The Role of Streetscape Factors in Pedestrian Path Choices in Shinjuku, Tokyo

Ryan Whitney

A Thesis

in

The Department

of

Geography, Planning & Environment

Presented in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Geography, Urban & Environmental Studies
at Concordia University in
Montreal, Quebec, Canada

April 2009

Your file Votre référence
ISBN: 978-0-494-63066-2
Our file Notre référence
ISBN: 978-0-494-63066-2

ABSTRACT

The Role of Streetscape Factors in Pedestrian Path Choices in Shinjuku, Tokyo

Ryan Whitney

This research evaluates the impact of streetscape variables on pedestrian path choices in a walking environment. Emphasis is increasingly being placed on pedestrian-oriented urban design in an attempt to mitigate the negative consequences associated with automobile-based development. However, little research exists on the actual impact o individual streetscape variables on the distribution of pedestrians within a pre-defined street network. Information regarding pedestrian choice and distribution can be extracted through studying highly-visited streets in existing walking environments (i.e., areas that give priority to pedestrians by restricting vehicular traffic). The focus of this research is the highly-visited walking environment of Shinjuku in Tokyo, Japan. The goal is to identify whether specific streetscape variables (e.g., path maintenance, street width, number of street-level retail outlets, space syntax) impact the distribution of pedestrians within the district. Streetscape variables were assessed using a streetscape evaluation rubric and pedestrian behaviour was recorded through a "tracking" exercise. In addition, pedestrian distribution data collected in 2006 by another researcher working in the same area was analyzed. Findings highlight that retail, trees, path maintenance, paving material, and path width are positively correlated with high pedestrian distribution on street segments. The tracking data highlights the importance of retail in shaping pedestrian path choices and the number of stops made *en route* from origin to destination in a walking environment.

ACKNOWLEDGEMENTS

I would like to thank several people for their contribution to this research. First, I would like to thank Dr. John Zacharias, my supervisor, who has guided me throughout the research process by, among other things, helping set up my experiment in Tokyo, providing me with access to pedestrian distribution data previously collected in Shinjuku, and by guiding my data collection and analysis. Without his guidance this research would not have been possible. Secondly, I would like to thank Deljana Iossifova who assisted me in the collection of pedestrian tracking data in Shinjuku. Without their help there may not have been enough time to complete the on-site data collection. In addition I would like to thank Dr. Craig Townsend and Dr. Jun Munakata, who assisted me in my research design and provided me with constructive criticism to help improve the overall quality of this research. Finally, I would like to thank Dr. Jochen Jaeger who graciously answered questions regarding my statistical analysis.

Nadia Sbaihi and Edith Tam, both fellow M.Sc. candidates in the Geography, Planning and Environment Department and Concordia University, provided significant support during the writing process. I am grateful for their assistance as well as friendship.

Finally, lots of love goes out to my cavemates, Ryan and Tom, and to Shambles too.

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Research Focus

This research has two primary purposes: the first is to decipher the impact of streetscape variables on pedestrian path choices; the second is to describe micro-level pedestrian behaviour. A street segment is defined as the portion of a street located between two intersections (Hillier and Hanson, 1984) whereas streetscape variables differentiate the environment of one street from the next and include characteristics such as the number of trees, the width of the street, building height, paving materials, and the level of automobile traffic. The purpose of this research is to investigate scientifically the relationship between streetscape variables and pedestrian distributions on street segments within a walking environment. The second purpose is to describe micro-level pedestrian behaviour through analyzing pedestrian tracking data. The purpose of providing a micro-level description of pedestrian behaviour is to understand the path choices of pedestrians within a walking environment.

1.2 Research Question and Hypothesis

The hypothesis of this research is that streetscape variables influence discrepancies in pedestrian distributions on street segments in walking environments (e.g., people are attracted to street segments based on the characteristics of the street). The purpose of the research is to test the hypothesis and, if true, decipher what streetscape variables help explain the distribution of pedestrians on street segments in a walking environment (Table 1.1). Proving or disproving this hypothesis can inform planners about the streetscape elements related to the distribution of pedestrians and provide a theoretical contribution to the environment and behaviour field.

1.3 Definition of Planned Walking Environments

Walking environments share three common elements. The first is that a walking environment must give pedestrian movement priority; the second is that it must be considered 'public' in the sense that anyone can enter into the space at any given time; and the third is that collective pedestrian decisions must drive movement within the environment.

The first element of walking environments is that pedestrian movement is dominant, where other modes of transportation, such as automobiles, may have a place, but pedestrians have de facto priority (Zacharias, 2001). The walking environment ends when pedestrian priority is surpassed by another transportation mode. Within the walking environment pedestrians are free to move throughout space and are not prevented from doing so by other forms of transportation. In other words, the entire surface area of the walking environment is pedestrian priority regardless of what vehicles might be using the same space.

The second element of walking environments is that they must remain public. For the purposes of this research, public space is defined as a physical place that is accessible to anyone regardless of gender, class, or race, and is not owned by a specific individual (Sheller and Urry, 2003). In the case of walking environments, streetscapes are often

Table 1.1
List of Investigated Streetscape Variables

Independent Variables	Dependent Variable
Paving Material	Pedestrian Distribution
Number of Retail Outlets	
Walking Path Maintenance	
Number of Food Outlets	
Level of Automobile Traffic	
Number of Retail Outlets	
Number of Service Outlets	
Number of Other Outlets	
Number of Gambling Outlets	
Number of Trees	
Number of Lampposts	
Average Building Height (floors)	
Average Number of Buildings	
Presence or Absence of a Sidewalk	
Path Width	
Space Syntax	
Lighting Level	
Enter and Exit Data	

maintained financially by the city or a cooperative of local business owners, but any one person does not own the space itself. Conversely, private space is defined as space that restricts entry and is owned by a specific individual (Sheller and Urry, 2003). Walking environments can therefore be differentiated from other spaces, such as lifestyle centres[1] that are owned and developed by private companies and therefore lose their public element.

The third element of walking environments is that individual decisions drive movement. More specifically, a defining characteristic of walking environments is the spatial decision making process that is 'integral to the dynamics of pedestrian traffic'

[1] A lifestyle center is a small-scale outdoor retail environment that caters to the retail needs of affluent consumers. It restricts motorized traffic by providing parking at its periphery and provides a pedestrianized street where people are able to walk and shop free of automobile traffic (ICSC, 2004).

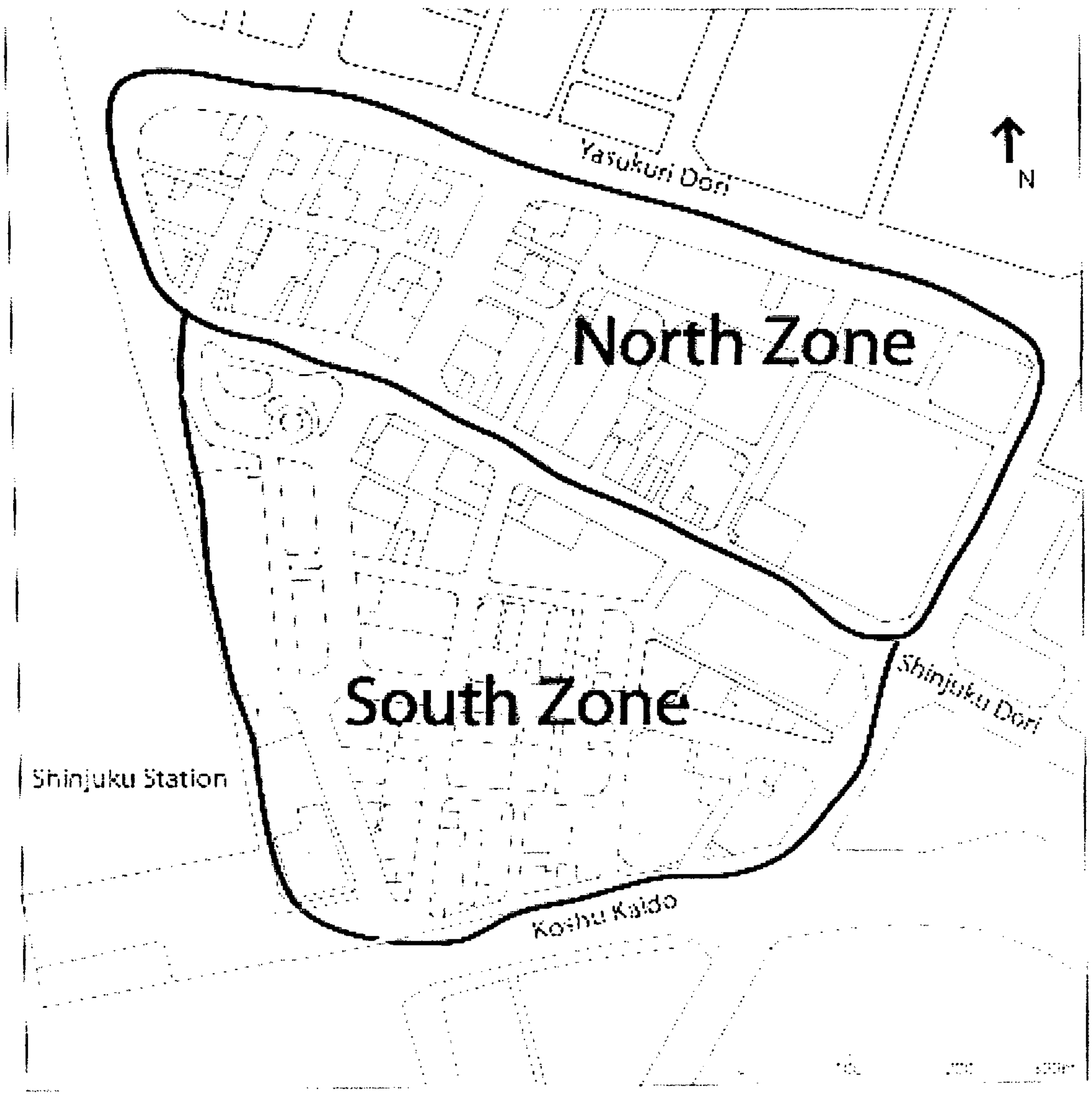
where pedestrian decisions and behaviour drive the local movement pattern (Zacharias, 2001, 3). Other environments, such as those dominated by automobiles, are not as sensitive to individual decisions as there are fewer directions that one can go based on the predetermined network. In walking environments, however, pedestrians are free to move throughout and the result is that the overall movement pattern emerges as a collection of individual decisions.

1.4 Choosing a Case Study

The southeastern portion of the Shinjuku District in Tokyo, Japan, with a total of 87 street segments, was chosen as a case study. (Figure 3.1). The southeastern portion of the Shinjuku District is bound by Shinjuku Station to the west, Yasukuni Dori to the north, and Koshu Kaido to the south. The area is characterized by a heavy retail presence but also features restaurants, a few services (e.g., banks, travel agents), and a small public square. Furthermore, clientele in this area tend to be young in comparison to other areas within Shinjuku. For instance, the western portion of Shinjuku is very business oriented and contains major government offices such as the Tokyo Metropolitan Government Office; to the north, in Kabukicho, is Tokyo's red-light district and features an older, mature clientele with few shopping opportunities; to the east is a more residential-style area with far less pedestrian traffic and a developing gay neighbourhood; the south features the high-end shops of Takashimaya Times Square.

Currently, Shinjuku Station covers approximately 15 hectares (PPS, 2008) whereas the surrounding walking environment investigated by this research covers approximately 40 hectares. Shinjuku station is the busiest train station in the world with

Figure 1.1
Case Study Area: Southeastern Shinjuku



a daily passenger volume of 3.22 million. The station opened in 1885 as a component of the Japan Rail (JR) system and evolved into a very complex transportation hub featuring five JR lines, three metro lines, three privately owned lines, and a high-speed line. The station plays a major role in the movement of commuters throughout the Tokyo Metropolitan Region as it provides connections to a total of nine lines.

Shinjuku was chosen as a case study for two reasons. The first reason is that the borders correspond with the area that was studied by Zacharias and Munakata (2006) and as a significant portion of the analysis in this research is dependent on their collected pedestrian distribution data it was necessary that the borders were consistent. The second reason is that North American walking environments remain small-scale and often do not incorporate a large pedestrian generator. A pedestrian generator is responsible for bringing pedestrians into a walking environment and includes a public transportation terminus, a street, or a parking facility. This research is interested in investigating behaviour in a preexisting large-scale pedestrian environment with many pedestrian generators and therefore North American environments were not appropriate.

1.5 Thesis Structure

This thesis contains seven chapters designed to explore the relationship between pedestrian path choices on street segments in walking environments. The second chapter reviews literature in the behaviour and environment field first discussing the connection between land-use and walking trips followed by the streetscape variables that have been found to impact pedestrian distribution. The third chapter explains the methodology (e.g., streetscape evaluation, tracking) used to test the hypotheses. The fourth chapter discusses the analysis techniques (e.g., multiple regression analysis, pedestrian tracking interpretation) used to analyze the collected data. The fifth chapter reports the quantitative and qualitative results from the analysis with a focus on how the urban environment impacts pedestrian path choices. Attention is given to the streetscape evaluation variables that have the most significant impact on pedestrian distributions.

The sixth chapter concludes by summarizing the findings from the results section and situates the results within the body of previous research. Both the similarities and differences in the findings of this research and previous research in the field are discussed. The seventh and final chapter presents theory surrounding the impact of streetscape elements on pedestrian distributions in walking environments.

Chapter 2

Literature Review

Research on the distribution of pedestrians in walking environments can be summarized under two subheadings: the role of streetscape variables on pedestrian distribution and land-use, environmental complexity, and walking trips. The first subheading will discuss the impact of indentified streetscape variables on pedestrian distribution and the second will discuss the role of land-use planning in walking environments.

2.1 Environment and Walking Behaviour

Previous literature has found that streetscape variables impact pedestrian distribution. However, literature remains piecemeal leading to debate regarding impact of individual streetscape variables on the distribution of pedestrians (Clifton et. al., 2007). Table 2.1 summarizes some of the findings from the literature by highlighting the proportion of variance values (R^2) that were found for streetscape variables responsible for explaining differences in pedestrian distribution on street segments. This research will add to the literature by providing another proportion of variance value for Shinjuku. The most consistent finding from the literature is the significance of space syntax and the presence of retail opportunities in explaining differences in pedestrian distribution on street segments.

Table 2.1
Proportion of Variance (R^2) Values for Pedestrian Distribution

Author	Year	Location	N*	R^2
Pushkarev and Zupan	1975	New York City	600	0.43
Bentham and Patel	1976	Milwaukee	20	0.752
Peponis et. al.	1987	Greece	6 cities	-
Hillier et. al.	1993	London	239	0.547
Peponis et. al.	1997	Atlanta	36	0.55
Read	1999	The Netherlands	5 cities	-
Dysyllas et. al.	2003	London	7526	0.82
Foltête and Piombini	2007	Lille	2148	0.56

***refers to the number of street segments or cities used in the respective study**

2.1.1 Space Syntax Variable

Space syntax is a technique used in the environment and behaviour field to relate the layout of a street network to the number of pedestrians on each street segment. Space syntax methods are based on the theory that the layout of a street network can be used to explain and predict the distribution of pedestrians. The technique assists architects, planners, academics, and designers to understand the likely social consequences of their designs (Hillier and Hanson, 1984). More specifically, space syntax breaks space into components allowing the spaces to be analyzed as networks of choices. The result is that space can be understood numerically, by measuring the integration of the spaces, and quantified, to explain and predict phenomena. Integration refers to the number of connections a single street segment has to all other street segments in a network and is measured in terms of the number of changes in direction. A key question space syntax asks is 'what is the effect of the built environment *in itself* on what happens in cities?' (Hillier, 1999, 345). Space syntax explores the impact of the structure of the built environment on a predetermined variable such as pedestrian or vehicular volumes or the prediction of crime (Nubani and Wineman, 2005); it attempts to explain how the structure of the city itself can be quantified to explain behaviour.

There are many examples of research that use space syntax to explain and predict pedestrian distributions in cities. One of the first studies analyzed the layout of six Greek towns and found that the integration of a street network was strongly associated with the distribution of pedestrians (Peponis et. al., 1989). Similar results were found in Atlanta where a high level of integration was associated with dense pedestrian movement in both downtown and residential locations despite an overall lower pedestrian distribution compared to European cities (Peponis et. al., 1997). Desyllas et. al. (2005) found that space syntax was an appropriate measure of the distribution of pedestrians on street segments in London whereas Foltête and Piombini (2007) found that the space syntax measure of integration accounted for 25 percent of variance on street segments in pedestrian frequency in Lille, France. Furthermore, Read (1999) discovered that space syntax could partially account for the distribution of pedestrians in public space in various Dutch cities whereas Krüger (1980) suggests that the intensity of land use and the number of intersections within a walking environment (i.e., the connectivity of the area) are related to pedestrian distribution where centrally located paths tend to attract more pedestrians. Overall research has generally concluded that 25 percent of the variance in pedestrian distribution in walking environments is explained by the integration of a pathway system (Zacharias, 2001) and that pedestrian movement through is space is a function of integration (Peponis et al, 1997, 345).

The space syntax literature highlights the structure of the urban environment determines pedestrian distribution in predefined network ranging in size from the neighbourhood to city scale. The argument is that the higher the integration measure for a street segment the more likely it is to be filled with pedestrians. These results have been confirmed across a number of environments including regular urban girds (Foltête and Piombini, 2007), fragmented urban grids, business districts (Peponis et. al., 1997), residential districts (Peponis et. al., 1997), small towns (Peponis et. al., 1989) and sections of major metropolitan areas (Desyllas et. al., 2005; Peponis et. al., 1997). The relationship holds across the hours of operation for retail establishments showing that the space syntax relationship still exists when retail shops are closed (Peponis et. al, 1989). Space syntax literature also suggests that the structure of an urban environment, as opposed to the culture of place and space, is important in dictating pedestrian movement and distribution patterns. This is an important point because space syntax is a tool that allows pedestrian distribution to be predicted across space regardless regional differences in culture. Similar results have been found across cultures (the US, UK, Greece, Netherlands) suggesting that the configuration of the space impacts pedestrian distribution uniformly regardless of differences in local culture.

It is important to note that space syntax has criticisms. The main criticism is that space syntax does not account for building height and land use and is very sensitive to boundaries (Ratti, 2004). Boundary sensitivity refers to the fact that different integration values may be found for street segments depending on the number of street segments under investigation. Another criticism comes from the use of axial lines to measure integration. Axial lines represent the longest straight lines in a street network and are linked to the notion of pedestrian visibility (Turner, 2007). From these lines integration can be measured based on the number of intersections one axial line has with all other axial lines in the network. The result is that long linear roads cutting through cities receive the highest integration values. A criticism of axial lines is that there is no consensus on how they should be drawn leading to inconsistent axial representations of real-world environments (Turner, 2007). Another issue is that axial lines often include numerous street segments (i.e., the stretch of road between two intersections) and therefore do not allow for the representation of characteristics specific to each individual street segment. Finally, space syntax has received criticism because it does not account for the qualitative or aesthetic aspects of the streetscape suggesting that the visual aspects of the streetscape, such as the presence of vegetation or the maintenance of the paving materials, leading to an incomplete understanding of the impact of the streetscape on pedestrian distribution (Foltête and Piombini, 2007; Zachariadis, 2005).

2.1.2 Other Variables

Other variables that have been identified as significant in the prediction of pedestrian presence include retail use, trees, level of motorized traffic, building height, sidewalk width, street maintenance, and lighting.

Retail is a consistently used variable in research on pedestrian distributions on street segments. For example, Pushkarev and Zupan (1971) measured the impact of ten different variables (e.g., retail space, office space, restaurant space etc.) on the distribution of pedestrians on street segments in midtown Manhattan. The ten variables each measured the amount of floor space dedicated to each use within the study area discovering that retail, office, and restaurant floor space were the only significant variables in explaining differences in pedestrian distributions. Benham and Patel (1976) also used commercial space as a variable to explain pedestrian distributions and included retail stores, shopping areas, restaurants, and inns in their measurements. They found that 60 percent of the variance in pedestrian distribution was explained by land use variables where retail accounted for a significant proportion. Peponis (1999) also used retail space as a predictive measure of pedestrian distribution finding correlations between the number of retail shops and pedestrian movement. Furthermore, it has been discovered that retail intensifies the effect of space syntax integration over movement because retail establishments tend to be located along the most integrated spaces (Hillier et. al., 1993). This suggests that retail in combination with the space syntax measure of integration account for a higher level of variance in pedestrian distribution than they would on their own.

The presence of trees and motorized traffic impact pedestrian distribution on street segments. Most notably, Shriver (1997) and Foltête and Piombini (2007) have documented the importance of vegetation on the frequency and distribution of pedestrians on street segments. More specifically, Shiver (1997) discovered that trees are one of the most important environmental attributes to encourage people to walk in urban environments whereas Foltête and Piombini (2007) discovered that the presence of vegetation, such as trees and shrubs, are favourable to pedestrian movement but also correlate positively with space syntax integration measures. Motorized traffic was discovered by Shriver (1997) to have little impact on a pedestrian's desire to walk in an urban environment yet Peponis et. al. (1997) discovered that heavy motorized traffic was more correlated with the space syntax measure of integration as opposed to dense pedestrian movement. In addition, Benham and Haynes (1985) found that a reduction in motorized traffic without full pedestrianization was related to an increase in pedestrians on individual street segments. This research suggests that automobile traffic is higher on streets with high space syntax integration values and low pedestrian distributions and that low levels of motorized traffic are related to high pedestrian distributions.

Building height and sidewalk width have been used to explain variance in pedestrian distributions on street segments. Foltête and Piombini (2007) found an inverse relationship between the height of buildings, classified as either 'tall' or 'small', and the distribution of pedestrians on street segments in central Lille, France (a correlation of -0.16 and -0.11 respectively). A low correlation was also discovered for parameters related to the sidewalk (e.g., presence of sidewalks, width of sidewalks) where the former had a correlation of 0.03 and the latter 0.00 with pedestrian distribution. Other studies, have found that building height does not appear to play a large role in pedestrian distribution (Zachariadis, 2005). Street width, however, was related to the distribution of pedestrians on street segments in midtown Manhattan (Pushkarev and Zupan, 1971).

The level of lighting on street segments has been associated with pedestrian distribution on street segments after dark. For instance, Painter (1996) found that light significantly contributes to a person's willingness to walk at night. Therefore if a walking environment features nighttime activities, such as theatres or bars, it is important to provide adequate lighting to attract pedestrians. However, Shriver (1997) reported that lighting had little impact on decisions to walk in an urban environment during the day suggesting that lighting levels might play a more significant role at night when pedestrians are less likely to feel safe.

2.2 Land Use, Environmental Complexity, and Walking Trips

Research has established that land use is linked to walking and that walking trips tend to remain simple and direct despite potential for complex path choices. Land use refers to the physical use of land (e.g. commercial, office, recreational, industrial) and is controlled by zoning regulations that are a reflection of political decisions made at the local, national, or global level (Saelens et. al., 2003). Much research has focused on case studies comparing walking within mixed-use[2] 'traditional' and single use 'suburban' neighbourhoods finding that people in suburban neighbourhoods walk less.

The most consistent result from the land use literature is the importance of mixed-use development and continuous pedestrian systems to encourage walking (Pushkarev and Zupan 1977; Mogridge 1985; Ewing et. al., 1994). In other words, individuals living in mixed-use environments with continuous pedestrian systems (i.e., the central city) are far more likely to walk than those in low-density environments. Examples include Moudon et. al. (1997) who found that neighbourhoods designed with direct and continuous pedestrian systems, as represented by block size and sidewalk length, featured more pedestrians and Vernez-Moudon and Hess (2000) who discovered that retail and residential clustering encourage higher pedestrian exchange between neighbourhoods. Additionally, Peponis et. al. (1997) found that pedestrians are attracted to walking environments depending on the land use mix where dense, centrally located paths with commercial development are most favourable. However, it has been discovered that pedestrian trips tend to be simple and direct despite the layout of the urban environment (Zacharias, 1997). This suggests that pedestrians tend to choose the most direct route

---

[2] In the context of land use, mixed-use development refers to the integration of a variety of land uses (e.g., commercial, residential, and recreational) within the same area.

from their origin to destination despite opportunities for different path choices created by the layout of the urban environment.

The sum of this research highlights that mixed-use development with a heavy retail component is most suitable to encourage walking yet pedestrians tend to take the simplest and often shortest route from origin to destination regardless of the layout of the environment. This suggests that the land use mixture of the walking environment is important to encourage walking and the itinerary of the pedestrian is important in determining path choice.

Chapter 3

Methods

This chapter will discuss the data collection methods for the streetscape variables and the tracking data. The limitations of the data collection methods will also be discussed.

3.1 Data Collection

Data was collected on site in the southeastern portion of the Shinjuku District from Thursday, March 20th, 2008 to Saturday, March 29th, 2008 and again from Wednesday, April 9th, 2008 until Friday, April 11th, 2008 for a total of 13 days. Data collection involved three methods: street evaluation, a tracking exercise, and observation. Details each of the methods will be explained in the following paragraphs.

3.2 Streetscape Evaluation Rubric

A streetscape evaluation rubric was developed to discover what if any streetscape variables influence discrepancies in pedestrian distribution on the 87 street segments in Shinjuku. The street evaluation rubric identified 18 streetscape variables that were recorded by the researcher. All of the 87 street segments in the study area were coded with a number and subsequently evaluated through the use of the rubric (Appendix 1).

The identification of the streetscape variables for collection is based on the findings of previous research. Much research has focused on the importance of configuration of built space in explaining pedestrian movement, such as space syntax, but recently literature has recognized the importance of the visual landscape on walking behaviour (Clifton et. al., 2007; Foltete and Piombini, 2007). However, there is yet to be a universal consensus on what streetscape variables impact pedestrian distribution on street segments. The measures collected in the study area were formulated prior to the data collection process based on previous research and theory.

3.2.1 Retail and Service Variables

The first set of variables recorded were entitled 'retail', 'food', 'service', 'gambling', and 'other' and involved the collection of numerical data on the ground-level floor of each building on each street segment. The retail and service data was important to consider because it has been identified as having an impact in pedestrian distribution (Pushkarev and Zupan, 1971; Benham and Patel, 1976; Peponis, 1999; Hillier et. al., 1993). The theory is that different retail and service uses (i.e., retail, food, service outlets) play roles in attracting pedestrians.

The retail and service variables were collected by a single researcher who walked on each street segment counting and recording the number of each outlet. Retail was classified as stores that sold any sort of commercial product including clothing, electronics, discount goods, convenience goods, and groceries; food included outlets that sold prepared food in an environment with seating; service included banks, ticket sale offices (such as travel agencies) and hotels; gambling included gambling parlours; other included any retail use that did not fit into one of the above categories or retail uses that were ambiguous.

The classification of retail activity included only the ground-level built space for each building on every street segment because of the difficulty presented by evaluating all services available on every floor of each building. In order to complete this task the researcher would physically need to enter into each building and count the various services on every floor, a practice that would be too labour-intensive for a single researcher to complete in a two week period. Furthermore, when in the field it was observed that most pedestrians utilized the ground-floor services of each building suggesting that services on subsequent floors play a less significant role in generating pedestrian traffic.

3.2.2 Landscaping Object Variables

The landscaping object data identified the presence of landscaping objects. Specifically, the number of lampposts, trees, the presence or absence of sidewalks, and the width of the sidewalk on each street segment were recorded.

Lampposts and trees were counted on each street segment if they were over one meter in height (shrubs were not counted). The 'sidewalk' measure was a 'yes' / 'no' evaluation that required the researcher to record if the street segment had a sidewalk on at least one side of the street. The sidewalk was required to run the entire length of the street segment on at least one side of the street in order for the street segment to be classified as having a sidewalk. The width of the sidewalk on each street segment measured in metres and was completed for each street segment.

3.2.3 Building Variables

The number of buildings on each street segment and the number of floors located in each building were counted and recorded. It was concluded that the number of floors located in each building was more important in dictating pedestrian distribution than the physical height of the building because the former corresponds with more commercial space compared to the latter.

Once the building data were collected the average building height for each street segment (average number of floors) and the average number of buildings on each street segment were calculated. The result was two categories: the average building height on each street segment and the number of buildings on each street segment. Each of these measures was treated as an independent variable in a multiple regression.

3.2.4 Presence or Absence Variables

The next section of street measures required the researcher to evaluate each street segment in relation to the presence or absence of specific characteristics on a 'yes' / 'no", 'good' / 'poor', or 'high' / 'low' scale (depending on the measure under investigation). The evaluation involved the following street features: sidewalk material, street segment maintenance, and level of automobile traffic. All of the measures were easily observable by the researcher and did not involve highly qualitative judgments.

The 'sidewalk material' measure was a 'yes' / 'no' evaluation that dealt with the paving material of the sidewalk or path[3] and included two categories: paving bricks or

---

[3] Streets that did not have a sidewalk were considered 'paths' meaning that there was no differentiation between road and sidewalk on the street segment. On paths there was less automobile traffic and pedestrians were able to use the entire segment as opposed to only the sidewalk.

asphalt (Figure 3.1). The segment maintenance was a qualitative observation made by a single researcher regarding the quality of the streetscape on each segment (either 'good' or 'poor'). The difference between a 'good' and 'poor' segment was a qualitative evaluation on the basis of the quality of the signage, the building facades, and the overall maintenance of the street. There were significant differences between 'good' and 'poor' that were easily distinguishable according to the above characteristics (Figure 3.2). Finally, a single researcher judged the level of motorized traffic on each street segment as either 'high' or 'low'. There were significant and observable differences between the motorized traffic on different street segments. In fact, street segments not adjacent to a major thoroughfare (e.g., Koshu-Kaido, Shinjuku-Dori, Yasukuri-Dori) restrict motorized traffic to delivery vehicles during delivery hours (generally before 11 AM when pedestrian traffic is low) therefore reserving the streets for pedestrian use only. The result is that observable differences exist between the amount of traffic on each street segments that can be classified as either 'high' or 'low' relative to all other streets in the district.

3.2.5 Space Syntax, Enter and Exit, and Lighting Variables

The space syntax integration measure was used to calculate the integration of each individual street segment in the study area. Calculating the integration measure involves counting the number of street segments between each street segment and all other street segments in the study area using the shortest possible path. Each street segment represents a decision point where a pedestrian must choose a walking direction; counting the number of street segments from one street segment to another represents the total

Figure 3.1
Paving Materials: Asphalt (above) versus Paving Bricks (below)

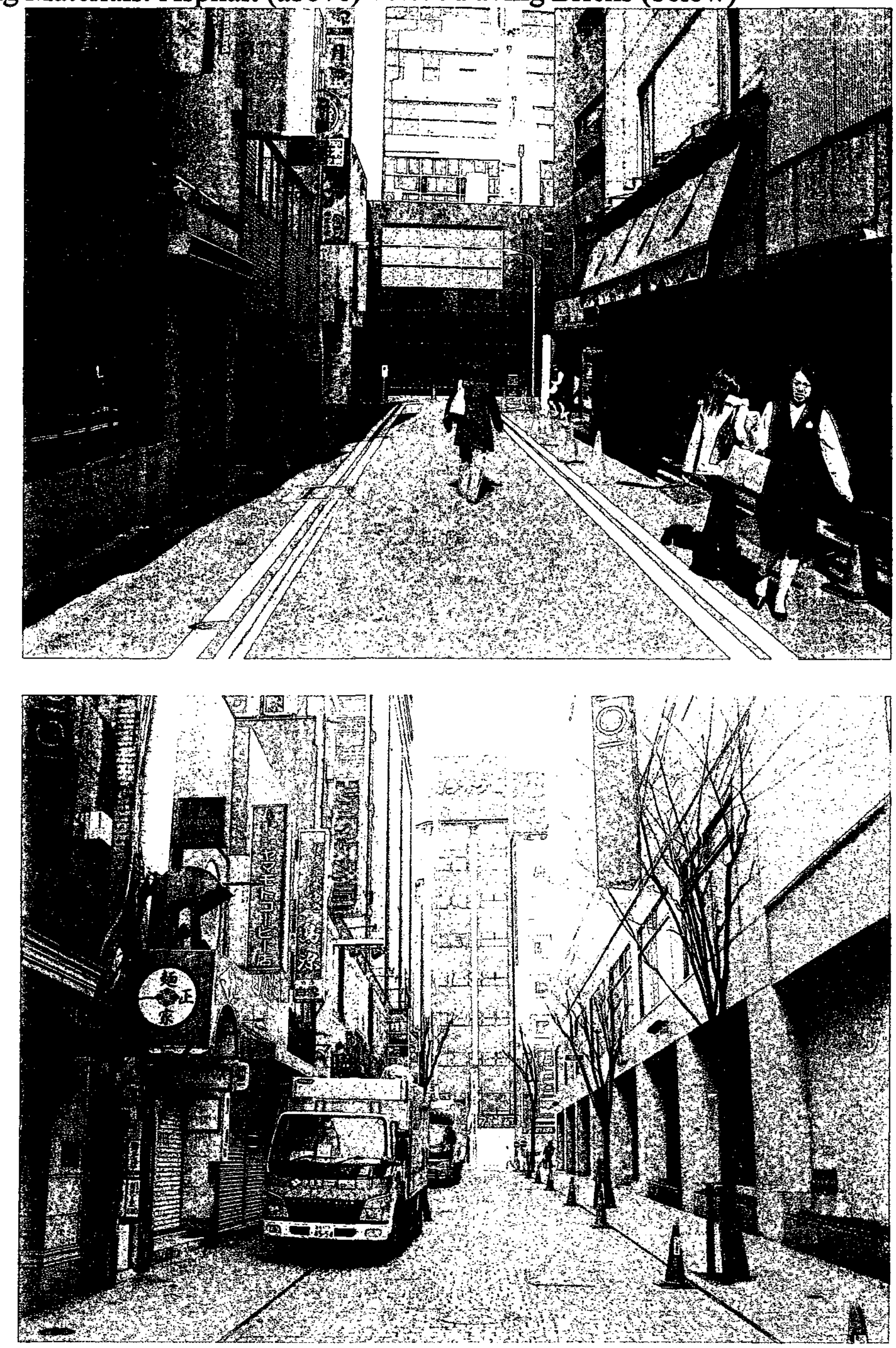
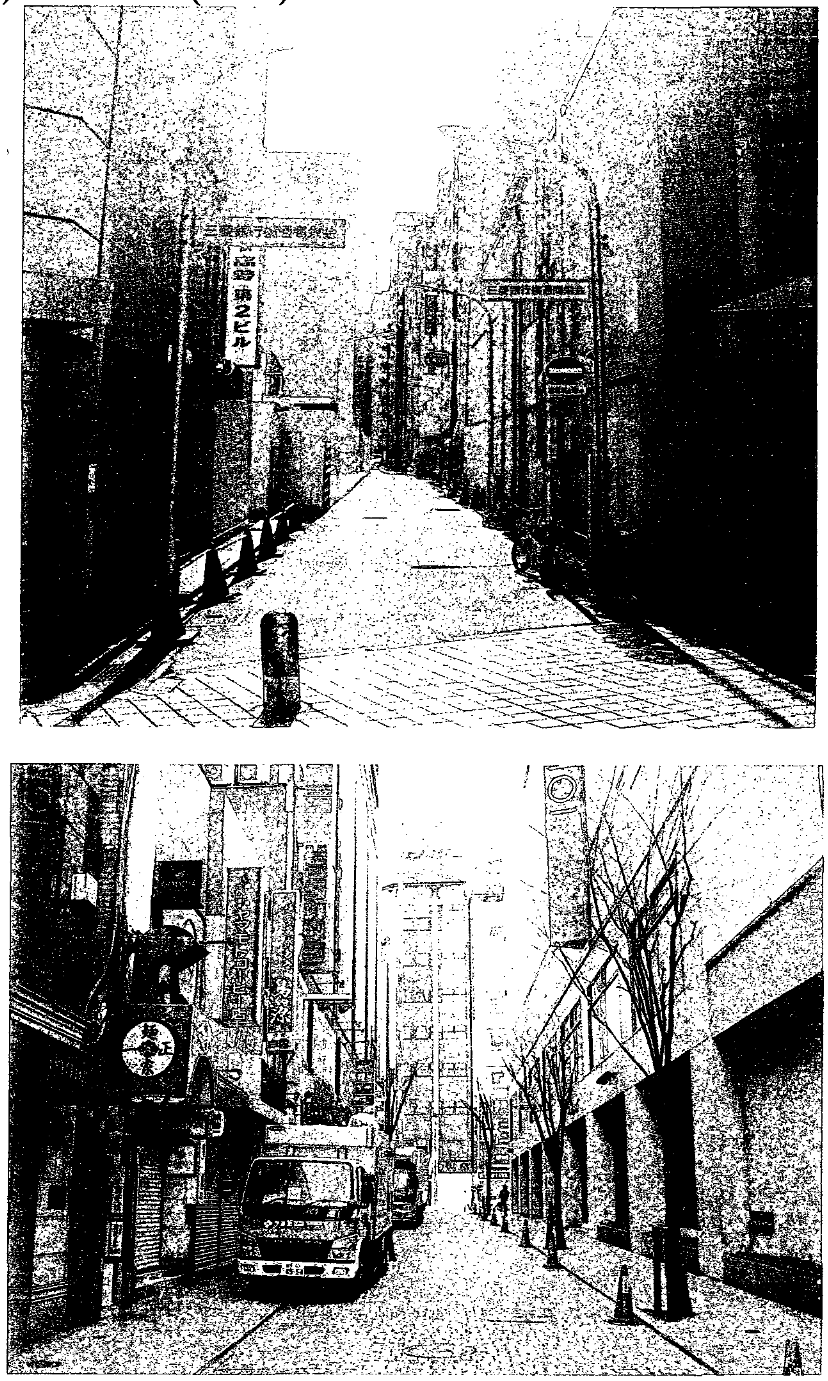


Figure 3.2
Poor (above) versus Good (below) Path Maintenance



number of turning decisions. This process results in a row of numbers for each street segment where, subsequently, the mean value for each row is calculated. Next the mean value for each street segment is plugged into an equation to calculate the measure of centrality for each street segment. The equation is as follows:

$$C = \frac{2\,(M-1)}{k-2}$$

C = Measure of centrality
M = The mean step value
K = The number of segments in the study area
(Hillier and Hanson, 1984)

This equation is applied to every street segment in the study area. The resulting centrality values can then be used as a representation of the connectivity of each street segment.

The space syntax integration value was calculated manually for the Shinjuku study area following the methods described above. There were 87 street segments in the study area requiring the calculation of 7569 (87*87) mean step values. However, as one half of the matrix is the mirror image of the first set of numbers, only half of the values needed to be calculated. The mean step values were entered into Excel where the centrality measure was calculated for each street segment. The data was then entered into SPSS along with all of the other independent variables mentioned above.

A pedestrian enter and exit exercise was conducted on each street segment in the study area that involved the researcher walking at a steady pace down each street segment and recording the number of people entering and exiting from the buildings. The researcher completed this exercise three times between the hours of 4 PM and 6 PM on three consecutive days beginning on April 9th, 2008. The researcher timed how long it took to walk the entire length of each street segment during each observation to ensure that a similar amount of time was spent making observations over the three sampling periods. The amount of time taken on each street segment varied depending on the length of the segment. The walking direction corresponded to the direction pedestrians left the two exits of Shinjuku Station where the tracking exercise was conducted, either on a east / west or a north / south axis, to ensure that the data was collected in accordance the movement of pedestrians within the district.

The average number of pedestrians entering and exiting all buildings on each street segment was calculated for all of the time intervals. The mean calculation resulted in a single number for each street segment. It is important to note that this variable was not treated in a multiple regression with the other independent variables because it is 'dependent' on the mean pedestrian distribution of each street segment as opposed to 'independent'. Instead the variable was treated to a linear multiple regression with the mean pedestrian distribution data to test for a potential relationship.

Light saturation on each street segment was recorded on a sunny day by using a digital light meter. The lighting measurements were recorded between the hours of 11 AM and Noon whereas the distribution data was collected between the hours or 4 PM and 6 PM. Due to discrepancies between collection times the lighting level was not used in the final regression model but was instead treated to a separate linear regression.

3.2.6 Pedestrian Distribution Variable

Pedestrian distribution data was collected to understand the distribution of pedestrians on each street segment within the study area. The data were collected between the hours of 4 PM and 6 PM over a four-day period in April 2006 by a research team assembled by Zacharias and Munakata (2006). In the study the data were used to identify the impact of rail and street-based pedestrian generators on the distribution of pedestrians within the district. In this research, however, the distribution data are used with the street evaluation rubric data to relate streetscape variables to pedestrian distributions. The distribution data was used as the dependent variable to which all of the independent variables were measured.

In total 673 samples of pedestrian distribution were collected at 79 different counting points within the study area. A single counting point was located in the centre of each street segment where bidirectional counts were recorded in a series of two-minute counts. In addition, pedestrian distributions were collected from 19 pedestrian generators (i.e., exits from Shinjuku Station, street-level entrances such as crosswalks, and underground stations) and 17 exits in the underground railway station. Every street segment was represented by at least three counts over the four-day data collection period and the generator counts were represented by at least two counts. Zacharias and Munakata (2006) tested for variance and found that pedestrian generators in Shinjuku were partially responsible for the distribution of pedestrians on street segments. For this research the mean distributions were calculated for each of the 87 street segments. Bi-directional data was averaged together to gain the total average number of pedestrians on each street segment. Each street segment was associated with a single number representing the average two-minute distribution count for that segment.

It is important to note that a limitation exists in the distribution data. Specifically, because the distribution data was collected between the hours of 4 PM and 6PM it cannot be assumed that the pedestrian distributions remain constant throughout the day. For example, it is unlikely that the number of people in the district at 4 PM is the same as the number of people in the district at 11 AM. In fact, based on unstructured observations made by the researcher throughout the data collection process, pedestrian traffic is lowest in the morning and gradually increases throughout the day. However, it appears, based on unstructured observation, that pedestrian distribution on each street segment remains stable throughout the day. Therefore, although the actual number of people in the district changes with time, the proportion on people on each street segment remains stable. This assumption has been proven by previous research on walking environments where it was discovered that pedestrian distribution remains stable throughout the day (Peponis et. al., 1989).

3.3 Tracking Exercise

A tracking exercise was undertaken to record the behaviour of pedestrians in Shinjuku. Tracking involves following participants "from origin until destination or boundary in a designated system, without their knowledge" (Chang, 2002, p. 589) and has been used in various studies investigating pedestrian behaviour (e.g., Chang, 2002; Zacharias 1997, 2007). Tracking information was useful in deciphering if people were travelling direct to destination, lingering in the district, and what establishments they visited. This information was then used to describe movement patterns in the study area.

Tracking is the most appropriate method for this research because it allows the exact spatial behaviour of pedestrians to be recorded. More specifically, tracking provides information regarding the duration of the trip, the chosen path, and stops along the way and does not rely on a participant's ability to recall information about their trip. Questionnaires, surveys, and interviews, on the other hand, are not ideal for this research because the accuracy of responses is dependent on the ability of participants to remember detailed travel behaviour. Unfortunately, it has been found that error is associated with such methods. For example, participants might provide information based on what they believe the interviewer wishes to hear or report behaviour that deviates significantly from their actual behaviour (Bryman and Teevan, 2005). This occurs, in part, because it is difficult for a pedestrian to remember their trip in the detail required by this research (e.g., the exact path taken, all stops along the way, the exact time of the trip). Therefore, for the purpose of this research, tracking remains the most accurate method. To avoid reactive effects, participants were unaware that they were being observed.

3.3.1 Tracking in Shinjuku

A tracking exercise was undertaken in southeastern Shinjuku where the path and final inferred destination of pedestrians were recorded. A total of 201 pedestrians were tracked over a 13 day period: 100 pedestrians from the south exit and 101 from the north (Table 3.1). All of the tracking data were collected between the hours of 11 AM and 6 PM. A single researcher collected nearly all of the tracking data to help ensure uniform data collection; the remainder of the tracks (n=30) were completed by two other individuals: Dr. John Zacharias, the supervisor of this research, and Deljana Iossifova, a PhD candidate in civil engineering in Tokyo.

Table 3.1
Number of Tracks Completed by Date

Date	Number of Tracks (South)	Number of Tracks (North)
March 22nd	10	-
March 23	13	-
March 24	19	-
March 25	20	7
March 26	-	40
March 27	-	6
March 28	-	7
March 29	8	11
March 30	-	-
April 9	22	10
April 10	-	10
April 11	8	10
TOTAL	100	101

*Note: All tracks were collected between the hours of 11 AM and 6 PM

Pedestrians were only tracked in outdoor public space; when a pedestrian entered an indoor or private facility, such as a store or restaurant, the researcher waited outside for two minutes for the pedestrian to reemerge. If the pedestrian did not reemerge after two minutes then that destination was recorded as the pedestrian's final destination. Two minutes was chosen because stops in Shinjuku were infrequent and short and generally en route to a specific destination making it plausible to assume that a stop longer than two minutes inferred a final destination. The two-minute wait was not included total time associated with the trip.

Pedestrians were chosen randomly: the fifth pedestrian leaving the exit was tracked. When the number of pedestrians exiting the station was too high to observe the fifth person exiting accurately a timing system was used. The timing system involved using a stopwatch to initiate a one-minute countdown where the researcher tracked the first pedestrian who exited the station after the one-minute countdown. Both methods ensured that an unbiased sample of pedestrians was collected.

Information collected during the pedestrian tracking exercise was based on the prior decision of which behaviours should be observed and how they should be recorded. Specifically, because tracking can be considered a structured observational method, i.e. a social research tool that involves the development of rules dictating which behaviours will be observed and how they should be recorded (Bryman and Teevan, 2005), an observation framework was formed to structure the observations, separate them into categories / variables, and prepare the data for qualitative and quantitative analysis. The framework focused on the specifics of each individual and their trip (see 'tracking map' Appendix 1). The first piece of information recorded was the exit where the track began (either the south or north exit) followed by the pedestrian's sex and approximate age. In addition the time that the track started and finished was recorded to allow the researcher to calculate the duration of each track. As the pedestrian walked through the case study area their path choice was recorded on a paper map. A major pause or stop in the public environment was determined by the pedestrian making at least a five second stop. The tracking data was entered into a GIS where the distance travelled by each tracked pedestrian was recorded.

The weather in Shinjuku during the data collection period (March 20th - 29th, 2008 and April 9th -11th, 2008) was fair. Fair weather was especially important when conducting the tracking exercise as pedestrian behaviour, such as the total length of an outdoor walking trip, is likely to be impacted by poor weather (e.g., rain). As a result tracking was only completed when the weather was fair (i.e. when it was not raining outside).

3.4 Unstructured Observations and Photographs

Unstructured observations were made throughout the data collection process and photographs were taken as a supplement to the streetscape evaluation rubric. Particular attention was given to changes in pedestrian distributions from mid-morning to late afternoon, the general behaviour of the people in the area, and how the southeastern portion of Shinjuku differs from neighbouring districts. The purpose of these observations was to provide a qualitative supplement to the quantitative landscape evaluation and tracking data.

3.5 Data Limitations

A limitation of this research is the discrepancy in data collection times between the distribution data, collected in April 2006, and the landscape evaluation data / tracking data, collected in March / April 2008. To ensure that no major differences exist between the case study area in April 2006 and April 2008 the researcher compared photographs taken of the study area in 2006 with those taken in 2008. The most significant change in the area was the in-progress construction of a new department store encompassing the entire southern side of street segment 'c' (see 'street classification map' in Appendix 1). In terms the actual streetscape (e.g., trees, street width, sidewalk material etc.) few, in any, observable differences were noticed.

Chapter 4

Analysis

The analysis chapter is structured in two sections; the first section details the analysis of the streetscape classification rubric and the second section deals with the analysis of the tracking data.

4.1 Distribution Maps

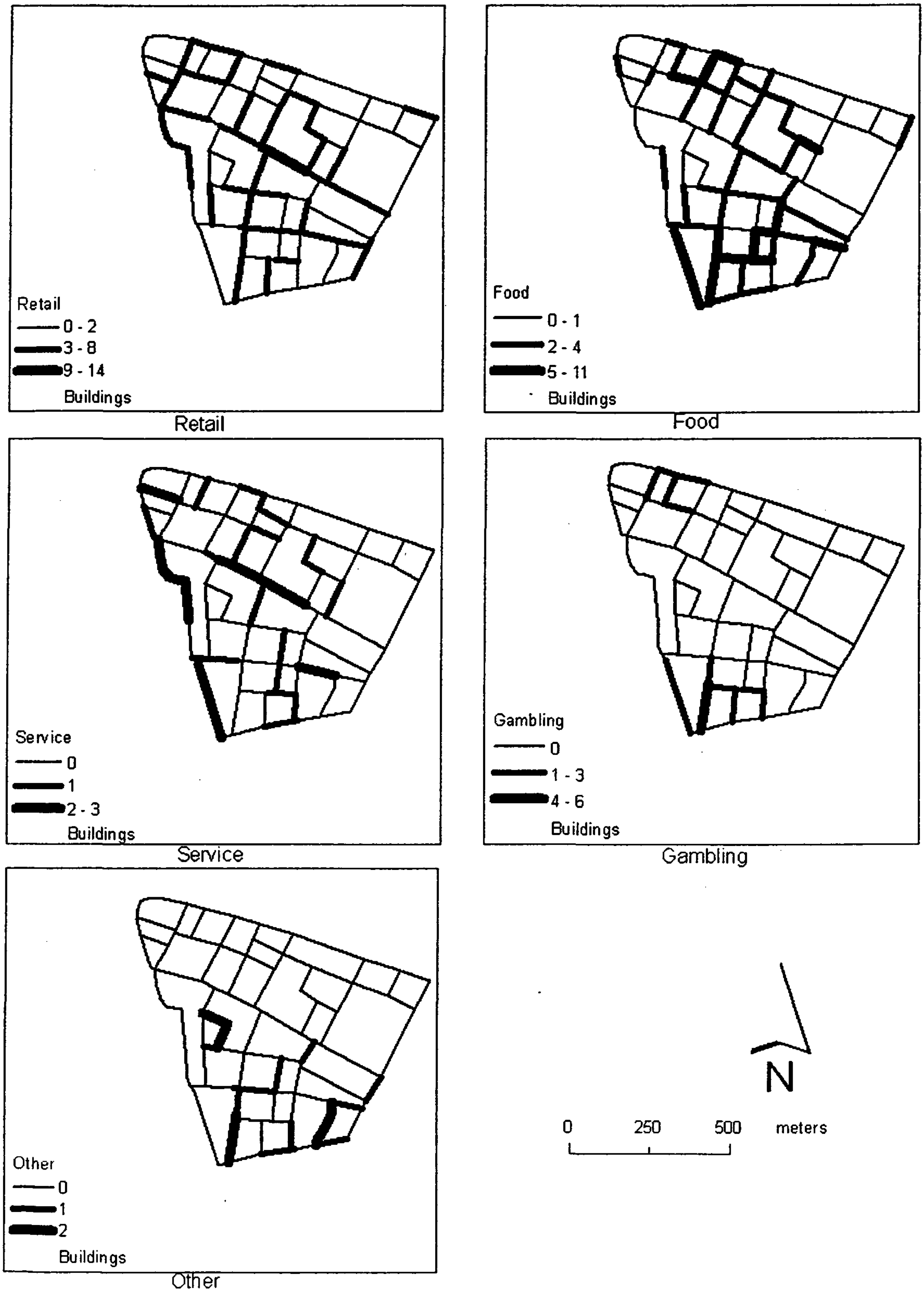
This section will detail the geographical distribution of the 18 variables in to understand how they are distributed on the 87 street segments. The variables will be presented in the same order that they were presented in the methods chapter. All of the variables were checked visually to assess their distribution.

4.1.1 Retail and Service Variables

The retail and service variables (retail, food, service, gambling, and other) are relatively evenly distributed with the exception of 'gambling' and 'other' (Figure 4.1). The following paragraph will discuss the distribution of the normally distributed variables followed by the spatially concentrated.

'Retail' was relatively evenly distributed throughout Shinjuku. The exception was on street segments that had a large single-building department store that acted to reduce the overall number of retail outlets on that street segment. 'Food' was also relatively evenly distributed except for a small concentration of restaurants in the

Figure 4.1
Geographical Distribution of Retail and Service Variables



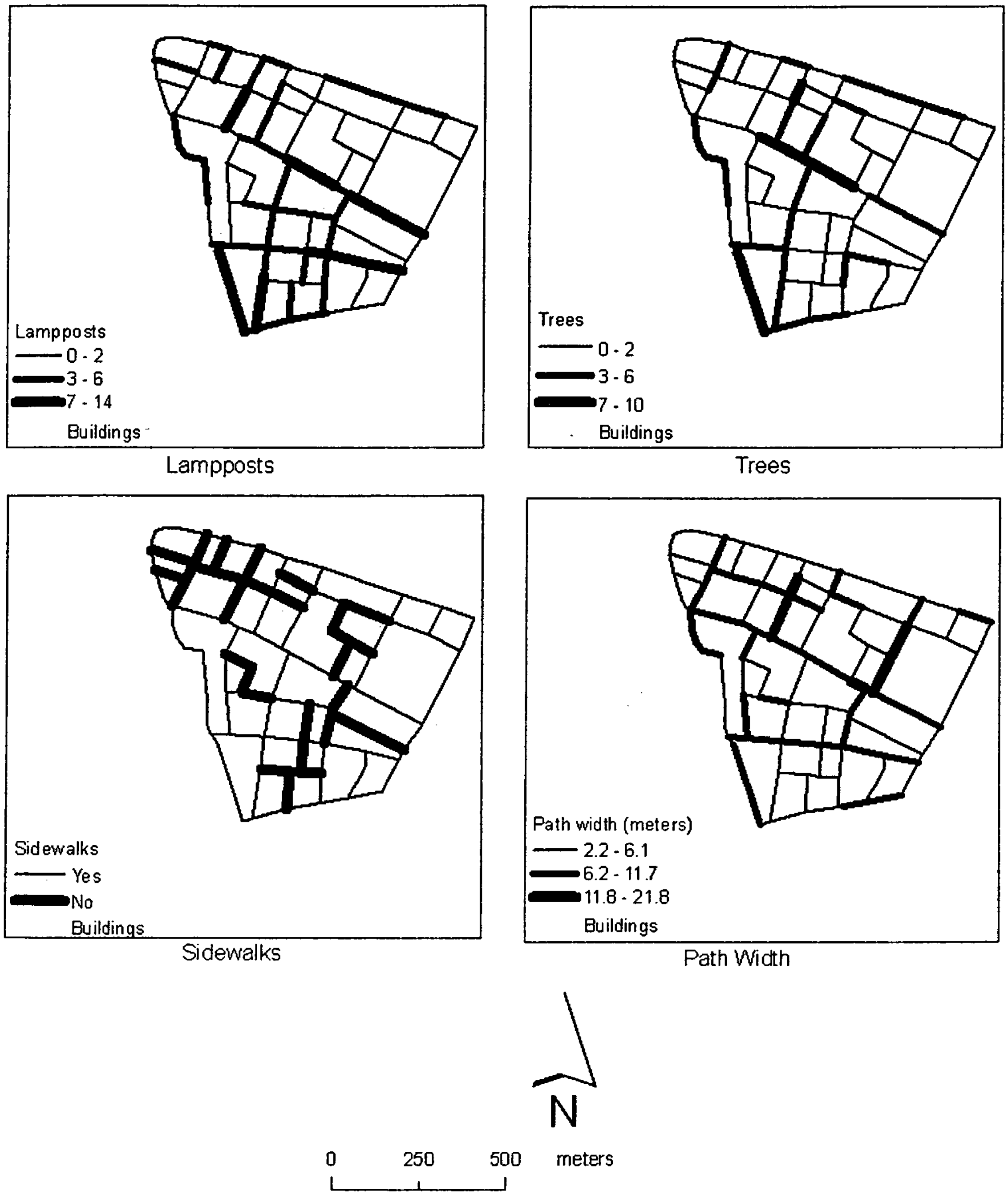
southern portion of the case study area. A small concentration of food outlets in the southern portion may be explained by the fact that the pedestrian distribution is not as high on the street segments in the interior of the study area. 'Service' outlets are evenly distributed throughout the study area with the exception of the northeast corner that tends to be dominated by large buildings such as department stores and parking structures leaving little room for service outlets.

There were two variables that were spatially concentrated according to the maps ('gambling' and 'other'). 'Gambling' services tend to be located near the major exits of Shinjuku Station in the southwest and northwest corners corresponding to street segments with high pedestrian distributions. 'Other' establishments are located only in the southern portion of the study area and are primarily concentrated near the periphery of the zone. A possible reason for this could be that less signage is present in the southern portion of the study area causing some of the establishments to be classified as 'other' when using the landscape classification rubric.

4.1.2 Landscaping Object Variables

All four landscaping object variables (lampposts, presence of sidewalks, trees, path width) are evenly distributed (Figure 4.2). 'Lampposts' are relatively evenly distributed with a slight concentration in the southern portion of the study area. The southern portion of the study area tends to be highly visited after dark, according to the researcher's unstructured observations, and this might be an explanation as to the higher concentration of lampposts. In addition, lampposts tend to be spatially concentrated in areas with a high level of food outlets. The distribution of 'sidewalks' was mostly even

Figure 4.2
Geographical Distribution of Landscaping Object Variables



with a small cluster of streets without sidewalks appearing in the northwestern portion of the study area. 'Trees' and 'path width' were evenly distributed throughout the study area suggesting that there are no major differences in the variables between the street segments.

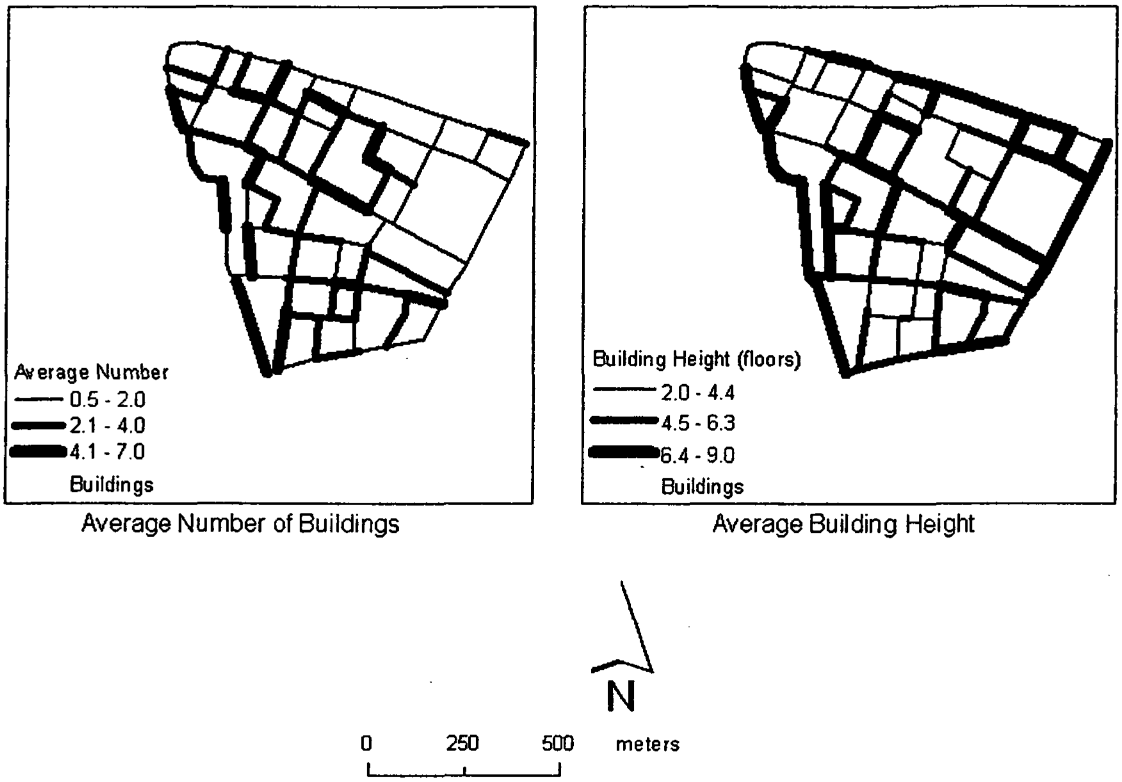
4.1.3 Building Variables

The building variables (average building height, number of buildings) were split with one being normally distributed and the other being slightly spatially concentrated (Figure 4.3). Specifically, 'average building height' is evenly distributed throughout the study area suggesting that there are no major differences in the variables between the street segments. The 'number of buildings' variable was slightly skewed with more buildings being located on street segments in the western portion of the study area. The reason for this is that there are more single-building department stores in the eastern portion of Shinjuku.

4.1.4 Presence or Absence Variables

All three of the presence or absence variables (paving material, path maintenance, level of motorized traffic) showcased a slightly spatially concentrated distribution (Figure 4.4). Street segments paved with asphalt under the 'paving material' variable are generally located in the eastern portion of the study area whereas those with paving bricks are located in the western portion. Overall, 'path maintenance' is generally high in Shinjuku with the exception of the northeast portion of the study area. It is likely that the northeast section of the study area features poor quality street segments because the area provides room for delivery trucks for department stores causing the landscaping to accommodate traffic as opposed to pedestrians. The 'level of motorized traffic' variable

Figure 4.3
Geographical Distribution of Building Variables



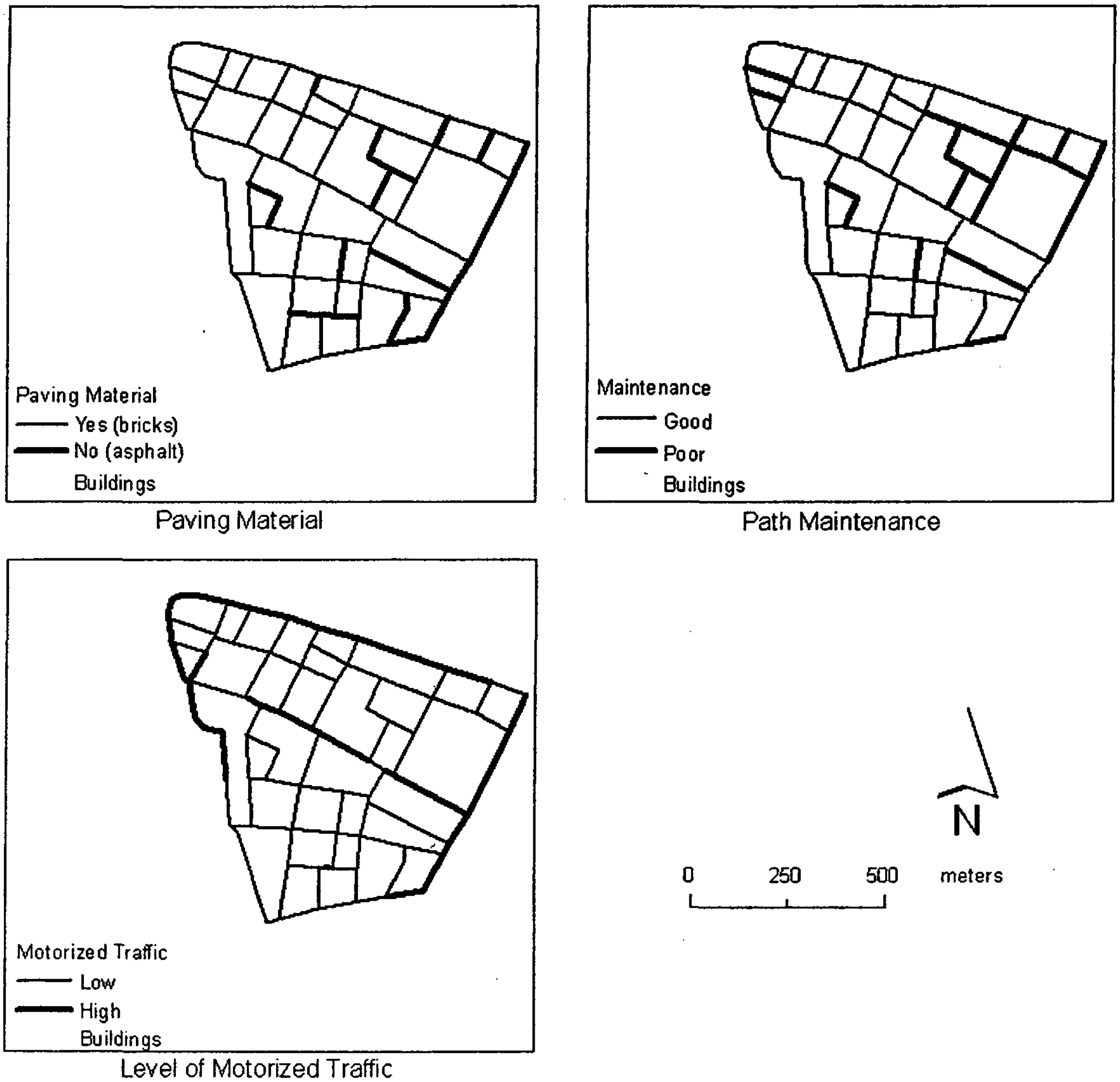
Average Number of Buildings | Average Building Height

is spatially concentrated as well with high traffic volumes occurring on the periphery of the zone and on Shinjuku Dori, the street that bisects the study area. Traffic is restricted to the periphery of the study area because the internal street segments are reserved for pedestrians (rules restrict the entry of motorized traffic).

4.1.5 Space Syntax, Enter and Exit, and Lighting Variables

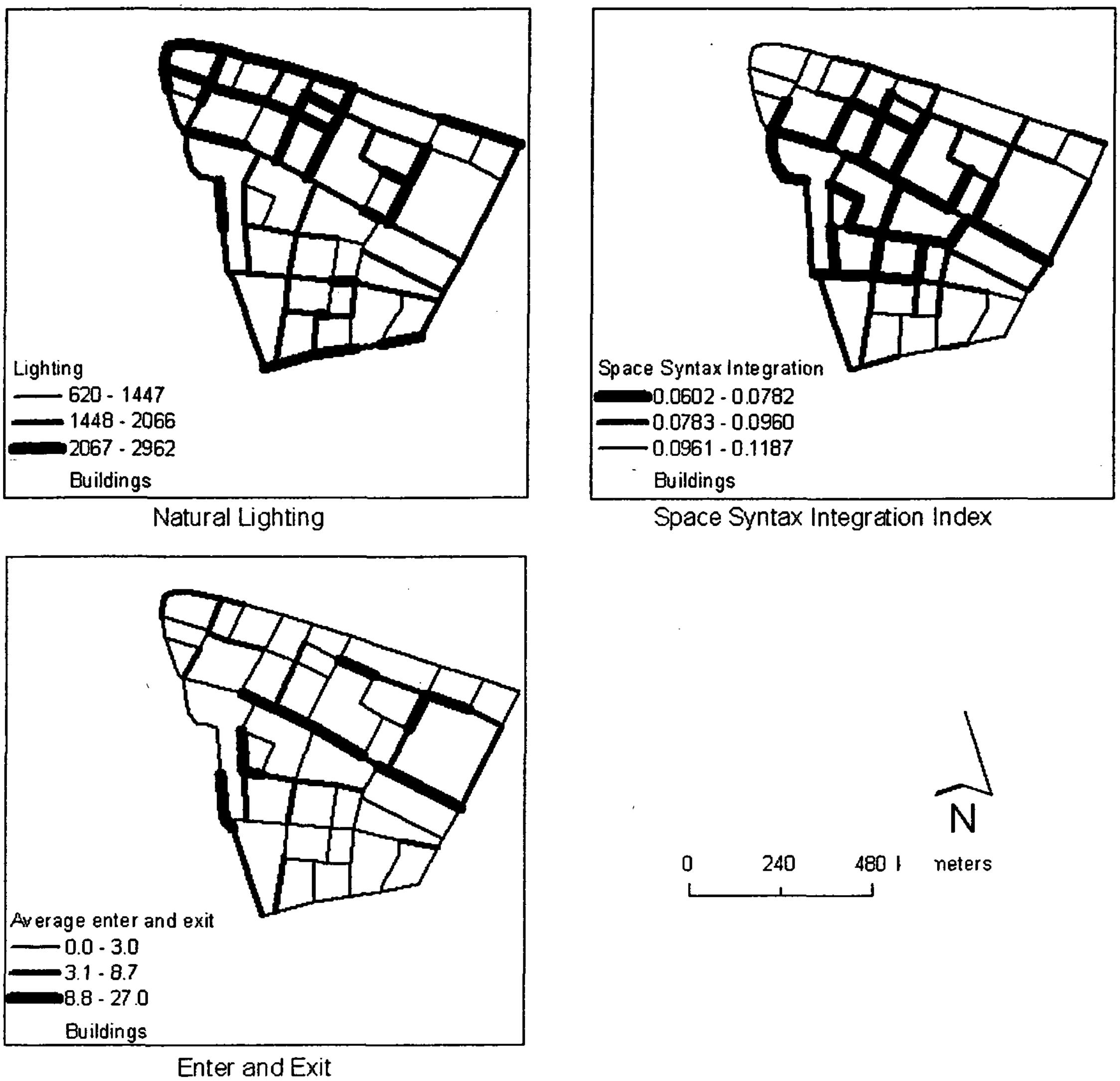
Two of the three variables were spatially concentrated (Figure 4.5). The 'enter and exit' data is evenly distributed and tends to showcase a higher number of pedestrians entering and exiting buildings on street segments that are in close proximity to large shopping centers. The 'space syntax integration measure' was slightly skewed with the most integrated segments located near the center of the study area. However, this pattern

Figure 4.4
Geographical Distribution of Presence and Absence Variables



was expected because highly integrated segments have many connections to other street segments and are generally located near the center of a study area. Street segments featuring high levels of 'lighting' or natural light are located in the northwest corner of the study area and on wide street segments featuring buildings with few floors. It must be remembered, however, that the lighting data was collected between 11 AM and Noon suggesting that the distribution might be different if the measurements were conducted at an alternative time.

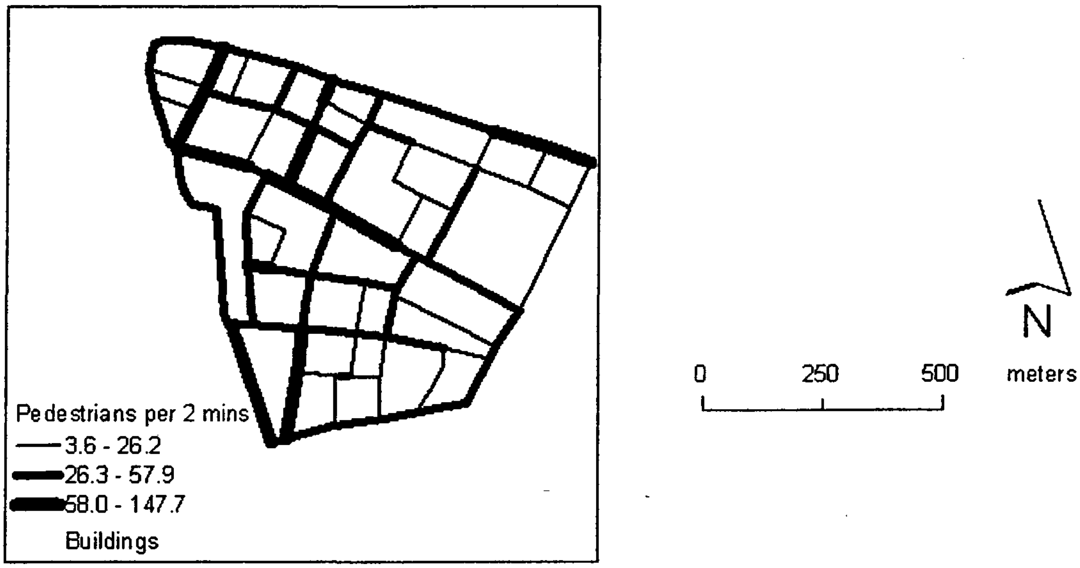
Figure 4.5
Geographical Distribution of Space Syntax, Enter and Exit, and Lighting Variables



4.1.6 Pedestrian Distribution Variable

Overall the movement of pedestrians in Shinjuku is high near the periphery of the district, adjacent to pedestrian generators, and on wide streets with a high number of retail outlets. Narrow streets with a low number of retail outlets located in the center of the study area and away from pedestrian generators tend to have lower pedestrian distributions (Figure 4.6).

Figure 4.6
Geographical Distribution of the Pedestrian Distribution Variable



Pedestrian Flow Data

Overall the flow of pedestrians into the study area from Shinjuku Station is high generating approximately 14,500 people per hour whereas flow from the streets adjacent into the study area is even higher at approximately 23,000 people per hour. Of this flow, it is important to note that some of it may be return traffic represented by pedestrians who are returning to the case study area from adjacent neighbourhoods to either a) visit the district or c) enter into Shinjuku Station. The result is that both Shinjuku Station and the adjacent streets provide a heavy flow of pedestrians into the case study area with movement between the adjacent districts appearing to be more valuable in bringing people to the district in terms of the number of people per hour. This relationship is evident from the high pedestrian distributions on street segments adjacent to pedestrian generators (Figure 4.6). While levels of pedestrian entries from Shinjuku Station to the east are high, the cumulative contribution from the surrounding streets is far higher. The contribution of pedestrians from the surrounding streets also creates an even distribution of pedestrians throughout Shinjuku. The even distribution of pedestrians in Shinjuku would not be present if the movement of pedestrians between neighbouring districts was significantly lower.

4.2 Multiple Regression

Once the data were entered into SPSS they were screened according to the criteria required for multiple regression analysis. Multiple regression permits researchers to explore the relationship between a single continuous dependent variable (in this case the pedestrian distribution variable for each street segment) and various independent variables (Pallant, 2007; Nardi, 2006). The main purpose is to determine which independent variables best predict and explain variance in the dependent variable. According to Pallant (2007), multiple regression is "ideal for the investigation of more complex real-life, rather than laboratory-based, research questions" (p. 146) because of its ability to explore interrelationships among a set of variables in more complexity than a simple correlation. Furthermore, multiple regression tests the contribution of each independent variable in explaining the variance of the dependent variable allowing inferences to be made regarding the importance of each independent variable. This makes multiple regression a valuable tool for this research: it allows the research to explore what streetscape variables, if any, influence discrepancies in pedestrian distirbutions on street segments in Shinjuku.

4.2.1 Multiple Regression Assumptions

A multiple regression model cannot be applied to a data set with confidence until specific assumptions are met. These assumptions are outlined by Pallant (2007), Tabachnick and Fidell (2007), and Nardi (2006): the independent variables must have low intercorrelations (e.g., multicollinearity), the dependent variable must be evenly distributed (i.e., not too many outliers with a centralized scatterplot), and all data must be collected on the correct scale. The data for this research was collected on the correct scale (i.e., the dependent variable was not categorical). To test for multicollinearity the tolerance and variance inflation factor were calculated and to test for outliners a P-plot, a scatterplot, and casewise diagnostics were performed (Tabachnick and Fidell, 2007). It was discovered that all of the independent variables were suitable for a multiple regression.

However, that the correlation table shows that many independent variables are not completely dependent of each other. While no independent variables showcased a correlation above 0.7, some correlations did still exist. One of the higher correlations was between retail and path maintenance (-.506). While both independent variables were kept in the final analysis, the correlation may have skewed the results. This issue is addressed in Chapter 5 through running three separate multiple regression models.

4.2.2 Reducing the Number of Independent Variables

Often independent variables must be excluded from the final multiple regression model in order to ensure that the sample size is sufficient to support the number of independent variables. This is important to ensure the scientific validity of the research because it confirms that the data can be generalized to other samples (Pallant, 2007); if the sample is too small then its ability to accurately represent the real-world decreases. In the case of this research the removal of independent variables must be done for two reasons: first, this research has 17 independent variables, far too many for a sound regression model; second, the number of cases (N=87) must be proportional to the number of independent variables. While there is no consensus on the number of cases required for multiple regression, it is commonly accepted that there should be between 15 to 20 cases per independent variable. For example, Stevens (1996) recommends about 15 cases per independent variable to ensure a reliable equation whereas Tabachnick and Fidell (2007) provide an equation to assist researchers in calculating the optimum number of cases: $N > 50 + 8m$ (where m = the total number of independent variables). Therefore, this research should ideally include between 4 and 5 independent variables in the final multiple regression. For instance, according to Stevens (1996), to use five independent variables 75 cases would be needed (15*5) whereas according to Tabachnick and Fidell (2007), to use five independent variables 90 cases would be needed {50 + (8*5)}. Five independent variables will be used in this research given that this research contains 87 cases yet started out with 17 independent variables.

Data reduction techniques[4] were used to reduce the number of independent variables in this research. These methods included excluding independents by evaluating their significance based on the R^2 value, the pearson's r, and p-value. Backwards regression, forward selection, stepwise regression, and a model that selected significant variables based on their standardized beta coefficient were also used as exploratory options but were abandoned for the final model because of the difficulty in interpreting what is happening to the variables in the statistical calculation.

[4] Factor analysis was not used as a data reduction technique because of its theoretical complexity. For example, factor analysis suggests combining variables that might otherwise not naturally fit together (Pallant, 2007). The result is the formation of theoretically complex variables that are difficult to understand and apply to real-world situations.

4.3 Tracking Data

Information obtained from the tracking data (e.g., trip duration, number of stops etc.) was organized, coded, and entered into SPSS. Each track was also entered individually into a GIS to obtain the distance traveled by each tracked pedestrian. Subsequently, descriptive statistics were calculated and analyzed for all of the tracks. The tracks were first analyzed together (i.e., tracks from both exits) and then analyzed based on their exit of origin to look for differences in pedestrian behaviour and spatial patterns between both exits.

The tracking data were further analyzed according to the complexity of each tracked trip in accordance to the methods used by Zacharias (1997). The method involves assigning each trip to a category based on the complexity of that trip as judged by the overall shape and number of turns displayed by the track. The goal of this method is to evaluate if the tracked trips were complex and varied or if they were simple and uniform. The precept is that pedestrian trips often exhibit a simple path configuration even though the environment can technically allow for very complex and varied configurations.

Chapter 5

Results

This chapter presents the research findings in two sections: an explanation of how the regression models were chosen and what they revealed about the data followed by the results from the tracking data.

5.1 Multiple Regression Models

Three regression models were run. The following paragraphs will detail how the independent variables were selected for the models, how and why the models were chosen, and what the models revealed.

5.1.1 Selecting the Variables: The R^2 Value, Pearson's r, and P-Value

The R^2 value, pearson's r, and p-value were recorded for each of the independent variables and entered into a table (Table 5.1). The r-value was found by running a single linear regression model for each independent variable, the pearson's r by looking at the bi-variate correlation table, and the significance value by running a multiple regression model that included all of the independent variables. All three of these values were recorded to discover which independent variables were the most important and should therefore be included in the final multiple regression model. This method of choosing

Table 5.1
R Value, Pearson's Correlation, and Significance for all Independent Variables

Independent Variable	R^2 Value*	Pearson's r	Significance
Retail	*.213*	*.461*	*.013*
Food	.002	-.049	.583
Service	.001	.025	.189
Gambling	.019	.137	.035
Other	.012	-.111	.962
Lamppost	.044	.209	.062
Trees	*.212*	*.461*	*.067*
Average # Buildings	.028	.166	.310
Average Building Height	.019	.136	.792
Sidewalk	.010	-.098	.561
Paving Material	*.237*	*-.487*	*.027*
Path Maintenance	*.221*	*-.470*	*.002*
Motorized Traffic	.041	-.203	.091
Path Width	*.172*	*.414*	*.009*
Space Syntax	.054	-.232	.047

*The R^2 Value was found by running a simple linear regression for each independent variable. This was done to discover the importance of each individual variable in explaining variance in the dependent variable. As such it is not valid to simply add the R^2 values together to reach their total predictive value. When all of the variables were included in a single model the R^2 value was .623 model $p < .0005$ but this model is invalid as it includes too many independent variables for the sample size (n=87).

significant variables through the assessment of the R^2 value, pearson's r, and the p-value was selected to give the researcher control over the independent variables entering the model and to allow the researcher to explain why each variable was either included or excluded.

The five most significant variables were chosen for inclusion in the final regression model based on the five highest pearson's r values. The five most significant variables were paving material (-.487), path maintenance (-.470), retail (.461), trees (.461), and path width (.414) (Table 5.1). Each variable chosen also represented the five highest R^2 values and had significance values of at least $p < 0.1$. In addition, the space syntax variable was included in the final regression model because of its theoretical importance as emphasized in the literature review. To account for this, the least significant of the independent variables was excluded (for the first model this variable was 'path width').

5.1.2 The Three Regression Models

Three multiple regression models were run. The first model included the four most significant independent variables (retail, trees, paving material, path maintenance) and the space syntax variable, the second model included retail, trees, path width, and space syntax, and the third model included path width, trees, paving material, and path maintenance (Table 5.2). The second model was run because of potential problems associated with the first model. Businesses in Shinjuku contribute heavily to the street landscaping budget and this includes the paving material and path maintenance. The street segments with low maintenance and low-quality paving materials are generally those that do not have a large number of retailers and as a consequence little money or incentive exists to improve the quality of these street segments. In this sense path material and path maintenance become dependent as opposed to independent variables because in order for the quality of the path to increase there needs to be a higher number of retail outlets. For this reason another regression model was completed that excluded paving material and path maintenance. The third model was run to decipher the impact of paving material and path maintenance without the influence of 'retail'.

Table 5.2
Summary of Regression Models

Model One
$R^2 = .448$ $p = .000$

Variable	Beta	Sig
Retail	.242	.013
Trees	.170	.085
Paving Material	-.220	.028
Path Maintenance	-.272	.006
Space Syntax	-.055	.527

Model Two
$R^2 = .353$ $p = .000$

Variable	Beta	Sig
Retail	.271	.010
Trees	.236	.026
Path Width	.247	.012
Space Syntax	-.074	.425

Model Three
$R^2 = .463$ $p = .000$

Variable	Beta	Sig
Trees	.173	.070
Paving Material	-.165	.100
Path Maintenance	-.341	.001
Path Width	.271	.004
Space Syntax	-.081	.340

Secondary Regression Models

Model 1 (lighting and flow data)	$R^2=.199$	p. = .000
Model 2 (flow data and enter / exit)	$R^2 = .152$	p. = .000

5.1.3 Multiple Regression Models

The multiple regression models are strong at $p < .0005$. The first model explains approximately 45 percent of the variance in the dependent variable, the second model explains approximately 35 percent, and the third approximately 46 percent. Path maintenance has the two best values for significance (.006 in model one and .001 in model three) and a negative correlation because fewer people were observed on street segments with poor maintenance. The next most important variable in terms of significance was 'path width' (.012 in model two and .004 in model three) followed by retail (.013 model one and .010 model two), 'trees' (.085 model one, .026 model two, and .070 model three), and 'paving material' (.028 model one and .100 model three). 'Paving material' had a negative correlation because of the way the variable was coded in SPSS; it actually proves that there are more pedestrians on street segments with paving bricks as opposed to asphalt. In all three models, however, the space syntax measure was non-significant suggesting that it is not contributing uniquely to the overall prediction of the model.

The significance of the independent variable on the dependent variable is judged by the standardized beta value that "compares the contribution of each independent variable" to the dependent variable (Fidell, 2007, p. 159); the higher the beta coefficient the more significant the independent variable. Using this method, it can be understood that path maintenance, with a beta of -.341 in model three and -.272 in model two, is the most significant variable showing up in the models. The standardized beta values are negative for path maintenance because of the coding rubric used in SPSS. The next most significant variable was 'path width' with a beta value not dropping below .247 followed by 'retail' with a beta value never dropping below .242. 'Trees' had a beta value ranging from .170 to .236 whereas 'path material' had values of -.165 (model three) and -.220 (model one). 'Space syntax' had a beta value significantly below that of all the others with a maximum value of -.081 in model three.

Cumulatively these results support the hypothesis by proving that streetscape variables impact pedestrian distribution on street segments. The first significant streetscape characteristic is path maintenance where people are less likely to visit street segments that are of poor quality than those that are of high quality. Poorly maintained street segments, in addition to being aesthetically displeasing, are also less likely to have a significant number of retail outlets that, in turn, discourage investment or landscaping improvements. Secondly, path width is highly related to pedestrian distribution on street segments where wide paths attract more pedestrians. This is an interesting finding as it relates the amount of available pedestrian space to the amount of pedestrian traffic. Next, it was proven that a high number of retail outlets relates to high number of pedestrians. In this research, retail was differentiated from other storefront uses, such as gambling, office, and service businesses, and came out by far the most significant suggesting that actual shopping opportunities are more important in attracting pedestrians than other storefront uses. Fourth, the street landscape in terms of vegetation and path material (i.e., paving stones versus asphalt), are important elements in encouraging pedestrian distribution. In terms of distribution levels there appears to be a strong preference towards street segments that feature trees and paving bricks as opposed to no trees and asphalt. Finally, the overall unimportance of street segment integration, as measured by space syntax, suggests that it is the quality of the street and its retail opportunities that attract people as opposed to its integration to the surrounding street network.

5.1.4 Impact of Pedestrian Generators on Pedestrian Distributions

A correlation table was run between the mean number of people entering into Shinjuku from a pedestrian generator and the mean pedestrian distribution of street segments within 100 meters of a generator. This was done to account for the role of all of the 19 pedestrian generators in Shinjuku on the distribution of people on street segments.

The strength of the correlation ranges from a low of .296 to a high of .681 suggesting that there is a relationship between generator and street segment distribution but that relationship varies depending on the street segment under investigation. To further test for a correlation the mean pedestrian distribution was calculated for all of the street segments within 100 metres of the generator (i.e., producing one distribution value for all of the street segments within 100 metres of the pedestrian generator). This method produced a much higher correlation of .858 suggesting that the pedestrian distribution on street segments is highly dependent on proximity to a pedestrian generator. Therefore, caution must be exercised when interpreting the importance of the streetscape variables in explaining the distribution of pedestrians on street segments within 100 meters of a pedestrian generator. The streetscape elements are not entirely responsible for determining the pedestrian distribution of street segments, especially when the street is in close proximity to a pedestrian generator.

5.2 Secondary Linear Regression Models

Two linear multiple regression models were run between the lighting variable (independent variable) and pedestrian distribution (dependent variable) as well as pedestrian distribution (independent variable) and enter/exit data (dependent variable) (Appendix 2). These two models were run to test for potential relationships between lighting levels and distribution data as well as distribution data and the number of pedestrians entering and exiting buildings on each street segment. The lighting variable was not included in the main regression model because the collection time (11AM-Noon) differed from that of the distribution data (4-6 PM); the enter and exit data was not included because it is a dependent variable as opposed to an independent variable making it invalid for the main regression model.

Both models are strong at $p < .0005$ (Table 5.2). The first model, with lighting as the independent variable, explained 19.9 percent of the variance in pedestrian distribution whereas pedestrian distribution accounted for 15.3 percent of the variance in the enter and exit data. The first model suggests that the level of natural light may play an important role in pedestrian distribution and should be considered in future research. The second model suggests that the number of pedestrians entering and exiting buildings on a street segment is positively related to the pedestrian distribution on that street segment. In terms of this case study, it contributes to understanding the district by proving that streets where pedestrian distributions are highest are more 'active'. In this case 'active' is a word used to describe the frequent exchange of pedestrians between buildings and the street.

5.3 Bi-Variate Correlations

The bi-variate correlation table between the independent variables and dependent variable further provides information on variables that were not included in the final regression models. The most significant finding is that the presence of a high level of automobile traffic, as opposed to a low level of automobile traffic, is correlated to pedestrian distribution (.203; sig. = .030) suggesting that a high level of automobile traffic is related to more pedestrians (Appendix 2). This result is contrary to what most literature suggests: that pedestrian traffic is reduced by automobile traffic. This result suggests that it should not be assumed that a traffic reduction alters pedestrian distributions. However, caution must be exercised when interpreting this result as both variables were not collected on the same scale.

5.4 Tracking Data (Micro-Level Description of Pedestrian Behaviour)

The following section will review the results from the tracking data. The first section will highlight trip characteristics through a discussion of descriptive statistics and the second section will evaluate the overall cognitive complexity of the trips. The cumulative results from the tracking data help provide an understanding of pedestrian behaviour in Shinjuku.

5.4.1 Descriptive Qualities of Tracked Trips (Both Exits)

Overall the tracked trips were short and direct suggesting that that the case study area is very destination oriented. The average length of all of the trips was 4.3 minutes with a maximum trip length of 14 minutes and a minimum of 20 seconds (Table 5.3). The average number of stops made en route was 0.8, excluding the final destination stop, with the highest number of stops being 3 and the lowest being 0. The majority of people,

Table 5.3
Selected Descriptive Statistics for Tracking Data (Average)

Exit	Time (min)	Age (approx)	Stops (#)	Distance (m)	Segments (#)
North	4.6	32.9	1.1	211.1	3.5
South	3.9	30.5	.4	239.4	3.4
TOTAL	4.3	31.7	.8	225.3	3.5

74.6 percent, did not make any stops[5] en route to their inferred final destination. The average distance travelled by the participants was 225.2 metres where an average of 3.5 street segments constituted the trip. However, when accounting for participants who exited the case study area (33.3 percent) the average distance travelled was 215.9 meters.

Some stop purposes were much more frequent than others. In fact, the three most popular stops purposes (traffic light, window shop, and smoking / cell phone use) were responsible for 92 percent of all observed stops (Table 5.4). The most important of the three most popular stop purposes, traffic lights, accounted for 54 percent of the stops made. The next most frequent stop purpose was 'window shop' accounting for 22 percent of all stops followed by smoking / cell phone use accounting for 17 percent of all stops. The remainder of five stop purposes (vending machine use, asking for directions, meeting a friend, mode switch, and small purchase) accounted for only 8 percent of the stops suggesting that they are far less frequent than the first three stop purposes.

Some interesting conclusions can be made from the frequency of the stop purpose data. The first is the importance of traffic lights in stopping pedestrians in the district; the second point is the importance of window shopping in the district highlighting the

[5] This does not include stops made at a traffic light. Traffic light stops are not included because the stop was forced and not dependent on an individual decision.

Table 5.4
Distribution of Stop Types for All Stops

Exit	Stop Type	Percent (%)	Number
Total	Light	54	73
	Window Shop	22	30
	Smoke / Phone	17	23
	Vending Machine	3	4
	Meet Friend	2	3
	Ask for Directions	1	1
	Mode Switch	1	1
	Small Purchase	1	1
		100	136
North	Light	65	64
	Window Shop	17	17
	Smoke / Phone	13	13
	Meet Friend	3	3
	Small Purchase	1	1
	Mode Switch	1	1
		100	99
South	Window Shop	35	13
	Smoke / Use Cell Phone	27	10
	Light	24	9
	Vending Machine	11	4
	Ask for Directions	3	1
		100	37

importance of window space along storefronts to encourage sales and entice pedestrians that might otherwise be heading direct to destination. Finally, it may be appropriate to have designated cell phone and / or smoking zones within the district so that pedestrians would have a comfortable space to complete both activities. Currently smoking is prohibited in the case study area with the exception of the public space adjacent to the north exit, yet many people are still choosing to smoke as they travel through the district. Reevaluating this rule may be necessary as pedestrians continue to smoke in the district despite the regulations.

Retail and out of zone trips constituted the most common final destination accounting for 71 percent of all tracked trips (Table 5.5). The most frequently recorded final destination was a retail establishment represented by 37.8 percent of all tracked trips (Table 5.5). This is not surprising given the retail oriented nature of the case study area. However, another 33.2 percent of tracked participants exited the case study area suggesting that the examined exits of Shinjuku Station project pedestrians further into adjacent districts than captured by this research. The remainder of the final destinations was accounted for by gambling (8.5%), food (8%), service (5%), unknown (4%), office (2%), and public space (1.5%).

The majority of the trips in Shinjuku were direct to destination. Direct to destination meant that the pedestrian did not make a stop from the beginning of the track to their final destination (excluding a stop at a traffic light) and took a direct route from origin to destination (i.e., the pedestrian took a direct route and did not backtrack on their path or take a roundabout path or usually described as the shortest possible trip to destination). Overall, just over 50 percent of trips were classified as direct to destination reinforcing that Shinjuku is primarily destination orientated. By comparison only 14 percent of trips were classified as not direct to destination meaning that the pedestrian made at least one stop along the way and / or they did not take a direct route from origin to destination. The remainder of the trips (35.8%) were unclassified as pedestrians in this category either exited the study area or their final destination was unknown.

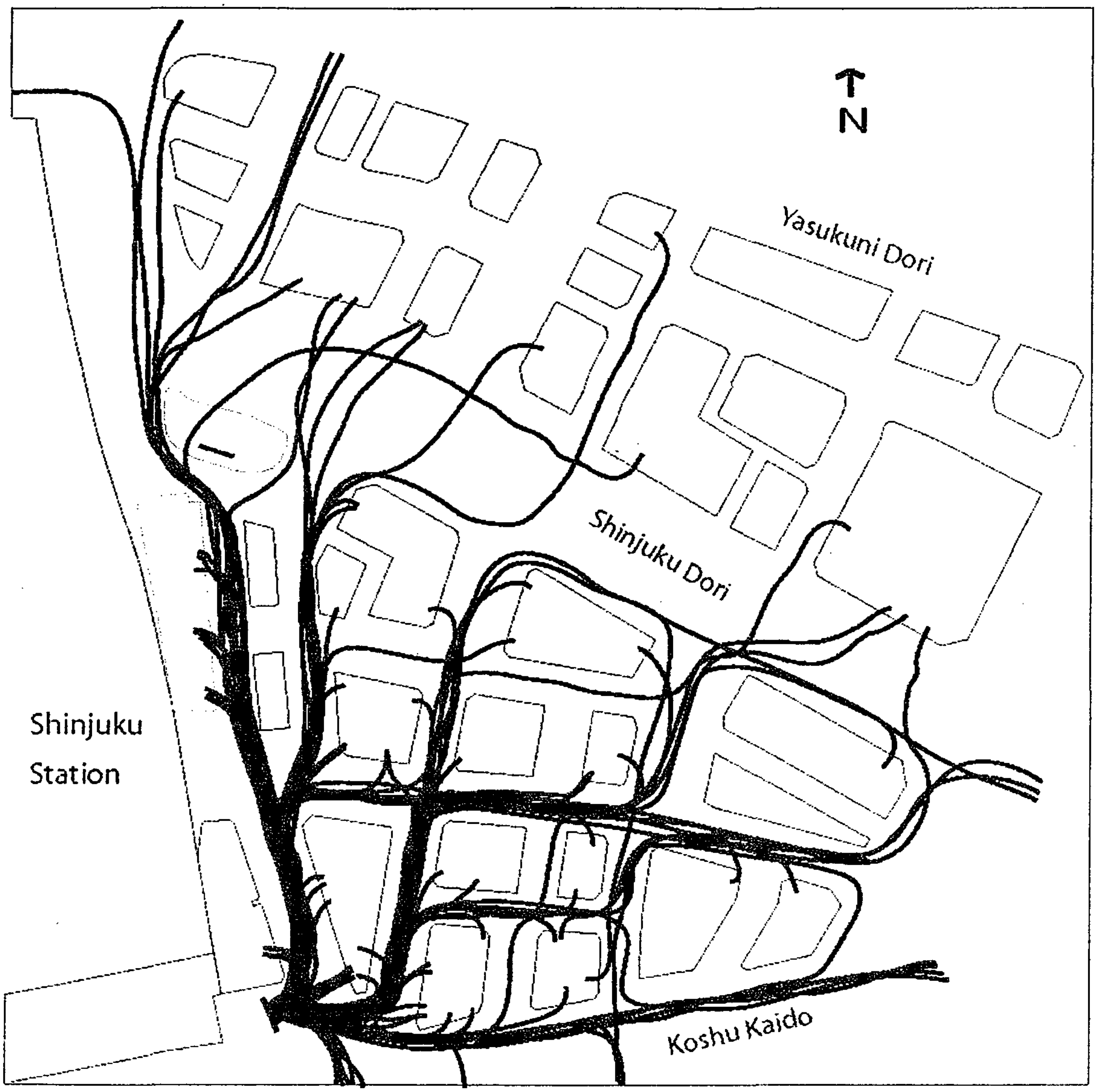
There was little crossover in pedestrian traffic between the north and south zone. Crossover means that a tracked pedestrian left the north exit and then headed south into the south zone thereby crossing Shinjuku-Dori (or vice-versa). Only 10 percent of the

Table 5.5
Selected Frequency Statistics for Tracking Data (All Tracks)

Exit	Category	Percent	Number
Total	Male	58.2	117
	Female	36.9	74
	Couple	5	10
	Final Destination		
	Retail	37.8	76
	Out of Study Area	33.2	67
	Gambling	8.5	17
	Food	8	16
	Service	5	10
	Unknown	4	8
	Office	2	4
	Public Space	1.5	3
		100	201
	Direct to Destination	50.2	101
	Not Direct to Destination	14	28
	Unknown	35.8	72
		100	201
	Cross-Over into Other Zone	10	20
	No Cross-Over	90	181
		100	201

tracked pedestrians exhibited this behaviour suggesting that pedestrians choose their exit from Shinjuku Station in accordance to their destination. In other words, people have a plan about where they are going in the district prior to exiting the station and choose the exit that is closest to their destination. This relationship is best highlighted visually (Figure 5.1 and 5.2). In the figures it can be seen that little crossover exists between both zones of the study area and that the tracked pedestrians tend to either stay in the zone that they originated in or exit the zone completely. It also highlights how pedestrians tend to head straight towards this destination or straight through the zone reinforcing the destination nature of Shinjuku. In fact, to reach their final destinations pedestrians do not

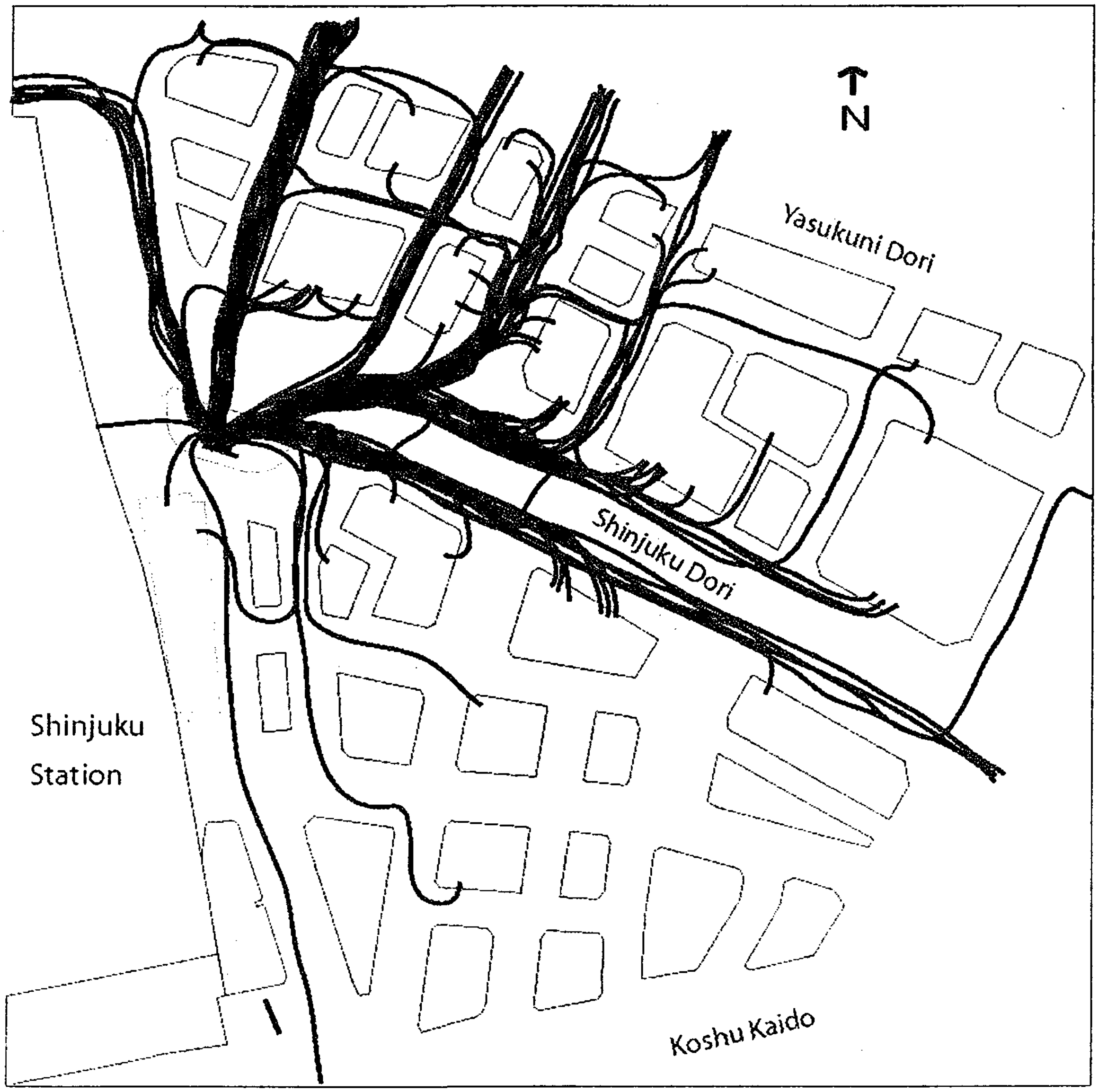
Figure 5.1
Distribution of Tracked Trips from the South Exit



*Note: Map not to scale

travel too far from the exit from which they entered the district. This is proven by the fact that street segments near the exits receive the highest distribution of tracked pedestrians whereas the eastern portion of the north and south zone feature very few of the tracked trips.

Figure 5.2
Distribution of Tracked Trips from the North Exit



*Note: Map not to scale

5.4.2 Descriptive Qualities of Tracked Trips (North Versus South Exit)

Differences exist between the tracking data collected in the north zone and the south zone. Overall the tracking data suggests that the south zone is more retail oriented and attracts pedestrians who wish to shop and gamble as opposed to the north zone which tends to be more of a 'transition zone' that people walk through en route to somewhere else.

One of the most significant differences between the north and south zone was the number of stops as well as the reasons for the stops. For example, there was an average of 1.1 stops in the tracking data originating from the north exit compared to 0.4 stops (Table 5.3) from the south exit where 65 percent (n=64) of the stops commencing in the north zone occurred because of traffic lights compared to 24 percent (n=9) in the south zone (Table 5.6). The reason for the disparity between zones is that the south zone has no traffic lights whereas the north zone has three sets directly adjacent to the north exit on Shinjuku-Dori. Stops in the south zone due to traffic lights occurred because the pedestrian entered into the north zone and was stopped by a light when a) trying to cross Shinjuku-Dori or b) when trying to exit the case study area on the periphery of the zone.

Another major difference between tracking data collected from the two exits was that the north zone featured many more out of zone pedestrians compared to the south (45.5 percent versus 21 percent) (Table 5.6). Most of the pedestrians exiting the north zone were heading towards Kabukicho presumably because the area lacks a direct exit from Shinjuku Station and is therefore most accessible from the north exit[6]. It may also be related to the shopping patters of pedestrians in both zones. In the south zone, the most common final destination of the tracked pedestrians was a retail establishment (43 percent) compared to 32.7 percent in the north zone. This suggests that the south zone may provide a more desirable retail environment compared to the north zone. The

[6] There is an exit that links Shinjuku Station to Kabukicho via an underground pathway. There is no direct above ground exit that links Shinjuku Station to Kabukicho.

Table 5.6
Selected Frequency Statistics for Tracking Data (North and South Exit)

Exit	Category	Percent	Number
North	Male	61	62
	Female	33	33
	Couple	6	6
		100	101
	Final Destination		
	Retail	33	33
	Out of Zone	45	46
	Gambling	0	0
	Food	9	9
	Service	3	3
	Unknown	5	5
	Office	3	3
	Public Space	2	2
		100	101
	Direct to Destination	34	34
	Not Direct to Destination	15	15
	Unknown	51	52
		100	101
	Cross-Over into Other Zone	6	6
	No Cross-Over	94	95
		100	101
South	Male	55	55
	Female	41	41
	Couple	4	4
		100	100
	Final Destination		
	Retail	43	43
	Out of Zone	21	21
	Gambling	17	17
	Food	7	7
	Service	7	7
	Unknown	3	3
	Office	1	1
	Public Space	1	1
		100	100
	Direct to Destination	67	67
	Not Direct to Destination	13	13
	Unknown	20	20
		100	100
	Cross-Over into Other Zone	14	14
	No Cross-Over	86	86
		100	100

result is that people are more likely to use the south zone to shop and the north zone as a transition from Shinjuku Station to Kabukicho.

Pedestrians in the south zone were far more likely to enter a gambling facility as their final destination compared to the north zone (Table 5.6). The primary reason for this is the absence of gambling facilities in the north zone and the presence of them in the south zone. Again, this is related to the idea that the south zone is more of a retail destination compared to the north zone and therefore has more shopping and gambling opportunities. Furthermore, there were far more direct to destination tracks in the south zone (67 percent versus 33.7 percent). The main reason for this difference was the high percentage of pedestrians exiting the north district into Kabukicho and therefore preventing the researcher from discovering their final destination. Judging by the researchers' observations in the area there is little reason to believe that the pedestrians were not going direct to their destination once they reached Kabukicho.

Finally, there was a difference in the percentage of pedestrians who crossed over into the other zone depending on the zone where they commenced their journey. For instance, 14 percent of the tracked pedestrians from the south zone entered into the north zone compared to only 5.9 percent entering from the north zone into the south zone (Table 5.6). There are two likely reasons for this. The first is that pedestrians in Shinjuku tend to choose their exit according to the destination that they wish to reach accounting for the overall low crossover between the zones. The second reason is likely due to the forward motion bias where pedestrians are more likely to move forward when given the choice, as opposed to left, right, or backwards (McBeath et. al., 1992). When exiting the south exit pedestrians can easily walk forwards until the reach the north zone;

however, to reach the south zone from the north, the pedestrians would need to turn in the opposite direction from where they began. The likely explains, in part, the differences in crossover. It may also explain why so many pedestrians' head from the north zone into Kabukicho.

5.4.3 Complexity of Tracked Trips

Each trip was categorized depending on its complexity to further understand pedestrian behaviour in the study area. This method was used to classify pedestrian itineraries in a public market with the goal of deciphering if the tracked trips were complex or simple in relation to the environment (Zacharias, 2007). The precept is that pedestrian trips often exhibit a simple path configuration even though the environment can technically allow for very complex and varied configurations.

Seven distinct patters emerged from the tracking data (Figure 5.3). The two most common patterns ('straight through' and 'one turn') accounted for 86.6 percent of all of the tracked trips. Overall, the most popular pattern 'straight through' was also the simplest; it involved a pedestrian walking from origin to destination without making a major turn along the way. The second most popular pattern 'one turn' was the second simplest pattern involving the pedestrian only making one major turn from origin to destination. The remainder of the patterns were not nearly as prevalent as the first two and were also more complex suggesting that pedestrian behaviour in Shinjuku remains simple despite a complex street network.

Figure 5.4 shows an example of a 'straight through' trip, a 'one turn' trip, a 'half-loop' trip and a 'single loop' trip. From the figure it can be understood that the trips tend

Figure 5.3
Chosen Path Configurations Abstracted from Tracked Trips (N=201)

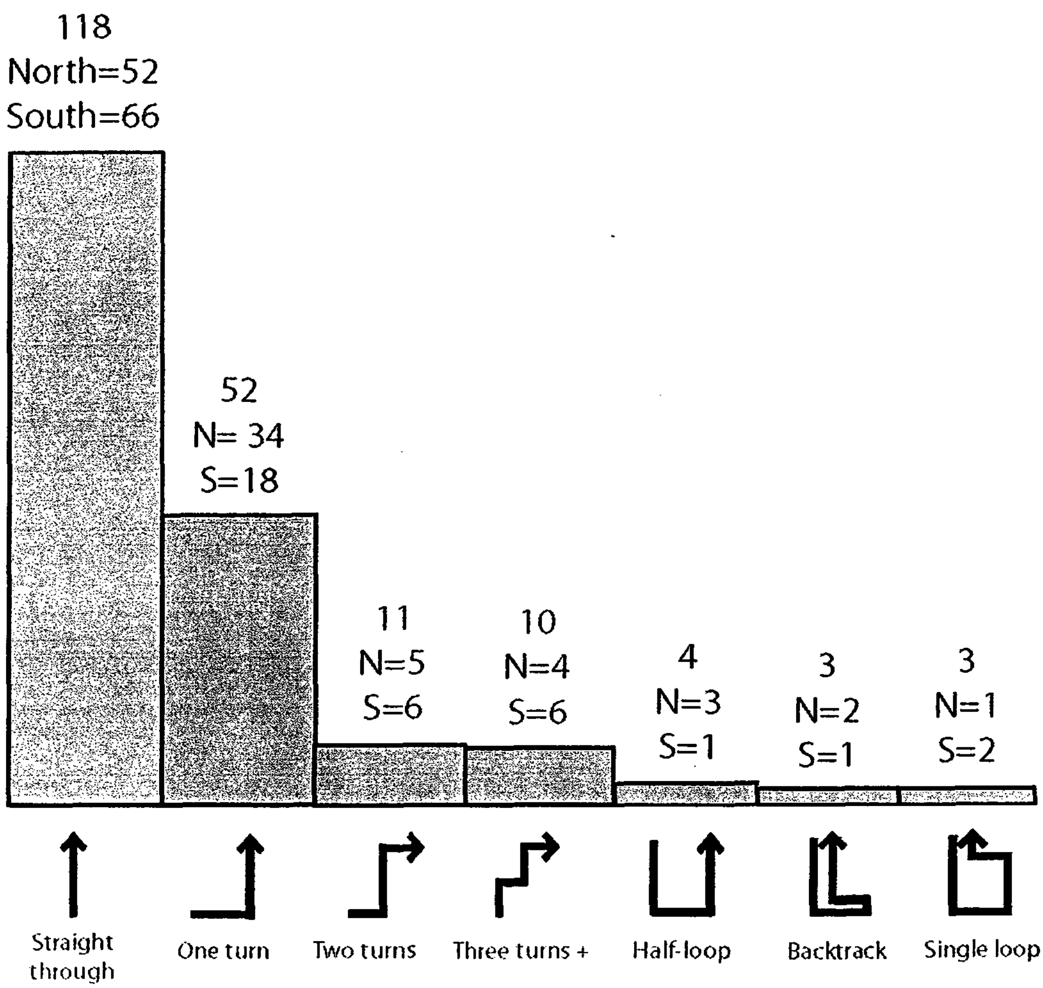
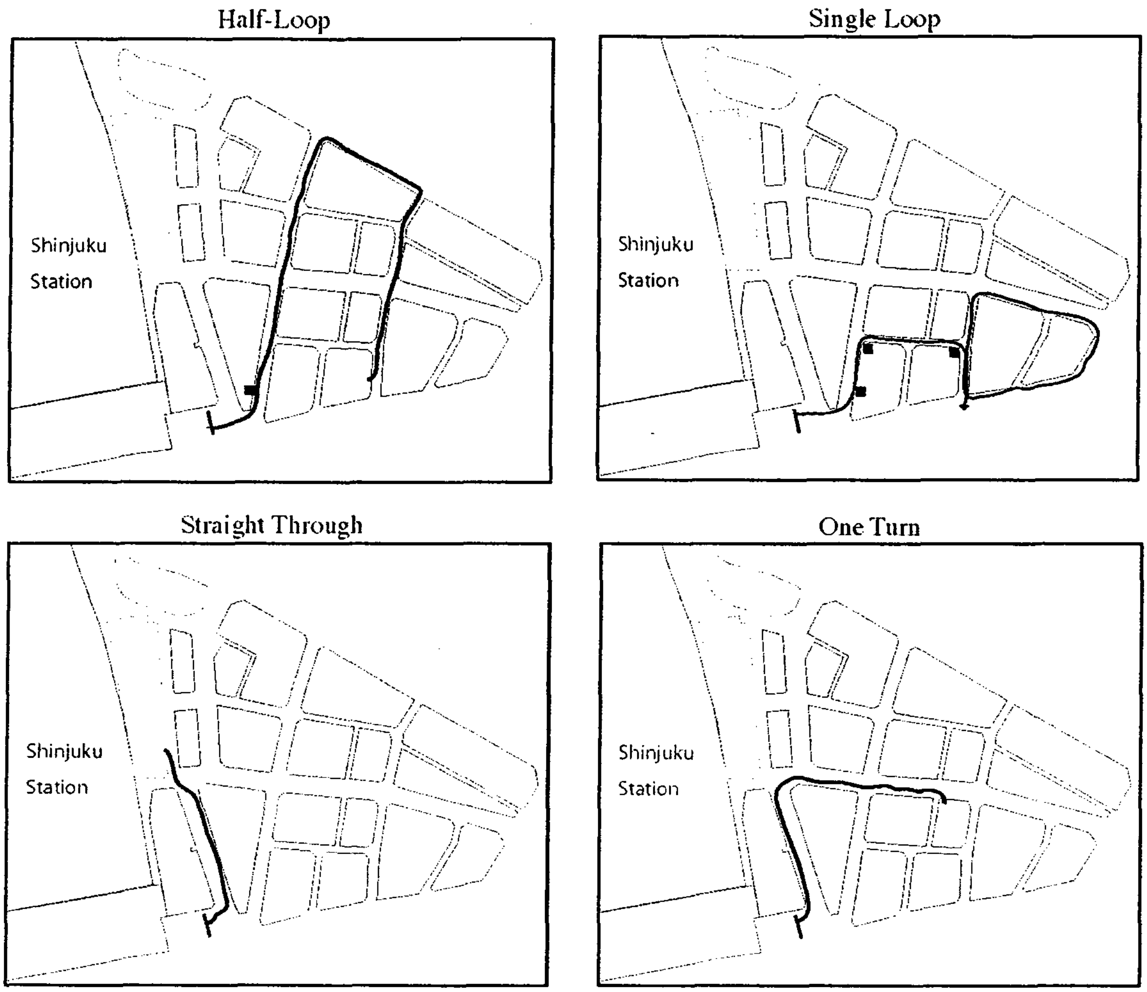


Figure 5.4
An Example of Four Tracks from the South Exit



Indicates a stop .■

to be simple and not very complex given the potential for path choices provided by the physical environment. The exception to this rule can be observed by trips that did not fall into the 'straight through' or 'one turn' category. For instance, 'single loop' features a much more complex movement pattern than the other tracks in the figure. The track is more complex both in the number of stops that were made along the way as well as itsoverall shape. When further analyzing this track it is discovered that the stops made along the way were done because the pedestrian was window shopping. This suggests that the pedestrian did not have a predetermined retail outlet in mind as a final destination and was therefore more likely to move through the district in a complex pattern (i.e., more susceptible to their surrounding environment and therefore more likely to stop along the way and make more turns).

Chapter 6

Conclusion

The conclusion chapter is divided into two sections: the first section will detail the outcomes of the regression models by relating the findings to the literature and the second will discuss findings from the tracking data.

6.1 Primary Multiple Regression Models

The most significant variable found in the primary multiple regression models, 'path width', has also been discovered to have an influence of pedestrian distributions in previous research (Pushkarev and Zupan, 1971). In this research, however, the relationship between pedestrian distribution and street width is more significant compared to previous research. For example, Foltête and Piombini (2007) found that street width and the presence of sidewalks had low correlations with pedestrian distribution (0.00 and 0.03 respectively). In Shinjuku the correlations were much higher where the presence of a sidewalk was correlated at -.098 and the path width, defined as the space where pedestrians can walk, with a positive correlation of .414. In Shinjuku path width is a very important variable predicting the distribution of pedestrians and this may be due, in part, to the large amount of pedestrians in Shinjuku compared to other walking environments. Over three million passengers use Shinjuku Station daily and over 30,000 pedestrians enter into the case study area hourly, thus wide street segments are better suited to accommodate the demand.

Two other significant variables, 'retail' and 'trees', have been related to the distribution of pedestrians in previous research. 'Retail' has been found to be a significant variable in the prediction of pedestrian distribution by many researchers since the early 1970s (Pushkarev and Zupan, 1971; Benham and Patel, 1976; Hillier et. al., 1993; Peponis, 1999) whereas the importance of 'trees' and other forms of streetscape vegetation, like shrubs, has been found more recently (Shiver, 1997; Foltête and Piombini, 2007). Both 'retail' and 'trees' were very significant in the regression models for Shinjuku each with a correlation of .461 and standardized beta coefficients of .271 and .236 respectively in the second model. 'Trees' and 'retail' are correlated to each other (.449) as well, suggesting a variant relationship that may have an impact on their significance values; however, the importance of these factors should not be overlooked. Evidently, the presence of both 'retail' and 'trees' play a significant role in the distribution of pedestrians on street segments in Shinjuku, supporting the aforementioned conclusions by other researchers. As such, the planning of walking environments should encompass allocating sufficient space for the establishment of a solid retail base while also ensuring an appropriate amount of landscaping with particular emphasis on the presence of trees and other streetscape vegetation.

The final two variables of significance according to the regression models were 'path maintenance' and 'paving materials'. Both variables are not supported by previous research but had a significant impact on pedestrian distribution in Shinjuku. For instance, 'path maintenance' had the highest standardized beta value of all of the independent variables in the third model at -.341. 'Paving material' had a high value in model one at -.220. However, both variables show a correlation with each other (.485) as well as with 'retail' (-.260 and -.262) and 'path width' (.289 and .062) suggesting that their overall significance may be impacted by co-variance. In addition there are problems with the variables becoming dependent as opposed to independent giving reason to remove them from one of the final regression models (model two). Regardless, streets paved with asphalt, as opposed to paving bricks, with 'poor' maintenance are less likely to attract high pedestrian distributions in Shinjuku. These findings have significant applications because they highlight the importance of the quality of the street environment in attracting pedestrians. Given these results, future research should include analysis of street paving materials and level of maintenance when analyzing the impact of streetscape variables on pedestrian distributions.

The results of this study indicate that space syntax plays an inconsequential role in predicting the distribution of pedestrians on street segments in Shinjuku. In all three regression models the space syntax variable maintained a low standardized beta coefficient (the highest value was -.081 in model three) and remained insignificant (p was not less than .1). These results contradict previous research which espouses the importance of space syntax in predicting pedestrian distribution (Hillier and Hanson, 1984; Peponis et. al, 1989; Peponis et. al., 1997; Read, 1999; Desyllas et. al., 2005; Foltête and Piombini, 2007); however, it confirms that there may be issues with the measurement of the variable as suggested by Ratti (2004) and Turner (2007), namely that the integration measure is too dependent on the number of street segments in the study area and that the definition of axial lines is too subjective.

There are a number of potential factors that may have caused space syntax to prove insignificant in this research; the first is the low sample of street segments and the second is the 'generator effect'. The sample of street segments (n=87) used to calculate space syntax might have been too small. If the measure was completed at a more global level, such as for the entire district of Shinjuku or the entire City of Tokyo, as done in London by Desyllas et. al. (2005), the integration measure may have been more significant in explaining pedestrian distribution in Shinjuku. Another problem may have been the influence of pedestrian generators on the distribution of pedestrians on street segments within 100 meters of that generator. For example, even though a street segment in close proximity to a pedestrian generator may have a low space syntax value, it may still have a high pedestrian distribution because of the generator. The 'generator effect' would skew the analysis by inflating the pedestrian distributions on street segments with low integration values in close proximity to pedestrian generators. Regardless, the results of this investigation act as a warning to future researchers who wish to use space syntax as a predictive measure of pedestrian distribution; specifically, that the measure may not be as monumental in explaining pedestrian distribution as previously thought. The results also suggest the importance of measuring the impact of the pedestrian generators on the pedestrian distributions of adjacent street segments. Previous research has not attempted to account for the impact of pedestrian generators and this research highlights that if generators are not considered the final results may be significantly altered.

6.2 Secondary Linear Regression Models and Correlations

The secondary multiple regression models suggest the importance of lighting in pedestrian distribution and validates the enter and exit variable in predicting pedestrian distribution. Specifically, lighting may play an important role in pedestrian distribution on street segments and future research in the environment and behaviour field should consider it. Previous research has discovered that lighting is important to improve feelings of safety and therefore attract pedestrians (Painter, 1996) and, based on the experimental results from Shinjuku, this research appears to confirm this notion.

The mean pedestrian distirbution data were responsible for explaining 15.3 percent of the variance in the enter and exit variable. As such, the method is valuable in determining the 'activity level' of the street. In this case 'active' is a word used to describe the frequent exchange of pedestrians between buildings and the street. In theory, streets that are 'highly active' would have a greater exchange of pedestrians between buildings and the street. The enter and exit method appears to be successful at measuring the activity level of a street and future research can adapt the method to see if it remains significant across walking environments.

6.3 Tracking Data

The tracking data collected in Shinjuku highlight that pedestrian trips tend to be short and direct to destination with few stops being made en route from origin to destination. Most of the final destinations as well as the stops made en route were a result of the presence of retail (i.e., people were coming to Shinjuku to shop or were stopping en route to their final destination to window shop). These results confirm the importance of retail in walking environments (Peponos et. al., 1997; Vernez-Moudon and Hess, 2000; Zacharias, 2001; Zacharias, 2007) further proving that retail plays a vital role in pedestrian distribution in walking environments.

A second result from the tracking data is that individual pedestrian walking itineraries tend to be simple despite the potential for complexity based on the environment (Zacharias, 1997). This suggests that pedestrian trips remain simple regardless of the complexity of the walking environment. Opportunity for trip complexity is determined by the layout of the environment and is measured by the potential for pedestrians to make a large number of turns. In Shinjuku trips remain simple because pedestrians are destination oriented and appear to have a predetermined itinerary established where they take the most direct route to their destination.

It is unclear if the results from the tracking data collected in Shinjuku can be generalized to other walking environments. For example, it is not appropriate to conclude that all walking environments attract pedestrians who are destination oriented. Future research on walking environments should address if pedestrians are destination oriented or if they tend to linger and make more complex trips on route to their destination. This information can then be used to compare walking environments across the globe to gain a comprehensive understanding of how streetscape factors, such as the number of retail outlets, impact the path choices of pedestrians.

6.4 Role of Pedestrian Generators

The 'generator effect' is a key concern that must be addressed in future research as it has the potential to have more influence on pedestrian distributions than streetscape variables. Specifically, the question that should be addressed is: what is the impact of pedestrian generators on the pedestrian distribution on street segments in close proximity to a generator? Results from this research suggest that there is a strong relationship but it must continue to be investigated.

Chapter 7

Discussion

The discussion chapter will interpret the results and relate them to the planning of future walking environments. The section will also discuss the need for future research in the field and will provide a conclusion to summarize the findings of the research.

7.1 Primary Multiple Regression Models

The multiple regression models suggest that numerous streetscape variables are responsible explaining pedestrian distribution and path choice. Therefore, the hypothesis stated at the beginning of this research, that streetscape variables impact pedestrian distribution on street segments was proven correct.

7.1.1 The Streetscape

The multiple regression models highlight the importance of path maintenance and paving materials in explaining the distribution of pedestrians. In planning terms this suggests that the overall quality of a street segment, as measured by its maintenance and paving material (e.g., paving bricks as opposed to asphalt), are important elements in attracting pedestrians. Therefore, planning authorities responsible for the design of walking environments should ensure that street segments remain well maintained and are paved with materials other than asphalt. This is not suggesting that paving bricks are the only material appropriate for walking environments but rather that asphalt is undesirable and other materials might be more aesthetically pleasing and should be considered.

A large number of diversified retail establishments strongly relates to the distribution of pedestrians. When planning walking environments planners must consider the retail composition of the street and encourage a diverse set of retailers. Methods to encourage a diverse set of could include policy incentives such as restricting the presence of large-scale stores (e.g., major department stores). In Shinjuku, street segments in close proximity to large department stores have lower pedestrian distributions suggesting that pedestrian movement is a) either relocated into the department store or b) people are less likely to walk along the street segments with department stores because there are fewer retail opportunities. However, one thing is clear: street segments that do not provide many retail opportunities do not attract pedestrians in Shinjuku.

The number of trees and the width of the pedestrian path are both related to high distributions of pedestrians. Planners must continue to consider the importance of trees and other forms of vegetation in creating a highly visited street segment. This has already begun in Shinjuku; however, trees are still missing on various streets and planners should consider adding them to improve the overall quality of the district.

In terms of street width, planners must continue to consider the width of pedestrian pathways. If a path is too narrow there will not be enough room for pedestrians and, on the other hand, if it is too wide the street segment might appear unattractive or empty. While the width of the street is important, the most appropriate width of street segments remains unclear. For example, is the width of the pedestrian path dependent on the distribution of pedestrians or is the number of pedestrians dependent on the width of the path? To help address the most appropriate width for street segments, future research could investigate pedestrian preferences regarding street segments featuring a variety of widths with the goal of establishing how the width of pedestrian space impacts pedestrian desirability to visit a street.

Future research should focus on developing a comprehensive rubric designed to measure the impact of streetscape variables on pedestrian distribution in walking environments. The rubric should include the variables found to be significant in this research but also other variables not considered by this research. Other factors that might be considered in the rubric include sound (Korte and Grant, 1980) and a visual vegetation index (Foltête and Piombini, 2007) designed to quantify the aesthetic appeal of one street segment over another based on the presence of vegetation. Creating a rubric that classifies the streetscape will further assist the design of walking environments.

Another interesting investigation would be evaluating the impact of the streetscape on individual pedestrians. Specifically, measuring pedestrian response to environmental factors, such as a high versus low automobile traffic, would be beneficial in determining the impact of specific variables on pedestrian behaviour. A possible method for this research could be the development of a sensory devise that would be placed on pedestrians to measure their physiological responses (i.e., raised heart rate) to key elements of the environment. This information would provide micro level data on pedestrian response to key elements of the sensory environment and could be used to help design walking environments (i.e., excluding design elements that produced a 'negative' physiological response by a large number of pedestrians).

The strong correlation between high levels of automobile traffic and high pedestrian distributions on street segments suggests that motorized traffic often attracts pedestrians. At first glance this relationship appears to suggest that a high level of automobile traffic is a precursor for high pedestrian distributions. This is not the case as many walking environments experience high pedestrian distributions yet completely exclude motorized traffic (Zacharias, 2007). What this relationship does suggest, however, is that streets that have a high number of retail outlets, good path maintenance, and high quality paving materials also tend to have a high level of motorized traffic. Furthermore, these streets also tend to have high integration levels as measured through space syntax (Peponis et. al., 1997). Previous research has discovered that a pedestrian's decision to visit a street is not dependent on the level of motorized traffic (Shiver, 1997) and that street segments with high levels of motorized traffic tend to be those that are well integrated according to space syntax (Peponis et. al., 1997). Cumulatively this suggests that more research is necessary on the relationship between pedestrian distributions and the presence of motorized traffic as the relationship remains unclear.

Specifically, more research must be completed on both the impact of motorized traffic on pedestrian perceptions' of walking environments as well as the relationship between motorized traffic, pedestrian distribution on street segments, and the speed and frequency of automobile movements. A good method to measure the relationship between motorized traffic and pedestrian distribution would be to complete comprehensive traffic and pedestrian counts and correlate the numbers. This would lead to a precise result explaining the relationship between motorized traffic and pedestrian distribution and it would avoid classifying motorized traffic subjectively as either 'high' or 'low'. This information would also allow planners to better understand the impact of motorized traffic on pedestrian levels.

Space syntax was not an important factor in predicting pedestrian distribution in Shinjuku. This is not to suggest that the physical layout of the street network does not impact pedestrian distribution but rather that space syntax, in isolation of other streetscape factors, is not significant in explaining pedestrian distribution. The insignificance of space syntax suggests that research must take on a more comprehensive approach when evaluating pedestrian distribution in walking environments by integrating the measure with other aspects of the aesthetic and physical streetscape. Explaining pedestrian distribution through the use of a single variable does not take into account the complexities of the urban environment and therefore cannot adequately account for and predict pedestrian distribution.

7.2 Secondary Linear Regression Models and Correlations

The level of natural light in Shinjuku was found to play a role in pedestrian distributions on street segments yet the impact of lighting levels at different times of the day on pedestrian distribution remains unknown. An interesting investigation would be the exploration of natural light (e.g., sunlight) in accordance to pedestrian distributions during the day as well as an analysis of pedestrian distributions at night in relation to artificial lighting. Such an investigation would provide valuable information on the importance of lighting in the distribution of pedestrians in walking environments. Discovering that natural lighting plays a role in pedestrian distribution may suggest that streets should be orientated towards the sun and that building height and street width should be controlled to maximize exposure to light. Discovering that lighting plays an important role in pedestrian distribution at night would suggest the importance in providing more lampposts and other lighting sources on street segments in walking environments.

7.3 Tracking Data

The tracking data highlights the importance of retail clusters in determining the behaviour and destination of pedestrians in walking environments. Shinjuku is an environment based around consumption; people visit to Shinjuku to purchase consumer goods and often have their destination predetermined before arrival. Therefore, the placement of retail establishments on street segments in Shinjuku is vital to attract pedestrians.

Planners must consider the distribution and number of retail outlets on street segments when planning walking environments with the ultimate goal being a relatively even distribution of retail outlets across street segments. An even distribution of retail establishments will encourage all street segments in the walking environment to be highly visited and will help prevent segments with low pedestrian distributions and economic instability. Emphasis should also be placed on encouraging numerous small-scale retail outlets as opposed to large-scale department stores. Providing small-scale retail outlets might encourage activity to remain on the street by preventing pedestrian movement from being concentrated large shopping complexes.

When designing walking environments planners should consider that pedestrians tend to take the most direct route from origin to destination giving attention to the layout of the street network. A grid pattern that provides small blocks with many connections to other street segments will help ensure that pedestrians can make direct trips from their origin to destination but will also allow for the environment to influence path choice. For example, by providing small blocks, and therefore many connections to other street segments, pedestrians might be enticed to take a new route to look for shopping opportunities. Encouraging pedestrians to take a new route can introduce them to new retail opportunities and impact the economic sustainability of the walking environment.

Future research in the field should focus on the impact of different forms of retail (i.e., small-scale retail outlets versus large-scale department stores) on the desirability of visiting walking environments. For example, what shopping opportunities do pedestrians prefer in walking environments? Another key investigation would focus on how many pedestrians deviate from their planned shopping itinerary in walking environments and how this deviation relates to streetscape variables. Further research investigating the potential for more leisure space in walking environments, as opposed to consumption space, could also prove beneficial. For instance, do pedestrians wish to have more leisure space in walking environments? In Shinjuku, there is a single small park that permits pedestrians to congregate and, based on unstructured observations by the researcher, it was highly used throughout the day. Providing more leisure and park space might be beneficial in attracting pedestrians to walking environments; however, future research must investigate this precept further.

7.4 Theory and Conclusions

The results of this research prove that the streetscape influences pedestrian distributions on street segments. This builds on knowledge developed in previous studies that have emphasized the importance streetscape (e.g., width of the sidewalk, number of retail outlets, etc.) in the prediction of pedestrian distribution in walking environments. More specifically, this research supports the findings of Pushkarev and Zupan (1971), Benham and Patel (1976), Hillier et. al. (1993), and Peponis (1999), which indicate that elements of the streetscape play a critical role in predicting pedestrian distribution, yet space syntax, often highlighted as the most important variable in pedestrian distribution (Hillier and Hanson, 1984; Peponis et. al., 1989; Peponis et. al., 1997; Read, 1999; Desyllas et. al., 2005; Foltete and Piombini, 2007) in fact, plays an insignificant role.

In conclusion discrepancies in pedestrian distribution between street segments in Shinjuku are primarily explained by specific streetscape variables (e.g., number of trees, path maintenance, paving materials, number of retail outlets, width of the walking path). New streetscape variables not identified by previous research (e.g., path maintenance and paving materials) suggest that some aspects of the streetscape have been overlooked. Future research, as well as planning practices surrounding the design and landscaping of walking environments, must therefore integrate the importance of these new streetscape variables to allow for the design of better pedestrian environments, as measured through distribution levels, and to further understanding of how the streetscape impacts pedestrian distributions in walking environments.

Municipal planners, developers, and individual business owners who contribute to the street landscaping budget in Shinjuku and other walking environments would benefit from this research because it provides information on the exact streetscape variables that are related to high pedestrian distributions. Opportunities to improve the quality of walking environments by making this research available to the actors directly responsible for landscaping and designing such environments will ensure that these environments attract pedestrians and remain viable in the future. In terms of this research this will be done by actively promoting the results to the planners responsible for overseeing development in Shinjuku.

References

BENHAM, J. and PATEL, B.G. 1976 'A method for estimating pedestrian volume in a central business district' *Highway Research Record* 355, 22-26

BENTHAM, C.G. and HAYNES, R.M. 1985 'The effects of vehicular traffic restriction on pedestrian numbers' *Traffic Engineering and Control* 26(4), 210

BRYMAN, A and TEEVAN, J.J. 2005 *Social Research Methods: Canadian Edition* (Oxford: University Press)

CHANG, D. 2002 'Spatial choice and preference in multilevel movement networks' *Environment and Behavior* 34(5), 582-615

CLIFTON, C.J., LIVI SMITH, A.D., and RODRIGUEZ, D. 2007 'The development and testing of an audit for the pedestrian environment' *Landscape and Urban Planning* 80(1), 95-110

DESYLLAS, J., DUXBURY, E, WARD, J. and SMITH, A. 2005 'Pedestrian demand modelling of large cities: an applied example from London' *Centre for Advanced Spatial Analysis, Working Series* (London: University College London)

EWING, R, HALIYUR, P., and PAGE, G.W. 1994 'Getting around a traditional city, a suburban planned unit development, and everything in between' *Transportation Research Record* 1466, 53–62

FOLTÊTE, J.C. and PIOMBINI, A. 2007 'Urban layout, landscape features and pedestrian usage' *Landscape and Urban Planning* 81, 225-34

HILLIER, B and HANSON, J. 1984 *The Social Logic of Space* (Cambridge: Cambridge University Press)

HILLIER, B. 1999 'The common language of space: A way of looking at the social, economic and environmental functioning of cities on a common basis' *Journal of Environmental Science* 11(3), 344-49

HILLIER, B., PENN, A., HANSON, J., GRAJEWSKI, T., and JIANMING, X. 1993 'Natural movement: or, configuration and attraction in urban pedestrian movement' *Environment and Planning B* 20, 29-66

ICSC (International Center for Shopping Center Research) 2004 'Lifestyle center tenant space allocation: A look inside the tenant mix of lifestyle centers' *ICSC Research Quarterly* 11(2), 1-6

KOTE, C. and GRANT, R. 1980 'Traffic noise, environmental awareness, and pedestrian behavior' *Environment and Behavior* 12(3), 408-20

KRÜGER, M. 1980 'An approach to built-form connectivity at an urban scale: Relationships between built-form connectivity, adjacency measures, and urban spatial structure' *Environment and Planning B: Planning and Design* 7, 163-94

MCBEATH, M.K., MORIKAWA, K., KAISER, M.K. 1992 'Perceptual bias for forward-facing motion' *Psychological Science* 3(6), 362-67

MOGRIDGE, M.J.H. 1985 'Transport, land use, and energy interaction' *Urban Studies* 22, 481-92.

MOUDON, A.V., HESS, P.M., SNYDER, M.C., and STANILOV, K. 1997 'Effects of site design on pedestrian travel in mixed-use, medium density environments' *Transportation Research Record* 1578, 48-55

NARDI, P.M. 2006 *Interpreting data: A guide to understanding research* (Boston: Pearson Education)

NUBANI, L and WINEMAN, J. 2005 'The role of space syntax in identifying the relationship between space and crime' *Proceedings of the 5th Space Syntax Symposium on Space, Delft*

PALLANT, J. 2007 *SPSS survival manual (3rd Edition)* (New York: Open University Press)

PEPONIS, J., HADJINIKOLAOU, E., LIVIERATOS, C. and FATOUROS, D.A. 1989 'The spatial core of urban culture' *Ekistics* 334, 43-55

PEPONIS, J., ROSS, C., and RASHID, M. 1997 'The structure of urban space, movement and co-presence: The case of Atlanta' *Geoform* 28(3-4), 341-58

PROJECT FOR PUBLIC SPACES (PPS) 2008 'Shinjuku Eki' at URL < http://www.pps.org/great_public_spaces/one?public_place_id=761# > (version current at 28 Janurary, 2008)

PUSHKAREV, B. and ZUPAN, J. 1975 *Urban space for pedestrians* (Cambridge, MA: MIT Press)

PUSHKAREV, B. and ZUPAN, J. 1977 *Public Transportation and Land Use Policy* (Bloomington: Indiana University Press)

PUSHKAREV, B and ZUPAN, J.M. 1971 'Pedestrian Travel Demand' *Highway Research Record* 355, 37-53

RATTI, C. 2004 'Space syntax: some inconsistencies' *Environment and Planning B* 31, 487-99

READ, S. 1999 'Space syntax and the Dutch city' *Environment and Planning B* 26, 251-64

ROBERTSON, K.A. 1992 'Downtown pedestrian malls in Sweden and the United States' *Transportation Quarterly* 46(1), 37-55

RUBENSTEIN, H.M. 1992 *Pedestrian malls, streetscapes, and urban spaces* (New York: Wiley)

SAELENS, B., SALLIS, J, and FRANK, L.D. 2003 'Environmental correlates of walking and cycling: Findings from the transportation, urban design, and planning literatures' *Annals of Behavioral Medicine* 25(2), 80-91

SHELLER, M. and URRY, J. 2003 'Mobile transformations of 'public' and 'private' life' *Theory, Culture and Society* 20(3), 107-25

SHRIVER, K. 1997 'Influence of environmental design of pedestrian travel behaviour in four Austin neighbourhoods' *Transportation Research Record* 1578, 64-75

STEVENS, J. 1996 *Applied multivariate statistics for the social sciences (3rd edition)* (Mahwah, NJ: Lawrence Erlbaum)

TABACHNICK, B.G. and FIDELL, L.S. 2007 *Using multivariate statistics (5th edition)* (Boston: Pearson Education)

TURNER, A. 2007 'From axial to road-centre lines: a new representation for space syntax and a new model of route choice for transport network analysis' *Environment and Planning B* 34(3), 539-55

VERNEZ-MOUDON, A. and HESS, P.M. 2000 'Suburban clusters: The nucleation of Multifamily Housing in suburban areas of the central Puget Sound' *Journal of the American Planning Association* 66(3), 243-64

ZACHARIAS, J. 1997 'The impact of layout and visual stimuli on the itineraries and perceptions of pedestrians in a public market' *Environment and Planning B* 24(1), 23-35

ZACHARIAS, J. 2001 'Pedestrian behavior and perception in urban walking environments' *Journal of Planning Literature*, 16(1), 4-18

ZACHARIAS, J. 2007 'The non-motorized core of Tianjin' *International Journal of Sustainable Transportation*, 1(4), 231-48

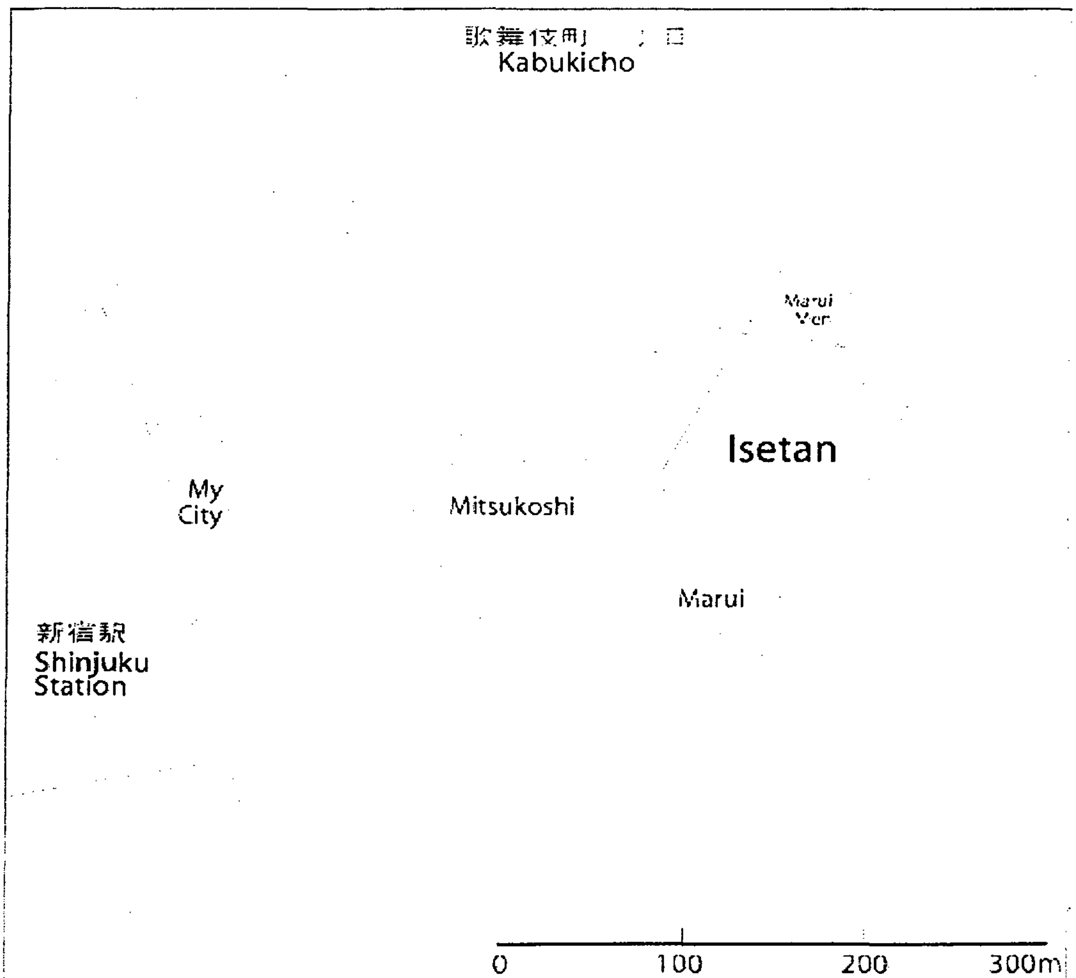
ZACHARIAS, J. and MUNAKATA, J., 2006 'Understanding the dynamics of a large pedestrian zone – the case of Shinjuku' *Proceedings of the 7th International Symposium for Environment - Behavior Studies, Harmony in Transition*, 10, 402-12

ZACHARIAS, J., STATHOPOULOS, and WU, H. 2001 'Microclimate and downtown open space activity' *Environment and Behavior*, 33(2), 296-315

ZACHARIADIS, V. 2005 'An agent-based approach to the stimulation of pedestrian movement and factors that control it' In *CUPUM '05: Computers in Urban Planning and Urban Management* (London: University College London) at Internet URL < http://128.40.111.250/cupum/searchpapers/index.asp> (version current at 09 March, 2009)

Appendix 1

Tracking Map



Date.
Time Started.
Time Finished.
Station Exit.
Sex.
Approximate Age
Track Number

Step Number.
1 EF Y / N TIME
2 EF Y / N TIME
3 EF Y / N TIME
4 EF Y / N TIME
5 EF Y / N TIME
6 EF Y / N TIME

Stop Type
1
2
3
4
5
6

Inferred Destination

Direct to Destination

Streetscape Evaluation Rubric

Urban Landscape Evaluation

Segment Number:
Date:
Time Finished:
Time Finished:

Segment Detail	Numerical Value
Pedestrian Volume	
Length of Segment	
Number of Retail Outlets	
Number of Food Outlets	
Number of Services (e.g., pharmacies, ticket sellers etc.)	
Number of Other Building Types (e.g., office, hotel)	

Local Environment	Numerical Value
Crowd Congregation (raw number, 10+ people)	
Lampposts	
Trees	
Building Height (for each building in the segment)	
Lighting Conditions	

Pedestrian Facilities	Yes / No / Value
Type of Path	1) Sidewalk 2) Pedestrian Street (no cars)
If 1) Buffer	1) Trees 2) Lamppost 3) Curb 4) No buffer
If 1) Crossing Aids	1) Yield to Pedestrians 2) Pavement Markings 3) Pedestrian Signal Light 4) Overpass / Underpass
If 1) Parallel parking	1) Yes 2) No
If 1) Traffic Calming	1) Yes a) Speed Bumps b) Stop Signs c) Traffic Lights 2) No
Path: Material	1) Asphalt 2) Concrete 3) Paving Bricks
Path: Obstructions	1) Pedestrian Congestion 2) Parked Cars 3) Signs / Poles 4) Garbage Cans 5) Trees 6) Other
Path: Maintenance	1) Poor 2) Fair 3) Good 4) Under Repair
Number of Connections to Other Segments	
Path: Width (feet)	

Appendix 2

First Model – Retail, Trees, Paving Material, Path Maintenance, Space Syntax

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	[illegible][a]	.445	.413	15.838

a. Predictors: (Constant), Space Syntax Centrality Measure, Is the street segment path maintenance needed or not?, RETA, TREES, Is the sidewalk paved with paving bricks? If not, it is with asphalt

b. Dependent Variable: Mean flow values for each segment in direction for each segment at 2 minute counts

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	16448.624	5	3289.725	13.122	.000[a]
	Residual	[illegible]	81	250.706		
	Total	36756.037	86			

a. Predictors: (Constant), Space Syntax Centrality Measure, Is the street segment path maintenance needed or not?, RETA, TREES, Is the sidewalk paved with paving bricks? If not, it is with asphalt

b. Dependent Variable: Mean flow values for each segment in direction for each segment at 2 minute counts

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	41.421	11.551		3.551	.001	18.439	64.4[illegible]
	RETA	2.326	.917	.242	2.536	.013	.501	4.156
	TREES	1.4[illegible]	.835	.170	1.743	.085	.207	3.128
	Is the sidewalk paved with paving bricks? If not, it is with asphalt	11.170	4.962	.220	2.244	.028	21.083	1.255
	Is the street segment path maintenance needed or not?	13.509	4.817	.272	2.804	.006	23.094	3.924
	Space Syntax Centrality Measure	26.745	121.754	.055	.636	.527	217.007	163.519

a. Dependent Variable: Mean flow values for each segment in directional for each segment at 2 minute counts

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	7.454	83.505	37.460	13.8208	87
Residual	-32.760	44.564	.000	15.3[illegible]	87
Std. Predicted Value	-2.142	3.322	.000	1.000	87
Std. Residual	-2.0[illegible]	2.816	.000	.97[illegible]	87

a. Dependent Variable: Mean flow values for each segment in directional for each segment at 2 minute counts

Second Model – Retail, Trees, Path Width, Space Syntax

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.594[a]	.353	.322	17.0255

a. Predictors: (Constant), Space Syntax Centrality Measure, width of the sidewalk only or path (metres). Does not include road with motorized traffic), RETAIL, TREES

b. [illegible]

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	12986.909	4	3246.727	11.201	.000[a]
	Residual	23769.128	82	289.867		
	Total	36756.037	86			

a. Predictors: (Constant), Space Syntax Centrality Measure, width of the sidewalk only or path (metres). Does not include road with motorized traffic), RETAIL, TREES

b. [illegible]

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	26.073	12.919		[illegible]	.046	1.272	[illegible]
	RETAIL	2.607	.983	.271	2.652	.010	.651	4.563
	TREES	2.022	.891	.236	2.270	.026	.250	3.795
	width of the sidewalk only or path (metres). Does not include road with motorized traffic)	1.395	.542	.247	2.576	.012	.318	2.472
	Space Syntax Centrality Measure	103.066	128.221	.074	.802	.425	[illegible]	[illegible]

a. [illegible]

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	19.556	91.544	37.480	12.2886	87
Residual	52.144	47.824	.000	16.6248	87
Std. Predicted Value	1.456	4.399	.000	1.000	87
Std. Residual	1.877	2.809	.000	.976	87

a. [illegible]

Third Model – Path Width, Trees, Paving Material, and Path Maintenance

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.681[a]	.463	.430	15.6033

a. Predictors: (Constant), Space Syntax Centrality Measure, Is the street segment path maintance good or poor?, width of the sidewalk only or path (metres). Does not include road with motorized traffic, TREES, Is the sidewalk paved with paving bricks? If not it is with asphalt.

b. Dependent Variable: Mean flow values for each segment (bi directional for each segment at 2 minute counts)

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	17035.123	5	3407.025	13.994	.000[a]
	Residual	19720.914	81	243.468		
	Total	36756.037	86			

a. Predictors: (Constant), Space Syntax Centrality Measure, Is the street segment path maintance good or poor?, width of the sidewalk only or path (metres). Does not include road with (motorized traffic), TREES, Is the sidewalk paved with paving bricks? If not it is with asphalt.

b. Dependent Variable: Mean flow values for each segment (bi directional for each segment at 2 minute counts).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1	(Constant)	40.026	11.308		3.531	.001	17.420	62.426
	TREES	1.464	.809	.173	1.809	.070	.123	3.094
	Is the sidewalk paved with paving bricks? If not it is with asphalt	8.375	5.020	.163	1.668	.100	18.364	1.620
	Is the street segment path maintance good or poor?	16.930	4.790	.341	3.539	.001	26.461	7.410
	width of the sidewalk only or path (metres). Does not include road with (motorized traffic)	1.526	.508	.271	3.003	.004	.510	2.537
	Space Syntax Centrality Measure	112.820	116.066	.081	.960	.340	343.643	120.403

a. Dependent Variable: Mean flow values for each segment (bi directional for each segment at 2 minute counts)

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	6.643	68.637	37.480	14.0742	87
Residual	33.235	43.436	.000	15.1431	87
Std. Predicted Value	2.191	2.215	.000	1.000	87
Std. Residual	2.130	2.912	.000	.970	87

a. Dependent Variable: Mean flow values for each segment (bi directional for each segment at 2 minute counts)

Lighting Model

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Lighting measure for each street segment[a]		Enter

a. All requested variables entered.

b. Dependent Variable: Mean flow values for each segment [illegible]

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	[illegible]	[illegible]	[illegible]	[illegible]

a. Predictors: (Constant), Lighting measure for each street segment

b. Dependent Variable: Mean flow values for each segment [illegible]

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Residual	[illegible]	[illegible]	[illegible]		
	Total	[illegible]	[illegible]			

a. Predictors: (Constant), Lighting measure for each street segment

b. Dependent Variable: Mean flow values for each segment [illegible]

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1	(Constant)	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	Lighting measure for each street segment	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

a. Dependent Variable: Mean flow values for each segment [illegible]

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Residual	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Std. Predicted Value	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Std. Residual	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

a. Dependent Variable: Mean flow values for each segment [illegible]

Enter and Exit Model

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Mean flow values for each segment b directional for each segment at 2 minute counts[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Enter and exit data for each street segment

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.391[a]	.153	.143	4.25208

a. Predictors: (Constant), Mean flow values for each segment b directional for each segment at 2 minute counts

b. Dependent Variable: Enter and exit data for each street segment

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	251.583	1	251.583	15.350	.000[a]
	Residual	[illegible]	87	[illegible]		
	Total	[illegible]	88			

a. Predictors: (Constant), Mean flow values for each segment b directional for each segment at 2 minute counts

b. Dependent Variable: Enter and exit data for each street segment

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.473	.955		.496	.621	-1.423	2.372
	Mean flow values for each segment b directional for each segment at 2 minute counts	8.733E-02	.022	.391	3.918	.000	.043	.130

a. Dependent Variable: Enter and exit data for each street segment

Casewise Diagnostics[a]

Case Number	Std. Residual	Enter and exit data for each street segment	Predicted Value	Residual
[illegible]	4.981	27.00	5.0726	21.9274
[illegible]	4.106	23.30	5.7513	17.5487

a. Dependent Variable: Enter and exit data for each street segment

Bi-Variate Correlation Table

Correlations

		Mean flow values for each segment (bidirectional for each segment at 2 minute counts)	RETAIL	FOOD	SERVICE	GAMBLING	OTHER	LAMPPOST	TREES	NUM AV
Pearson Correlation	Mean flow values for each segment (bidirectional for each segment at 2 minute counts)	1.000	.461	.049	.025	.137	.111	.209	.461	.166
	RETAIL	.461	1.000	.116	.169	.065	.131	.326	.449	.511
	FOOD	.049	.116	1.000	.016	.422	.101	.400	.178	.423
	SERVICE	.025	.169	.016	1.000	.067	.114	.451	.497	.369
	GAMBLING	.137	.065	.422	.067	1.000	.323	.284	.241	.259
	OTHER	.111	.131	.101	.114	.323	1.000	.033	.021	.007
	LAMPPOST	.209	.326	.400	.431	.284	.033	1.000	.627	.408
	TREES	.461	.449	.178	.497	.241	.021	.627	1.000	.349
	NUM AV	.166	.511	.423	.369	.259	.007	.408	.349	1.000
	BHEIGHT	.136	.205	.463	.011	.203	.042	.019	.162	.356
	SIDEWALK	.098	.058	.002	.019	.038	.161	.239	.317	.173
	MATS	.457	.260	.006	.082	.019	.224	.405	.369	.252
	MAINTAIN	.506	.262	.193	.056	.160	.030	.354	.338	.279
	AUTOS	.203	.026	.300	.166	.113	.116	.079	.164	.130
	WIDTHS	.414	.261	.094	.110	.035	.190	.202	.339	.041
	CENTRAL	.232	.272	.110	.123	.147	.054	.223	.106	.268
Sig. (2-tailed)	Mean flow values for each segment (bidirectional for each segment at 2 minute counts)		.000	.327	.409	.103	.153	.027	.000	.062
	RETAIL	.000		.142	.058	.274	.114	.001	.000	.000
	FOOD	.327	.142	.	.441	.000	.177	.000	.049	.000
	SERVICE	.409	.058	.441	.	.269	.147	.000	.000	.000
	GAMBLING	.103	.274	.000	.269	.	.001	.004	.012	.008
	OTHER	.153	.114	.177	.147	.001		.382	.424	.476
	LAMPPOST	.027	.001	.000	.000	.004	.382		.000	.000
	TREES	.000	.000	.049	.000	.012	.424	.000		.000
	NUM AV	.062	.000	.000	.000	.008	.476	.000	.000	
	BHEIGHT	.104	.029	.000	.459	.032	.350	.430	.068	.000
	SIDEWALK	.184	.297	.493	.430	.363	.005	.013	.001	.155
	MATS	.000	.008	.475	.224	.431	.019	.000	.000	.000
	MAINTAIN	.000	.007	.039	.157	.009	.391	.000	.001	.004
	AUTOS	.050	.405	.002	.062	.149	.143	.233	.065	.132
	WIDTHS	.000	.007	.134	.155	.373	.039	.051	.001	.352
	CENTRAL	.015	.005	.156	.127	.057	.309	.019	.035	.006

Bi-Variate Correlation Table Continued

B HEIGHT	SIDEWALK	MAT S	MAINTAIN	AUTOS	WIDTH S	CENTRAL
130	.098	.487	300	.203	.414	232
.203	.058	.260	262	.026	.261	272
.463	002	.006	193	.300	094	110
.011	.019	.082	096	.166	.110	123
.200	038	.019	160	.113	035	.147
.042	.161	.224	030	.116	190	054
019	.239	.405	354	.079	.202	223
162	.317	.360	336	.164	.359	196
356	173	.252	279	.120	.041	268
1.000	.307	.039	061	.435	.164	010
.307	1.000	.039	010	.086	190	.224
039	079	1.000	453	.095	259	.105
.061	010	.485	1.000	.116	062	.127
.435	.086	.095	116	1.000	.042	208
.164	.190	.283	062	.042	1.000	154
.010	224	.198	127	.208	154	1.000
.104	154	.000	000	.030	.000	.315
329	297	.008	007	.405	.007	.005
000	493	.478	020	.002	.194	.156
[illegible]	[illegible]	.214	157	062	.155	127
332	363	.431	009	.149	.375	057
.350	008	.019	391	.147	.039	.309
420	013	.000	000	.255	.031	.019
465	001	.000	001	.065	.000	035
000	055	.009	004	.133	.352	.006
.	002	.294	258	.000	.065	462
002		.339	465	.215	.039	.019
294	359		000	.192	.003	.033
.255	465	.000		.142	.284	.120
.000	215	.192	143		.351	026
.065	039	.003	254	351		077
.402	019	.053	120	.026	.077	.

Appendix 3 – Full Data Set

Table 1: Variable Set

Street #	Retail	Food	Service	Gamble	Other	Lamps	Trees	Building #	Building height
1	2	6	3	3	0	14	9	4.5	7
2	2	3	1	0	0	6	3	1.5	5.3
3	3	7	0	2	1	6	4	4	3.9
4	4	9	0	6	2	7	6	5.5	5.1
5	1	6	0	3	0	1	0	3.5	2.9
6	4	2	0	1	0	3	0	3	3.7
7	2	2	0	0	0	3	4	2	5
8	0	3	1	0	1	3	4	3	5.5
9	0	0	1	1	1	4	2	1.5	5.7
10	4	5	1	1	0	2	0	3.5	2.8
11	2	6	1	0	0	3	0	3.5	3.3
12	1	3	0	0	0	4	3	2.5	5.2
13	4	8	0	0	0	9	2	5	5.2
14	5	1	0	0	1	4	1	3.5	6.3
15	0	0	1	0	1	0	0	1.5	4
16	4	4	0	0	0	6	4	2.5	5
17	4	3	0	0	0	4	0	3	5.2
18	5	2	1	0	0	6	4	3.5	6.6
19	2	0	0	0	2	1	0	3	5.5
20	4	2	0	0	0	4	0	2.5	4.8
21	2	4	0	0	0	4	0	2	4.3
22	2	3	0	0	1	3	0	1.5	7.7
23	3	5	0	0	0	4	0	3.5	3.4
24	0	3	0	0	0	0	0	2.5	5.8
25	4	2	2	0	0	13	6	2.5	7
26	2	2	0	0	2	0	0	3	5.5
27	4	9	0	0	1	8	2	4.5	5.7
28	0	0	0	0	1	0	0	0.5	9
29	3	0	0	0	0	0	0	0.5	6
30	5	1	3	0	0	5	9	4	7.4
31	14	2	2	0	0	8	10	7	6.1
32	4	1	0	0	0	9	5	2	7.8
33	1	0	0	0	0	0	0	0.5	7
34	2	3	0	0	0	0	0	1	8
35	1	0	0	0	0	0	0	1	7.5
36	0	0	0	0	0	0	0	1	8
37	0	0	0	0	0	0	0	1	8
38	1	0	0	0	0	0	0	1	8.5
39	1	0	0	0	0	0	0	1	5.5
40	3	0	1	0	0	0	0	2	6
41	0	11	0	0	0	0	0	2.5	3.2
42	4	2	0	0	0	0	0	3.5	4.9
43	4	2	1	0	0	0	0	4.5	3.9

44	1	1	0	0	0	0	0	1.5	6.3
45	3	2	0	0	0	0	3	2.5	4.4
46	1	3	0	0	0	2	2	1	8
47	2	4	1	0	0	1	0	4.5	4.4
48	4	3	0	0	0	0	2	3	3.5
49	2	0	1	0	0	2	2	2	6.8
50	6	2	0	0	0	0	3	2.5	5.2
51	1	3	0	0	0	6	8	4	5.8
52	5	2	1	0	0	6	6	3.5	7.4
53	2	3	0	0	0	2	1	4	4
54	5	6	0	0	0	6	0	6	3.2
55	1	3	0	0	0	8	0	3.5	4.4
56	4	6	0	1	0	0	1	4.5	3.1
57	2	3	1	1	0	6	0	3.5	4
58	3	1	0	0	0	0	1	2	3.5
59	8	0	0	1	0	2	4	4	4.4
60	2	1	2	0	0	5	0	3	3.3
61	6	4	0	0	0	2	4	2.5	4
62	4	0	0	0	0	2	0	3	5.3
63	7	0	0	0	0	1	2	3.5	4
64	2	1	0	0	0	3	3	1.5	6.7
65	1	0	0	0	0	3	5	0.5	8
66	3	0	0	0	0	2	1	2	8
67	2	5	1	0	0	3	5	2	5.8
68	3	0	0	0	0	0	1	1.5	8.7
69	4	2	0	1	0	3	1	2	5.5
70	2	0	0	1	0	1	0	1.5	4.3
71	1	2	0	0	0	2	2	1	9
72	1	0	1	0	0	1	2	5.5	6.7
73	3	2	2	0	0	3	5	7	7.7
74	0	0	0	0	0	0	0	2	7
75	0	0	0	0	0	0	0	0.5	7
76	3	2	0	0	0	1	0	4.5	8.5
77	2	1	0	0	0	2	0	5.5	5
78	3	0	0	0	0	0	0	3.5	4.3
79	0	0	1	0	0	2	0	5	6.2
80	3	1	2	0	0	3	3	4	7
81	0	0	0	0	1	0	0	0.5	7
82	1	1	0	0	0	1	0	1	9
83	0	0	0	0	1	0	0	0.5	8
84	2	1	1	0	0	0	0	1.5	5
85	1	4	1	0	0	0	0	1.5	2
86	3	0	0	0	0	3	2	1.5	8
87	3	0	0	0	0	2	0	2	7

Table 1: Variable Set Continued

Street #	Sidewalk	Path Width	Space Syntax	Enter Exit	Ped. Data	
1	0	10.6	0.0845	8.7	62.1	
2	0	8.9	0.0747	3	44.4	Sidewalk
3	0	5	0.081	2	61.1	0=Yes
4	0	5	0.0933	5.3	61.1	1=no
5	1	5.6	0.0982	2	24.3	
6	1	5.6	0.1018	1	11.3	
7	0	6.1	0.0952	1.3	33.3	
8	0	6.1	0.1004	2	30.9	
9	0	5	0.1026	0	13	
10	1	5.6	0.0977	0.3	16.4	
11	1	3.2	0.0859	0.7	6.3	
12	0	3.4	0.0911	0	12.8	
13	0	8.4	0.0796	3	41.7	
14	0	8.4	0.0744	3	47.1	
15	1	3.6	0.075	0	3.6	
16	0	5	0.07	4	54	
17	1	7	0.0681	4.7	50.7	
18	0	5.6	0.061	4.3	55.2	
19	1	3.1	0.0755	0	5.7	
20	0	2.8	0.0665	3.7	30.7	
21	0	2.2	0.072	4.3	31.6	
22	1	7.3	0.0722	2.3	49.3	
23	1	6.7	0.0796	1.3	39.2	
24	1	2.8	0.0837	0	4.1	
25	0	8.9	0.0906	2.3	30.6	
26	0	2.2	0.1064	0	7.9	
27	0	8.9	0.099	4.3	18.3	
28	0	3.9	0.0889	1.3	31.9	
29	0	3.4	0.0999	2.3	35.6	
30	0	10.1	0.0618	11.3	73	
31	0	10.1	0.0602	27	59.4	
32	0	10.1	0.0777	23.3	60.3	
33	0	5.6	0.0925	4.7	26.2	
34	0	5.6	0.1062	1	21.3	
35	0	4.5	0.1004	7	18.5	
36	0	2.8	0.1089	0	9.7	
37	0	4.5	0.096	10	23.8	
38	0	7.3	0.0922	0	14.6	
39	0	18.4	0.0851	11	29.8	
40	0	18.4	0.0769	5	31.8	
41	1	5.9	0.0818	0.7	11.4	
42	1	3.6	0.0731	0.3	10.9	
43	1	5.9	0.0826	2.3	20.1	
44	1	5.9	0.0886	4.3	20.6	
45	0	7	0.0818	10.7	37.6	

46	0	7.8	0.0856	1.7	47.5
47	1	4.2	0.0815	0	13.5
48	0	3.4	0.0725	0.7	47.5
49	1	8.1	0.0709	1.3	30.2
50	0	3.4	0.0627	3	47.2
51	0	16.8	0.0782	4	44.5
52	0	16.8	0.0692	4.3	66.8
53	1	7.8	0.0782	0.7	33.7
54	1	4.5	0.0859	2.3	38.5
55	1	4.5	0.0752	1.3	22.4
56	1	7.8	0.0876	4.7	47.5
57	1	3.9	0.104	1.7	19.6
58	1	7.8	0.1053	4	47.1
59	1	11.7	0.1152	7	79.8
60	1	4.2	0.1187	0	10.6
61	1	11.7	0.1056	1	97.3
62	1	4.2	0.1116	1	6.8
63	1	11.7	0.0938	1.7	95.5
64	1	6.1	0.1105	2	69.2
65	1	6.1	0.1018	2.7	30.9
66	1	6.1	0.0919	2.7	38.6
67	1	6.1	0.0903	2.3	39.2
68	1	6.1	0.0944	2	48.3
69	1	6.1	0.0999	6	47.5
70	1	6.1	0.1168	3.7	45.4
71	1	6.1	0.1185	1	41
72	1	3.9	0.1083	0	33.4
73	1	3.9	0.0947	1.3	33.4
74	1	5.3	0.0922	13	39.7
75	0	5.3	0.084	13.3	39.7
76	0	7	0.0747	4	47.4
77	1	7	0.0807	2.7	47.4
78	1	7	0.0657	2.7	63.3
79	1	7.8	0.0802	10.7	57.9
80	1	7.8	0.0698	3	51.5
81	0	4	0.0876	12	71.3
82	1	7	0.0796	0.7	50.7
83	1	7.7	0.1105	1.1	30.9
84	0	5	0.1114	2.6	32.5
85	1	5.6	0.1045	0.9	14.7
86	0	21.8	0.0911	4	32.7
87	0	10.1	0.0684	6.1	75

Table 1: Variable Set Continued

Street #	Paving Material	Maintenance	Auto Level	Lighting
1	0	0	1	8.7
2	0	0	1	3
3	0	0	1	2
4	0	0	1	5.3
5	1	0	1	2
6	0	0	1	1
7	0	0	1	1.3
8	0	0	1	2
9	0	0	1	0
10	1	0	1	0.3
11	0	0	1	0.7
12	0	0	1	0
13	0	0	1	3
14	0	0	1	3
15	1	1	1	0
16	0	0	1	4
17	0	0	1	4.7
18	0	0	1	4.3
19	1	1	1	0
20	0	0	1	3.7
21	0	0	1	4.3
22	0	0	1	2.3
23	0	0	1	1.3
24	1	1	1	0
25	0	0	1	2.3
26	1	0	1	0
27	0	0	1	4.3
28	1	0	0	1.3
29	1	0	0	2.3
30	0	0	0	11.3
31	0	0	0	27
32	0	0	0	23.3
33	1	1	0	4.7
34	1	1	0	1
35	0	1	1	7
36	1	1	1	0
37	0	1	1	10
38	1	1	1	0
39	0	1	1	11
40	0	1	1	5
41	1	1	1	0.7
42	1	1	1	0.3
43	1	1	1	2.3
44	0	1	1	4.3

Paving Material
0 = Paving Bricks
1 = Asphalt

Maintenance
0 = Good
1 = Poor

Auto Level
0 = Low
1 = High

45	0	1	1	10.7
46	0	0	1	1.7
47	0	0	1	0
48	0	0	1	0.7
49	0	0	1	1.3
50	0	0	1	3
51	0	0	1	4
52	0	0	1	4.3
53	0	0	1	0.7
54	0	0	1	2.3
55	0	0	1	1.3
56	0	0	1	4.7
57	0	0	1	1.7
58	0	0	1	4
59	0	0	1	7
60	0	1	1	0
61	0	0	1	1
62	0	1	1	1
63	0	0	1	1.7
64	0	0	0	2
65	0	0	0	2.7
66	0	0	0	2.7
67	0	0	0	2.3
68	0	0	0	2
69	0	0	0	6
70	0	0	0	3.7
71	0	0	0	1
72	0	0	0	0
73	0	0	0	1.3
74	0	0	1	13
75	0	0	1	13.3
76	0	0	1	4
77	0	0	1	2.7
78	0	0	1	2.7
79	0	0	0	10.7
80	0	0	0	3
81	0	0	1	12
82	0	0	1	0.7
83	1	1	0	1.1
84	1	0	0	2.6
85	1	0	1	0.9
86	0	0	1	4
87	0	0	0	6.1