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APPENDIX A.

LITERATURE REVIEW SUMMARY

A. HCM Pedestrian LOS Design and Impact

Pedestrian Planning & Design - John Fruin

Pedestrian Planning & Design is the basis of the current pedestrian LOS methodology. Many of the LOS tenets-the idea of speed/density relationships, personal body shape and dimensions, and the very idea of a pedestrian level of service and how to distinguish between levels-originate from this book. Fruin is in favor of taking a combined quantitative/qualitative approach to evaluating sidewalks. The LOS measurement is to be used to ensure that pedestrian facilities are adequate for peak periods, while other criteria that may worsen the LOS (street vendors, sidewalk cafes, retail stores with nice windows) are important to maintain a quality of pedestrian life.

Fruin cites studies of bi-directional pedestrian flow, stating that flows of equal strength will not have much of an effect on one another, but that a strong flow will slow a weaker opposing flow somewhat. This is an observation that we should be able to confirm based on our field work and analysis. Fruin also notes that the measured effective widths of sidewalks should be automatically decreased by 12-18” on each side to account for the buffer space required by pedestrians as they try to avoid sidewalk obstacles.

Fruin indicates that “pedestrian service standards should be based on the freedom to select normal locomotion speed, the ability to bypass slow-moving pedestrians, and the relative ease of cross- and reverse-flow movements at various pedestrian traffic concentrations.” He also indicates that design standards are not universal across all environments and that his level of service guidelines are, ultimately, subjective, though based on a great deal of observed evidence.

Some useful figures included by Fruin are: “the fully clothed dimensions of the 95th percentile of the population (95% are less than this) are 13 inches body depth and 23 inches shoulder breadth…the plan view of the average male human body occupies an area of approximately 1.5 ft^2.” These figures could be helpful in determining the “buffer zone” between pedestrians required for comfortable use of walkways to be applied in our study. In addition, “behavioral experiments involving personal space preferences have shown minimum desirable occupancies ranging between 5 and 10 ft^2/person, where physical contact with others is avoidable.”

More interestingly for the purposes of this study, Fruin has found that “people require a lateral space of 28 to 30 inches…for comfortable movement. The longitudinal spacing for walking…would be 8 to 10 feet. This results in a minimum personal area of 20 to 30 ft^2/person for relatively unimpeded walking in groups on level surfaces.” Later, Fruin writes that “photographic studies of pedestrian traffic flow on walkways have shown that individual area occupancies of at least 35 ft^2/person are required for pedestrians to attain normal walking speeds and to avoid conflicts with others."

In addition, Fruin has found that unimpeded walking speed varies between 150 and 350 feet per minute, and the average is 270 feet per minute. Also, "healthy older adults are capable of increasing their walking speed by 40% for short distances." Fruin writes later that "average walking distances in Manhattan were found to be 1,720 feet, with a median at 1,070 feet. Higher average walking distances were found for passengers at the New York Port Authority Bus Terminal."

Fruin defines two types of queues, the "linear or ordered queue, in which pedestrians line up and are served in their order of arrival, and the undisciplined or bulk queue, where there is more general, less ordered crowding." He then states that spacing between people in linear queues is generally 19 to 20 inches; the "recommended lateral single-file width for railings or other dividers is 30 inches." He also provides a chart which includes "queuing LOSs based on pedestrian area occupancies and relative degrees of mobility within the waiting space" on page 229 of his book.

Urban Space for Pedestrians - Boris S. Pushkarev and Jeffrey M. Zupan

Pushkarev and Zupan's *Urban Space for Pedestrians* is often quoted in the HCM methodology. The authors advocate "mandatory minimum" standards for pedestrian space on New York City streets based on proportionate volumes of building floor space. At the time of their study, pedestrian space was allocated on a case-by-case basis, using "special zoning districts." The authors state that the purpose of their study is "to develop a quantitative relationship between building floor space and pedestrian circulation space". They acknowledge the importance of setting "firm factual basis" in pedestrian facilities planning. One of the authors' innovations is a new definition of service levels. Their new scale includes the levels Open Flow, Unimpeded, Impeded and Constrained to replace the A to F scale. They determine that New York City pedestrian flow is often gathered in platoons because of intersection signal control.

The authors state that the "average flow rates in excess of 10 people per foot per minute…are generally not found on outdoor walkways and cannot be handled by signalized intersections". Note that a flow rate of 10.0 is the lowest end of LOS D, so it would be very unusual to see an LOS D anywhere outside a train station or special event. This explains why a LOS D is rarely seen in pedestrian LOS analysis as opposed to vehicular LOS analysis.

There are several interesting findings in the Pushkarev and Zupan book. The first is that flow rate and speed are closely related. Pushkarev and Zupan find that "people, or vehicles, tend to move at a faster speed if the flow rate is low." One by-product of the measurement of flow rate and speed which the authors put forth is the calculation of space per person. According to the authors, "…if the flow rate is 60 persons per hour, or one person passing a point every minute, and the people are walking at a speed of 260 ft per minute, then the average distance between them is 260 ft. Multiplying that by the width of the path will give us the space allocation per person at that flow rate and that speed."

The authors also propose that the true perception of a sidewalk's quality has its root in platoon conditions rather than an overall "average" condition. This is because the sidewalk could be perceptibly empty during one minute, but relatively crowded during the next because of platooning due to crosswalk signal timing, subway egress, etc. The average of these conditions would not represent the perception of walking on the sidewalk, rather a combination of walking conditions and emptiness. The true representation of walking conditions would be determined from times when there were actually people walking on the sidewalk, which occurs primarily in platoons. The authors highly emphasize the importance of platooning as a focus of analysis, writing that "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."

Pushkarev and Zupan assert that building size and use can be used to estimate the volume of pedestrian travel on perimeter sidewalks. In terms of the flow rate at different times of day, Pushkarev and Zupan find that the highest flow in their study is attained from 12:30 to 1:30 PM, "if an area is shopping oriented," and from 5:00 to 5:30 PM, "if an area is office-building oriented."

In reference to the issue of counter-flow, Pushkarev and Zupan find that "two thirds to three quarters of the peak flow occur in the predominant direction. The greatest imbalances occur during the morning peak and are followed by the evening peak. Midday, by contrast, is split rather evenly by direction," and "directional distribution in pedestrian design is generally less important than in the design of mechanical systems: a walkway has more flexibility in accommodating varying directional flows than a reversible lane or a reversible track can ever achieve," however, "…the capacity of a walkway is about the same whether 100 percent of the flow is moving in one direction or whether the movement is split 50-50. The only troublesome condition that can arise is when there is a significant minor flow against the predominant direction of movement. The resulting turbulence can reduce capacity and speed and be psychologically unpleasant for both the minority and majority."

Pushkarev and Zupan suggest studying pedestrian behavior in the presence of street furniture and other obstacles. They write that the "dead space" (building walls, grates, etc.) of walkways must be calculated in order to achieve a true effective width on a sidewalk. Also, it is necessary to exclude "strips preempted by physical obstructions, such as light poles, mail boxes, and parking meters, though their exact effect on pedestrian flow has not been sufficiently investigated." And "the exact effect of the various obstacles on pedestrian capacity and flow is a good subject for further study; paths could be traced with time-lapse photography…each obstacle leaves an unused sidewalk area in its 'wake' in the pedestrian stream."

B. Studies Recommending Changes in LOS Calculation

There are many studies which recommend changes in pedestrian LOS calculation. Some of them propose new methodologies in evaluating pedestrian flow on facilities while others propose adjustments in the current HCM scale. This section includes some of the most relevant studies that helped to shape our methodological approach.

Pedestrian Time-Space Concept: A New Approach to the Planning and Design of Pedestrian Facilities - Gregory Benz.

Gregory Benz has a slightly different way of determining the pedestrian LOS than using Fruin's flow rate method. Benz's method is probably best suited for transportation terminals and other complex pedestrian spaces, could be applied to sidewalks, as well. His methodology is called the time-space approach.

In the time-space approach, pedestrian activities generate time-space needs. The areas where these activities take place are time-space zones. They have limited capacity to meet pedestrian time-space needs. Mathematically, the time-space concept can be described as:

$$T\text{-}S_{req.} = \sum P_i M_i T_i$$

Where

$T\text{-}S_{req.}$ = time-space required
P_i = number of people involved in activity i
M_i = space required per person for activity i
T_i = time required for activity i

$T\text{-}S_{req.}$ is then compared with the time-space available. The time-space available ($T\text{-}S_{avail.}$) is simply the product of the area available ($A_{avail.}$) and the time it is available ($T_{avail.}$).

Number of people involved in an activity is based from counting at peak period. The determination of what type of activity the person is involved in, such as commuter or shopper, is from observation. Space required for a person in the activity is found using published space-speed guidelines, such as Fruin and some of the tables in this particular report. The time required for an activity is based on observation and based on the speed a person is moving when they are engaged in that activity. Activity could be another word for 'trip purpose' or even for 'sub-trip purpose' (buying a coffee from a vendor on the way to work where the trip purpose is commuting, but the sub-trip purpose for that specific time-space zone is buying a coffee).

Note that Benz's approach focuses on area (sq. ft.) and not simply the effective width at an imaginary point. In calculating the $A_{avail.}$, Benz also recommends taking into account "cushions" around obstacles that represent unused space. But, he doesn't clearly identify how big those cushions ought to be.

Multi-Modal Quality of Service Project - Rhonda Philips, John Karachepone, and Bruce Landis

The Florida DOT commissioned this study to determine the best way to evaluate multi-modal linkages (bicycle, pedestrian, transit). The purpose is to improve the design of facilities in order to encourage use of non-automobile transportation.

This study includes a comprehensive literature review of various pedestrian quality of service methodologies. In contrast to the HCM LOS methodology, the methods cited in the document are based on factors that contribute to a pedestrian's perceived level of comfort rather than the expected density of the facility given its width and pedestrian volume.

The investigators outlined a pedestrian route in Pensacola, Florida, with varying conditions and advertised a "FunWalk for Science" to the community to attract participants. These participants walked around the course in reverse directions (to create friction). Along the way, investigators observed the participants while the participants ranked each segment of the course on a scale from "A" to "F" as "how safe / comfortable they felt as they traveled each segments", level A as the most safe or comfortable and Level F as the worst.

Using regression analysis, a pedestrian LOS model was developed, the model considers factors including width of outside lanes, width of shoulder or bike lane, on-street parking effect coefficient, percent of segment with on-street parking, buffer area barrier coefficient, buffer width, sidewalk presence coefficient, width of sidewalk, average traffic during a fifteen minute period, total number of lanes, and average running speed of motor vehicle traffic. The report suggests that the Pedestrian LOS Model "coupled with the capacity (Fruin) measure and a quality performance measure (i.e., "Walkability Audit" to asses the enjoyment and convenience of the walking experience…) 'completes the picture' of the roadside walking environment."

Calculating Multi-Modal Levels of Service (Abridged) - David Mozer

Mozer presents interesting ideas about the calculation of LOS for all transportation modes (including bicycle and pedestrian). The LOS levels are tailored to each mode, using a "stress level" measurement based on several transportation facility measurements.

Mozer introduces a measurement called the "walkarea width volume" (WWV) for pedestrians. The WWV is determined using an equation which includes measures of peak hour pedestrian volumes, mode split that is not pedestrian (wheelchairs, bicyclists, skaters, runners, etc.), usable width of the walk area, and a "travel pattern factor" representing the one way or bi-directional nature of the facility's pedestrian traffic.

Capacity Analysis of Pedestrian and Bicycle Facilities: Recommended Procedures for the "Pedestrians" Chapter of the Highway Capacity Manual (no author) - The www.tthrc.gov website.

The Turner-Fairbank Highway Research Center report (TFHRC, which is the home of the Federal Highway Administration's (FHWA's) Office of Research, Development and Technology) contains a useful measure of a seemingly subjective term. In calculating walking speed for crosswalks, the report suggests, the speed should be expected to be lower where "large numbers of older pedestrians" are present. In defining "large numbers," the report suggests that "large numbers of older pedestrians exist when the elderly proportion begins to materially affect the *overall* speed distribution at the facility." In this case, a material effect on the overall speed distribution occurs when the percentage of elderly using a crosswalk facility exceeds 20 percent.

This overview of the current (when it was written) literature seeks to advance the thesis that the HCM "procedures rely on incomplete and outdated information." Although this is in reference to the 1994 HCM, some of the insights outlined in this report have current relevance. In addition, the report puts forth the idea that pedestrian considerations need to have a higher priority in the HCM analysis.

Some of the recommendations outlined are related to pedestrian space requirements, pedestrian walking speeds, pedestrian start-up times and pedestrian traffic flow relationships.

In reference to space requirements, specific body ellipse sizes and body buffer zone sizes are recommended for analyzing the maintenance of walking speeds. This information might help in developing criteria for analyzing pedestrians' preferred distance from other pedestrians and in fine-tuning buffer zone and body ellipse criteria to specific conditions and pedestrian attributes on New York City sidewalks.

Pedestrian Arrivals at Signalized Intersections in Central Business Districts - Venkata Chilukuri

This study challenges the current (in 2000) equation used by the HCM to calculate pedestrian delay at signalized intersections. According to the author, the HCM equation assumes that pedestrian arrival at intersections is random. The study tests this assumption by observing pedestrian progression between upstream and downstream signals on seven St. Louis sidewalks. Chilukuri's statistical analysis of high and low flow rates on sidewalks between signalized intersections indicates that the arrival of pedestrians at those intersections had a significantly non-random pattern. In addition, it is found that, in a coordinated signal network (such as those which exist in large urban areas), "pedestrians arriving randomly at an intersection will move in a group after the signal turns green and might continue as a significant group towards the downstream signal."

Quality of Service for Uninterrupted Pedestrian Facilities in the 2000 Highway Capacity Manual - Joseph S. Milazzo, et al.

The most important concept in the Milazzo *et al.* article in terms of this study is the authors' suggestion that platooning in specific locations such as airport terminals is more common and thus more expected than it is on normal everyday walkways. They introduce the idea of "transportation terminals," in which LOS calculations for platooning are adjusted to reflect the special nature of certain walkway facilities. The LOS rating is relative to the expectation of platooning on particular walkways.

There is also some useful information in the literature review of the Milazzo article. The authors cite a study of crossflow by Khisty in which a "major flow" is defined as the predominant flow of pedestrian traffic and a "minor flow," or crossflow, is the opposing, less predominant flow. According to Khisty (paraphrased by Milazzo *et al.*), "the major flow did not undergo a significant change up to a pedestrian density of about 0.8 to 1.0 peds/ m^2. The minor flow begins to change when densities approach 0.7 to 0.8 peds/m^2." In addition, "Khisty hypothesized that minor flow speeds are actually higher than major flow speeds because pedestrians in the former group must act aggressively to cross the major flow."

Evaluation of Pedestrian Level-of-Service on Sidewalks and Crosswalks Using Conjoint Analysis - Muraleetharan Thambiah, Takeo Adachi, Toru Hagiwara, Seiichi Kagaya, and Ken'etsu Uchida

The authors intend to re-configure the calculation of pedestrian levels of service using a statistical method named "conjoint analysis." They are interested in updating the Highway Capacity Manual 2000 method of calculating level of service, which they describe as being primarily dependent upon capacity and space requirement measurements (in the form of flow-speed-density relationships). They cite several studies which have found that pedestrians perceived LOS depends upon factors other than flow, speed and density, including separation from moving traffic and the number of obstructions on the sidewalk. They contend that a new method of LOS computation should be developed to directly include these factors.

The conjoint analysis technique, which is undertaken in this study via an SPSS extension, is intended as a tool to determine what people value in particular services or products. In this study, the conjoint analysis technique is used to determine how pedestrians prioritize the attributes of sidewalks and how different levels of the above factors (or attributes) affect their perceived level of service on a sidewalk. According to the authors, the conjoint analysis tool "estimates an individual's 'value system,' which specifies how much value a user puts on each level of the attributes… we can determine what attributes are important or unimportant to the pedestrians…"

The "levels" to which the authors refer are similar to the LOS A-F rating levels, but are simplified for surveying purposes "because too many levels can greatly increase the burden on respondents and affect the quality of data." There are three levels (Levels 1-3) in this study, and each level is applied to a specific sidewalk condition for each of the above factors. In the pedestrian survey, the respondents are asked to rate the probability of their using a sidewalk facility based on the conditions of sidewalk factors represented by levels 1-3. 1,000 pedestrians were surveyed as to which factor was the most important and how willing they would be to use a facility based on each factor's particular service level. Using the conjoint analysis function, the authors find that differences in levels of flow rate on sidewalks effect pedestrian perceived LOS more than differences in levels of any other sidewalk attributes.

C. Pedestrian Case Studies

In the following section, pedestrian case studies are reviewed. They are primarily studies that do not use the traditional HCM pedestrian LOS analysis methodology. They provide an insight into the ways pedestrian studies can be undertaken without following a pre-existing set of guidelines.

City. Rediscovering the Center - William H. Whyte

This book is the result of an extensive study of street life in New York City in the 1980s. The author and his research team observed pedestrians in several locations in New York, as well as in other cities, during three years. They were interested in the design and management of public spaces, how these spaces were used by pedestrians and the relationship between the design and pedestrians' behavior. The study was also very concerned with density, which was the main quantitative variable used to determine whether the design of a street or an open space was adequate to satisfy the pedestrians' demands for space.

The basic methodology for Whyte's study was observation. However, the research team occasionally did some interviews and experiments. After several tests in the field, the methodology evolved into filming only from scaffolding placed at a certain height and distance from the study area, to obtain some perspective.

The author notes how time-consuming it is to analyze a time-lapse photography video for the peak hour. It is a tedious task, and that is why few time-lapse study programs are undertaken.

The author enumerates the chief characteristics of pedestrians:

– Pedestrians usually walk on the right.
– A large proportion of pedestrians walk in pairs or threesomes.
– "Men walk a little faster than women."
– "Younger people walk a little faster than older people."
– "People in groups walk a little slower than people walking alone."
– Carrying bags or suitcases does not slow people significantly.
– Pedestrians usually take the shortest path possible.
– "Pedestrians form up in platoons at traffic

lights and they move in platoons for a block or more" after crossing the street.

- "Pedestrians often function most efficiently at the peak of rush-hour flows."

Whyte notes how speeds and pace vary according to the time of day and the trip purpose. People walk progressively slower as the day wears on. He found that the morning rush hour is the fastest time of the day in terms of pedestrian speed. The evening rush hour is also fast, but more sociable. Pedestrian observation led the author to conclude that when there is a dominant flow in one direction, pedestrians in that flow walk at higher speeds than pedestrians walking in the opposite direction.

The author indicates that pedestrian behavior is very similar in every city. The main difference which affects people's walking speed is the city size and pedestrian density. According to Whyte, people in big cities walk faster than people in small cities.

Whyte mentions the cluttering of sidewalks by several different types of street furniture, placed without any logic or uniformity. He asserts that such obstacles reduce the effective walkway width considerably.

In conclusion, Whyte observes that "there is no one all-purpose optimum sidewalk width." However, he believes that sidewalks should always accommodate pedestrian flow comfortably, even in the most congested situations, but with a certain degree of crowdedness at the same time. Whyte also thinks that it is better to provide more than less space for pedestrians, but without giving them too much room, in order to keep the street lively and vibrant.

Field Studies of Pedestrian Walking Speed and Start-Up Time - Richard L. Knoblauch, Martin T. Pietrucha, and Marsha Nitzburg

This article finds that age, gender, and site environment have significant impacts on pedestrian walking speed and start-up time at crosswalks. The researchers use a stopwatch to time the speed of pedestrians between the time they step off a curb and the time they step on the opposite curb. The study's population includes two age groups, under 65 years old and 65 years old and over. The population was further divided into groups of males and females, and groups of those walking with others or walking alone. Data was collected during dry, rainy, and snowy conditions.

The study concludes that walking speeds have statistically significant variations across a variety of site and environmental conditions. The mean speed for pedestrians 65 years old and younger was 4.95ft/sec. The mean speed for pedestrians older than 65 was 4.11 ft/sec. Meanwhile, females 65 years old and under walked 0.32 ft/sec slower than males, while 65 and above females walk 0.4ft/sec slower than males. Weather conditions also had a significant effect on walking speed. Site and environmental conditions did not have as significant an impact on start-up time as walking speed. Overall, the study indicates that aggregated times and speeds for pedestrians should be used in designing crosswalks.

Comparison of CBD pedestrian characteristics in Canada and Sri Lanka - John F. Morrall, L.L. Ratnayake, and P.N. Seneviratne

Walking speed data was collected in Calgary, Canada and Colombo, Sri Lanka by researchers who manually timed pedestrians over a test section. In Colombo, the average walking speed for male pedestrians was 4.43ft/s, 0.16 ft/s faster than that of females. In Calgary, the average walking speed for male pedestrians was 4.70 ft/s, 0.27 ft/s faster than that of females. The elderly were observed to walk slower than the general population. The study also compared average walking speeds observed in other studies from other Asian countries. Concluding that different geographic areas yield different walking speeds, the study recommends that pedestrian planning should be based on local pedestrian characteristics rather than on pedestrian characteristics from cities with dissimilar cultures.

Analysis of Pedestrian Behavior and Planning Guidelines with Mixed Traffic for Narrow Urban Streets - Young-In Kwon, Shigeru Morichi, and Tetsuo Yai

The authors test HCM measures for sidewalk level of service on the primarily narrow and busy streets around a railway station in Tokyo, Japan. They aim to develop modifications of HCM methods to build LOS measurements that reflect the atypical geometry and pedestrian density of narrow Tokyo sidewalks and streets, considering that many people walk on the actual streets rather than the sidewalks (because of the narrowness of the entire roadbed and consequent narrowness of the sidewalk) and need to negotiate street obstacles and opposing travel modes.

The data collection for this study was undertaken using video recording at elevated vantage points such as the tops of buildings and railway station platforms. The authors marked the streets they recorded in 10 cm lateral intervals and 50 cm longitudinal intervals using a vaguely described method of "marking the distance points on a TV screen based on the markings on the screen during survey." An elevated, relatively distant vantage point makes it relatively easy for Kwon *et al.* to mark the streets at shorter lateral distances (they mark every 10 cm = approx. 4 inches) and longitudinal distances (they mark every 50 cm = approx. 20 inches).

Kwon *et al.* also develop equations and models for determining the distance pedestrians walk from street obstacles, based on the "distance to keep personal space" and "the distance caused by the pedestrian's forward movement." They also analyze the decision of pedestrians to walk on the sidewalk or on the roadbed, trying to "find any trends or parameters that reflect these behavioral characteristics." They found this decision to be based on car speed on the adjacent street, car flow on the street and pedestrian flow on the sidewalk.

The authors go on to outline models for analyzing time and space occupancy rates for different modes of transportation based on the speed of the mode, traffic volume of the mode and the geometry of the transportation facility on which the mode is traveling. These rates are used to build an "occupancy index" in order to determine how much space on a street is needed for each mode of travel. Space occupancy is related to the size of pedestrians or cars, etc., and time occupancy is related to their speed. According to the authors, "the new index…could be applied for the design of planned streets and the evaluation of street space improvements…considering not only traffic flow but also the physical size of traffic modes and the time needed to traverse the street." The authors suggest that the occupancy concept be applied to the LOS measurement procedure for streets with "mixed traffic" modes, i.e. streets which are so narrow that pedestrians sometimes walk in automobile and bicycle lanes. This seems to be a useful measure for planning particularly narrow, busy streets with limited roadbed (such as those in Lower Manhattan).

Walking Behavior in Bottlenecks and its Implications for Capacity - Serge P. Hoogendoorn

The author conducted walking experiments in a controlled environment (hallway surrounded by "soft" material walls) to determine how pedestrians behave when confronted with three different bottlenecks: no bottleneck, a wide bottleneck and a narrow bottleneck. The pedestrians walked in one direction only; the study does not consider bi-directional flow. It was noticed that when the bottleneck created congestion, pedestrians formed two distinct travel lanes. According to Hoogendoorn, "upstream of the bottleneck…pedestrians will use more of the available space…Inside the bottleneck, lanes are formed as soon as the bottleneck becomes over-saturated." It was also noted that the lateral distance required between pedestrians walking in a bottleneck is less than the lateral distance between the lanes, as peoples' shoulders are wider than their legs. The lateral space required by pedestrians between other pedestrians and the wall (obstacle similar to a building wall, but softer) equals the shoulder width of the pedestrian plus the amount of space required to move side to side while walking. It is found that this additional lateral space amounts to 10 centimeters in 95% of all Hoogendoorn's cases.

In addition, the speed of a pedestrian in one lane is independent of the speed of pedestrians in an adjacent lane, but is mostly reliant on the speed of the pedestrian in the front of the pedestrian in question's platoon. Hoogendoorn writes that "the leader - i.e. the pedestrian which is effectively being followed - is thus the pedestrian in front that is impairing the ability of the follower to make a step, and not necessarily the pedestrian in front who is closest in terms of distance." The experiment also showed that the surface of the obstacles which made up the bottleneck, which were soft, resulted in the pedestrians' needing "only a few centimeters distance between themselves and the obstruction." This indicates that the "buffer" distance required between pedestrians and obstacles might vary with the obstacle material and its physical make-up.

The author concludes that the capacity of a bottleneck does not have a linear relationship with the effective width of the bottleneck. The capacity per unit width of a bottleneck depends on the composition of the pedestrian flow – walking direction, gender, age, trip purpose, infrastructure characteristics – grade of ramp, stairs, and external conditions – weather, ambient conditions. The unused sidewalk width in a bottleneck depends on the type of obstruction – the material, the cleanness, the bulk, etc., of the obstacle. The author proposes a method to calculate the effective width of a bottleneck.

Obstacles in Pedestrian Simulations - Pascal Stucki, Christian Gloor and Kai Nagel

This thesis develops two new pedestrian simulation models that incorporate the influence of obstacles and other pedestrians in walking behavior.

To calibrate these models, the author uses empirical pedestrian data collected by Weidmann in his report "Transporttechnik der Fussgänger".

In the models, the walking speed of a pedestrian depends on:

- Attributes of the agent itself, such as gender, age, size, health, mood, stress and baggage.
- Attributes of the agent's environment, such as trip purpose, time of the day and the year, weather, trip length, steepness, attractiveness, safety of the route and shelter.
- The pedestrian density in the area.
- The distance to obstacles.

Weidmann obtained a normally distributed average speed of 1.34 m/s (4.83 km/h or 4.40 ft/s) and a standard deviation of 0.26 (19.3%) for pedestrians walking on the street. This value decreased for pedestrians walking on stairs and escalators. (Our team spoke with Weidmann about his methodology. Weidmann stated that his data was based on publications he collected, and he did not conduct the field work. He built a synthesis upon all the information compiled.)

Weidmann measured an average (maximal) body diameter of 0.46 m (1.51 ft) and a body depth of 0.23 m (0.75 ft). This equals a rectangular area of 0.11 m^2 (1.18 ft^2), although he chose to work with a more conservative value of 0.15 m^2 (1.61 ft^2). This translates into a maximum density of 6.6 persons/m^2. For densities above 3.0 persons/m^2 physical contact is inevitable.

According to the authors, when a person is walking, he/she needs an extra lateral space of around 0.30 m on each side, plus an extra longitudinal space which depends on the speed, and increases with speed. According to field measurements done by Mauron, pedestrians normally keep a distance of 1.03 m when crossing each other.

The measured distances to obstacles for pedestrians walking on sidewalks are:

- To walls: 0.45m.
- To fences: 0.35 m.
- To the roadway: 0.35 m.
- To small obstacles, like street lights, signals, trees or benches: 0.30 m.
- In curves, pedestrians keep an extra distance of 0.15 m.

According to the author, if an obstacle is more than half meter away from a pedestrian, it does not affect that pedestrian's walking behavior.

Experimental Research of Pedestrian Walking Behavior - Winnie Daamen and Serge P. Hoogendoorn

The authors recognize the lack of microscopic pedestrian data to describe pedestrian flow in detail. They find this data necessary to evaluate and calibrate simulation models used to design pedestrian infrastructure. Therefore, to overcome this problem, the authors develop a series of pedestrian experiments to collect microscopic pedestrian data.

According to the authors, walking speeds of pedestrians depend on the pedestrian density and on the following exogenous factors:

- Personal characteristics of pedestrians, such as age, gender, size, health, etc.
- Characteristics of the trip, such as walking purpose, route familiarity, luggage, trip length, etc.
- Properties of the infrastructure, such as type, grade, attractiveness of environment, shelter, etc.
- Environmental characteristics, such as weather and ambient conditions.

They also find that the necessary width for an adequate walkway depends on each pedestrian's speed. The longitudinal space use increases with speed exponentially. A relationship between the elliptical area needed by a pedestrian and his/her speed has been established.

In addition, "dynamic lane formation" or "streaming" in bidirectional pedestrian flows is a well-known phenomenon, in which pedestrians walking in opposite directions tend to separate and form lanes when they are walking in crowds. This lane formation is responsible for capacity loss – between 4% and 14.5% - that occurs in a bidirectional pedestrian flows.

D. Pedestrian Simulation Models

Pedestrian simulation studies evaluate the advantage of projecting and forecasting pedestrian flow using computer simulations. There are a few pedestrian simulation packages being used in the field, such as PEDFLOW, which simulates pedestrian interaction with obstacles found on walking facilities (Kukla, 2001). Researchers such as Hoogendoorn have come up with innovations in pedestrian modeling like using a gas-kinetic modeling technique to simulate pedestrian flows (2000). Regardless of which model one chooses to use, we have determined that pedestrian simulation often requires extensive data input and complicated parameters to build and calibrate. The following section deals with pedestrian simulation related literature. It presents some of the simulation options for pedestrian LOS analysis. It also outlines some of the difficulties in designing, building and implementing a simulation model.

Modeling for Four-Directional Pedestrian Flows - Victor Blue and Jeffrey Adler

The authors of this study state that the standard pedestrian LOS methodology does not adequately address bi-directional pedestrian flows that are not "directionally separated," cross-flows, or other n-directional flows.

The authors distinguish between traffic flows in the model they develop by identifying them as: 1) directionally separated flows (flows that, like vehicle traffic lanes, are stable and well-defined); 2) dynamic multi-lane flows (flows that grow or shrink based on demand and, in some cases, may split into multiple flows in a single direction); and 3) interspersed flows (flows without lanes that last a short period of time). The authors focus primarily on dynamic multi-lane flows. They also argue that the existing LOS methodology takes directionally separated flows into account already while interspersed flows are too random to model and calibrate against actual data with certainty.

Using their modeling technique, the authors find that directional pedestrian flows exhibit unique characteristics depending on the number and the type of flows. In particular, the authors focus on pedestrian behavior in conflict situations, i.e. how pedestrians react when confronted by another pedestrian moving toward them or perpendicular to them. In general, the researchers find that two pedestrians that perceive impending conflict will first attempt to find a path that allows them both to move forward, then to find a path that allows one to move forward while the other side-steps or pauses.

One important finding in this study is that the standard LOS bi-directional flow method is incomplete and can be better modeled using their simulation. Unfortunately, the authors do not attempt to qualify how pedestrians perceive resolving these directional conflicts in level of service terms.

Behavioral Dynamics for Pedestrians - Michel Bierlaire, Gianluca Antonini and Mats Weber
The authors propose the best combination of modeling techniques based on criteria such as ease of data collection, realism, ability to calibrate against actual data, and the ability to generate simulation data given a few parameters (volume of pedestrians and the physical characteristics of pedestrians and the space being modeled).

The authors found that microscopic, agent-based pedestrian behavior models best met their criteria and should be used for future pedestrian simulations.

The paper is interesting for the following reasons:

- The authors indirectly questioned a key tenet of the standard pedestrian LOS calculation: the relationship between walking speed and pedestrian density. They cited a study by AlGhadhi entitled, "A Speed-Concentration Relation for Bi-directional Crowd Movements", that deems the relationship to be unreliable. We investigated this; however the study is specific to large religious festivals and events in India only.
- The authors presented a good survey of microscopic pedestrian modeling techniques. Macroscopic techniques are briefly discussed, but only long enough to discount them for serious simulation. The authors argued that an agent-based approach taking into account each individual's line-of-sight is best because it is the most realistic.

Modeling the behavior of individual pedestrians may be useful theoretically, but may not be practical. In the introduction, the authors mentioned that this technique is most useful for simulating panic situations.

The models described in this paper require extensive, detailed data collection, much more than could be compiled manually. The authors disclose that, although automated video analysis is necessary for this model development, it "does not cover all aspects of data collection and focuses mainly on short-range behavior." This data collection is also expensive given the equipment requirements and error-prone due to the problems of automatically identifying pedestrians via video data.

Pedestrian Flow Modeling by Adaptive Control - Serge P. Hoogendoorn
The author proposes a theory and a model to describe pedestrian walking behavior. He reviews some literature concerning pedestrian behavior and the factors that influence it. According to his theory, pedestrians are driven by cost minimization. Pedestrians behave according to predictions on other pedestrians' behavior, but they have a limited predictive ability. Walking too close to other pedestrians and obstacles has a cost for a pedestrian: the "proximity discomfort" or "proximity cost". Accelerating and deviating from the planned path have also a cost for a pedestrian.

Another hypothesis of this model is that walkers avoid proximity to groups of pedestrians more than to a single pedestrian, because it is assumed that proximity costs are additive. The author concludes that this model is able to predict pedestrian walking behavior quite accurately, based on several application examples.

E. Data Collection Methodology

In order to design an effective data collection methodology, studies were reviewed based on their video surveying techniques and uses of pedestrian surveys. In seeking ideas related to motion sensing and detection of pedestrians, we expanded our review of literature beyond pedestrian and traffic studies, and found ideas from the realms of reinforced soil design (Arriaga, 2000), coastal science (Black, 1999; Hume, 1998) and biometric technologies (Bolle, 2001). However, automating the process of data collection may be too expensive and labor intensive for the scope of this study. The purpose of this section is to summarize some of the literature we studied, and to outline which data collection procedures others used and which might inform the development of data collection methodologies for this project.

Laying the Foundations: the Use of Video Footage to Explore Pedestrian Dynamics in PEDFLOW - Alexandra Willis, Robert Kukla, Jon Kerridge, and Julian Hine
According to the authors, the best way to obtain a comprehensive and complete knowledge of pedestrian behavior is with a combination of observational and interview methodologies. Observation allows us to determine quantitative values of pedestrian movement – such as number of pedestrians, speeds, distance to obstacles – as well as moving patterns. Interviews help us to understand the decision-making process underlying pedestrian movement, and to estimate the actual demand for pedestrian facilities.

Pedestrian observation can be done with a video camera. The main advantage of using a video camera instead of other visual techniques is that it provides a permanent record that can be observed and analyzed as often as needed, thus considerably reducing the amount of on-site field work. However, there are two main problems with the use of a video camera. First of all, the videotapes need to be calibrated for the foreshortening that occurs when the camera is not positioned perpendicular to the ground. Second, manual analysis of every pedestrian in every tape is extremely laborious and time-consuming. Recent developments in image and motion analysis software can help overcome these problems in the future and make systematic exploration of pedestrian movement at a microscopic level a reality.

Pedestrian Simulation Methods - Laurent Mauron
In his thesis, the author develops two simulation methods to model pedestrian flow in large infrastructures.

Mauron states that pedestrians tend to walk with a desired speed which depends on the age, gender, time of the day, trip purpose, environmental conditions, etc.; previous field measurement found that desired speeds in crowds are usually normally distributed with a mean value of 1.34 m/s approximately; pedestrians choose the fastest route, not the shortest; pedestrians avoid other pedestrians, and they also try to keep a certain distance from obstacles and walls; it has been shown that pedestrians walk further away from a dirty wall than from a clean one; when the walkway is sufficiently crowded, pedestrians tend to form directional lanes.

In chapter 5, Mauron performs some field measurements to calibrate and test his models. The location chosen by the author is a sidewalk at the Tannenstrasse in the ETH campus in Zurich. The author chose this block to observe bidirectional flow because it is devoid of elements that interfere in pedestrian behavior, such as shopping windows and zebra crossings. The methodology consists of the following steps:

1. A video camera is placed above the study location, fixed to a tripod in a window, to reduce image deformation due to perspective for shortening as much as possible.
2. A planar Cartesian coordinate system is defined on the field; the x axis is the curb. Four reference points are marked on the sidewalk with bright tape, and their relative locations are measured. These points are used as a calibration of the field coordinate system.
3. Videos are filmed at different times of the day to observe different travel characteristics.
4. The videos are captured and compressed in a computer with Adobe Premiere.
5. The pedestrians' trajectories are tracked with an image analysis software. The author decided to create his own tracking software because none of the commercially available programs were adequate of affordable. Since the experiment was done on a real sidewalk with real people not knowing that they were being observed, the software could not automatically track pedestrians – this would have been possible if all pedestrians were wearing a bright hat. Therefore, pedestrians had to be tracked manually, one by one, in a very time-consuming task. The camera coordinates were calibrated with the four reference points. Errors are estimated by measuring in the video a one meter stick that was placed in the study area.
6. For every pedestrian, his/her position on the

sidewalk relative to the curb is measured. The author distinguishes two groups: pedestrians walking alone and -not interacting with other pedestrians, and two pedestrians walking alone but crossing each other.

MauronThe author found that non-interacting pedestrians tend to walk in a straight line at a constant distance from the curb side. These distances are statistically distributed around a peak value of 1.611 m, with a standard deviation of 0.412. In the case of crossing pedestrians, the peak values for the distances are 0.852 m with a standard deviation of 0.264, and 1.8795 m with a standard deviation of 0.21. The author uses these values to test and compare the proposed simulation models.

Operational Characteristics of Inline Skaters - Elizabeth Birriel, Juan C. Pernia, Juan John Lu, and Theodore A. Petritsch

The Florida Department of Transportation (FDOT) sponsored this study of the operational characteristics, speed, sweep width (lateral distance), stopping technique, stopping distance, and stopping width of inline skaters. After, placing orange cones at 40 feet apart, a video camera was set up to film skaters as they passed the cones. The 50th and 85th percentile speeds were estimated.

The sweep width (lateral distance) was measured by drawing twenty feet longitudinal lines one foot apart on the sidewalk. The number of lines that the skaters crossed, using their skates or hands, were captured by video cameras. Three cameras, one facing skaters, one set up on the side of the first 60 feet of the skaters stopping distances, and the last one of the last 40 feet, were used to capture the stopping technique, distance and width. Horizontal lines of five feet apart within a distance of 100 feet before the stopping sign were drawn to study the stopping distance. Then the stopping width was measured by two feet apart longitudinal lines. The study also divided up the sample group into male, female, learner, and advanced skaters.

This study is relevant to pedestrian level of service study because it shows how data could be collected using video camera and lines on the ground. Using relatively simple methodology, data of speed, lateral spacing, stopping technique and distance of in-line skaters could be collected.

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APPENDIX B.

PEDESTRIAN SURVEY RULES

A. General Rules

– The pedestrian characteristics survey was designed to be completed quickly based on visible pedestrian features. It is best to try not to overanalyze characteristics.
– Conservatism is the rule. If you have a lengthy internal debate about whether someone is sufficiently larger than average or is slowed by a bag, indicate they are not. If you have a lengthy internal debate about someone's trip purpose, indicate that you don't know what it is.

B. Person Size

– One study = 99th percentile (men) = 20.7" shoulder width + 1.5" clothing
– Another study 95th percentile (men) = 22.8" width, 13" deep
– Standard, according to Fruin: 24" wide and 18" deep which accounts for body sway, personal articles, and space buffer
– Extra large people are about 30" X 22.5"

C. Group

– Indicate the number of people walking together in a group.
– A baby does not count as a person in a group, unless it is walking.
– In case of an extremely large group (tour/school group, for example), pick out a single group within that large group (2-3 people walking together), record their time and their characteristics. Note this sub-group's size in the Group column and the approximate size of the entire group in the Comments column.

D. Trip Purpose

– Indicate '0' if you are not sure of the pedestrian's trip purpose. This is an extremely important characteristic so never guess about someone's trip purpose, just indicate '0'. You can write something in the Comment column if you want to highlight a difficult-to-assign case.
– Indicate '1' if the person's primary purpose in the area is tourism. Some characteristics of tourists include: casual clothing, visible camera, maps/guidebooks, looking around.
– Indicate '2' if the person's primary purpose in the area is work. This includes people who are going to work, coming from work, taking a lunch/shopping break from work, or actually working. Some signals of work include: visible ID card, slightly more formal clothing or a uniform.
– Indicate '3'if the person's primary purpose in the area is non-work, but they are not a tourist. This includes people who are shopping or taking a recreational walk. It also includes people whose work entails casual activity: nannies and dog walkers, for example.

E. Bag(s)

- Indicate '1' if a person is carrying any type of bag. This includes paper lunch/deli bags, plastic bags, shopping bags, backpacks, suitcases (being carried), purses, briefcases, baby backpacks.
- Mark '2' if a person is visibly straining against a bag and appears to be slowed by it.
- Indicate '0' otherwise. Notebooks, wallets, newspapers, folders, portfolios, etc. are not considered bags.

F. Phone

- Indicate '1' if someone is actively using their cell phone: talking, dialing, fiddling, etc. Count people whether they are speaking with it up to their ear or if they are using a headset.
- Indicate '0' otherwise.

G. Headphones

- Indicate '1' if someone has headphones on their ears. Note that this characteristic should only be used for headphones attached to music/audio devices—not mobile phone headsets, which should be marked as "phone" usage (above).
- Indicate '0' otherwise.

H. Drink / Food

- Indicate '1' if someone is holding food or drink in their hand in its elemental packaging as if it could be consumed easily at any time. Examples: drink with a straw, capped bottle of water, open/closed bag of chips (because it can easily be opened an eaten while walking), fruit, pretzel, candy bar, unwrapped sandwich.
- Indicate '0' if someone is not holding food or drink or if their food/drink is inside another container or bag. For example, a fast food bag should not be counted as food/drink (but should be counted as a bag). A brown paper bag that seems to contain a bottle should not be counted as food/drink unless it is clearly drinkable – a straw poking out the top, for example.

I. PDA

- Indicate '1' if someone is actively using an electronic organizer.
- Indicate '0' otherwise.

J. Cigarette

- Indicate '1' if someone is actively using a cigarette, cigar, or pipe. Examples: removing a cigar/cigarette from a pack, lighting it, smoking.
- Indicate '0' otherwise.

K. Pushing

- Indicate '0' if someone is pushing/pulling nothing.
- Indicate '1' if someone is pushing a stroller.
- Indicate '2' if someone is pushing/pulling a service cart. This includes vendor carts, grocery carts, and hand trucks / dollies.
- Indicate '3' if someone is pushing a wheelchair.
- Indicate '4'if someone is pushing / pulling a rolling suitcase.

L. Walking Aide

- Indicate '0' if someone is not using a walking aide.
- Indicate '1' if someone is using crutches.
- Indicate '2' if someone is riding in a wheelchair (that is being pushed by someone else or self-propelled.
- Indicate '3' if someone is using a cane or a walker.

M. Impeded

- Make sure you pay attention to this column as you are watching pedestrians
- A pedestrian is impeded if he/she is involuntarily slowed by conditions on the sidewalk. Examples include: a pedestrian who slows down and changes direction abruptly due to crowded conditions or an unavoidable obstacle or a pedestrian who trips due to a sidewalk obstacle or feature.

N. Comment

- Write comments here that help explain why a pedestrian's speed is particularly slow or fast or explain behavior that might affect speed or sidewalk usage. For example, an unusual gait or disability, a person actively window shopping, someone in a big hurry, someone dribbling a basketball, etc. Also, include any comments about sidewalk conditions – physical, environmental or social – which may affect traffic flows.

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APPENDIX C.

SAMPLE FORMS

Table C.1. Sample Speed Survey

Ped Count Sample Pedestrian Speed
Location: Control Location

Speed Timing Length on Sidewalk (ft): 40
Name Betsy
Date: 5/12/2004
Weather: Sunny
Time: 11:45

PED #	Travel Time (s)	DIRECTION	GENDER	AGE	PERSON SIZE	GROUP	TRIP PURPOSE	BAG(S)	PERSONAL ITEMS: Phone	PERSONAL ITEMS: Headphone	PERSONAL ITEMS: Drink	PERSONAL ITEMS: PDA	PERSONAL ITEMS: Cigarette	PUSHING	WALKING AIDE	COMMENT
		N = north S = south E = east W = west	F = Female M = Male	1 = under 14 2 = 14-65 3 = over 65	0 = Average 1 = Large (well over average space req'd)	# = people in group 1 = 1 person 2 = 2 people etc.	0 = Not sure 1 = Tourist 2 = Service 3 = Business 4 = Non-business	0 = None 1 = Yes, no effect 2 = Yes, affects speed						0 = Nothing 1 = Stroller 2 = Service cart 3 = Wheelchair 4 = Rolling suitcase	0 = No 1 = Crutches 2 = Wheelchair 3 = Cane 4 = Stroller	
1	11.09	N	M	2	0	1	0	1						4		
2	12.37	S	F	2	0	1	4	1								
3	12.09	N	F	2	0	2	1	1								
4	12.09	N	F	2	0	2	1	1								
5	10.09	S	M	2	0	1	0	1			1					
6	10.37	N	M	2	0	1	3	0								
7	9.38	S	F	2	0	1	0	1								
8	16.16	N	F	2	0	2	4	0						1		Kids
9	16.16	N	F	2	0	2	4	0						1		Kids
10	9.7	S	F	2	0	1	4	2								
11	9.5	N	F	2	0	1	4	1								
12	8.4	S	F	2	0	2	0	1								
13	8.4	S	F	2	0	2	0	1								
14	11.25	S	F	2	0	1	0	0	1							
15	7.18	S	M	2	0	1	0	0	1							
16	11.25	S	F	2	0	1	0	2								

Table C.2. Lower Manhattan 62 Locations

Location ID	Street	Between 1	Between 2	Side
01N	Chambers	Greenwich	W. Broadway	N
01S	Chambers	Greenwich	W. Broadway	S
02W	Hudson	Reade	Chambers	W
03E	W. Broadway	Reade	Chambers	E
04E	W. Broadway	Warren	Chambers	E
04W	W. Broadway	Warren	Chambers	W
05E	Church	Reade	Chambers	E
05W	Church	Reade	Chambers	W
06N	Chambers	Church	Broadway	N
06S	Chambers	Church	Broadway	S
07E	Church	Chambers	Warren	E
07W	Church	Chambers	Warren	W
08E	Broadway	Chambers	Warren	E
08W	Broadway	Chambers	Warren	W
09E	Church	Warren	Murray	E
09W	Church	Warren	Murray	W
10E	Broadway	Warren	Murray	E
10W	Broadway	Warren	Murray	W
11W	Broadway	Murray	Park Pl	W
11E	Broadway	Murray	Park Pl	E
12E	Church	Murray	Park	E
12W	Church	Murray	Park	W
13E	Church	Park Pl	Barclay	E
13W	Church	Park Pl	Barclay	W
14E	Church	Barclay	Vesey	E
16N	Vesey	Church	Broadway	N
18N	Fulton	Broadway	Nassau	N
18S	Fulton	Broadway	Nassau	S
20N	Fulton	Nassau	William	N
20S	Fulton	Nassau	William	S
22N	Fulton	William	Gold	N
22S	Fulton	William	Gold	S
25N	Dey	Church	Broadway	N
25S	Dey	Church	Broadway	S
27N	John	Nassau	Broadway	N
30E	Church	Cortlandt	Dey	E
31N	Cortlandt	Church	Broadway	N
32E	Church	Cortlandt	Liberty	E
34N	Liberty	Church	Broadway	N
35W	Church	Liberty	Cedar	W
37W	Trinity Pl	Thames	Rector	W
38E	Broadway	Pine	Wall	E
38W	Broadway	Wall	Rector	W
39N	Chambers	W. Broadway	Church	N
39S	Chambers	W. Broadway	Church	S
41N	Wall	Nassau	William	N
41S	Wall	Nassau	William	S
43N	Wall	William	Hanover	N
43S	Wall	William	Hanover	S
44S	Rector	Trinity Pl	Broadway	S
45E	Broadway	Wall	Exchange	E
45W	Broadway	Wall	Exchange	W
46E	Nassau	Wall	Exchange	E
51E	Broadway	Exchange	Morris	E
52E	Broad	Exchange	Beaver	E
52W	Broad	Exchange	Beaver	W
53S	Beaver	Broad	William	S
54N	William	Pearl	Water	N
55S	Beaver	Whitehall	New	S
56W	Broadway	Morris	Battery Pl	W
60E	Whitehall	Battery	Stone	E
57S	Beaver	Broad	New	S

Table C.3. 7-day Sample Count

Project LOS 7-Day Pedestrian Count

Broadway between Duane and Reade, West Sidewalk

Name:	Altan	Date:	5/12/2004
Start Time:	11:00AM	Weather:	Sunny, hot

	5 min	10 min	15 min	20 min
Northbound	71	128	207	265
Southbound	60	129	201	254

	25 min	30 min	35 min	40 min
Northbound	338	394	445	511
Southbound	343	395	469	557

	45 min	50 min	55 min	60 min
Northbound	569	633	718	788
Southbound	605	693	798	889

Table C.4. Sample Speed Walk

PEDESTRIAN LOS SPEED WALK SHEET

ROUTE CHARACTERISTICS

Route:	Broadway to Wall Street to William & back		Date:	4/27/2004
Walker:	Monica	Timer: Monica	Time of Day:	2:35pm
Weather:	Parly sunny, a little windy, 60s		Route time:	17:30.74 / 14:28.48

	Name	Arrive	Depart	Comments
Intersection 1:	Bway/Duane South	00:00.00	00:00.00	
Intersection 2:	Bway/Reade North	00:45.08		
Intersection 3:	Bway/Reade South	00:51.36		
Intersection 4:	Bway/Chambers North	01:28.45		
Intersection 5:	Bway/Chambers South	01:35.28		
Intersection 6:	Bway/Warren North	02:17.70		
Intersection 7:	Bway/Warren South	02:24.63		
Intersection 8:	Bway/Murray North	03:07.28		
Intersection 9:	Bway/Murray South	03:14.27		
Intersection 10:	Bway/Park North	03:51.88	04:00.78	
Intersection 11:	Bway/Park South	04:09.50		
Intersection 12:	Bway/Barclay North	04:48.87		
Intersection 13:	Bway/Barclay South	04:56.11		
Intersection 14:	Bway/Vesey North	05:46.26		
Intersection 15:	Bway/Vesey South	05:52.98		
Intersection 16:	Bway/Fulton North	06:32.43		
Intersection 17:	Bway/Fulton South	06:37.44		
Intersection 18:	Bway/Dey North	07:14.52		
Intersection 19:	Bway/Dey South	07:19.54		
Intersection 20:	Bway/Cortlandt North	08:09.89		
Intersection 21:	Bway/Cortlandt South	08:15.33		
Intersection 22:	Bway/Liberty North	09:07.43		
Intersection 23:	Bway/Liberty South	09:16.28		
Intersection 24:	Bway/Cedar North	09:40.43		
Intersection 25:	Bway/Cedar South	09:44.27		
Intersection 26:	Bway/Thames North	10:00.45		
Intersection 27:	Bway/Thames South	10:03.97		
Intersection 28:	Bway/Rector North	11:43.75		
Intersection 29:	Bway/Rector South	11:48.41		
Intersection 30:	Bway/Exchange Northwest	12:40.98	13:12.99	
Intersection 31:	Bway/Exchange Northeast	13:20.65		
Intersection 32:	Bway/Wall South	14:41.42		
Intersection 33:	Bway/Wall North	14:48.35		
Intersection 34:	Wall/Nassau West	15:54.49		
Intersection 35:	Wall/Nassau East	15:59.06		
Intersection 36:	Wall/Willam West	17:30.74		
Northbound				
Intersection 1:	Wall/Willam West	00:00.00		
Intersection 2:	Wall/Nassau East	01:32.46		
Intersection 3:	Wall/Nassau West	01:36.49		
Intersection 4:	Bway/Wall North	02:44.87		
Intersection 5:	Bway/Pine South	03:29.42		
Intersection 6:	Bway/Pine North	03:33.38		
Intersection 7:	Bway/Cedar South	04:11.64		
Intersection 8:	Bway/Cedar North	04:15.28		
Intersection 9:	Bway/Liberty South	04:45.42		
Intersection 10:	Bway/Liberty North	04:52.86		
Intersection 11:	Bway/Maiden South	05:47.59		
Intersection 12:	Bway/Maiden North	05:52.56		
Intersection 13:	Bway/John South	06:33.67		
Intersection 14:	Bway/John North	06:38.52		
Intersection 15:	Bway/Fulton South	07:25.77		
Intersection 16:	Bway/Fulton North	07:32.23		
Intersection 17:	Bway/Ann South	08:09.38		
Intersection 18:	Bway/Traffic Island South	08:25.57		
Intersection 19:	Bway/Traffic Island North	08:59.11	09:27.74	
Intersection 20:	Bway/City Hall Park South	09:41.07		
Intersection 21:	Bway/Chambers South	12:47.67		
Intersection 22:	Bway/Chambers North	12:58.31		
Intersection 23:	Bway/Reade South	13:37.44		
Intersection 24:	Bway/Reade North	13:44.18		
Intersection 25:	Bway/Duane South	14:28.48		

Table C.5. Video Locations

Video Location				Day(s) Filmed	Time(s) Filmed
Street	Between 1	Between 2	Side		
Broadway	John St	Cortland St	East	9-Dec-03	10:30 AM
Beaver St	Broad St	New St	North	9-Dec-03	12:30 PM
42nd St	Park Avenue	Lexington Ave	North	12-Jan-04	11:25 AM
42nd St	Park Avenue	Lexington Ave	South	12-Jan-04	11:30 PM
Lexington	40th St	41st St	West	12-Jan-04	12:00 PM
					1:30 PM
					3:00 PM
					4:30 PM
				13-Jan-04	5:15 PM
					6:00 PM
				14-Jan-04	8:30 AM
					8:45 AM
					10:30 AM
Chambers St	Broadway	Church St	South	22-Jan-04	4:05 PM
Chambers St	Broadway	Church St	South	10-Feb-04	11:15 AM
Broadway	Thomas St	Duane St	West	10-Feb-04	3:45 PM
Broadway	Duane St	Reade St	West	11-Mar-04	3:10 PM
(Control Location)				15-Mar-04	3:05 PM
				19-Apr-04	3:15 PM
				20-Apr-04	3:17 PM
				20-May-04	3:15 PM
				10-Jun-04	3:13 PM
Broadway	Exchange Pl	Rector St	West	15-Mar-04	4:05 PM
Fulton St	Dutch St	William St	South	19-Apr-04	4:05 PM
John St	Cliff St	Pearl St	South	20-Apr-04	1:20 PM
Church	Reade	Chambers	East	10-Jun-04	12:15 PM
Fulton St	Broadway	Nassau St	South	27-Aug-04	1:15 PM
Broadway	John St	Maiden Ln	East	1-Sep-04	12:35 PM
Church	Liberty St	Cedar St	West	1-Sep-04	1:25 PM

Table C.6. Sample Obstacle Form

Location:

Date: **Time:** **Observer:**

Ped #	Gender	Pedestrian Direction	Left of Screen				Right of Screen			
			Obstacle: Distance (ft)	Impeded? (Y/N)	# of Pedestrians NB	# of Pedestrians SB	Obstacle: Distance (ft)	Impeded? (Y/N)	# of Pedestrians NB	# of Pedestrians SB
1	F	N	5.5	N	2	0			0	2
2	F	N	5	N	2	0			0	1
3	F	N	5.5	N	2	0			0	2
4	M	S	1.5	N	1	1			0	1
5	M	S	5	N	0	1			0	1
6	F	S	2.25	N	0	1			0	1
7	F	N	5	N	1	0			0	0
8	F	N	2.5	N	1	0			0	0
9	M	S	1.5	N	0	3			0	1
10	M	N	2.25	N	1					
11	M	N	7		1					1
12	F	N	3		2					
13	F	N	6		1					
14	M	N	5.5		1					
15	F	N	4		2					1
16	M	S	4.5			2				
17	F	S	4.5			1				1
18	F	S	3			1				
19	F	N	1.5		1					
20	M	S	0.5	Y		4				
21	M	N	2		1					
22	F	S	4.5			1				
23	M	N	4.25		1				1	
24	M	N	6.5		1					
25	M	N	2.5		2					
26	F	N	3.5		1					
27	M	N	3		3					1
28	F	N	3		3				1	2
29	F	N	5		1					1
30	M	N	0.5	Y	3					
31	F	N	6							
32	M	S	0.5		2	2				1
33	M	N	0.5	Y	3					
34	M	N	3		1					2
35	M	N	4.5		1					1
36	F	N	1		3					
37	M	N	3.5		2				1	
38	F	N	2.5	Y	3	1				
39	M	N	1.5		2					

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APPENDIX D.

PERSPECTIVE DRAWING: BLUE SCREEN VIDEO METHOD

In a one-point perspective drawing all lines which are parallel to each other converge towards a single point, the vanishing point, when the image is represented in the perspective. Since we want to draw longitudinal lines on any specific sidewalk, we need to find the vanishing point of the all the lines parallel to the curb line. Thus, a still image is captured from the video (see Figure D.1, first picture on the left column) and imported into AutoCad, where all visible lines parallel to the curb line are drawn (see Figure D.1, second picture on the left column). Because these lines are "hand-drawn" over the image and the original ones might not be accurately parallel, they don't converge at one point exactly, but they all tend to converge in a small area. One point is chosen in the approximate center of that area. This is the vanishing point of all the lines parallel to the curb line.

From this vanishing point, three lines are drawn, they are usually lines that define the concrete square blocks of the sidewalk. These three lines have been previously chosen on the field, and their distance measured with a tape measurer. The criteria to select these lines are that they have to be parallel to the curb line and to each other, and visible in the video (see Figure D.1, third picture on the left column). Now we can solve the following problem.

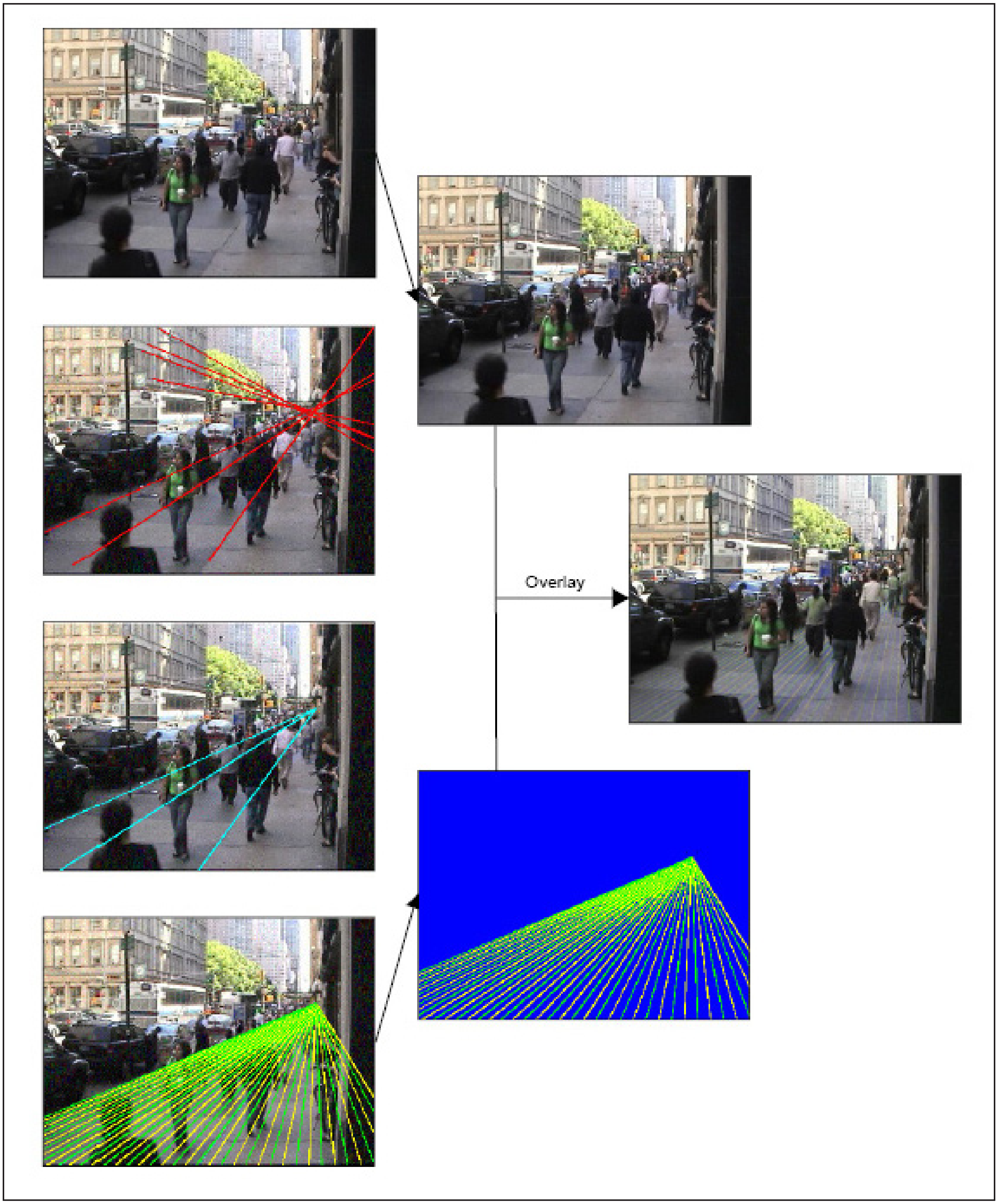

Figure D.1. Blue Screen Video Overlay

Problem: Given three lines a, b, c intersecting in O, draw a line r so that, if A, B, C are the intersection points of r with a, b, c respectively, it verifies that AB/BC = m/n, being m and n known (see Figure D.2.).

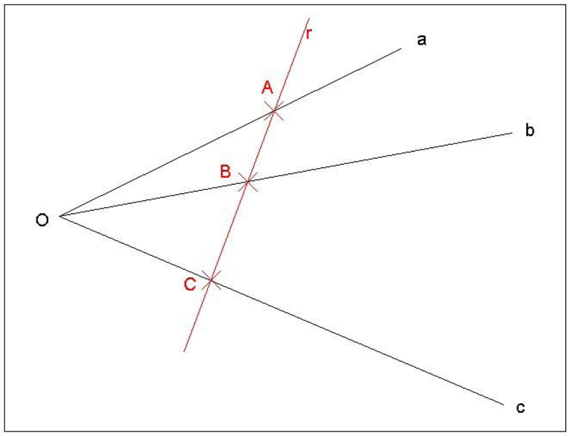

Figure D.2. Problem to Solve

Data: a, b, c, O, m, n. m/n = k (see Figures D.3. and D.4.).

g. m and n are the real distances between the lines measured in the field.
h. a, b, c have to be parallel lines in real life.
i. O is the imaginary point where perspective lines converge.

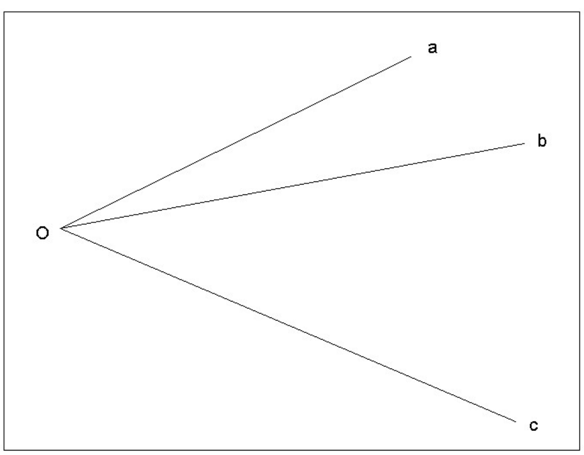

Figure D.3. Problem Data 1

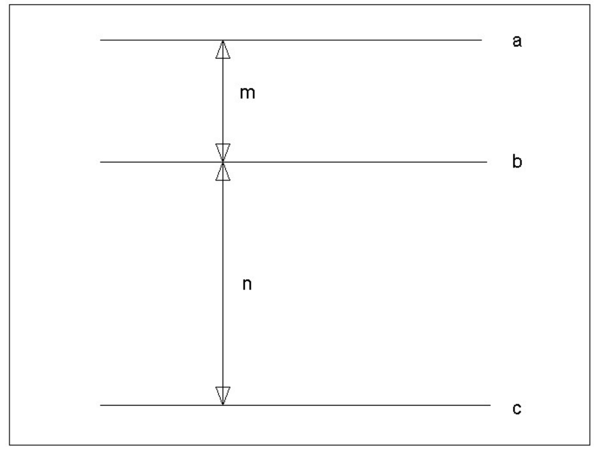

Figure D.4. Problem Data 2

Solution:

1. Draw an arbitrary line s that intersects a, b, c. The intersection points of s with a, b, c are X, Y, Z, respectively (see Figure D.5.).

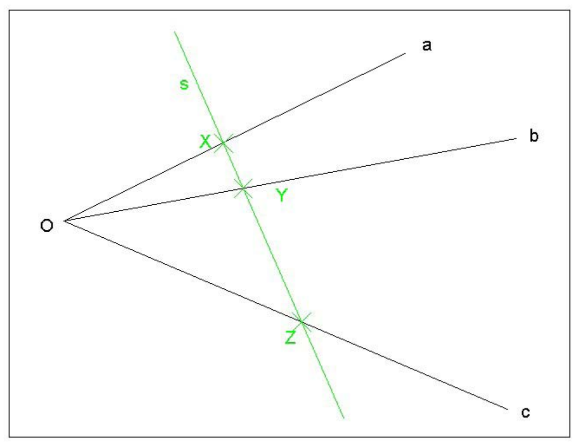

Figure D.5. Problem Solution Step 1

2. Measure the length of segment XY.
3. Divide this length by k. The result is the length of a segment YP, with P belonging to line s, so that XY/YP = k. Draw point P. For this drawing we are assuming that m/n = ½ (see Figure D.6.).

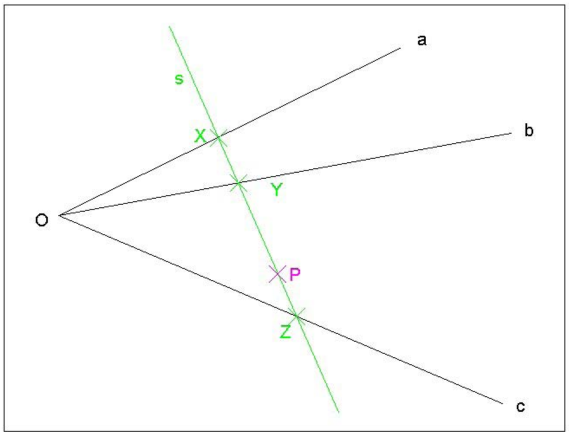

Figure D.6. Problem Solution Step 3

4. Draw a parallel line to line a through point P. This would be line a' (see Figure D.7.).

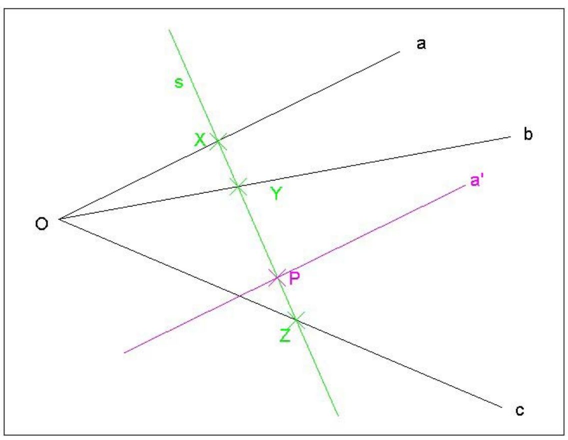

Figure D.7. Problem Solution Step 4

5. Intersection of lines a' and c is point C (see Figure D.8.).

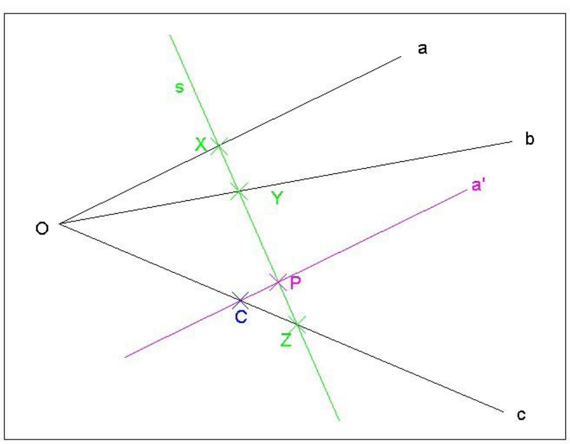

Figure D.8. Problem Solution Step 5

6. Draw a line through points Y and C. This line intersects line a at point A. This will be the line r that we are looking for, and point Y is also point B. Segments AB and BC verify the relationship AB/BC = k (see Figure D.9.).

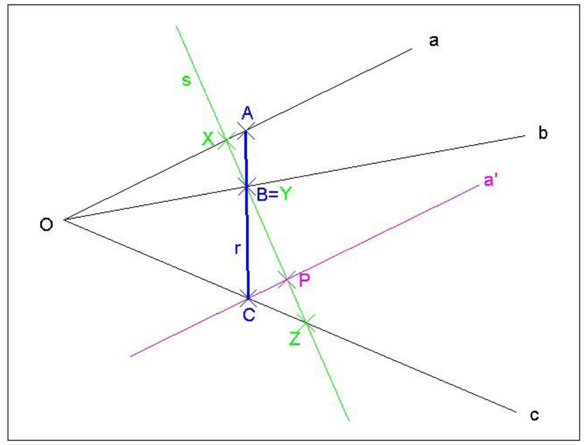

Figure D.9. Problem Solution Step 6

Let us now draw the 6 inch intervals. We will draw them on line r.

7. Multiply the length of segment AB by 6 (for the 6 inch) and divide the result by length m (in inches). This is the length of a 6 inch segment scaled to be drawn on line r.
8. Draw segments with this length on line r. These will mark the points on line r which are 6 inches apart.
9. Join these points with point O. You will obtain the 6 inch lines (see Figure D.10.).

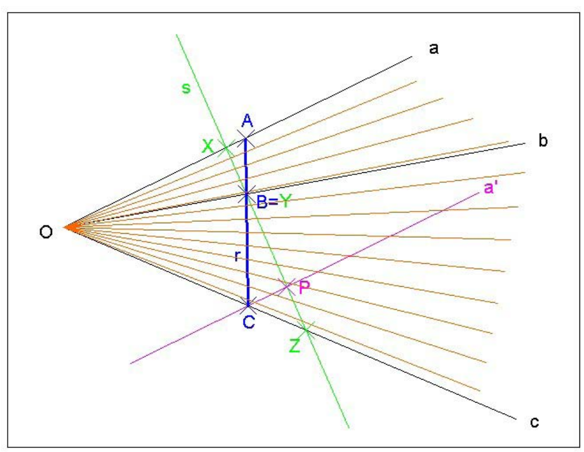

Figure D.10. Problem Solution Final Step

APPENDIX E.

DATA CLEANSING

We began the data analysis process by cleansing the data. We corrected for two potential problems: data entry mistakes and inconsistencies in our data collection methodology.

Identifying and correcting data entry mistakes required auditing the data files in SPSS and comparing them with their Excel counterparts. Specifically, we looked for pedestrian speed outliers to ensure they were exceptional cases and not data entry mistakes. We also audited the dates, times, and locations against the original data collection sheets.

When we began analyzing the data, we identified a few rules in our original methodology that seemed problematic.

A. Group Size Cleanup

In cases of large groups, we entered only one line on the pedestrian characteristic data entry form and noted the number of group members on that line. That had the effect of undercounting the cases of large (more than 5 member) groups. To resolve this problem, we added cases for all members of the group, while leaving those additional members' pedestrian characteristics as missing values. The exceptions were location characteristics and the speed of the group—we assume all members of the group are traveling at the same speed while they are walking together.

B. Strollers and Walking Aides

In cases of baby strollers, we typically entered only one line on the pedestrian characteristics form for the person pushing the stroller. In some cases we included the child in the group number. In other cases we did not. In order to resolve these inconsistencies, we reorganized this data in the following ways:

1. We located every person who was pushing a stroller.
2. If a second line already existed for a child—as part of the adult's group—we made sure the child's entry was using the stroller as a walking aide.
3. If no second line existed for the child, we added it. We left most pedestrian characteristics missing except: speed (which we adopted from the person pushing the stroller), age (to which we assigned a '1'—under 14 years old), group (which we incremented by 1 to show that the baby in the stroller is part of the group), walking aide (to which we assigned a '4'—stroller), and impeded (which we adopted from the person pushing the stroller).
4. We reconciled this data cleanup by comparing the number of people pushing strollers to the number of people riding in strollers.

C. Consolidation of Data

During the data analysis process, we realized we had collected a lot of data and needed to focus it on factors that emerged as the most important. To reduce the overall number of variables, we created a consolidated location data file with the following adjustments:

- Consider only female, assuming the opposite of female is male.
- Consider only proportion of pedestrians with no bags, assuming the opposite of this is proportion with bags + proportion with bags that affect their speed. In the individual data set, this is represented by a variable called new_bag.
- Consider only proportion of pedestrians aged 14 through 65, assuming the opposite of this is the proportion aged 14 and under + the proportion aged 65 and older.
- Consider only proportion of pedestrians who are average in size, assuming the opposite of this is the proportion who are large in size.
- Combined proportions of pedestrians in groups of 4 or more into a single group: group_4p. For group size analyses with the consolidated data set, we will consider only proportion of pedestrians in groups of 1, groups of 2, groups of 3, and groups of 4 plus (group_4p).
- Combined proportion of pedestrians with headphones, phones, drinks, PDAs, and cigarettes into a single variable called "distract". This variable indicates the proportion of people who are distracted by one or more of these items as they walk.
- Consider only proportion of pedestrians not pushing anything, assuming the opposite of this is the proportion pushing a stroller + proportion pushing a wheelchair + proportion pushing a cart + proportion pushing (or pulling) a rolling suitcase. In the individual data set, this grouping is represented by a variable called new_push.
- Consider only proportion of pedestrians with no walking aide, assuming the opposite of this is proportion of pedestrians using a cane + proportion of pedestrians using a wheelchair + proportion of pedestrians using crutches + proportion of pedestrians using a stroller. In the individual data set this grouping is represented by a variable called new_aide.
- Consider only proportion of pedestrians not impeded by street furniture or by other pedestrians, assuming the opposite of this is proportion of pedestrians impeded.

This reduces the total number of variables to be included in analysis and combines some variables with lesser proportions together.

APPENDIX F.

EXPLORATORY DATA ANALYSIS (EDA)

Prior to statistically analyzing our collected data, we performed an exploratory data analysis (EDA), using several SPSS processes, to make sure the data was statistically valid, and that it met the variable criteria required to perform linear regression analyses. The two important EDA methods employed were tests for variable collinearity and the distribution of residuals. Both of these methods are discussed below.

Collinearity in a regression model refers to a situation in which two or more of the predictor (independent) variables are related to each other in a linear fashion. In other words, collinearity (or multicollinearity) involves two or more predictor variables whose variances are related to each other, and are therefore explaining the same results in the model. Collinearity reveals redundancy in the predictor variables, and has a distorting effect on the regression equation's coefficient estimation as well as in the coefficient standard errors. One method for testing collinearity in SPSS regression models involves examining the "tolerance" and the variance inflation factor (VIF), which can be selected by the SPSS user to be displayed in a regression output. The tolerance measurement indicates the percentage of variance in each predictor variable in a regression model which can not be attributed to the other predictor variables. Therefore, a low tolerance value indicates a high collinearity between the predictor variable in question and one or more of the other predictor variables. The VIF value is essentially the reciprocal of the tolerance value, and higher VIF values are a cause for concern, as they indicate larger factors of regression model inflation due to collinearity in the predictor variables. A rule of thumb is that tolerance values of 0.20 and under are cause for concern, as are VIF values of 20 and over.

Our data analysis includes regression models with three different dependent variables: mean speed, impedance and flow rate. Prior to finalizing the three different regression models, we checked the tolerance and VIF values for the predictor variables in each, to make certain there was no significant collinearity involved in any model. We used the backward stepwise regression process in analyzing our data, so these tolerance and VIF values refer to those of the final models reached, with the most significant predictor variables. In the backward stepwise regression model with mean speed as the dependent variable, the predictor variable tolerance values ranged from 0.531 to 0.797, well above the 0.20 minimum threshold. The VIF values ranged from 1.255 to 1.884, well below the maximum threshold of 20. In the backward stepwise regression model with flow rate as the dependent variable, the predictor variable tolerance values ranged from 0.565 to 0.907, well above the 0.20 minimum threshold. The VIF values ranged from 1.103 to 1.769, well below the maximum threshold of 20. In the backward stepwise regression model with proportion impeded as the dependent variable, the predictor variable tolerance values are both 0.803, well above the 0.20 minimum threshold. The VIF values are both 1.246, well below the maximum threshold of 20. These results all indicate a lack of significant collinearity in this study's regression models.

It was also necessary to examine the residuals (the differences between observed values and expected or "predicted" values) in the regression models to determine if their distribution was normal. In order for the linear regression to have valid results, the regression residuals must have a normal distribution (values of the residuals concentrated around their mean, diminishing in frequency as residual values move away from the mean in either direction). To test for the normality of residual distribution, we performed the stepwise and backward stepwise regression analyses. There were three different analyses, with three different dependent variables: mean pedestrian speed at locations, flow rate at locations and proportion of impeded pedestrians at locations. We saved the residuals for each of these regression models, and performed a "descriptive statistics" analysis on the residuals, using the SPSS Descriptives function. Two crucial measurements of residual distribution in the descriptive statistics procedure are the skewness statistic and the kurtosis statistic. Skewness measures the degree to which a variable's distribution (in this case, residual distribution) is pulled out in the positive or negative direction by outliers. The most desirable skewness statistic would be zero, which would indicate a perfectly normal distribution. However, skewness statistics of between -1 and 1 are acceptable; with values less than two standard errors of skewness being the most desirable.

Kurtosis is a measurement which complements the skewness statistic. An in-depth discussion of Kurtosis is beyond the scope of this report, however, it also has an acceptable value of -1 to 1.

If the skewness or Kurtosis value of a residual's distribution is not within the acceptable range (-1 to 1), it is recommended to transform the dependent variable of a regression model in order to bring its outliers closer to the variable's mean value. Some typical transformation techniques are: taking the square root or $\log_{10}$ of a variable's values in order to correct for significant positive skew, and squaring or cubing a variable's values in order to correct for significant negative skew.

After we performed the three stepwise regression analyses, it was revealed that the flow rate analysis was the only one with significant residual skew. Flow rate had some seriously high skew and kurtosis values, indicating a significant positive skew in its residual distribution. We performed a Log_{10} transformation on the flow rate variable (created a new variable), re-regressed it using the new Log_{10} variable as the dependent, and noticed a change in the distribution of residuals toward normalcy (skewness and kurtosis statistics were much lower). The impeded regression did not create significantly skewed residuals. In addition, the regression analysis with speed as the dependent variable (excluding the 8W PM and 60E AM cases) resulted in skewness and kurtosis statistics which were acceptable.

APPENDIX G.

LOCATION CHARACTERISTICS AND SPEED REGRESSION SUMMARY

Regression Analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
8*	0.861	0.741	0.726	0.124536	-0.001	0.357	1	109	0.551

* Model 8 Predictors: (Constant), Group:1, Impeded, Flow Rate, Bag: No, Female, Trip: Work
** Dependent Variable: Mean Speed

Table: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
8	Regression	4.871	6	0.812	52.346	.000(h)
	Residual	1.706	110	0.016		
	Total	6.577	116			

Predictors: (Constant), Group: 1, Impeded, Flow Rate, Bag: No, Female, Trip: Work

Table: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
8	(Constant)	4.493	0.13		34.631	0	4.236	4.75					
	Group: 1	0.358	0.113	0.209	3.16	0.002	0.133	0.582	0.628	0.289	0.153	0.541	1.849
	Impeded	-0.48	0.104	-0.278	-4.602	0	-0.687	-0.274	-0.594	-0.402	-0.223	0.648	1.542
	Flow Rate	-0.037	0.01	-0.218	-3.772	0	-0.056	-0.018	-0.47	-0.338	-0.183	0.706	1.417
	Bag: No	-0.667	0.125	-0.321	-5.341	0	-0.915	-0.42	-0.49	-0.454	-0.259	0.653	1.531
	Female	-0.547	0.165	-0.18	-3.309	0.001	-0.875	-0.219	-0.315	-0.301	-0.161	0.798	1.253

APPENDIX H.

SPEED BY TIME OF DAY REGRESSION SUMMARY

Regression: AM

Model Summary(e)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.542(a)	0.294	0.268	0.100338	0.294	11.245	1	27	0.002
2	.787(b)	0.619	0.59	0.075112	0.325	22.182	1	26	0
3	.829(c)	0.688	0.65	0.06937	0.069	5.482	1	25	0.027
4	.862(d)	0.743	0.7	0.064252	0.055	5.141	1	24	0.033

a Predictors: (Constant), Flow Rate
b Predictors: (Constant), Flow Rate, Trip: Work
c Predictors: (Constant), Flow Rate, Trip: Work, Engaged in activity
d Predictors: (Constant), Flow Rate, Trip: Work, Engaged in activity, Group: 3
e Dependent Variable: Mean Speed

ANOVA(e)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	0.113	1	0.113	11.245	.002(a)
	Residual	0.272	27	0.01		
	Total	0.385	28			
2	Regression	0.238	2	0.119	21.124	.000(b)
	Residual	0.147	26	0.006		
	Total	0.385	28			
3	Regression	0.265	3	0.088	18.338	.000(c)
	Residual	0.12	25	0.005		
	Total	0.385	28			
4	Regression	0.286	4	0.071	17.317	.000(d)
	Residual	0.099	24	0.004		
	Total	0.385	28			

a Predictors: (Constant), Flow Rate
b Predictors: (Constant), Flow Rate, Trip: Work
c Predictors: (Constant), Flow Rate, Trip: Work, Engaged in activity
d Predictors: (Constant), Flow Rate, Trip: Work, Engaged in activity, Group: 3
e Dependent Variable: Mean Speed

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	4.646	0.036		127.563	0	4.571	4.721
	Flow Rate	-0.061	0.018	-0.542	-3.353	0.002	-0.099	-0.024
2	(Constant)	4.304	0.078		55.497	0	4.145	4.464
	Flow Rate	-0.117	0.018	-1.034	-6.468	0	-0.154	-0.08
	Trip: Work	0.679	0.144	0.753	4.71	0	0.382	0.975
3	(Constant)	4.276	0.073		58.868	0	4.126	4.426
	Flow Rate	-0.115	0.017	-1.021	-6.916	0	-0.15	-0.081
	Trip: Work	0.599	0.137	0.664	4.358	0	0.316	0.882
	Engaged in activity	0.5	0.214	0.274	2.341	0.027	0.06	0.94
4	(Constant)	4.321	0.07		61.612	0	4.176	4.466
	Flow Rate	-0.118	0.015	-1.045	-7.617	0	-0.15	-0.086
	Trip: Work	0.575	0.128	0.637	4.499	0	0.311	0.838
	Engaged in activity	0.471	0.198	0.258	2.375	0.026	0.062	0.88
	Group: 3	-0.892	0.393	-0.241	-2.267	0.033	-1.704	-0.08

a Dependent Variable: Mean Speed

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	4.21604	4.73845	4.54128	0.101059	29
Residual	-0.10328	0.14051	0	0.059486	29
Std. Predicted Value	-3.218	1.951	0	1	29
Std. Residual	-1.607	2.187	0	0.926	29

a Dependent Variable: Mean Speed

Regression: MIDDAY

Model Summary(c)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.621(a)	0.385	0.375	0.140594	0.385	37.627	1	60	0
2	.655(b)	0.429	0.41	0.136637	0.044	4.525	1	59	0.038

a Predictors: (Constant), Impeded
b Predictors: (Constant), Impeded, Flow Rate
c Dependent Variable: Mean Speed

ANOVA(c)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	0.744	1	0.744	37.627	.000(a)
	Residual	1.186	60	0.02		
	Total	1.93	61			
2	Regression	0.828	2	0.414	22.181	.000(b)
	Residual	1.102	59	0.019		
	Total	1.93	61			

a Predictors: (Constant), Impeded
b Predictors: (Constant), Impeded, Flow Rate
c Dependent Variable: Mean Speed

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	4.291	0.03		142.632	0	4.231	4.351
	Impeded	-0.732	0.119	-0.621	-6.134	0	-0.971	-0.493
2	(Constant)	4.343	0.038		114.411	0	4.267	4.419
	Impeded	-0.612	0.129	-0.519	-4.74	0	-0.87	-0.353
	Flow Rate	-0.027	0.012	-0.233	-2.127	0.038	-0.052	-0.002

a Dependent Variable: Mean Speed

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	3.83284	4.31229	4.14257	0.116524	62
Residual	-0.29602	0.25102	0	0.134379	62
Std. Predicted Value	-2.658	1.457	0	1	62
Std. Residual	-2.166	1.837	0	0.983	62

a Dependent Variable: Mean Speed

Regression: PM (EXCLUDE 98)

Model Summary(e)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.716(a)	0.512	0.492	0.13601	0.512	25.219	1	24	0
2	.807(b)	0.651	0.621	0.117467	0.139	9.175	1	23	0.006
3	.846(c)	0.716	0.677	0.108463	0.064	4.977	1	22	0.036
4	.896(d)	0.803	0.766	0.092375	0.087	9.33	1	21	0.006

a Predictors: (Constant), Group: 1
b Predictors: (Constant), Group: 1, Trip: Work
c Predictors: (Constant), Group: 1, Trip: Work, Bag: No
d Predictors: (Constant), Group: 1, Trip: Work, Bag: No, Impeded
e Dependent Variable: Mean Speed

ANOVA(e)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	0.467	1	0.467	25.219	.000(a)
	Residual	0.444	24	0.018		
	Total	0.91	25			
2	Regression	0.593	2	0.297	21.492	.000(b)
	Residual	0.317	23	0.014		
	Total	0.91	25			
3	Regression	0.652	3	0.217	18.465	.000(c)
	Residual	0.259	22	0.012		
	Total	0.91	25			
4	Regression	0.731	4	0.183	21.425	.000(d)
	Residual	0.179	21	0.009		
	Total	0.91	25			

a Predictors: (Constant), Group: 1
b Predictors: (Constant), Group: 1, Trip: Work
c Predictors: (Constant), Group: 1, Trip: Work, Bag: No
d Predictors: (Constant), Group: 1, Trip: Work, Bag: No, Impeded
e Dependent Variable: Mean Speed

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	3.623	0.151		23.933	0	3.311	3.936
	Group: 1	1.116	0.222	0.716	5.022	0	0.657	1.575
2	(Constant)	3.602	0.131		27.504	0	3.331	3.873
	Group: 1	0.871	0.208	0.558	4.18	0	0.44	1.302
3	Trip: Work	0.465	0.153	0.405	3.029	0.006	0.147	0.782
	(Constant)	3.848	0.164		23.49	0	3.509	4.188
	Group: 1	0.781	0.197	0.501	3.973	0.001	0.373	1.188
	Trip: Work	0.435	0.142	0.379	3.062	0.006	0.141	0.73
4	Bag: No	-0.685	0.307	-0.263	-2.231	0.036	-1.322	-0.048
	(Constant)	3.98	0.146		27.248	0	3.677	4.284
	Group: 1	0.713	0.169	0.458	4.226	0	0.362	1.065
	Trip: Work	0.524	0.125	0.456	4.207	0	0.265	0.783
	Bag: No	-0.872	0.269	-0.335	-3.244	0.004	-1.43	-0.313
	Impeded	-0.528	0.173	-0.313	-3.055	0.006	-0.888	-0.169

a Dependent Variable: Mean Speed

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	4.04805	4.71905	4.37176	0.17103	26
Residual	-0.16514	0.1516	0	0.084663	26
Std. Predicted Value	-1.893	2.031	0	1	26
Std. Residual	-1.788	1.641	0	0.917	26

a Dependent Variable: Mean Speed

Regression: ALL

Model Summary(i)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.628(a)	0.395	0.39	0.186018	0.395	75.072	1	115	0
2	.764(b)	0.584	0.576	0.155005	0.189	51.622	1	114	0
3	.792(c)	0.628	0.618	0.147182	0.044	13.441	1	113	0
4	.817(d)	0.668	0.656	0.139635	0.04	13.544	1	112	0
5	.840(e)	0.705	0.692	0.132165	0.037	14.019	1	111	0
6	.854(f)	0.73	0.715	0.127031	0.025	10.153	1	110	0.002
7	.861(g)	0.741	0.725	0.124901	0.011	4.783	1	109	0.031
8	.861(h)	0.741	0.726	0.124536	-0.001	0.357	1	109	0.551

a Predictors: (Constant), Group: 1
b Predictors: (Constant), Group: 1, Impeded
c Predictors: (Constant), Group: 1, Impeded, Trip: Unknown
d Predictors: (Constant), Group: 1, Impeded, Trip: Unknown, Flow Rate
e Predictors: (Constant), Group: 1, Impeded, Trip: Unknown, Flow Rate, Bag: No
f Predictors: (Constant), Group: 1, Impeded, Trip: Unknown, Flow Rate, Bag: No, Female
g Predictors: (Constant), Group: 1, Impeded, Trip: Unknown, Flow Rate, Bag: No, Female, Trip: Work
h Predictors: (Constant), Group: 1, Impeded, Flow Rate, Bag: No, Female, Trip: Work
i Dependent Variable: Mean Speed

ANOVA(i)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.598	1	2.598	75.072	.000(a)
	Residual	3.979	115	0.035		
	Total	6.577	116			
2	Regression	3.838	2	1.919	79.87	.000(b)
	Residual	2.739	114	0.024		
	Total	6.577	116			
3	Regression	4.129	3	1.376	63.538	.000(c)
	Residual	2.448	113	0.022		
	Total	6.577	116			
4	Regression	4.393	4	1.098	56.329	.000(d)
	Residual	2.184	112	0.019		
	Total	6.577	116			
5	Regression	4.638	5	0.928	53.106	.000(e)
	Residual	1.939	111	0.017		
	Total	6.577	116			
6	Regression	4.802	6	0.8	49.596	.000(f)
	Residual	1.775	110	0.016		
	Total	6.577	116			
7	Regression	4.877	7	0.697	44.657	.000(g)
	Residual	1.7	109	0.016		
	Total	6.577	116			
8	Regression	4.871	6	0.812	52.346	.000(h)
	Residual	1.706	110	0.016		
	Total	6.577	116			

a Predictors: (Constant), Group: 1
b Predictors: (Constant), Group: 1, Impeded
c Predictors: (Constant), Group: 1, Impeded, Trip: Unknown
d Predictors: (Constant), Group: 1, Impeded, Trip: Unknown, Flow Rate
e Predictors: (Constant), Group: 1, Impeded, Trip: Unknown, Flow Rate, Bag: No
f Predictors: (Constant), Group: 1, Impeded, Trip: Unknown, Flow Rate, Bag: No, Female
g Predictors: (Constant), Group: 1, Impeded, Trip: Unknown, Flow Rate, Bag: No, Female, Trip: Work
h Predictors: (Constant), Group: 1, Impeded, Flow Rate, Bag: No, Female, Trip: Work
i Dependent Variable: Mean Speed

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	3.577	0.084		42.391	0	3.41	3.744
	Group: 1	1.078	0.124	0.628	8.664	0	0.831	1.324
2	(Constant)	3.844	0.08		48.318	0	3.687	4.002
	Group: 1	0.86	0.108	0.501	7.957	0	0.646	1.074
	Impeded	-0.783	0.109	-0.453	-7.185	0	-0.999	-0.567
3	(Constant)	3.999	0.087		46.182	0	3.828	4.171
	Group: 1	0.827	0.103	0.482	8.032	0	0.623	1.031
	Impeded	-0.768	0.104	-0.443	-7.406	0	-0.973	-0.562
	Trip: Unknown	-0.362	0.099	-0.212	-3.666	0	-0.557	-0.166
4	(Constant)	4.102	0.087		47.286	0	3.93	4.274
	Group: 1	0.802	0.098	0.468	8.197	0	0.608	0.996
	Impeded	-0.554	0.114	-0.32	-4.846	0	-0.78	-0.327
	Trip: Unknown	-0.421	0.095	-0.246	-4.43	0	-0.609	-0.233
	Flow Rate	-0.041	0.011	-0.239	-3.68	0	-0.062	-0.019
5	(Constant)	4.388	0.112		39.096	0	4.166	4.611
	Group: 1	0.618	0.105	0.361	5.896	0	0.411	0.826
	Impeded	-0.52	0.108	-0.3	-4.791	0	-0.735	-0.305
	Trip: Unknown	-0.467	0.091	-0.273	-5.148	0	-0.647	-0.287
	Flow Rate	-0.04	0.01	-0.235	-3.821	0	-0.061	-0.019
	Bag: No	-0.468	0.125	-0.225	-3.744	0	-0.716	-0.22
6	(Constant)	4.647	0.135		34.434	0	4.379	4.914
	Group: 1	0.58	0.102	0.338	5.707	0	0.378	0.781
	Impeded	-0.447	0.107	-0.258	-4.188	0	-0.659	-0.236
	Trip: Unknown	-0.393	0.09	-0.23	-4.35	0	-0.572	-0.214
	Flow Rate	-0.038	0.01	-0.222	-3.742	0	-0.058	-0.018
	Bag: No	-0.583	0.125	-0.28	-4.646	0	-0.831	-0.334
	Female	-0.541	0.17	-0.178	-3.186	0.002	-0.878	-0.205
7	(Constant)	4.529	0.143		31.632	0	4.245	4.813
	Group: 1	0.396	0.13	0.231	3.038	0.003	0.138	0.655
	Impeded	-0.472	0.106	-0.273	-4.473	0	-0.682	-0.263
	Trip: Unknown	-0.097	0.162	-0.057	-0.598	0.551	-0.418	0.224
	Flow Rate	-0.038	0.01	-0.221	-3.802	0	-0.057	-0.018
	Bag: No	-0.653	0.127	-0.314	-5.125	0	-0.906	-0.401
	Female	-0.534	0.167	-0.176	-3.198	0.002	-0.866	-0.203
	Trip: Work	0.317	0.145	0.233	2.187	0.031	0.03	0.604
8	(Constant)	4.493	0.13		34.631	0	4.236	4.75
	Group: 1	0.358	0.113	0.209	3.16	0.002	0.133	0.582
	Impeded	-0.48	0.104	-0.278	-4.602	0	-0.687	-0.274
	Flow Rate	-0.037	0.01	-0.218	-3.772	0	-0.056	-0.018
	Bag: No	-0.667	0.125	-0.321	-5.341	0	-0.915	-0.42
	Female	-0.547	0.165	-0.18	-3.309	0.001	-0.875	-0.219
	Trip: Work	0.389	0.079	0.287	4.914	0	0.232	0.546

a Dependent Variable: Mean Speed

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	3.85126	4.71099	4.29233	0.204919	117
Residual	-0.3058	0.30367	0	0.121272	117
Std. Predicted Value	-2.152	2.043	0	1	117
Std. Residual	-2.455	2.438	0	0.974	117

a Dependent Variable: Mean Speed

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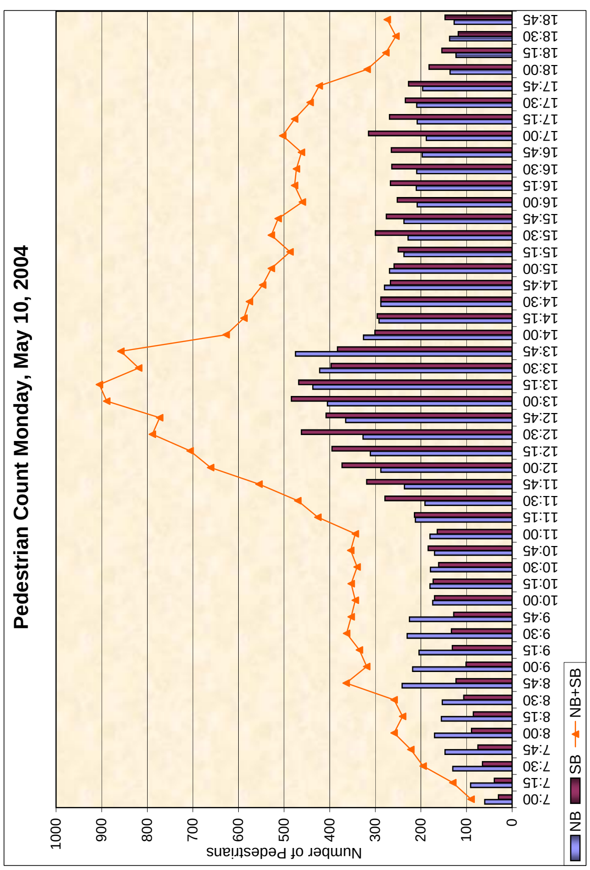
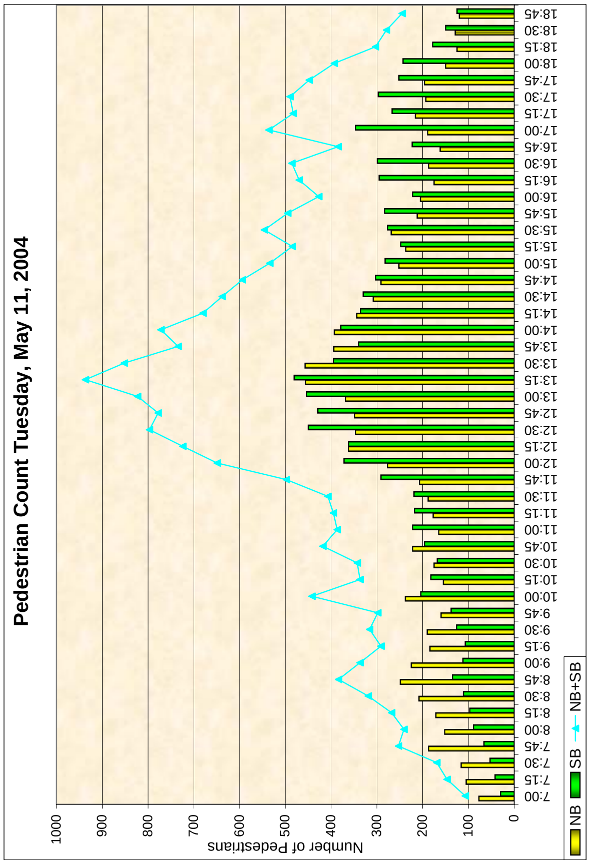
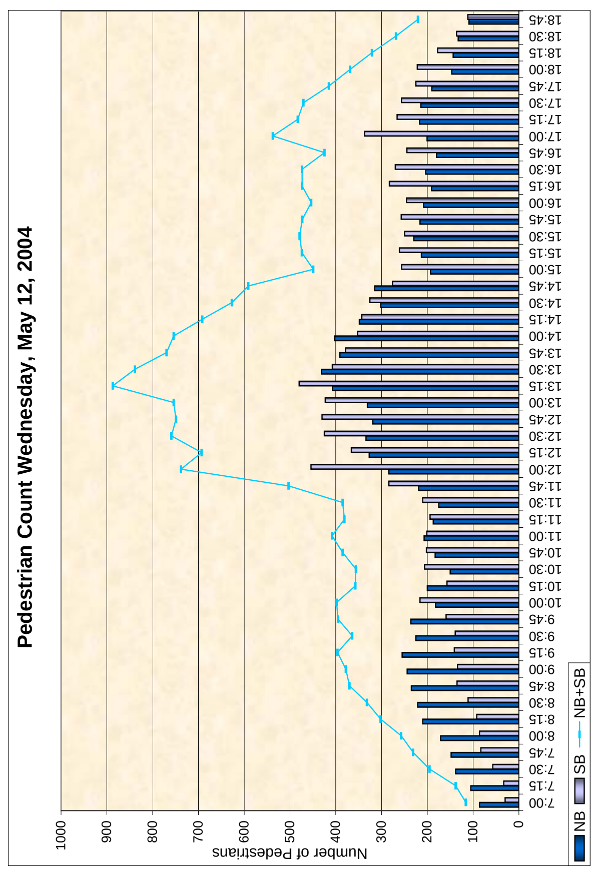
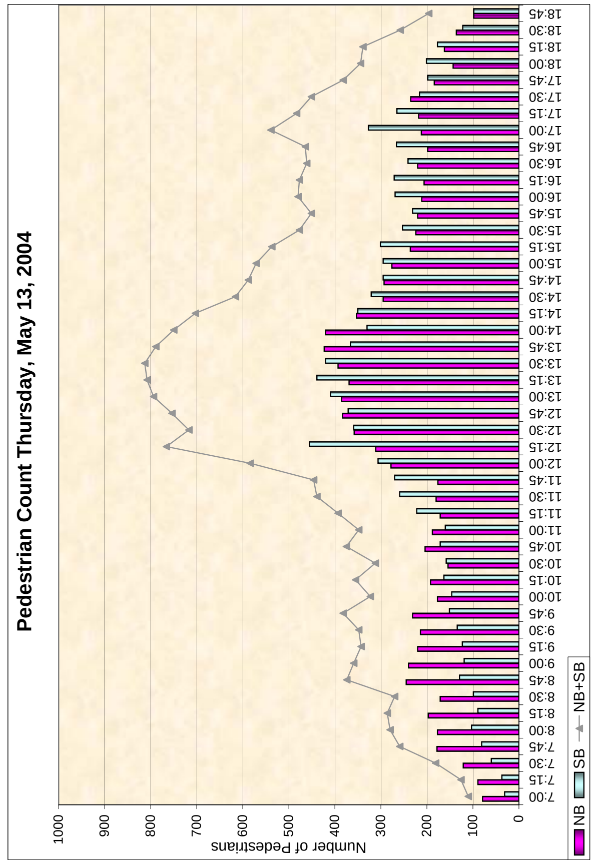
APPENDIX I.

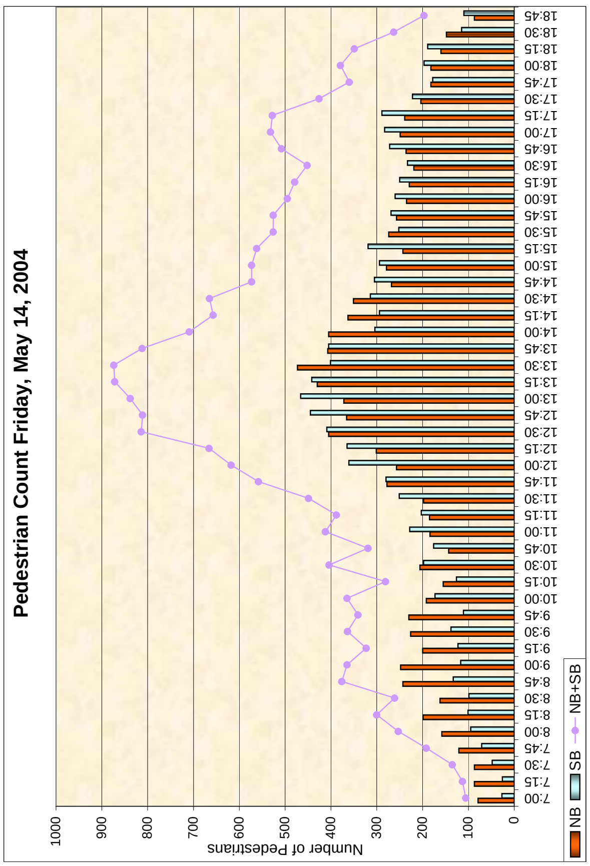
SEVEN DAY PEDESTRIAN AND VEHICULAR COUNT SUMMARY

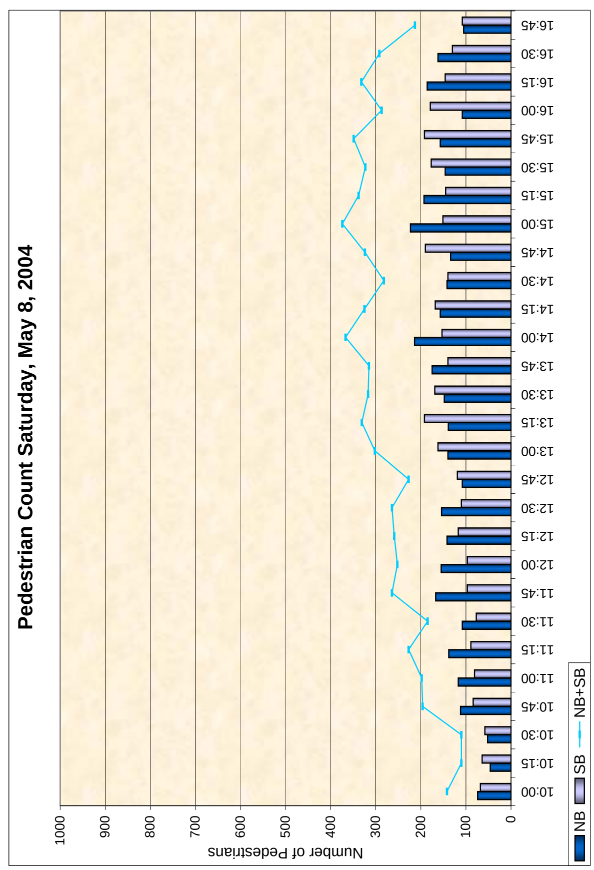

Pedestrian Count Monday, May 10, 2004
Number of Pedestrians
NB
SB
NB+SB

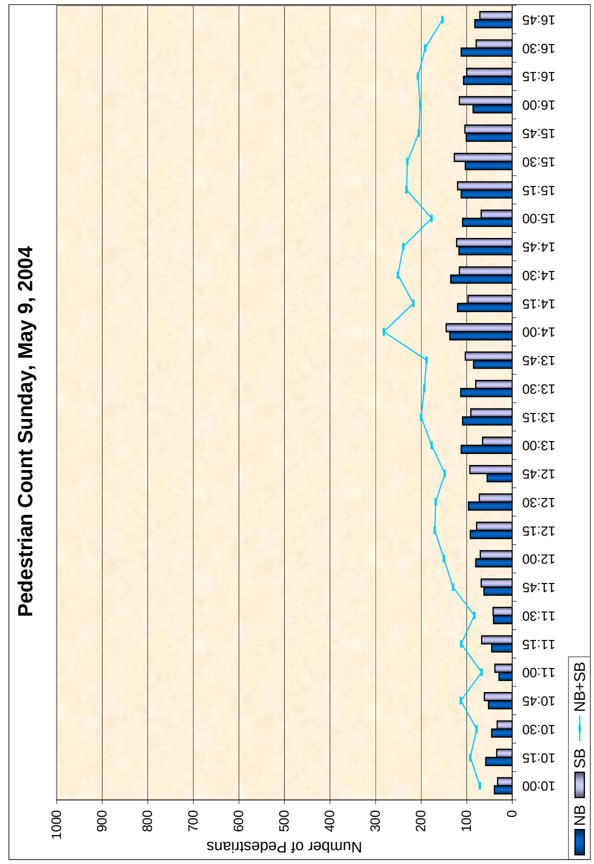

Pedestrian Count Tuesday, May 11, 2004
Number of Pedestrians
NB
SB
NB+SB

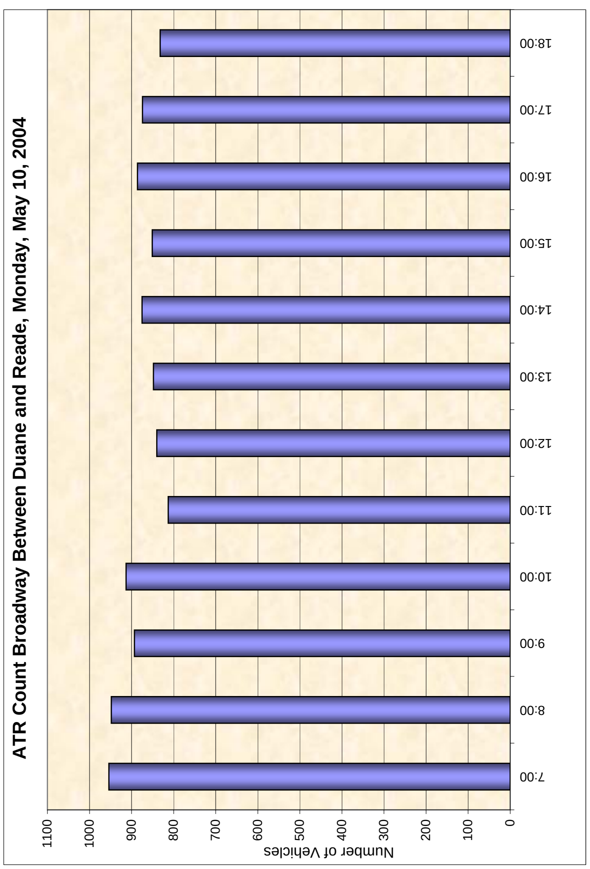

Pedestrian Count Wednesday, May 12, 2004
Number of Pedestrians
NB
SB
NB+SB

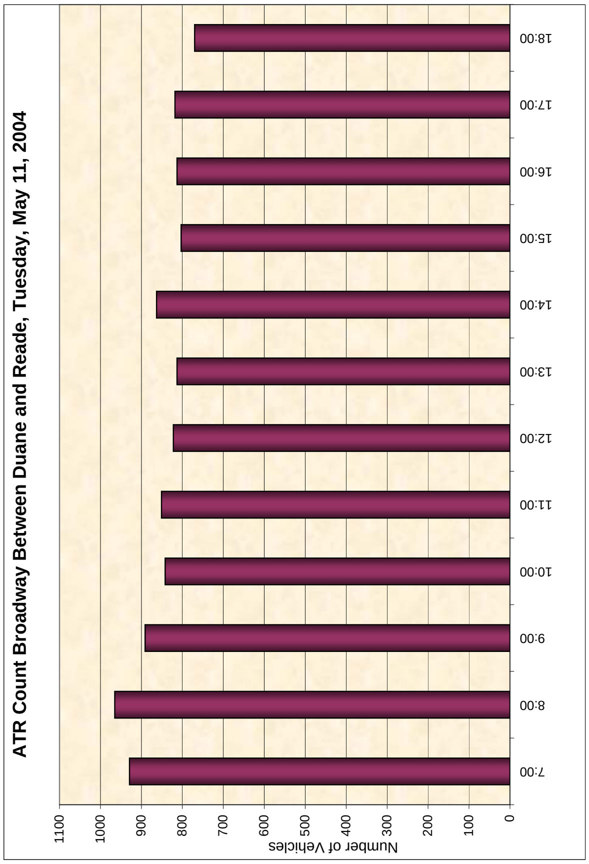

Pedestrian Count Thursday, May 13, 2004
Number of Pedestrians
NB
SB
NB+SB

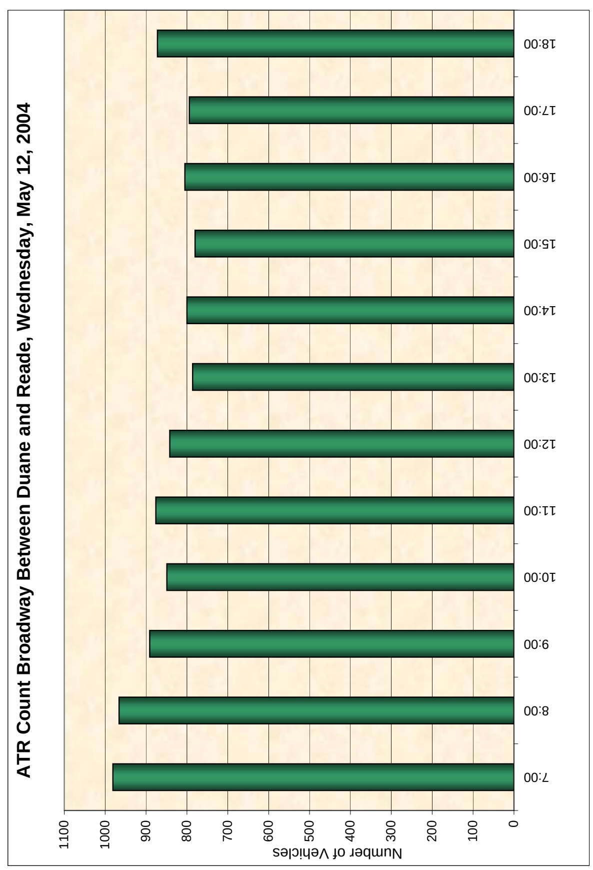

Pedestrian Count Friday, May 14, 2004
Number of Pedestrians
NB
SB
NB+SB

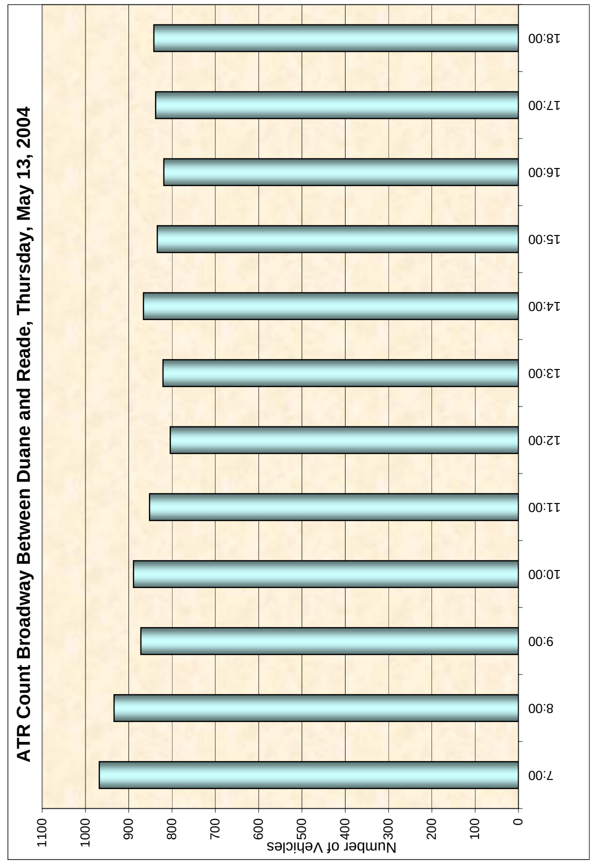

Pedestrian Count Saturday, May 8, 2004
Number of Pedestrians
NB
SB
NB+SB

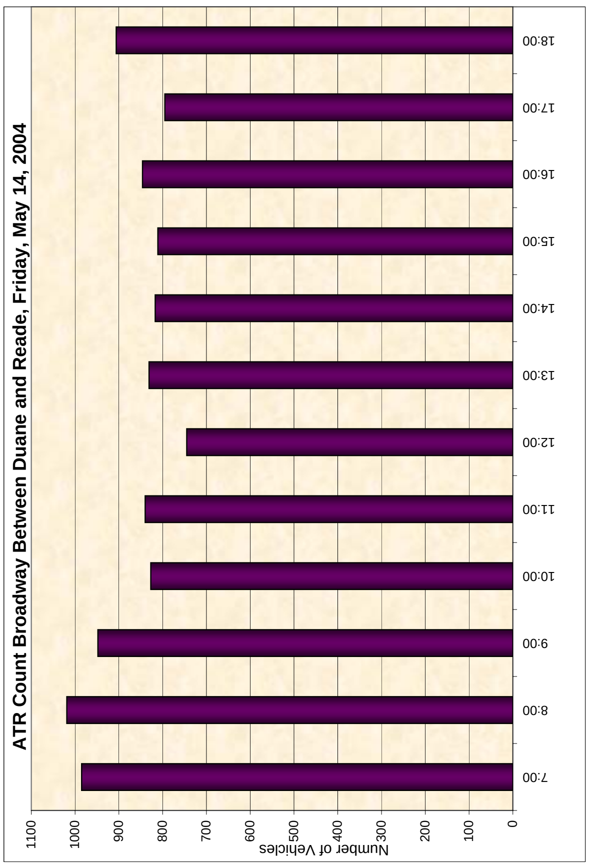

Pedestrian Count Sunday, May 9, 2004
Number of Pedestrians
NB
SB
NB+SB

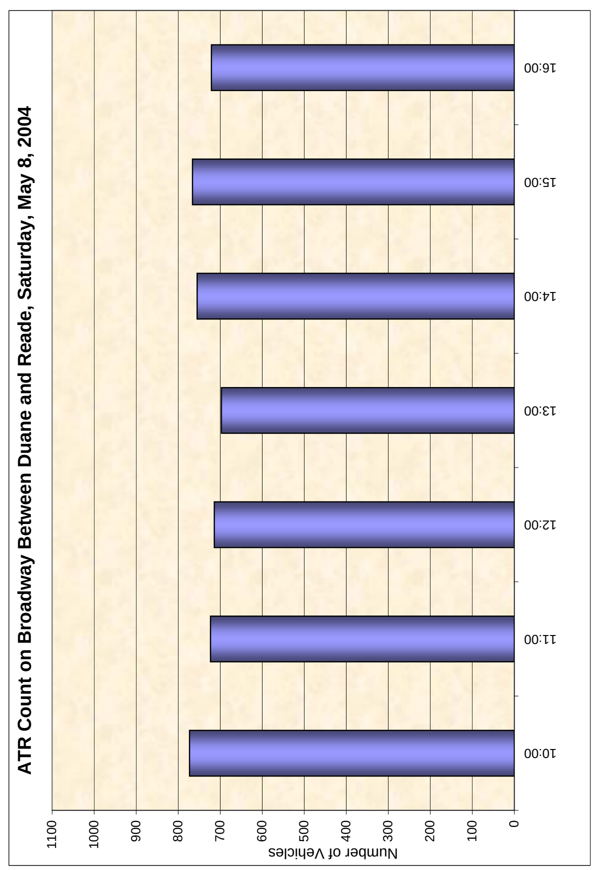

ATR Count Broadway Between Duane and Reade, Monday, May 10, 2004
Number of Vehicles
0 100 200 300 400 500 600 700 800 900 1000 1100
7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00


ATR Count Broadway Between Duane and Reade, Tuesday, May 11, 2004
Number of Vehicles
0 100 200 300 400 500 600 700 800 900 1000 1100
7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00


ATR Count Broadway Between Duane and Reade, Wednesday, May 12, 2004
Number of Vehicles
0 100 200 300 400 500 600 700 800 900 1000 1100
7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00


ATR Count Broadway Between Duane and Reade, Thursday, May 13, 2004
Number of Vehicles
0 100 200 300 400 500 600 700 800 900 1000 1100
7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00


ATR Count Broadway Between Duane and Reade, Friday, May 14, 2004
Number of Vehicles
0
100
200
300
400
500
600
700
800
900
1000
1100
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00


ATR Count on Broadway Between Duane and Reade, Saturday, May 8, 2004
Number of Vehicles
0
100
200
300
400
500
600
700
800
900
1000
1100
10:00
11:00
12:00
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14:00
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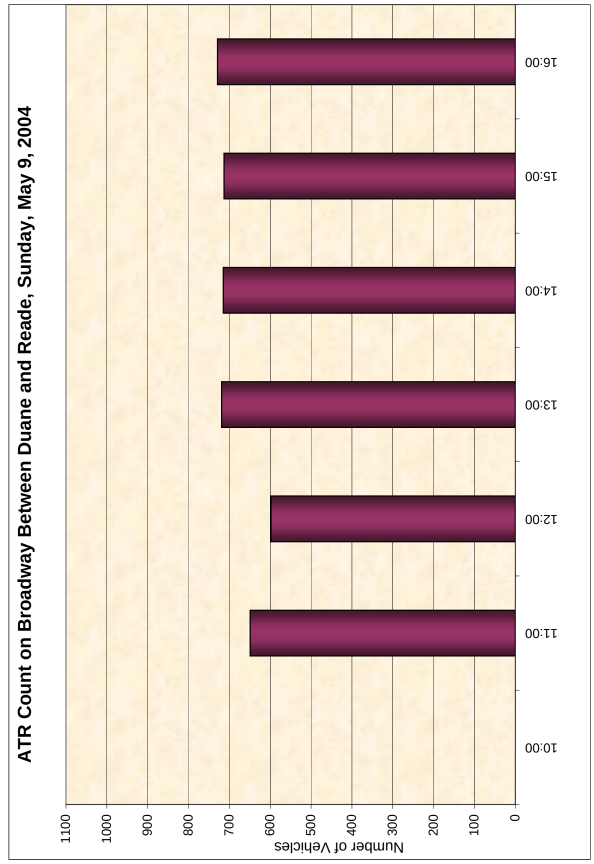
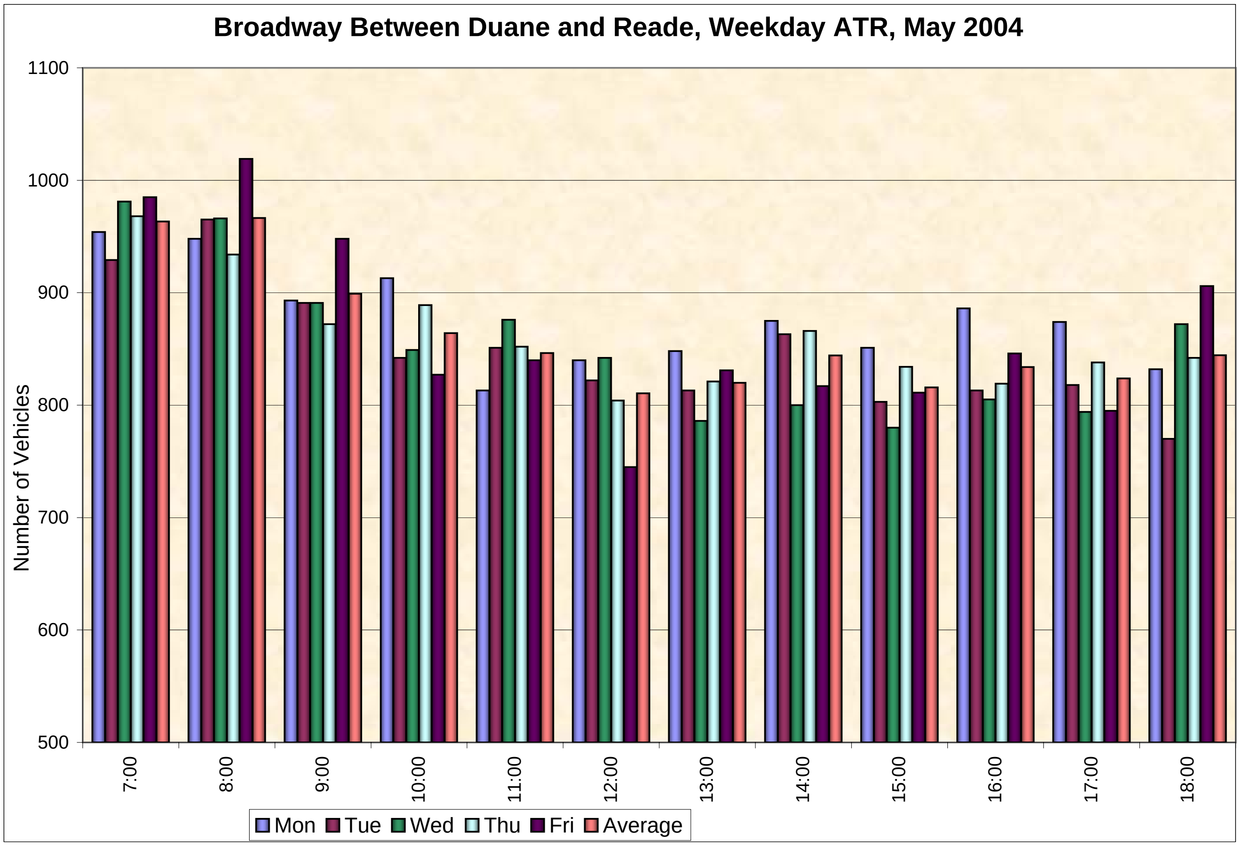
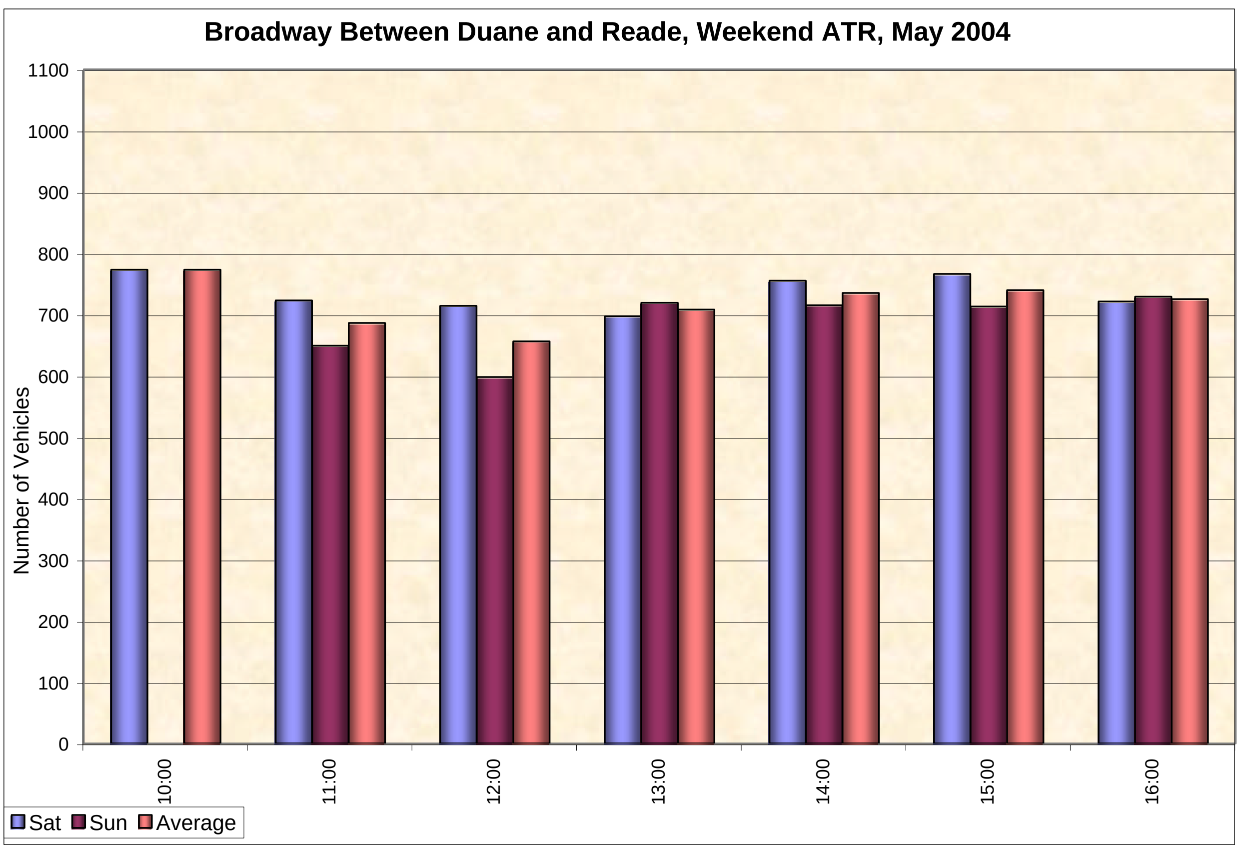
16:00


ATR Count on Broadway Between Duane and Reade, Sunday, May 9, 2004
Number of Vehicles
0
100
200
300
400
500
600
700
800
900
1000
1100
10:00
11:00
12:00
13:00
14:00
15:00
16:00


Broadway Between Duane and Reade, Weekday ATR, May 2004
Number of Vehicles
1100
1000
900
800
700
600
500
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
Mon
Tue
Wed
Thu
Fri
Average


Broadway Between Duane and Reade, Weekend ATR, May 2004
Number of Vehicles
1100
1000
900
800
700
600
500
400
300
200
100
0
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Sat
Sun
Average

APPENDIX J.

SPEED AND DELAY WALK SUMMARY BY WALKER & TIME

Walker A						
	All		Around 12:30pm		Around 3:30pm	
	Average	Median	Average	Median	Average	Median
Time (s) (Walk Time)						
Southbound	821.03	803.64	854.60	846.20	794.17	790.72
Northbound	667.09	658.39	685.46	672.14	652.39	653.62
Total	1488.12	1452.79	1540.07	1518.34	1446.56	1442.83
Time (s) (Stop Time)						
Southbound	39.34	39.89	35.97	26.32	42.03	43.93
Northbound	35.40	35.99	36.88	35.83	34.21	35.99
Total	74.73	78.95	72.85	75.22	76.24	78.95
All Speed (ft/s)						
Southbound	6.06	6.15	5.74	5.72	6.31	6.30
Northbound	6.18	6.25	5.92	5.97	6.38	6.40
Average	6.12	6.23	5.83	5.89	6.35	6.33
All Sidewalk Speed (ft/s)						
Southbound	5.89	6.03	5.68	5.71	6.06	6.06
Northbound	5.92	5.99	5.75	5.89	6.05	6.04
Average	5.90	6.02	5.71	5.81	6.06	6.04
Sidewalk Speed, No Stop at Crosswalk (ft/s)						
Southbound	5.87	5.98	5.66	5.68	6.03	6.03
Northbound	5.87	5.93	5.69	5.77	6.02	6.03
Average	5.87	5.98	5.67	5.73	6.02	6.04
Sidewalk Speed, After Stop at Crosswalk (ft/s)						
Southbound	6.08	6.16	5.85	5.95	6.26	6.24
Northbound	6.09	6.16	5.99	6.12	6.18	6.19
Average	6.09	6.14	5.92	6.02	6.22	6.19
All Crosswalk Speed (ft/s)						
Southbound	6.23	6.41	5.80	5.74	6.57	6.54
Northbound	6.48	6.59	6.12	6.06	6.77	6.69
Average	6.36	6.52	5.96	5.93	6.67	6.62
Crosswalk Speed After Stop (ft/s)						
Southbound	6.16	6.12	6.08	6.08	6.22	6.18
Northbound	5.71	6.45	6.02	5.96	5.46	6.63
Average	5.58	6.29	6.05	5.96	5.20	6.38
Crosswalk Speed with No Stop (ft/s)						
Southbound	6.24	6.39	5.75	5.74	6.63	6.51
Northbound	6.47	6.57	6.11	6.17	6.76	6.67
Average	6.36	6.47	5.93	5.94	6.69	6.64

Walker B						
	ALL		Around 12:30pm		Around 1:30pm	
	Average	Median	Average	Median	Average	Median
Time (s) (Walk Time)						
Southbound	958.23	973.02	954.07	973.02	964.47	964.47
Northbound	791.14	783.71	812.77	814.24	758.69	758.69
Total	1749.37	1753.03	1766.84	1756.73	1723.16	1723.16
Time (s) (Stop Time)						
Southbound	45.43	51.16	50.29	54.87	38.13	38.13
Northbound	59.29	56.69	65.25	61.78	50.35	50.35
Total	104.71	93.37	115.54	93.37	88.48	88.48
All Speed (ft/s)						
Southbound	5.07	5.03	5.08	5.03	5.06	5.06
Northbound	5.09	5.21	4.95	4.85	5.31	5.31
Average	5.08	5.10	5.01	4.99	5.18	5.18
All Sidewalk Speed (ft/s)						
Southbound	5.02	4.95	4.98	4.95	5.07	5.07
Northbound	5.01	5.01	4.89	4.84	5.20	5.20
Average	5.02	4.98	4.94	4.95	5.14	5.14
Sidewalk Speed, No Stop at Crosswalk (ft/s)						
Southbound	5.00	4.96	4.98	4.96	5.04	5.04
Northbound	5.01	5.00	4.93	4.91	5.13	5.13
Average	5.01	4.97	4.95	4.96	5.09	5.09
Sidewalk Speed, After Stop at Crosswalk (ft/s)						
Southbound	4.94	4.94	4.72	4.93	5.28	5.28
Northbound	5.07	5.04	4.79	4.68	5.49	5.49
Average	5.00	4.99	4.75	4.79	5.38	5.38
All Crosswalk Speed (ft/s)						
Southbound	5.13	5.09	5.18	5.12	5.04	5.04
Northbound	5.18	5.35	5.02	4.88	5.43	5.43
Average	5.16	5.19	5.10	5.03	5.24	5.24
Crosswalk Speed After Stop (ft/s)						
Southbound	4.52	4.48	4.43	4.48	4.65	4.65
Northbound	4.97	4.89	5.03	4.81	4.89	4.89
Average	4.75	4.65	4.73	4.65	4.77	4.77
Crosswalk Speed with No Stop (ft/s)						
Southbound	5.21	5.22	5.28	5.28	5.10	5.10
Northbound	5.22	5.43	5.02	4.90	5.52	5.52
Average	5.21	5.24	5.15	5.06	5.31	5.31

Walker C						
	ALL		Around 2:30pm		Around 3:30pm	
	Average	Median	Average	Median	Average	Median
Time (s) (Walk Time)						
Southbound	1001.62	1006.70	1009.44	1007.11	931.22	931.22
Northbound	832.25	836.83	839.49	837.31	767.11	767.11
Total	1833.87	1842.95	1848.93	1849.68	1698.33	1698.33
Time (s) (Stop Time)						
Southbound	75.82	73.51	77.91	76.55	57.08	57.08
Northbound	79.47	83.99	87.31	93.59	8.94	8.94
Total	155.29	154.99	165.21	177.96	66.02	66.02
All Speed (ft/s)						
Southbound	4.88	4.88	4.86	4.87	5.11	5.11
Northbound	4.97	4.90	4.93	4.88	5.29	5.29
Average	4.93	4.88	4.89	4.87	5.20	5.20
All Sidewalk Speed (ft/s)						
Southbound	4.82	4.79	4.77	4.78	5.19	5.19
Northbound	4.74	4.72	4.70	4.71	5.15	5.15
Average	4.78	4.75	4.74	4.75	5.17	5.17
Sidewalk Speed, No Stop at Crosswalk (ft/s)						
Southbound	4.80	4.79	4.76	4.78	5.23	5.23
Northbound	4.71	4.67	4.66	4.66	5.15	5.15
Average	4.76	4.74	4.71	4.71	5.19	5.19
Sidewalk Speed, After Stop at Crosswalk (ft/s)						
Southbound	4.86	4.80	4.84	4.76	5.08	5.08
Northbound	4.79	4.77	4.76	4.76	5.13	5.13
Average	4.83	4.78	4.80	4.76	5.11	5.11
All Crosswalk Speed (ft/s)						
Southbound	4.96	4.99	4.95	4.98	5.04	5.04
Northbound	5.23	5.14	5.20	5.14	5.46	5.46
Average	5.09	5.11	5.08	5.11	5.25	5.25
Crosswalk Speed After Stop (ft/s)						
Southbound	4.68	4.60	4.61	4.55	5.31	5.31
Northbound	4.82	4.71	4.77	4.63	5.29	5.29
Average	4.75	4.70	4.69	4.63	5.30	5.30
Crosswalk Speed with No Stop (ft/s)						
Southbound	5.04	5.08	5.06	5.10	4.92	4.92
Northbound	5.36	5.32	5.35	5.30	5.48	5.48
Average	5.20	5.21	5.20	5.22	5.20	5.20

Walker D						
	ALL		Around 12:30pm		Around 3:30pm	
	Average	Median	Average	Median	Average	Median
Time (s) (Walk Time)						
Southbound	1023.85	1021.24	1033.66	1051.65	1014.05	1011.30
Northbound	830.04	834.42	825.82	850.20	834.26	831.73
Total	1853.89	1843.58	1859.48	1907.53	1848.31	1840.22
Time (s) (Stop Time)						
Southbound	58.01	62.37	39.36	38.10	76.67	74.31
Northbound	60.93	52.07	48.61	51.68	73.24	82.37
Total	118.94	108.47	87.97	89.78	149.91	154.00
All Speed (ft/s)						
Southbound	4.74	4.73	4.75	4.65	4.73	4.75
Northbound	4.82	4.78	4.87	4.78	4.76	4.77
Average	4.78	4.76	4.81	4.76	4.75	4.76
All Sidewalk Speed (ft/s)						
Southbound	4.75	4.75	4.75	4.68	4.76	4.75
Northbound	4.74	4.77	4.72	4.66	4.76	4.78
Average	4.75	4.76	4.73	4.63	4.76	4.76
Sidewalk Speed, No Stop at Crosswalk (ft/s)						
Southbound	4.76	4.77	4.75	4.70	4.77	4.81
Northbound	4.73	4.75	4.71	4.61	4.76	4.77
Average	4.75	4.77	4.73	4.64	4.76	4.78
Sidewalk Speed, After Stop at Crosswalk (ft/s)						
Southbound	4.38	4.68	4.01	4.59	4.74	4.68
Northbound	4.77	4.80	4.76	4.80	4.77	4.80
Average	4.40	4.73	4.04	4.67	4.76	4.75
All Crosswalk Speed (ft/s)						
Southbound	4.73	4.73	4.76	4.81	4.70	4.70
Northbound	4.90	4.86	5.05	4.96	4.76	4.76
Average	4.82	4.77	4.90	4.80	4.73	4.77
Crosswalk Speed After Stop (ft/s)						
Southbound	4.18	4.57	3.98	4.62	4.38	4.52
Northbound	4.82	4.80	4.82	4.92	4.82	4.62
Average	4.34	4.56	4.07	4.49	4.60	4.57
Crosswalk Speed with No Stop (ft/s)						
Southbound	4.76	4.76	4.78	4.78	4.73	4.74
Northbound	4.85	4.84	4.93	4.84	4.77	4.83
Average	4.80	4.80	4.85	4.78	4.75	4.80

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APPENDIX K.

PEER REVIEW COMMITTEE COMMENTS AND MEMBER LIST

A peer review committee received a draft of this report. The committee comprised New York City policymakers, selected experts in the field of pedestrian travel and Level of Service analysis, representatives of New York City agencies involved in the review of environmental and traffic analyses, transportation oriented citizens groups, and academics in the fields of urban planning and transportation. A list of recipients is included at the end of this section. Below is a summary of the responses received from members of the peer review committee.

Jeffrey Zupan and Michael Fishman

As part of the peer review for this project, the TD met with Jeffrey Zupan, Senior Transportation Fellow at the Regional Plan Association (RPA) and Michael Fishman, Associate Director for the Halcrow Group.

The Regional Plan Association is a private regional planning and advocacy organization that concentrates on the New York, New Jersey and Connecticut region. In addition to his work at the RPA, Jeffrey Zupan co-authored *Urban Space for Pedestrians* (1975) with Boris Pushkarev, which is cited in this report, in addition to two books and numerous published reports focused on transportation issues in the New York City region.

The Halcrow Group is a private consulting firm, which, according to its web site, "specializes in the provision of planning, design and management services for infrastructure development worldwide." Michael Fishman's consulting focus is in urban design and transportation, among other things.

Zupan and Fishman suggested that the next phase of this project should include methods of quantifying qualitative pedestrian characteristics in the interest of creating a usable street typology for the study area. The TD should apply land use, trip purpose and street typology to the developing database of sidewalk obstacles and shy distance measurements.

Fishman suggested that it might be beneficial to explore the public/private relationship on sidewalks, to develop a way of engaging the private sector in this study's purview. To achieve this, the TD might want to look at the relationship between the city and the property owner as it relates to the sidewalk. According to Fishman in a subsequent email, "(by) effectively answering the question 'What can the City do to help the property owners improve their sidewalks?' you are providing a common platform for issues to emerge and be addressed…These divergent interests are brought together for one purpose, improving the quality of experience on NYC's sidewalks."

In terms of an opposing flow methodology, Zupan pointed out that problems with opposite flows mostly occur not on sidewalks but on stairways, where flow can be highly unbalanced.

In a subsequent email correspondence, Zupan recommended that the TD focus on specific objectives such as "us(ing) your work to clean up streets of clutter, widen sidewalks and even close some streets to vehicle traffic. Your database for Lower Manhattan is critical in redesigning it for pedestrians and to turn over space now used for vehicle space for more effective use." Zupan went on to suggest that the impact of street furniture on the sidewalk is important, and with the right methodology, this study could be applied to situations in which removing street furniture would be advisable.

He also suggested that the study should focus on trip generation and its relationship with land use instead of on the relationship between pedestrian speeds and land use. Land use would then be used as a predictor of the sidewalk space required to achieve a comfortable LOS. In addition, he asserted that time of day and trip purpose determine pedestrian speed more closely than the pedestrian characteristics highlighted in the report. He suggested that the TD "work with variables you can change: land use and walking space."

Further, Zupan recommended that the TD work toward establishing platoon-oriented LOS analysis as the standard for pedestrian sections of review procedures such as ULURP or EIS. He would like to see any non-platoon analyses in these procedures replaced by platoon analyses.

Fishman, in his email comments (with input from Niels Hoffman, Halcrow "Paxport" software specialist) wrote, among other things, that:

- He agrees with Zupan regarding the importance of identifying obstacles on the sidewalk in order to recommend better sidewalk organization, and recognizes the value of the TD's obstacle study methodology outlined in the report for further analysis in Phase II.
- He supported the report's stated goal of gathering a comprehensive collection of pedestrian characteristics for New York City (page 31). Also, he saw the report as beneficial in serving as a guide to developing a comprehensive pedestrian LOS methodology for Manhattan and other urban environments. He pointed out, however, that each relevant characteristic added to the database adds complexity to the study.
- The TD survey methodology "offers a unique and site specific way of capturing critical information and analyzing patterns and conditions. However, it can also be misleading or too broad in scope to hone in on actual issues with accuracy. This appears to be the case in the Phase I study, where the survey that was undertaken gathers a fair amount of broad baseline information, but falls short in formulating accurate conclusions."
- He recommended the use of origin/destination (O/D) information for trips to the study area, as "this information can be critical in determining many aspects of pedestrian behavior." In keeping with the above recommendation to develop street typologies, Fishman noted that "within the Study Locations…residential influences are abundant and growing at the edges of the study area (Gold Street, Greenwich Street, Hudson Street)…Understanding how commercial and residential patterns compete/overlap or otherwise enhance one another over the course of the day/week is critical to improving New York City pedestrian conditions."

John J. Fruin

According to John J. Fruin's correspondence, he "is the developer of the original level of service standards (FLOS) for pedestrian traffic, and the co-developer with Mr. Gregory Benz of the times space analysis (TSA) technique." In addition, he "has organized, supervised, and analyzed pedestrian traffic surveys within virtually all of the DCP LOS study area, including most of the transit stations in it." He is the author of *Pedestrian Planning and Design* (1971), cited in this report.

Mr. Fruin thinks real problems affecting pedestrian traffic occur at corners and crosswalks, not at mid-block locations. Corners have multi-directional pedestrian flow and queuing pedestrians. Crosswalks are where pedestrian flows from opposite corners mingle and interact with turning vehicles.

Mr. Fruin states that the Level of Service methodology is intended for transportation facilities and interior building space, and that "all the LOS standards represent crowded conditions, except for the unbounded ends of LOS A." As such, it has its drawbacks when it is applied to sidewalk pedestrian activity. Fruin points out that the LOS methodology has worked reasonably well for the study of busy pedestrian crosswalks and corners in New York City.

Fruin advises that any method to determine pedestrian LOS should be simple and easy to apply. It should also be tested to make sure that it is reasonable, because too much sidewalk space allocation could result in an unattractive, boring pedestrian environment.

Mr. Fruin recommends the use of digital photography, computer analysis techniques and touch screen technology to develop reliable counting techniques. He also suggests that sidewalk data in mid-block locations could be collected by having a passenger in a moving car count or photograph sidewalk occupants.

Gregory P. Benz
Senior Vice President/Operations Manager
PB Consult Inc.

Gregory P. Benz is a transportation consultant, the co-developer with John J. Fruin of the pedestrian time-space analysis (TSA) concept, and the author of *Pedestrian Time-Space Concept* (1986), which is cited in this report.

Mr. Benz notes that one of the factors affecting shy distance is the length of the obstacle being studied, and it should somehow be incorporated in the TD's obstacle study methodology (page 45).

As regards to the analysis of the Highway Capacity Manual (HCM), Mr. Benz believes that the HCM methodology needs to be applied and interpreted at each specific situation with certain judgment based on observation and circumstances, and the report should acknowledge that. Even though John Fruin's *Pedestrian Planning and Design* is included as a reference, Mr. Benz recommends that the report reviews this book more thoroughly, given its importance to the subject of study. His experience is that "there is not a very good appreciation and ability to fully understand what a particular LOS standard means," and that a particular LOS is usually perceived as being worse than what it is analytically.

According to Mr. Benz, the report should specify the intended application of the refined, New York City adjusted pedestrian analysis methodology that the TD is seeking to develop. He states that there are three main application categories: physical design, impact analysis and operational/crowd management. According to Benz, the acceptable LOS standard and its interpretation and judgment vary depending on the intended application; LOS should also be dependent on "duration of the period under consideration, nature of the activities, frequency of condition, and characteristics of the analysis population." He also points out that if this refined methodology is going to be used with projections of future conditions, it does not have to be highly precise, since the forecast has a certain degree of uncertainty.

Mr. Benz suggested additional literature for our review. In particular:

- Edward Hall's *The Hidden Dimension* and Robert Sommer's *Personal Space: The Behavioral Basis of Design* talk about "the underlying behavioral basis for pedestrian activities and the speed-density basis for the level of service concept";
- The second edition of his Pedestrian Time-Space publication from 1992, which provides additional discussion on the applications of the methodology developed in his first edition "Pedestrian Time-Space Concept: A New Approach to the Planning and Design of Pedestrian Facilities", Parsons Brinckerhoff Quade & Douglas, Inc., 1986 (already included in the project's literature review);

- His paper co-written with Jack Fruin "Pedestrian Time-Space Concept for Analyzing Corners and Crosswalks", Transportation Research Record 959, Transportation Research Board, National Research Council, Washington, D.C., 1984, which analyzes corners and crosswalks and could be useful for our future research.
- New developments and advances in "the theory and practice for pedestrian flow analysis and simulation of high volume, multi-directional and multi-activity facilities and spaces", even though Mr. Benz recognizes this is beyond the scope of the present project.

Sigurd Grava
Professor Emeritus of Urban Planning
Columbia University

Sigurd Grava's teaching and research focuses on urban transportation and infrastructure, among other things. He has studied urban areas throughout the world and has authored books and papers on issues related to regional transportation and the interaction between land use and transportation.

According to Mr. Grava, one of the main shortcomings of the project is the assumption that sidewalks are linear spaces with only two-directional movements. He would also add "External Environment" and "Pedestrian Intent" to the diagram on page 24. He also thinks that pedestrian walking speed appears to be relevant only for crosswalks.

Mr. Grava distinguishes between at least three modes of walking or using a public space: walking briskly towards a specific destination; meandering and enjoying the scene along the way; and tarrying, or not going anywhere specific. The current HCM methodology would be valid only for the first mode. In his opinion, it is not the personal characteristics but the mode and the mood – which differ from the trip purpose – which are the most important factors affecting pedestrian behavior.

Mr. Grava questions the generalized quantitative approach to pedestrian analysis by transportation experts. He agrees that a scientific, quantitative basis is needed, but he believes that it should be accompanied by a qualitative analysis, with established rankings and classifications. This is acknowledged in the TD's report, but no intent to develop the qualitative approach is shown. Mr. Grava also reminds the TD of the uncertain and chaotic nature of pedestrian behavior to prevent an attempt to be extremely precise when the subject studied is not precise by nature.

According to Mr. Grava, the concept of dynamic density might be of special importance to a pedestrian sidewalk study. This translates into determining the size of the personal space bubble, or how much space a person needs to feel comfortable, which in his opinion might be the key to determining pedestrian standards of service and shy distances.

Finally, Mr. Grava recommends that the study review William Whyte's *Social Life or Small Urban Spaces*, and to do a more thorough review of Gregory Benz's space-time analysis work.

Transportation Alternatives
Amy Pfeiffer
Program Director, Safe Routes for Seniors

Transportation Alternatives is a New York City based citizens group which focuses on urban mobility issues, and advocates for the expansion of the availability and use of alternative modes of transportation.

Amy Pfeiffer believes this study lacks:

- A consideration of vehicle speed as a factor in the correlation between vehicular and pedestrian volumes, and between pedestrian volumes and counts (page 79 of the report). In Pfeiffer's opinion, vehicular speed is an important factor in safety.
- The project's control location is not representative of the city, since its proximity to the center of city government means that this block is mainly used by government

workers who all travel at approximately the same time and only on weekdays; the block is quite empty during weekends.

– A consideration of how the use of the curb lane adjacent to each location affects pedestrians' behavior on the sidewalk; behavior is different if the curb lane is a travel lane, a bus lane, a parking lane or a bike lane. In particular, she states, this would affect the "shy distance" determination methodology (page 45, obstacle study methodology).

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Thanks to all the staff who participated in data collection.