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MEASURING PEDESTRIAN VOLUMES AND CONFLICTS

VOLUME III: MEASURING PEDESTRIAN VOLUMES A USERS MANUAL

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16. Abstract Users of the manual are expected to be in divisions responsible for pedestrian safety in cities, counties, and other jurisdictions.

The users manual outlines a step-by-step procedure to measure pedestrian volumes using small count intervals. Appendixes are given to present and discuss the methodology of this procedure, the MUTCD Warrant 3 minimum pedestrian volume, and the accuracy and reliability of this procedure.

This volume is third in a series. The others in the series are:

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I	Measuring Pedestrian Volumes (Report, #FHWA/RD-88/306)
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Introduction

The measurement of pedestrian volumes is considerably more difficult than the measurement of vehicle volumes. At present there are no reliable and workable mechanical methods available for counting pedestrian volumes. Therefore, manual counts must be used for obtaining pedestrian volumes. A problem with manual counts is that they are labor intensive, and therefore expensive.

One method for reducing pedestrian-volume data-collection costs is to make short sample counts of pedestrians that can be expanded to represent hourly or daily pedestrian volumes by use of appropriate expansion factors.

The procedures described in this users manual allow reasonable estimates to be made of pedestrian volumes at intersections or mid-block crossings based on sample counts of shorter time periods. This can result in significant cost savings compared with continuous counting.

The two primary uses of pedestrian crossing volume information are to evaluate whether or not pedestrian volumes meet traffic signal warrants and to develop exposure data for use in analyzing pedestrian accident rates. These two uses require that estimates of pedestrian volumes be made for different time periods (hourly for signal warrants, daily for accident rates) and with varying levels of accuracy, so this manual allows the user to select sampling rates that are appropriate for the particular use.

The manual is designed as a step-by-step approach to choosing and carrying out an appropriate pedestrian volume counting strategy. The methodology upon which this approach is based is covered in appendix A. The MUTCD Pedestrian Volume Warrant is contained in appendix B. A discussion of the accuracy and reliability of the counting procedure is presented in appendix C.

Procedure for Counting Pedestrians

The procedure for estimating hourly and average daily pedestrian volumes involves seven steps:

1. Select the time period for estimating pedestrian volumes
2. Select count interval
3. Develop data collection plan
4. Collect data
5. Select expansion model coefficient and exponent
6. Compute estimated volumes
7. Determine estimated volume ranges

Each step is described and illustrated by an example in the following paragraphs.

Step 1: Select the Time Period for Estimating Pedestrian Volumes

To evaluate signal warrants, hourly pedestrian volumes per crosswalk are needed, since the MUTCD bases the warrant upon either the highest or the four highest hourly volumes in an average day. On the other hand, development of exposure data generally only requires knowledge of overall average daily volumes.

Since pedestrian volumes are likely to vary greatly by hour of the day, accurate determination of either hourly or average daily volumes requires some type of count throughout the day.

To estimate average daily pedestrian volumes, a day may be divided into time periods 2, 3, or 4 hours long. Estimates of pedestrian volumes for each of these time periods could be based on short sample counts taken at the middle of each of these periods.

To estimate peak hourly pedestrian volumes, however, requires that pedestrian counts be made during each hour that is likely to have heavy pedestrian travel. Again, these counts could be for short sample periods of 5, 10, 15, or 30 minutes each.

Consider, for example, an intersection in a downtown office area in an eastern city having high transit usage. Hourly estimates of pedestrian volumes made by taking counts during lunch time and the morning and afternoon commuting times would likely contain the four highest hourly pedestrian volumes. Average daily pedestrian volume estimates, on the other hand, would be more accurately determined by dividing the day into 1, 2, or 4 hour time periods and making estimates of pedestrian volumes for each of these time periods based on sample counts. The time period 6:30 am to 6:30 pm, for example, could be divided into 2-hour increments and sample pedestrian counts taken in the middle of each 2-hour time period.

Depending on the type of pedestrian flows (school trip, shopping, work, entertainment, or other), you may need to cover more or less than a 12 hour period. You may also be able to make pedestrian volume estimates for fairly long time periods, if necessary for the sake of economy, especially during times of little activity. In choosing how you divide the day into time periods for estimating pedestrian volumes, you should consider the likely variability of pedestrian flows and try to specify periods that have relatively uniform pedestrian flows.

Step 2: Select Count Interval

The choices are 5, 10, 15, or 30 minutes of counting in the middle of each time period for which pedestrian volume estimates are being made, as selected in Step 1. The trade off in the choice of sample counting interval is between economy and accuracy. Counting pedestrians for the middle 30 minutes of each time period clearly decreases the uncertainty of an estimate compared with counting during the middle 5 minutes, but also clearly costs more.

Much of the choice involves logistics. If pedestrian volume estimates are needed only at a single intersection at a remote location, counts might as well be made for the whole hour since it makes little sense to have someone count for awhile, then wait with nothing to do until the next counting period. If there are many nearby intersections, however, travel might be possible to several of them, taking 5- or 10-minute counts at each location every hour.

The rest of the choice involves assessing the relative value of decreasing the level of uncertainty. If a likely outcome is being verified, higher levels of uncertainty may be satisfactory. A shorter counting interval, therefore, may be used than if a close decision is needed. Suppose, for example, that one needs to justify installing a pedestrian signal at a location that almost certainly has a much-higher-than-required volume. If 500 pedestrians per hour use that crossing, it does not really matter if volume estimates are off by plus or minus 200-- the signal is still warranted.

Tables 1 to 4 give the levels of uncertainty associated with various count intervals and estimate time periods. These tables assume that the count is made in the exact middle of the corresponding time period. For example, consider an expanded estimate (expansion process to be described in succeeding steps) of 800 pedestrians in a 4-hour period based on a count taken from 10:10 to 10:20 am. This is the exact middle of the 4-hour period from 8:15 am to 12:15 pm. From Table 4, used because it is a 4-hour time period, we see that the uncertainty associated with a 10 minute count that produces a time period volume estimate of 800 is plus or minus 27 percent. This means that the true volume of pedestrians on that cross walk during the 4-hour period from 8:15 am to 12:15 pm is very likely to be within the range of 692 to 904 pedestrians.

Table 1. Range factors for 1-hour predictions (in percent)

Pedestrian Volume Level	Count Interval (minutes) 5	10	15	30
0 - 100	+34	35	27	16
101 - 200	35	26	19	13
> 200	27	22	15	9

Table 2. Range factors for 2-hour predictions (in percent)

Pedestrian Volume Level	Count Interval (minutes) 5	10	15	30
0 - 500	+42	32	24	22
> 500	24	25	23	19

Table 3. Range factors for 3-hour predictions (in percent)

Pedestrian Volume Level	Count Interval (minutes) 5	10	15	30
0 - 500	35	37	34	26
> 500	32	27	24	22

Table 4: Range factors for 4-hour predictions (in percent)

Pedestrian Volume Level	Count Interval (minutes) 5	10	15	30
0 - 750	34	30	29	26
> 750	33	27	26	21

Step 3. Develop Data Collection Plan

Choose the order of counting and the specific time periods for each intersection. Remembering that the count interval (that is, the 5, 10, 15 or 30 minute interval) must be at the middle of the time period specified, a multiple-intersection data collection plan implies a different estimating time period at each intersection. This simply means that time periods are shifted to centrally encompass the times of the sample count intervals that result from the rotating intersection schedule, as illustrated below.

As an example of a data collection plan, consider 3 intersections within 10 minutes travel time of each other, with 10-minute sample count intervals that will be expanded to estimates of hourly pedestrian volumes. The first intersection could be sampled from 5 minutes before the hour to 5 minutes after the hour, the second one from 15 minutes to 25 minutes after the hour, and the third one from 35 to 45 minutes after the hour. The cycle would then keep repeating as long as desired. Each intersection would then have volume estimates for slightly different time periods, (since the sample counts must be in the middle of the time period being estimated) but there should be no problem with that unless direct comparison of volumes among these intersections is desired.

Step 4: Collect Data

Collect data for each mid-block crossing or for each crosswalk at an intersection according to the schedule developed in Step 3. For most intersections, a single data collector should be adequate, but a second data collector may be required for major downtown intersections during peak periods. It is suggested that a single data collector be sent, but that a provision for follow up counts be made for those relatively rare intersections where it turns out a second data collector is needed.

It is important that the timing of the periods be fairly precise. If queues of pedestrians are forming at signalized crosswalks, and the number of queues counted is off by just one, significant error could result, especially for the shorter count intervals. If count intervals are not even multiples of signal cycles, counts should be made for an even number of cycles and prorated to the appropriate count interval. For example, for a 90-second signal cycle with a 5-minute count interval, 3 full cycles (taking up 4 1/2 minutes), plus one-third of the number crossing during the 4th cycle should be counted. This procedure is difficult with variable-cycle signals unless the time of each initial green signal is carefully noted.

Step 5: Select Expansion Model Coefficient and Exponent

From table 5, select the proper values of a and b for the expansion equation:

$$\text{VOLUME} = (a)\cdot(\text{COUNT})^{b}$$

where: VOLUME is the estimate of pedestrian volume for the 1-, 2-, 3-, or 4-hour period of interest.

COUNT is the number of pedestrians counted during the counting interval.

a and b are derived parameters (described in appendix A)

For example, suppose pedestrians were counted from 7:28 to 7:33 am at a selected crosswalk. To estimate the volume of pedestrians from 7:00 to 8:00 am, look in table 5 for a 1-hour time period and a 5-minute interval and find a = 19.9 and b = 0.786. This yields the following formula:

$$\text{VOLUME} = (19.9)\cdot(\text{COUNT})^{0.786}$$

Table 5: Expansion model parameters

Time Period	Counting Interval (Minutes) 5		10		15		30	
	a	b	a	b	a	b	a	b
1 hour	19.9	.786	9.8	.847	5.8	.900	2.4	.963
2 hours	43.0	.769	20.9	.823	14.7	.824	6.1	.892
3 hours	60.2	.785	32.2	.818	17.4	.884	9.5	.890
4 hours	62.4	.811	44.9	.762	27.1	.809	15.6	.813

Step 6: Compute Estimated Volumes

Substitute the count of pedestrians during the count interval into the formula specified in Step 5 to obtain the estimated pedestrian volume during the selected time period.

For the example started in Step 5, if 20 pedestrians had been counted, the estimated volume for 1 hour would be:

$$\text{VOLUME} = (19.9)\cdot(20)^{0.786}$$

$$= (19.9)\cdot(10.53)$$

$$= 210$$

Therefore, based on the sample count of 20 pedestrians in 5 minutes (from 7:28 am to 7:33 am), it would be concluded that 210 pedestrians use this crossing in the one hour between 7 am and 8 am. Since a sample count was used, however, one cannot be sure that the actual number of pedestrians is equal to this estimate. Step 7 indicates a procedure for estimating the accuracy of the estimated volume.

Step 7: Determine Estimated Volume Ranges

Since the figures derived from the above equations are estimates, it is important to establish the range within which the actual volumes would fall. This is done by using the prediction range factors in tables 1 to 4.

In the example used in the previous two steps, table 1 would be used since we are making a 1-hour estimate. With a count interval of 5 minutes and an estimated pedestrian volume of 210, that table indicates a range of plus or minus 27 percent from the prediction. Thus the actual volume most likely lies between 153 and 267 pedestrians in that time period.

Although this level of uncertainty may seem large, it is not necessary in many situations to know pedestrian volumes with much more precision. Often, it is sufficient to know that a given crossing has moderate or high pedestrian activity when deciding what kind of pedestrian accommodation should be present.

Even in cases where relatively high levels of precision may be required, determination of pedestrian volumes based on short sample counts (as covered in this users manual) may serve as a good initial screening device. Crossings that appear likely to require a higher level of pedestrian accommodation can then be subjected to more detailed study. Further, it is useful to know the pedestrian volume level and its variability throughout the day when specifying level-of-effort required for more thorough pedestrian study, when such study appears to be warranted.

Appendix A

Summary of Methodology for Development of Expansion Equations

The pedestrian volume estimating procedure outlined in this users manual is based on an expansion model that allows estimates of hourly or multi-hourly pedestrian volumes from short sample counts. As outlined in the main part of the manual, the accuracy of the estimate depends upon the length of the count period and the position of the count period within the hour.

In the development of the expansion model, numerous sampling strategies were investigated. Sampling periods that were analyzed varied in length and in position within the hour. Regression techniques were used to evaluate and compare the various schemes in order to determine an optimum procedure.

Pedestrian volume counts were made in Washington, D.C. during July 1986 at eight intersection and six mid-block locations. Both signalized and unsignalized locations were included. A 100 percent sample of pedestrians observed crossing was recorded at each site during each 12-hour collection period. These samples consisted of continuous counts taken on weekdays from 7 am to 7 pm. Pedestrian volumes were recorded by crosswalk every 5 minutes.

In the analysis, 10 sites were randomly selected from the 14-site data base to develop the regression equations and the remaining four were used to validate the equations. A total of 408 hours of observations were used in developing the expansion models and a total of 120 hours in their validation.

The sampling interval times investigated were 5, 10, 15, and 30 minutes. All of these sampling intervals were analyzed for the first, middle, last, and random positions in the time period for which predicted volumes were being made. Examination of positions other than the middle was made to determine what compromises in accuracy might result if a user chooses to collect data at varying positions in order to conveniently maintain uniform time periods at different locations.

In reviewing the data distributions for use in developing the prediction models, all variables showed positive skewness. Since the data were not normally distributed, a choice had to be made between using nonparametric tests (which are distribution free) or transforming the volume variable so that parametric tests could be applied. The latter approach was chosen based primarily on the greater power available with parametric tests. Pedestrian volume data were transformed logarithmically in order to produce a normal distribution.

Using regression analysis, the count intervals and the position of samples within the time period were analyzed. For all count intervals, the middle event produced the best model since it exhibited the highest coefficient of determination and the lowest standard error about the mean. Also, it was apparent that as the count interval increased from 5 to 10 to 15 to 30 minutes, the prediction models became better. This is to be expected since the variation among counts decreases as the count interval increases.

As stated earlier, 4 sites were excluded from the modeling effort and used in validating the models developed. These sites produced 120 observations for the 1-hour models, 60 observations for the 2-hour models, 40 observations for the 3-hour models, and 30 observations for the 4-hour models. All four counting intervals were studied for each model.

The purpose of the validation study was to investigate the accuracy of the expansion model using data that were not incorporated into the development of the models. Even though these four sites were from the same city from which the models were developed, their volume distribution patterns were all different. As was observed in the development of the models, the result was that the middle counting interval produced the best models regardless of the volume distributions. Therefore, the hourly or multi-hourly counts made at these four sites are intuitively representative of any observation that could have been taken from any site in any city.

The validation of the expansion models produced estimates of the error in prediction of pedestrian volumes based on differences between the actual and the predicted volumes. It was found that the level of uncertainty varied with pedestrian volume, count interval, and time period of estimation.

For a complete discussion of the development of the expansion models and counting procedures, refer to volume I of this series.

Appendix B

MUTCD Warrant 3, Minimum Pedestrian Volume (1987 Revision)

A traffic signal may be warranted where the pedestrian volume crossing the major street at an intersection or mid-block location during an average day is:

100 or more for each of any 4 hours; or
190 or more during any 1 hour.

The pedestrian volume crossing the major street may be reduced as much as 50 percent of the values given above when the predominant pedestrian crossing speed is below 3.5 feet per second.

In addition to a minimum pedestrian volume of that stated above, there shall be less than 60 gaps per hour in the traffic stream of adequate length for pedestrians to cross during the same period when the pedestrian volume criterion is satisfied. Where there is a divided street having a median of sufficient width for the pedestrian(s) to wait, the requirement applies separately to each direction of vehicular traffic.

Where coordinated traffic signals on each side of the study location provide for platooned traffic which results in fewer than 60 gaps per hour of adequate length for the pedestrians to cross the street, a traffic signal may not be warranted.

This warrant applies only to those locations where the nearest traffic signal along a major street is greater than 300 feet and where a new traffic signal at the study location would not unduly restrict platooned flow of traffic. Curbside parking at nonintersection locations should be prohibited for 100 feet in advance of and 20 feet beyond the crosswalk.

A signal installed under this warrant should be of the traffic-actuated type with push buttons for pedestrians crossing the main street. If such a signal is installed within a signal system, it shall be coordinated if the signal system is coordinated.

Signals installed according to this warrant shall be equipped with pedestrian indications conforming to requirements set forth in other sections of this manual.

Appendix C

Accuracy and Reliability of the Method

The expansion modeling effort resulted in good pedestrian volume prediction models based on the coefficient of determination and standard error (SE_y) about the mean. In all cases, the middle interval position event produced the best model regardless of the size of the count interval. It was apparent, however, that the larger the count interval, the better the volume prediction. All middle count interval models were presented in order to leave the determination of the prediction accuracy to the user.

Additional findings were that when the multihour volume period increased, the multihour prediction became less accurate. This was due to the increase in variation of the counting intervals as the 1-hour volumes increased to 4-hour volumes. Also, the expansion models for the middle counting intervals were not affected by the different volume distributions that existed for the hour or multihour volume counts. This was evident by the constant result of the middle event being the best predictor of pedestrian volumes.

A validation study was conducted using the middle count expansion models. The purpose of this study was to determine the prediction error associated with various volume ranges since the SE_y calculated in regression is meaningless when values of X move far away from the mean of X. The prediction error (percent error) was emperically derived for various prediction volume ranges. Findings of this validation reflected the earlier findings in the modeling effort. As the count interval increased, the smaller the percent error became, thus, the better the volume prediction. Also, as the prediction of hourly volumes increased to multihour volumes, the percent error became larger.

An observation that was not found in the modeling effort was the increase in accuracy as the prediction volume range increased. This was the result of the erratic occurrence of volume peaks and valleys that often existed at low volume sites. Thus, the probability of sampling at a peak or valley would be approximately 50 percent, which in turn may not be a true representation of the hourly or multihourly volume.

Regardless of the positive results of the expansion modeling approach, one question will arise for studies constrained to using data in one city: Are these models valid in other cities that have different characteristics? The answer, at present, is unknown. However, the hourly expansion models were derived using some 400 hourly observations and validated with 120 observations. This means that there were possibly 400 different 1-hour volume distributions in the modeling derivations and 120 different distributions in the modeling validations. Thus, the potential of encompassing many of the typical 1-hour distributions found in any city is good.

As for the multihour models, the sample sizes were less than for the 1-hour models. Confidence in the reliability and validity of these models was not as great as in the 1-hour models. Therefore, additional research would probably improve these multihour models.

This additional research might take two approaches. To test the validity of the models developed in this study, data should be collected at several sites for several cities throughout the country. The validity would be tested by comparing the percent errors calculated in this study to the percent errors calculated for the additional data. If these percent errors are found to be statistically the same then the models developed here would be valid.

The second approach would test the models' reliability. In testing model reliability, expansion models would have to be developed for various cities and then compared to the models of this study. The models developed in this study would be reliable for use in other cities if the expansion models developed for other cities had the following characteristics: positively skewed data (corrected by logarithmic transformation), optimum counting intervals occurring at the middle event, and regression equations and parameters similar to those of this study.

In conclusion, promise has been shown for the use of expansion models in predicting pedestrian volumes. The ease and cost reduction in the use of these models is clear. With the additional research conducted in other cities, these models could prove to be very beneficial in the prediction of pedestrian volumes for use in signal warrant evaluations and exposure data applications.