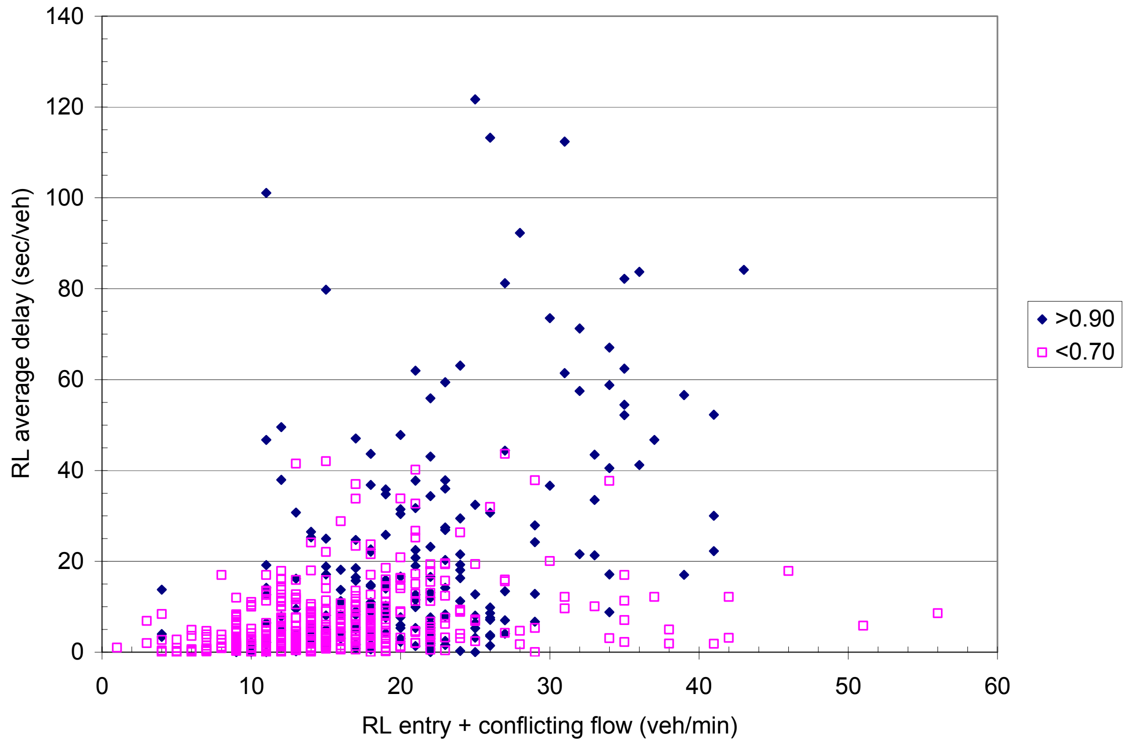



**Figure 26. Average right lane delay vs. right lane entry plus conflicting flow, one minute data, two lane sites**

### *4.2.3 Range of proportion time queued data*

Figure 27 shows the frequency distribution for the proportion time queued for the one-minute data for the two-lane sites. Of the 923 one-minute data points included in the sample, 135 left lane data points and 218 right lane data points exceed 0.90. Another 70 left lane data points and 146 right lane data points exceed 0.80. The mean proportion time queued is 0.55 for the left lane data and 0.65 for the right lane data.

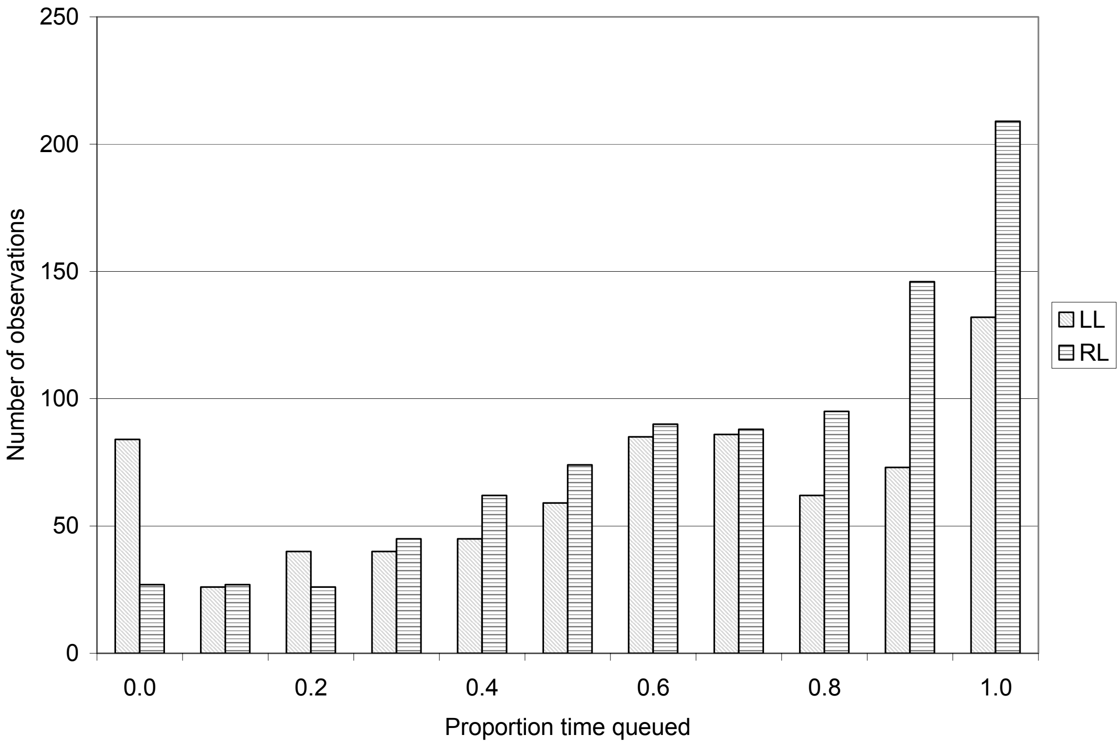



**Figure 27. Number of one-minute observations, proportion time queued, two-lane sites**

## Section 5. Gap Data

The events that were noted during the data extraction can be processed to identify the gaps that were accepted and rejected by each entering vehicle. There are several important issues for the project team to consider regarding how these gaps are defined. For example, the exiting vehicle (as noted by the "a" event) has some effect on the behavior of the entry vehicle, most likely a function of the width of the splitter island. And, for two-lane sites, the lane placement of the conflicting vehicle also has an effect on the behavior of the entry vehicle.

However, until additional analysis of the data is conducted to identify these effects, a more standard assumption is made regarding the gap data, at least so that we can present some initial conclusions regarding the data. Here, we have assumed that the exiting vehicle has no effect on the entering vehicle. A similar assumption has been made regarding the effect of the location or lane placement of the conflicting vehicle on the entering vehicle.

The following terms are used in the subsequent analysis of the gap data.

- The lag is defined as the time between the arrival of the vehicle in the first in queue position (the "1" event) and the passage of the next conflicting vehicle (the "s" event).
- The gap is defined as the time between consecutive passages of two conflicting vehicles (the "s" event).

### 5.1 One-lane data

A total of 10,785 gap sequences were measured. A gap sequence is considered to be all of the gaps that must be considered by a given entering vehicle. Table 9 shows the number of gap sequences for each of three cases.

- In case 1, the entry vehicle accepts the lag (8,282 gap sequences).
- In case 2, the entry vehicle rejects the lag but then accepts the first gap (1,318 gap sequences).
- In case 3, the entry vehicle rejects the lag, rejects the first gap, but then accepts a subsequent gap (1,151 gap sequences).

**Table 9. Summary of gap data, one-lane sites**

| Site | Case 1 | Case 2 | Case 3 | Total |
|---|---|---|---|---|
| MD06-N | 701 | 31 | 2 | 734 |
| MD06-S | 38 | 9 | 79 | 126 |
| MD07-E | 1413 | 131 | 67 | 1611 |
| ME01-E | 622 | 133 | 64 | 853 |
| ME01-N | 47 | 23 | 59 | 129 |
| OR01-S | 352 | 112 | 219 | 683 |
| WA01-N | 49 | 18 | 63 | 130 |
| WA01-W | 116 | 32 | 94 | 242 |
| WA03-E | 174 | 22 | 1 | 197 |
| WA03-S | 982 | 223 | 170 | 1375 |
| WA04-E | 377 | 81 | 34 | 492 |
| WA04-N | 2665 | 422 | 226 | 3313 |
| WA04-S | 170 | 37 | 51 | 258 |
| WA05-W | 492 | 32 | 5 | 529 |
| WA07-S | 84 | 12 | 17 | 113 |

While the case 1 data are interesting, they do not provide much useful information. It is the case 2 and case 3 data, in which at least one lag or gap is rejected, that we can use to identify the critical gap. Figure 28 shows a plot of the cumulative frequency distribution for the rejected gaps and the accepted gaps. While this method is not statistically precise, the crossing of these two lines provides an approximation for the critical gap. Here, the critical gap is estimated to be 4.1 seconds.

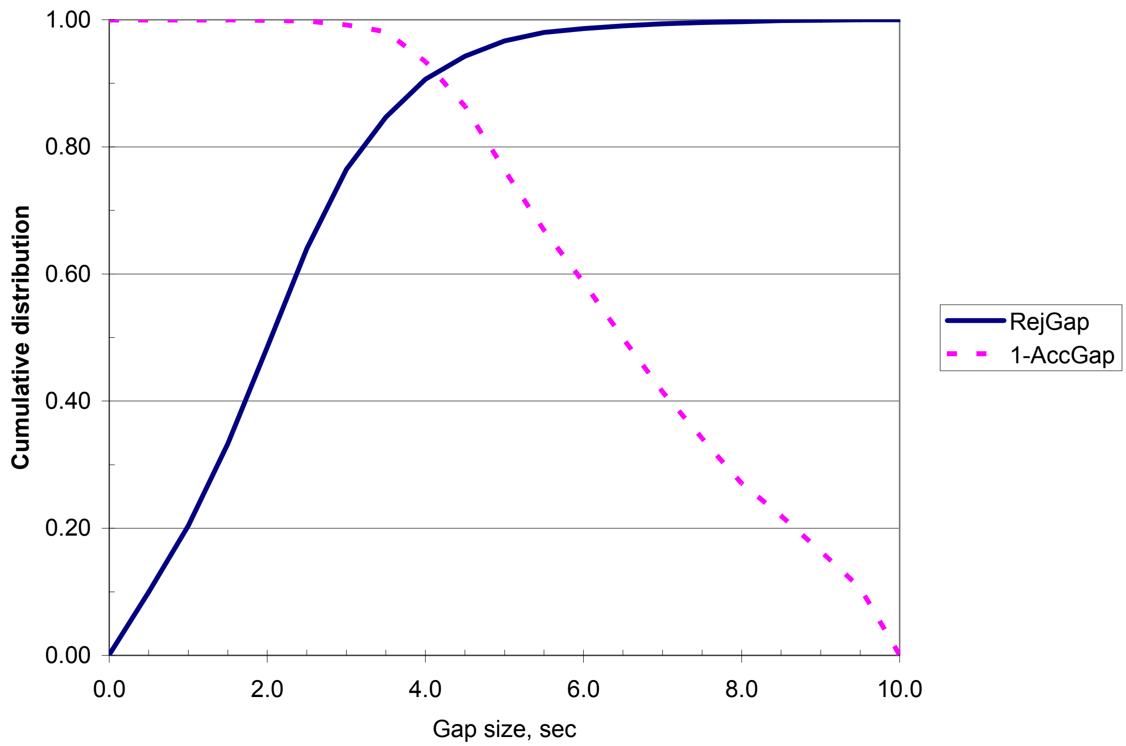



**Figure 28. Cumulative distribution of accepted and rejected gaps/lags, one-lane sites**

### *5.2 Two-lane sites*

A total of 13,530 gap sequences were measured. Table 10 shows the number of gap sequences for each of three cases.

- In case 1, the entry vehicle accepts the lag (5,295 gap sequences).
- In case 2, the entry vehicle rejects the lag but then accepts the first gap (1,067 gap sequences).
- In case 3, the entry vehicle rejects the lag, rejects the first gap, but then accepts a subsequent gap (7,168 gap sequences).

**Table 10. Summary of gap data, two-lane sites**

| Site | Case 1 | Case 2 | Case 3 | Total |
|---|---|---|---|---|
| MD04-E-L | 2269 | 244 | 1523 | 4036 |
| MD04-E-R | 1473 | 137 | 961 | 2571 |
| MD05-SW/NW | 216 | 91 | 1617 | 1924 |
| MD05-SW/W-L | 11 | 4 | 106 | 121 |
| MD05-SW/W-R | 14 | 13 | 113 | 140 |
| MI01-E | 50 | 9 | 44 | 103 |
| VT03-E-L | 50 | 29 | 332 | 411 |
| VT03-E-R | 87 | 34 | 332 | 453 |
| VT03-S-L | 70 | 31 | 194 | 295 |
| VT03-S-R | 192 | 104 | 337 | 633 |
| VT03-W-L | 194 | 100 | 626 | 920 |
| VT03-W-R | 669 | 271 | 983 | 1923 |

Figure 29 shows a plot of the cumulative frequency distribution for the rejected gaps and the accepted gaps using the case 2 and 3 data. Here, the critical gap is estimated to be 2.3 seconds, using the crossing point of the two lines. However, this number is not precise as gap events defined by vehicles in both lanes in the circulating flow are included in this estimate.

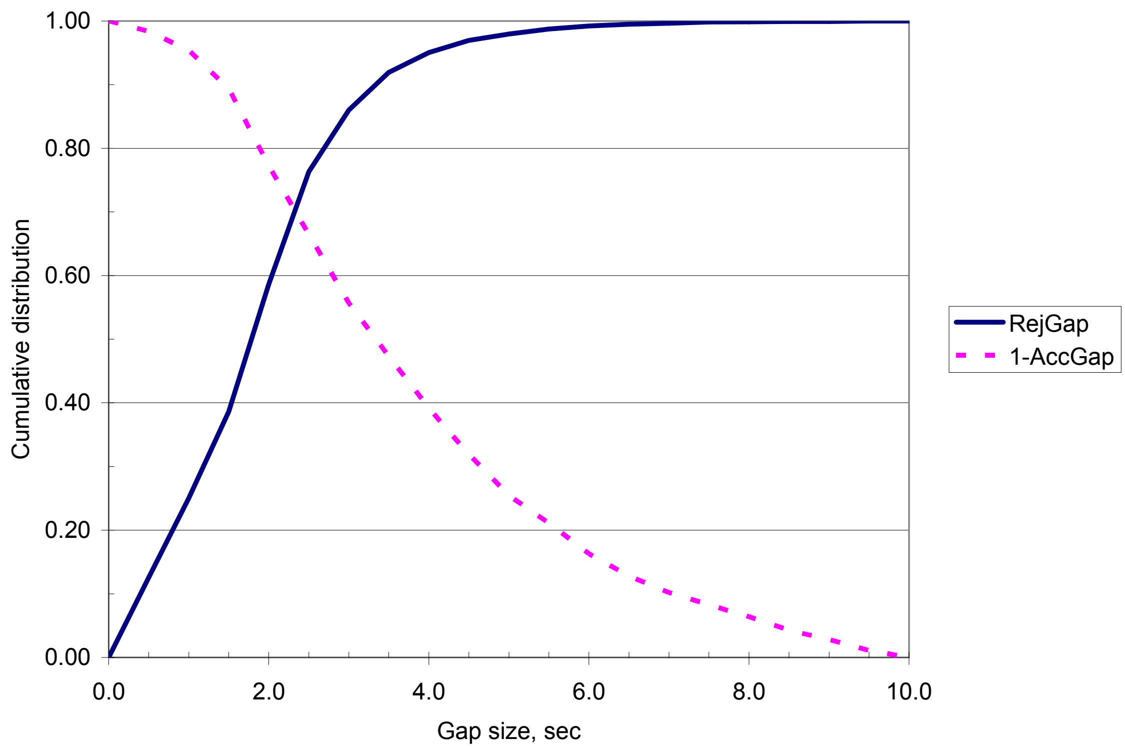



**Figure 29. Cumulative distribution of accepted/rejected gaps/lags, two-lane sites**

## Section 6. Turning Movement Data

Thirty minute samples were taken for each of the one-lane and two-lane sites to estimate the turning movement proportions. During each thirty minute period, a sample of vehicles entering each approach were tracked, from their entry point to their exit point. Lane usage for both the entry and exit points were also recorded.

### *6.1 Turning movement proportions*

The range of turning movement proportions for the one lane and two lane sites are summarized in Table 11 and Table 12. It should be noted that all could not be tracked at the site MD05; here, the size of the roundabout precluded a view of the entire roundabout showing all entrances and exits in one camera view.

**Table 11. Turning movement proportion ranges, one-lane sites**

| | LT | TH | RT | U-Turn |
|---|---|---|---|---|
| Minimum | 0.00 | 0.00 | 0.00 | 0.00 |
| Maximum | 0.95 | 0.98 | 0.97 | 0.02 |
| Mean | 0.29 | 0.46 | 0.31 | 0.00 |

**Table 12. Turning movement proportion ranges, two-lane sites**

| | LT | TH | RT | U-turn |
|---|---|---|---|---|
| Minimum | 0.00 | 0.00 | 0.00 | 0.00 |
| Maximum | 0.95 | 0.66 | 0.59 | 0.13 |
| Mean | 0.23 | 0.22 | 0.11 | 0.01 |

## *6.2 Travel times*

The travel times were measured for each of the vehicles tracked, by noting the time that each vehicle entered and exited the roundabout. A summary of the travel times for each turning movement for the one-lane and two-lane sites are shown in Figure 30 and Figure 31. The number of observations for each one second time bin are shown in the figures.

For the one-lane sites, the mean travel time for each movement is listed below:

- Left turn: 10.8 seconds
- Through: 6.6 seconds
- Right turn: 3.1 seconds
- U-turn: 16.2 seconds

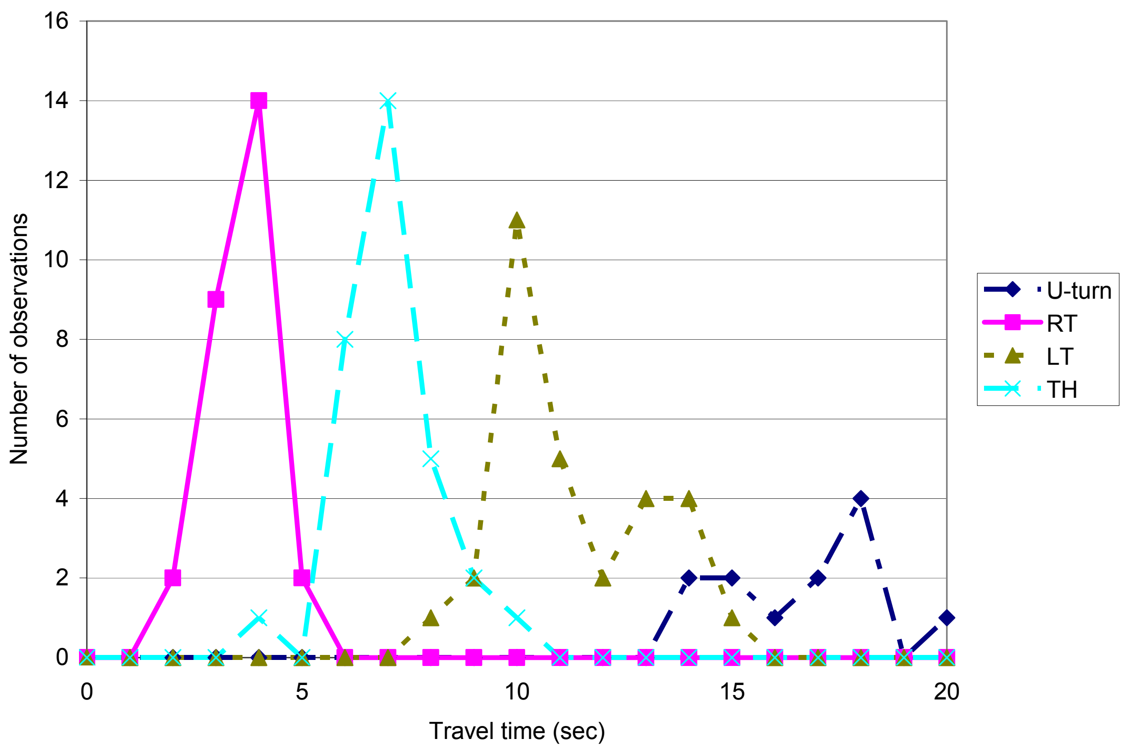



**Figure 30. Travel time distribution, one lane sites**

For the two-lane sites, the mean travel time for each movement is listed below:

- Left turn: 11.8 seconds
- Through: 7.4 seconds
- Right turn: 2.7 seconds
- U-turn: 18.8 seconds

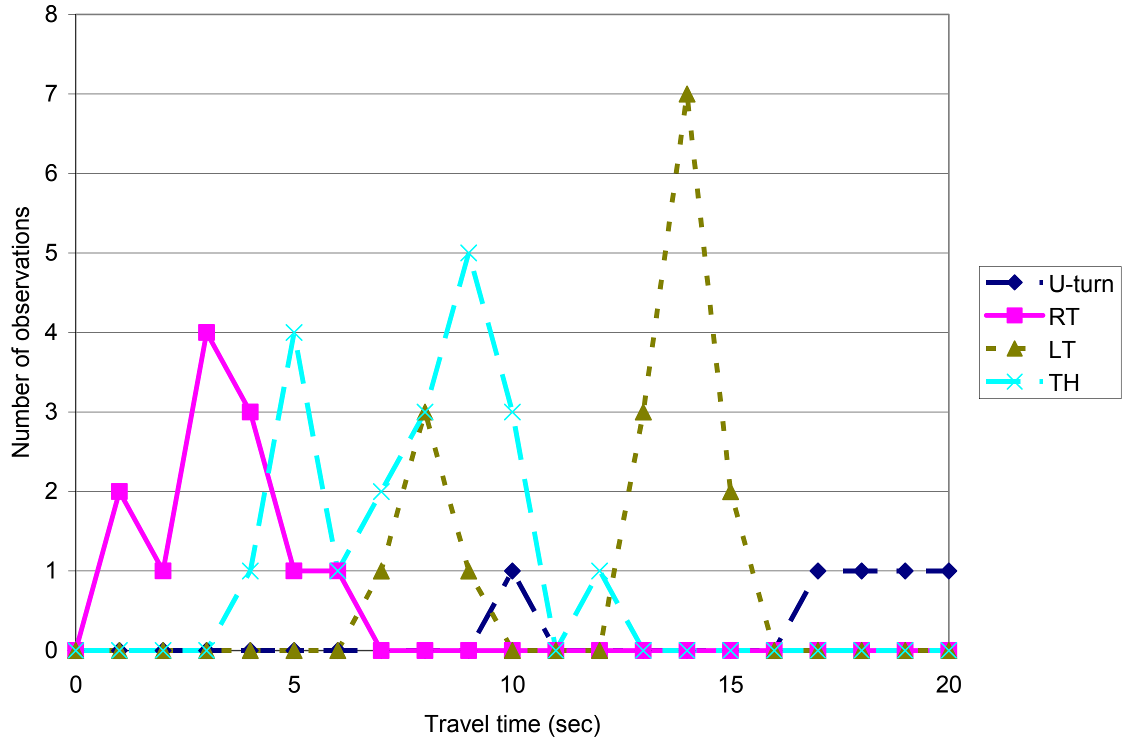



**Figure 31. Travel time distribution, two lane sites**

## Section 7. Guide to Spreadsheet Datasets

One of the purposes of this working paper is to document the data sets that have been developed, including the information that is included in each data set. The CD-ROM that accompanies this working paper includes all of the data sets that were generated as part of this effort. The CD is organized in a web-like structure, so that navigation from one data set to another is efficient.

A list of spreadsheet files with all of the raw data is included in Appendix A of this working paper. Site photographs are included in Appendix B. Example data sets are shown in Appendix C.

## Appendix A

This appendix, through Table 13 and Table 14, lists each of the sites, approaches, and time periods for which data were extracted for one-lane and two-lane sites.

**Table 13. Data extraction time periods, one lane sites**

| Site | DVD Name | File Name | Beginning Time | End Time | Time duration | Total Time | Time by Approach |
|---|---|---|---|---|---|---|---|
| MD06 | N1 | *MD06-N1-2.08.00.xls* | 2:08:00 | 2:41:00 | 0:33:00 | 0:55:00 | 0:55:00 |
| | | *MD06-N1-2.44.00.xls* | 2:44:00 | 2:58:00 | 0:14:00 | | |
| | | *MD06-N1-3.06.00.xls* | 3:06:00 | 3:14:00 | 0:08:00 | | |
| MD06 | S1 | *MD06-S1-2.59.00.xls* | 2:59:00 | 3:14:00 | 0:15:00 | 0:15:00 | 0:15:00 |
| MD07 | E1 | *MD07-E1-0.09.00.xls* | 0:09:00 | 0:29:59 | 0:20:59 | 2:25:09 | 2:25:09 |
| | | *MD07-E1-0.29.50.xls* | 0:29:50 | 0:44:56 | 0:15:06 | | |
| | | *MD07-E1-0.44.56.xls* | 0:44:56 | 1:10:22 | 0:25:26 | | |
| | | *MD07-E1-1.10.22.xls* | 1:10:22 | 1:39:14 | 0:28:52 | | |
| | | *MD07-E1-1.39.14.xls* | 1:39:14 | 2:07:00 | 0:27:46 | | |
| | | *MD07-E1-2.07.00.xls* | 2:07:00 | 2:22:53 | 0:15:53 | | |
| | | *MD07-E1-2.22.53.xls* | 2:22:53 | 2:34:00 | 0:11:07 | | |
| ME01 | N2 | *ME01-N2-0.38.00.xls* | 0:38:00 | 0:59:00 | 0:21:00 | 0:21:00 | 0:21:00 |
| ME01 | E2 | *ME01-E2-0.27.00.xls* | 0:27:00 | 1:16:35 | 0:49:35 | 1:13:00 | 1:13:00 |
| | | *ME01-E2-1.16.35.xls* | 1:16:35 | 1:40:00 | 0:23:25 | | |
| OR01 | S1 | *OR01-S1-1.11.00.xls* | 1:11:00 | 1:21:00 | 0:10:00 | 0:10:00 | 1:14:30 |
| OR01 | S2 | *OR01-S2-0.13.00.xls* | 0:13:00 | 0:57:00 | 0:44:00 | 1:04:30 | |
| | | *OR01-S2-1.18.00.xls* | 1:18:00 | 1:26:00 | 0:08:00 | | |
| | | *OR01-S2-1.42.00.xls* | 1:42:30 | 1:55:00 | 0:12:30 | | |
| WA01 | W1 | *WA01-W1-0.5.00.xls* | 0:05:00 | 0:14:00 | 0:09:00 | 0:26:00 | 0:26:00 |
| | | *WA01-W1-3.21.00.xls* | 3:21:00 | 3:38:00 | 0:17:00 | | |
| WA01 | N1 | *WA01-N1-3.09.00.xls* | 3:09:00 | 3:25:00 | 0:16:00 | 0:16:00 | 0:16:00 |
| WA03 | S1 | *WA03-S1-0.02.00.xls* | 0:02:00 | 0:25:00 | 0:23:00 | 1:25:00 | 2:17:03 |
| | | *WA03-S1-1.20.00.xls* | 1:20:00 | 1:34:00 | 0:14:00 | | |
| | | *WA03-S1-2.55.00.xls* | 2:55:00 | 3:25:00 | 0:30:00 | | |
| | | *WA03-S1-3.30.00.xls* | 3:30:00 | 3:48:00 | 0:18:00 | | |
| WA03 | S2 | *WA03-S2-0.54.15.xls* | 0:54:15 | 1:06:00 | 0:11:45 | 0:29:53 | |
| | | *WA03-S2-1.13.20.xls* | 1:13:20 | 1:31:28 | 0:18:08 | | |
| WA03 | S3 | *WA03-S3-0.15.50.xls* | 0:15:50 | 0:27:00 | 0:11:10 | 0:22:10 | |
| | | *WA03-S3-1.50.00.xls* | 1:50:00 | 1:55:00 | 0:05:00 | | |
| | | *WA03-S3-2.23.00.xls* | 2:23:00 | 2:29:00 | 0:06:00 | | |
| WA03 | E1 | *WA03-E1-0.37.15.xls* | 0:37:15 | 0:57:00 | 0:19:45 | 0:19:45 | 0:19:45 |
| WA04 | S1 | *WA04-S1-1.46.02.xls* | 1:46:02 | 2:01:00 | 0:14:58 | 0:14:58 | 0:25:28 |
| WA04 | S2 | *WA04-S2-0.33.00.xls* | 0:33:00 | 0:37:00 | 0:04:00 | 0:10:30 | |
| | | *WA04-S2-1.44.30.xls* | 1:44:30 | 1:51:00 | 0:06:30 | | |
| WA04 | N1 | *WA04-N1-0.12.00.xls* | 0:12:00 | 0:19:38 | 0:07:38 | 3:16:38 | 4:25:38 |
| | | *WA04-N1-0.19.38.xls* | 0:19:38 | 0:34:26 | 0:14:48 | | |
| | | *WA04-N1-0.34.26.xls* | 0:34:26 | 1:07:00 | 0:32:34 | | |
| | | *WA04-N1-1.19.00.xls* | 1:19:00 | 1:33:15 | 0:14:15 | | |
| | | *WA04-N1-1.33.15.xls* | 1:33:15 | 1:49:20 | 0:16:05 | | |

| Site | DVD Name | File Name | Beginning Time | End Time | Time duration | Total Time | Time by Approach |
|---|---|---|---|---|---|---|---|
| | | *WA04-N1-1.49.20.xls* | 1:49:20 | 2:10:00 | 0:20:40 | | |
| | | *WA04-N1-2.13.35.xls* | 2:13:35 | 2:47:13 | 0:33:38 | | |
| | | *WA04-N1-2.51.00.xls* | 2:51:00 | 3:02:00 | 0:11:00 | | |
| | | *WA04-N1-3.02.00.xls* | 3:02:00 | 3:14:53 | 0:12:53 | | |
| | | *WA04-N1-3.14.53.xls* | 3:14:53 | 3:32:40 | 0:17:47 | | |
| | | *WA04-N1-3.32.40.xls* | 3:32:40 | 3:48:00 | 0:15:20 | | |
| WA04 | N2 | *WA04-N2-0.07.00.xls* | 0:07:00 | 0:22:00 | 0:15:00 | 1:09:00 | |
| | | *WA04-N2-0.28.00.xls* | 0:28:00 | 0:42:00 | 0:14:00 | | |
| | | *WA04-N2-1.17.00.xls* | 1:17:00 | 1:30:00 | 0:13:00 | | |
| | | *WA04-N2-1.48.00.xls* | 1:48:00 | 1:55:00 | 0:07:00 | | |
| | | *WA04-N2-2.09.00.xls* | 2:09:00 | 2:29:00 | 0:20:00 | | |
| WA04 | E1 | *WA04-E1-0.30.00.xls* | 0:30:00 | 0:37:00 | 0:07:00 | 0:38:00 | 0:38:00 |
| | | *WA04-E1-1.30.00.xls* | 1:30:00 | 1:43:00 | 0:13:00 | | |
| | | *WA04-E1-1.57.00.xls* | 1:57:00 | 2:04:00 | 0:07:00 | | |
| | | *WA04-E1-2.38.00.xls* | 2:38:00 | 2:43:00 | 0:05:00 | | |
| | | *WA04-E1-2.59.00.xls* | 2:59:00 | 3:05:00 | 0:06:00 | | |
| WA05 | W3 | *WA05-W3-2.23.00.xls* | 2:23:00 | 2:38:00 | 0:15:00 | 0:33:40 | 0:33:40 |
| | | *WA05-W3-3.15.20.xls* | 3:15:20 | 3:34:00 | 0:18:40 | | |
| WA07 | S2 | *WA05-S2-1.18.57.xls* | 1:18:57 | 1:27:00 | 0:08:03 | 0:08:03 | 0:08:03 |
| | | | | ***Total:*** | **15:53:16** | **15:53:16** | **15:53:16** |

**Table 14. Data extraction time periods, two-lane sites**

| Site | DVD Name | File Name | Beginning Time | End Time | Time duration | Total Time | Time by Approach |
|---|---|---|---|---|---|---|---|
| MD04 | E1 | *MD04-E1-0.00.05.xls* | 0:00:05 | 0:14:57 | 0:14:52 | 3:35:20 | 5:46:19 |
| | | *MD04-E1-0.14.57.xls* | 0:14:52 | 0:28:55 | 0:14:03 | | |
| | | *MD04-E1-0.28.55.xls* | 0:28:55 | 0:44:53 | 0:15:58 | | |
| | | *MD04-E1-0.44.53.xls* | 0:44:53 | 0:59:40 | 0:14:47 | | |
| | | *MD04-E1-0.59.40.xls* | 0:59:40 | 1:18:00 | 0:18:20 | | |
| | | *MD04-E1-1.18.00.xls* | 1:18:00 | 1:33:50 | 0:15:50 | | |
| | | *MD04-E1-1.33.50.xls* | 1:33:50 | 1:58:00 | 0:24:10 | | |
| | | *MD04-E1-1.59.00.xls* | 1:59:00 | 2:28:23 | 0:29:23 | | |
| | | *MD04-E1-2.28.23.xls* | 2:28:23 | 2:55:00 | 0:26:37 | | |
| | | *MD04-E1-3.07.40.xls* | 3:07:40 | 3:28:23 | 0:20:43 | | |
| | | *MD04-E1-3.28.23.xls* | 3:28:23 | 3:49:00 | 0:20:37 | | |
| MD04 | E2 | *MD04-E2-0.02.15.xls* | 0:02:15 | 0:23:14 | 0:20:59 | 2:10:59 | |
| | | *MD04-E2-0.23.14.xls* | 0:23:14 | 0:44:03 | 0:20:49 | | |
| | | *MD04-E2-0.44.03.xls* | 0:44:03 | 1:01:39 | 0:17:36 | | |
| | | *MD04-E2-1.01.39.xls* | 1:01:39 | 1:21:13 | 0:19:34 | | |
| | | *MD04-E2-1.21.14.xls* | 1:21:14 | 1:51:11 | 0:29:57 | | |
| | | *MD04-E2-1.53.28.xls* | 1:53:28 | 2:15:32 | 0:22:04 | | |
| MD05 | SW-NW1 | *MD05-SW-NW1-0.53.00.xls* | 0:53:00 | 1:19:53 | 0:26:53 | 2:06:54 | 2:06:54 |
| | | *MD05-SW-NW1-1.19.59.xls* | 1:19:59 | 1:37:01 | 0:17:02 | | |
| | | *MD05-SW-NW1-1.37.01.xls* | 1:37:01 | 2:05:28 | 0:28:27 | | |
| | | *MD05-SW-NW1-2.05.28.xls* | 2:05:28 | 2:28:00 | 0:22:32 | | |
| | | *MD05-SW-NW1-2.28.00.xls* | 2:28:00 | 3:00:00 | 0:32:00 | | |
| MD05 | SW-W1 | *MD05-SW-W1-1.56.32.xls* | 1:56:32 | 2:18:00 | 0:21:28 | 0:21:28 | 0:21:28 |
| MI01 | E2 | *MI01-E2-1.08.55.xls* | 1:08:55 | 1:20:00 | 0:11:05 | 0:11:05 | 0:11:05 |
| VT03 | W1 | *VT03-W1-0.03.00.xls* | 0:03:00 | 0:21:09 | 0:18:09 | 1:51:00 | 6:44:03 |
| | | *VT03-W1-0.21.09.xls* | 0:21:09 | 0:35:28 | 0:14:19 | | |
| | | *VT03-W1-0.35.28.xls* | 0:35:28 | 0:52:50 | 0:17:22 | | |
| | | *VT03-W1-0.52.50.xls* | 0:52:50 | 1:10:20 | 0:17:30 | | |
| | | *VT03-W1-1.10.20.xls* | 1:10:20 | 1:26:58 | 0:16:38 | | |
| | | *VT03-W1-1.26.58.xls* | 1:26:58 | 1:41:43 | 0:14:45 | | |
| | | *VT03-W1-1.41.43.xls* | 1:41:43 | 1:54:00 | 0:12:17 | | |
| VT03 | W2 | *VT03-W2-0.02.05.xls* | 0:02:05 | 0:13:28 | 0:11:23 | 0:11:23 | |
| VT03 | W2b | *VT03-W2b-0.05.30.xls* | 0:05:30 | 0:22:00 | 0:16:30 | 4:41:40 | |
| | | *VT03-W2b-0.26.35.xls* | 0:26:35 | 0:38:52 | 0:12:17 | | |
| | | *VT03-W2b-0.56.18.xls* | 0:56:18 | 1:19:25 | 0:23:07 | | |
| | | *VT03-W2b-0.05.30.xls* | 0:05:30 | 2:15:00 | 2:09:30 | | |
| | | *VT03-W2b-2.07.10.xls* | 2:07:10 | 2:49:24 | 0:42:14 | | |
| | | *VT03-W2b-2.41.47.xls* | 2:41:47 | 3:03:00 | 0:21:13 | | |
| | | *VT03-W2b-3.22.11.xls* | 3:22:11 | 3:59:00 | 0:36:49 | | |
| VT03 | E3 | *VT03-E3-3.21.08.xls* | 3:21:08 | 3:38:00 | 0:16:52 | 0:16:52 | 1:03:17 |
| VT03 | E4 | *VT03-E4-0.20.45.xls* | 0:20:45 | 0:36:00 | 0:15:15 | 0:46:25 | |
| | | *VT03-E4-0.51.17.xls* | 0:51:17 | 1:01:40 | 0:10:23 | | |
| | | *VT03-E4-1.06.43.xls* | 1:06:43 | 1:17:50 | 0:11:07 | | |
| | | *VT03-E4-1.42.00.xls* | 1:42:00 | 1:51:40 | 0:09:40 | | |
| VT03 | S1 | VT03-S1-0.37.39.xls | 0:37:39 | 0:54:00 | 0:16:21 | 0:37:09 | 1:22:05 |

| Site | DVD Name | File Name | Beginning Time | End Time | Time duration | Total Time | Time by Approach |
|---|---|---|---|---|---|---|---|
| | | VT03-S1-1.00.12.xls | 1:00:12 | 1:21:00 | 0:20:48 | | |
| VT03 | S4 | *VT03-S4-0.00.50.xls* | 0:00:50 | 0:10:31 | 0:09:41 | 0:44:56 | |
| | | *VT03-S4-0.12.28.xls* | 0:12:28 | 0:28:00 | 0:15:32 | | |
| | | *VT03-S4-0.31.02.xls* | 0:31:02 | 0:37:00 | 0:05:58 | | |
| | | *VT03-S4-0.49.15.xls* | 0:49:15 | 1:03:00 | 0:13:45 | | |
| VT03 | W4 | *VT03-W4-0.02.53.xls* | 0:02:53 | 0:18:25 | 0:15:32 | 0:55:07 | 0:55:07 |
| | | *VT03-W4-0.18.25.xls* | 0:18:25 | 0:36:56 | 0:18:31 | | |
| | | *VT03-W4-0.36.56.xls* | 0:36:56 | 0:58:00 | 0:21:04 | | |
| | | | | ***Total:*** | **18:30:18** | **18:30:18** | **18:30:18** |

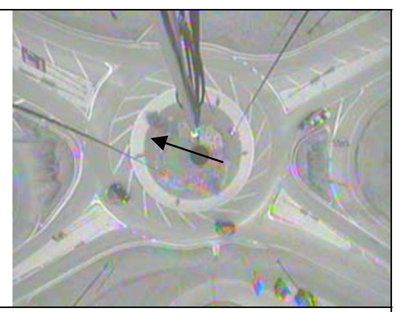
## Appendix B

This appendix provides a visual record of the roundabouts that are included in this working paper. Each directional view and the omni-directional view are shown, as well as the number of lanes on the approaches and on the circulatory roadway.

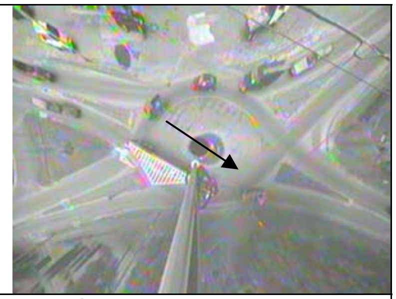
**Table 15. MD06. MD 2 at MD 408/MD 422, Lothian, Maryland**

| | | |
|---|---|---|
| Lanes on circulatory roadway<br>Lanes on approaches<br>Number of approaches | 1<br>1<br>4 |  |
| MD06-E1 | MD06-N1 | MD06-S1 |
|  |  |  |

**Table 16. MD07, MD 140/MD 832/Antrim Blvd, Taneytown, Maryland**

| | | |
|---|---|---|
| Lanes on circulatory roadway<br>Lanes on approaches<br>Number of approaches | 1<br>1<br>4 |  |
| MD07-E1 | MD07-N1 | MD07-W1 |
|  |  |  |

### Table 17. ME01 (1) US 202/State Route 237, Gorham, Maine

| | | |
|---|---|---|
| Lanes on circulatory roadway<br>Lanes on approaches<br>Number of approaches | 1<br>1<br>4 |  |
| ME01-E1 | ME01-N1 | ME01-S1 |
|  |  |  |

### Table 18. OR01 Colorado/Simpson, Bend, Oregon

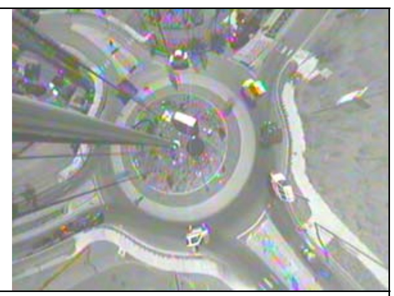
| | | |
|---|---|---|
| Lanes on circulatory roadway<br>Lanes on approaches<br>Number of approaches | 1<br>1<br>1 |  |
| OR01-N1 | OR01-S1 | OR01-W1 |
|  |  |  |

**Table 19. WA01 SR 16 SB Ramp Terminal (near Pioneer at Stinson), Gig Harbor, Washington**

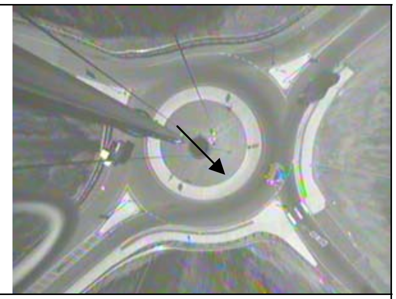
| | | |
|---|---|---|
| Lanes on circulatory roadway<br>Lanes on approaches<br>Number of approaches | 1<br>1<br>4<br>(3 +1 exit) |  |
| WA01-E1 | WA01-N1 | WA01-W1 |
|  |  |  |

**Table 20. WA03 High School Rd/Madison Ave, Bainbridge Island, Washington**

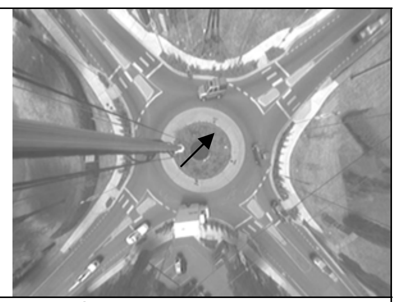
| | | |
|---|---|---|
| Lanes on circulatory roadway<br>Lanes on approaches<br>Number of approaches | 1<br>1<br>4 |  |
| WA03-N1 | WA03-E1 | WA03-S1 |
|  |  |  |

**Table 21. WA04 Mile Hill Dr. (Hwy 166)/Bethel Ave, Port Orchard, Washington**

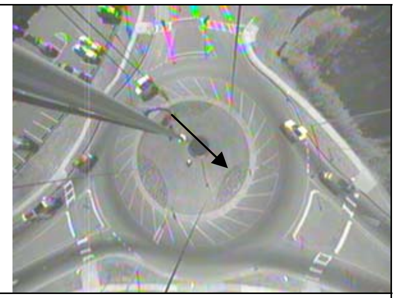
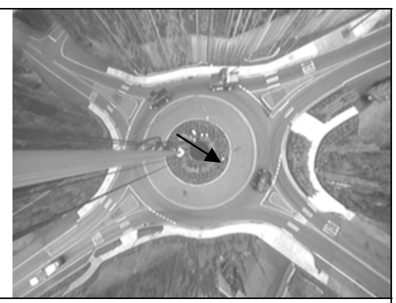
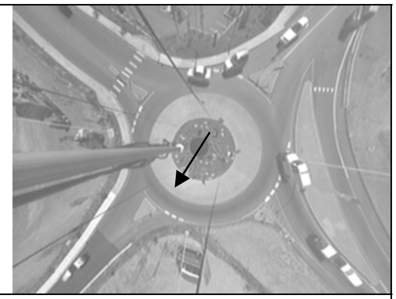
| | | |
|---|---|---|
| Lanes on circulatory roadway<br>Lanes on approaches<br>Number of approaches | 1<br>1<br>3 |  |
| WA04-N1 | WA04-S1 | WA04-E1 |
|  |  |  |

**Table 22. WA05 NE Inglewood Hill/216th Ave NE, Sammamish, Washington**

| | | |
|---|---|---|
| Lanes on circulatory roadway<br>Lanes on approaches<br>Number of approaches | 1<br>1<br>4 |  |
| WA05-N1 | WA05-W1 | WA05-E1 |
|  |  |  |

### Table 23. WA07 I-5 off-ramp/Quinault Dr/Galaxy Dr, Lacey, Washington

| | | |
|---|---|---|
| Lanes on circulatory roadway<br>Lanes on approaches<br>Number of approaches | 1<br>1<br>4<br>(3 + 1 entrance only) |  |
| WA07-N1 | WA07-S1 | WA07-E1 |
|  |  |  |

### Table 24. MD04, MD139(CharlesSt.)@Bellona Ave, Baltimore County, Maryland

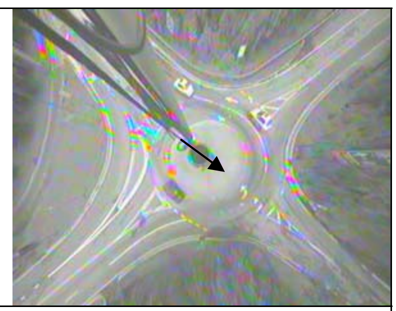
| | | |
|---|---|---|
| Lanes on circulatory roadway<br>Lanes on approaches<br>Number of approaches | 2<br>2, 1<br>4 |  |
| MD04-E1 | MD04-S1 | MD04-W1 |
|  |  |  |

**Table 25. MD05, MD45 at MD146/Joppa Rd, Towson, Maryland**

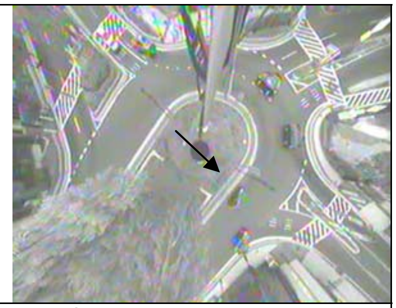
| | | |
|---|---|---|
| Lanes on circulatory roadway<br>Lanes on approaches<br>Number of approaches | 2<br>2<br>5 |  |
| MD05SW-NW1 | MD05SW-S1 | MD05SW-W1 |
|  |  |  |

**Table 26. MI01 Hamilton Rd/Marsh Rd, Okemos, Michigan**

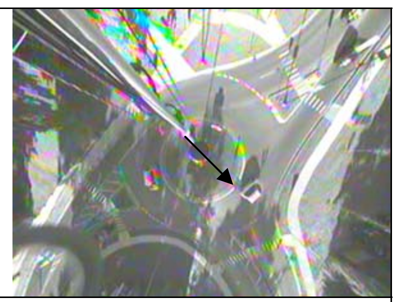
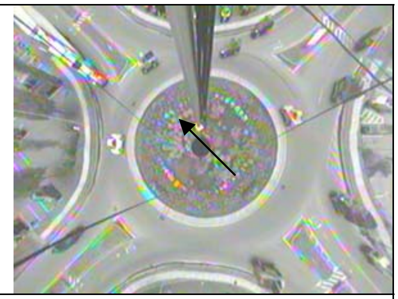
| | | |
|---|---|---|
| Lanes on circulatory roadway<br>Lanes on approaches<br>Number of approaches | 2?<br>2,1<br>3 |  |
| MI01-E1 | MI01-N1 | ME01-W1 |
|  |  |  |

**Table 27. VT03 (1) RT 9/RT 5, Brattleboro, Vermont**

| | | |
|---|---|---|
| Lanes on circulatory roadway<br>Lanes on approaches<br>Number of approaches | 2<br>2<br>4 |  |
| VT03-N1 | VT03-S1 | VT03-W1 |
|  |  |  |

## Appendix C

Several sets of data have been prepared as part of the data extraction effort. These data sets are summarized below: The data sets are included as a CD-ROM companion to this working paper.

- *Raw data*. All of the original keystroke/time event data are stored in files with a .csv file extension. These files have not been processed or corrected in any way. Each file is named according to the scheme used in this document. These files can be directly read by a text editor or spreadsheet software.
- *Summary data.* These raw data have been processed into summary files for each site. Included in these summary files are the flow rate, delay, and other similar data into a set of files, one per roundabout approach. Another set of data were processed for the gap data and the turning movement data.
- *Final data.* The final data includes the one minute summaries that were assembled in a small number of spreadsheet files that can be processed by the modeling team.

Figure 32 shows an example of the data set structure for the MD06-N data. In part 1 of the figure, the list of the fifteen one-lane approach data sets is given. For MD06-N, there are three individual time periods that make up this data set. These are shown in part 2 of the figure, and include MD06-N1-2:08:00, MD06-N1-2:44:00, and MD06-N1-3:06:00. In addition to the data for each of these three time periods, there are also data for the Traffic Tracker configuration files (noted with the extensions .tdp) and a file indicating the specific points at which the events were collected for this approach (the word file, with a .doc extension). These files are shown in part 3 of the figure. In part 4, the two raw data sets that were produced by Traffic Tracker, one for delay and one for gaps (noted as "D" and "G", respectively, in the file names, are shown. Finally, also in part 4, the spreadsheet with much of the summarized data is shown, with an .xls file extension.

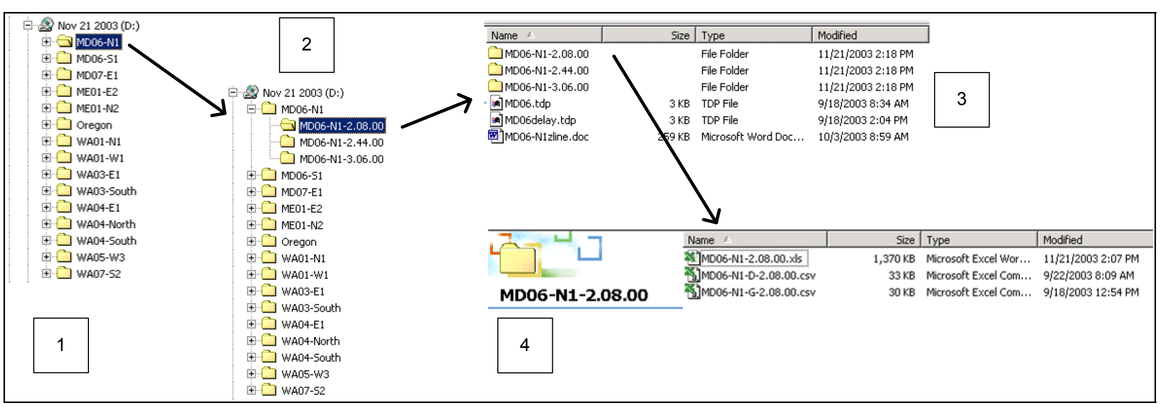



**Figure 32. Example file structure, raw and summary data sets**

This latter .xls file includes the data as shown in Table 28.

**Table 28. Description of worksheet tabs in summary data sets**

| Worksheet tab | Description |
|---|---|
| Gap Raw | Raw event data produced through Traffic Tracker including entry time, first in queue time, conflicting point time, and exit time. |
| Gap-Correct | Corrected gap data, accomplished by reviewing discrepancies in raw gap data. |
| Conflict events | List of conflict and exit events. |
| Delay Raw | Raw delay data produced through Traffic Tracker including entry time, first in queue time, and upstream time. Free flow travel time data are also included as collected. |
| Delay Correct | Corrected delay data, accomplished by reviewing discrepancies in raw delay data. Time correction between gap and delay data sets are calculated in this worksheet. Delay is computed using free flow travel time data. |
| Merged Data | Events from the delay and gap data sheets are merged. Service time, entry headway, and arrival headway are computed for each vehicle. |
| Vehicle Type | Vehicle type is added for each entry, conflicting, and exit event. |
| Summary 1 | One minute summaries for first in queue time, entry time, conflicting time, exit time, upstream time, and average delay. |
| Summary 2 | One minute summaries for first in queue time, entry time, conflicting time, exit time, upstream time, and average delay. Also computed are one minute data for conflicting plus exit flow and conflicting plus entry flow. |
| Event | Gap events are computed for each minor stream vehicle, including first in queue time ("1" event), entry time ("2" event), vehicle type, and all relevant gap events, including the previous "a" and "s" events, all intervening "a" and "s" events (between the "1" and "2" events for each vehicle), and the immediately subsequent "a" and "s" events. |
| Average Delay Output | Summary of VB script that summarizes one-minute average delay from list of individual vehicle delays. |
| Move up time calc | Computation of move up time for each consecutive vehicle pair; the move-up time is the difference in the "2" event for one vehicle and the "1" event for the next vehicle. |
| Veh in system calc | Computation of the number of vehicles in the system and the number of vehicles in the server. The system is defined as the space between the upstream event location and the yield line. |
| Avg delay ind veh chart | Time plot of individual vehicle delay vs time. |
| Veh in system chart | Time plot of number of vehicles in system vs time. |
| Delay-veh in system chart | Combination time plot of number vehicles in system and individual vehicle delay vs time. |
| Delay vs flow chart | Plot of one-minute values of delay and conflicting plus entry flow rates. |
| Service time chart | Time plot of individual vehicle service time vs time. |
| Move-up time chart | Time plot of individual vehicle move up time vs time. |
| Entry headway chart | Time plot of individual entry headway vs time. The entry time is the difference between two vehicles entering the roundabout. |
| Arrival headway chart | Time plot of individual arrival headway vs time. The arrival headway is the difference between two vehicles passing the upstream point. |
| Entry-conflicting flow chart | Plot of one-minute values of entry flow vs conflicting flow rates. |
| Entry-conflicting-exit flow chart | Plot of one-minute values of entry flow vs the sum of conflicting plus exit flow rates. |
| Veh in server chart | Time plot of number of vehicles in the server vs time. |

**Table 29. Parameter definitions for one-minute summaries**

| Parameter | Parameter definition |
|---|---|
| Time | The beginning of the one-minute time interval. |
| FirstQTime | The number of vehicles arriving at the first in queue position during this time interval; data were extracted twice, once during the gap data extraction and once during the delay data extraction. |
| EntryTime | The number of vehicles entering the roundabout during this time interval; data were extracted twice, once during the gap data extraction and once during the delay data extraction. |
| ExitTime | The number of vehicles exiting the roundabout just upstream of the entry during this time interval; data were extracted during the gap data extraction. |
| Upstream event, delay data | The number of vehicles passing the beginning of the upstream speed trap during this time interval. |
| Conflict time | The number of vehicles passing the conflict point on the circulating roadway during this time interval. |
| Average delay | The mean delay for all vehicles entering the roundabout during this time interval; individual vehicle delay was computed as the difference between the travel time on a segment of the approach (from the “z” line to the entry point”) for a given vehicle and the free flow travel time. |
| Conflicting + exit flow | The sum of the conflicting and exiting flow during the time interval. |
| Conflicting + entry flow | The sum of the conflicting and entry flow during the time interval. |

**Table 30. Example of one-minute summaries**

| Time | FirstQTime | | EntryTime | | ExitTime | Upstream event | Conflict Time | Ave Delay | Con + Exit Flow | Con + Entry Flow |
|---|---|---|---|---|---|---|---|---|---|---|
| | Gap data 1 | Delay data 1 | Gap data 2 | Delay data 2 | Gap data a | Delay Data z | Gap data s | | | |
| 0:09:00 | 12 | 10 | 12 | 10 | 5 | 11 | 3 | 9.6 | 8 | 13 |
| 0:10:00 | 6 | 6 | 6 | 6 | 4 | 10 | 1 | 5.2 | 5 | 7 |
| 0:11:00 | 12 | 12 | 12 | 12 | 4 | 12 | 4 | 15.9 | 8 | 16 |
| 0:12:00 | 12 | 12 | 12 | 12 | 6 | 8 | 1 | 20.4 | 7 | 13 |
| 0:13:00 | 2 | 2 | 2 | 2 | 12 | 1 | 2 | 1.2 | 14 | 4 |
| 0:14:00 | 4 | 4 | 3 | 3 | 2 | 8 | 2 | 0.0 | 4 | 5 |
| 0:15:00 | 6 | 6 | 7 | 7 | 3 | 2 | 6 | 10.8 | 9 | 13 |
| 0:16:00 | 5 | 5 | 5 | 5 | 12 | 12 | 3 | 10.2 | 15 | 8 |

**Table 31. Parameter definitions for gap data**

| Parameter | Parameter definition |
|---|---|
| “1” event | Clock time that vehicle arrived at the first in queue position (server). |
| “2” event | Clock time that vehicle entered the roundabout. |
| Previous “a” | Clock time that vehicle on circulating roadway passed the conflict point just prior to the arrival of the minor stream vehicle at the first in queue position. |
| Previous “s” | Clock time that vehicle on circulating roadway exited the roundabout just upstream from the entry point and just prior to the arrival of the minor stream vehicle at the first in queue position. |
| Next “a” | Clock time that the vehicle on the circulating roadway passed the conflict point just after the entry of the minor stream vehicle into the roundabout. |
| Next “s” | Clock time that the vehicle on the circulating roadway exited the roundabout just upstream from the entry point and just after the entry of the minor stream vehicle into the roundabout. |
| Intermediate event | Vehicle exiting the roundabout or vehicle passing the conflicting point while a minor stream vehicle is waiting at the entry point. |
| Intermediate time | Clock time that vehicle exited the roundabout or vehicle passed the conflicting point while a minor stream vehicle is waiting at the entry point. |

**Table 32. Example gap data output table**

| 1 | 2 | Previous "a" | Previous "s" | Next "a" | Next "s" | Intermediate event | Intermediate time |
|---|---|---|---|---|---|---|---|
| 09:05.9 | 09:06.7 | 09:05.1 | | 09:07.3 | 09:13.4 | | |
| 09:09.5 | 09:14.7 | 09:07.3 | | 09:16.6 | 09:22.1 | s | 09:13.4 |
| 09:17.6 | 09:18.0 | 09:16.6 | 09:13.4 | 09:31.1 | 09:22.1 | | |
| 09:21.5 | 09:22.8 | 09:16.6 | 09:13.4 | 09:31.1 | 09:25.7 | s | 09:22.1 |
| 09:27.6 | 09:28.7 | 09:16.6 | 09:25.7 | 09:31.1 | | | |