MUTCD as information signs to inform pedestrians of the meaning of existing signal messages.

4. The WALK WITH CARE signal display should be added to the MUTCD as a special device that can be used as an option at locations with a high pedestrian accident rate or at locations with an unusual problem of heavy vehicular turning maneuvers and moderate to high pedestrian volumes.

5. Because of its beneficial effect at three of four test sites, further testing of the three-section DONT START pedestrian signal indication is justified to determine under what conditions it is effective. However, even if it is more understandable than the flashing DONT WALK signal, its adoption on a national basis may not be practical, because all pedestrian signals would require the addition of a third signal head and additional electronic work.

ACKNOWLEDGMENT

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Pedestrian Time-Space Concept for Analyzing Corners and Crosswalks

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ABSTRACT

The preliminary version of the new Highway Capacity Manual, Interim Materials on Highway Capacity (Transportation Research Board Circular 212), contains procedures for determining pedestrian levels of service at street corners and in crosswalks. Problems encountered during several applications of the Circular 212 procedures are discussed and a new conceptual approach for analyzing crosswalks and corners is introduced. Based on a time-space concept, this analysis method has several advantages over the Circular 212 procedure. Simply stated, the method is based on developing an estimate of total pedestrian occupancy time for a corner or crosswalk and relating this occupancy value to the available time and space. Average pedestrian occupancies derived from these values are compared with level-of-service criteria to determine relative degrees of convenience. The time-space analysis method and an illustrative problem are presented and compared with the Circular 212 procedure. Additional research to further increase the utility of the time-space technique is discussed.

Increasingly planners and engineers must address the problem of pedestrians at intersections. In the past the primary concern was to provide adequate walk time for safe crossing of the street, and little attention was paid to the volume of pedestrian activity and relative convenience. Vehicular traffic was accommodated first. Sidewalk widths were often reduced to create turning or parking lanes. However, the concentration of workers, shoppers, and visitors in many urban centers is becoming so intense that sidewalks and crosswalks are proving inadequate. Beyond safety concerns, attractive pedestrian environments and enhancement of pedestrian activity are being recognized as important determinants of the usefulness of urban centers. Until recently few analytical tools existed to evaluate pedestrian-related issues.

Building on previous work (1,2), TRB Circular 212, Interim Materials on Highway Capacity (3), introduced an analytical procedure for evaluating crosswalks and corner spaces. However, several conceptual and application problems make it difficult to use. A new approach based on a time-space (TS) concept of the functioning of street corners and crosswalks is described that presents several advantages over the TRB Circular 212 procedure.

CORNER AND CROSSWALK ANALYSIS

The concentration of pedestrian activity at street corners and in crosswalks makes them the critical links for both sidewalk and highway networks in the urban core. Overloaded corners and crosswalks affect not only pedestrian convenience and safety but also roadway capacity by delaying vehicle turning movements and thereby reducing the through capacity of an intersection.

The corner is a difficult analysis problem because of the many events that occur there. Pedestrians entering a corner space from the sidewalk or crosswalk can turn left or right or continue ahead (Figure 1). Pedestrians that accumulate at corners during the red signal phase require standing space, which reduces the space for circulation. Pedestrians accumulating during the red phase also create denser platoons when they cross. Conflicts with turning vehicles during the crossing cycle reduce crosswalk capacity and can cause pedestrians to drift outside the marked crosswalk area, which potentially endangers them.

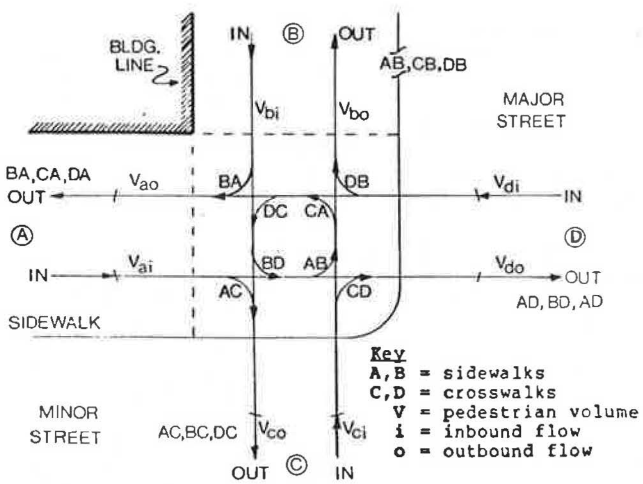

FIGURE 1 Intersection corner: pedestrian movements.

The basis for determining the adequacy of pedestrian facilities used in both the Circular 212 procedure and the TS method are the level-of-service (LOS) criteria for walkways and queuing spaces. These criteria provide a measure of relative degrees of convenience based on the average amount of space available per person. For walkways the criteria relate average space per person to the flow rate per unit of walkway width, conflict probability, ease of pedestrian movement, and average walking speed. LOS criteria for standing or queuing spaces relate average pedestrian space to degrees of personal comfort and individual mobility within the queuing space. LOS criteria presented in Circular 212 are summarized in Tables 1 (3, p. 124) and 2 (3).

Both the Circular 212 procedure and the TS method focus on pedestrian space demands at the corner and in the crosswalk. For corners there are two distinctly different types of pedestrian space requirements:

- Circulation space: Space needed to accommodate the movement of pedestrians crossing during the green signal phase, those joining the red phase queue, and those moving between the adjoining sidewalks but not crossing the street.
- Hold space: Space needed to accommodate standing pedestrians waiting during the red signal phase.

CIRCULAR 212 PROCEDURE

In 1980 TRB published Circular 212: Interim Materials on Highway Capacity (3), which contained a section on analysis techniques for pedestrian facilities. A new technique for analyzing corners was presented that included procedures for both intersection reservoirs (corner space) and crosswalks. The adequacy of the reservoir space for an assumed pedestrian LOS standard is compared with that of the space available. For crosswalks the procedure estimates the width required to accommodate the surge of pedestrians during the walk phases.

The reservoir space analysis technique estimates the space required for circulation--pedestrians passing through the corner. It includes pedestrians approaching the corner by way of the intersecting sidewalks and from the crosswalk with the walk phase. Pedestrian flow volumes expanded by peaking factors for platooning are converted into equivalent flow rates and the required circulation space is determined by using an assumed level of service, for example, level of service C. Requirements for holding space are determined by the maximum number of waiting pedestrians who would accumulate just before the walk signal phase. A space requirement per person, again using an assumed level of service, is applied to the build-up and the required holding space is determined. The combined circulation and holding-space requirements plus dead space (region not available for circulation or queuing) are then compared with the space available at the corner.

As the procedure is set up, the evaluation determines whether the pedestrian demands satisfy the assumed levels of service. Some analysts have developed a use measure by comparing the space required with the space available. A use under 1.0 would indicate that excess capacity exists.

In crosswalks crossing-pedestrian volumes are factored to account for signal phasing and converted into equivalent flow rates. By using LOS curves supplied in Circular 212, the required width of the crosswalk is determined for the flow rates. The required width is then compared with the actual or proposed width of the crosswalk.

The Circular 212 procedure was applied in several studies in midtown Manhattan where intensive pedestrian activity is both common and an increasingly sensitive planning and design issue. In the course of these applications, some problems were encountered with the procedure:

1. The data-collection requirements are expensive in terms of manpower; in addition to crosswalk

TABLE 1 Pedestrian LOS Standards for Walkways: Average Flow Conditions (3)

Level of Service	Space (ft^2/pedestrian)	Avg Unit Width Flow Rate[a] [pedestrians/(min · ft)]	Avg Speed[b] (ft/min)	Volume/Capacity Ratio[c]
A	>40	<6	>250	<0.24
B	24-40	10-6	240-250	0.24-0.40
C	16-24	14-10	224-240	0.40-0.56
D	11-16	18-14	198-224	0.56-0.72
E	6-11	25-18	150-198	0.72-1.00
F	<6	0-25	0-150	Variable

[a]Flow rates are relative to effective walkway width.
[b]Speeds are computed from speed = flow x space.
[c]Assumed capacity = 25 pedestrians/(min · ft).

TABLE 2 Pedestrian LOS Standards for Queuing Spaces (3)

Level of Service	Avg Pedestrian Space Occupancy (ft^2)	Avg Interpersonal Spacing (ft)	Description
A	13+	4+	Standing and free circulation
B	10-13	3.5-4.0	Standing and partly restricted circulation without disturbance to others
C	7-10	3.0-3.5	Standing and limited circulation with disturbance to others
D	3-7	2-3	Standing without touching others, circulation severely restricted
E	2-3	<2	Unavoidable physical contact, circulation not possible
F	<2	Close contact	Close physical contact, discomfort, no movement, potential danger

volumes, directional volumes on sidewalks are required;

2. The series of trial assumptions required makes the procedure cumbersome, particularly because the majority of corners are not in the problem range;
3. The methodology and the output are conceptually difficult for laymen to understand;
4. Many professionals, especially those accustomed to vehicular traffic analysis, have difficulty with the cut-and-try assumptions required;
5. The procedure is sensitive to certain of its parameters, particularly the space assumed per queuing pedestrian;
6. The analysis is not responsive to changes in approach volumes and at higher volumes requires interpolation on a logarithmic curve;
7. The corner analysis measures the maximum build-up of pedestrians on the corner just before the signal change and does not adequately respond to crowding conditions existing over longer periods of time.

The Circular 212 procedure advanced the state of the art in pedestrian analysis. However, in the spirit of the issuance of the interim materials for review, testing, comment, and revision, an alternative concept is proposed.

TS CONCEPT

The theoretical capacity of any traffic system is definable in terms of time and space. Transportation engineers are familiar with time-and-space graphs and diagrams for signal phasing, train scheduling, and terminal operations studies, but TS principles can be applied to other problems where different types of traffic elements occupy a system (space) for varying times related to their speeds or other operational characteristics. (The TS concept as used here is different from the time-and-space diagram used in vehicular and railroad traffic analyses in which the relative location of vehicles is plotted over time.) TS analysis is useful for corner and crosswalk evaluations because it is a relatively simple technique that is sensitive to changes in corner and crosswalk geometry, pedestrian volumes, and signal phasing. The method also provides a potential means of evaluating the effects of vehicle turning movements on crosswalk adequacy.

Conceptually the method assumes that corners and crosswalks are TS zones in which moving and standing pedestrians require different amounts of space and occupy the zones for different periods of time. The total amount of time and space available for these activities is simply the net usable area of the zone in square feet multiplied by the time of the analysis period, usually the peak 15 min. The time and space used by queuing pedestrians at corners becomes the product of the average number waiting to cross during the red phases and an assumed standing area. The analysis presented assumes that pedestrians waiting for a signal change form a competitive queue with an average space occupancy of 5 ft^2 per person (level of service D). This is the typical average occupancy observed at most crowded corners, and the assumption simplifies the calculations. In the corner analysis this queuing or holding TS is deducted from the total TS to determine the net available for circulation.

In order to determine the average circulation space for moving pedestrians and corner level of service, the total volume of pedestrians using the corner during the analysis period is multiplied by an estimated corner occupancy time (typically in the range of 3 to 5 sec) needed to walk through the corner space. In the problem presented, this time is estimated at 4 sec, based on the longest travel path. An assumption of travel on the longest path is conservative, because many pedestrians cut across the corner edges. The resulting product in pedestrian minutes is divided into the available circulation TS in area minutes to determine average circulation area per pedestrian. This area is then compared with the LOS criteria for walkways and translated into relative degrees of pedestrian convenience.

The crosswalk can also be analyzed as a TS zone. The TS for pedestrian movement is the product of the green-phase crossing time less 3 sec platoon start-up time and the area of the crosswalk in square feet. The product of pedestrian crossing volume and the average pedestrian crossing time gives the demand for this TS in pedestrian minutes. Division of demand into the available TS produces the area per moving pedestrian available during crossing. This area can also be compared with LOS criteria for walkways.

A brief maximum flow or surge condition occurs in crosswalks during the green phase when the two lead platoons from opposite corners, accumulated during the red waiting phase, are simultaneously moving in the crosswalk. Excessive pedestrian flows during this surge could cause pedestrians to drift out of the marked crosswalk area, which potentially endangers them. The time element used in the analysis of this surge is the time it takes for the lead pedestrian in each platoon to walk across the street.

Neither the average nor the maximum surge estimate of the crosswalk level of service accounts for the effects of turning vehicles during the pedestrian crossing phase. A rough estimate of pedestrian LOS degradation by turning vehicles has been made in the problem presented by assuming a vehicle-swept path and the time that the vehicle occupies the crosswalk. The method can be used to make approximate evaluations of the effects of different signal-phasing and vehicle-turning strategies on pedestrian movement, but it is emphasized that this approach has not been validated by field observations and will require further research.

ANALYSIS PROCEDURES

In order to simplify the understanding and application of the TS method, the development of its equations is presented in parallel with the solution of a sample corner and crosswalk problem. The problem is based on actual data from a street corner in midtown Manhattan previously analyzed by the Circular 212 procedure. The results of the two analysis methods are then compared. (Users of these procedures should review assumed values presented in this paper for appropriateness for their locality and adjust the assumed values accordingly.)

Figures 2 and 3 show the two signal phase condi-

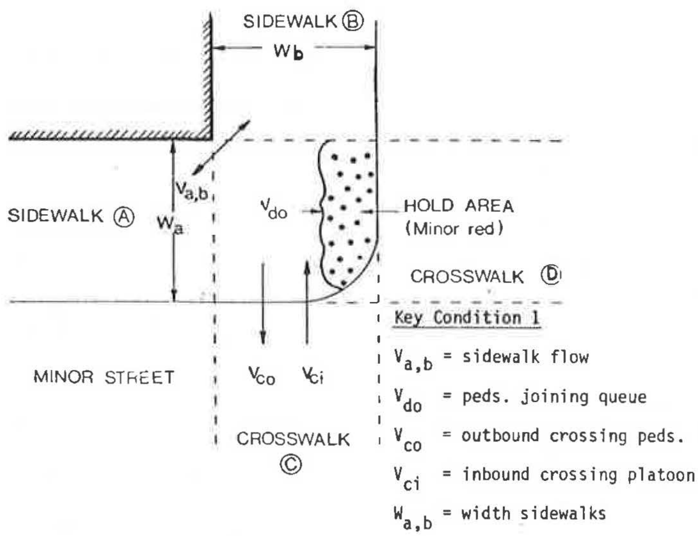

FIGURE 2 Intersection corner: condition 1—minor-street crossing.

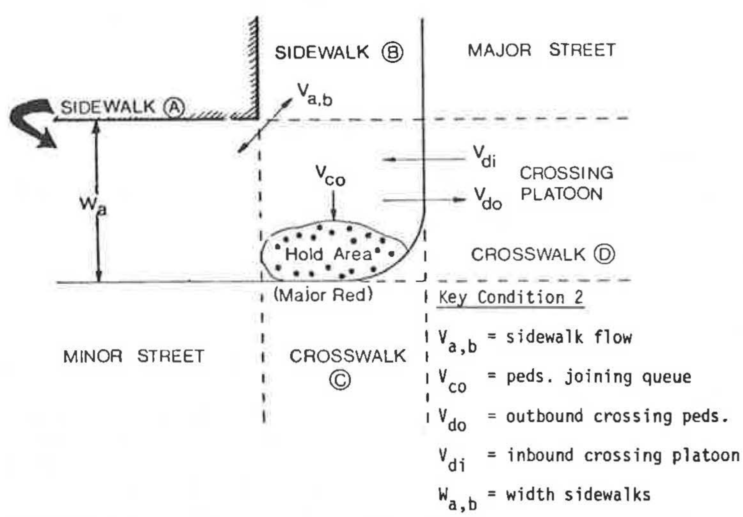

FIGURE 3 Intersection corner: condition 2—major-street crossing.

tions that are analyzed in both corner and crosswalk computations. Condition 1 is the crossing of the minor street occurring during the major-street green phase; a maximum queue is built up on the major-street side. Condition 2 is the major-street crossing occurring during the minor-street green; a maximum queue is built up on the minor-street side.

The sidewalks at the intersection of a major and a minor street are 20 ft and 15 ft wide, respectively, with a corner radius of 10 ft. The roadway width for the major street is 50 ft and for the minor street, 30 ft. The cycle length of the signal is 90 sec, with a two-phase split of 50 sec of green plus amber for the major street (56 percent) and 40 sec of green plus amber for the minor street (44 percent). The 15-min peak-period pedestrian crossing and sidewalk volumes (Figures 2 and 3) are as follows:

Flow	Peak 15-min Count	Flow Rate (pedestrians/min)
V_{ci}	354	24
V_{co}	276	18
V_{di}	505	34
V_{do}	797	53
$V_{a,b}$	227	15
Total	2,159	144

The problem is to find

1. The average level of service for pedestrian circulation at the street corner,
2. The average level of service for pedestrians crossing in minor- and major-street crosswalks for the green phase and maximum surge conditions, and
3. The decrement in average crosswalk pedestrian level of service due to five turning vehicles per cycle on the major-street crossing.

Corner Analysis

1. Total available TS in the intersection corner in area minutes for both queuing and circulation for an analysis period of tp min is the product of this time and the net corner area (Ac). Ac is found by multiplying the intersecting sidewalk widths (W_a, W_b) and deducting the area lost because of the corner radius and any obstructions:

Ac (area corner radius segment = $0.215R^2$) = $15 * 20 - 0.215 * 10 * 10 = 279\ ft^2$.

TS = Ac * tp, or

TS = 279 * 15 min = 4,185 $ft^2 \cdot$ min.

2. Assuming uniform arrivals at the crossing queues, the average pedestrian holding times (Qt_{do} and Qt_{co}) of persons waiting to use crosswalks C and D, respectively, are one-half the product of the 15-min outbound flows (V_{do}, V_{co}), the proportion of the analysis period that these flows are held up, and their holding time based on the red signal length, determined as follows:

Condition 1 (minor-street crossing on major green):

Qt_{do} = (V_{do} * ratio minor red * minor red t)/(2 * 60), or

Qt_{do} = (797 * 0.56 * 50)/(2 * 60) = 186 pedestrian min.

The ratio of minor red is the proportion of time that the major-street crossing flow is held back and as used determines the total number of pedestrians waiting in the major-street queue (V_{do} * ratio minor red). Minor red t is the time that these pedestrians wait to cross, in seconds, converted to minutes (sec/60). The divisor 2 converts the total waiting time distribution based on the assumption of uniform arrivals to an average waiting time in pedestrian minutes.

Condition 2 (major-street crossing on minor green):

Qt_{co} = (V_{co} * ratio major red * major red t)/(2 * 60), or

Qt_{co} = (276 * 0.44 * 40)/(2 * 60) = 40 pedestrian min.

The variables are similar to those described previously.

3. Holding-area TS requirement (Tsh) is the product of the average waiting times (Qt_{do}, Qt_{co}) and the average area used by a waiting pedestrian, assumed to be 5 ft^2/pedestrian (level of service D), determined as follows:

Tsh = (Qt_{do} + Qt_{co}) * 5, or

Tsh = (186 + 40) * 5 = 1,130 $ft^2 \cdot$ min.

4. Net circulation area TS (Tsp) is the total TS available minus that used for holding (Tsh), as follows:

Tsp = TS - Tsh, or

Tsp = 4,185 - 1,130 = 3,055 $ft^2 \cdot$ min.

5. Total circulation volume (P), which must use the available circulation TS (Tsc), is the sum of all pedestrian flows for the 15-min analysis period, as follows:

P = $V_{ci} + V_{co} + V_{di} + V_{do} + V_{a,b}$, or

P = 354 + 276 + 505 + 797 + 227 = 2,159 pedestrians.

All values are in pedestrians per 15 min and all volumes are defined in Figures 2 and 3 and stated in the data given.

6. Total circulation time (Ct) that pedestrians consume while circulating through the corner area is taken as the product of P and an assumed average circulation time of 4 sec:

Ct = P * (4/60), or

Ct = 2,159 * (4/60) = 144 pedestrian min,

where 60 is a conversion from seconds to minutes.

7. Circulation area per pedestrian (M) (called the pedestrian space module) is computed as Tsp divided by Ct:

M = Tsp/Ct, or

M = 3,055/144 = 21.2 ft^2/pedestrian.

8. For the corner level of service M is compared with the LOS standards of Table 1 to obtain an approximate measure of pedestrian circulation convenience for the street corner. Values equal to or below level of service C indicate a potential problem and should be the subject of further field study

and possibly remedial actions, which could include changes in signal-cycle timing, prohibition of vehicle turning movements, sidewalk widening, and removal of sidewalk obstructions.

From Table 1 a value for M of 21.2 ft^2/pedestrian falls within the range of level of service C (16 to 24 ft^2/pedestrian), which is indicative of a busy corner potentially requiring more detailed study.

Crosswalk Analysis

1. The total available TS in each crosswalk (Tsc, Tsd) is the product of their areas and the effective green times. The corner radius area segment of 1.5 ft^2 subtracted from the corner area is added to the crosswalk area (there are two corner area segments for each crosswalk). Therefore,

Area crosswalk C = (15 * 30) + (2 * 21.5) = 493 ft^2.

Area crosswalk D = (20 * 50) + (2 * 21.5) = 1,043 ft^2.

2. The TS available for each condition is as follows:

Condition 1 (minor-street crossing, crosswalk C):

Tsc = Ac * (major green t - 3)/60, or

Tsc = 493 * (50 - 3)/60 = 386 ft^2 • min.

Condition 2 (major street crossing, crosswalk D):

Tsd = Ad * (minor green t - 3)/60, or

Tsd = 1,043 * (40 - 3)/60 = 643 ft^2 • min.

3. Crosswalk time (tc, td) is the average time a pedestrian occupies each crosswalk, obtained by dividing the street width by the assumed pedestrian walking speed. Street widths are in feet, and walking speed is assumed to be 4.5 ft/sec. Then

Condition 1 (crosswalk C, L = 30 ft):

tc = 30/4.5 = 6.6 sec.

Condition 2 (crosswalk D, L = 50 ft):

td = 50/4.5 = 11.1 sec.

4. Total crosswalk occupancy time (Tc, Td) is the product of the pedestrian volumes using each crosswalk during the green phase and the street crossing times (tc, td). The average pedestrian volume or number crossing during a given green phase is the product of the crosswalk flow rates and the total cycle length (St). This includes pedestrians held in the red phase and new arrivals during the green phase.

Condition 1 (crosswalk C):

Tc = (v_{ci} + V_{co}) * (St/60) * (tc/60), or

Tc = (24 + 18) * (90/60) * (6.6/60) = 6.9 pedestrian min.

Condition 2 (crosswalk D):

Td = (V_{di} + V_{do}) * (St/60) * (td/60), or

Td = (34 + 53) * (90/60) * (11.1/60) = 24.1 pedestrian min.

5. Average circulation space (Mc, Md) per pedestrian is determined by dividing the TS available during each crossing phase (Tsc, Tsd) by the respective occupancy times (Tc, Td). This yields the average space module available for each crosswalk, a value that can be compared directly with LOS criteria in Table 1.

Condition 1 (minor street):

Mc = Tsc/Tc = 386/6.9 = 56 ft^2/pedestrian.

From Table 1, this is equivalent to level of service A.

Condition 2 (major street):

Md = Tsd/Td = 643/24.1 = 27 ft^2/pedestrian.

From Table 1, this is equivalent to level of service B.

In the foregoing procedure only average conditions in the crosswalk during the green phase are considered. The maximum surge condition, the condition with the maximum number of pedestrians in the crosswalk, should also be examined. This occurs when the lead pedestrians in each crossing platoon accumulated during the red phase reach the opposite corner. The space module (Mc, Md) for the surge is the area of the crosswalk divided by the maximum number of pedestrians in the crosswalk (Pc_{max}, Pd_{max}). The major and minor red times plus 3 sec and the outbound volumes determine the size of the crossing platoon. The addition of the crossing times (tc, td) determines the new arrivals as these platoons cross the street.

Condition 1 (minor street):

Pc_{max} = (V_{ci} + V_{co}) * (major red t + 3 + tc)/60, or

Pc_{max} = (24 + 18) * (40 + 3 + 6.6)/60 = 35 pedestrians.

Mc = Ac/Pc_{max} = 493/35 = 14.1 ft^2/pedestrian.

Condition 2 (major street):

Pd_{max} = (V_{di} + V_{do}) * (minor red t + 3 + td)/60, or

Pd_{max} = (34 + 53) * (50 + 3 + 11.1)/60 = 93 pedestrians.

Md = Ad/Pd_{max} = 1,043/93 = 11.2 ft^2/pedestrian.

From Table 1 pedestrian area modules of 14.1 and 11.2 ft^2/pedestrian fall within the range of level of service D (11 to 16 ft^2/pedestrian), indicative that these crosswalks are both quite congested but still below capacity limits.

Estimating the Decrement to Crosswalk Level of Service due to Turning Vehicles

The TS method allows a rough estimate to be made of the effect of turning vehicles on the average level of service for pedestrians crossing in a given green phase. This is done by assuming an average area occupancy of a vehicle in the crosswalk based on the product of the vehicle-swept path and crosswalk widths and an estimate of the time that the vehicle preempts this space.

For this example, the vehicle-swept path has been assumed to be 8 ft wide, and the time the vehicle preempts the crosswalk space is taken as 5 sec to allow for some avoidance behavior on the part of either the driver or the crossing pedestrians. The vehicle TS decrement in square feet minutes would then be as follows:

Veh.Dec. = swept path * crosswalk width * preempt time/60, or

Veh.Dec. = 8 * 15 * 5/60 = 10.0 ft^2 • min/vehicle.

The impact for the average level of service on the major-street crossing (not the maximum surge) of five turning vehicles is as follows:

5 vehicles x 10.0 = 50 ft^2 • min/phase.

For the major crossing, the total available Tsd was found to be 643 ft^2 • min in each phase. Deducting 50 ft^2 • min for the five turning vehicles reduces Tsd to 593 ft^2 • min. The average crosswalk area per pedestrian may now be recomputed as follows:

Md = 593 ft^2 • min/24.1 pedestrian min = 24.6 ft^2/pedestrian.

This is in the range of level of service C, one level of service worse than originally indicated in the major-street crossing analysis. This method could be adapted to evaluate various signal-phasing and vehicle-turning strategies on pedestrian convenience. However, further research is necessary to validate its use for these applications.

Comparison with Circular 212

This same corner was analyzed by using the Circular 212 procedure. Using level of service C for the analysis, the corner area required under condition 1 was 537 ft^2, whereas for condition 2, the area required was 368 ft^2. In this procedure, dead areas (including the buffer spaces) are included in the area required. The corner space available is 480 ft^2. (This procedure extends the corner space back up the adjacent sidewalks by multiplying the product to the two sidewalk widths by a factor of 1.67.) For condition 1, the corner is functioning below level of service C in the peak period, whereas for condition 2, it is functioning within level of service C.

The TS analysis for the corner, which encompasses both conditions, indicated that the corner is functioning at level of service C, showing general consistency with the more involved Circular 212 procedure.

The Circular 212 crosswalk analysis procedure is comparable to the average condition during the walk phase. The Circular 212 procedure does not directly determine a level of service, but one can be found by converting the flow into an equivalent flow rate of pedestrians per foot per minute rather than using the space module. For condition 1, the crosswalk is functioning at level of service A and for condition 2 at level of service C, as compared to the level of service A and B using the TS method. The difference may result from the use by the TS concept of crosswalk area, whereas the Circular 212 procedure uses crosswalk width. Circular 212 does not examine maximum surge conditions in the crosswalk.

CONCLUSIONS AND CONSIDERATIONS FOR FURTHER RESEARCH

The TS technique represents a different way of examining pedestrian conditions at sidewalk corners and crosswalks. TS is the product of the space (area) available or occupied and the time it is available or occupied. The output is an area per person that can then be compared with the commonly used pedestrian level of service criteria. The method can be used to test means of improving problem pedestrian corners, such as changes in sidewalk and crosswalk geometry, changes in signal timing, and vehicle turning strategies. It yields results comparable with those of the more cumbersome Circular 212 procedure but with less involved computations.

A subject for further research would be the development of general values to use in the analysis (default values) if the user does not have local data. Extensions of this analysis procedure to such issues as the influence of turning vehicles on crosswalk capacity or, conversely, heavy pedestrian volumes on the vehicle throughput of intersections require further examination. The TS technique also has potential application in the analysis of other pedestrian facilities involving circulation and queuing spaces, such as transit platforms. The relatively simple computational steps also make it adaptable to programming on a microcomputer.

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