Analysis of Some Characteristics of Pedestrian Travel

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As serious attempts are made to alleviate the problem of congestion in the central business districts, it becomes apparent that knowledge of pedestrian travel behavior is very important. This paper describes a pedestrian travel survey for the central business district of Chicago and analyzes the results. The factors that affect trip-length distributions and time of travel are described; comparisons are made with other urban centers.

A downtown business area is viable only if it can absorb many people while minimizing conflicts among them: closeness without congestion. The typical central business district (CBD) today is highly congested, and proposals are being evaluated to alleviate this condition.

Pedestrians are a major component of the problem and the focus of recent proposals, but little is known about pedestrian travel behavior. Although mathematical models exist to predict vehicular travel, pedestrian travel has been ignored. Many of the latest suggestions for transportation in the CBD (moving walkways, personal rapid transit) compete with walking; if ridership for these alternatives is to be reliably predicted, better information on pedestrian travel must first be obtained and analyzed.

This paper analyzes a little-known but extensive survey of Chicago's CBD in 1963. These data represent the most comprehensive pedestrian travel survey yet done and provide significant insights into an area that has been little studied.

DATA COLLECTION

Characteristics of Chicago's Loop

The CBD of downtown Chicago, the Loop, is an intensely developed and congested area. The total number of person-vehicle trips to the CBD each day has remained at about 450 000 over the past 15 to 20 years. Of these daily trips to the Loop, 27 percent are made by rapid transit, 18 percent by suburban railroad, 26 percent by bus, and 29 percent by automobile (1).

Automobiles compete for about 19 000 parking spaces in the Loop, and the remaining vehicles must be parked in the fringe-area lots contiguous to the Loop or on the street. The number of people making walking trips to the Loop, i.e., trips solely by walking and involving no other mode, is not known. However, it is known that about 1 percent of the people employed in the Loop walk to work.

In 1965, employment in the Loop was estimated to be about 304 000 (2). In addition to being an employment center, Chicago's CBD is also a major retailing area with more than 1200 ground-floor businesses and 1 million m^2 (11 million ft^2) of retail floor space. By 1966, there were nearly 3.7 million m^2 (40 million ft^2) of total office space in the Loop. Actual and committed construction by 1971 increased the total by an additional 2.4 million m^2 (26 million ft^2) (3).

It seems curious, then, with this expansion of the base that the total number of person-vehicle trips has remained constant. There are three possible explanations. First, office space is used less intensively than retail and service space; therefore, increases in office-building space may be offset by decreased shopping activity. Second, new office space might be used at a less intensive level. Third, with the greater number of residences to the north of the Loop, more people may be walking or riding bicycles.

The Pedestrian Survey

The pedestrian survey was conducted by the Chicago Area Transportation Study (CATS) using 36 people from various city departments as interviewers (4, pp. 32-53). The survey was taken during the period from 7:00 a.m. to 7:00 p.m., with each interviewer collecting a predetermined number of interviews. These interviews were collected randomly along 98 stations consisting of one side of a street about three blocks in length for each hour in the time period.

The survey collected data for each station by hour, including the purpose of the trip, the direction of travel, and whether the respondent was coming from work. The

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interviewer also obtained addresses for the origin and destination of the trip. The total number of people interviewed was 11 632. The sample rates for each station were based on pedestrian volume counts done by regular traffic counters the previous year.

These sampling techniques produced a sample that was uniformly distributed across the Loop area; i.e., it included an approximately equal number of interviews at each station. This distribution has two beneficial effects from a statistical standpoint. First, it ensures that blocks with low volumes on the edge of the Loop are not ignored; i.e., if a uniform sample were taken, very few trips from low-volume areas would be sampled, thus producing a possible bias. Second, when the sample is expanded, there will be a tendency to equalize the percentage of standard error of expansion across blocks. That is, if one takes a certain sample percentage from a low-volume location and an equal percentage from a high-volume location and expands both, the expansion for the low-volume location will have a larger percentage of standard error than that for the high-volume location. If larger percentages in low-volume areas and smaller percentages in high-volume areas are surveyed, the expansions should have a smaller variance in the percentage of standard error than if a uniform sample were taken for the entire area (the problems in obtaining a uniform sample, should one want it, would be nearly insurmountable with sidewalk interviews in a location such as Chicago's Loop).

The expansion of the sample of pedestrian trips to represent the total number of such trips in the Loop area takes into account two factors: the sample rate and a correction for trip length.

The sample-rate expansion factor in this survey varies for each survey station. The sampling varied according to the volume of pedestrians at that particular station. The sample-rate expansion factor is simply the reciprocal of the sample rate; i.e., if 1 of every 200 people was questioned, the expansion factor would be 200. This factor was coded for each trip on the basis of its station location, hour of interview, and direction of travel.

A second factor is necessary because a random sample of pedestrians on sidewalks, as done by CATS, will not yield the proper distribution of trip lengths. Consider a trip of one block in length and another of two blocks; the two-block trip has twice the "life" and therefore (everything else being equal) twice the probability of being sampled. This means that the sample taken in the Loop contains an overrepresentation of long trips. Therefore, this sample must not only be multiplied by the sample-rate expansion factor but must also be adjusted for length bias.

To correct the trip-length bias, it is necessary to adjust the number of trips within a specified length range by their probability of being intercepted. The size of the length range depends on the data. Therefore, starting with the first length range, e.g., 0 to 91.4 m (0 to 300 ft), each successive range is then divided by its probability of being sampled relative to the first length range; e.g., 91.4 to 182.9 m (300 to 600 ft) is divided by 2, 182.9 to 274.3 m (600 to 900 ft) by 3, and so on. However, this technique alone would have the effect of reducing the number of trips in various length ranges and would therefore yield the proper distribution but not the correct total for each range. To keep the total the same, a constant must be included with each term, as shown in the following equation:

$$X_p = Y_{1p}C_p + (Y_{2p}C_p)/2 + (Y_{3p}C_p)/3 + \ldots + (Y_{np}C_p)/n \quad (1)$$

where

X_p = total number of walking trips in the sample for purpose p;
$Y_{1,2,3,\ldots,np}$ = total number of trips sampled at length L = 1, 2, 3, ..., n for purpose p; and
C_p = constant for purpose p.

If the trip-length intervals 1, 2, 3, ..., n are of equal length, Y_2 has twice the probability of being sampled as does Y_1, Y_3 has three times that of Y_1, and so forth. Dividing by the successive probabilities 1, 2, 3, ..., n ensures that trips are assigned their proper proportion. The constant (which is solved from the sample data for each purpose) is required so that the two sides of the equation remain equal.

Combining the sample-rate expansion factor and the length-correction factor gives the following final expansion:

$$T_{ijbtdp} = t_{ijbtdp} \times E_{btd} \times C_p/L_m \quad (2)$$

where

T_{ijbtdp} = number of expanded trips from point i to point j derived from interviews in block b, during hour t, going in direction d, for purpose p;
t_{ijbtdp} = sampled trip from point i to point j derived from interview in block b, during hour t, going direction d, for purpose p;
E_{btd} = expansion factor for block b, time t_n, and direction d;
C_p = length-correction constant for purpose p; and
L_m = length range m of trip.

In the application of the above equation, trips were grouped into increments of 91.4 m (300 ft) so that the cell sizes of the length-increment groups to be expanded were large enough to maintain information about short trips. As the trip length approaches zero, the theoretical length-correction factor would approach infinity; clearly, small increments are to be avoided.

The technique described here for trip-length correction can generally be applied to any situation in which sampling is performed on a random basis from a process with a predictable variability in its life, length, time, and so forth. This method must be applied if a true distribution is to be obtained. Thus, the expansion technique developed here could be applied whenever travel data are collected by sampling trips in progress, such as in cordon or roadside-interview methods.

DATA ANALYSIS

Trip-Length Distribution by Purpose

The expanded trips total more than 2.6 million. Since about 450 000 person-vehicle trips have destinations in the Loop, that figure amounts to about 5.8 pedestrian trips for each vehicle-trip destination, or 3.8 trips other than those relating to vehicles. At first glance, this seems too high, and a critical look at the expansion follows. A pedestrian trip is defined as any walking trip made outside of a building. After each stop, a new pedestrian trip is begun. Thus, a lunch trip that includes a stop at a retail store and then a return to work would be counted as three separate pedestrian trips.

Figure 1 plots the trip-length distribution for the total expanded sample. Distance is a very important factor in describing a pedestrian trip. This figure represents the total pedestrian trips for the entire day (7:00 a.m. to 7:00 p.m.) and for all areas of the Loop (including trips with origins or destinations outside of the Loop itself).

The numbers and percentages for each trip purpose are shown below.

Purpose	Number	Percent
Work	581 646	22.2
Home	428 446	16.3
Shopping	372 938	14.3
Work-related business	475 256	18.7
Personal business	403 279	15.5
Social-recreation	281 531	10.7
School	76 173	2.3
Total	2 619 269	100.0

The work trips are the greatest, with the workplace forming the focal point of CBD pedestrian travel. This category includes the morning trip to work and also trips returning from lunch and so forth throughout the day. The work-related business trips and personal business trips together comprise 34.2 percent of the total; this percentage reflects the importance of the face-to-face communication that is often mentioned as a primary activity in the CBD.

The reliability of the data expanded by trip purpose can be assessed in several ways. In 1966, about 304 000 persons were employed in the Loop (3), and about 70 to 80 percent of office employees left their office buildings during midday for lunch (5). Therefore, about 528 000 pedestrians could be expected to go to work either from vehicular transportation terminals at the beginning of the workday or from lunch at midday. This number would be reduced by absenteeism and increased if workers made other trips during the day. Overall, the surveyed and expanded number of 582 000 in the table appears to be quite reasonable.

Trips home can be checked in a similar way. It is estimated that about 450 000 people leave the Loop each day; the table lists 428 000 home trips. These would be included in the 450 000, except for persons returning to hotels. However, home does not necessarily have to be the destination for a person leaving the Loop, so these figures are inconclusive. Tabulating the data another way gives 340 000 trips home for Loop workers, a number that is clearly too high since only about 304 000 people are employed there (and not all of those would be there on a given day). The employment figures given were for 1966 and, since the survey was taken in 1963 and employment has presumably grown (office space has), there were probably fewer employees in 1963, making this comparison somewhat worse. The possibility that the expansion of trips could be 10 to 15 percent too large should be considered and the results interpreted with that understanding. In the absence of better information, these numbers must tentatively be accepted.

The number of trips to school seems to be unreasonably large and should be viewed with suspicion. A check of the unexpanded data revealed that a small number of school trips in locations with high expansion factors make up a substantial portion of this total. Such a large expansion of only a few trips is likely to lead to error, and the value is probably much lower. Since school trips represent only a small percentage of total travel, the effect of this expansion was ignored.

The curve in Figure 1 assumes the familiar form of a vehicular trip-length distribution, i.e., only a few very short trips followed by a quick peak, reflecting either a lack of ability to survey very short trips, the possibility that destinations are so spaced that a minimum distance must be traveled to go from one to another, or the possibility that many short trips are captured within buildings. The median trip length for this curve is about 296 m (970 ft); a block in downtown Chicago is about 137 m (450 ft). Fewer than 1 percent of those interviewed were walking farther than 1.6 km (1 mile); the north-south length of the Loop is about 1.2 km (0.75 mile). Figure 2 shows the median trip lengths for various purposes. It demonstrates how short shopping trips (which include lunch trips) and social-recreation trips are, which reflects the compact nature of shopping areas; this effect is common and will be discussed later.

Trips home are the longest, perhaps because many of these are to parking lots and transit stations, some of which are on the periphery of the Loop. Work, work-related business, and personal business trips have very similar median lengths, probably reflecting the similarity in type of destination.

Trip-Length Distribution by Time of Day

Figure 3 plots the median trip length by time of day for all trips. Curiously, trips are relatively short very early in the morning and then gain in length from 8:00 to 10:00 a.m. as the majority of workers converge on the Loop. Early-morning trips may be shorter because of the greater availability of parking and taxis. The coffee-break trips at 11:00 a.m. and 2:00 p.m. are fairly short (perhaps because of the limited time available for them); midday (lunchtime) trips are somewhat longer. Toward evening, trips again gain in length, possibly reflecting the trip to the transportation terminals for home.

Distribution of Trips by Time of Day

Figure 4 shows total trips as they vary by time of day. This plot is characteristic of similar plots done for vehicular traffic that show pronounced peaking in the morning and evening with another peak at midday. The major difference is that the maximum peak occurs in the evening for vehicular traffic instead of at midday as shown here. The buildup of nonworkers, combined with the workers' lunch hour, produces the effect shown. The sharp peak during midday reflects the multiplicity of trips for Loop employees that are related to lunch, i.e., trips to the bank, recreation walks, and so on.

Loop Workers Versus Others

People who work in the Loop may have travel characteristics that are different from those who do not. To test this hypothesis, the sample was divided into these two classes, and each was analyzed separately. Figure 5 displays the median trip length for workers and for others by purpose. This figure shows the importance of trip purpose in the analysis. While the difference for total trips is not great, workers do have a tendency toward longer trips. This difference probably reflects the multiplicity of short shopping trips nonworkers might make and the dominance of the trips to work and to home for the worker. In addition, even though employees arrive early in the day, the parking rates for very convenient spaces are high in order to discourage long-term parking and to save space for shoppers. In this light, the difference between the groups may be influenced by other factors than behavioral considerations; i.e., the price structure of parking may create part of the response. Workers make about 68 percent of the trips to the Loop and 57 percent of the Loop pedestrian trips; therefore, workers on the average make fewer pedestrian trips than nonworkers.

Most worker-related trips are longer because the employment areas are spread over the entire Loop and have poorer access to transit than do shopping areas. Workers' social-recreation trips are shorter, reflecting the walk-after-lunch trip. Their personal business trips

Figure 1. Trip-length distribution, all purposes.

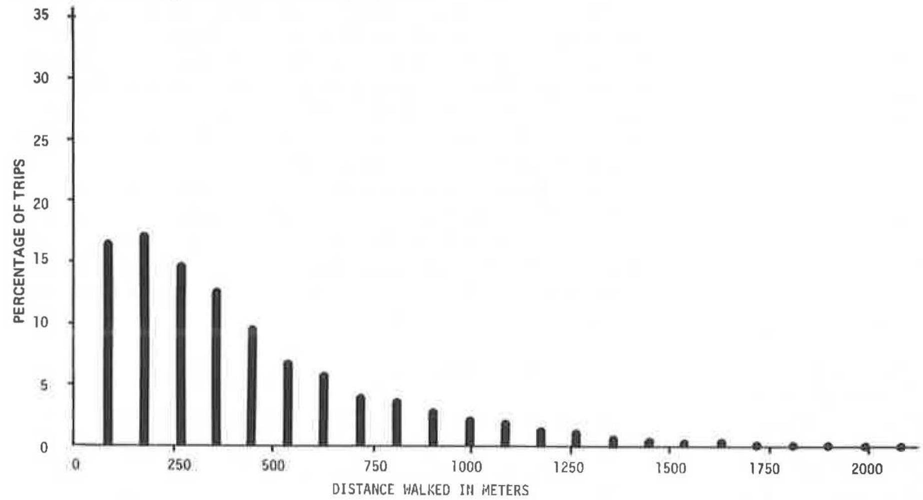


Figure 2. Median walking distance by purpose.

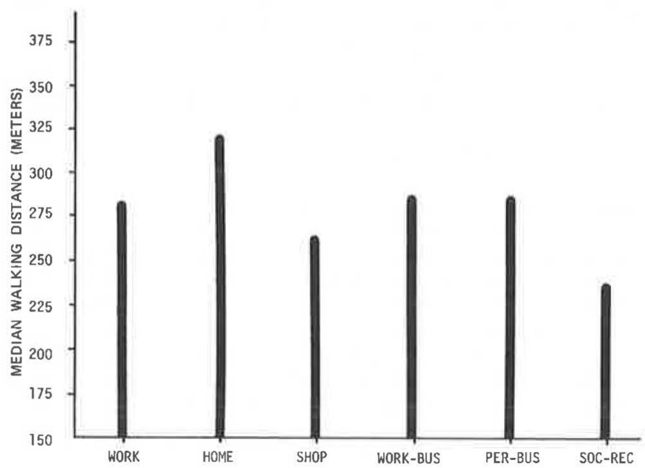


Figure 3. Median trip length by time of day, all purposes.

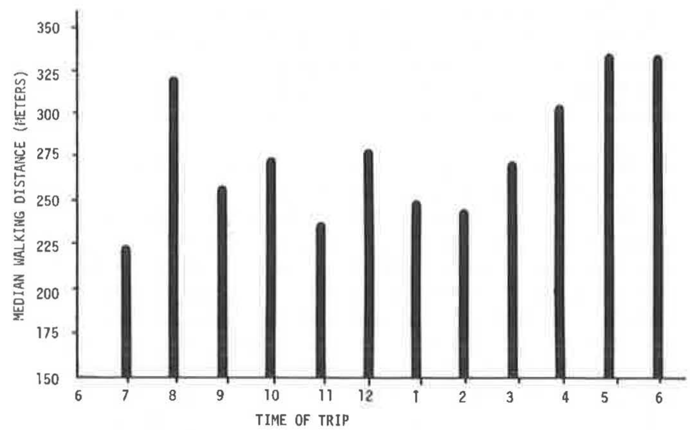


Figure 4. Number of trips by time of day, all purposes.

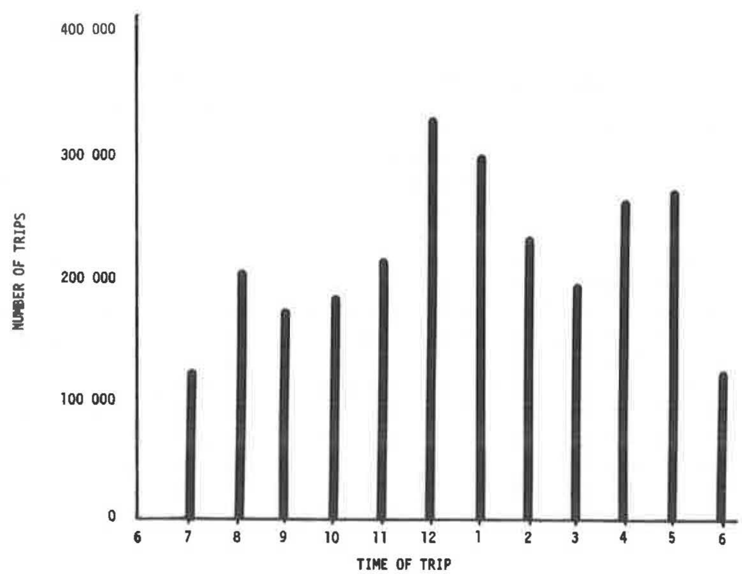


Figure 5. Median trip length by purpose for Loop employees and for others.

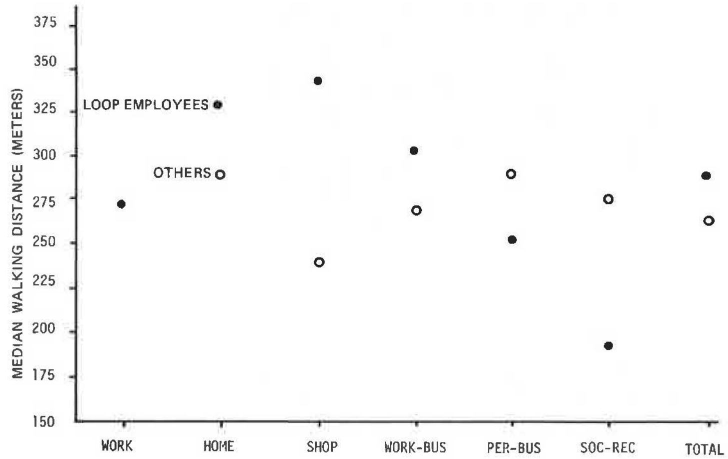


Figure 6. Percentage of trips by time of day for Loop employees and for others, all purposes.

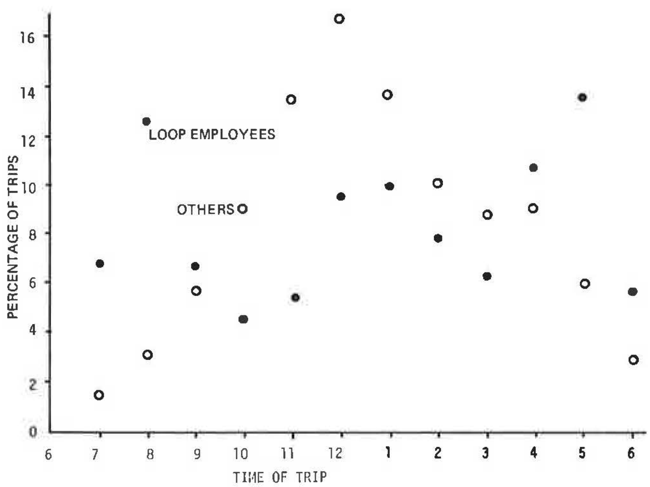
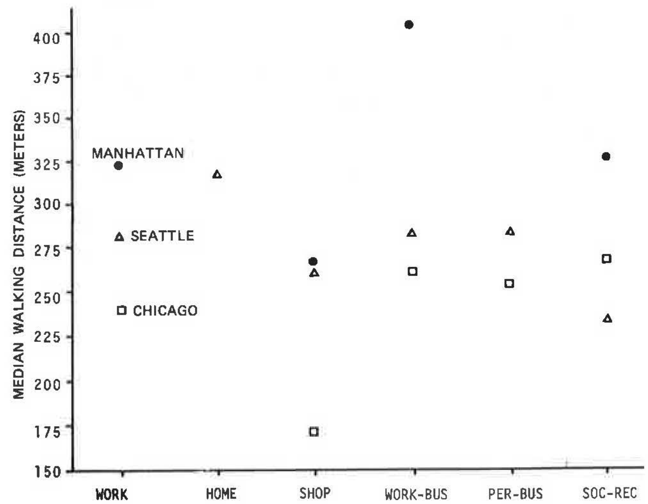


Figure 7. Median trip length by purpose for three cities.



are shorter, because the financial and government offices are in the same area as the offices where most of them work.

The difference in the generation of trips by time of day for workers and for others is shown in Figure 6. The Loop workers show peaks in the morning, at midday, and in the evening as one would expect. The nonworkers' trips build to a peak at midday, then appear to become far fewer, and generally disappear before the office rush hour at 4:00 to 6:00 p.m.

This analysis suggests that trip purpose is an important factor in describing the trip-length distribution and that, while differences between workers and nonworkers exist, the reason for much of this difference is the structure of the Loop; i.e., the transit facilities are near shopping, which promotes shorter trips.

COMPARISONS WITH PEDESTRIAN TRAVEL ELSEWHERE

The majority of pedestrian travel studies to date have dealt almost exclusively with egress from various transportation modes or terminals, usually parking facilities. Two studies have been done that are somewhat similar to the one analyzed here. One dealt with Seattle (6) and the other with Manhattan (7). Seattle is not nearly so dense as Chicago and has two downtown centers (one retail and one financial) separated by about nine blocks. Travel in Manhattan is unique.

Figure 7 compares the median trip length for Chicago, Seattle, and Manhattan by purpose. Trips in Manhattan for every purpose are longer. The numbers for Seattle are for building-to-building trips only. Since trips to parking facilities in Seattle are fairly short, these median lengths would be even lower if these trips were included. This indicates that trips in Seattle are generally shorter than those in Chicago.

In general, comparisons are very difficult to make, and any conclusions reached must be considered tentative. Until standard survey methods are developed, reliable comparisons cannot be made. One of the major dissimilarities is always the definition of trip purposes; standardization in this factor alone would make comparisons much easier.

CONCLUSION

The pedestrian exhibits travel characteristics that are very similar to and probably as predictable as those for travelers by other modes of transportation. We have outlined and analyzed several major aspects of pedestrian travel. We hope that insight gained from this article can be applied to planning in CBDs. This type of information is also required for the development of possible analytic models to predict future travel or probable response to new technologies. The information presented here was originally developed for use in a gravity-distribution model (4). This calibrated pedestrian distribution model was then used to test various assumptions about situations in which there was a choice between walking and riding a moving sidewalk.

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