

MECHANICAL MEASUREMENT OF PEDESTRIAN VOLUMES

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A pedestrian flow map developed from manually counted data during 1969 that led to the development of the pedestrian counting device is described. A brief description is given of the counter's development, application, and refinement. The initial studies of pedestrian volumes were made of a downtown employee population, a downtown shopper population, and a mixed population of employees, shoppers, visitors, and residents. The highest daily total at all locations occurred on Friday, and the highest hourly (usually 15 percent of the weekday total) volume occurred between 12 and 1 p.m. for all 3 studies. Saturday volumes were small at the employee station and high at the shopper and mixed stations. General and particular pedestrian volume characteristics that would be considered in design of pedestrian facilities are quantitatively described. The tabulated data represent general pedestrian volume trends and can be used for factoring volumes measured during short periods into comparative volumes. Surveys can be designed to measure the most representative sample; sidewalk closure standards can be established by using Fruin's capacity values and known pedestrian volumes in the same manner that lane closures are established from capacity values and traffic counts. Pedestrian volumes can be measured mechanically because daily and weekly pedestrian volumes recurred in regular patterns. Different types of pedestrian populations have different volume patterns, and the studies indicated the effects of weather and shopping days.

•MUCH attention is now being devoted to the planning, designing, and operation of pedestrian facilities. Navin, Wheeler, Hoel, Fruin, Pushkarev, and Zupan have developed specific design criteria from manual counts of pedestrians, time-lapse photography, and relations between existing sidewalk pedestrian volumes and adjacent types of building floor space (3, 4, 10, 11). Applying these criteria to a central business district (CBD) or any area of pedestrian concentration requires knowing the area's existing pedestrian characteristics.

This paper discusses an alternative method in which an automatic counter is used to obtain pedestrian volumes for use as control data; correction factors are developed for weather, season, area, day of week, and time of day; and these factors are applied to short-term manual counts throughout the study area.

A pedestrian flow map was made of the Seattle central business district in 1969 by

1. Subdividing the CBD into 12 areas such as theater, department store, financial, government, and the like;
2. Determining and graphing hourly average volumes and developing expansion factors;
3. Making short ($\frac{1}{2}$ to 1 hour) manual counts on weekdays at all the remaining intersections; and
4. Expanding short-term counts from 9 a.m. to 4 p.m. by applying the area hourly correction factor.

Areas that were not in agreement were rechecked and a final map was drawn. The data were collected during the summer, and some seasonal factoring was accomplished by applying retail sales variations to volumes in retail areas. However, reliability of the volumes was questioned because no long-term trends had been measured and evaluated. Also, no corrections had been made for season, day of the week, weather, time of the month, new buildings, building usage change, and the difficulty in manually counting large numbers of pedestrians.

Therefore, an automatic counter was developed and refined during 1971 and 1972. This counter was made up of eight 28-in. by 36-in. (71.12-cm by 91.44-cm) hand-constructed detector pads. The pads were silicon conductor disks sealed in neoprene. They were mounted on 2 stainless steel plates $\frac{1}{4}$ in. (6.35 mm) thick 3 in. (7.62 cm) apart. The 2 plates were laid on the sidewalk with the 36-in. (91.44-cm) dimension in the direction of pedestrian flow. Leads from the pads ran back to summators in a signal control box. A 4-ft by 14-ft (1.2-m by 4.3-m) rubber carpet was installed over the detectors and glued to the sidewalk. The total rise was less than $\frac{5}{8}$ in. (15.875 mm) located 6 in. (15.24 cm) in from the carpet edge to minimize the possibility of tripping. More than fifty 15-minute checks were made during its first operation in a 2-month period, which showed overcounting of 15 to 20 percent because of the pads being too long.

Refinements made after that period included

1. A surplus military radio equipment box for the traffic counter, summators, and dc batteries;
2. New 17- by 23-in. (43.18- by 58.42-cm) detector pads that could be spot-glued to the sidewalk and together with the carpet laid over them would give less than a $\frac{1}{2}$ -in. (12.7-mm) vertical rise at any point; and
3. A compact, solid-state 8-channel summator.

Detector pad durability is increased by placing a cushioning material between the pad and concrete. Sidewalk installation must be made on dry sidewalks because glue will not adhere to a wet sidewalk.

Counter units can be installed anywhere traffic patterns permit (doorways and lingering areas should be avoided—direct traffic flow produces the most accurate results). Locating counters 5 ft from a major doorway will avoid multiple counts. Counter units can be installed on various width walkways in less than one-half hour. They produce much pedestrian data for a small cost and computer summarization of the data is the same as that for traffic counts, thereby lowering data reduction costs. Continuing manual checks show that counter accuracy is within 5 percent of volume measurements.

Equipment in the most recent counter includes a Leopold-Stevens traffic counter, a Fischer-Porter 8-channel summator, two $7\frac{1}{2}$ Vdc batteries, 8 Tapeswitch CVP-1723 switching mats (detection pads), and 14 ft of Vertitred gray matting for the overlay.

Until July 1973, two 4-channel summators were connected in parallel to the counter, and there were no missed counts from summator interference. Two 8-channel summators should work as well in locations requiring more than 8 detectors.

Older traffic counters do not recognize the 45 ms signals from the summator; this can be remedied by changing the summator's capacitor C103 from $0.33\mu\text{F}$ to a 0.47 to $0.50\mu\text{F}$ ± 5 percent value to increase the output pulse to 50 to 55 ms.

Measurements were made at 3 sidewalk locations through June 1, 1973. (Table 1).

The first location was on the west side of 4th Avenue south of Pike Street in the core of Seattle's CBD. This sidewalk was selected for its known high pedestrian volume, its free-flowing pedestrian traffic, and its level, unbroken walkway. There was a signal control case nearby with room for the counter and summators and a source to provide 115 Vac to operate the equipment.

Data for 59 days from April 30, 1971 through July 3, 1971 were collected and indicated definite volume patterns. Volumes on Monday and Friday were the highest. This substantiates the employee classification for this location. Saturday volumes were 63 percent of the average daily volumes; the other 2 locations had Saturday volumes of more than 100 percent. Weekday average hourly volumes are shown in Figure 1, and the percentage each day deviates from the total daily average is given in Table 2. The hourly volume curve at this location was highest during morning and evening peak

Table 1. Survey locations and pedestrian volumes.

Location	Population	Date of Counts	Number of Count Days	Total Average Volumes	
				Daily	Weekday
4th Avenue	Employee	May-June 1971	27	10,200	12,250
Pine Street	Shopper	May-Dec. 1972	86	7,900	8,200
Pike Street	Mixed	Feb.-May 1973	69	11,250	12,700

Figure 1. Fourth Avenue, weekday average hourly volumes.

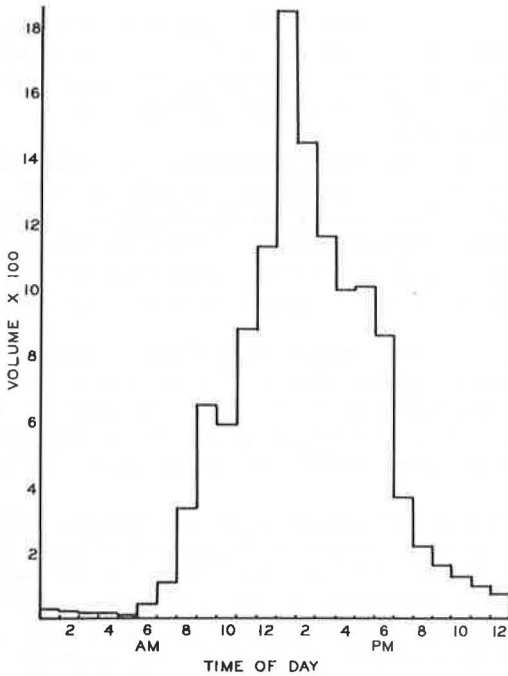


Table 2. Hourly volumes as percentages of total average weekday volumes.

Location	Percentage Deviation From Total Daily Average						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
4th Avenue	130	118	116	111	128	63	22
Pine Street	121	109	105	108	121	107	26
Pike Street	114	114	109	107	122	103	41

periods. Friday afternoon hourly volumes were 15 percent higher than the weekday, which is similar to urban vehicle volume patterns.

Mechanical counts at 2 employee population locations in the summer of 1973 had curves similar to the 4th Avenue location. The noon peaks (12:15 to 1:15 p.m.) had the largest volumes, but morning and evening peaks were also clearly visible. Table 3 gives the hourly volumes as a percentage of total average weekday volumes.

Seattle's downtown department stores have traditionally stayed open until 9 p.m. on Monday nights. The 4th Avenue Monday evening hourly volumes showed no significant difference from other weekday evening hourly averages, which would have been expected at an employee population location. The 2 locations with shopper populations had much higher volumes on Monday evenings.

Weather was the only recognizable factor that affected volumes on 4th Avenue. Day-to-day volumes regularly repeated themselves.

All but 1 of the weekday peak-hour volumes began at 12 or 12:15 p.m. and averaged 15.3 percent of the daily total. The standard deviation of the 41 peak-hour percentages was 1.03. The noon peak-hour volume did not occur on days when there was recorded precipitation during that time. On Fridays and days when it was more than 65 F (291.48 K) and clear, peak volumes continued until 2 p.m.

After some modifications were made to the counter, it was installed in the center of the CBD department store area, less than 2 blocks from the 4th Avenue south of Pike Street survey. This area's pedestrian population is composed mostly of shoppers. This location was selected because of its free-flowing pedestrian traffic and its serviceability.

The Pine Street south of 5th Avenue study was conducted for the longest period of time—May 3, 1972, to December 1, 1972—and provided the largest amount of data and further refinement of the counter.

Total average volumes for Mondays and Fridays were larger than those for other days of the week and their hourly volumes were distributed differently. Friday afternoon volumes were consistently higher than those for other days of the week. Monday evening (6 p.m. to 9 p.m.) shoppers raised the Monday total. The 6 p.m. to 9 p.m. Monday evening volumes averaged 360 pedestrians per hour which was 89 percent greater than the 190 pedestrian weekday evening average.

Saturday totals were greater than 100 percent of the total average daily volume in the retail core. This contrasted sharply with the Saturday volume of 63 percent of the daily average for employees at 4th Avenue and Pike Street. Figures 2 and 3 show that Saturday totals were comparable to weekday totals but that hourly distributions were different. Saturday volumes developed later in the morning and built to a peak near 3 p.m. Theatergoers and after-dinner window shoppers could have caused Saturday evening volumes to be higher than Monday evening volumes.

When weekday hourly volumes on days with recorded precipitation were compared with total weekday hourly averages, it was discovered that only between noon and 4 p.m. were volumes less than the average hourly volume during rain. Generally, there were 10 to 12 instances of recorded precipitation for each hour, which was a small sample for determining volume precipitation correlations. Volume decrease percentages for 1-hour periods were

<u>Time</u>	<u>Percent</u>
12 to 1 p.m.	7
1 to 2 p.m.	17
2 to 3 p.m.	7
3 to 4 p.m.	3

The highest volume of the day occurred in the afternoon immediately after it stopped raining or after it let up had it been raining during the noon hour.

A review of the daily hourly volumes revealed that before noon and after 4 p.m. pedestrians were unaffected by rain; rain affected shopper-pleasure trips between noon and 4 p.m. more than it affected business-work trips; the first rain after a period of dry weather had more effect on volume than did continuing rain day after day; and days with

Table 3. Percentage deviation of volumes on each day from total average daily volumes.

Time	4th Avenue	Pine Street	Pike Street
12 to 1 a.m.	0.3	0.2	0.7
2 a.m.	0.2	0.1	0.4
3 a.m.	0.1	0.1	0.2
4 a.m.	0.1	0.0	0.1
5 a.m.	0.1	0.0	0.1
6 a.m.	0.4	0.1	0.3
7 a.m.	0.9	0.5	0.9
8 a.m.	2.7	2.1	2.4
9 a.m.	5.3	3.9	4.1
10 a.m.	4.8	4.1	4.4
11 a.m.	7.2	6.0	5.8
12 noon	9.2	9.1	7.4
1 p.m.	15.1	14.3	11.6
2 p.m.	11.8	12.7	10.5
3 p.m.	9.5	11.2	9.2
4 p.m.	8.2	10.0	8.9
5 p.m.	8.3	9.4	9.1
6 p.m.	7.0	7.6	8.7
7 p.m.	3.0	3.3	4.9
8 p.m.	1.8	2.0	3.0
9 p.m.	1.3	1.6	2.5
10 p.m.	1.1	0.9	2.0
11 p.m.	0.8	0.4	1.6
12 midnight	0.6	0.4	1.1

Figure 2. Pine Street, weekday average hourly volumes.

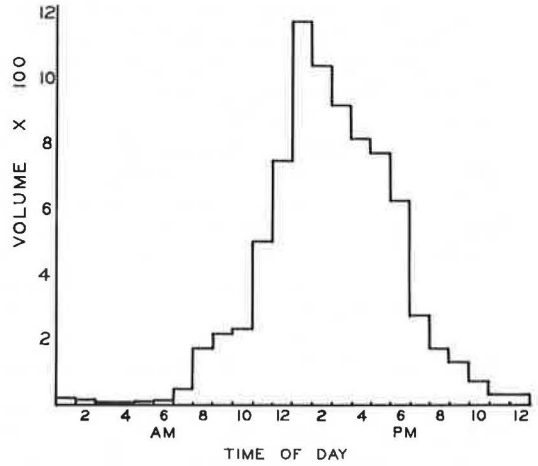


Figure 3. Pine Street, Saturday average hourly volumes.

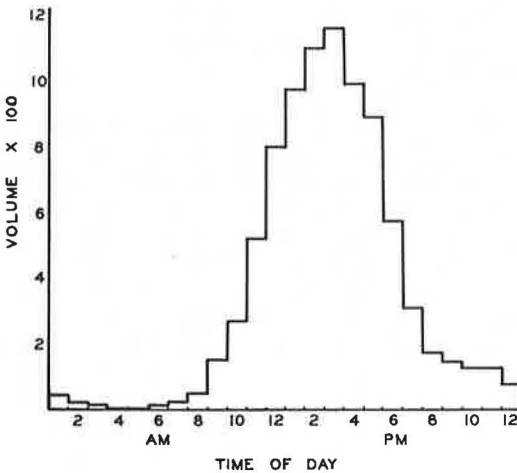
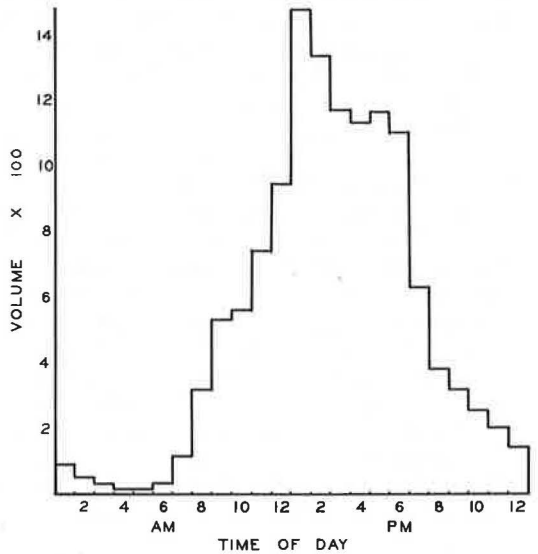


Figure 4. Pike Street, weekday average hourly volumes.



more than 0.05 in. of rain generally had 5 percent less volume.

A study of 3 special shopping days gave the following information:

1. A sale was held on a Thursday after 1 of the 2 largest department stores had been closed for 2 weeks because of a fire. The total day's volume of 11,054 was 40 percent more than the total average daily volume and 30 percent more than the average Thursday volume. The peak-hour volume of 1,642 (14.9 percent of the day's total) occurred between 12:15 and 1:15 p.m. with a peak-hour factor of 0.946.

2. An all-week downtown advertising campaign was held during the middle of October before a downtown sale on Friday, October 20. The sale day volume of 11,636 was 48 percent higher than the total average daily volume and 22 percent higher than the average Friday volume. The peak-hour volume of 1,454 (12.5 percent of the day's total) occurred between 12:15 and 1:15 p.m. with a peak-hour factor of 0.977.

3. The highest volume recorded was 13,232 on the Friday after Thanksgiving. This was 68 percent greater than the total average daily volume and 38 percent higher than the average Friday volume. The peak-hour volume of 1,879 (14.1 percent of the day's total) occurred from 1:15 to 2:15 p.m. with a peak-hour factor of 0.985.

Weekday peak hours occurred between noon and 2 p.m. usually between 12:15 and 1:15 p.m. The peak-hour volume averaged 14.5 percent of the daily volume with a standard deviation of 1.184 for the 68 recorded peaks. The only weekdays that did not have peak hours fitting these criteria were days when there was precipitation recorded during the peak period. Saturday peak hours were distributed throughout the afternoon and averaged 14 percent of the Saturday total volume.

Volumes recorded in the latter part of August before school openings were greater than other daily totals but not so large as the 3 shopping days.

The third location was on Pike Street east of 3rd Avenue (less than 1 block from the 4th Avenue location), again in the CBD core. This location serves bus patrons on major bus routes, shoppers to the department store area 1 block to the north, shoppers and visitors to the public market 2 blocks to the west, and employees of the office area 1 block to the south. It is located next to the large dime stores. The pedestrian population was composed of shoppers, employees, visitors, and downtown residents.

This sidewalk location was selected for its general pedestrian volume characteristics, its free-flowing large volumes, and its serviceability. A volume difference comparison to the employee location less than 1 block away was also possible.

Measurements were taken during the week before Christmas 1972 and from February 5, 1973, to June 1, 1973. Fridays had the highest daily volumes of any day with 122 percent of the 11,250 total average daily volume. Sunday volumes were 41 percent of the total daily average here in contrast to 20 percent at other locations. Monday evening shoppers raised the Monday evening average volume to 482 pedestrians per hour from the 441 pedestrians per hour average—an increase of 9 percent. The evening hourly average of data collected in the week before Christmas was 26 percent more than the average 441 pedestrians per hour, and precipitation was recorded every hour.

Pre-Christmas weekday volumes approached 15,000—one-third more than those of the spring survey. The highest hour volume was 1,833 from 12:30 to 1:30 p.m. on Friday, December 15, 1972. (There was a trace of precipitation recorded.) The highest 15-minute volume during this hour was 502 pedestrians and it was exceeded 4 times during April and May 1973 during lunchtime peaks. Saturday hourly and total volume trends were comparable to the retail location volume patterns.

Figure 4 shows that average weekday hourly volumes increase through the morning to the noon peak and gradually drop off through the afternoon.

CONCLUSIONS

Pedestrian sidewalk volumes follow cyclical patterns depending on population classification and weather. They can be measured mechanically to provide a reliable, economical data base for planning and designing pedestrian movement systems.

There are many possible uses for mechanical measurement data including:

1. Developing warrants for minimum walkway area openings during construction closure periods;
2. Developing warrants for sidewalk furniture control;
3. Evaluating walkway use;
4. Planning pedestrian malls, bus zones, and public transit stations;
5. Determining pedestrian accident factors to increase highway safety; and
6. Determining high pedestrian densities (e.g., for people entering parking garages) to change traffic signal timing.

Peak pedestrian flow rates occurred in surges of less than 15 minutes making it impossible to evaluate service level by Fruin's criteria—pedestrians per foot width per minute (10). The 15-minute volume summaries do not show the maximum values reached during surges. Recording the volumes in 5-minute increments should provide sufficient data to evaluate service levels. The average of the 15 highest 15-minute recordings at Pike Street east of 3rd Avenue was 940 pedestrians per 15 minutes, which reduces to 7 pedestrians per foot width per minute. This average value, according to Fruin, would be at service level B (10, p. 6, Fig. 5). Further study should evaluate level-of-service values for periods of time summarized by automatic count.

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