# Pedestrian Flow Characteristics in Hong Kong

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The findings of a study of pedestrian flow characteristics in Hong Kong are described. The objective was to collect walking distance, speed, flow, and density data on indoor and outdoor walkways, signalized crosswalks, light rail transit crosswalks, and stairways. The data collected were used to develop speed-flow-density relationships for each type of pedestrian link. In addition, pedestrian characteristics from various international cities are compared. The data collected and the relationships established could be used as the basis for the development of pedestrian design standards and simulation models for Hong Kong.

Hong Kong, a city of more than 6 million people and a land area of only 1060 km$^2$, is one of the most densely populated cities in the world, with residential densities of approximately 39,000 persons per square kilometer of developed land. Although pedestrian facilities have always been used intensively, the rapid development of Hong Kong, as well as traffic generators such as the Mass Transit Railway (MTR) and Kowloon-Canton Railway (KCR) stations and great concentrations of people focused in high-rise office and residential buildings, has put tremendous pressure on the pedestrian system. In recognition of the importance of the pedestrian mode, the Hong Kong government has developed a pedestrian action plan as documented in its *Transportation Planning and Design Manual* (*1*), and a pedestrian simulation model (2) is being used to carry out congestion and safety assessments of congested pedestrian networks in an objective and consistent fashion.

## INTRODUCTION

High-rise buildings and high occupancy rates of buildings in Hong Kong result in tremendous concentrations of people and a great deal of conflict between the needs of pedestrians and vehicles, imposing noise and air pollution and threatening the lives of the pedestrians. Figure 1 illustrates the pedestrian movements in the urban areas of Hong Kong. Almost half of road accident casualties are pedestrians, and police estimate that pedestrian negligence causes 26 percent of road accidents. To maintain and improve mobility, the Hong Kong government is planning pedestrian facilities as an integral part of new transportation systems in developing areas. There are now more than 1,000 such facilities, which include footbridges, subways, zebra crossings, and signal-controlled pedestrian crossings. The government has selected possible sites for additional grade-separated footbridges and subways and is continuing to provide additional crossings at grade. Pedestrian access to public transportation interchanges such as the MTR and KCR stations, which is particularly important, will be obtained by elevated walkways or tunnels connecting to the nearby bus terminus.

The lack of land in the old, established and highly developed urban areas limits the construction of grade-separated facilities (such as pedestrian footbridges and subways). Experiments in providing pedestrian-only streets have not proved very popular with government, although the scale of their provision has been small because of the difficulties of finding other routes for the displaced traffic. Furthermore, any road or building works take place adjacent

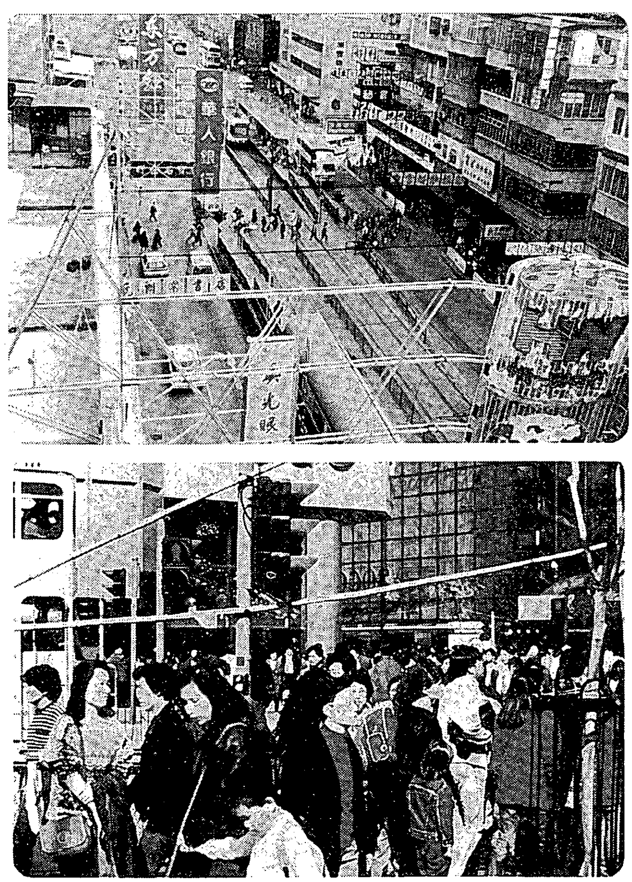

FIGURE 1 Pedestrian movements in Hong Kong.

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**TABLE 1 Data Collection Sites and Their Characteristics**

| STAIRCASES | | | | | | |
|---|---|---|---|---|---|---|
| FACILITY | LOCATION | | RISER HEIGHT (mm) | TREAD WIDTH (mm) | ANGLE (deg) | |
| MTR | Tsim Sha Tsui & Wan Chai Stations | Up : | 158 | 292 | 28.4 | |
| | | Down : | 158 | 292 | 28.4 | |
| KCR | Kowloon Station | Up : | 152 | 285 | 28.1 | |
| | | Down : | 148 | 294 | 26.7 | |
| **WALKWAYS** | | | | | | |
| FACILITY | LOCATION | WIDTH (m) | WALKING DISTANCE MEASURED (m) | | | |
| Outdoor | Haiphong Road | 2.0 | 7.5 | | | |
| | Mody Square | 3.5 | 7.5 | | | |
| Indoor | Nan Fung | 6.0 | 5.0 | | | |
| | Tsuen Wan | 8.0 | 5.0 | | | |
| | KCR Kowloon | 10.0 | 5.0 | | | |
| CROSSWALKS | LOCATION | | CURB-TO-CURB DISTANCE (m) | SIGNAL TIMING CYCLE LENGTH | PHASING | AVERAGE DAILY TRAFFIC (VEHICLES) |
| Signalized | Yim Po Fong St | 5.0 | 20.5 | 90 sec. | 4 | 29,710 |
| | Hennessy Road | 8.0 | 17.5 | 78 sec. | 2 | 21,730 |
| | Cheung Yip Street | 3.5 | 6.7 | 60 sec. | 2 | 9,920 |
| LRT Signalized | Tai Tong Station | 6.5 | 20.5 | 72 sec. | 2 | 21,480 |

to footpaths in the urban area, so the pedestrian loses pavement space and often is forced to walk on the roads. It is clear that the difficulties of pedestrian planning in Hong Kong's limited area are considerable.

For purposes of pedestrian planning and design, pedestrian characteristics in Hong Kong should be well understood. The walking speed of pedestrians is of prime importance in a study of the functioning and design of pedestrian facilities, as it is associated closely with the ability of a walkway to maintain a desired flow of pedestrians along its length. Certain primary factors relating to the pedestrian and his or her environment will have an effect on walking speeds. The incidence of a speed-flow relationship leads one from the consideration of "primary" factors affecting walking speeds to the "secondary" factors, which revolve principally around the effect of flow rate and density.

For this paper, walking speeds were monitored on six pedestrian facilities in Hong Kong. The times and locations were chosen to minimize variation due to physical factors. An outline of the data collection surveys is presented, followed by a discussion of the survey results on walking distances, walking speeds, and maximum observed flow rates. A range of speed-density-flow models have been developed for each facility type. Finally, conclusions are drawn and recommendation is given for further study.

## DATA COLLECTION

Data collection surveys were undertaken during peak and off-peak periods in November and December 1991. Six categories of pedestrian facilities were used for data collection; they are presented in Table 1 with their locations and location characteristics. In total, data were collected at 12 sites for the six categories of pedestrian facilities.

Walking speed and pedestrian flow data were collected using a video camera and on-site manual counts. Walking distance information was gathered at three sites using a questionnaire with an area map on which interviewees were asked to trace their actual walking paths. Walking distances were scaled from the survey maps.

## SURVEY RESULTS

### Walking Distances

Mean walking distances for light rail transit (LRT), MTR, and KCR at three selected sites are given in Table 2 along with the relevant statistics. It was found that the KCR riders tend to walk farther than LRT and MTR passengers, as KCR mainly provides service for subregional travel between new towns and urban areas with larger station spacings. Although walking distances are a function of density and the spatial distribution of generators and attractors, the LRT and MTR walking distances in Hong Kong are not dissimilar to those observed in Canada. For example, in the Calgary central business district, the mean walking distance to and from LRT is 278 m, whereas access and egress to regular and express bus service before the introduction of LRT was 273 and 311 m, respectively (*3*).

### Walking Speeds

Walking speeds were measured on six pedestrian facilities as given in Table 3. Walking speeds are considerably higher on outdoor

**TABLE 2 Pedestrian Walking Distances by Mode**

| MODE | MEAN WALKING DISTANCE (m) | STD. DEVIATION (m) | RANGE | | SAMPLE SIZE |
|---|---|---|---|---|---|
| | | | LOW (m) | HIGH (m) | |
| LRT | 262 | 110 | 63 | 663 | 192 |
| MTR | 280 | 107 | 97 | 759 | 156 |
| KCR | 493 | 260 | 125 | 1025 | 260 |

walkways than on indoor walkways. The walking speed indoors is slower because there are more distractions and congestion than there are outdoors. Walking speeds were slightly higher for men than women, 75.0 versus 70.2 m/min, respectively. Walking speeds at signalized crosswalks are higher during the red phase than the green, because pedestrians are hurrying to finishing crossing to avoid conflicts with vehicular traffic. Walking speeds observed at the LRT crosswalk are higher than they are at the signalized crosswalk. Walking speeds on stairways are higher descending than ascending, as to be expected. The lower ascending walking speeds on the MTR stairway are due to the higher riser on the MTR stairway. A comparison of walking speeds for various cities is presented in Table 4. The mean walking speed of 72 m/min for Hong Kong is typical for other Asian cities such as Bangkok (*4*), Singapore (*5*), and Colombo (*6*). A comparison of walking speeds on stairways is also given in Table 4. For similar riser heights, ascending and descending walking speeds are higher for Hong Kong than Bangkok. Hong Kong ascending and descending walking speeds for the MTR are similar to those observed under free-flow conditions in passageways in the London Underground, as reported by Daly et al. (*7*). In addition, Table 4 provides a comparison of mean walking speeds at signalized crossings in Bangkok, Hong Kong, and Calgary.

### Maximum Observed Flow Rates

Table 5 gives the maximum observed flow rates by facility type. The maximum flow rate reported for Singapore (*5*) is 89 pedestrians (ped)/m/min, which is comparable to 90 ped/m/min for Hong Kong at LRT crosswalks.

## SPEED-DENSITY-FLOW MODELS

A range of speed-density-flow models were developed for each facility type. Table 6 summarizes the models developed for each pedestrian facility. Figure 2 displays the variations of walking speed and pedestrian flow data for indoor and outdoor walkways, and Figure 3 illustrates their fitted relationships by speed-density, flow-density, flow-speed, and flow-space. The models developed for each facility are discussed in turn.

### Indoor Walkways

The Greenshields model was adopted for indoor walkways. As shown in Table 6 and Figure 3, the relationships are as follows:

- The speed-density relationship is linear.

$$\mu = 77.4 - 21.5\,k \quad (1)$$

where $\mu$ equals walking speed, in meters per minute, and $k$ is density, in pedestrians per square meter.

- The flow-density relationship is parabolic.

**TABLE 3 Pedestrian Walking Speeds by Facility Type**

| FACILITY | MEAN WALKING SPEED (m/min) | STD. DEVIATION (m/min) | RANGE | | SAMPLE SIZE |
|---|---|---|---|---|---|
| | | | LOW (m/min) | HIGH (m/min) | |
| INDOOR WALKWAY | 49.8 | 22.2 | 10.2 | 75.2 | 908 |
| OUTDOOR WALKWAY | 71.6 | 15.6 | 9.0 | 88.8 | 395 |
| SIGNALIZED CROSSWALK | | | | | |
| GREEN | 76.2 | 17.0 | 21.6 | 216.0 | 916 |
| RED | 90.0 | 27.0 | 28.2 | 265.8 | 1147 |
| LRT CROSSWALK | | | | | |
| SIGNALIZED CROSSWALK | 98.4 | 10.2 | 19.8 | 210.0 | 91 |
| RAMP (1:12) | 39.6 | 18.6 | 15.6 | 70.8 | 26 |
| MTR STAIRWAY | | | | | |
| ASCENDING | 35.4 | 13.9 | 10.1 | 56.6 | 143 |
| DESCENDING | 40.8 | 16.3 | 10.5 | 79.8 | 124 |
| KCR STAIRWAY | | | | | |
| ASCENDING | 38.7 | 16.2 | 14.4 | 71.6 | 77 |
| DESCENDING | 48.2 | 19.6 | 15.6 | 82.8 | 80 |

TABLE 4 International Comparison of Walking Speeds on Various Pedestrian Facilities

| Facility | CITY | MEAN WALKING SPEED (m/min) | | REMARKS |
|---|---|---|---|---|
| **Walkways** | RIYADH (*6*) | 65 | | |
| | HONG KONG | 72 | | |
| | BANGKOK (*4*) | 73 | | |
| | SINGAPORE (*5*) | 74 | | |
| | COLOMBO (*6*) | 75 | | |
| | CALGARY (*6*) | 84 | | |
| | LONDON (*7*) | 88 | | |
| **Stairways** | | Ascending | Descending | Riser Height (mm) |
| | BANGKOK (*4*) | 27.9 | 35.0 | 200 |
| | | 29.8 | 35.9 | 150 |
| | | 32.3 | 36.6 | 140 |
| | | 33.8 | 37.2 | 130 |
| | HONG KONG | 35.4 | 40.8 | 158 |
| | | 38.7 | 48.2 | 148 |
| | LONDON (*7*) | 35.4 | 40.2 | FREE-FLOW |
| | | 21.6 | 33.6 | CAPACITY |
| **Signalized Crossings** | BANGKOK (*4*) | 76.5 | | |
| | HONG KONG | 76.2 | | GREEN SIGNAL |
| | | 90.0 | | RED SIGNAL |
| | | 98.4 | | LRT CROSSWALK |
| | | 80.2 | | OBSERVED AVERAGE |
| | CALGARY | 72.0 | | PLANNING STANDARD |
| | | 60.0 | | ELDERLY PEDESTRIANS |

$$q = 77.4\,k - 21.5\,k^2 \qquad (2)$$

where $q$ is pedestrian flow, in pedestrians per meter per minute.

- The flow-speed relationship is also parabolic.

$$q = 3.6\,\mu - 0.0465\,\mu^2 \qquad (3)$$

- The flow-space relationship is inverse parabolic.

$$q = 77.4/M - 21.5/M^2 \qquad (4)$$

where $M$ is the area module, in square meters per pedestrian.

The relationships for indoor walkways are compared with results obtained for Singapore in Table 7 (*5*). It is noted that the Greenshields model developed for Hong Kong indoor walkways compares favorably with speed-flow-density models developed for Singapore.

## Outdoor Walkways

As shown in Table 6, the Underwood model fit the best for outdoor walkways resulting in an $R^2 = .91$. Figure 3 shows the relationships of speed-density, flow-density, flow-speed, and flow-space for outdoor walkways.

## Crosswalks

For signalized crosswalks the Bell model was the best-fitting model, whereas the Underwood model was the best fit for the LRT crosswalk data.

## Stairways

As indicated in Table 6, a range of models was developed for stairways for both ascending and descending flows. A comparison of

TABLE 5 Maximum Observed Flow Rates by Facility Type

| FACILITY | MAX FLOW RATE (ped/m/min) |
|---|---|
| INDOOR WALKWAY | 68 |
| OUTDOOR WALKWAY | 71 |
| SIGNALIZED CROSSWALK | 60 |
| LRT CROSSWALK | 90 |
| MTR STAIRWAY | |
| ASCENDING | 71 |
| DESCENDING | 77 |
| KCR STAIRWAY | |
| ASCENDING | 66 |
| DESENDING | 73 |

**TABLE 6 Speed-Density-Flow Models for Pedestrian Facilities**

| FACILITY | MODEL ADOPTED | RELATIONSHIP | MODEL EQUATION |
|---|---|---|---|
| INDOOR WALKWAY | GREENSHIELDS<br>$R^2 = 0.82^{(1)}$ | SPEED-DENSITY<br>FLOW-DENSITY<br>FLOW-SPEED<br>FLOW-SPACE | $\mu = 77.4 - 21.5\ k$<br>$q = 77.4\ k - 21.5\ k^2$<br>$q = 3.6\ \mu - 0.0465\ \mu^2$<br>$q = 77.4/M - 21.5/M^2$ |
| OUTDOOR WALKWAY | UNDERWOOD<br>$R^2 = 0.91$ | SPEED-DENSITY<br>FLOW-DENSITY<br>FLOW-SPEED<br>FLOW-SPACE | $\mu = e^{(4.47 - 0.572\ k)}$<br>$\ell nq = 4.47 + \ell nk - 0.57\ k$<br>$q = 7.8\ \mu - 1.75\ (\mu \ell n \mu)$<br>$\ell nq = 4.47 + \ell n(1/M) - 0.57/M$ |
| SIGNALIZED CROSS WALK | BELL<br>$R^2 = 0.81$ | SPEED-DENSITY<br>FLOW-DENSITY<br>FLOW-SPEED<br>FLOW-SPACE | $\mu = 85e^{-(0.347k^2)}$<br>$q = 85ke^{-(0.347k^2)}$<br>$q^2 = -2.9\mu^2 \ell n(\mu/85)$<br>$q = (85/M)e^{-(0.347/M^2)}$ |
| LRT CROSS WALK | UNDERWOOD<br>$R^2 = 0.75$ | SPEED-DENSITY<br>FLOW-DENSITY<br>FLOW-SPEED<br>FLOW-SPACE | $\mu = 100\ e^{-(0.5k)}$<br>$q = 100\ k\ e^{-(0.5k)}$<br>$q = -2\ \mu \ell n(\mu/100)$<br>$q = (100/M)\ e^{-(0.5/M)}$ |
| MTR STAIRWAY (ASCENDING) | UNDERWOOD<br>$R^2 = 0.67$ | SPEED-DENSITY<br>FLOW-DENSITY<br>FLOW-SPEED<br>FLOW-SPACE | $\mu = 53.3 - 9.9\ k$<br>$q = 53.3\ k - 9.9\ k^2$<br>$q = 5.4\ \mu - 0.1\ \mu^2$<br>$q = 53.3/M - 9.9/M^2$ |
| MTR STAIRWAY (DESCENDING) | UNDERWOOD<br>$R^2 = 0.46$ | SPEED-DENSITY<br>FLOW-DENSITY<br>FLOW-SPEED<br>FLOW-SPACE | $\mu = 65.4\ e^{-(0.41\ k)}$<br>$q = 65.4\ k\ e^{-(0.41\ k)}$<br>$q = -3.42\mu \ell n(\mu/65.4)$<br>$q = (65.4/M)\ e^{-(0.414\ M)}$ |
| KCR STAIRWAY (ASCENDING) | BELL<br>$R^2 = 0.84$ | SPEED-DENSITY<br>FLOW-DENSITY<br>FLOW-SPEED<br>FLOW-SPACE | $\mu = e^{(3.89 - 0.2k^2)}$<br>$\ell nq = 3.89 - \ell nk - k$<br>$q^2 = \mu^2/0.22(3.89 - \ell n\mu)$<br>$\ell nq = 3.89 + \ell(1/M) - 0.22/M^2$ |
| KCR STAIRWAY (DESCENDING) | UNDERWOOD<br>$R^2 = 0.86$ | SPEED-DENSITY<br>FLOW-DENSITY<br>FLOW-SPEED<br>FLOW-SPACE | $\mu = e^{(4.6-k)}$<br>$\ell nq = 4.6 + \ell nk - k$<br>$q = -2\mu\ (\ell n\mu - 4.6)$<br>$\ell nq = 4.6 + \ell n(1/M) - 1/M$ |

Note: (1) $R^2$ is the coefficient of determination which is a measure to reflect the accuracy of the model equation adopted for the relationship between speed and density.

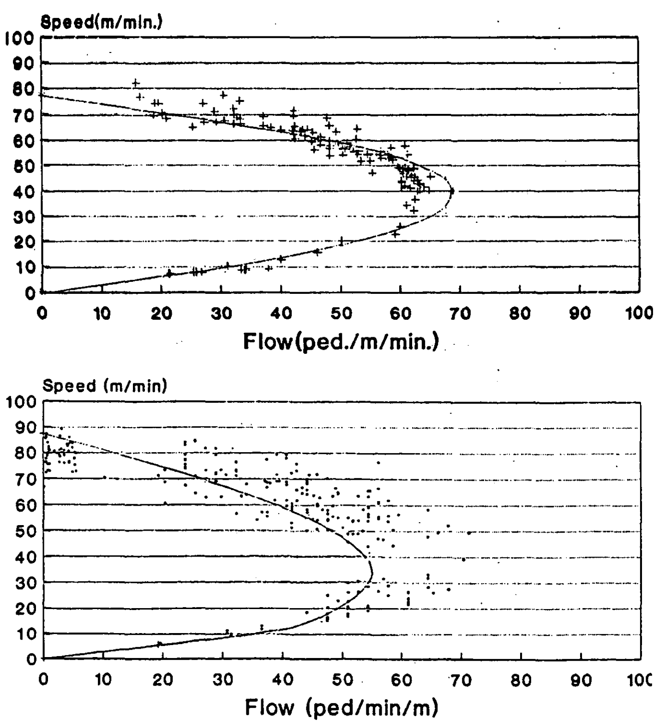


**FIGURE 2 Pedestrian speed and flow data for indoor (*top*) and outdoor (*bottom*) walkways.**

capacity and speed at capacity for stairways on the MTR, KCR, and London Underground is presented in Table 8. For both ascending and descending stairways, the MTR and the KCR data show slightly higher speeds but with comparatively much higher capacity than the London Underground (*7*). The higher capacities can be partially explained by the smaller physique of Oriental people. In addition, as observed by Tanaboriboon et al., Asians "tend to require less space and are more tolerant to invasion of this space" (*5*). Finally, the higher capacities observed on the MTR are also attributed to the predominant unidirectional flow on MTR stairways.

## CONCLUSIONS

It was found that mean walking distances for LRT and MTR are smaller than the KCR, as the LRT and the MTR mainly serve urban areas with shorter station spacings. Pedestrian characteristics in Hong Kong show that the population tends to walk slower than pedestrians in North America, a finding that has been observed by other researchers who have compared walking speeds in Asian and North American cities. The speed-density-flow models developed for Hong Kong are similar to those developed for Singapore for similar facilities. The fact that no single model fits all pedestrian facilities indicates that more data collection is required for a larger range of flow conditions.

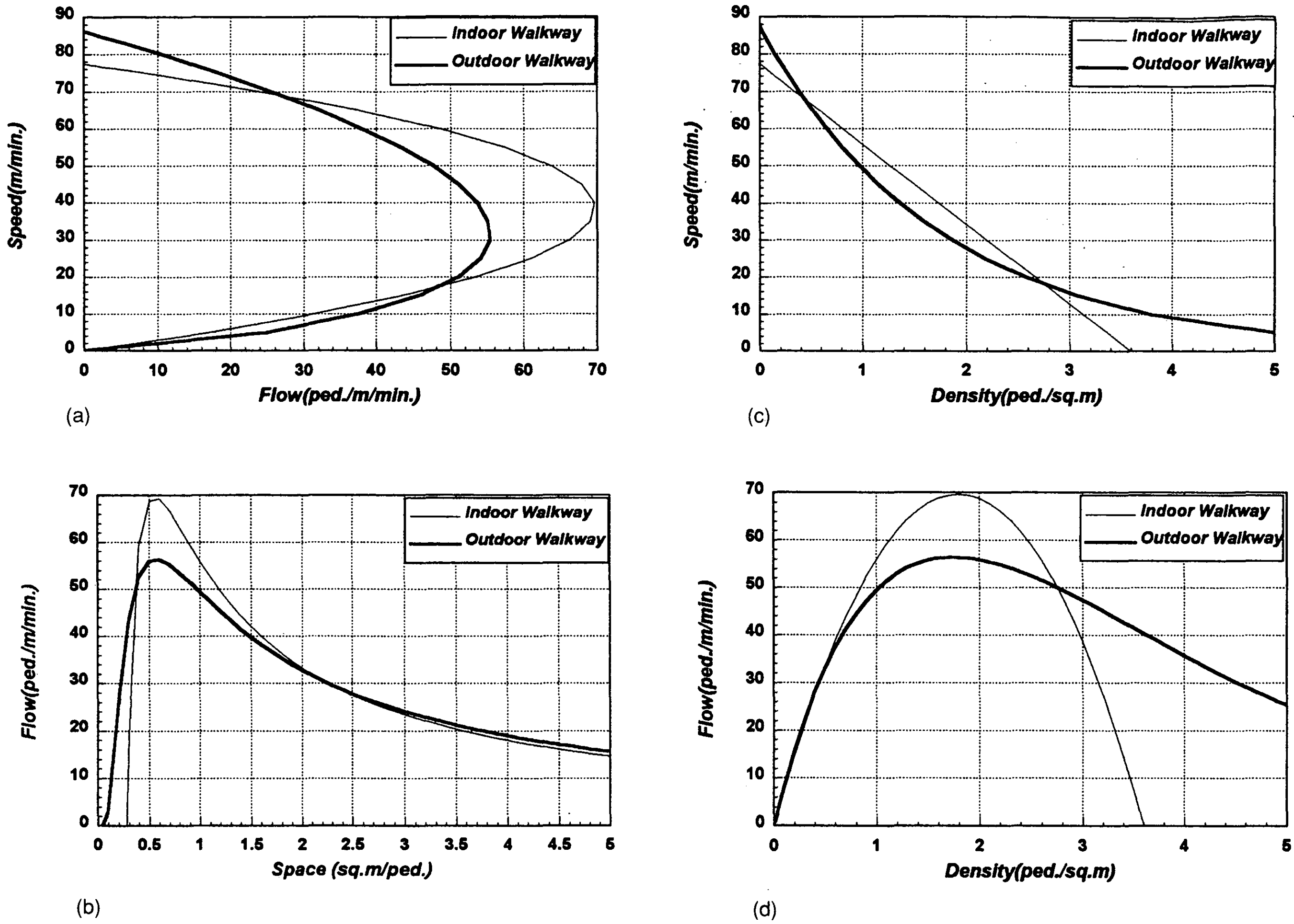


**FIGURE 3** Speed versus flow (*a*), flow versus space (*b*), speed versus density (*c*), and flow versus density (*d*) for indoor and outdoor walkways.

**TABLE 7** Comparison of Speed-Flow-Density Models for Singapore (*5*) and Hong Kong (Indoor Walkway)

| RELATIONSHIP | HONG KONG | SINGAPORE |
|---|---|---|
| SPEED-DENSITY | $\mu = 77.4 - 21.5\ k$ | $\mu = 73.9 - 15.3\ k$ |
| FLOW-DENSITY | $q = 77.4\ k - 21.5\ k^2$ | $q = 73.9k - 15.3\ k^2$ |
| FLOW-SPEED | $q = 3.6\mu - 0.0465\mu^2$ | $q = 4.8\mu - 0.065\mu^2$ |
| FLOW-SPACE | $q = 77.4/M - 21.5/M^2$ | $q = 73.9/M - 15.3/M^2$ |

**TABLE 8** Comparison of Capacity and Speed at Capacity for London Underground (*7*), Hong Kong MTR, and KCR

| FACILITY COMPARISON | | CAPACITY (ped/m/min) | SPEED AT CAPACITY (m/min) |
|---|---|---|---|
| STAIRWAYS ASCENDING | LONDON UNDERGROUND (7) | 62 | 21.6 |
| | HONG KONG MTR | 71 | 25.2 |
| | HONG KONG KCR | 66 | 26.0 |
| STAIRWAYS DESCENDING | LONDON UNDERGROUND (7) | 68 | 33.6 |
| | HONG KONG MTR | 77 | 34.8 |
| | HONG KONG KCR | 73 | 38.0 |

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