

Evaluation of Average Delay as a Measure of Effectiveness for Signalized Intersections

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ABSTRACT

This paper describes the analyses of individual vehicle delay distributions of lane groups at two intersections in the Borough of State College, PA and 120 drivers' quality-of-service ratings associated with a third intersection. The purpose of these analyses was to assess the appropriateness of using an average measure of delay (i.e., mean) as the primary measure of effectiveness (MOE) for signalized intersections.

The observed delays consistently resulted in similarly-shaped distributions that varied with v/c ratio. At low v/c ratios, a large proportion of the vehicles passed through the intersection without experiencing delay, while the delay experienced by the remaining vehicles was more or less constant up to about the length of the red phase. At higher v/c ratios, the proportion of vehicles that experienced no delay fell, and the amount of delay experienced by the remaining vehicles increased.

When the 26 delay distributions were subjected to criteria established to test if mean delay was an appropriate MOE, none of the cases met all of the criteria. In one case, two (33 percent) of the criteria were not met; in twelve cases, three (50 percent) of the criteria were not met; in twelve cases, four (67 percent) of the criteria were not met; and in one case, five (83 percent) of the six criteria were not met. These results suggest that the use of average delay does not adequately characterize delay at signalized intersections.

Although the perceptual data could not be directly compared to the delay distributions, subjects' overall QOS ratings were lower for lane groups with higher average delays. More detailed QOS ratings (by lane group and time of day) would be needed to compare the distribution of the ratings to the distribution of delay. It has been hypothesized that users are likely to have two related concerns about the quality of service at signalized intersections: 1) What is the probability that I will be delayed? and 2) How long will the delay be? Considering this hypothesis and the resulting delay distributions, perhaps a more appropriate MOE for signalized intersections, in terms of operations and users' perceptions, would be the probability of no delay and the average or range of delays encountered by the remaining vehicles.

INTRODUCTION

The concept of level of service is defined by the Highway Capacity Manual (HCM) (1) as “a qualitative measure describing operational conditions within a traffic stream, and their perception by motorists and/or passengers.” For each facility type, level of service is based on one or more operational parameters known as “measures of effectiveness” (MOE). The MOEs are available measures that are thought to best describe the operational quality of a facility type, and according to the HCM definition, are measures that motorists should perceive. Although the concept of level of service attempts to address a wide range of operating conditions, it is not usually practical to treat the full range of operational parameters for every facility type. The MOE used to define level of service for signalized intersections is average vehicle control delay (seconds per vehicle).

The objective of this research is to assess whether average vehicle delay is an appropriate MOE for signalized intersections. “Appropriateness” is assessed in terms of individual delay distributions and motorists’ perceptions of service quality. This paper describes the data collection and analyses undertaken to achieve this objective.

BACKGROUND

Estimating Average Delay at Signalized Intersections

The method described in the 1997 HCM for analyzing the capacity and level of service at signalized intersections requires estimating the average control delay for an intersection lane group during a 15-minute analysis period. Chapter 9 of the HCM presents a detailed computational methodology for estimating average control delay, d , which is represented by the equation:

$$d = d_1 PF + d_2 + d_3$$

where

PF = progression adjustment factor.

The progression factor applies to coordinated lane groups and represents the quality of signal progression. The uniform control delay component, d_1 , assumes uniform arrivals and is expressed in seconds per vehicle as follows:

$$d_1 = \frac{0.50C(1 - g/C)^2}{1 - \text{Min}(1, X)g/C}$$

where

- C = cycle length, sec;
- g/C = effective green ratio; and
- X = (v/c) ratio.

The incremental delay component, d_2 , accounts for the effect of random and over-saturation queues, adjusted for the duration of the analysis period and the type of signal control. This delay component assumes that there is no residual demand for the lane group at the start of the analysis period and is expressed in seconds per vehicle as follows:

$$d_2 = 900T \left[(X - 1) + \sqrt{(X - 1)^2 + \frac{8kIX}{cT}} \right]$$

where

- T = duration of analysis period in hours;
- k = incremental delay factor that is dependent of controller settings;
- I = upstream filtering/metering adjustment factor; and
- c = lane group capacity, vehicles/hour.

The residual demand delay, d_3 , accounts for oversaturation queues that may have existed before the analysis period. If no residual queue remains at the start of the analysis period, d_3 , is zero.

There are a variety of models that offer delay estimation techniques based on these equations and complex software algorithms. Most of these models require additional field data such as traffic volumes, intersection geometrics, and signal timings.

Average vehicle delay can also be directly measured in the field. There are a number of measurement techniques, including: the use of test-car observations, path tracing of individual vehicles, and recording of arrival and departure volumes on a cycle-by-cycle basis. The HCM outlines a procedure for measuring intersection control delay in the field based on direct observation of vehicle-in-queue counts. The HCM points out that, “the method does not directly measure delay during deceleration and a portion of acceleration, which are very difficult to measure without sophisticated tracking equipment. However, this method has been shown to yield a reasonable estimate of control delay.”

Related Research

Since its inception in 1985, the use of delay as a MOE for signalized intersections has been based on an average measure (whether stopped delay, control delay, or travel time delay). Although average delay has been used as a MOE for signalized intersections for 15 years, little research has examined the distribution of delays at signalized intersections nor the meaning of “average” for different distributions. For instance, the average of a normal distribution does not have the same meaning as the average of a uniform distribution nor the average of a bi-modal distribution.

Heidemann (2) pointed out, “relatively few authors have dealt with statistical distributions instead of mean values.” Heidemann discussed Meissl’s probability generating function (pgf) for the distribution of overflow queues and states that from this function all relevant statistical distributions concerning queues and delays at traffic signals can be obtained in a straightforward manner “...but rather surprisingly, this has not been fully exploited by Meissl himself or by other authors.”

Teply and Evans (3) examined the use of individual delays (i.e., delay distributions) as indicators of the quality of signal coordination. They devised a field survey to collect individual vehicle delay by recording vehicle arrivals and departures and the beginning and end of the green intervals. Data were manually collected by two surveyors for a “typical” lane that was considered to be representative of an approach. Because the data collection time required for each approach was relatively short, it was possible to collect data for two intersection approaches within an hour. A software program then matched arrivals and departures, determined the unimpeded travel time,

calculated delays of individual vehicles, sorted and classified delays, and calculated aggregate delay statistics.

Teply and Evans stated, “because most of these distributions are bimodal, simple statistical parameters cannot describe them adequately” and concluded, “it appears that a single numerical indicator of the quality of coordinated signal operation—such as the platoon ratio or a mode of the delay distribution—cannot sufficiently describe such a complex issue.”

In terms of motorists’ perceptions of delay, a study, performed as part of a related research project, examined users’ quality-of-service ratings of 24 different intersection delay scenarios (4). The results suggested that many users did use delay as a criterion for rating service quality, but whether it was some average measure of delay remains to be seen. The results also suggested that, regardless of how users translated their experience of delay into service quality ratings, they did not perceive service quality on six levels, but rather three or four levels.

DELAY DATA COLLECTION AND REDUCTION

Three intersections in the Borough of State College, PA were chosen at which to observe traffic and record individual vehicle delays. One video camera recorded each intersection approach from 7:00 a.m. to 10:00 a.m. and from 4:00 p.m. to 7:00 p.m. on a typical weekday. The first intersection, at University Dr. and Hastings Road, operated on a 84-second, fixed-time cycle with 57 seconds of green and yellow dedicated to the main street (University Dr.) and 27 seconds of green and yellow dedicated to the minor street (Hastings Road). The intersection is located between the Penn State main and east campuses and serves traffic to and from campus research buildings and on-campus graduate student housing. Heavy vehicles made up less than five percent of the average daily traffic, and there was no adjacent on-street parking. Along University Dr., there was one signalized intersection located approximately one-tenth of a mile south of the study intersection and another signalized intersection located approximately four-tenths of a mile north of the study intersection. These three signals were not coordinated.

The second intersection, at University Dr. and Easterly Pkwy., was treated as a T-intersection (with the fourth leg of the intersection a no-outlet street with little in and out traffic) and was semi-actuated, with inductive loop detectors on the Easterly Pkwy., minor-street approach. The intersection is located in a residential neighborhood approximately one mile south of the Penn State

campus and mainly serves traffic between residential neighborhoods and the campus and downtown State College area. Heavy vehicles made up less than five percent of the average daily traffic, and there was no adjacent on-street parking. Because there were no other signalized intersections within a mile of the University Dr. and Easterly Pkwy. intersection, it was considered to be isolated.

The third intersection was Atherton St. and Vairo Blvd. This intersection was semi-actuated, with inductive loop detectors on Vairo Blvd. and the exclusive left-turn lanes on Atherton St. The intersection is located along Business 322 (Atherton St.) and serves high volumes of traffic between Penn State/downtown State College and US 322, shopping centers, city neighborhoods, and student housing. Heavy vehicles made up less than five percent of the average daily traffic, and there was no adjacent on-street parking. There were nearby upstream and downstream signalized intersections on Atherton St. that were coordinated with the Vairo Blvd. intersection. Table 1 illustrates the differences between the three subject intersections.

<Insert TABLE 1>

The HCM points out that delay is a complex measure and that it is dependent on a number of variables including the quality of progression, the cycle length, the green/cycle ratio, and the volume to capacity (v/c) ratio for the lane group in question. In other words, the distribution of delays for an intersection lane group is expected to vary with these and other factors (e.g., number of approach lanes, type of signalization). At this point, it is not important to become overly concerned with how the distributions might vary with different factors. What is important is to determine what these distributions look like and if an average measure of delay is an appropriate MOE in terms of the distributions and the drivers' perceptions of the conditions they experience.

After data were collected, individual vehicles were tracked on the video on a lane-by-lane basis as they entered and left the intersection. Data were reduced from the videos using a computer program that marked the time a vehicle entered and exited a queue. A vehicle was considered to enter the back of the queue when it was estimated to be traveling less than five miles per hour and was considered to exit the queue when it began accelerating and there were no more potential delays (e.g., accelerating and leaving the intersection). Thus, this method measured stopped delay. Because delay due to deceleration and acceleration were not taken into account, it cannot be referred

to as control delay as defined by the HCM. However, individual delays were consistently recorded and are therefore directly comparable to the control delay by a constant multiplicative factor.

In addition to recording when the vehicles entered and exited the queue, the program recorded the intersection approach, lane group, signalization type (e.g., fixed time or actuated) and movement of each vehicle (e.g., left turn, through, or right turn). All data were written to a database where the data could be easily extracted and analyzed.

DELAY DISTRIBUTIONS

Examples of the delay frequency, or probability distributions, resulting from the field delay studies at the intersections of University Dr. and Hastings Road and University Dr. and Easterly Pkwy. are illustrated in Figures 1 - 3. Each graph illustrates the frequency or probability of delays. The morning and evening peak hours were determined from the observed traffic volumes during three hours in the morning and three hours in the evening, respectively. Individual vehicle delays during the peak hours were plotted as frequency distributions for each lane group. The observed delays consistently resulted in similarly-shaped distributions that varied with v/c ratio. Referring once again to the work of Heidemann (2), he wrote of his derived delay distributions:

All curves pertaining to the lower degrees of saturation (namely, 5 percent and 50 percent) show extremely high [probabilities] for the lowest delays. This means that many vehicles can pass [through the intersection] without suffering delay. The curves then decrease sharply and remain more or less constant for a time interval the length of which is about one red period; thereafter they decrease to almost zero. The constant level observed indicates that the delays are mainly determined by the randomness of the arrivals and that queuing effects on the delays are not predominant.

The curves pertaining to the higher degrees of saturation (namely, 95 percent and 99 percent) are much more constant over the entire range of delays. This shows that a relatively large number of vehicles suffers a considerable amount of delay.

<Insert FIGURES 1 - 3>

Heidemann's results were confined to simple general assumptions of Poisson-distributed arrivals, a generalized service distribution, a fixed-time controller, and a one-lane approach. Comparing Heidemann's results with those obtained in this research, the delay distributions obtained from empirical data support those derived mathematically by Heidemann. When v/c ratios were low (e.g., Figure 2) the majority of vehicles passed through the intersection without delay. In general, the remaining vehicles uniformly experienced a range of delays up to about the length of the red phase. At higher v/c ratios, the proportion of vehicles that experienced no delay fell, and the amount of delay experienced by the remaining vehicles increased (e.g., Figures 1 and 3).

Although Heidemann's paper concentrated on the derivation of these distributions and not necessarily how well the average represents the distribution, its publication stresses the importance of, and lack of research in, the area of applying distributions rather than mean values.

Similarly, it appears that the delay distributions obtained in this research through a longer and more involved data collection and reduction process support the results obtained by Teply and Evans (3). Therefore, it is likely that delay distributions can be adequately described through shorter and less detailed data collection and reduction efforts than the video methodology used for this study.

DISTRIBUTION CRITERIA

Prior to data collection, several criteria were established that would be used to assess the appropriateness of average (i.e., mean) delay as a MOE for signalized intersections. These criteria, and particularly the quantitative values in the criteria, were derived from reviewing methods for analyzing statistical distributions, and were based upon the researchers' judgement. The HCM defines LOS as a qualitative measure that represents operational characteristics and the perception of the operations by motorists and passengers. Thus, it is important when choosing a MOE that it be representative of both operations as well as how the users perceive them. Intuitively, it makes sense that the longer the delay, the more poorly the intersection will operate and the more frustrated drivers will become. However, the metric used to quantify this should adequately represent both situations. Figure 4 illustrates a normal distribution and the percentage of the sample that should fall within one standard deviation of the mean. While mean is a good measure of central tendency for the normal distribution, problems occur when the mean is applied to populations that have other

distributions (e.g., uniform, bimodal). For instance, too few observations fall close to the mean, and therefore the mean is not representative of the central tendency.

<Insert FIGURE 4>

With this in mind, the criteria established were as follows:

1. The mean, median, and mode should be similar. Differences in these values would suggest variability in the delays, or lack of variability in certain delays, such that the average might not adequately the delay.
2. The distribution should not be bi-/multi-modal. For a distribution with more than one mode, a simple average measure of delay (falling between the modes) would not sufficiently describe the sample.
3. If the distribution is symmetrical, the kurtosis should be less than or equal to three (i.e., the curve should be mesokurtic or leptokurtik not platykurtic). Kurtosis describes the “peakedness” of a distribution. Mean values are more representative of the central tendency of distributions with higher and more narrow peaks (i.e., mesokurtic and leptokurtik) than they are of those with shorter and wider “plateaus” (i.e., platykurtic).
4. The standard deviation should be less than the mean. When the standard deviation is greater than the mean, the distribution is positively skewed and thus the variability tends to be concentrated on one side of the mean.
5. At least 50 percent of the vehicles should have experienced the average delay or less. In other words, more than half of the vehicles should experience a delay that is “better” than the average.
6. At least 10 percent of the vehicles should have experienced the average stopped delay. The higher this percentage, the more appropriate the measure.
7. At least 50 percent of the vehicles should have experienced a delay within the level of service category associated with the average delay. In other words, each level-of-service category is associated with a range of delays.

For the MOE to be representative of the distribution, at least half of the vehicles should experience a delay within the range of the associated level-of-service category.

A priori, if any of the criteria do not hold for the distributions, using average delay as the MOE for signalized intersections should be questioned. This is merely an early assessment of delay distributions based on prior judgements.

The statistical parameters associated with the seven criteria for the delay distributions at University Dr. and Hastings Road. and University Dr. and Easterly Pkwy. are summarized in Tables 2 and 3, respectively. Cells with parameters not meeting the above criteria are shaded.

<Insert TABLES 2 and 3>

For the first criterion, the mean, median, and mode were compared. If an average or mean value of delay is to represent the central tendency of the delay experienced by vehicles passing through an intersection, these values should be similar. Because “similar” is a vague term, as assumption was made about the meaning in terms of drivers’ perceptions. The assumption was that, from the drivers’ perspective, encountering (on average) some delay at a signal will be perceived differently than encountering (on average) no delay at the signal.

In all but one case the mode was zero, and therefore the mode was considered to be dissimilar to both the mean and median. In 10 of the 26 cases, the median was also zero. In these 10 cases, the median and mode were considered to be similar to each other, but dissimilar to the mean. Thus, in all but one case, the parameters did not meet the first criterion.

Only one of the distributions was considered to be bi- or multi-modal, and, in all but one case, the mode was zero. However, in most cases the distribution of the delayed vehicles did appear to “peak” at one or more delays. Although these peaks were substantially lower than those at zero delay, the results suggest that an average value may not be a good indicator of the delays encountered due to the shape of the distributions.

The third criterion, kurtosis, was eliminated because none of the 26 distributions were symmetrical (kurtosis values apply only to symmetrical distributions).

In 15 of the cases, the standard deviations were larger than the mean, and therefore did not meet the fourth criterion, “small” variability. This result suggests that the delays are positively skewed, and in some cases, too great for a mean value to be an appropriate representation of the central tendency.

Because of the large proportion of vehicles that experienced no delay, the distributions met the fifth criterion in all but three cases. In the three cases that did not meet this criterion, 49, 49, and 48 percent of the vehicles experienced the average delay or less, values very close to 50 percent.

None of the distributions met the sixth criterion that at least 10 percent of the vehicles should have experienced the average delay. The maximum and minimum percentage of vehicles that actually experienced the average delay was nine percent (in three cases) and was zero (in three cases), respectively.

Finally, only five of the distributions met the last criterion that at least 50 percent of the vehicles should have experienced a delay within the level-of-service category associated with the average delay. In each of the five cases the level-of-service was A, which is not surprising considering the large proportion of vehicles that experienced no delay. In several cases, the average delay was just slightly higher than the upper threshold value of 5.0 seconds per vehicle for LOS A. These cases therefore failed to meet the last criterion, although the lane groups were operating at a very high level-of-service with very little delay, (six or seven seconds per vehicle). If the LOS A category were slightly wider (perhaps up to 10 seconds per vehicle), these six cases would have met the last criterion. This result raises a question as to why the delay range for the LOS A category (i.e., five seconds) is relatively small compared to the delay ranges of the other level-of-service categories (i.e., 10, 10, 15, and 20 seconds per vehicle for LOS B, C, D, and E, respectively). Many of the cases may have come much closer to meeting the last criterion if the level-of-service ranges were wider (or perhaps if there were fewer level-of-service categories overall).

In most cases, the delays were nearly uniformly distributed. In the case of uniform distributions, simple measures of central tendency cannot adequately characterize the data sample, especially when there is a large range of values along the X-axis.

Considering the distribution of delays for the southbound University Dr. through plus right-turn approach to Easterly Pkwy (p.m. peak hour), which is shown in Figure 2, 60 percent of the 882 peak-hour vehicles experienced no delay. The distribution of the remaining 40 percent appears to be slightly “mound-shaped,” with the average delay around 15 seconds per vehicle. Thus, an

average of four seconds of delay per vehicle for all vehicles does not accurately represent the 60 percent that experienced no delay, nor does it represent the 40 percent that experienced (on average) about 15 seconds of delay per vehicle.

Perhaps a more appropriate way of defining level of service for a lane group would be to consider the probability of experiencing no delay as well as the average or range of delays experienced by the remaining vehicles. Further research is needed to assess the feasibility and applicability of such a method.

FIELD QUESTIONNAIRE

The delay distribution criteria discussed in the previous section focused on how representative average delay is in terms of operating conditions. However, because the HCM definition of level of service is two-fold, it is important to also consider how representative the average delay is in terms of drivers' perceptions of the conditions they experience. During the delay data collection at Atherton St. and Vairo Blvd., questionnaires were administered to drivers in the parking lot of the Walmart located adjacent to the intersection. Questionnaires were administered simultaneously with field data collection to determine drivers' delay estimates and perceptions of service quality based on the delay they had just experienced. In addition, subjects were asked how often they travel through the intersection, the time of day they generally travel through the intersection, and the direction/movements they generally make. Finally, subjects were asked to give their overall perception of service quality at the intersection by rating the quality of service (QOS) (based on their experience) on a scale of 1 to 10, with 1 representing unacceptable conditions and 10 representing excellent conditions. In all, 120 questionnaires were administered.

Because of the original purpose of the field questionnaire, the subjects were not asked to rate QOS separately for each movement or for each peak hour. Thus only one overall QOS rating was available for each subject, and subjects' QOS ratings could not be directly compared to the delay distributions. One observation that could be made from the data was that subjects' that typically made movements in lane groups with lower average delay tended to rate the intersection service quality higher than those subjects who made movements in lane groups with higher average delay.

A more interesting question, however, would be if the range of QOS ratings reflected the range of delay. If users' perceptions of service quality are based mainly on the delay they

experience, a statistic (i.e., MOE) that is inappropriate for representing the delays should also be inappropriate in describing the level of service that the users perceive. If an MOE is to represent operational conditions and user perceptions, the distribution of the two should be “similar.” Future research should address this topic by studying user perception of individual delays (rather than overall QOS).

DISCUSSION

This paper has discussed delay data collected at three intersections in the Borough of State College, Pennsylvania and presented the results for two of the three intersections. The results have been discussed in terms of the distribution of delays for each lane group at two intersections and the perceptions of delay by motorists at the third intersection.

The observed delays consistently resulted in similarly-shaped distributions that varied with v/c ratio. At low v/c ratios, a large proportion of the vehicles passed through the intersection without experiencing delay, while, in general, the remaining vehicles uniformly experienced a range of delays up to about the length of the red phase. At higher v/c ratios, the proportion of vehicles that experienced no delay fell, and the amount of delay experienced by the remaining vehicles increased.

None of the 26 delay distributions analyzed met all of the six pre-specified “suitability criteria” established to test if average delay is an appropriate MOE. In one case, two (33 percent) of the criteria were not met; in twelve cases, three (50 percent) of the criteria were not met; in twelve cases, four (67 percent) of the criteria were not met; and in one case, five (83 percent) of the six criteria were not met. These results suggest that the use of average delay does not adequately characterize the delay distributions.

This paper also briefly discussed a field questionnaire that was administered during delay data collection at a third intersection in State College. Although the perceptual data could not be directly compared to the delay distributions, subjects’ overall QOS ratings were lower for lane groups with higher average delays. More detailed QOS ratings (by lane group and time of day) would be needed to compare the distribution of the ratings to the distribution of delay.

From here it could be hypothesized that users are likely to have two related concerns about the quality of service at signalized intersections:

- 1) What is the probability that I will be delayed?
- 2) How long will the delay be?

In other words, quality of service is low if there is a high probability of being delayed and/or the possibility of a “long” delay. In contrast, quality of service is good when there is a high probability of no delay. To test this hypothesis, delay measures that reflect these probabilities are needed. Examining the delay distributions once again, it can be seen that these probabilities can be quantified. Perhaps, then, a more appropriate MOE for signalized intersections, in terms of both operations and users’ perceptions, would be the probability of zero delay and the average or range of delays encountered by the remaining vehicles. Future studies should attempt to test this hypothesis.

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TABLE 1 Study Intersections

Intersection	Signal Timing	Number of Major Street Approach Lanes	Number of Minor Street Approach Lanes	Intersection Locality
University Dr. and Easterly Pkwy.	Semi-actuated Not coordinated	3	2	Isolated
University Dr. and Hastings Road	Fixed-time Not coordinated	5	3	Not isolated
Atherton St. and Vairo Blvd.	Semi-actuated Coordinated	6	4	Not isolated

TABLE 2 Peak Hour Delay Distributions for the Intersection of University Dr. and Hastings Road

Lane Group	Time Period	Mean	Median	Mode	Hourly volume	Multi-modal	Standard deviation	Percent less than average delay	Percent with average delay	Percent in LOS
Southbound University Dr. -Thru+RT	AM	3	0	0	170	N	6	75	8	77
	PM	6	0	0	203	N	10	72	1	10
Southbound University Dr. -Thru	AM	5	0	0	215	N	9	71	3	13
	PM	7	0	0	402	N	10	63	2	17
Southbound University Dr. -LT	AM	19	13	0	22	N	19	66	9	18
	PM	15	7	0	20	N	16	65	5	20
Northbound University Dr. -Thru+RT	AM	6	0	0	633	N	10	72	1	6
	PM	8	0	0	434	N	11	62	2	16
Northbound University Dr. -LT	AM	13	8	0	312	N	14	59	1	14
	PM	18	14	0	100	N	17	57	0	10
Eastbound Hastings Road -Thru+LT	AM	34	39	0	49	N	26	49	0	10
	PM	24	25	0	140	N	19	49	1	9
Eastbound Hastings Road -RT	AM	7	4	0	59	Y	9	72	9	25
	PM	18	15	0	493	N	15	56	4	20
Westbound Hastings Road -Thru+RT+LT	AM	25	27	0	61	N	20	48	2	30
	PM	26	22	0	105	N	20	52	1	19

TABLE 3 Peak Hour Delay Distributions for the Intersection of University Dr. and Easterly Pkwy.

Lane Group	Time Period	Mean	Median	Mode	Hourly volume	Multi-modal	Standard deviation	Percent less than average delay	Percent with average delay	Percent in LOS
Southbound University Dr. -Thru+RT	AM	2	0	0	357	N	4	77	1	87
	PM	4	0	0	882	N	7	71	1	72
Nothbound University Dr. -Thru	AM	4	0	0	494	N	6	66	2	68
	PM	3	0	0	265	N	6	73	1	75
Northbound University Dr. -LT	AM	12	8	0	29	N	13	69	7	34
	PM	18	14	7	23	N	16	61	0	22
Eastbound Easterly Pkwy. -LT	AM	20	17	0	263	N	16	62	4	33
	PM	20	17	0	225	N	15	64	8	31
Eastbound Easterly Pkwy. -RT	AM	12	7	0	41	N	13	66	2	26
	PM	6	4	0	47	N	6	63	7	39

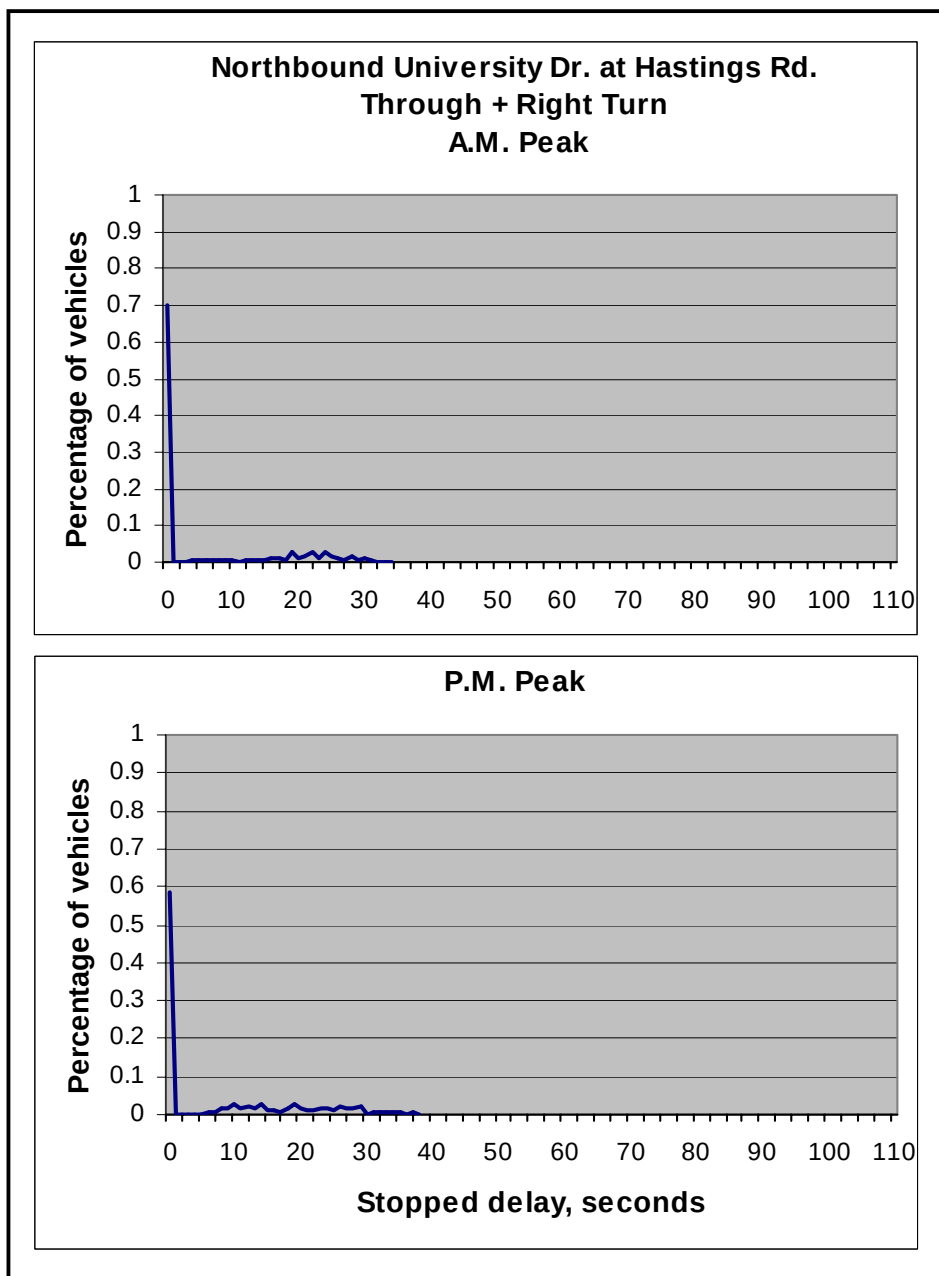


FIGURE 1 Delay Distributions for Northbound University Dr. at Hastings Rd. (Through Plus Right-Turn Lane)

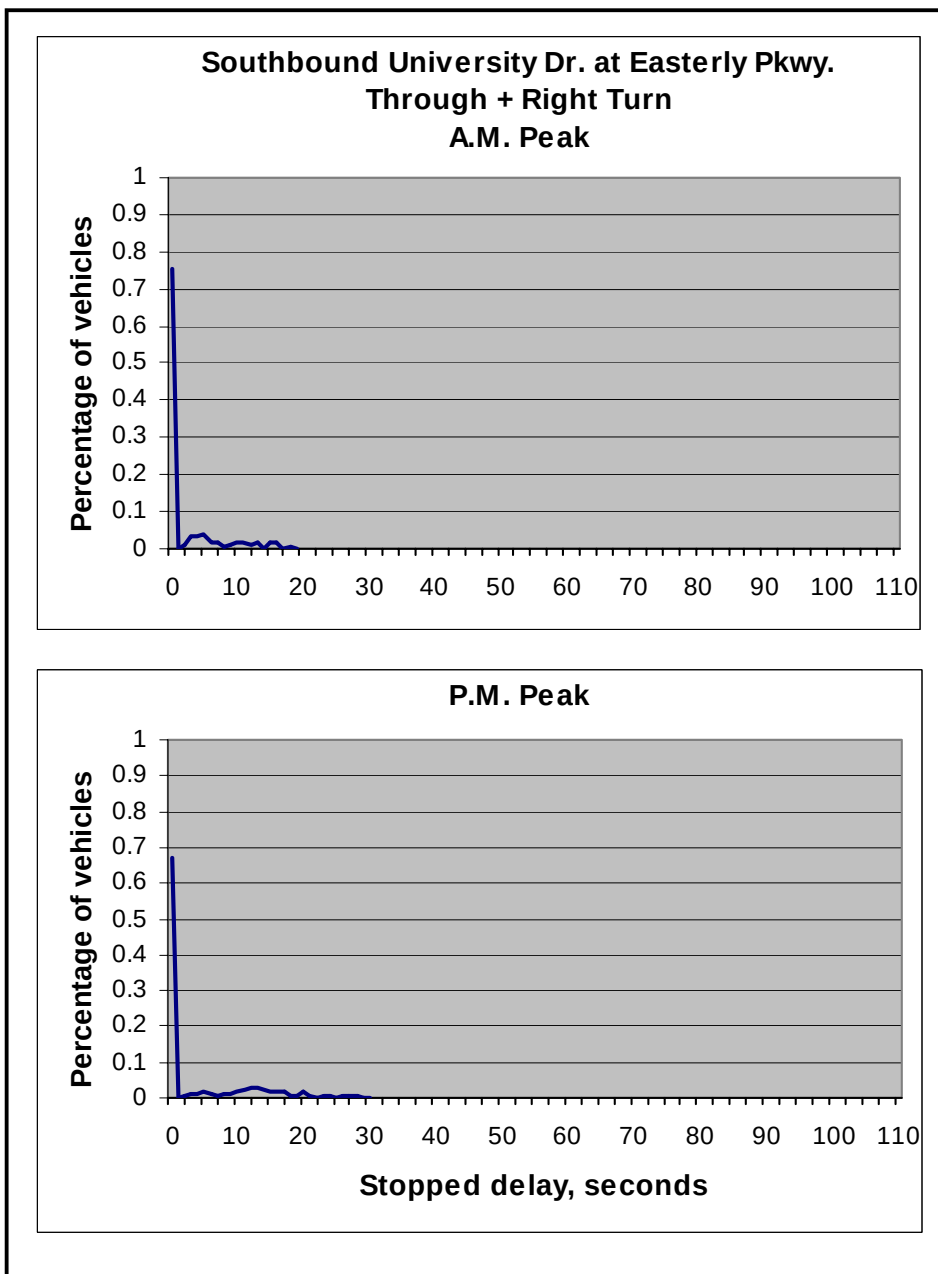


**FIGURE 2 Delay Distributions for Southbound University Dr. at Easterly Pkwy.
(Through Plus Right-Turn Lane)**

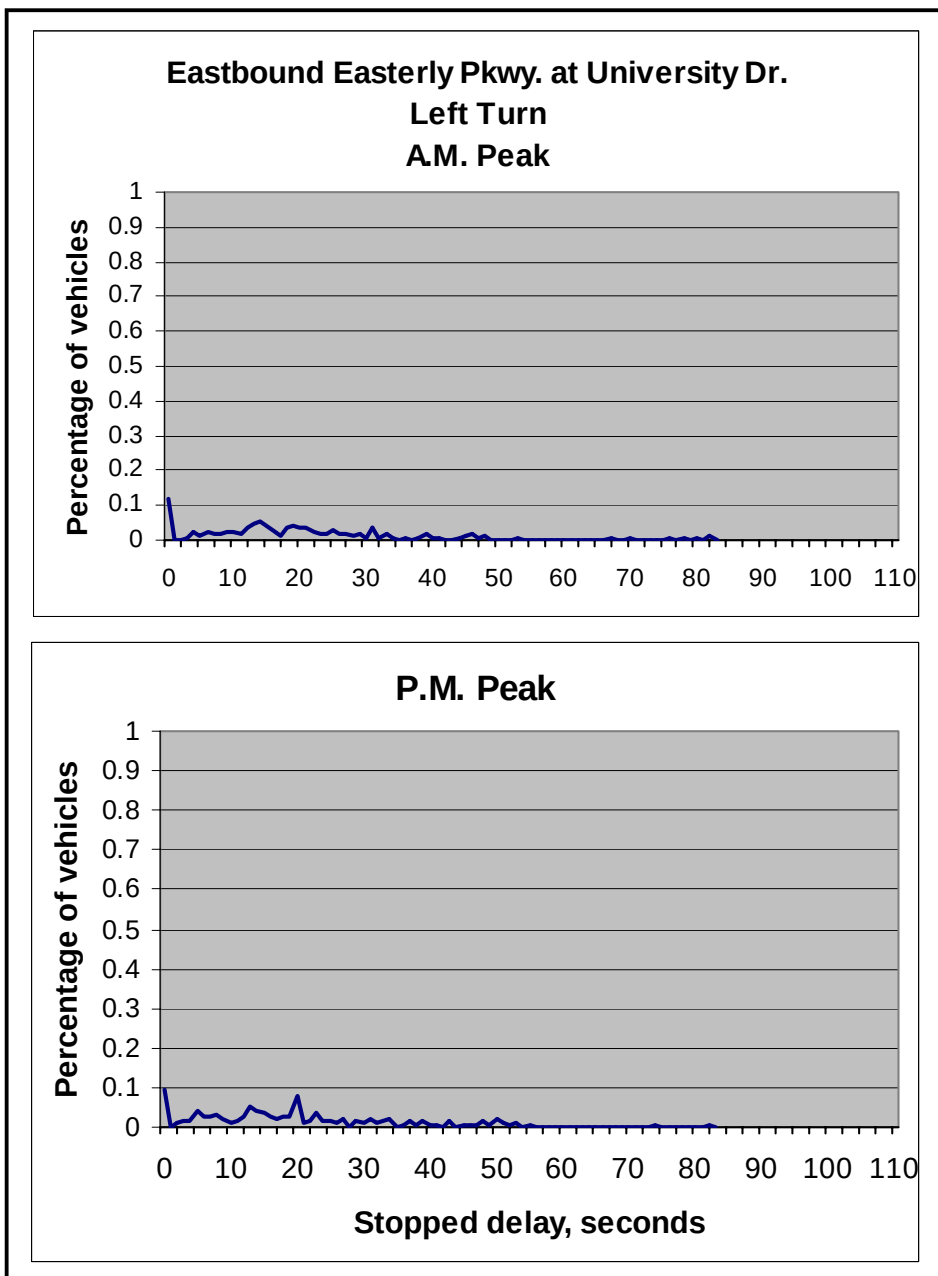


FIGURE 3 Delay Distributions for Eastbound Easterly Pkwy. at University Dr. (Left-Turn Lane)

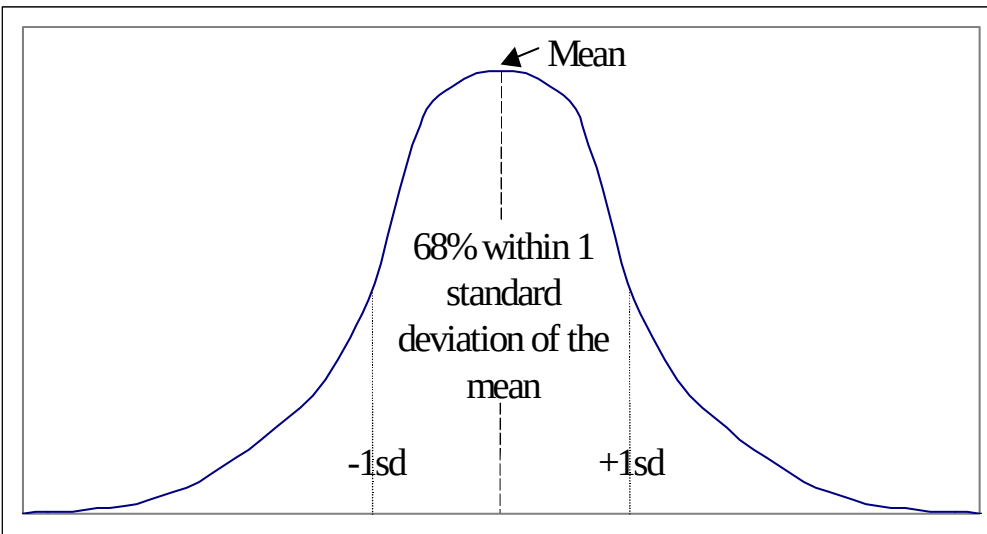


FIGURE 4 Example of Normal Distribution