PEDESTRIAN FLOW ANALYSIS AT YOGYAKARTA, INDONESIA*

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1. INTRODUCTION

Walking is one of the modes of travel, and walking is also a basic movement for everybody who wants to make a journey using all kinds of other modes. But especially in developing countries, research which is concerned with walkway and pedestrian sometime was lack of attention than for motorway.

Pedestrian - Flow Models have been developed by a number of researchers. Among thems are Detlef Oeding, S.J.Older, Francis P.D.Navin and R.J.Wheeler, and Fruin. This models have a close concepts with those used for vehicular streams such as flow is given in term of pedestrians per unit width of a walkway per unit time, and the speed of pedestrians is given in units of distance divided by time.

Characteristic of pedestrian, level of service for pedestrian and other inputs will support planning and design of the walkways, also any study concerned with improved transportation systems. Different countries with different race and habit will have different walking speed, therefore the purpose of this paper is to find flow and characteristic of pedestrians (shoppers) in Yogyakarta, using Pedestrian-Flow Models and compare the result with other's countries.

2. OUTLINE OF EXISTING MODELS IN STUDY OF PEDESTRIANS

PUSHKAREV et al (1975) and Highway Capacity Manual 1985 mention that relationships between flow, speed and density of pedestrians are as follow:

Flow (F) = Speed(V) x Density (d) ..... (2.1)

Flow (F) = Speed(V) / Space(S) ..... (2.2)

Where flow is the average flow of pedestrians per unit of effective walkway width, expressed as pedestrians per minute per foot (per meter). Speed is the average pedestrian walking speed, represented by feet (meters) per minute. Density is the average number of pedestrians per unit of area within a walkway or queuing area, expressed as pedestrians per square foot (per square meter), and space is represented by square feet (square meters)per pedestrian.

The fundamental relationships among speed, flow and density are similar to those used for vehicular streams. When density and volume of a pedestrian stream increases, speed and movement will decreases. While pedestrians have freedom to choose desired speeds and to bypass others, the reductions in effective walkway width caused by various items of street "furniture" will affect pedestrian flow on the sidewalks. Although space is the reciprocal of density, the average area provided for each pedestrian in a walkway or queuing area, it is a practical unit for the analysis of pedestrian facilities.

Speed = A - B x Density ..... (2.3)

$$\text{Flow} = \frac{(A \times \text{Space} - B)}{\text{Space}^2} \quad \text{..... (2.4)}$$

A = the theoretical speed attained by a traffic stream under conditions of completely free flow,with an unlimited amount of space per pedestrian;

B = is a factor that, divided by A, as the theoretical minimum space allocation per pedestrian at a point where all movement in the traffic stream grinds to a halt and speed is zero.

B/A = theoretical minimum space

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Coefficients of B/A in (m2/pedestrian) are as follow:

1. Shoppers (Older)	0.2570
2. Commuters (Fruin)	0.2515
3. Mixed traffic (Oeding)	0.2627
4. Students (Navin & Wheeler)	0.3714
5. Shopper (Tanaboriboon)	0.2070
6. Shopper (Yoshioka)	0.2478

(Source : Ref. 1, 3 & 4)

Due to trip purposes, age, sex, land use, type of group of pedestrian, and other factors, also pedestrian flow is generally based on mean, or average, walking speeds of groups of pedestrians, within any group, or among groups, pedestrian flow characteristics would be consider different.

3. CASE STUDY IN YOGYAKARTA

(1) Data Collection

Survey of pedestrians (Ref.2) was mainly done by observers manually at Malioboro street, the business centre of Yogyakarta. Data were collected per unit time (15 minutes), in two directions, two side of walkways(east side with effective walkway width = 2.2 meters and in the west side with effective walkway width = 1.2 meters) , and in a certain observant distance (10 meters). While data collection was conducted from 6.00 am until 10.00 pm for two days (14th and 15th May 1994), and every 1.5 hours during peak period in one week (14th until 20th May 1994) so that fluctuation of pedestrian flows in hours by day, days by week can be detected. Saturday night is assumed as the weekly busiest day of the walkway at Malioboro, data were collected every Saturday in 1,5 hours for one month (7th, 14th, 21st,and 28th May 1994) in order to detect fluctuation of pedestrian flow in weeks by month.

(2) Analysis of Survey Data

The survey data were used to compute theoretical maximum speed at free flow, maximum pedestrian flow, mean speed at maximum flow and space allocation per pedestrian at maximum flow.

Every hour of group data have there own average speed at free flow and standard deviation, so that theoretical maximum speed at free flow (A) can be produced by average speed at free flow which has the smallest value of standard deviation at statistical data test. A =52.0 meters/minute from sample data of speed at 14th May 1994 during 6.00am-7.00am with 298 pedestrian. For a further breakdown by age, collecting data of pedestrians consist of adults and elementary school children, For adult they were found to have average walking speed of 52.21 meters/minute and 51.36meters/minute for children. Furthermore, data can also be classified by sex, it was found that Yogyakarta males and females's mean walking speed not so much different, although males generally walked faster than females as their mean walking speeds are 53.68 meters/minute for males and 50.75 meters/minute.

In this study, the value of B/A = 0.2070 m2/pedestrian (Tanaboriboon) has been used which is assumed that posture of the shoppers in Yogyakarta is similar with the shoppers in Singapore.

The previous models which were mention by Pushkarev et al (1975) and Highway Capasity Manual (1985) can be used to find speed-density relationships. as shown in Figure 3-1

B/A = 0.207 ---> B = 0.207 A

V = A - B x d

V = 52.0 - 0.207 x 52.0 x d

V =52.0-10.76d ..... (3.1)

Speed-density relationships V = f (d) for the shoppers from Yogyakarta, Singapore, Japan and England are as follow :

V = 52.0 - 10.76 d (Yogyakarta)

V = 73.9 - 15.3 0d (Singapore, Ref. 4)

V = 67.8 - 16.8 0d (Japan, Ref. 1)

V = 78.6 - 20.2 0d (England, Ref. 3)

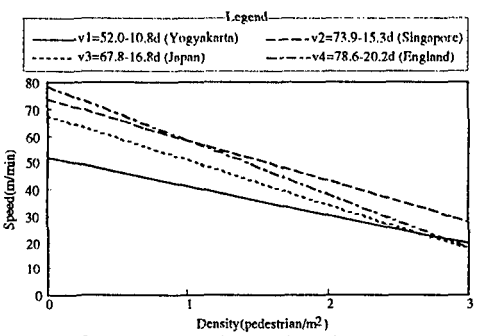

Figure 3-1 Speed-density relationships

The Flow- density relationships was expressed in

F = f (d)

F = V x d .....(2.1)

F = V / S .....(2.2)

V = 52.0 - 10.76 d ..... (3.1) , thus substituting for V, expression F= f(d) become :

F = 52.0 d - 10.76 d2 or
F = (52.0 - 10.76/S) / S
Maximum flow can be produced if differential of F = 0,
52.0 - 2 x 10.76 x d = 0
d = 2.42 pedestrian/m2
V= 25.96 ~ 26 meters/minute
thus maximum flow of pedestrian and space allocation per pedestrian at maximum flow can be computed,
F = 62.92 ~ 63 pedestrians/meter/minute.
S = 0.413 square meters/pedestrian.
Flow-density relationships F = f (d) for the shoppers from various countries are as follow :
F = 52.0 d - 10.76 d2 (Yogyakarta)
F = 73.9 d - 15.30 d2 (Singapore)
F = 67.8 d - 16.80 d2 (Japan)
F = 78.6 d - 20.20 d2 (England)

From the equations above, maximum flow rate from four countries can be computed :
F (Yogyakarta) = 63 pedestrians/meter/minute
F (Singapore) = 89 pedestrians/meter/minute
F (Japan) = 68 pedestrians/meter/minute
F (England) = 76 pedestrians/meter/minute
Thus speed(V) and Space allocation per pedestrian (Smax) at maximum flow can be produced from equation (2.1) and (2.2) as follow :
V (Yogyakarta) = 26 meters/minute
V (Singapore) = 37 meters/minute
V (Japan) = 34 meters/minute
V (England) = 39 meters/minute

S (Yogyakarta) = 0.413 (m2)
S (Singapore) = 0.416 (m2)
S (Japan) = 0.500 (m2)
S (England) = 0.513 (m2)

Flow-speed equation F = f (V) for the shoppers :
V = A - B x d .....(2.3)
d = (A-V) / B
F = V x d ..... (2.1), thus the equation become :
F = V (A-V) / B
F = f (V) for the shoppers in Yogyakarta can be produced :
F = V (52.0 - V) / 10.76
F = 4.833V - 0.093 V2 (Yogyakarta)
Furthermore, flow-speed relationships F = f (V) for the shoppers from Singapore, Japan and England are as follow :
F = 4.830V - 0.065 V2 (Singapore)
F = 4.036V - 0.059 V2 (Japan)
F = 3.891V - 0.050 V2 (England)
Theoretical maximum speed at free flow (A) from various countries can be produced from Speed-density relationships as shown as follow :
A (Yogyakarta) = 52.0 meters/minute
A (Singapore) = 73.9 meters/minute
A (Japan) = 67.8 meters/minute
A (England) = 78.6 meters/minute

From accumulation of collectable data, fluctuation flow of pedestrian in Yogyakarta days by week can be computed and as shown in Figure 3-2 that it has a various flow in different day in one week. Furthermore, the maximum flow occured at Friday, with 1178 pedestrians or 18 % of total sample of pedestrian for one hour's observation (7.00-8.00 pm) in one week. While fluctuation flow of pedestrian in Yogyakarta weeks by month can be shown in Figure 3-3. The higher concentration was occured at the fourth week with 1548 pedestrians/ hour.

The characteristics of pedestrians in Yogyakarta need theoretical minimum space for 0.207m2/pedestrian at zero speed and flow, and for maximum space 0.413m2/pedestrian at maximum flow 63 pedestrians/ meter/minute, while mean speed is only 26 meters/ minute, the lowest space and flow, and also the lowest mean speed if compare with Singapore, Japan and England as shown at Table 1.

4. CONCLUSIONS

From all of comparisons above, the characteristics of pedestrian in Yogyakarta appears the smallest one. It is because of walking is one of the modes of transportation system in develop countries. While walking activity acts as a connector for people who want to change from one mode to the other mode, therefore walking speed of pedestrian will be high due to "time is money" and precise time in transportation modes. Although shopping activity sometimes no need to keep in a hurry, people were in a custom to there's speed. But in Indonesia, especially in Yogyakarta, walking mode is not the only connector, its can be replaced by other modes such as andong and becak. And pedestrians in Yogyakarta have tendencies not to walk at a high speed, because public buses in Yogyakarta are not based on time schedule but

based on driver's volition. In addition vendors at Malioboro street perhaps have certain characteristic so that pedestrians will enjoy the surrounding environment while walking.

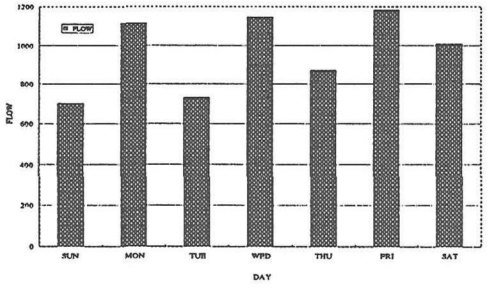

Figure 3-2 Fluctuation of pedestrian flow days by week

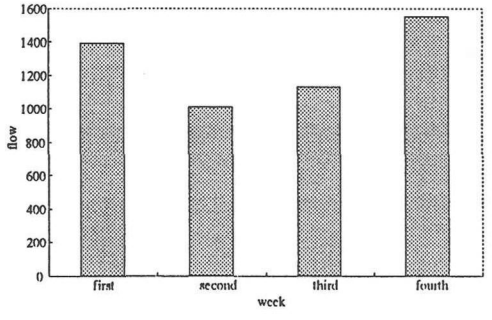

Figure 3-3 Fluctuation of pedestrian flow weeks by month

5. REFERENCES

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Table 1 : Comparison of Studies Between Yogyakarta and Various Countries

	B/A theoretical minimum space per pedestrian at zero speed(m2)	space allocation per pedestrian at maximum flow(m2)	maximum flow, pedestrians per meter per minute	maximum speed at maximum flow (m2/minute)
Yogyakarta	0.2070	0.413	63	26
Singapore	0.2070	0.416	89	37
Japan	0.2478	0.500	68	34
England	0.2570	0.513	76	39