CHAPTER 5.

DATA SUMMARY AND ANALYSIS

The following chapter describes in detail the data that the TD has collected, summarized, and analyzed. Below are four main concepts which represent the key findings for this study.

1. Pedestrian Characteristics
   Pedestrians in Lower Manhattan are diverse in personal characteristics and trip purpose. This diversity is correlated with significant differences in individual walking speeds. The characteristics that are associated with the greatest differences in walking speed are gender, group size, headphone use, and trip purpose.

2. Location Characteristics
   a. Land Use
   Different land uses attract different pedestrian trips; and pedestrians trips are made up by different pedestrian characteristics. The trip purpose variations between sidewalks are affected by the proportions of land use within the lots surrounding the sidewalks; therefore, it is valuable to examine variations in land use proportions. The results suggest that land use is related to trip purpose in expected ways (i.e., the more office space, the more work trips), and trip purpose can be used as a proxy for land use while studying speed in our overall data analysis.
   b. Time of Day
   There is a relationship between the time of day and the proportion of each trip purpose on a sidewalk. The TD observed that the majority of pedestrians during the AM peak have a work trip purpose. Tourists and pedestrians with non-work trip purposes were observed more often at the midday and the afternoon peaks.

3. Impedance
   Impedance is defined as the pedestrian being involuntarily slowed by conditions on the sidewalk. There was significant variation in the extent of pedestrian impedance across different times-of-day. Impedance is negatively correlated with mean speed and positively correlated with flow rate. In other words, when a location's overall mean speed increases, the proportion of impeded pedestrians at that location decreases. Time of day appears in itself to be a strong predictor of the proportion of impedance.

4. Pedestrian Delay Analysis
   This study has found that pedestrian characteristics, land use, and time of day have a strong influence on impedance; and that impedance has a strong influence on midblock sidewalk speed. It was decided that measuring pedestrian delay based on

impeded and unimpeded speed would be a good quantitative method to add to the pedestrian LOS methodology, so the TD derived a pedestrian delay analysis.

In this study, pedestrian delay is the difference between the "ideal" speed and "actual" speed at a location. The result is the delay, in seconds, in excess of the "ideal" walking time which would be experienced at each location if each location were a uniform representative walking length (i.e. 1,070 feet).

Sidewalk Delay = [(1,070 feet / median unimpeded speed) – (1,070 feet / median actual speed)]

As discussed in Chapter 4, the TD has developed several pedestrian data collection methodologies to observe walking habits and to determine the effects of the New York City walking environment on pedestrian behavior. These methodologies include speed and delay walks (See Chapter 4), filming on sidewalks, surveying pedestrian characteristics, and pedestrian counts. The objective was to compile a New York City pedestrian characteristics database. From the data collected, some conclusions about pedestrian characteristics in New York City and their interaction with sidewalk factors will be drawn. The TD is interested in laying the groundwork for making recommendations to improve the current HCM pedestrian LOS methodology.

At the end of August 2004, the preliminary stage of data collection was concluded. The following tasks were completed during this stage:

- In March and April 2004, 50 speed and delay walk tests were conducted, over a 1.66 mile route from Broadway and Duane Street to Wall Street and William Street in Lower Manhattan.
- In May 2004, a 7-day pedestrian count was undertaken, in which pedestrian speed samples and Automated Traffic Recorder (ATR) counts were collected on Broadway between Duane Street and Reade Street.
- In July and August of 2004, sixty locations in Lower Manhattan were surveyed during the AM, Mid-Day, and PM peak periods. Over 9,000 pedestrian characteristics, a sample of pedestrian speeds and 30 hours of pedestrian counts were collected.
- Since November, 2003, 15-minute videos were filmed in various locations in midtown and downtown Manhattan. Sixteen locations have been documented. Some locations have been filmed more than once in order to show hourly variations, seasonal variations, or daily variations.
- Previous pedestrian counts collected by the Department of City Planning and by Business Improvement Districts (BIDs) have also been compiled as part of the study.

At the current stage of data summary and analysis, the TD is concentrating on acquiring basic pedestrian characteristics in New York City. The focus is in finding out which critical factors affect pedestrians in order to plan for the next stage of this study. The TD is also concentrating on determining which of the methodologies developed is best for this study's purposes.

A. Pedestrian Characteristics and Speed Data Collection

A sample speed and count collection was conducted in Lower Manhattan in order to:

- Compare Lower Manhattan speed/flow relationships with studies that have been conducted in the past;
- Gather data on the personal attributes of pedestrians that have not been studied in detail in the past in order to make generalizations about their relationship (or lack of relationship) with walking speed;
- Test the methodology for rapidly observing pedestrian attributes and speeds in the field; and
- Evaluate the data collection methodology as well as the results of the summarized data in order to: 1) improve the methodology in the future, 2) focus on the most meaningful factors in determining pedestrian speed and flow.

In this section of the report, the count and speed data gathered are summarized. The chapter focuses on four areas: pedestrian characteristics, location characteristics, delay analysis, and flow analysis.

1. General Information

Speed and attribute data was collected on a sample of 8,978 pedestrians observed at various sidewalk locations in Lower Manhattan over about four weeks. In the same locations, over the same time period, all 23,739 pedestrians were counted in order to determine sidewalk flow rates, and basic information about each of the 62 locations was recorded. Based on these sets of data, two databases were built: a database containing each sample pedestrian's attributes and speed and an aggregate database of each of the study locations. This aggregated locational database includes the calculated flow rate based on the count at the location, the effective width of the sidewalk, and land use proportions based on the New York City Primary Land Use Tax Lot Output (PLUTO) data set. It also includes the mean and median speeds of all sampled pedestrians at each location, in addition to the proportion of sampled pedestrians at the location exhibiting particular attributes.

All subsequent analyses were based on these databases.

a. Data cleansing

Before the data analysis began, a data cleansing was undertaken to correct for potential inconsistencies introduced in the data gathering process. A detailed discussion of the data cleansing can be found in Appendix E.

b. Exploratory Data Analysis (EDA)

An exploratory data analysis (EDA) was also undertaken as the first step of the data analysis process. The purpose of the EDA was to familiarize ourselves with the distribution of the data, and to determine the statistical validity of the data distribution. The EDA is a crucial first step in determining the possibility of specific methods of statistical analysis. A detailed discussion of the EDA can be found in Appendix F.

2. Analysis of Pedestrian Characteristic Frequencies

In general, the frequencies of pedestrian characteristics identified are in line with expectations. The ratio of men to women is skewed slightly toward men more than in the city as a whole (where men make up only 47% of the population according to Census 2000 data). The age distribution is definitely skewed toward those aged 14-65, but that is expected in a central business district with a small residential population.

About 13.5% of all pedestrians observed were engaged in some activity: talking on the phone, listening to headphones, using a PDA, smoking, or eating/drinking. 16% of all pedestriansobserved were visibly impeded by street furniture or by other pedestrians.

The predominant trip purpose observed was 'work' at 49% of all observed pedestrian trips. However, the 'not sure' category was not far behind, accounting for 37% of pedestrian trips. This high proportion of 'not sure' trips is a result of a decision to be cautious about assigning trip purposes to pedestrians via observation.

About 66% of pedestrians observed were walking alone, with most of the remainder walking in pairs. The time of day influenced whether or not pedestrians were observed walking in groups. In the morning, with most pedestrians making their morning commute, relatively few groups were observed. At midday, about 42% of all observed pedestrians were part of a group of 2 or more, compared with 16% in the morning and 33% in the afternoon. These findings are in line with other researchers' findings in midtown Manhattan.

It was found that most observed pedestrians (67%) carry some sort of bag while they walk. A very small number of all pedestrians (1%) were visibly impeded by a heavy or awkward bag.

Very few observed pedestrians used walking aides (0.9%) or pushed devices such as strollers or wheelchairs (1.7%). See Figure 5.1. for Pedestrian Characteristics Frequencies.

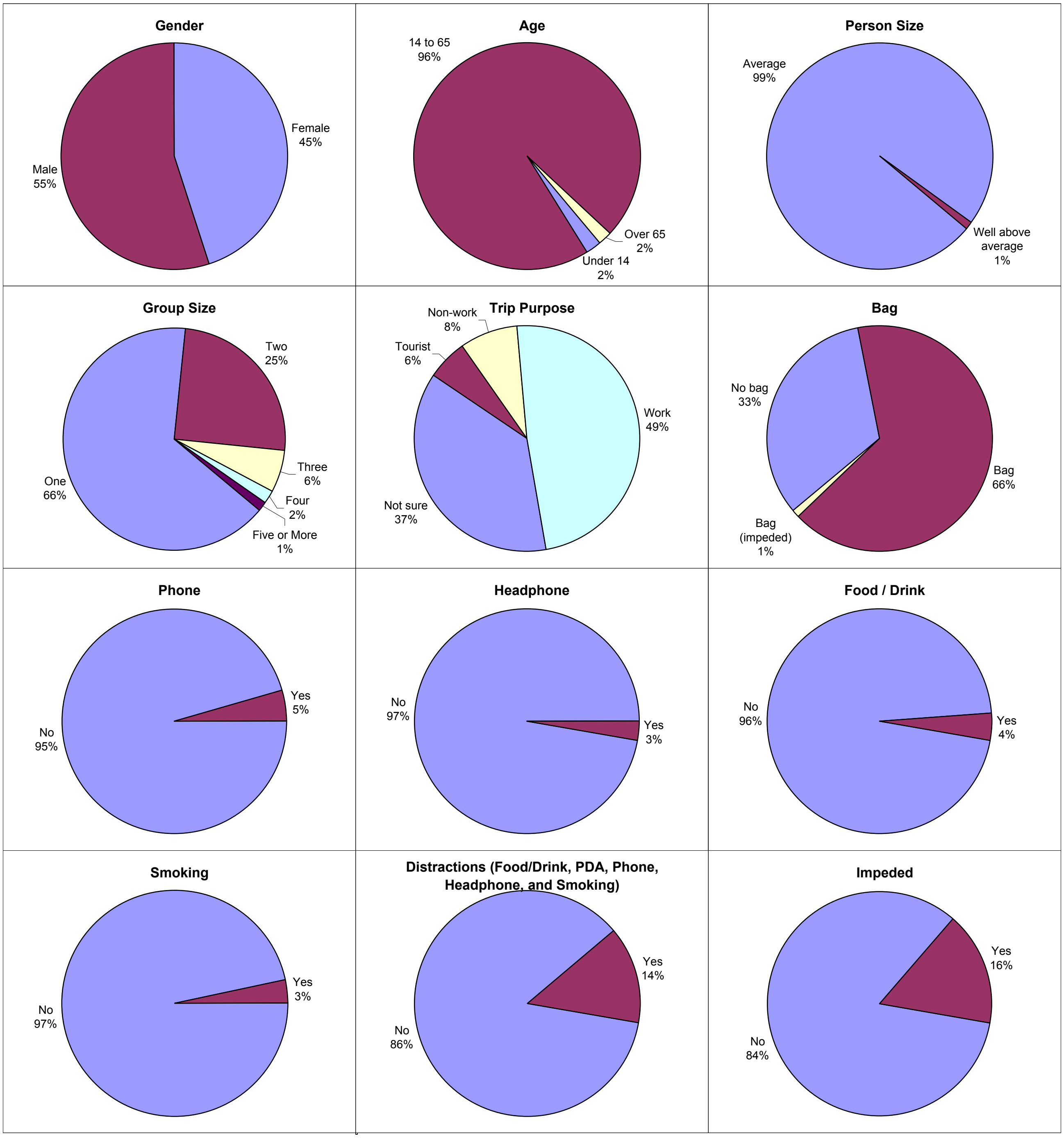

Figure 5.1. Pedestrian Characteristics Frequencies

3. Analysis of Pedestrian Characteristics & Speed

The TD also sought to quantify the relationship between pedestrian characteristics and pedestrian walking speeds—independent of location characteristics. Prior research has suggested some probable findings—that age, group size, gender, and trip purpose influence walking speed; and that carrying a bag does not.

a. All pedestrians

The speed of all observed pedestrians was distributed normally, as shown in Figure 5.2, with a mean speed of 4.27 ft/s and a median speed of 4.26 ft/s. This is a little lower than Fruin's average speed of 4.5 ft/s and Weidmann's average speed of 4.40 ft/s (Fruin, 1971; Weidmann, 1991), but this could be due to the fact that most of the observations were mid day. The indirect influence of time of day on walking speed is discussed later in this chapter.

b. Gender

It was observed that men's walking speeds (mean = 4.42 ft/s) are faster than women's speeds (mean = 4.10 ft/s).

This result is complicated by the fact that, according to the observations, women are more likely to walk in groups than men and are less likely to have a work trip purpose. But, even holding those factors constant and comparing men and women walking alone with a work trip purpose, it was still found that women walk slightly slower than men (see Figure 5.3, Table 5.1, and Table 5.2).

c. Age

As shown in Figure 5.4., pedestrians between 14-65 years old walk faster (median = 4.29 ft/s) than those under 14 years old (median = 3.64 ft/s) and over 65 years old (median = 3.63 ft/s). A relatively small

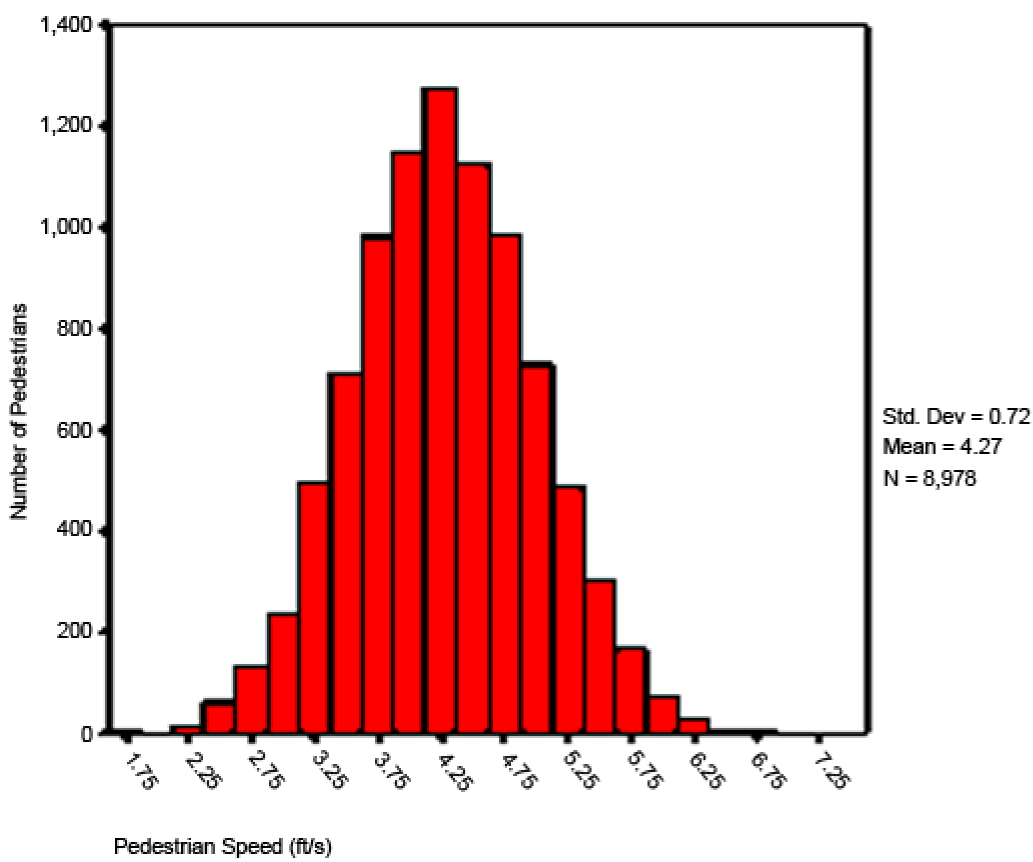

Figure 5.2. Pedestrian Speed Distribution

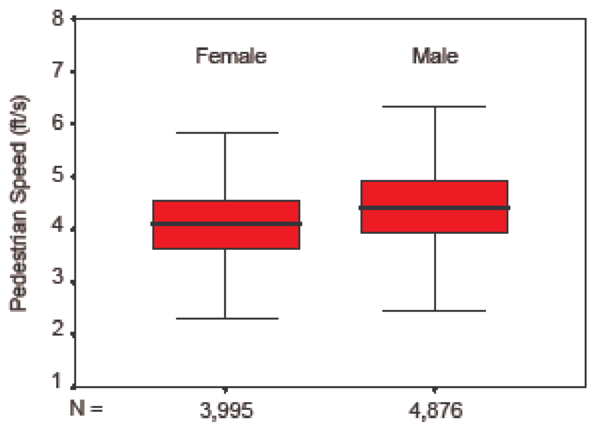

Figure 5.3. Pedestrian Speed by Gender

*A note regarding the interpretation of our box plot figures:

- The box plot represents the distribution of values in a data set. In this case (Figure 5.3), the box plots are illustrating the distribution of pedestrian speeds (in feet per second) observed by gender.
- "N" is the number of cases we observed for each variable. In this case, N is 3,996 female pedestrians and 4,876 male pedestrians.
- The median value of the data distribution is represented by the black line at the center of each red box. 50% of values in the data distribution for each variable are greater than the median and 50% are less than the median.
- The top line of each box is the 75th percentile (upper quartile) and the bottom line of each box is the 25th percentile (lower quartile). 75% of the values in the data distribution for each variable are less than the 75th percentile value, and 25% are less than the 25th percentile value. The space between the 75th percentile and 25th percentile values is called the "inter-quartile range."
- The line below the box plot parallel to the 25th percentile line is drawn according to a formula in which the inter-quartile range value (75th percentile value – 25th percentile value) is multiplied by 1.5; the product is then subtracted from the 25th percentile value. The resultant value is named L1. The line parallel to the 25th percentile line is drawn at the smallest value which is greater than L1.
- Similarly, the line above the box plot parallel to the 75th percentile line is drawn according to a formula in which the inter-quartile range is multiplied by 1.5. The product is then added to the 75th percentile value. The resultant value is named U1. The line parallel to the 75th percentile line is drawn at the greatest value which is smaller than U1.

Some of the figures and tables in this chapter which refer to individual characteristics have different total number of cases ("N"). For example, Figure 5.2 refers to a total pedestrian sample size N of 8,978 while the sum of N in Figure 5.3 is only 8,871. This discrepancy is due to the fact that a number of the pedestrians we observed were walking in large groups from which it was not possible to record the individual characteristics of each group member. In these cases, the pedestrians were counted, but their individual characteristics were not recorded. In addition, babies in strollers were considered "pedestrians," but it was difficult to discern their individual characteristics (such as gender), so they were also counted but some of their characteristics were not recorded. Overall, however, the number of individuals with missing characteristics was relatively small ("person size" was not recorded for 111 individuals; it was the characteristic left blank the most).

Table 5.1. Group Size Distribution by Gender

Gender		Group size 1	2	3	4	>4	Total
Female	Count	2,528	1,071	281	84	31	3,995
	Percentage	63.3%	26.8%	7.0%	2.1%	0.8%	100.0%
Male	Count	3,366	1,150	243	94	23	4,876
	Percentage	69.0%	23.6%	5.0%	1.9%	0.5%	100.0%
Total	Count	5,894	2,221	524	178	54	8,871
	Percentage	66.5%	25.0%	5.9%	2.0%	0.6%	100.0%

Table 5.2. Trip Purpose Distribution by Gender

Gender		Trip Purpose: Not Sure	Tourist	Non-Work	Work	Total
Female	Count	1,693	261	440	1,601	3,995
	Percentage	42.4%	6.5%	11.0%	40.1%	100.0%
Male	Count	1,600	262	290	2,724	4,876
	Percentage	32.8%	5.4%	5.9%	55.9%	100.0%
Total	Count	3,293	523	730	4,325	8,871
	Percentage	37.1%	5.9%	8.2%	48.8%	100.0%

number of pedestrians were observed in the outlying age ranges (under 14 and over 65), though, and as evidenced by the irregular distribution of speeds in those cases, it may not be possible to draw conclusions about those populations. In addition, many of the pedestrians under age 14 were in a stroller and unable to control their own speed.

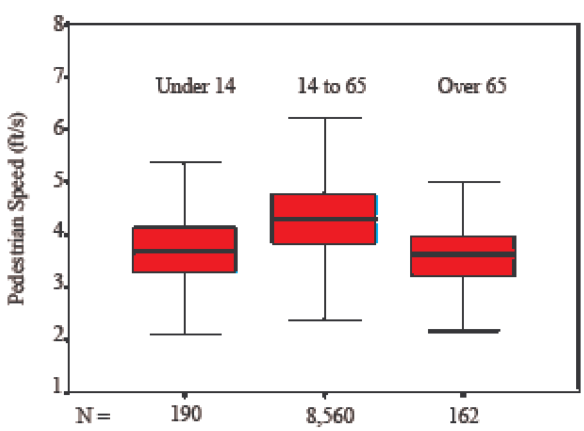

Figure 5.4. Pedestrian Speed by Age

d. Person size

Early in the study, it was hypothesized that pedestrians may be physically larger in 2004 than they had been in the mid-1970s when many of the landmark pedestrian studies had been completed. This could lead to slower walking speeds and larger body ellipses—changing the fundamental relationships between flow rate, speed, and density.

It was observed that pedestrians who were well above average size (according to the observations) walked slower than all other pedestrians (median speed = 3.74 ft/s vs. 4.26 ft/s). However, large pedestrians make up a very small proportion of the overall sample (about 1.1%) so they probably had only a limited impact on the overall flow of traffic (see Figure 5.5).

e. Group size

It was observed that groups of pedestrians have lower speeds overall than pedestrians walking alone. And, as the size of groups increases in number, the median speed decreases. It is not clear whether the difference in group size speeds is due to pedestrians choosing

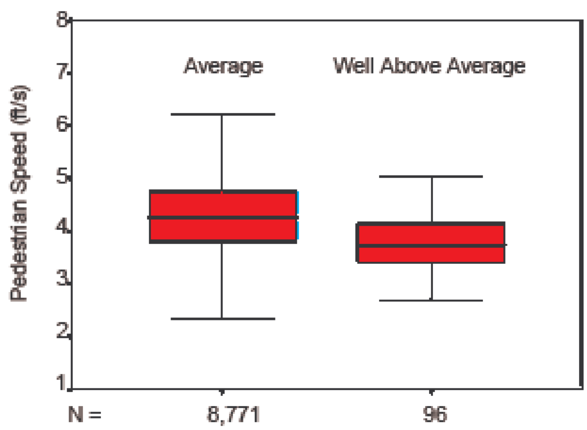

Figure 5.5. Pedestrian Speed by Person Size

the speed of the slowest member, walking slower to be able to talk, or due to the fact that pedestrians tend to walk in groups for less urgent trip purposes (going to lunch, for example).

In this sample, over 30% of all pedestrians were walking with at least one other person. The data may be skewed toward more groups because the TD counted at mid-day more often than it counted in the morning (when most pedestrians walk alone), but this is still an important finding. Does the HCM properly account for the tendency of people to walk in groups? It might be argued that this is just a specific type of platooning, but a platoon of strangers probably behaves differently than a group of friends when confronted with an opposing pedestrian flow.

It was found that tourists and pedestrians with non-work trip purposes tend to walk in groups (see Table 5.3. and Figure 5.6.)

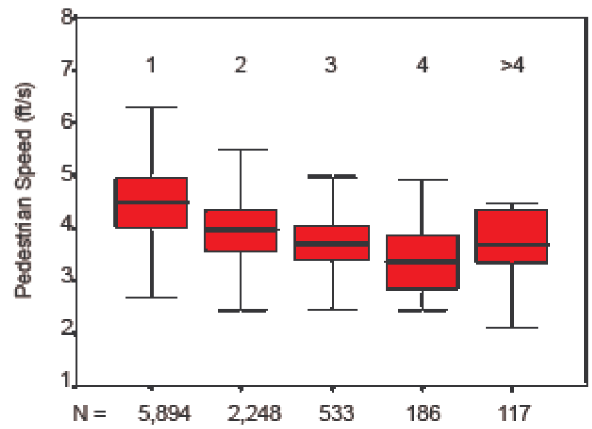

Figure 5.6. Pedestrian Speed by Group Size

f. Trip Purpose

Generally, the relationship observed between a pedestrian's trip purpose and his or her walking speed is in line with past studies and common sense. As shown in Figure 5.7, it was observed that pedestrians whose trip purpose is work tend to walk the fastest, with a median speed of 4.41 ft/s. Tourists tend to walk the slowest (median speed = 3.79 ft/s) and non-tourists with a recreational or casual trip purpose

Table 5.3. Group Size Distribution by Trip Purpose

Trip Purpose		**Group Size**					**Total**
		1	**2**	**3**	**4**	**>4**	
Not Sure	Count	2,428	727	113	20	5	3,293
	Percentage	73.7%	22.1%	3.4%	0.6%	0.2%	100.0%
Tourist	Count	64	224	115	75	45	523
	Percentage	12.2%	42.8%	22.0%	14.3%	8.6%	100.0%
Non-work	Count	248	332	109	39	3	731
	Percentage	33.9%	45.4%	14.9%	5.3%	0.4%	100.0%
Work	Count	3,154	938	188	44	1	4,325
	Percentage	72.9%	21.7%	4.3%	1.0%	0.0%	100.0%
Total	Count	5,894	2,221	525	178	54	8,872
	Percentage	66.4%	25.0%	5.9%	2.0%	0.6%	100.0%

walk just slightly faster (median speed = 3.90 ft/s). The large group of pedestrians whose trip purpose was unclear to us walked at a median speed in line with the overall sample (4.25 ft/s).

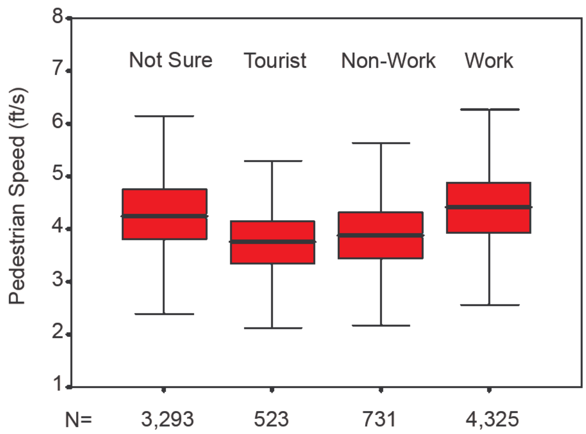

Figure 5.7. Pedestrian Speed by Trip Purpose

g. Bag

Fruin and Whyte found that the walking speed of pedestrians does not change if they are carrying bags or not. The observations validate their findings. The median speed of all pedestrians carrying bags (including those observed as being impeded by the weight or size of their bag) was 4.27 ft/s while the median speed of pedestrians without bags was 4.25 ft/s—not a significant difference (see Figure 5.8).

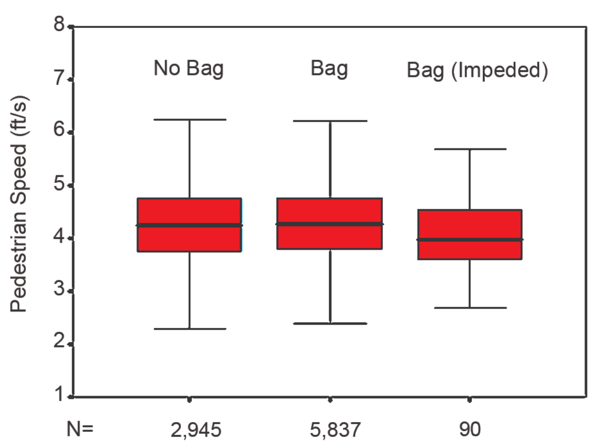

Figure 5.8. Pedestrian Speed by Use of a Bag

h. Distractions

It was also hypothesized that the use of devices such as cell phones and portable stereos (portable cassette, CD, and MP3 players) might change the speed at which individual pedestrians walk on the sidewalk. It was observed that 13.8% of all pedestrians are engaged in one (or more) of the five activities the TD decided to monitor—using a cell phone, listening to headphones, using a PDA, smoking a cigarette, or consuming food and drink.

As shown in Figure 5.9, when analyzed in aggregate, there appears to be no significant difference in walking speed between pedestrians engaged in one or more of these activities vs. pedestrians who are not. However, pedestrians who engage in specific activities do have different walking speeds than those who do not.

The mean walking speeds for pedestrians listening to headphones, talking on cellular phones, and smoking are significantly different than the mean walking speed of pedestrians who are not. Remarkably, pedestrians wearing headphones have slightly faster walking speeds (mean = 4.64 ft/s) than those without (mean = 4.27 ft/s). This could indicate that pedestrians who wear headphones are focused on reaching their destination without being distracted by activity on the sidewalk. It could also indicate that another variable influences both a pedestrian's likelihood of wearing headphones and his or her walking speed (e.g. youthful physical fitness). Gender may be one of those factors: according to the sample, men are more likely to be wearing headphones than women (see Table 5.4).

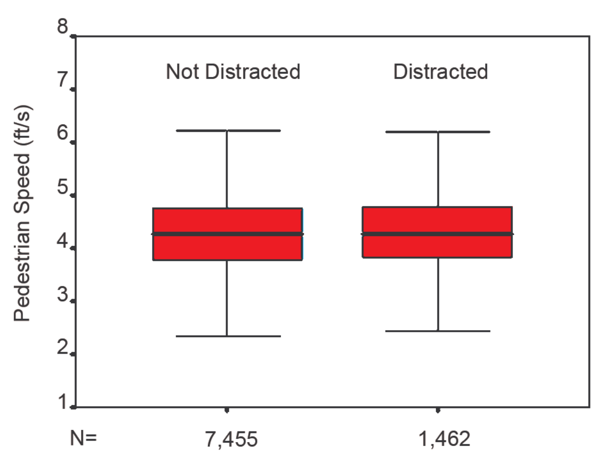

Figure 5.9. Pedestrian Speed by Distraction

Table 5.4. Headphone Use Distribution by Gender

Gender		Headphone		Total
		No	Yes	
Female	Count	3,915	80	3,995
	Percentage	98.0%	2.0%	100.0%
Male	Count	4,714	162	4,876
	Percentage	96.7%	3.3%	100.0%
Total	Count	8,629	242	8,871
	Percentage	97.3%	2.7%	100.0%

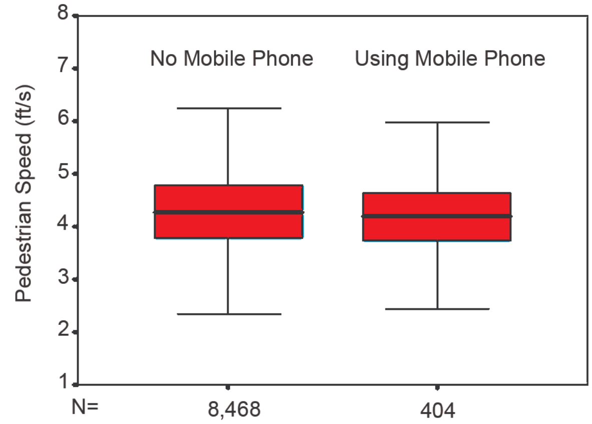

Figure 5.10. Pedestrian Speed by Use of a Phone

Pedestrians talking on cell phones and smoking have lower walking speeds than those who are not engaged in those activities. Smokers' mean walking speed is 4.17 ft/s while cell phone users' walking speed is 4.20 ft/s. In both cases, the mean walking speed of all others is 4.28 ft/s. These are small differences and, given that only 5% of pedestrians are talking on cell phones and 3% are smoking in the sample, these factors probably have little impact on the overall flow on the sidewalk.

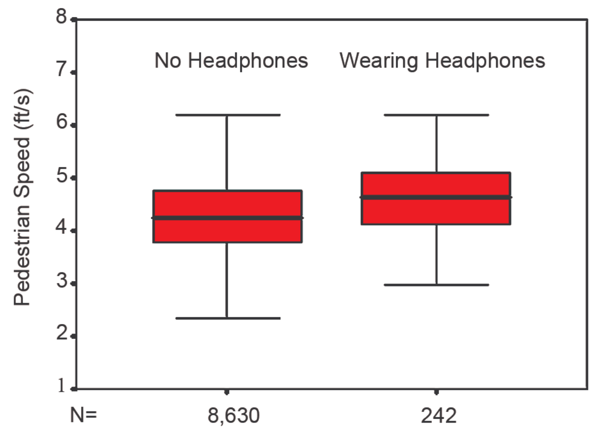

Figure 5.11. Pedestrian Speed by Use of Headphones

Because of small sample sizes, food & drink and PDA use were not analyzed individually. See Figures 5.9, 5.10, 5.11, and 5.12 for pedestrian speed by distractions.

i. Impeded

As defined in Appendix B, a pedestrian is impeded if he/she is involuntarily slowed by conditions on the sidewalk. Perhaps unsurprisingly, it was found that pedestrians who were observed as being impeded have a significantly slower walking speed than pedestrians who are not impeded. As shown in Figure 5.13, impeded pedestrians have a mean walking speed of 3.96 ft/s while unimpeded pedestrians have a mean speed of 4.34 ft/s.

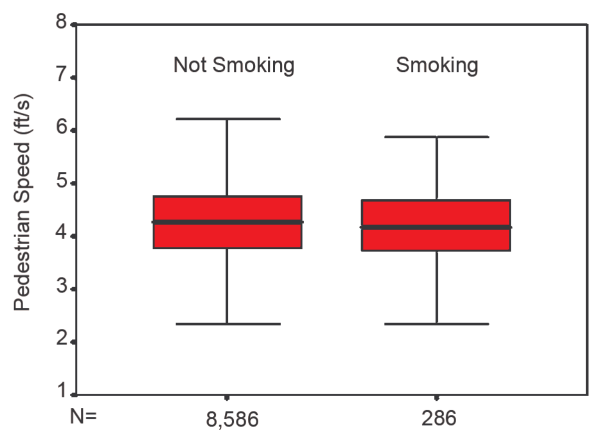

Figure 5.12. Pedestrian Speed by Use of a Cigarette

It was found that women are more likely to be impeded than men, pedestrians are more likely to be impeded at midday than morning or afternoon, and that groups of 2 and 3 are more likely to be impeded than larger groups or single pedestrians. An unusual finding is that tourists tend to be impeded more often than pedestrians with other trip purposes. This is

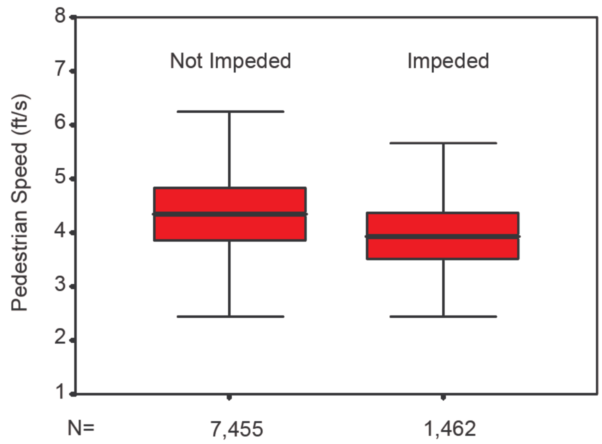

Figure 5.13. Pedestrian Speed by Impedance

surprising because one might expect that tourists, with slower walking speeds, might not be held up very often by other pedestrians. Whyte observed that, in his experience, New York pedestrians are particularly skilled at navigating city sidewalks efficiently. Perhaps out-of-towners are just not as used to the crowds as residents. In addition, it seems that tourists would be most attracted to sidewalks which typically exhibit high activity, as they are probably primarily interested in well-known and therefore highly traveled sites. See Tables 5.5, 5.6, 5.7, and 5.8 for a summary of gender, time and day, trip purpose, group size crosstabulation with impedance.

j. Summary of Pedestrian Characteristics

Based on this analysis a few general conclusions were drawn:

– Pedestrians in Lower Manhattan are diverse in personal characteristics and trip purpose. This diversity is correlated with significant differences in individual walking speeds.

Table 5.5. Impedance Distribution by Gender

Gender		Impeded		Total
		No	Yes	
Female	Count	3,288	707	3,995
	Percentage	82.3%	17.7%	100.0%
Male	Count	4,129	747	4,876
	Percentage	84.7%	15.3%	100.0%
Total	Count	7,417	1,454	8,871
	Percentage	83.6%	16.4%	100.0%

Table 5.6. Impedance Distribution by Time of Day

Time of Day		Impeded		Total
		No	Yes	
AM	Count	1,882	159	2,041
	Percentage	92.2%	7.8%	100.0%
MD	Count	3,909	1,012	4,921
	Percentage	79.4%	20.6%	100.0%
PM	Count	1,664	291	1,955
	Percentage	85.1%	14.9%	100.0%
Total	Count	7,455	1,462	8,917
	Percentage	83.6%	16.4%	100.0%

Table 5.7. Impedance Distribution by Trip Purpose

Trip Purpose		Impeded		Total
		No	Yes	
Not Sure	Count	2,714	579	3,293
	Percentage	82.4%	17.6%	100.0%
Tourist	Count	414	109	523
	Percentage	79.2%	20.8%	100.0%
Non-work	Count	633	98	731
	Percentage	86.6%	13.4%	100.0%
Work	Count	3,657	668	4,325
	Percentage	84.6%	15.4%	100.0%
Total	Count	7,418	1,454	8,872
	Percentage	83.6%	16.4%	100.0%

Table 5.8. Impedance Distribution by Group Size

Group Size		Impeded		Total
		No	Yes	
1	Count	5,050	844	5,894
	Percentage	85.7%	14.3%	100.0%
2	Count	1,778	470	2,248
	Percentage	79.1%	20.9%	100.0%
3	Count	418	115	533
	Percentage	78.4%	21.6%	100.0%
4	Count	158	28	186
	Percentage	84.9%	15.1%	100.0%
More than 4	Count	51	5	56
	Percentage	91.1%	8.9%	100.0%
Total	Count	7,455	1,462	8,917
	Percentage	83.6%	16.4%	100.0%

The characteristics that are associated with the greatest differences in walking speed are gender, group size, headphone use, and trip purpose.

– Pedestrians are being impeded on Lower Manhattan sidewalks, primarily by other pedestrians, bus stop and vendor queues, bus shelters, and subway entrances. In all, 16% of all pedestrians in the sample were impeded. Pedestrian impediments will be analyzed further in the discussion of a methodology to measure pedestrian delay.

This analysis leaves out some important factors which might affect pedestrians, such as: how do the locations themselves impact the speed of pedestrians? Do these pedestrian characteristics, when taken at an aggregate level at a location, influence the overall walking speed and flow characteristics of a location? Finally, are pedestrian speeds and rates of impediment distributed evenly across all locations or were some locations more likely to influence these outcomes than others? What are the characteristics of those locations? These factors are discussed in the next section.

B. Location Characteristics

1. Land Use

One of the most basic characteristics of space in a CBD like lower Manhattan is its land use. The office and retail-oriented nature of Lower Manhattan is what defines it as a CBD. However, different streets within the CBD have different proportions of primary land use classifications (residential, office, retail, etc.). These proportional differences have an impact on the makeup of each street's pedestrian traffic, as different land uses attract different kinds of pedestrian trips. As is discussed above, differences in pedestrian trip purposes (work, tourism, etc.) yield variations in walking speeds. The trip purpose variations between sidewalks are affected by the proportions of land use within the lots surrounding the sidewalks (see correlation discussion below). Therefore, it is valuable to examine variations in land use proportions, to get a better sense of the interaction between location characteristics and pedestrian characteristics, which have an impact on overall sidewalk conditions and, eventually, the calculation of LOS.

In order to determine the proportions of primary land use types surrounding the study locations, the Primary Land Use Tax Lot Output (PLUTO), the Department of City Planning's database of land use based on tax lots, was consulted. The PLUTO database includes such information as the zoning district of each tax lot, each tax lot's owner's name, the area of the lot, and the floor area of buildings on the lot by land use. Land use types include commercial and residential, with the designation of commercial land use encompassing office, retail, garage, storage and factory. By isolating the lots surrounding each study location and dividing the lots' total building area into the area of each land use type, the proportion of primary land use types at each individual study location was determined. Although pedestrian data was collected on specific sides of streets (i.e. east or west, north or south), the land uses were aggregated for both sides of the street for each location, and the proportions of land use types reflect the land use areas for both sides of the street for each location. It was assumed that pedestrians on study sidewalks could have buildings on either side of the street as their trip origin or destination, so aggregating the land use areas on both sides makes sense.

Most of the locations in the study have office space as their primary surrounding land use. The average proportion of office space for all study locations is 66.3%. The average residential land use for all study locations is 16.7%, and the average retail land use is 9.2%. Of course, there are locations that are primarily residential or retail in character. For instance, West Broadway between Reade Street and Chambers Street has residential space comprising 73.6% of its surrounding land use; it is the location with the greatest proportion of residential land use among the study spots. Church Street between Chambers Street and Warren Street is the location with the greatest proportion of retail land use, with 53.6% of its surrounding land use comprised of retail space. See Figures 5.14., 5.15. and 5.16.

In the interest of testing the relationship between the mean speed of pedestrians at study locations and the proportions of different land uses surrounding the sites, a backward stepwise regression in SPSS was performed, with the mean speed as the dependent variable, and the proportions of retail, office and residential land use as the independent (predictor) variables. These three land use types were chosen to be analyzed because, as is apparent in the land use maps (see below), they are the predominant land use types around the lower Manhattan sidewalks on which data was gathered. None of the resultant regression models had predictor coefficients that were significant at the 95% confidence level. In addition, the coefficient of determination (r^2), which is the proportion of the variation in mean speed that can be explained by the predictors in the regression equation, was just 0.032.

These regression results indicate that, in this study, differences in the proportions of the three land use types surrounding the study locations did not have a significant impact on the mean speed measured at the locations. This may be because most of the study locations have surrounding land uses that are over 50% office oriented; several sites have land use proportions approaching 100% office. Because this analysis zone (lower Manhattan) is a CBD, the primacy of office space is not surprising. The near homogeneity of land use surrounding the study sites renders land use proportions, as predictive variables, quite unrevealing. However, as mentioned in the Pedestrian Characteristics section above, trip purpose has a direct influence on walking speed. Because land use appears to have an influence on trip purpose variations on sidewalks, it can be said to have an indirect influence on sidewalk speed. Therefore, it is important to illustrate the connection between land use and trip purpose as it applies to this study.

Pushkarev and Zupan (1975) suggest that the use and size of buildings on Manhattan streets can be predictive of the amount of traffic experienced on their bordering sidewalks. By extension, building use and size might also be predictive of primary sidewalk trip purpose. It seems intuitive that a sidewalk whose surrounding buildings are primarily office oriented would be populated by primarily work oriented traffic; the same can be said for primarily residential and retail oriented buildings, which would bound sidewalks with primarily non-work traffic. In Table 5.9., generated from an SPSS correlation analysis, there appears to be a moderate positive correlation between the proportion of pedestrians whose trip purpose was recorded as “non-work” on this study’s sidewalks and the total surrounding building area dedicated to a retail land use. In addition, there is also:

- a moderate negative correlation between the “non-work” proportion and the surrounding office area;
- a moderate positive correlation between the “work” proportion and the surrounding office area;
- a moderate negative correlation between the “work” proportion and the surrounding retail area;
- a moderate negative correlation between the “unknown” proportion and the surrounding office area; and
- a moderate positive correlation between the “unknown” proportion and the surrounding retail area.

These results suggest that land use is related to trip purpose in expected ways (i.e., the more office space, the more work trips), and trip purpose can be used as a proxy for land use while studying speed in the overall data analysis.

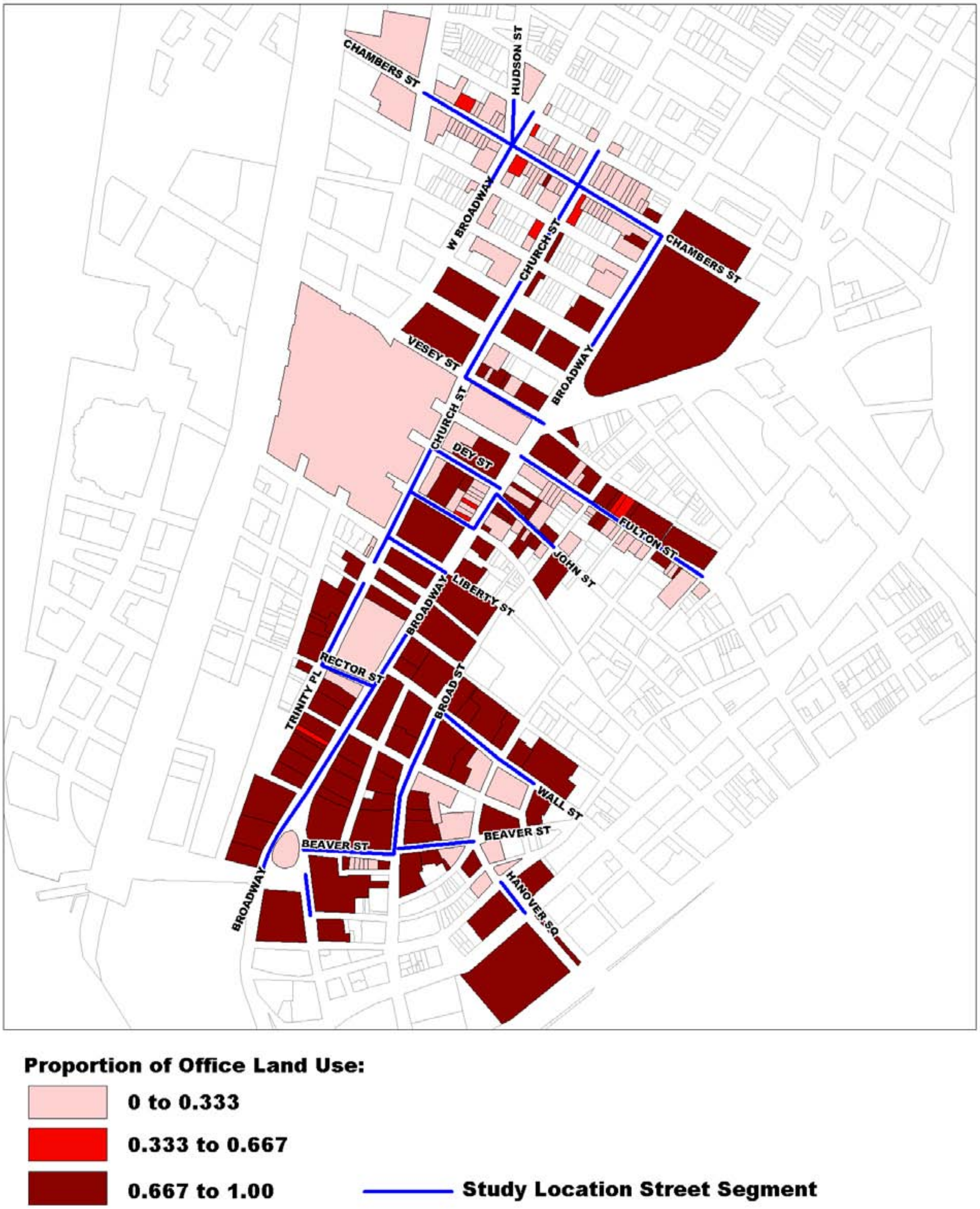

Figure 5.14. Proportion of Office-Oriented Land Use at Study Sites

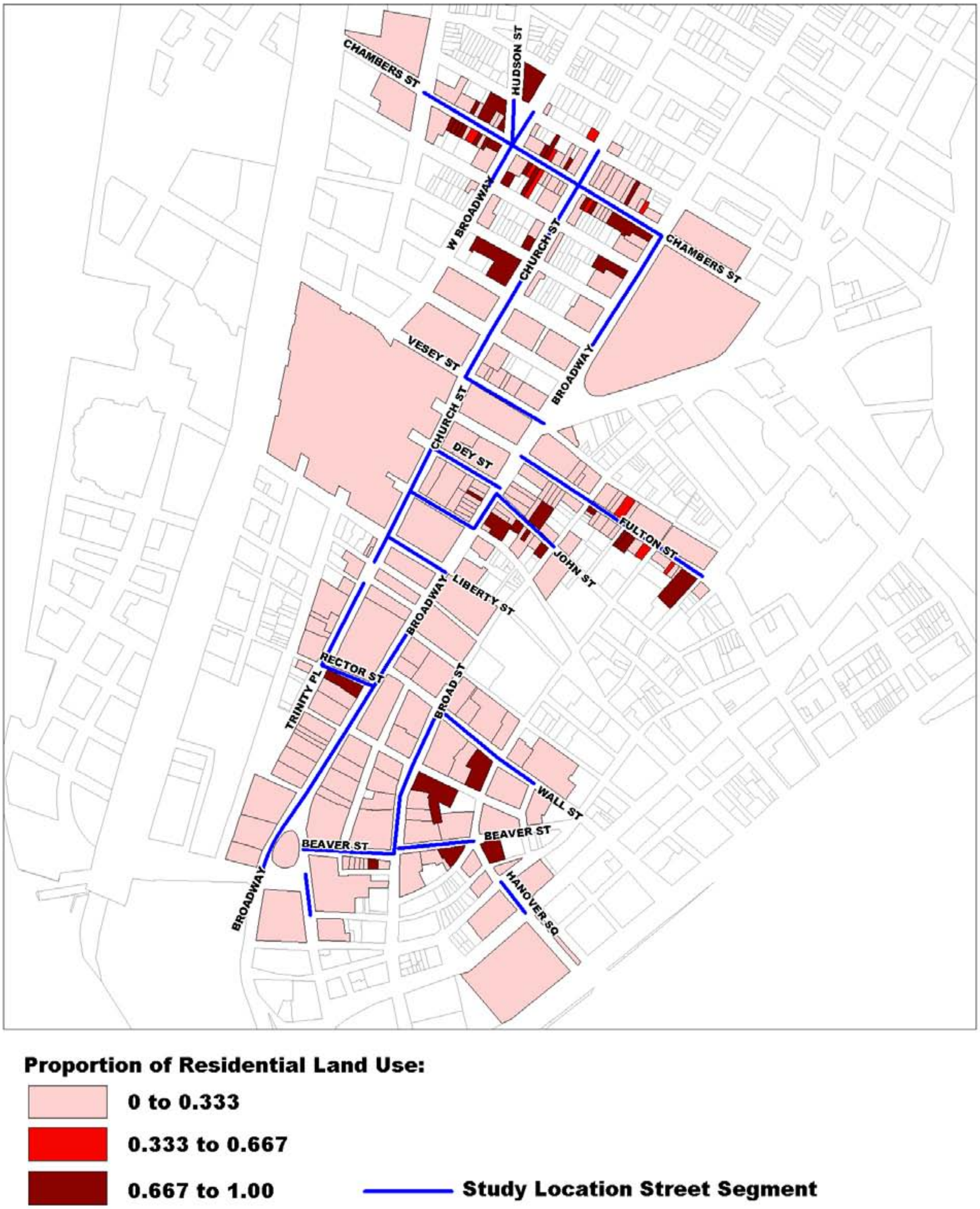

Figure 5.15. Proportion of Residential Land Use at Study Sites

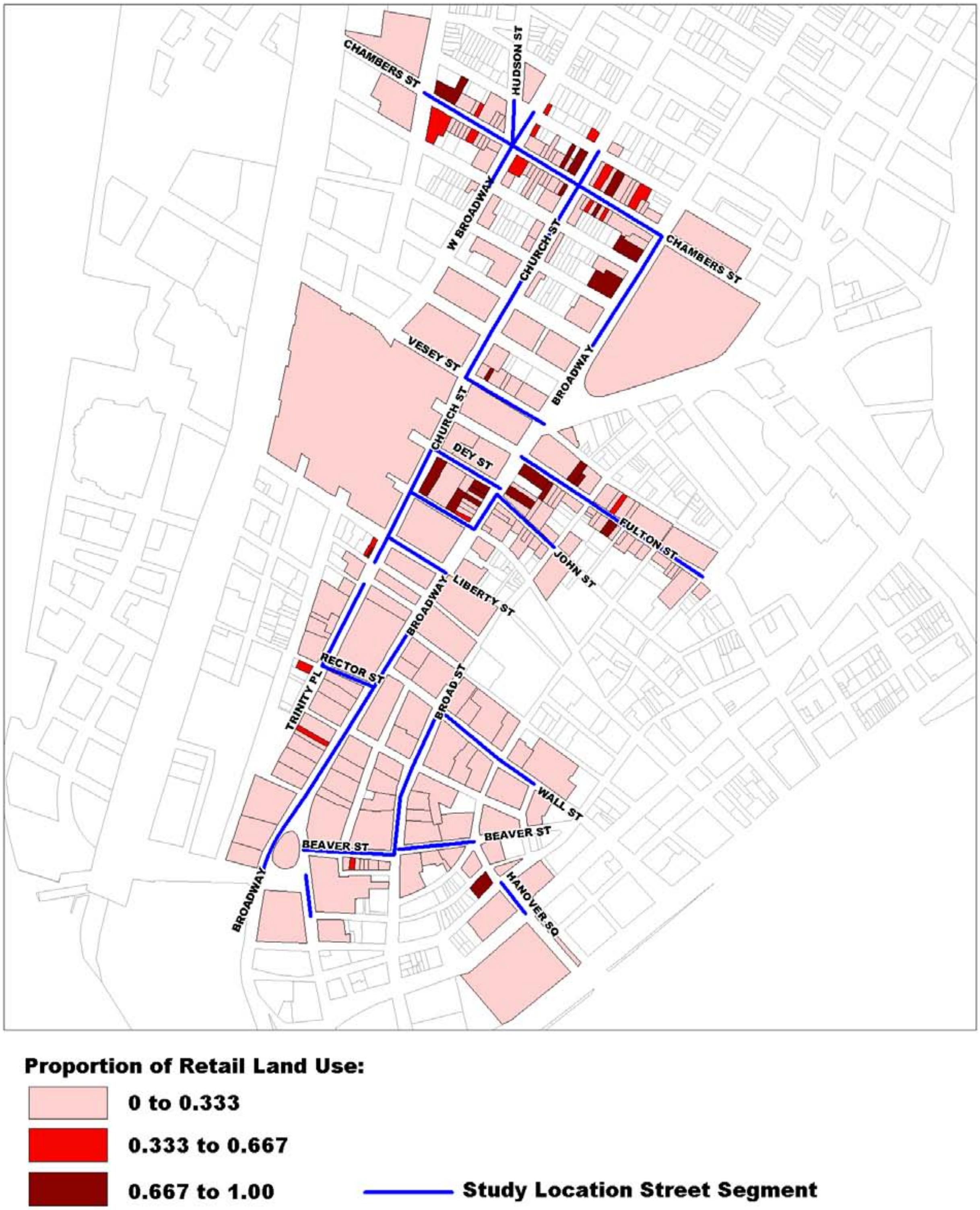

Figure 5.16. Proportion of Retail-Oriented Land Use at Study Sites

Table 5.9. Correlation between Land Use Area and Pedestrian Trip Purpose at Study Locations

		Trip: Unknown	Trip: Tourist	Trip: Non-work	Trip: Work	Area of Land Use: Residential	Area of Land Use: Office	Area of Land Use: Retail
Trip: Unknown	Correlation Coefficient	1.000	0.035	0.043	-0.800**	-0.149	-0.442**	0.387**
	Sig. (2-tailed)		0.707	0.639	0.000	0.107	0.000	0.000
Trip: Tourist	Correlation Coefficient	0.035	1.000	0.095	-0.333**	-0.108	0.190*	-0.155
	Sig. (2-tailed)	0.707		0.303	0.000	0.241	0.038	0.092
Trip: Non-work	Correlation Coefficient	0.043	0.095	1.000	-0.450**	0.013	-0.320**	0.201*
	Sig. (2-tailed)	0.639	0.303		0.000	0.891	0.000	0.029
Trip: Work	Correlation Coefficient	-0.800**	-0.333**	-0.450**	1.000	0.216*	0.431**	-0.368**
	Sig. (2-tailed)	0.000	0.000	0.000		0.019	0.000	0.000
Area of Land Use: Residential	Correlation Coefficient	-0.149	-0.108	0.013	0.216*	1.000	-0.067	-0.513**
	Sig. (2-tailed)	0.107	0.241	0.891	0.019		0.469	0.000
Area of Land Use: Office	Correlation Coefficient	-0.442**	0.190*	-0.320**	0.431**	-0.067	1.000	-0.366**
	Sig. (2-tailed)	0.000	0.038	0.000	0.000	0.469		0.000
Area of Land Use: Retail	Correlation Coefficient	0.387**	-0.155	0.201*	-0.368**	-0.513**	-0.366**	1.000
	Sig. (2-tailed)	0.000	0.092	0.029	0.000	0.000	0.000	

Note: N = 119
**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

2. Location Characteristics and Speed

Analyzing pedestrian characteristics alone leads us to conclusions about how individuals' speeds relate to different factors. This level of analysis does not address a simple fact about pedestrian level of service: pedestrian LOS is assigned to locations rather than pedestrians. Questions about how locations—with their confluence of diverse pedestrian characteristics and speeds—impact the flow of pedestrians themselves still need to be addressed.

In this section, several key factors are analyzed:

- Which pedestrian characteristics, in aggregate within a location, explain the most variation in the speed and flow rate at that location?
- How do location characteristics, such as the land use and width of the sidewalk, help explain variation in pedestrian speed?

In order to determine what proportions of pedestrian characteristics at a location best explain variations in its walking speed, a stepwise regression analysis was carried out. The regression shows that a small number of factors contribute to most of the variation in the mean walking speed: the flow rate at the location, the proportion of pedestrians carrying a bag, walking alone, walking with a 'work' trip purpose, impeded, and the proportion of pedestrians of each gender. The coefficient of determination (r^2) is a fairly high 0.659, indicating that nearly two-thirds of the variation in mean speed by location can be explained by these factors. See Appendix G for Location Characteristics and Speed Regression Summary.

NOTE: When two cases from the regression analysis, 60E in the morning peak and 8W in the afternoon peak, are excluded, an r^2 of 0.741 is achieved—a very high coefficient of determination.

An unusual finding is the model's fairly strong negative coefficient for pedestrians who do not carry a bag. In other words, sidewalk locations with a higher proportion of people carrying bags tend to have higher walking speeds. Intuitively, this result appears suspect—especially because no significant relationship between individuals carrying bags and their own walking speed was found.

Several explanations for this anomaly were considered, given what was learned about the relationship between pedestrian characteristics and speed. Particularly, it was considered that some other factor—trip purpose or gender, for example—may be influencing whether people carry bags in addition to explaining differences in walking speed. The single most important factor appears to be the time of day. During the morning peak, the vast majority of pedestrians are carrying bags and walking quickly. At midday, fewer pedestrians carry bags and the average walking speed is much lower across locations.

The proportion of pedestrians exhibiting certain characteristics at each location and time of day was plotted in Figure 5.17. For example, at the majority of locations, the proportion of pedestrians without bags changes from between 20-30% in the morning to 40-50% at midday and back down to 20-35% in the evening.

Whether or not pedestrians are carrying bags is not the only factor explained by the time of day. Based on an analysis of variance of all the factors in the regression model, time of day explains variance in all of them except gender at a significant level ($\alpha = 0.05$).

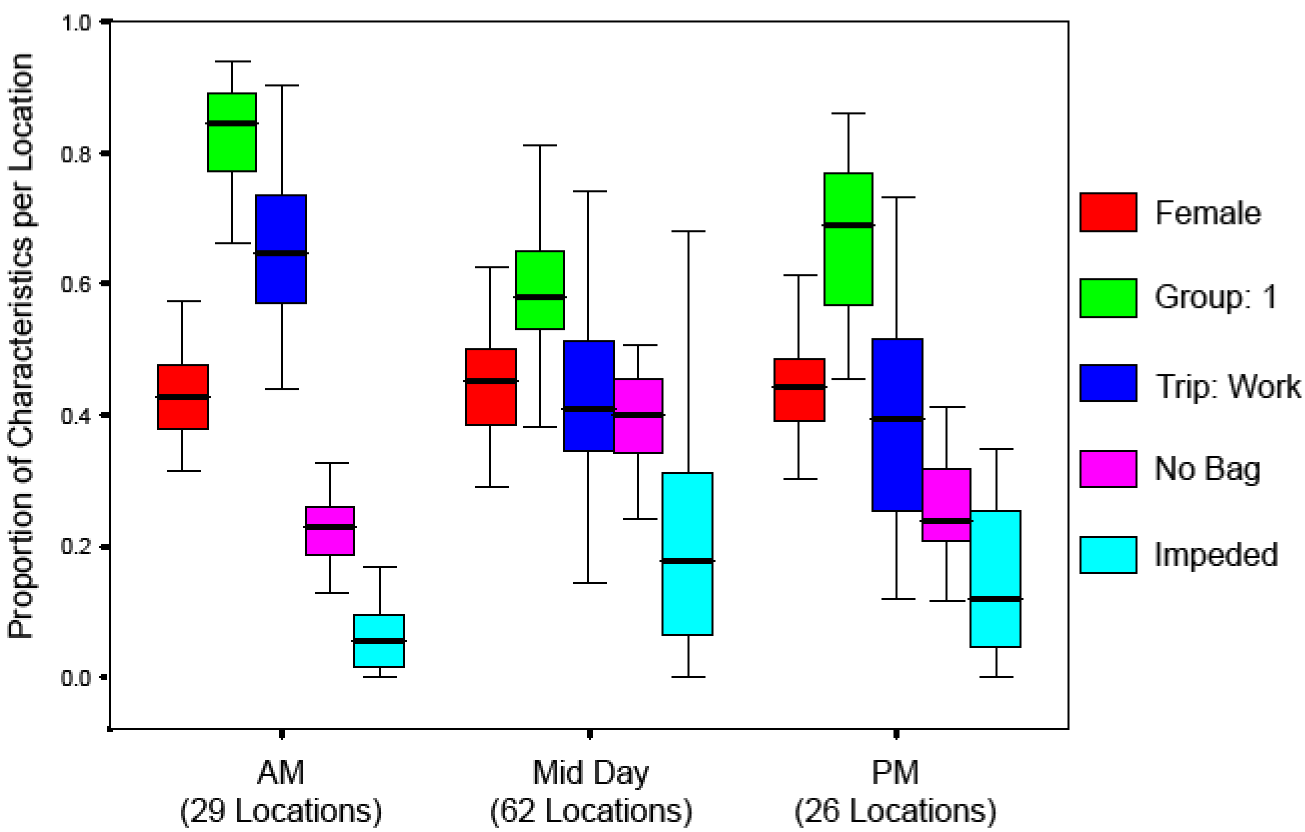

Figure 5.17. Pedestrian Characteristics by Time of Day

This example illustrates the difficulty in isolating variables to explain pedestrian speed at a location. It is also a reminder that, while this regression model helps predict a location's mean walking speed given these factors, assigning causation to any factor is not possible given the nature of this non-experimental study.

3. Speed by Time of Day

Intuitively, there is a relationship between the time of day and the proportion of each trip purpose on a sidewalk. It was observed that the majority of pedestrians during the AM peak have a work trip purpose, for example. Also, tourists and pedestrians with non-work trip purposes were observed more often at the midday and the afternoon peaks.

Time of day also explains directional flow on the sidewalk. The ratio between counts in each direction (eastbound/northbound count divided by the westbound/southbound count) was plotted in Figure 5.18. A ratio of 1.0 at a location would indicate that there were exactly the same number of eastbound and northbound trips as westbound and southbound trips. A ratio greater than 1.0 at a location would indicate a higher volume of northbound or eastbound pedestrians. A ratio less than 1.0 at a location would indicate a higher volume of southbound or westbound pedestrians.

During the AM peak the ratio is skewed slightly toward northbound and eastbound pedestrians, during the midday peak the ratio is centered around 1.0, and during the PM peak the ratio is skewed slightly to the opposite direction of the AM peak. Lower Manhattan is a CBD with a relatively small residential population of its own, so most workers in the area arrive by subway. They typically arrive in the subway station nearest their office building in the morning and leave by the same station in the evening. This accounts for the slightly unequal directional flow in the morning and afternoon. At midday, workers are already distributed among the downtown office buildings and make short round trips for lunch and errands. This accounts for the symmetry in flow during this time.

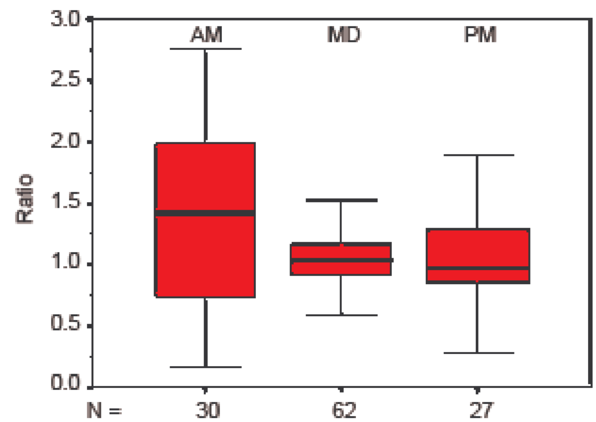

Figure 5.18. Pedestrian Directional Ratio by Time of Day

To produce Figure 5.18, locations were simply grouped by time of day. If locations had been plotted just north or east of a subway station separately from locations just south or west of a subway station, the directional differences would be even more striking.

There is also a relationship between time of day and the number of pedestrians walking alone. During the morning and, to a lesser extent, the evening peak, pedestrians tend to walk alone. This is because commuters tend to walk alone from their subway stop to the office and vice versa. At midday, workers frequently take lunch in groups and mingle with groups of tourists and non-workers who are shopping or sight-seeing.

Because time of day explains so much about the proportion of pedestrian characteristics and the mean pedestrian speed at a location, regression analyses were run to determine the factors that explained the most variance in pedestrian speed, proportion of impeded pedestrians, and flow rate for each time of day (see Table 5.10. for summary of AM, Mid-day and PM mean speed regression factors).

a. Regression – Speed AM

According to a stepwise regression, the most important set of factors in explaining the mean speed of a location in the morning peak period are the flow rate, the proportion of pedestrians whose trip purpose is work, the proportion of pedestrians engaged in some activity like talking on the phone or carrying

Table 5.10. Speed by Time of Day – Mean Speed Factors

	AM	MD	PM
r^2	0.743	0.429	0.803
Mean Speed Factors	Flow Rate	Flow Rate	Impeded
	Trip Purpose: Work	Impeded	Walking Alone
	Activity: Talking on phone or carrying food or drink		Carrying a bag
	Group Size: Three		Trip Purpose: Work

food/drink, and the proportion of pedestrians walking in groups of three (r^2 = 0.743).

Flow rate and work trip purpose were also important in explaining speeds for all times of the day, but the other factors were not. By itself, the proportion of distracted pedestrians by time of day explains 0.060 of the variance in speed. Groups of three explain 0.050 of the variance in speed. The distribution of pedestrians who have these characteristics is similar to pedestrians at other times of day (see Appendix H for Speed by Time of Day Regression Summary).

b. Regression – Speed Mid-Day

According to a stepwise regression, the most important set of factors in explaining the mean speed of a location in the midday peak period are the flow rate and the proportion of pedestrians who are impeded (r^2 = 0.429). The coefficient of determination is comparatively low at midday. This is because the mean speed at each location varies much more at midday than it does in the morning and afternoon peaks. In addition, midday flow is more complex. There are more (and larger) groups, more trip purpose diversity, and higher pedestrian volumes than at any other time of the day (see Appendix H for Speed by Time of Day Regression Summary).

c. Regression – Speed PM

According to a stepwise regression, the most important set of factors in explaining the mean speed of a location in the afternoon peak period are the proportion of pedestrians who are impeded, walking alone, carrying a bag, and whose trip purpose is work (r^2 = 0.803) (see Appendix H for Speed by Time of Day Regression Summary).

4. Location Characteristics and Impedance

A series of backward stepwise regression analyses were undertaken to determine the effect that variations in pedestrian characteristics had on the proportion of impeded pedestrians at each study site. The dependent variable in this analysis was the observed proportion of pedestrians at each study site who were impeded, and the independent (predictor) variables were the pedestrian characteristics described above in the pedestrian characteristics section. There were four backward stepwise regression analyses undertaken in this series: one for the morning (AM) observations, one for the mid-day (MD) observations, one for the evening (PM) observations and one for all observations regardless of the time of day. The reason that the analysis was divided into different times of day was because, in a preliminary examination of the impedance data, it appeared that there was significant variation in the extent of pedestrian impedance across different times-of-day. Therefore, time of day appears in itself to be a strong predictor of the proportion of impedance, so it is important to determine the effect of pedestrian variables while controlling for effect of the time of day.

In the overall (all times of day) analysis:

- The coefficient of determination (r^2) is a moderate 0.416;
- The pedestrian variables determined to be significant in the regression model are flow rate and mean speed; and
- Mean speed has a coefficient of -0.239, while flow rate has a coefficient of 0.033.

These coefficients indicate that impedance is negatively correlated with mean speed and positively correlated with flow rate. In other words, when a location's overall mean speed increases, the proportion of impeded pedestrians at that location decreases. This result seems intuitive. Also, when the flow rate (ped/min/ft) increases, the proportion of impeded pedestrians increases. This would seem to make sense too (when the density of people increases over a certain number of minutes, more people will likely be impeded by others). Recalling that the r^2 in this model is 0.416, the regression results state that 41.6% of the variation of impedance on the study sidewalks can be explained by the mean speed and flow rate of the pedestrians observed on the sidewalk.

The results of the AM analysis are more striking than those of the other three:

– The r^2 in the AM regression is 0.647, which is significantly higher than that of the overall model, described above;
– The significant predictor variables are flow rate, proportion of female pedestrians, and proportion of pedestrians without bags; and
– The female variable has a coefficient of -0.256, while the no bag variable has a coefficient of -0.249 and the flow rate variable has a coefficient of 0.046.

These coefficients indicate that, in the morning, impedance is negatively correlated with the proportion of females on the sidewalk, is negatively correlated with the proportion of pedestrians who are not carrying a bag, and is positively correlated with flow rate. In other words, in the morning, impedance on a sidewalk decreases when the sidewalk's proportion of female pedestrians and the proportion of pedestrians without bags increases. It could be because female pedestrians and pedestrians with bags walk slower than the overall population, they become obstacles to others which leads to impedance. Also, as in the previous model, impedance increases when the flow rate increases. The r^2 value indicates that 64.7% of the variation of sidewalk impedance in the morning can be explained by the proportion of women, the proportion of pedestrians without bags and the flow rate of pedestrians on the sidewalk.

In the MD analysis:

– The r^2 value is 0.424, also a moderate value;
– The significant predictor variables are flow rate, mean speed, and the proportion of pedestrians walking in groups of 4 or more; and
– The flow rate variable has a coefficient of 0.022, while the mean speed variable has a coefficient of -0.462 and the group of 4+ variable has a coefficient of -0.548.

As in the morning, the mid-day sidewalk impedance increases as the flow rate increases and decreases as the mean speed increases. In addition, the mid-day impedance decreases as the proportion of pedestrians in groups of 4 or more increases. This does not seem to make intuitive sense. The mid-day model's r^2 value indicates that 42.4% of the variation of sidewalk impedance can be explained by the proportion of pedestrians walking in groups of 4 or more, the flow rate and pedestrian mean speed on the sidewalk.

Finally, in the PM analysis, the r^2 value is the lowest, at 0.037. In this analysis, however, there are no predictor variables significant at the 95% level. Therefore, it does not appear that the impedance of sidewalks in the analysis during the evening hours can be explained

Table 5.11. Location Characteristics and Impedance Summary – Significant Variables

r^2	Overall		AM		MD		PM	
	0.416		0.647		0.424		0.037	
Significant Variables	**Variables**	**Coefficient**	**Variables**	**Coefficient**	**Variables**	**Coefficient**	**Variables**	**Coefficient**
	Flow Rate	0.033	Flow Rate	0.046	Flow Rate	0.022	None	
	Mean Speed	-0.239	Female	-0.256	Mean Speed	-0.462		
			No Bags	-0.249	Group Size >4	-0.548		

by the variation in any of the individual pedestrian variables (see Table 5.11. Location Characteristics and Impedance – Significant Variables).

5. Location Data and Pedestrian LOS

The pedestrian level of service was calculated for all locations using the HCM methodology and using the methodology derived by Pushkarev and Zupan. For every location, platoon conditions based on observations were assumed. In both cases, there were three locations with LOS 'D' based on the HCM methodology and 'CROWDED' based on the Pushkarev-Zupan methodology. The distribution between locations with higher scores differed, however. The HCM was a little more forgiving, assigning a LOS of 'B' to 89 locations and a LOS of 'C' to 27 locations. Pushkarev-Zupan's methodology resulted in 56 locations at the 'IMPEDED' level and 60 locations at the 'CONSTRAINED' level. In other words, Pushkarev-Zupan's methodology resulted in worse locations ratings than the HCM methodology (see Tables 5.12., 5.13. and 5.14.).

These HCM LOS categories were compared to variables with which the TD was more familiar: mean walking speed and the proportion of impeded pedestrians. As shown in boxplots 5.19., 5.20., 5.21., and 5.22. below illustrate the relationship between LOS and these variables. As the LOS categories at each location worsens, the mean speed decreases and the proportion of impeded pedestrians increases.

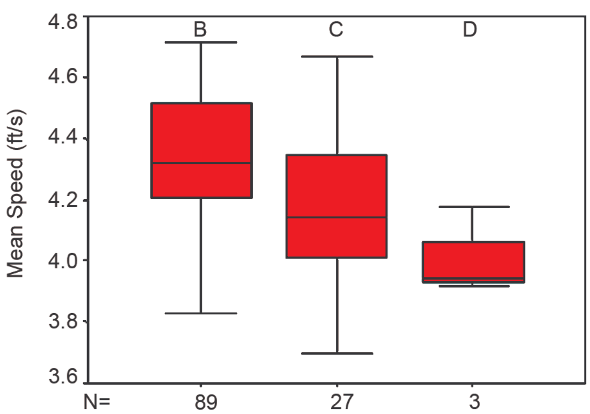

Figure 5.19. HCM LOS Platooning and Impedance

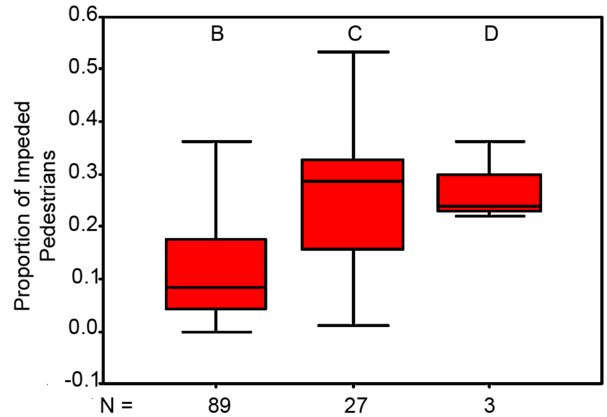

Figure 5.21. HCM LOS Platooning and Mean Speed

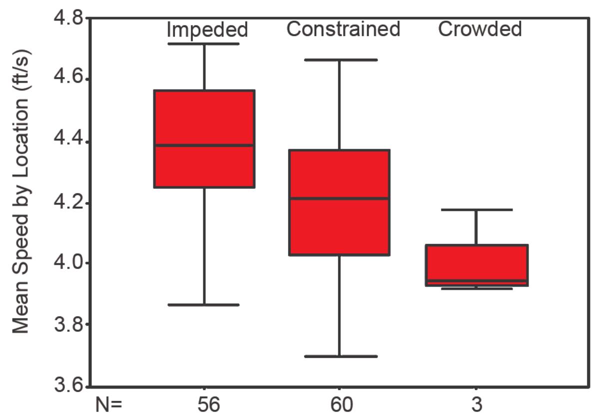

Figure 5.20. Zupan's LOS Platooning and Impedance

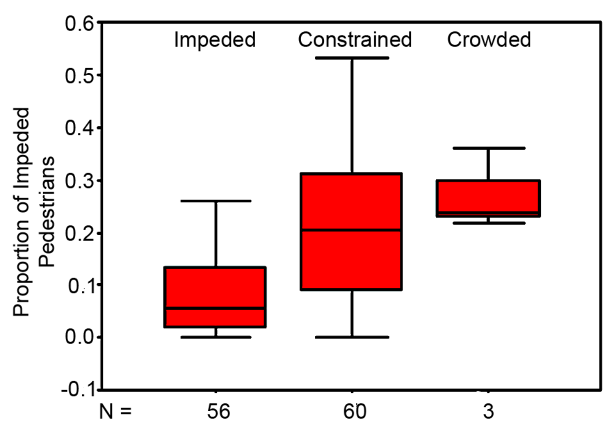

Figure 5.22. Zupan's LOS Platooning and Mean Speed

This indicates that level of service does appear to measure factors that pedestrians perceive on the sidewalk—changes in walking speed and rates of impediment. One question is still open: where should the lines between LOS grades be drawn? Should they be based on factors like walking speed and rate of impediment or should they be derived based on a delay calculation similar to the one discussed above? That the HCM and Pushkarev-Zupan methodologies do not agree on this point makes it even less clear that New York City pedestrians' preferences are incorporated in the pedestrian LOS calculation.

Table 5.12. HCM LOS, Zupan's LOS, and Pedestrian Delay Analysis, AM

LOC	HCM LOS		Zupan		Median Speed (ft/s)		% Delay*	Seconds** Lost (Gained) @1,070 ft***
	Average	Platoon	Average	Platoon	Unimpeded	All		
06N	A	B	Impeded	Constrained	4.36	4.30	1.23%	-3.05
06S	A	B	Unimpeded	Impeded	4.74	4.73	0.16%	-0.36
07E	A	B	Unimpeded	Impeded	4.74	4.69	1.07%	-2.43
07W	A	B	Unimpeded	Impeded	4.62	4.62	0.00%	0.00
08E	A	B	Unimpeded	Impeded	4.52	4.52	0.00%	0.00
08W	A	B	Unimpeded	Impeded	4.76	4.76	0.00%	0.00
09E	A	B	Unimpeded	Impeded	4.70	4.69	0.23%	-0.53
09W	A	B	Unimpeded	Impeded	4.55	4.55	0.00%	0.00
10E	A	B	Unimpeded	Impeded	4.48	4.48	0.00%	0.00
10W	A	B	Unimpeded	Impeded	4.35	4.36	-0.21%	(0.517)
11E	A	B	Unimpeded	Impeded	4.79	4.79	0.00%	0.00
11W	A	B	Unimpeded	Impeded	4.69	4.69	0.00%	0.00
12E	A	B	Unimpeded	Impeded	4.66	4.62	0.82%	-1.89
12W	A	B	Unimpeded	Impeded	4.48	4.49	-0.17%	(0.411)
13E	A	B	Unimpeded	Impeded	4.61	4.60	0.25%	-0.57
13W	A	B	Impeded	Constrained	4.62	4.57	1.01%	-2.36
14E	A	B	Unimpeded	Impeded	4.74	4.74	0.00%	0.00
38E	A	C	Impeded	Constrained	4.41	4.39	0.26%	-0.63
38W	A	B	Impeded	Constrained	4.54	4.53	0.30%	-0.72
39S	A	B	Unimpeded	Impeded	4.43	4.43	0.00%	0.00
41N	A	B	Impeded	Constrained	4.66	4.66	0.10%	-0.22
43N	A	C	Impeded	Constrained	4.60	4.59	0.34%	-0.80
43S	A	B	Unimpeded	Impeded	4.61	4.62	-0.16%	(0.373)
45E	A	B	Impeded	Constrained	4.58	4.57	0.41%	-0.97
45W	A	C	Impeded	Constrained	4.22	4.20	0.55%	-1.40
51E	A	B	Unimpeded	Impeded	4.78	4.72	1.22%	-2.77
55S	A	B	Unimpeded	Impeded	4.45	4.45	0.00%	0.00
56W	A	B	Unimpeded	Impeded	4.41	4.41	-0.07%	(0.181)
57S	A	B	Unimpeded	Impeded	4.68	4.54	2.96%	-6.98
60E	A	B	Impeded	Constrained	3.89	3.89	0.00%	0.00

* % Delay = (median unimpeded speed - median all speed) \ median unimpeded speed
** Seconds Lost/Gain = (1,070 feet / median unimpeded speed) – (1,070 feet / median actual speed)
*** 1,070 ft derived from Fruin's research.

Table 5.13. HCM LOS, Zupan's LOS, and Pedestrian Delay Analysis, MD

LOC	HCM LOS		Zupan		Median Speed (ft/s)		% Delay*	Seconds** Lost (Gained) @1,070 ft***
	Average	Platoon	Average	Platoon	Unimpeded	All		
01N	A	B	Unimpeded	Impeded	4.09	4.04	1.11%	-2.95
01S	A	B	Unimpeded	Impeded	4.46	4.30	3.47%	-8.63
02W	A	B	Unimpeded	Impeded	4.32	4.31	0.19%	-0.46
03E	A	B	Impeded	Constrained	4.34	4.26	1.66%	-4.17
04E	A	B	Unimpeded	Impeded	4.33	4.31	0.42%	-1.04
04W	A	B	Unimpeded	Impeded	4.16	4.16	0.00%	0.00
05E	A	C	Impeded	Constrained	4.11	4.06	1.15%	-3.03
05W	A	B	Impeded	Constrained	4.05	4.04	0.39%	-1.03
06N	A	B	Impeded	Constrained	4.08	3.88	4.88%	-13.46
06S	A	B	Unimpeded	Impeded	4.28	4.22	1.38%	-3.49
07E	A	C	Impeded	Constrained	4.24	4.18	1.42%	-3.65
07W	A	B	Impeded	Constrained	4.09	4.08	0.31%	-0.82
08E	A	B	Impeded	Constrained	4.35	4.35	0.13%	-0.32
08W	A	B	Impeded	Constrained	4.26	4.27	-0.28%	(0.71)
09E	A	B	Unimpeded	Impeded	4.30	4.27	0.64%	-1.62
09W	A	B	Unimpeded	Impeded	4.20	4.18	0.58%	-1.50
10E	A	B	Unimpeded	Impeded	4.38	4.38	0.00%	0.00
10W	A	C	Impeded	Constrained	4.28	4.14	3.14%	-8.10
11E	A	B	Unimpeded	Impeded	4.36	4.22	3.31%	-8.40
11W	C	D	Constrained	Crowded	4.23	4.17	1.48%	-3.80
12E	A	B	Impeded	Constrained	4.17	4.16	0.23%	-0.58
12W	A	B	Impeded	Constrained	4.27	4.24	0.65%	-1.65
13E	A	B	Unimpeded	Impeded	4.35	4.27	1.90%	-4.76
13W	A	C	Impeded	Constrained	4.00	4.04	-0.83%	(2.20)
14E	A	C	Impeded	Constrained	4.28	4.07	4.91%	-12.90
16N	A	B	Impeded	Constrained	4.41	4.19	4.89%	-12.49
18N	A	C	Impeded	Constrained	3.97	3.92	1.31%	-3.57
18S	A	C	Impeded	Constrained	3.66	3.33	8.98%	-28.85
20N	A	C	Impeded	Constrained	4.02	3.57	11.09%	-33.22
20S	A	B	Impeded	Constrained	4.17	3.68	11.77%	-34.26
22N	A	B	Impeded	Constrained	4.10	3.78	7.79%	-22.07
22S	A	C	Impeded	Constrained	3.89	3.76	3.35%	-9.55
25N	A	B	Unimpeded	Impeded	4.00	4.18	-4.47%	(11.44)
25S	A	B	Impeded	Constrained	4.52	4.42	2.14%	-5.17
27N	A	C	Impeded	Constrained	4.21	4.17	0.95%	-2.45
30E	A	B	Impeded	Constrained	4.24	4.24	0.00%	0.00
31N	A	C	Impeded	Constrained	3.90	3.77	3.28%	-9.31
32E	A	B	Unimpeded	Impeded	4.22	4.20	0.37%	-0.94
34N	A	B	Unimpeded	Impeded	4.37	4.39	-0.50%	(1.21)
35W	A	B	Impeded	Constrained	3.86	3.69	4.34%	-12.59
37W	A	B	Impeded	Constrained	4.17	4.14	0.68%	-1.76
38E	B	D	Constrained	Crowded	3.96	3.90	1.53%	-4.20
38W	A	C	Impeded	Constrained	3.99	3.99	0.04%	-0.12
39N	A	B	Unimpeded	Impeded	4.32	4.33	-0.22%	(0.54)
39S	A	B	Unimpeded	Impeded	4.13	4.13	0.00%	0.00
41N	A	C	Impeded	Constrained	4.37	4.28	1.95%	-4.86
41S	A	C	Impeded	Constrained	4.08	4.23	-3.72%	(9.41)
43N	A	B	Impeded	Constrained	4.37	4.35	0.49%	-1.20
43S	A	B	Unimpeded	Impeded	4.36	4.36	0.00%	0.00
44S	A	B	Unimpeded	Impeded	4.38	4.30	1.82%	-4.54
45E	C	D	Constrained	Crowded	3.99	3.84	3.77%	-10.51
45W	B	C	Impeded	Constrained	3.91	3.82	2.35%	-6.57
46E	A	C	Impeded	Constrained	4.33	4.24	2.06%	-5.20
51E	A	B	Impeded	Constrained	3.97	3.99	-0.59%	(1.58)
52E	A	B	Impeded	Constrained	4.16	4.16	0.08%	-0.21
52W	A	B	Unimpeded	Impeded	3.97	3.83	3.45%	-9.62
53S	A	B	Unimpeded	Impeded	4.21	4.11	2.57%	-6.70
54N	A	B	Unimpeded	Impeded	4.38	4.34	0.88%	-2.16
55S	A	B	Impeded	Constrained	4.17	3.98	4.55%	-12.23
56W	A	B	Impeded	Constrained	4.52	4.37	3.26%	-7.98
57S	A	B	Impeded	Constrained	4.20	3.95	5.92%	-16.02
60E	B	C	Impeded	Constrained	4.06	3.97	2.23%	-6.01

* % Delay = (median unimpeded speed - median all speed) \ median unimpeded speed
** Seconds Lost/Gain = (1,070 feet / median unimpeded speed) – (1,070 feet / median actual speed)
*** 1,070 ft derived from Fruin's research.

Table 5.14. HCM LOS, Zupan's LOS, and Pedestrian Delay Analysis, PM

LOC	HCM LOS		Zupan		Median Speed (ft/s)		% Delay*	Seconds** Lost (Gained) @1,070 ft***
	Average	Platoon	Average	Platoon	Unimpeded	All		
06N	A	B	Impeded	Constrained	4.14	3.99	3.81%	-10.24
06S	A	B	Impeded	Constrained	4.45	4.37	1.86%	-4.57
07E	A	B	Unimpeded	Impeded	4.86	4.80	1.24%	-2.77
07W	A	B	Unimpeded	Impeded	4.54	4.53	0.23%	-0.54
08E	A	B	Unimpeded	Impeded	4.42	4.42	0.00%	0.00
08W	A	B	Unimpeded	Impeded	3.95	3.94	0.39%	-1.06
09E	A	B	Unimpeded	Impeded	4.21	4.18	0.63%	-1.60
09W	A	B	Unimpeded	Impeded	4.46	4.40	1.33%	-3.24
10E	A	B	Unimpeded	Impeded	4.35	4.27	1.79%	-4.49
12E	A	B	Unimpeded	Impeded	4.10	4.10	0.00%	0.00
12W	A	B	Unimpeded	Impeded	4.69	4.66	0.72%	-1.66
13E	A	B	Unimpeded	Impeded	4.22	4.12	2.42%	-6.28
13W	A	C	Impeded	Constrained	4.46	4.32	3.13%	-7.77
14E	A	B	Impeded	Constrained	4.34	4.23	2.37%	-5.98
38E	A	C	Impeded	Constrained	4.43	4.43	0.00%	0.00
38W	A	C	Impeded	Constrained	4.72	4.70	0.31%	-0.72
39S	A	B	Unimpeded	Impeded	4.52	4.31	4.59%	-11.40
41N	A	C	Impeded	Constrained	4.73	4.62	2.15%	-4.97
43N	A	B	Impeded	Constrained	4.55	4.51	0.85%	-2.01
43S	A	C	Impeded	Constrained	4.50	4.45	1.19%	-2.86
45E	A	C	Impeded	Constrained	4.38	4.38	0.00%	0.00
45W	A	C	Impeded	Constrained	4.09	4.09	0.00%	0.00
51E	A	B	Impeded	Constrained	4.47	4.46	0.22%	-0.53
55S	A	B	Unimpeded	Impeded	4.63	4.46	3.65%	-8.76
56W	A	B	Unimpeded	Impeded	4.01	4.00	0.20%	-0.55
57S	A	B	Unimpeded	Impeded	4.23	4.23	0.00%	0.00
60E	A	B	Impeded	Constrained	4.56	4.36	4.25%	-10.42

* % Delay = (median unimpeded speed - median all speed) \ median unimpeded speed
** Seconds Lost/Gain = (1,070 feet / median unimpeded speed) – (1,070 feet / median actual speed)
*** 1,070 ft derived from Fruin's research.

C. Others

1. Pedestrian Delay

The HCM's measurement of delay for the vehicular LOS calculation does not have an equivalent in its pedestrian LOS analysis. As discussed in Chapter 2, control delay per vehicle is a crucial measurement in determining vehicular LOS for signalized and unsignalized intersections. According to HCM, "the average control delay per vehicle is estimated for each lane group and aggregated for each approach and for the intersection as a whole. LOS is directly related to the control delay value" (HCM). As mentioned in Chapter 2, control delay is a summation of "initial deceleration delay, queue move-up, stopped delay, and final acceleration delay" at vehicular intersections. Control delay is measured in seconds per vehicle, and at signalized intersections, an LOS of A corresponds with less than or equal to 10 seconds of delay per vehicle; an LOS of C corresponds with 20 to 35 seconds of delay per vehicle and an LOS of F corresponds with greater than 80 seconds of delay per vehicle.

In this study, the walking speeds of pedestrians who are both impeded and unimpeded by sidewalk obstacles and by other pedestrians have been measured. Assuming that, on any given sidewalk segment, the median unimpeded speed for all measured pedestrians is close to the "ideal" speed, then a measurement of the difference between the median unimpeded speed and the "actual" median speed (including unimpeded and impeded speeds) would represent the overall pedestrian delay for that segment.

The overall mean speed in this study, including all locations and pedestrian characteristics, is about 4.27 ft/sec. However, field work was undertaken at numerous sites at different times of day. The land use and pedestrian characteristics of sites varied widely, and because of this, mean speeds at each location also varied. In addition, the time of day had a profound influence on the median speeds of pedestrians throughout the study sites. Because 4.27 ft/sec. represents the overall mean speed, it is a measurement which lumps the speeds of unimpeded walkers in with impeded walkers, as well as speeds at different times of day on characteristically different sidewalk segments.

In order to more closely represent the actual differences in pedestrian conditions for individual sidewalk segments and to arrive at a more accurate LOS measurement, a delay component, representing the difference between the "ideal" speed and "actual" speed at a location, would be useful. It might also be beneficial to include a "time of day" factor in the LOS calculation, as median speeds vary widely at different locations by time of day, but perhaps it is more realistic in terms of data gathering to focus the analysis on planning for the time of day with the worst delay, which appears to be mid-day.

To compute delay in Table 5.15., the following formula was used for each location:

**[(1,070 feet / median unimpeded speed) –
(1,070 feet / median actual speed)]**

The result is the delay, in seconds, in excess of the "ideal" walking time which would be experienced at each location if each location were a uniform representative walking length (1,070 feet). In order to represent delay in a conceptually meaningful way, for the delay computation the TD has used John Fruin's (1971) determination that the median walking distance for pedestrians in Manhattan is 1,070 feet. It is assumed this distance has not changed significantly since the 1970s. If this length has changed significantly, it is not extremely important to this analysis, as the formula is only using Fruin's measurement as an aid in illustrating delay over a uniform walking distance. The distance can be changed to any deemed more accurate.

As is apparent in the table below (Table 5.15.), several locations (though a small proportion of all locations) show a "delay" of zero, or show a positive "delay," in which the median actual speed is faster than the median unimpeded (ideal) speed. Locations with zero delay are locations where the median actual speed exactly matched the median unimpeded speed; this most likely came about because the locations did not have any impeded pedestrians. Zero delay was observed in greatest proportion at locations studied in the morning hours. This may be due to the fact that many of the AM pedestrians were single, relatively fast walkers on their way to work.

Locations with positive delay are locations where, although pedestrians may have been impeded, overall the impeded pedestrians walked *faster* than the unimpeded pedestrians, and the median speed of the impeded and unimpeded pedestrians combined outpaced that of the unimpeded pedestrians alone. This was a phenomenon noticed primarily on sidewalks where heavy business-oriented traffic mixed with heavy non-business traffic, where those who tended to walk significantly faster than the median (male business pedestrians walking alone)

Table 5.15. Pedestrian Delay Analysis, All Time Periods

LOC	Median Speed (ft/s)		% Delay*	Seconds** Lost (Gained) @1,070 ft***
	Unimpeded	All		
01N	4.09	4.04	1.11%	-2.95
01S	4.46	4.30	3.47%	-8.63
02W	4.32	4.31	0.19%	-0.46
03E	4.34	4.26	1.66%	-4.17
04E	4.33	4.31	0.42%	-1.04
04W	4.16	4.16	0.00%	0.00
05E	4.11	4.06	1.15%	-3.03
05W	4.05	4.04	0.39%	-1.03
06N	4.20	4.07	3.21%	-8.44
06S	4.45	4.33	2.54%	-6.28
07E	4.55	4.51	0.87%	-2.07
07W	4.36	4.33	0.50%	-1.23
08E	4.46	4.40	1.32%	-3.20
08W	4.24	4.23	0.28%	-0.71
09E	4.32	4.30	0.43%	-1.07
09W	4.43	4.39	0.97%	-2.37
10E	4.44	4.36	1.99%	-4.90
10W	4.31	4.27	0.95%	-2.38
11E	4.61	4.48	2.72%	-6.50
11W	4.45	4.38	1.56%	-3.81
12E	4.30	4.19	2.67%	-6.81
12W	4.44	4.44	0.00%	0.00
13E	4.40	4.35	1.16%	-2.85
13W	4.42	4.34	2.02%	-4.99
14E	4.54	4.26	6.26%	-15.74
16N	4.41	4.19	4.89%	-12.49
18N	3.97	3.92	1.31%	-3.57
18S	3.66	3.33	8.98%	-28.85
20N	4.02	3.57	11.09%	-33.22
20S	4.17	3.68	11.77%	-34.26
22N	4.10	3.78	7.79%	-22.07
22S	3.89	3.76	3.35%	-9.55
25N	4.00	4.18	-4.47%	(11.444)
25S	4.52	4.42	2.14%	-5.17
27N	4.21	4.17	0.95%	-2.45
30E	4.24	4.24	0.00%	0.00
31N	3.90	3.77	3.28%	-9.31
32E	4.22	4.20	0.37%	-0.94
34N	4.37	4.39	-0.50%	(1.208)
35W	3.86	3.69	4.34%	-12.59
37W	4.17	4.14	0.68%	-1.76
38E	4.31	4.24	1.51%	-3.80
38W	4.49	4.37	2.65%	-6.48
39N	4.32	4.33	-0.22%	(0.536)
39S	4.30	4.28	0.41%	-1.04
41N	4.57	4.49	1.76%	-4.20
41S	4.08	4.23	-3.72%	(9.412)
43N	4.49	4.44	1.00%	-2.41
43S	4.51	4.48	0.62%	-1.49
44S	4.38	4.30	1.82%	-4.54
45E	4.40	4.30	2.25%	-5.60
45W	4.09	4.07	0.58%	-1.54
46E	4.33	4.24	2.06%	-5.20
51E	4.47	4.42	1.14%	-2.75
52E	4.16	4.16	0.08%	-0.21
52W	3.97	3.83	3.45%	-9.62
53S	4.21	4.11	2.57%	-6.70
54N	4.38	4.34	0.88%	-2.16
55S	4.39	4.27	2.77%	-6.93
56W	4.35	4.33	0.51%	-1.27
57S	4.29	4.21	1.99%	-5.05
60E	4.12	4.09	0.74%	-1.94

* % Delay = (median unimpeded speed - median all speed) \ median unimpeded speed
** Seconds Lost/Gain = (1,070 feet / median unimpeded speed) – (1,070 feet / median actual speed)
*** 1,070 ft derived from Fruin's research.

were impeded by those who tended to walk slower (tourists, non-business, etc.), creating a situation in which the median speed of those who were not impeded (but were naturally slower) was less than the median speed overall (including the impeded business walkers, who were naturally fast).

The inadequacy of the current HCM methodology can be illustrated by an analysis of the location which, using the above formula, provided pedestrians with the greatest delay of all the study locations. In a mid-day count, the conditions at location 20S (on the south side of Fulton Street between Nassau Street and William Street) would provide a pedestrian with 34.26 seconds of delay in excess of the amount of time it would take him or her to walk the sidewalk's median "ideal" speed for Fruin's typical Manhattan walking distance of 1,070 feet. Using the site's median "ideal" (unimpeded) speed of 4.167 ft/sec., the time it would take to walk 1,070 feet would be 256.779 seconds (4.28 minutes). Obviously, 34.26 seconds of delay, a 13% lost time, would represent a significant amount of lost time for the typical pedestrian "expecting" to walk a distance in 4.28 minutes. Although the high delay may indicate a poor perceived LOS at this location, the LOS calculated using the HCM methodology was "A" for the average and "B" for platoon conditions. There were 466 pedestrians counted over 15 minutes at this site, which is close to the 15-minute count average of 455 pedestrians for all sites. However, those present at this location's mid-day count agree that the sidewalk traffic conditions were relatively poor, and probably did not warrant an LOS A or B (by HCM, a LOS A is defined as "walking speeds are freely selected, and conflicts between pedestrians are unlikely" and a LOS B is defined as "sufficient area for pedestrians to select walking speeds freely to bypass other pedestrians, and to avoid crossing conflicts). In situations such as this, the inclusion of a measure of delay in the calculation of LOS could help to bring the grading system closer to a reflection of actual, observed sidewalk conditions.

One of the flaws of the current HCM methodology for determining average pedestrian LOS is that it focuses on the average overall conditions of sidewalk traffic for a set period of time. Because of things like pedestrian signal timing and subway egress, much of the pedestrian traffic encountered in the study sites in Lower Manhattan was in platoons. As Pushkarev and Zupan (1975) point out, "conditions in the platoons, not average conditions in a traffic stream, determine its perceived quality." Because of platooning, "more than half, and up to 73 percent of the people walk during minutes when flow exceeds the 15-minute average…the time period truly relevant for design appears to be not 15 minutes, 1 minute, or any other arbitrary time span, but rather that period during which flow in platoons occurs." In other words, one can not argue that pedestrian perception of sidewalk conditions is affected by the times when the sidewalk is empty (i.e. most of the time between platoons), so why are these times included in the determination of a sidewalk's level of service? This is partially addressed by the HCM calculation of a "platoon" LOS on sidewalks. However, because platooning may occur to differing degrees on different sidewalks, it would not be wise to advocate disposing of the average LOS measurement altogether.

The addition of a measurement of delay within both the "average" and "platoon" LOS calculations may bring their determined grades closer to a more descriptive illustration of realistic sidewalk traffic conditions. The consideration of delay-oriented LOS measurements, both average and platoon, may allow for a more coherent understanding of the range of pedestrian perceptions of sidewalks, which naturally encounter a range of crowding conditions over 15 minutes.

See Table 5.12., Table 5.13., and Table 5.14. for the result of the pedestrian delay analysis in the AM, MD, and PM periods.

2. Pedestrian Frictional Force

The HCM pedestrian LOS process does not include a measurement of effects from opposing pedestrian flows. In this section, it is measured whether variations in the proportions of opposing flow influence the speed of pedestrians.

Using the count data, pedestrian volumes were separated by direction. Then pedestrian speeds were analyzed according to their corresponding volumes. The ratio of the volume in the predominant flow direction to the volume in the counter-flow direction was calculated. The ratio of walking speed in the predominant flow direction to speed in the counter-flow direction was also calculated. It was then determined how many locations have higher speeds in their predominant flow direction than in their counter-flow direction, and how many locations have lower speeds in their predominant flow direction. It was assumed that a higher flow in a specific direction would either present a higher speed than the lower volume direction or higher volume direction would have a lower speed than the lower volume direction due to conflicting pedestrian flow (see Tables 5.16., 5.17., and 5.18 for volume, speed, and dominant ratio by direction, AM, MD, and PM respectively).

In other words, A and B are opposing directions at each locations and VolumeA > VolumeB:

– Volume Ratio AB = Volume A/Volume B
– Speed Ratio AB = Speed A/ Speed B

By comparing Volume Ratio AB to Speed Ratio AB, it can be determined whether there is a relationship between the direction of dominant flow and the speed in either direction.

During the AM period, 16 out of 30 locations showed that a higher volume in one direction corresponded with a higher average speed in that direction. For the midday, 27 out of 62 locations showed higher volumes in one direction corresponding with higher speeds and for the PM period, 14 out of 27 locations showed higher volumes in one direction corresponding with higher speeds. As we can see, the numbers show that almost half the time higher volumes in a particular direction are accompanied by higher speeds and

Table 5.16. Volume, Speed and Dominant Ratio by Direction, AM

Loc ID	Northbound/Eastbound		Southbound/Westbound		Dominant/Non-Dominant Ratio	
	Ped Count	Avg Speed	Ped Count	Avg Speed	Volume	Speed
06N	216	4.375	154	4.324	1.403	1.012
06S	143	4.658	72	4.613	1.986	1.010
07E	102	4.680	53	4.589	1.925	1.020
07W	112	4.656	51	4.608	2.196	1.010
08E	254	4.386	92	4.460	2.761	0.983
08W	154	4.595	110	4.718	1.400	0.974
09E	70	4.502	42	4.770	1.667	0.944
09W	118	4.578	57	4.806	2.070	0.953
10E	103	4.213	71	4.602	1.451	0.915
10W	123	4.427	132	4.540	1.073	1.026
11E	101	4.622	132	4.819	1.307	1.043
11W	118	4.647	210	4.535	1.780	0.976
12E	110	4.402	52	4.761	2.115	0.925
12W	96	4.457	51	4.515	1.882	0.987
13E	98	4.678	151	4.475	1.541	0.957
13W	186	4.618	284	4.382	1.527	0.949
14E	60	4.644	64	4.517	1.067	0.973
38E	329	4.215	377	4.464	1.146	1.059
38W	261	4.527	235	4.525	1.111	1.000
39S	76	4.393	37	4.789	2.054	0.917
41N	260	4.765	133	4.462	1.955	1.068
43N	623	4.481	129	4.590	4.829	0.976
43S	256	4.775	57	4.403	4.491	1.085
45E	117	4.452	213	4.559	1.821	1.024
45W	81	4.355	482	4.083	5.951	0.938
51E	116	4.622	262	4.745	2.259	1.027
55S	151	4.634	82	4.415	1.841	1.050
56W	115	4.481	155	4.637	1.348	1.035
57S	112	4.673	77	4.487	1.455	1.041
60E	163	3.890	330	4.107	2.025	1.056

almost half the time, higher volumes in one direction yield lower speeds. It appears that the impact of friction from opposing pedestrian volumes cannot be concluded with any statistical certainty from the initial data gathered at the study sites. A more detailed analysis of the impact of opposing volume frictional force might be advantageous. The frictional force of opposing pedestrian volumes could actually have an effect on sidewalk speeds, but that effect has not been comprehensively illustrated in the initial analysis.

Table 5.17. Volume, Speed and Dominant Ratio by Direction, MD

Loc ID	Northbound/Eastbound		Southbound/Westbound		Dominant/Non-Dominant Ratio	
	Ped Count	Avg Speed	Ped Count	Avg Speed	Volume	Speed
01N	221	4.127	145	4.249	1.524	0.971
01S	126	4.488	109	4.136	1.156	1.085
02W	117	4.513	94	4.053	1.245	1.113
03E	144	4.344	147	4.233	1.021	0.974
04E	79	4.102	106	4.390	1.342	1.070
04W	71	4.548	107	4.103	1.507	0.902
05E	229	3.939	239	4.329	1.044	1.099
05W	162	4.086	155	4.305	1.045	0.949
06N	231	4.033	270	3.923	1.169	0.973
06S	206	4.162	210	4.204	1.019	1.010
07E	199	4.140	155	4.449	1.284	0.930
07W	179	4.213	130	4.119	1.377	1.023
08E	289	4.212	256	4.357	1.129	0.967
08W	440	4.181	413	4.421	1.065	0.946
09E	206	4.221	160	4.388	1.288	0.962
09W	139	4.261	93	4.199	1.495	1.015
10E	277	4.334	272	4.404	1.018	0.984
10W	459	3.900	379	4.287	1.211	0.910
11E	352	4.160	336	4.271	1.048	0.974
11W	546	3.979	521	4.360	1.048	0.913
12E	245	4.228	220	4.059	1.114	1.042
12W	176	4.205	144	4.204	1.222	1.000
13E	148	4.553	126	4.156	1.175	1.096
13W	306	4.110	271	4.116	1.129	0.999
14E	205	4.080	216	4.079	1.054	1.000
16N	127	4.436	170	4.104	1.339	0.925
18N	213	3.782	256	4.039	1.202	1.068
18S	279	3.650	174	3.833	1.603	0.952
20N	161	3.708	223	3.681	1.385	0.993
20S	257	3.930	209	4.107	1.230	0.957
22N	210	3.966	200	3.905	1.050	1.016
22S	270	3.869	278	3.596	1.030	0.930
25N	89	4.098	96	4.076	1.079	0.995
25S	143	4.325	152	4.426	1.063	1.023
27N	230	4.169	209	3.999	1.100	1.043
30E	297	4.026	208	4.539	1.428	0.887
31N	326	3.746	337	3.893	1.034	1.039
32E	161	4.178	270	4.036	1.677	0.966
34N	81	4.513	94	4.165	1.160	0.923
35W	143	3.909	194	3.707	1.357	0.949
37W	214	4.209	209	4.261	1.024	0.988
38E	556	3.883	494	4.030	1.126	0.963
38W	391	4.099	312	3.952	1.253	1.037
39N	171	4.265	143	4.347	1.196	0.981
39S	166	4.310	170	4.080	1.024	0.947
41N	346	4.135	417	4.393	1.205	1.062
41S	140	4.212	111	4.436	1.261	0.950
43N	276	4.420	338	4.218	1.225	0.954
43S	146	4.266	161	4.554	1.103	1.068
44S	98	4.226	102	4.374	1.041	1.035
45E	484	3.824	529	4.045	1.093	1.058
45W	324	3.874	364	3.894	1.123	1.005
46E	333	4.209	319	4.233	1.044	0.994
51E	350	4.004	333	4.280	1.051	0.936
52E	225	4.207	195	4.208	1.154	1.000
52W	174	3.852	166	4.274	1.048	0.901
53S	78	4.046	95	4.092	1.218	1.011
54N	69	4.295	85	4.394	1.232	1.023
55S	240	3.705	242	4.124	1.008	1.113
56W	273	4.364	264	4.463	1.034	0.978
57S	227	4.093	177	3.940	1.282	1.039
60E	319	3.895	315	4.118	1.013	0.946

Table 5.18. Volume, Speed and Dominant Ratio by Direction, PM

Loc ID	Northbound/Eastbound		Southbound/Westbound		Dominant/Non-Dominant Ratio	
	Ped Count	Avg Speed	Ped Count	Avg Speed	Volume	Speed
06N	91	3.797	226	4.179	2.484	1.101
06S	150	4.168	169	4.506	1.127	1.081
07E	72	4.503	87	4.826	1.208	1.072
07W	111	4.422	104	4.650	1.067	0.951
08E	143	4.453	266	4.405	1.860	0.989
08W	213	3.812	238	3.954	1.117	1.037
09E	83	4.217	72	4.094	1.153	1.030
09W	108	4.666	102	4.435	1.059	1.052
10E	198	4.256	123	4.266	1.610	0.998
12E	117	4.579	132	4.189	1.128	0.915
12W	122	4.674	130	4.350	1.066	0.931
13E	120	4.339	100	4.122	1.200	1.053
13W	349	4.362	260	4.659	1.342	0.936
14E	128	4.202	131	4.337	1.023	1.032
38E	345	4.239	223	4.345	1.547	0.976
38W	396	4.727	209	4.614	1.895	1.024
39S	140	4.165	108	4.621	1.296	0.901
41N	199	4.805	477	4.562	2.397	0.950
43N	180	4.449	353	4.499	1.961	1.011
43S	105	4.354	372	4.494	3.543	1.032
45E	258	4.420	189	4.320	1.365	1.023
45W	253	3.852	157	4.196	1.611	0.918
51E	360	4.553	218	4.515	1.651	1.008
55S	83	4.612	163	4.356	1.964	0.945
56W	137	3.905	117	4.065	1.171	0.961
57S	76	4.031	84	4.427	1.105	1.098
60E	238	4.474	246	4.320	1.034	0.965

3. Seven-Day Vehicular and Pedestrian Count

During a seven day count, pedestrian characteristics data were collected in 5-minute intervals at the study's control location, on the west sidewalk of Broadway between Duane Street and Reade Street. The data was then aggregated and the hourly pedestrian volumes at the site for the seven days was determined. Looking at the weekday pedestrian volumes, similar trends were found Monday through Friday (see Appendix I for Seven Day Pedestrian and Vehicular Count Summary). From the graph, we can see that the pedestrian peak volume occurs between 1pm and 2pm. In contrast to vehicular flow, pedestrian volume in the morning period is relatively low, while late afternoon shows a second peak volume after the midday period peak (see Figure 5.23.). Weekend pedestrian volumes at this location are relatively low. This could be due to the land use of the area, which is primarily office oriented. See Appendix I for summarized weekend pedestrian volumes.

In Figure 5.23., there is an apparent trend: when pedestrian volume is high, pedestrian speed is low. In other words, there appears to be a negative correlation between speed and volume. Pedestrian characteristics such as trip purpose or impedance may be the causes of this negative correlation. The relationship between flow and speed will be discussed more in-depth in later sections.

The 7-day 24-hour ATR counts were summarized by the hour and the Tuesday to Thursday (vehicular analyses' standard in obtaining average weekday volume) volumes were averaged to obtain the average weekday vehicular volume. The average of the pedestrian volumes from Tuesday to Thursday was taken to determine the average weekday pedestrian volume. To understand the relationship

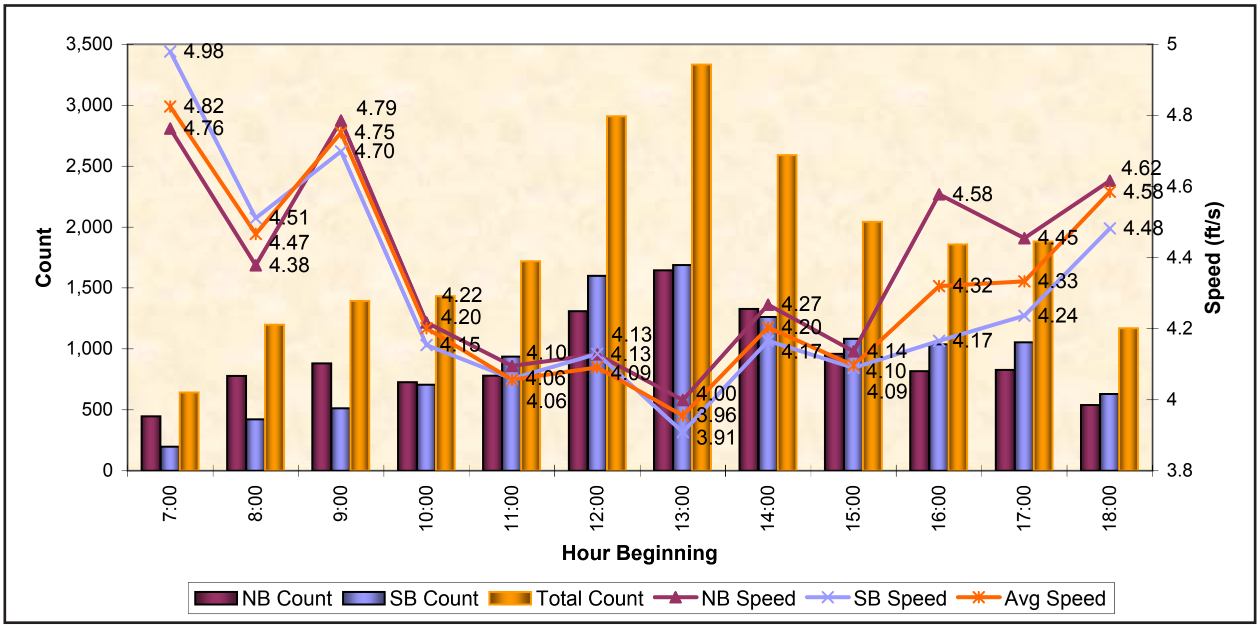

Figure 5.23. Seven-day Count: Pedestrian Count and Speed, Weekday Average

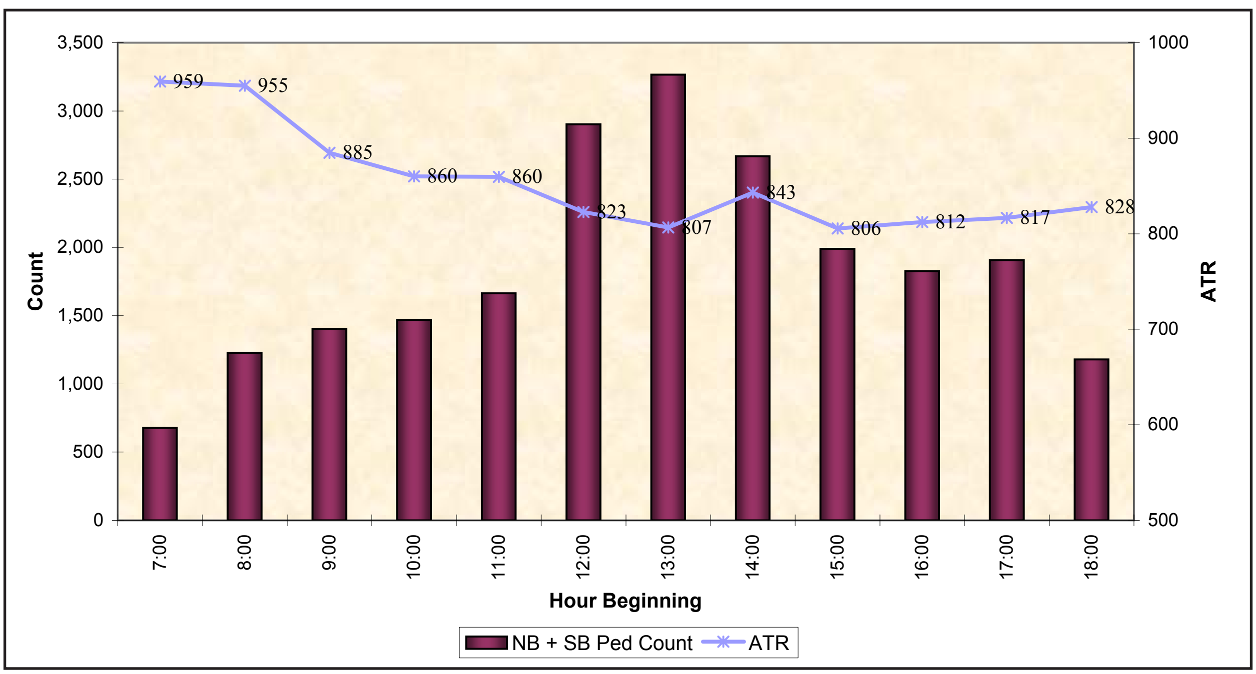

Figure 5.24. Seven-day Count: Pedestrian and Vehicular Count, Tuesday to Thursday Average

between vehicular and pedestrian flow, the two data sets were overlaid (see Figure 5.24.). The vehicular flow does not have the typical peak pattern in the morning between 7 to 9 am and afternoon peak pattern between 4 to 7 pm. Figure 5.24. shows that there was one peak during the morning, 7 to 9 am, around 960 vehicles per hour, then the traffic volume remained steady for the rest of the day, between 800 to 885 vehicles per hour. There is no evening peak, which is contrary to what one would expect in a CBD. This may be due to the fact that Broadway is a one way street running toward the downtown financial area; in the evening commuters are more likely to be driving uptown on a parallel street. Based on Figure 5.24., there is no direct correlation between pedestrian volume and vehicular volume.

4. Speed and Delay Walk

For the speed and delay walk, four team members walked the same route during specific time of day. The average walking speeds from each team member for this walk were generally higher than the HCM average of 4.00 to 4.25ft/s (see Appendix J for Speed and Delay Walk Summary by Walker and Time). One reason for the higher than average speed could be that the "speed walk" did not have a specific trip purpose (tourist, work, non-work,etc.) other than to walk on a prescribed route at the walker's desired speed, and the walker was trying to avoid interruptions. The team members' familiarity with the route could be another explanation for the higher than average speeds. Within the team, the speeds also varied due to individual physical differences.

Between March to May 2004, 50 walks were completed by four team members. Observations made during the walks include:

- On late afternoon walks, at around 3 pm to 4 pm, there were fewer pedestrians on sidewalks than at noontime walks. Because of the relative lack of impedance presented by other pedestrians, it was easier for team members to maneuver during late afternoon walks.
- Street construction on Wall Street between Broadway and Nassau created pedestrian bottleneck congestion, which reduced available sidewalk space and lowered pedestrian speed.

Figures 5.25. and 5.26. show the travel time versus distance during a typical "speed walk." From the figures, we can see the speed curves for each walker are almost a straight line, which indicates that there was no large variation in walking speed from one intersection to another. The graphs also confirm that the 3:30pm walk has the lowest travel time for walkers A, C, and D. Team walkers were able to walk faster partially due to there being fewer pedestrians on the sidewalk at these hours. Walker A has a much higher walking speed than the rest of the team because walker A has a much longer stride, which increases his walking speed.

Pedestrian speed and delay walk data are difficult to analyze because of the numerous anomalies in each walk. Unlike the vehicle speed and delay runs as described in Chapter 4, any vehicles would be adequate in performing the data collection; but with pedestrian speed and delay walks, different surveyors yield different results. If the instrument for collecting the data was constant as one tried to collect information about walking speed on sidewalks at different times of day, one would expect to acquire the same or close to the same results on every walk. However, with different walkers participating in the walk, personal characteristics allowed for different possibilities in the study outcomes. For example, from Figure 5.25., the Walker A 12:30pm walk was significantly different than the Walker D 12:45pm walk; Walker A had a much faster speed than Walker D. Therefore, it could not be concluded that in general a 12:30pm run takes approximately 800s to complete.

In addition, sidewalk and environmental conditions are difficult to control. For example, street or sidewalk construction, street closures, traffic breakdowns, weather, and other conditions can affect the speed and delay walk's outcome. When there are so many factors other than time of day, number of pedestrians on sidewalk, or signal timing can contribute to delay, quantitative conclusions in pedestrian delay can not be drawn as from vehicular speed and delay runs.

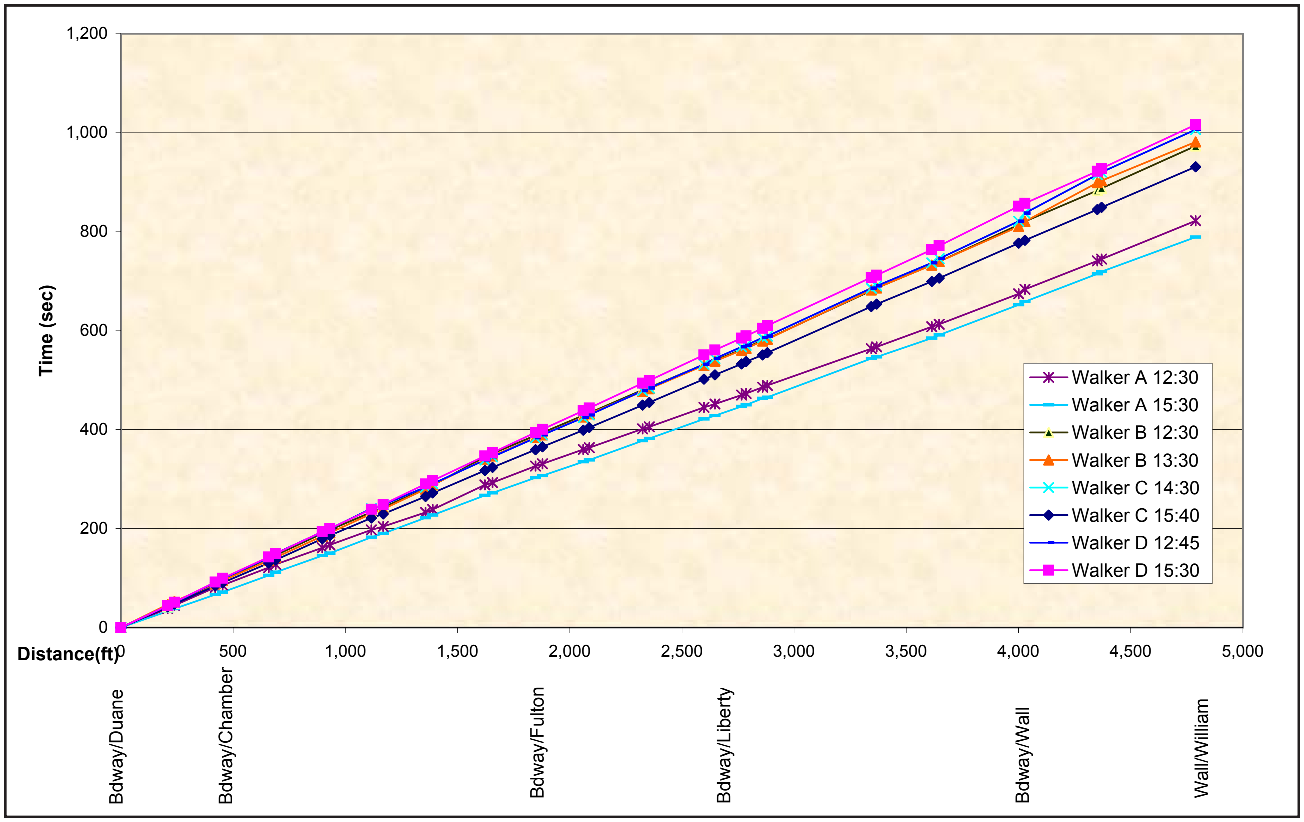

Figure 5.25. Travel Time and Delay Walk Typical Runs: Northbound

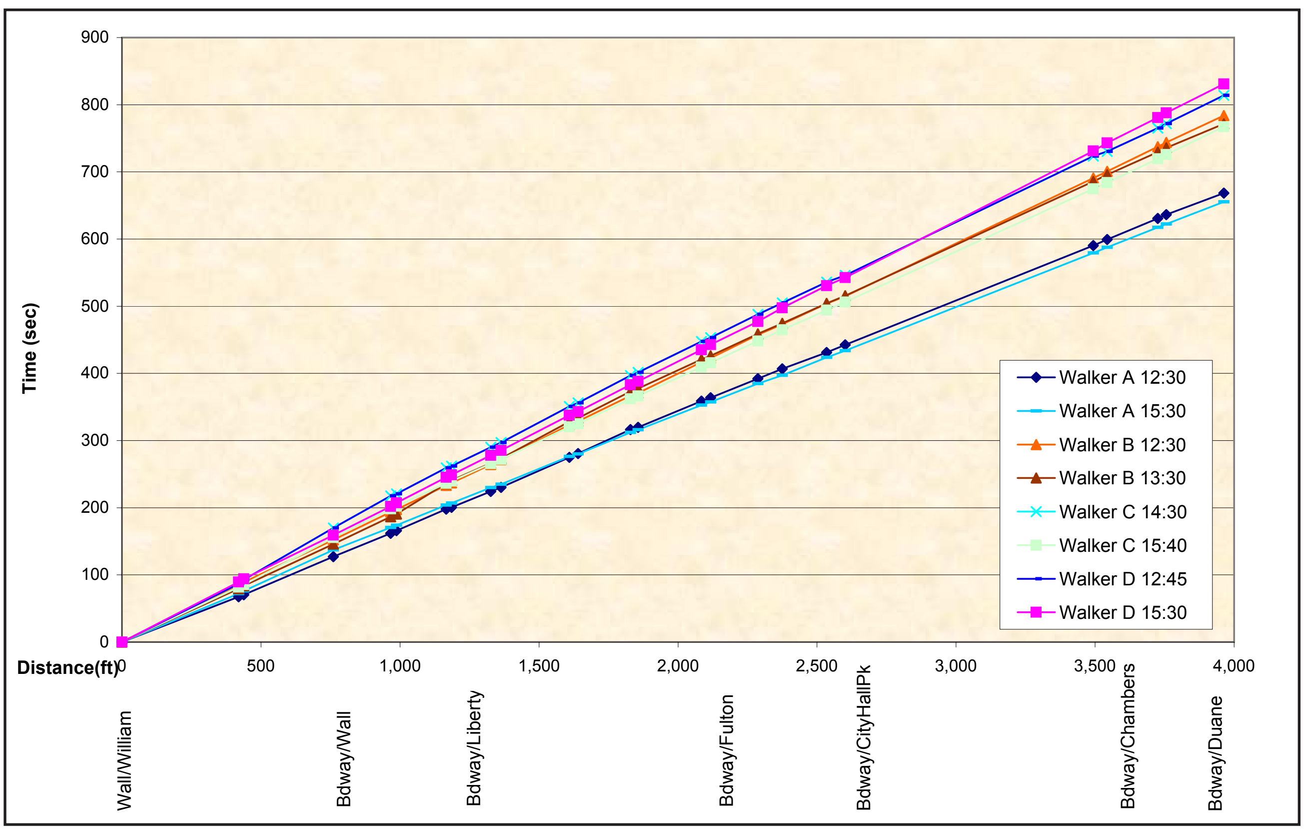

Figure 5.26. Travel Time and Delay Walk Typical Runs: Southbound