PEDESTRIAN CHARACTERISTICS FOR SIDEWALKS IN CENTRAL JAKARTA

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abstract : This study analyzed characteristics of pedestrian flow on sidewalks in Central Jakarta. Data were collected at three sites in the Central Business District of Jakarta. : on Jalan Sudirman, in front of the Niaga Tower Building and at Bendungan Hilir area and on Jalan Thamrin in the opposite direction of the Sarinah Building.
Pedestrian speed-flow-density mathematical relationships were formulated based on the linearity of the pedestrian speed-density relationship. The walking speed of men was found to be greater than that of women. Pedestrian speed-density relationships, represented by equation: u (speed in m/min) = A (max.speed) - B (slope). k (density in ped/m2) , were determined for the three sites as follows : Jalan Sudirman-Niaga Tower (u = 82-22.3.k); Jalan Thamrin-Sarinah (u = 76.8-18.5.k) and Jalan Sudirman-Bendungan Hilir (u = 75.7-24.9.k). The theoretical minimum space required per pedestrian at zero speed in Jalan Thamrin-Sarinah was found to be the smallest (0.241 m^2/ped) which gave the highest theoretical maximum flow (79.38 peds/min/m) amongst the three sites.

1.BACKGROUND

Walking is the most basic means of transportation. As a primary mode of transportation, it is generally limited in distance. Most transportation trips by other modes begin and end by walking.

As a metropolitan city, Jakarta lacks suitable pedestrian facilities. For example most streets in Jakarta do not have appropriate sidewalks. To design these facilities, standards for typical Jakarta pedestrian traffic are required. As the land in Jakarta has become limited and expensive, a knowledge of the characterictics of the typical Jakarta pedestrian could help in optimizing land use in pedestrian design which would result in more efficient and safer service for the pedestrians.

2.OBJECTIVES

The objectives of the study are :
1. To study the characteristics of pedestrian speeds on sidewalks in Central Jakarta.
2. To study the pedestrian speed-flow-density relationships and to investigate the pedestrian Levels of Service in Central Jakarta.

3. FIELD DATA COLLECTION

Variables measured in the fields were as follows :

- The width of sidewalks
- The number and width of items of street furniture
- The time needed by pedestrians when crossing the observation site, measured only when there are no standing pedestrians within the observation site.
- The number of pedestrians within the boundaries of the observation site at the time the subject pedestrian is approximately in the middle.

Three observation sites in Jalan Sudirman and Jalan Thamrin were chosen as the observation sites. Data collection was conducted in the morning (around 7.00 a.m to 9.00 a.m) when most of the walking trips were made for the purpose of going to work. The data for this study were collected by recording pedestrian traffic on sidewalks by means of a video camera. Pedestrian flow areas to be studied (4 or 6 meters in length) and width equal to the effective width were marked on the sidewalks.

The criteria from the TRB, 1985 were adopted to get the effective width of sidewalks, i.e :

- a minimum clearance from the street/roadway of 0.5 m
- a minimum clearance from the building line (wall/fence/ curb) of 0.5 m.

Layout of the effective width for this research is shown in Figure 1.

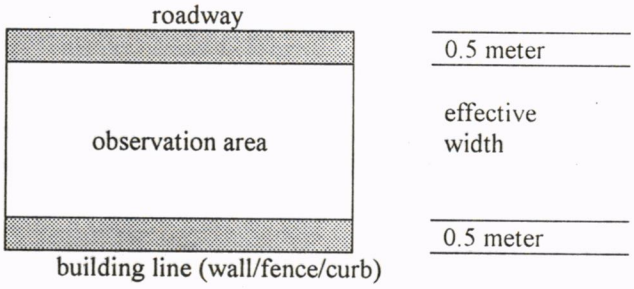

Figure 1. The Effective Width of the Observation Area

Pedestrian speed was obtained by recording the times when individual pedestrians entered and left the boundaries of the marked-off square. The speed was measured when there was no standing pedestrians within the boundary area. The density was obtained by counting the number of pedestrians within the boundaries of the square at the time the subject pedestrian was approximately in the middle. At each site, pedestrian flow was recorded for about 120 minutes. The video camera was situated at the pedestrian crossing bridge facing the major pedestrian flow at a height of approximately five meters, giving a view of approximately thirty meters as shown in Figure 2.

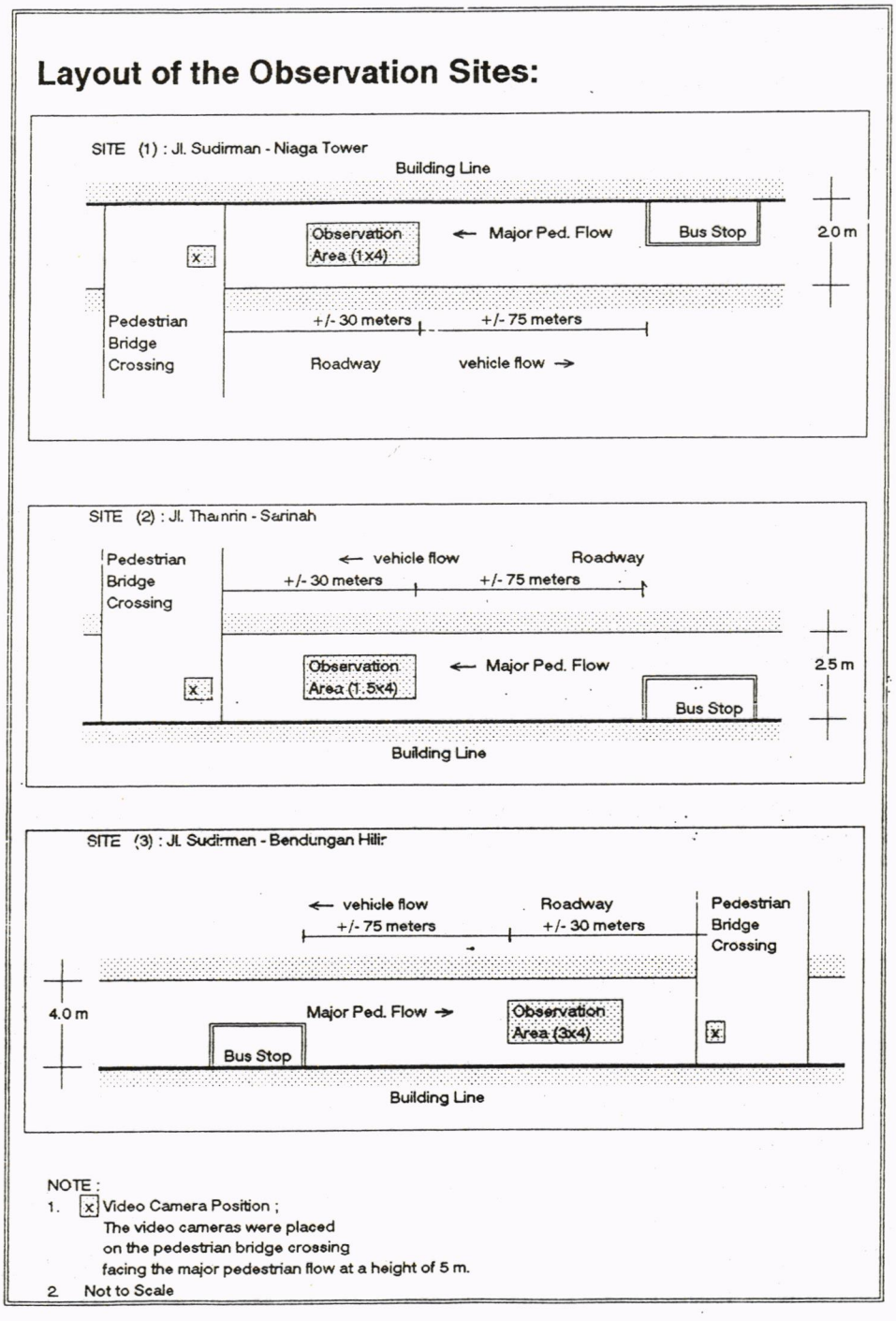

Figure 2. Layout of the Observation Site

4 .DATA ANALYSIS

4.1. Free-flow Walking Speed Studies

It has been found that the distribution of speeds closely follows the normal curve (Greenshields and Weida,1978). One method of determining whether the distribution is normal is to plot the cummulative percentage of frequency as the absisca and the corresponding upper limit of the measurement range as the ordinate on normal probability (graph) paper. If the distribution is normal, the observed data will be represented by a straight line. The arithmetic mean of free-flow walking speed is calculated with the formula (Greenshields and Weida, 1978) as follows :

$$X = Xo + c \frac{(f.x)}{n} \quad (1)$$

$$s = c \sqrt{\frac{f.(x)^2}{n} - \frac{(f.x)^2}{n}} \quad (2)$$

where :
X : the arithmetic mean of speeds (meter/minute)
Xo : the midpoint of the middle of the class
c : the size of the class interval
f : the frequency or number of times the variable X has the value Xi
s : standard deviation of free-flow speed (meter/minute)

As the free-flow walking speed distributions for all sites were normal distributions, the calculations of arithmetic mean free-flow walking speed were made using Equations 1 and 2. The results of speed study are shown in Table 1.

Table 1. Results of the Speed Study

	Jl. Sudirman-Niaga Tower			Jl.Thamrin-Sarinah			Jl.Sudirman-B.Hilir		
	M	W	C	M	W	C	M	W	C
1	2	3	4	5	6	7	8	9	10
Sample size	154	37	191	106	59	165	410	180	590
Mean free-flow walking speed (m/min)	80.5	71.7	78.8	75.6	70.4	73.7	73.0	68.3	71.6
standard deviation (m/min)	17.42	14.47	17.24	15.21	11.48	14.21	13.08	10.99	12.67
range HIGH	120	120	120	120	120	120	120	120	120
LOW	60	48	48	48	48	48	45	45	45
(m/min)									

Note : M=Men; W=Women; C=Combined

As shown in Table 1, the walking speed of women was generally lower than that of men. This findings is generally due to the larger and stronger body size of men.

Pedestrians in Jl.Sudirman-Niaga Tower were the fastest in walking speed (78.81 m/min) while pedestrians in Jl.Sudirman-Bendungan Hilir (71.57 m/min) were the slowest. This could be caused by the influence of land use at the observation sites. Most of land use in Jl.Sudirman-Niaga Tower and Jl.Thamrin-Sarinah are office buildings, while Jl.Sudirman-Bendungan Hilir is a mixture of office buildings, schools and markets. The other reason could be because the surveys were done in the morning when workers were trying to get to their offices as soon as possible.

4.2. Speed-Flow-Density Relationships Studies

In this study, the relationship between speed and density was assumed linear; the other relationships were formulated using Pushkarev & Zupan (1975) formulae.The speed-flow-density relationships obtained in this study was for one- way pedestrian flow.

a. Speed-Density Relationship

The equation of the speed-density relationship (Pushkarev and Zupan, 1975) is :

$$\text{speed} = a - b \times \text{density}$$

$$u = a - b.k \quad (3)$$

where

a : the speed that intercepts the Y axis
b : the slope of the straight line
u : speed (meters/minute)
k : density (pedestrians/meter^2)

$$k = (a - u)/b \quad (4)$$

Summary of the regression analysis results is shown in Table 2. The values of a and b were used to formulate the other speed-flow-density relationships.

Table 2. Summary of Speed-Density Relationship Regression Analysis Results

Observation Site	a	b	r squared
1	2	3	4
Jl.Sudirman-Niaga Tower	82	-22.3	0.65
Jl.Thamrin-Sarinah	76.8	-18.5	0.48
Jl.Sudirman-Bendungan Hilir	75.7	-24.9	0.33

b. Speed-Flow Relationship

$$\text{flow} = \text{speed} \times \text{density}$$

$$q = u \times (a-u)/b$$

$$q = a/b.u - 1/b.u^2$$

$$u_{12} = \frac{a + \sqrt{(a^2 - 4.b.q)}}{2} \quad (5)$$

q : flow (pedestrians/minute/meter)

c. Speed-Space Relationship

$u = a - b.1/M$ (6)

M : space (1/density)

d. Flow-Density Relationship

flow = speed X density

$q = (a - b.k) X k$

$= a.k - b.k^2$ (7)

e. Flow-Space Relationship

flow = speed/space ; space = 1/density

$q = (a - b.1/M)/M$

$= (a.M - b)/M^2$ (8)

4.3. Equations of the Speed-Flow-Density Relationships

Equations of the other speed-flow-density relationships that were derived from the equations of the speed-density relationship are shown in Table 3.

Table 3. Equations of the Speed-Flow-Density Relationships

	Jl. Sudirman - Niaga Tower	Jl. Thamrin - Sarinah	Jl. Sudirman - B.Hilir
Speed - Density	$u = 82 - 22.3\ k$	$u = 76.8 - 18.5\ k$	$u = 75.7 - 24.9\ k$
Speed - Flow	$u = (82 + \sqrt{[(82-89.2)/2]}$	$u = (76.8 + \sqrt{[(76.8-74q)/2]}$	$u = (75.7 + \sqrt{[(75.7 - 99.6\ q)/2]}$
Speed - Space	$u = 82 - (22.3/M)$	$u = 76.8 - (18.5/M)$	$u = 75.7 - (24.9/M)$
Flow - Space	$q = 1/M^2\ (82\ M - 22.3)$	$q = 1/M^2\ (76.8\ M - 18.5)$	$q = 1/M^2\ (75.7\ M - 24.9)$
Flow - Density	$q = 82\ k - 22.3\ k^2$	$q = 76.8\ k - 18.5\ k^2$	$q = 75.7\ k - 24.9\ k^2$

Value of coefficients of the pedestrian flow equations and maximum pedestrian flow in Central Jakarta are presented in Tables 4 and 5, respectively. The speed-flow relationships determined from the study are shown in Figure 3, the speed-space relationships in Figure 4, the flow-density relationships in Figure 5 and the flow-space relationships in Figure 6.

Because few observations were available at higher densities, the use of the site averaged data points would have given results more heavily weighted to lower density observations. Figure 3 and Table 2 show that the r^2 value in Jl.Sudirman-Niaga Tower was 0.65, which is the best in terms of statistical significance compared with Jl.Thamrin-Sarinah (r^2= 0.48) and Jl.Sudirman-Bendungan Hilir (r^2= 0.33).

As shown in Table 4, the theoretical maximum speed at free-flow in Jl.Sudirman-Niaga Tower was 82 m/min which is faster than the 76.8 m/min and 75.7 m/min speeds obtained in Jl. Thamrin-Sarinah and Jl. Sudirman-Bendungan Hilir, respectively.

The theoretical minimum space required per pedestrian at zero speed in Jl.Thamrin-Sarinah (0.241 m^2/pedestrian) is lower than the 0.272 m^2/pedestrian and the 0.329 m^2/pedestrian obtained in Jl.Sudirman-Niaga Tower and Jl. Sudirman-Bendungan Hilir, respectively.

The theoretical minimum space required per pedestrian at zero speed in Central Jakarta was generally higher than indicated by previous studies conducted in Britain for shoppers (0.257 m^2/pedestrian) and in West Germany for mixed traffic (0.263 m^2/pedestrian), although the physique of pedestrians in Jakarta is smaller than that of pedestrians in European countries.
Studies conducted in Central Business Districts and shopping areas in Singapore, indicated that the minimum space per pedestrian is 0.207 m^2 (Tanaboriboon et al, 1986).

Table 5 indicates that although the theoretical maximum speed at free-flow in Jl.Sudirman-Niaga Tower (82 m/min) is higher than in Jl.Thamrin-Sarinah (76.8 m/min), the theoretical maximum flow in Jl.Thamrin-Sarinah (79.7 peds/m/min) was higher than Jl.Sudirman-Niaga Tower (75.38 peds/m/min). This finding could be a result of the lower theoretical minimum space needed by pedestrians in Jl.Thamrin-Sarinah.

Table 4. Coefficients of Pedestrian Flow Equation

Type of flow	equation	A (theoretical maximum speed at free-flow) (m/min)	B	(theoretical minimum space per pedstrian at zero speed) (m^2/pedestrian)
Workers, Niaga	u = 82-22.29k	82.00	22.29	0.27
Workers, Sarinah	u = 76.8-18.53k	76.80	18.53	0.24
Mixed Traffic, B.Hilir	u = 75.68-24.94k	75.68	24.94	0.33

Table 5. Maximum Pedestrian Flow

Type of flow	maximum flow (peds/m/min)	mean speed at maximum flow (m/min)	space allocation maximum flow (m^2/pedestrian)
Workers, Niaga	75.36	42.09	0.54
Workers, Sarinah	79.58	38.40	0.48
Mixed Traffic, B. Hilir	57.41	37.84	0.66

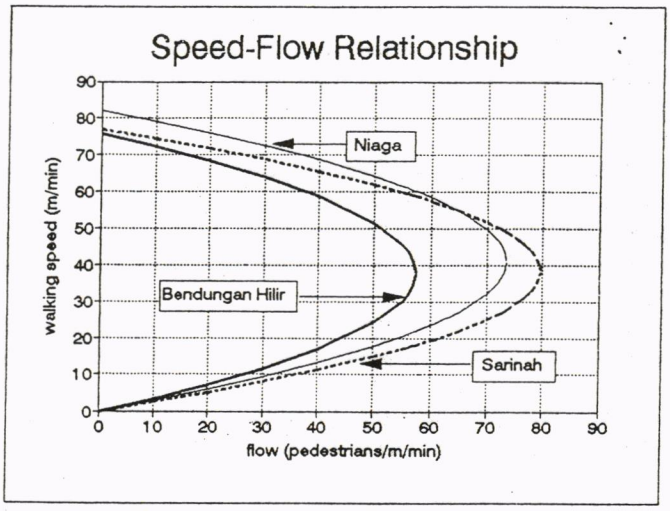

Figure 3. Speed-Flow Relationships

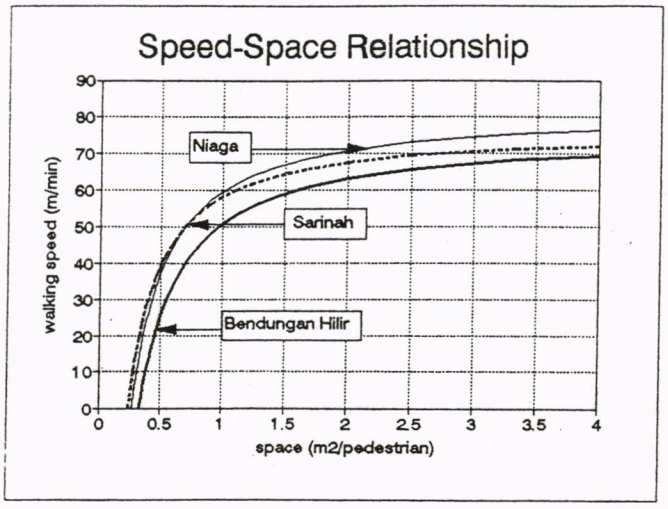

Figure 4. Speed-Space Relationships

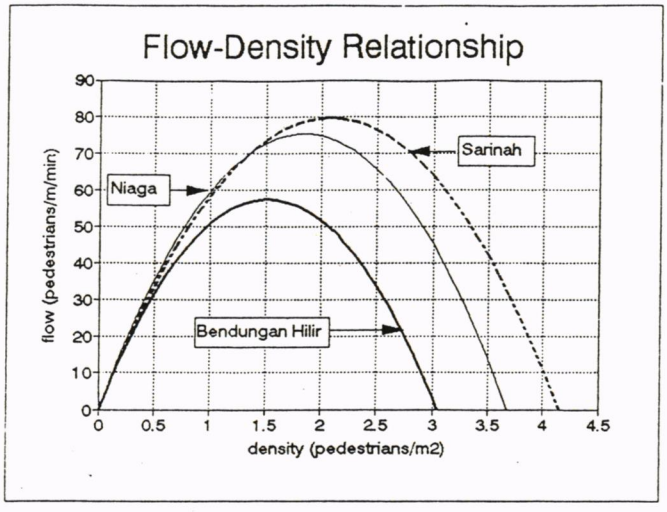

Figure 5. Flow-Density Relationships

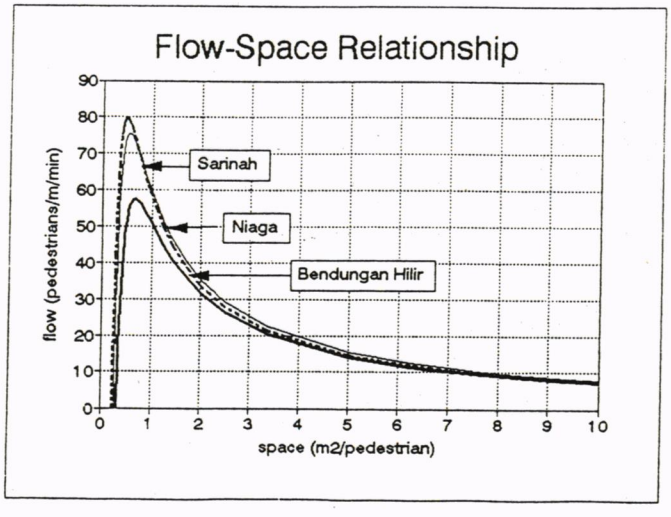

Figure 6. Flow-Space Relationships

4.4. Level Of Service

According to Fruin (1971), capacity was represented by the value of maximum flow. This condition also represented LOS E at which Volume/Capacity ratio is 1.0 and which is characterised as follows:
"At LOS E, virtually all pedestrians would have their normal walking speed restricted, requiring frequent adjustment of gait. At the lower range of this LOS, forward movement is possible only by "shuffling". Insufficient space is provided for passing of slower pedestrians. Cross or reverse flow movements are possible only with extreme difficulties. Design volumes approach the limit of walkway capacity, with resulting stoppages and interruptions to flow."

Using the formulae for the speed-density relationships, the values of flow rate, space, and speed may be calculated. The values of space, speed and flow rate for all Levels Of Service were calculated according to the HCM 1985. Based on the equations of Speed-Flow-Density relationships formulated from the linearity of the Speed-Density relationship, the criteria of pedestrian Level Of Service were calculated as shown in Table 6. Due to the limited range of the density observations, these LOS should be considered as suggested Levels Of Service, consistent with preliminiary study of Pedestrian Level Of Service criteria.

Table 6 Calculations of Pedestrians Levels of Service

Jl. Sudirman -Niaga Tower

Level of Service	Vol/Cap Ratio	Flow Rate (ped/m/min	Ave. Speed (m/min)	Space (m2/ped)	Density (ped/m2)
A	≤ 0.08	≤ 6	≥ 80.327	≥ 13.324	≤ 0.075
B	≤ 0.28	≤ 21	≥ 75.794	≥ 3.592	≤ 0.278
C	≤ 0.40	≤ 30	≥ 72.766	≥ 2.414	≤ 0.414
D	≤ 0.60	≤ 45	≥ 66.944	≥ 1.481	≤ 0.675
E	≤ 1.00	≤ 75	≥ 42.092	≥ 0.559	≤ 1.790

Jl. Thamrin-Sarinah

Level of Service	Vol/Cap Ratio	Flow Rate (ped/m/min	Ave. Speed (m/min)	Space (m2/ped)	Density (ped/m2)
A	≤ 0.08	≤ 6	≥ 75.232	≥ 11.817	≤ 0.085
B	≤ 0.28	≤ 22	≥ 70.983	≥ 3.186	≤ 0.314
C	≤ 0.40	≤ 32	≥ 68.145	≥ 2.141	≤ 0.467
D	≤ 0.60	≤ 48	≥ 62.686	≥ 1.313	≤ 0.762
E	≤ 1.00	≤ 80	≥ 38.400	≥ 0.483	≤ 2.072

Jl. Sudirman-Bendungan Hilir

Level of Service	Vol/Cap Ratio	Flow Rate (ped/m/min	Ave. Speed (m/min)	Space (m2/ped)	Density (ped/m2)
A	≤ 0.08	≤ 5	≥ 74.135	≥ 16.141	≤ 0.062
B	≤ 0.28	≤ 16	≥ 69.948	≥ 4.351	≤ 0.230
C	≤ 0.40	≤ 23	≥ 67.151	≥ 2.924	≤ 0.342
D	≤ 0.60	≤ 34	≥ 61.772	≥ 1.793	≤ 0.558
E	≤ 1.00	≤ 57	≥ 37.84	≥ 0.659	≤ 1.517

5. CONCLUSIONS

The following conclusions were drawn from the present study :

1. The mean free-flow walking speed for the women was generally lower that for men. The mean free-flow walking speeds for pedestrians in Central Jakarta were as follows:

Location	mean free-flow walking speed (m/min)		
	combined	men	women
Jl.Sudirman-Niaga Tower	78.8	80.5	71.7
Jl. Thamrin-Sarinah	73.7	75.6	70.4
Jl.Sudirman-Bendungan Hilir	71.6	73.0	68.3

2. The assumed relationship between pedestrian speed and density agreed with the study results where the speeds were found to be inversely related to density.
   The pedestrian speed-density relationship was represented by the following equations :
   Jl.Sudirman-Niaga Tower : $u = 82 - 22.3\ k$
   Jl.Thamrin-Sarinah : $u = 76.8 - 18.5\ k$
   Jl.Sudirman-Bendungan Hilir : $u = 75.7 - 24.9\ k$
   where pedestrians speed (u) is in meters/minute and pedestrians density (k) is in pedestrians/meter2.

3. Based on the pedestrian Level of Service concept of Highway Capacity Manual (TRB, 1985) and the formulated equations of speed-flow-density relationships, Levels of Service for pedestrian flows in Central Jakarta could be calculated.

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