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MODELING SATISFACTION WITH THE WALKING ENVIRONMENT: THE CASE OF AN URBAN UNIVERSITY NEIGHBORHOOD IN A DEVELOPING COUNTRY

by

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A thesis
submitted in partial fulfillment of the requirements
for the degree of Master of Engineering
to the Department of Civil and Environmental Engineering and Architecture
of the Faculty of Engineering
at the American University of Beirut

Beirut, Lebanon
April 2015

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ACKNOWLEDGEMENTS

I would like to thank Dr. Maya Abou-Zeid and Dr. Isam Kaysi for being the great advisers that they are and for their dedication towards this study and towards my education. I would also like to thank the committee members, Dr. Issam Srour and Dr. Mona Harb for their time and efforts towards this thesis.

I want to also acknowledge and thank the Dean's Office of the Faculty of Engineering and Architecture and the Neighborhood Initiative program at the American University of Beirut for funding this research study.

AN ABSTRACT OF THE THESIS OF

Maher Said for Master of Engineering
Major: Civil and Environmental Engineering

Title: Modeling Satisfaction with the Walking Environment: The Case of an Urban University Neighborhood in a Developing Country

In light of the numerous benefits of increased walkability, which is commonly defined as the extent to which the built environment encourages conducting walking trips, an increasing number of research efforts have been brought about on the topic by urban planners, transportation engineers, health scientists and many others.

This paper aims at developing a framework, using structural equation modeling, that enables better understanding (and possible quantification) of the overall level of satisfaction with the walking environment based on attributes of the walking environment. Such a framework, in turn, allows identifying to what extent these attributes have an effect on the perceived level of satisfaction with the walking environment.

As a case study, this paper investigates the level of satisfaction of students of the American University of Beirut, Beirut, Lebanon, with the walking environment of the university surroundings. This analysis is conducted by developing two structural equation models for estimating the causal relations between the level of satisfaction with the attributes of the walking environment and the level of satisfaction with the walking environment overall. The first model examines the sample of students who are frequent on-foot commuters, whereas the second model studies the remaining sampled students who typically conduct on-foot trips in the university surroundings for purposes other than commuting (shopping, eating, leisure, etc.).

The resulting models, specific to the case study, indicate that specific neighborhood attributes have the greatest impact on the level of satisfaction with the walking environment for both samples, the attributes being the ease of pedestrian crossing, sidewalk blockage, cleanliness of sidewalk, vehicular traffic on streets and motorcycles going against traffic on one-way streets. Diversifying activities along the streets serving the neighborhood has a positive impact on the level of satisfaction with the walking environment for both groups; there are, however, limitations to the extent to which activities in the neighborhood could be further diversified given their current highly diverse status. While the model also indicates that sidewalk width and quality for streets leading to the university have an insignificant impact on the level of satisfaction with the walking environment for either group, it is generally essential to target sidewalk width and quality in order to provide the suitable pedestrian infrastructure.

All in all, the findings of this thesis may contribute to a better understanding of walking environments and aid in future policy interventions.

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CHAPTER 1

INTRODUCTION

Walkability, commonly defined as the extent to which the built environment encourages conducting walking trips, is seen as a crucial ingredient to creating more livable communities (Stevens, 2005). The benefits of walkability are vast, extending from health benefits (Blaga, 2013; Frank, 2007; Owen, 2004, 2007), to economic (Blaga, 2013; Litman, 2009), to social and environmental benefits (Blaga, 2013). As a result, a growing interest in understanding the influence of attributes of the built environment on walkability has emerged (Leslie, 2005).

A multitude of studies have investigated the effects of different attributes of the built environment on walkability and identified over 80 such attributes, of which are the ease of pedestrian crossing (Clifton, 2007), sidewalk conditions (Weinberger, 2012), availability of bus stops (Yin, 2013), presence of way-finding aids (Clifton, 2007) and many others. Furthermore, a number of approaches to measuring such attributes and their impact in terms of walkability have been established. Different indices and models have been proposed, each of which has its strengths and weaknesses. Examples of such indices and models are Walk Score® (Weinberger, 2012), Level of Service (LOS) measures (Singh, 2011), Pedestrian Environment Data Scan (PEDS) (Clifton, 2007), Neighborhood Environment Walkability Scale (NEWS) (Cerin, 2009) and others.

1.1. Motivation and Research Problem

The main objective of this research is to develop a framework that enables a better understanding (and possible quantification) of the overall level of satisfaction with the walking environment based on attributes of the walking environment. This would allow identifying which of these attributes have an effect on the perceived overall satisfaction with the walking environment and to what extent. The framework can then be used to get insights about prioritizing planning interventions to efficiently improve walkability.

Accordingly, a case study area is selected upon which the latter framework is developed upon. In specific, the study area in this paper is the neighborhood of the American University of Beirut (AUB) located at the heart of Beirut, the capital of the developing-country (The International Statistical Institute, 2015), Lebanon. This study, consequently, also targets a number of concerns regarding the walking environment in Lebanese cities in general.

The first and most direct concern to this study is the generally poor walking conditions of the neighborhood of AUB, including but not limited to poor quality sidewalks and sidewalk infringement by shops, construction sites, large garbage bins and parked vehicles. The second is the extension of such poor walking conditions across the Greater Beirut Area and the majority of urban areas in Lebanon. Accordingly, individuals are highly discouraged from conducting short-distance trips on foot (Balaa, 2014; CDR, 2000) even in areas with dense residential and commercial development and an abundance of amenities within short distances making on-foot trips theoretically practical (Abou-Haidar, 1996; Walk Score®, 2014).

This study also touches upon the positive impact increased walkability has on improving health and decreasing obesity (Yin, 2013). Past studies and statistics have shown that the Lebanese population suffers from a relatively high percentage of overweight and obese individuals, including children (Abou Jaude, 2013; Majdoub, 2010; Nasreddine, 2012; Salhani, 2014; World Obesity, 2009; Yahia, 2008). Consequently, it is important to target walkability, being the most common moderate intensity activity, in order to decrease the adverse effects of obesity and the lack of sufficient exercise on health and subsequently on the economy.

A final matter is the heavy car-dependency owing to individuals' high tendency towards conducting trips by car (likely a result of the poor public transportation and walking environment conditions) and the government's and planners' insistence over the years on solving the vehicular congestion crisis solely by increasing supply for car-patrons (Abou-Haidar, 1996; Balaa, 2014; Myntti, 2014). Public transportation is given little to no attention by the government or planners, rendering it a low-quality service avoided by most who can afford to do so. Furthermore, biking and walking are generally rare modes of transport in most areas, with the exception of rather dense areas where walking may become a more prevalent mode of transport; biking still remains scarce even in such areas.

Although in past years the Council of Development and Reconstruction in Lebanon has aimed at proposing "creative and modern solutions" to the challenge imposed by increasing congestion levels (CDR, 2004), the latter didn't consider pedestrianization as one major solution for reducing vehicular congestion within urban areas while revitalizing urban life. More recently, however, there seems to be an increasing interest in facilitating soft mobility especially by the municipality of Beirut (Balaa, 2014). The project named *Liaison Douce* (French for *Soft Link*) aims at revitalizing the pedestrian environment by providing pedestrian links encompassed with green spaces from and to different areas of Beirut (Massena, 2014). Another project targets the study area more directly. Current plans by the Municipality of Beirut, in collaboration with the Neighborhood Initiative and the Center for Civic Engagement and Community Service at AUB, aim at redesigning Jeanne d'Arc Street (one of the streets under study in this thesis) as Beirut's first barrier-free walkway (Myntti, 2014). The project aims at providing wider sidewalks with improved quality over the current sidewalks, as well as providing sidewalk furnishing, including but not limited to greenery and seating, and elevated intersections in order to facilitate pedestrian crossing (Myntti, 2014).

All in all, there is a vital need to identify the most efficient interventions in order to increase people's level of satisfaction with the walking environment, which, in turn, would increase the rate of trips conducted on foot and reduce vehicular traffic, consequently improving urban life and overall health as well as positively impacting the economy.

1.2. Study Approach

Seeking to identify the most efficient intervention in order to increase people's level of satisfaction with the walking environment, this study mainly targets modeling the level of satisfaction of pedestrians with the walking environment.

Literature review is conducted on the topic of walkability, including a variety of papers and studies tackling different issues on the topic, from approaches for modeling walkability and level of satisfaction with the walking environment, to the pros and cons of different data collection schemes, to increased benefits of walkability in terms of health and urban lifestyle and many others. Based on literature review, a framework enabling better understanding and possible quantification of the overall level of satisfaction with the walking environment based on attributes of the walking environment is established.

The framework aims principally at evaluating the impact of specific attributes of the walking environment on the overall level of satisfaction with the walking environment while accounting for any latent variables forming the relationships between the first (attributes of the walking environment) and the second (overall level of satisfaction with the walking environment). This is achieved through making use of the flexible structural equation modeling (SEM) approach which allows the identification of latent constructs measuring the level of satisfaction of pedestrians with the walking environment and elements of the environment. Identifying such constructs allows recognizing which of the elements of the walking environment, if improved, would have the biggest impact on the level of satisfaction of pedestrians with the walking environment. The latter would allow for better structuring of policy interventions targeting increased satisfaction with the walking environment and, accordingly, targeting improved walkability. Improved walkability conditions would, in turn, attract a greater number of trips conducted on foot (whether for commuting or other purposes). Normally, the previous steps are preceded by data collection and preliminary analysis as described below.

1.2.1. Data Collection

With the neighborhood of AUB being the main case study in this research, the selected sample for data collection is a sample of students from AUB. Data was collected during the month of November 2013 through an online survey. The survey targeted two aspects related to student trip making, the first, unrelated to this study, being the feasibility of a taxi sharing service and the second being questions related to the framework of this thesis focusing on walkability. Based on the developed framework, the walkability part of the survey has been structured as follows. The first part inquires respondents about their overall level of satisfaction with the walking environment. The second and the third inquire respondents about their level of satisfaction or the extent to which they are bothered by a number of attributes of the walking environment on different streets in the neighborhood of AUB and the last requests respondents to indicate which interventions to the walking environment would improve their walking experience the most (in both, closed- and open-question forms). The selected attributes included in the survey have been extracted from literature review as later presented in Chapter 3 and, as well, from the author's familiarity with the neighborhood and the walking environment in Beirut.

1.2.2. Preliminary Analysis

Preliminary analysis consists of basic analysis in order to identify relations between the attributes of interest without delving into modeling procedures. This mainly relies on the analysis of averages (and standard deviations) of different indicators and the level of satisfaction with the walking environment across two main sub-groups (on-foot commuters vs. non-foot commuters) as well as across genders and possibly other categorizations.

1.2.3. Advanced Analysis

Advanced analysis, on the other hand, consists of quantifying relations between the attributes and the overall level of satisfaction with the walking environment through modeling procedures. The analysis is initiated through exploratory factor analysis (EFA) in order to identify the underlying relationships between the variables (attitudinal indicators) and the latent factors. Consequent to EFA, the models will be further developed through SEM in order to model the level of satisfaction with the walking environment as a function of covariates. Collected indicators of the satisfaction or bother levels towards given attributes of the walking environment will be utilized in order to identify latent variables which in turn impact the overall level of satisfaction with the walking environment. Students are segregated into two categories, those who are frequent on-foot commuters and those who typically conduct on-foot trips for purposes other than commuting; analysis utilizing structural equation modeling is conducted accordingly.

This would allow identifying the impacts of different attributes on the overall satisfaction for each of these two sub-groups.

1.2.4. Policy Analysis

Given the results of preliminary and advanced analysis, policy analysis can be conducted in order to identify which interventions should have the greatest impact on improving the walking environment. This is conducted by studying the shift in level of satisfaction of individuals with the walking environment given the shift in the level of satisfaction or bother with certain elements of the walking environment. Elements of highest impact would accordingly become apparent. Any significant segmentation, whether by gender or other attributes, would be tested and would contribute to the analysis and recommended policy interventions

1.3. Research Significance

Generally, the proposed research would allow the identification of attributes that have a significant impact on an individual's level of satisfaction with the walking environment and the extent of such impact, subsequently extending the literature on the emerging and heavily researched topic of walkability. Furthermore, through the case study of the neighborhood of AUB, this study would capture local characteristics of pedestrian needs in Lebanon as compared to most of the literature which typically investigates such characteristics in regions such as the U.S.A., Europe and Far East Asia.

Specific to the case study, being the neighborhood of AUB, the proposed research allows the identification of proper interventions for improving the walking environment in the neighborhood of AUB. Accordingly, policy interventions targeting walkability in the study area

(Bliss and Hamra region which is later described in this thesis in Chapter 5) can be based on the quantitative model which is specific to the region. In addition, the qualitative results of the policy analysis can be extended to urban neighborhoods other than AUB, including those in different regions of Lebanon and even cities of similar urban texture in developing countries. As for the quantitative results of the structural equation modeling, it is possible that the model results and resulting coefficients can be as well extended to different regions of Lebanon; however, that would not only require that the neighborhoods be of similar nature to that of AUB, that is, neighborhoods consisting of local, low-speed, streets which are highly diversified in terms of activities and amenities, but also that the population is of similar characteristics with regards to their perception of the walking environment and its attributes. Likewise, the model results can be extended to other countries, mainly developing countries, provided conditions are similar to those of the study.

Finally, the framework can be extended to any urban environment. The extension of the framework to different cities necessitates that selected examined attributes of the walking environment be revisited and altered to reflect the specific context of the study area.

1.4. Thesis Structure

This thesis is structured as follows. The current chapter introduces the thesis to the reader by presenting the motivation and research problem, study approach and research significance. The second chapter presents a literature review of the concept of walkability and previous studies conducted on the topic. The third delineates study objectives, importance of studying walkability, gaps in literature, modeling approach and study approach. The fourth introduces the reader to the concept of structural equation modeling. The fifth chapter describes the study area.

The sixth discusses the data collection process as well as the descriptive findings. In the seventh chapter, the modeling process is discussed, from exploratory factor analysis to structural equation modeling. The results are as well analyzed in the latter. The eighth chapter discusses the results and suggests policy interventions accordingly. The final chapter presents the most important conclusions from this study as well as possible extensions.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of Walkability

Despite the recent popularity of the concept of *walkability* in urban planning and design fields, the term is rarely found in popular dictionaries and lacks a specific definition. Nonetheless, general and broad definitions recognized by different agencies and authors are available. The New Zealand Transport Agency (2007) describes *walkability* simply as "the extent to which the built environment is walking-friendly". Another definition is provided by the Mayor of London (2004) being "the extent to which walking is readily available […] as a safe, connected, accessible and pleasant activity". *Walkability* has also been defined as "[t]he extent to which the built environment is friendly to the presence of people living, shopping, visiting, enjoying or spending time in the area" (Ricci, 2011).

Noticeably, the three latter definitions are complementary to one another by indicating that *walkability* is the extent to which the built environment encourages conducting walking trips. A *walkable* environment should be barrier free, safe, full of pedestrian infrastructure and destinations (Forsyth, 2008).

Within the same context, *soft mobility* is a movement which shares several goals with increased walkability. *Soft mobility* mainly aims at optimizing urban livability by encouraging non-motorized transport (such as walking, bicycling, roller skating, skateboarding, etc.) through supplying integrated facilities and services as an alternative to motorized vehicles (La Rocca, 2010). Accordingly, increased walkability should directly benefit the goals established by *soft mobility* movements by encouraging transformation at an urban level promoting human powered mobility (La Rocca, 2010). As mentioned by La Rocca (2010), this transformation, in turn, improves the following elements of the urban environment: levels of noise and air pollution, traffic congestion and road safety.

2.2. Walkability in Lebanon and Neighboring Regions

Studies on the topic of walkability specific to Lebanon are scarce. Recently, only a handful of studies have been conducted, with examples such as those by Al-Hagla (2009), Balaa (2014) and Majzoub (2013).

The study conducted by Al-Hagla (2009) targets evaluating the performance of different New Urbanism components influencing walkability in Saifi Village, a New Urbanism development in downtown Beirut. In his study, Al-Hagla reveals that, while the original plans for Saifi Village had high aspirations with regards to positively influencing walkability, its physical setting under performs in relation to walkability.

Majzoub (2013) presents a study which seeks to develop viable strategies for facilitating pedestrian mobility in Mar Maroon, a neighborhood in the city of Tripoli through the injection of public spaces and passages in the neighborhood. The study also places special emphasis on the experience of female respondents in order to account for their particular needs in the walking environment.

Balaa (2014) focuses on the case of Hamra and presents a study which tackles walkability from a strategic perspective proposing solutions for current problems plaguing the walking environment by creating an obstacle-free walking environment rich in pedestrian paths and safe pedestrian-vehicle interactions. According to Balaa, some of the factors discouraging walkability are, excessive take-over of sidewalks by security devices and/or private usage, the mismanagement of the public domain leading to the deterioration of its design quality, as well as the prioritization of physical infrastructure and traffic networks over pedestrian-centered urban developments (Balaa, 2014).

Similar factors affecting walkability negatively can also be seen in developing countries in the MENA (Middle East and North Africa) region. Such is the case of Cairo, Egypt, which is greatly affected by the mismanagement of the public domain and challenges concerning conflicts between pedestrian and vehicle traffic as presented in a study by Maarouf et al. (2012). Maarouf et al. also highlight the crammed nature of the sidewalks in Cairo which, at instances, do not exist at all, with most of the right-of-way devoted to vehicles. Taking Gameat Al Dowal Boulevard as their case study, Maarouf et al. propose an alternative design for the crowded boulevard which would alleviate several of the problems affecting the boulevard by providing better separation between pedestrian and vehicular traffic as well as improved pedestrian infrastructure.

Another study, by Dehman et al. (2015), explores the tendency of people towards conducting walking trips in Damascus, Syria. The study evaluates acceptable walking times and real walking times for different trip purposes and concludes that in the case of work trips, acceptable walking times are significantly higher than real walking times. The study also investigates incentives and disincentives for conducting walking trips. According to Dehman et al. (2015), parking unavailability, exercising and shopping are high ranking incentives for conducting walking trips, whereas accompanying children, having a busy schedule and bad weather conditions are significant disincentives for conducting trips on foot. Lastly, Dehman et al. (2015) also studies the impact of time-of-day on the willingness to conduct on-foot trips. Respondents indicate that mid-day (from 12 noon to 4PM) conditions are the most inappropriate for walking, whereas early-morning (from 6AM until 8AM) and evening (from 6PM to 10PM) conditions are the most preferable. Dehman et al. (2015) state that latter results are expected given the nature of the Mediterranean weather, which consists of mild weather in early and later times of the day but of sunny and hot weather during midday throughout most of the year.

Another notable study is that by Tarawneh (2000) investigating pedestrian crossing speed in Jordan while accounting for the effects of gender, age, distance crossed and whether pedestrians are walking individually, as couples or in groups of three or more. The study then recommends a walking design speed of typically 1.11m/s based on their results; however, a lower value of 0.97m/s is utilized to accommodate for the elderly in areas where older pedestrians are frequently encountered.

2.3. Attributes Affecting Walkability

A certain relationship between the walking environment and walkability exists as demonstrated by the prevalence of higher rates of walking in highly-walkable areas (Leslie, 2005; Cerin, 2007). Such a relationship is highlighted by some research and acts as a policy lever for making walking more pleasurable (Weinberger, 2012). Owen et al. (2004) indicate that "[t]here is a strong case that substantial and long-lasting environmental and policy initiatives are an important opportunity for making physically active choices easier and more realistic choices".

The literature recognizes numerous attributes of the walking environment which have an effect on walkability. Eighty-four such attributes have been identified and classified under 17 categories as displayed in Table 1 on the following page.

Although diverse in nature, a good amount of research has been conducted to date not only to identify which attributes of the walking environment have an effect on walkability, but to what extent. Much of the research aims at identifying certain indices or level of service measures which would enable analysts to easily measure walkability through significant walking-environment attributes.

Weinberger et al. (2012) study the power of the readily available Walk Score model as a cost-effective and transferrable predictor of walkability. The Walk Score model assigns scores, on a scale of 100, to neighborhoods by implementing a specific grading system (refer to Weinberger, 2012) to amenities located within a 1-mile buffer (Weinberger, 2012).

Furthermore, a distance decay function is utilized in order to give closer amenities a higher value on the point scale (Weinberger, 2012). A penalty of up to 10 points can be implemented based on density of intersections and average block length (Weinberger, 2012). However, the creators of Walk Score indicate that the score still lacks certain information on "design and safety elements including street characteristics (like sidewalk conditions and speeding traffic), safety from crime, and natural elements like topography" (Weinberger, 2012).

Table 1: Categories of Attributes Affecting Walkability and Their Respective Sources

Category \ Source	Clifton 2007	Kelly 2011	Siqueira 2013	Ricci 2011	Singh 2011	Wang 2011	Weinberger 2012	Yin 2013
overall street and sidewalk connectivity	✓		✓		✓	✓	✓	✓
street geometry	✓	✓		✓	✓			✓
street traffic	✓	✓	✓		✓		✓	✓
signal delays					✓			
pavement condition				✓			✓	
sidewalk geometry	✓	✓		✓	✓	✓		✓
sidewalk obstructions	✓		✓	✓	✓			
topography	✓		✓	✓			✓	
urban fabric and landscape	✓			✓	✓			✓
aesthetics	✓	✓		✓	✓	✓		✓
availability and variety of amenities							✓	✓
accessibility and distance to amenities			✓				✓	✓
density and diversity of built environment	✓		✓			✓	✓	✓
availability and proximity of transit	✓		✓				✓	
safety and comfort	✓				✓	✓	✓	✓
population (overall) attributes							✓	✓
trip attributes							✓	

Frank et al. (2010), on the other hand, propose an index for measuring walkability at a neighborhood level which uses readily available data such as residential density, land use mix, connectivity and retail floor area ratio. By sampling at a neighborhood level, the index allows isolating urban form from sociodemographic characteristics impacting travel and activity patterns (Frank, 2010). The index itself is calculated as the sum of the normalized values of the previously listed attributes (refer to Frank, 2010).

As for level of service (LOS) measures assessing walking conditions, otherwise known as pedestrian level of service (PLOS), several have been presented, such as the HCM (Highway Capacity Manual) method, SCI (Sprinkle Consulting, Inc.) LOS, Nicole Gallin's LOS, Trafitec model and others (Singh, 2011). The methods for evaluating PLOS are mainly categorized into two groups: *capacity based methods* and *roadway characteristics based methods* (Singh, 2011).

Capacity based methods, such as the HCM method, use adjusted principles of highway capacity to evaluate pedestrian facilities while neglecting acceptability by pedestrians of other core characteristics of the walking environment, such as measures of safety, the degree to which the environment encourages walking, etc. (Singh, 2011). The HCM method utilizes an approach similar to measuring vehicular LOS by measuring speed, density and volume (Singh, 2011). The logic, similarly to measuring highway LOS, is that as volume and density increase, speed decreases and accordingly LOS decreases. The pedestrian unit flow rate (ped/min/ft) is measured by dividing the ovserved 15-min pedestrian flow rate (ped/15-min) over the effective sidewalk width, where the effective sidewalk width is the resulting sidewalk width after accounting for a 1 to 1.5 foot buffer from every obstacle on the sidewalk (Singh, 2011).

Roadway characteristics based methods, on the other hand, are mainly oriented at measuring the comfort level of pedestrians as they are confronted with the diverse elements of the walking environment during their on-foot trip (Singh, 2011). SCI LOS, Nicole Gallin's LOS and Trafitec model fall under the latter category (Singh, 2011). The first, SCI LOS, is primarily based on the perception of safety while conducting an on-foot trip (Singh, 2011). Accordingly, the latter method investigates attributes of the walking environment such as the "lateral separation elements between pedestrians and motor vehicle traffic (such as presence and width of sidewalk, presence of on-street parking or bike lane, width of outside travel lane), motor vehicle traffic mix, volumes and speed" (Singh, 2011). The second, Nicole Gallin's LOS, measures the degree to which the environment encourages walking by inspecting design and location factors of the walking environment as well as user factors (Singh, 2011). According to Nicole Gallin's approach, design factors include pedestrian path width, surface quality, obstructions and crossing opportunities, while location factors target connectivity, path environment and potential for vehicle conflict (Singh, 2011). User factors take into account pedestrian volume, mix of path users and personal security (Singh, 2011). A third method, Trafitec model, is a highly exhaustive model for measuring pedestrian level of service, targeting a multitude of attributes affecting the walking experience, from vehicle and pedestrian volumes, type of walking area, type of roadside landscape, number of driving lanes, presence of trees and others (Singh, 2011).

Other instruments for assessing walking-environment attributes and measuring walkability have been presented as well. Clifton et al. developed the PEDS (Pedestrian Environment Data Scan) tool for examining pedestrian related information falling under four categories: [built] environment, pedestrian facility, road attributes and walking/cycling environment (Clifton, 2007). Of such information are sidewalk width, sidewalk connections, posted speed limit, degree of enclosure and building setback, slope, etc. (Clifton, 2007). Another tool, the Neighborhood Environment Walkability Scale (NEWS) and its different versions, assess “perceived environmental attributes believed to influence physical activity”, such as residential density, infrastructure for walking, neighborhood aesthetics, safety, etc. (Cerin, 2009), and have been utilized and tested in different regions of the world – including the U.S., Australia and China (Cerin, 2007; Leslie, 2005; Rosenberg, 2009).

Stevens (2005) presents a review of the most significant attempts of measuring walkability preceding the year 2005, including methods for measuring walkability such as those by Partnership for a Walkable America and Pikora and Colleagues. Partnership for a Walkable America’s method is a measurement approach targeting laypeople by providing respondents with a non-scientific user-friendly one-page questionnaire consisting of 5 questions: “*Did you have room to walk? Was it easy to cross streets? Were drivers well behaved?* and *Were safety rules easy to follow?*” (Stevens, 2005). The answers to these 5 questions ensues a score depicting walkability from 5 to 30 points (Stevens, 2005). Another more scholarly method is that proposed by Pikora and Colleagues based on an environmental audit instrument named SPACES for systematic pedestrian and cycling environmental scan (Stevens, 2005). The latter tool targets 4 categories of attributes of the walking environment, these categories being functional, safety, aesthetic and destination (Stevens, 2005). Other GIS-based methods, such as that of Aultman-Hall, Roorda and Baetz and that of Randall and Baetz, are more concerned with the impact of the urban grid on walkability (Stevens, 2005). Whereas the first, Aultman-Hall and et al.’s method, looks only into distances by analyzing walking distance from origins to destinations, the second, Randall and Baetz’ method, analyses both, distance and directness simultaneously (Stevens, 2005). Directness is a measure how straight the path from origin to destination is; a straight path from origin to destination is more direct than a curvilinear path (Stevens, 2005).

2.4. Data Collection Techniques

The methods of collecting the attributes discussed in the previous subsection for the different studies are diverse with different methods having their advantages and disadvantages. Popular methods include conducting surveys or interviews, collecting physical data or using readily available data.

Kelly et al. (2011) study the disadvantages and advantages of different data collection techniques. The three techniques discussed in the paper are conducting surveys (stated and revealed preference), stopping and interviewing pedestrians and interviewing pedestrians while walking (Kelly, 2011). According to Kelly et al., conducting surveys in the form of questionnaires has some limitations (Kelly, 2011). The first of such limitations is the inability to quantify all relevant factors given that some information cannot be captured through questionnaires (Kelly, 2011). Another limitation is the need for questions to be specific to the location under study (Kelly, 2011), which renders the collection method non-transferrable. Moreover, appropriate wording for the survey may be tricky to achieve and may require focus groups (Kelly, 2011). Interviewing while the respondent is stopped presents a few advantages, most important of which are the walking experience being fresh by the time the responses are provided and the ability to interpret respondents' gestures and indications (Kelly, 2011). However, similarly to conducting data collection through surveys, results rely heavily on how the questions are presented (Kelly, 2011). Finally, mobile interviews (i.e. interviewing respondents as they walk) have a multitude of advantages over other methods of data collection. In the same way as interviewing respondents while stopped, mobile interviews allow for the observation and interpretation of body language and gestures (Kelly, 2011). Furthermore, respondents are able to convey their thoughts with greater ease given that the discussion is in real-time while conducting the trip on foot (Kelly, 2011). Also, the interviewer himself/herself gets to experience the walking environment first-hand (Kelly, 2011). In terms of disadvantages, this method is highly reliable on resources for data collection and processing (Kelly, 2011), which may lead to it being infeasible in the case of shortage of resources. Moreover, results ensuing from using this collection method are less transferable (Kelly, 2011) than other methods which are more dependent on closed-form questions.

Other studies and tools use other methods of data collection. Walk Score stands out by using readily available data on the internet in order to display walkability scores promptly; “[d]ata sources include Google, Education.com, Open Street Map, the U.S. Census, Localeze and places added by the Walk Score user community" (*Walk Score Methodology*). Walk Score, as previously discussed, falls short in accounting for design and safety aspects of the walking environment (Weinberger, 2012). The previously discussed PEDS tool collects data by having trained auditors rate different physical aspects of the walking environment (Clifton, 2007). This method, however, is highly reliable on resources and is dependent on the auditors’ ability of guaranteeing homogeneity in the auditing. Wang et al. (2011) collect data through measuring emotional responses. While similar to conducting stated preference surveys, Wang measures emotional response by providing respondents with images of the segments from the study area and asking them to provide scores on bipolar adjectives describing the walking environment and a score for their general satisfaction with the sidewalk environment (Wang, 2011).

Finally, simpler and more straight-forward approaches for collecting data are used as well, such as the previously discussed Partnership for a Walkable America method which collects data by presenting individuals with a simple one-page questionnaire with only 5 questions based on which a walkability index ensues.

2.5. Pedestrian Satisfaction with the Walking Environment

In general, the more walkable an area is, the higher people's satisfaction with walking in that area is, leading to a greater extent of walking activity. Therefore, it is important to measure satisfaction and understand how it is influenced by the various factors that determine the walkability of an urban area. While methods to measure walkability are abundant, more direct measures of pedestrian satisfaction with the walking environment are uncommon. Wang et al. (2011) indicate that previous studies typically have not considered the "multiple and complex components in which the diverse setting of the environment may influence people's satisfaction". According to Zainol et al. (2014), "in order to measure walkability, pedestrian level of satisfaction is used [to] evaluate users' perception on the related facilities". Furthermore, for instance, Choi et al. (2013) indicate the importance of replacing the measure of pedestrian density in the HCM approach for measuring pedestrian level of service with "a more realistic measurement of effectiveness" being the level of pedestrian satisfaction.

Wang et al. (2011) state that walking satisfaction is not only based on the physical attributes of the environment but also on the emotional perception of such attributes. Therefore, their approach in the paper *Exploring Determinants of Pedestrians' Satisfaction with Sidewalk Environments: Case Study in Korea* is to conduct a perception survey targeting emotional response towards different physical attributes (Wang, 2011). Wang et al. (2011) investigate attributes such as wideness and surface condition of sidewalks, brightness, openness and tidiness of the walking environment, type of land use, etc.

By establishing a correlation plot for the research variables versus walking satisfaction as well as a path analysis model, the authors are able to identify which variables have a greater impact on satisfaction. In short, Wang et al. conclude that emotional perception factors have a greater correlation to satisfaction than physical attributes; they note that the correlation between satisfaction and the emotional perception factors representing the physical components indirectly is higher than that between satisfaction and the physical components directly (Wang, 2011). This relationship is well reflected in the following path model of satisfaction with sidewalk environments, where *harmoniousness* and *openness* are emotional perception factors.

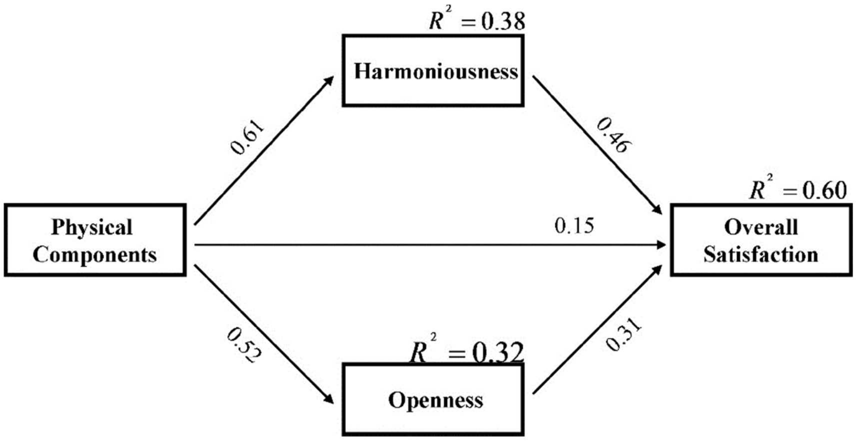

Figure 1: Path Model of Satisfaction with Sidewalks Environments (Wang, 2011)

Noticeably, the coefficients for *harmoniousness*, *openness* and *physical components* in the part of the path model explaining *overall satisfaction* are 0.46, 0.31 and 0.15, respectively, with *harmoniousness* having the highest coefficient, followed by *openness* and then *physical components* (Wang, 2011).

CHAPTER 3

STUDY OBJECTIVES AND APPROACH

3.1. Objectives

The main objective of this study, as indicated in previous chapters, is to identify which elements of the walking environment have the greatest impact on the level of satisfaction with the walking environment. This objective is a result of the need to identify suitable and efficient approaches for improving the walking environment which is essential for proper revitalization of pedestrian walkways in the urban areas in Lebanon. The improvement of pedestrian walkways, being sidewalks in this study, should in turn lead to improved overall health, decreased vehicular traffic within cities and improved lifestyle and economy.

This thesis focuses mainly on the physical context of the walking environment. While the non-physical elements, such as demographics, safety, personal security, vibrant nature of an area and others, are of importance to the walking environment, such elements are not within the scope of this research study. This study, however, provides a flexible framework which allows analysts to include such elements in their models. Lastly, one must note that non-physical elements may be harder to measure than the physical elements given their abstract nature.

3.2. Importance of Studying Walkability

The importance of studying walkability lies in the benefits of walking, which can be divided into different main categories. The first, an extensively studied aspect of increasing walkability, is the resulting health benefits. The second is the impact of walkability on the overall urban lifestyle, including social benefits, economic benefits and environmental benefits.

3.2.1. Health Benefits of Increased Walkability

The topic of walkability has been given much attention by researchers and policy makers due to the great amount of evidence of the health benefits resulting from moderate-intensity physical activities (Stevens, 2005), of which walking is the most common (Owen, 2007). Given the latter and that walking is the behavior or activity which is most likely to be amenable to influence (Leslie, 2005), encouraging adults to conduct higher levels of moderate-intensity physical activities through walking is a public health priority (Owen, 2004; Frank, 2010). Doing so may be the best way to reduce obesity and associated health risks as well as improve overall health (Yin, 2013). On the other hand, the direct and indirect costs of the health issues related to lack of physical activity and obesity accrue to a large monetary value (billions of dollars in the case of the U.S.) (Yin, 2013). Low level of physical activity is as well responsible for increased mortality rates (the death of 2.6 million individuals per year worldwide) (Frank, 2010; Gilderbloom, 2015).

The case of Lebanon in specific is similarly troublesome. A survey conducted on a sample size of 1953 individuals in the year 2009 indicates that for women aged between 25 and 64 years old, 32.9% are overweight and 26.5% are obese[1], while for men of the same age group, 44.2% are overweight and 28.7% are obese[1] (World Obesity, 2009). Such percentages are relatively high and are currently experiencing an increasing trend given the shift of dietary traditions in Lebanon (a shift from Mediterranean cuisine to fat-enriched fast-food) and a shift from an active to a sedentary lifestyle as a result of rapid urbanization and provision of alternative and prevalent forms of entertainment such as the television (Abou Jaude, 2013; Majdoub, 2010; Nasreddine,

[1] Here, *overweight* does not include *obese*.

2012; Yahia, 2008). Levels of child obesity in Lebanon are high as well, ranking as one of the highest countries in terms of child obesity in the region as well as globally with a similarly increasing trend as the case of adults (Abou Jaude, 2013; Nasreddine, 2012; Salhani, 2014).

Given the high obesity rates in Lebanon, the numerous health benefits of walkability and its impact on reducing obesity and associated health risks, studying walkability in the context of Lebanon and the potential to increase walking trips through targeted policy interventions is of utmost importance. Furthermore, the health benefits of walking go beyond reduction in obesity to other health benefits as well as psychological benefits (Blaga, 2013) The physical benefits of walking are the following: lower mortality, lower risk of heart disease, reduced blood pressure, reduced digestive problems, muscle relaxation, greater bone density and reduction in obesity and type II diabetes (Blaga, 2013). As for the psychological benefits, some are reduced stress, improved mental health, improved mood and growing self-esteem (Blaga, 2013).

3.2.2. Social, Environmental and Economic Benefits

It is noteworthy that benefits from increased walkability have been reported to extend beyond health to social, environmental and economic benefits (Blaga, 2013; Litman, 2009). Increased walkability bolsters social interaction and communication, encouraging family and community connection as well as increasing confidence and reducing isolation and loneliness (Blaga, 2013; Gilderbloom, 2015). All of the latter, in addition to the increased sense of safety, play a vital role in increasing the livability of urban areas. Environmental benefits also play an important role in improving the livability of urban areas through decreased air and noise pollution and traffic congestion by providing an environmentally friendly means of transport (Blaga, 2013). The latter environmental impacts, accordingly, also indirectly add to the health benefits of increased walking. As for the economic benefits of increased walkability, they are numerous. Initially, walking is generally a less expensive transportation mode compared to other alternatives, such as transport by private vehicle (Blaga, 2013; Litman, 2009). Savings also occur at the public level due to reduced need for maintenance costs for roads and the reduction of negative impacts of vehicle travel (Blaga, 2013; Litman, 2009). Other economic benefits of increased walkability are efficient land use and economic development resulting from increased accessibility and commercial activity (Blaga, 2013; Litman, 2009). Finally, increased walkability leads to improved community livability as a result of all the latter social, environmental and economic benefits (Blaga, 2013; Litman, 2009).

These benefits are of high importance to the Lebanese case and mostly to Beirut, especially the environmental and economic benefits resulting from increased walkability. Beirut currently suffers from high levels of air pollution above the acceptable values by the World Health Organization, with about 93% of the population of Beirut being exposed to these high levels of air pollution. (Al-Azar, 2011; Office of Communications, 2011; Wadvalla, 2011). It is estimated that the overall cost of such elevated levels of air pollution to health could be exceeding $10 million dollars a year (Al-Azar, 2011). Given the large number of vehicles per capita and traffic congestion typical to Beirut, motorized vehicles have been identified as the biggest contributors to this pollution (Al-Azar, 2011). Increased walkability could help remediate and reverse the effects of elevated air pollution by providing an eco-friendly transport alternative for short-trips as well as by reducing traffic congestion on local roads. Furthermore, in conjunction with improvements in public transportation, the positive impact of increased walkability can be exponential.

Furthermore, while acknowledging the vibrant lifestyle of Beirut, the walking environment remains unfriendly, which is a major cause for car-dependency for short trips. Therefore, besides the impact on traffic, increased walkability can lead to even greater urban livability in Beirut and other cities in Lebanon by increasing on-foot accessibility to destinations.

3.3. Gaps in Literature

The literature on walkability is quite diverse and includes a multitude of approaches to studying the topic (refer to Chapter 2). Almost every aspect of the walking environment has been accounted for in the literature by one study or another; however, given the high dependency of walkability on culture, locale and perceptions and the large number of attributes involved, globally applicable methods for measuring walkability are yet to be established. Furthermore, while there exist studies tackling the topic of walkability for regions such as the United States of America, Australia and South Korea, literature is almost absent on the topic in the case of Lebanon, as previously mentioned, with the exception of a few recent studies (e.g. Al-Hagla, 2009; Balaa, 2014; Majzoub, 2013).

Therefore, it is important to conduct a study which not only looks into the situation of the walking environment in Lebanon and proposes solutions based on intuition and engineering knowledge, but also models the perception of pedestrians towards separate elements of the walking environment in order to identify the individual impact of changes in different elements of the walking environment on the overall walking experience. Furthermore, conducting such a study not only directly impacts a lacking field of knowledge in Lebanon, but also adds to the overall literature on walkability.

3.4. Modeling Approach

Given their ability to represent hidden psychological constructs through latent variables and to handle measurement error (Bollen, 2013), linear structural equation models (SEM) have been widely used in social and behavioral sciences (Schreiber, 2006) and remain popular to the day. This popularity is highly attributed to the fact that "[s]tructural equation modeling provides a very general and convenient framework for statistical analysis" (Hox, 2001). At its core, structural equation modeling is described by Everitt (1984) as "a combination of the concept of latent variables, with the techniques of path analysis and simultaneous models". The main emphasis of SEM is on the fundamental hypothesis that given the population covariance matrix of observed variables, a correct model would exactly reproduce the latter (Bollen, 1989).

Therefore, the advantage of using SEM over other modeling approaches is the ability to, theoretically, correctly represent the latent constructs of the surveyed sample, which itself is representative of the studied population. This would allow creating a model true to the pedestrians of the Hamra neighborhood in Beirut and to other areas in Lebanon of similar attributes as Hamra (whether at the level of the population or urban constructs).

3.5. Study Approach

Given the above objective, the plan established at the early stages of this study is presented below.

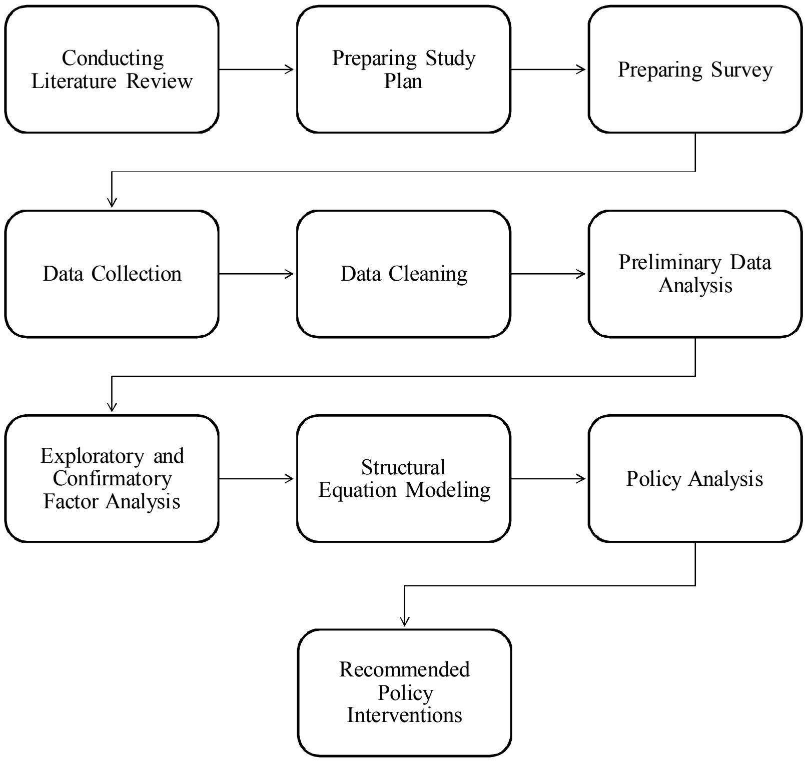

Figure 2: Study Plan

Preparing study plan and *preparing the survey* are the initial steps of this study in parallel to *conducting literature review* allowing going forth with the topic at hand. *Conducting literature review* has been presented in Chapter 2, describing the existing literature on the topic of *walkability* and *satisfaction with the walking environment.*

Consequently, subsequent to *data collection*, data is cleaned in order to create two data sets: on-foot commuter data and non-foot commuter (i.e. commuter of other modes) data.

Next, *preliminary data analysis* and *exploratory and confirmatory factor analysis* play an important role in identifying data constructs and correlations, whether at an observed or latent level. These two steps are essential for conducting *structural equation modeling*.

The last three elements of the above study plan directly fulfill the objective of interest. The process of *structural equation modeling* allows identifying which elements of the walking environment have an impact on the *level of satisfaction with the walking environment*. Identifying the latter then allows for *policy analysis*, through which *recommending policy interventions* becomes viable.

These steps are accordingly detailed throughout the study.

CHAPTER 4

STRUCTURAL EQUATION MODELING: THEORY AND ESTIMATION

Initially, this chapter presents a brief overview of structural equation models with ordinal latent variables before going into the detailed formulation of structural equation models. Then, the following sections first discuss the theory behind structural equation modeling with continuous observed variables, followed by modifications applied to the latter for the case of ordinal observed variables. The fourth section discusses the best estimation approach in the case of ordinal observed variables. The fifth section discusses the issue of model identification whereas the sixth and last section provides a simple illustration of the content in this chapter.

4.1 Overview of Structural Equation Model with Ordinal Dependent Variables

The general structural equation model is composed of two major parts, the latent variable model and the measurement model (Bollen, 1989). The first, latent variable model, being a structural equation, captures the causal dependencies between endogenous and exogenous variables (Hair, 2006). Measurement equations, on the other hand, show the relations between latent variables and their indicators (Khosrow-Pour, 2012). In order to accommodate non-continuous responses, which are common in behavioral sciences, conventional structural equation modeling has been generalized (Skrondal, 2005).

Accordingly, a structural equation model with ordinal dependent variables is divided into 3 major parts: the latent variable model, the first part of measurement equations showing the relations between latent variables and their indicators and the second part of measurement equations being the threshold model for the ordinal data. These parts are more conveniently displayed in the figures below. Here, x and y are vectors of observed ordinal data, x^* and y^* are vectors of continuous response variables and ξ is a vector of latent variables. Elements filled in black are dependent variables in each of their respective categories.

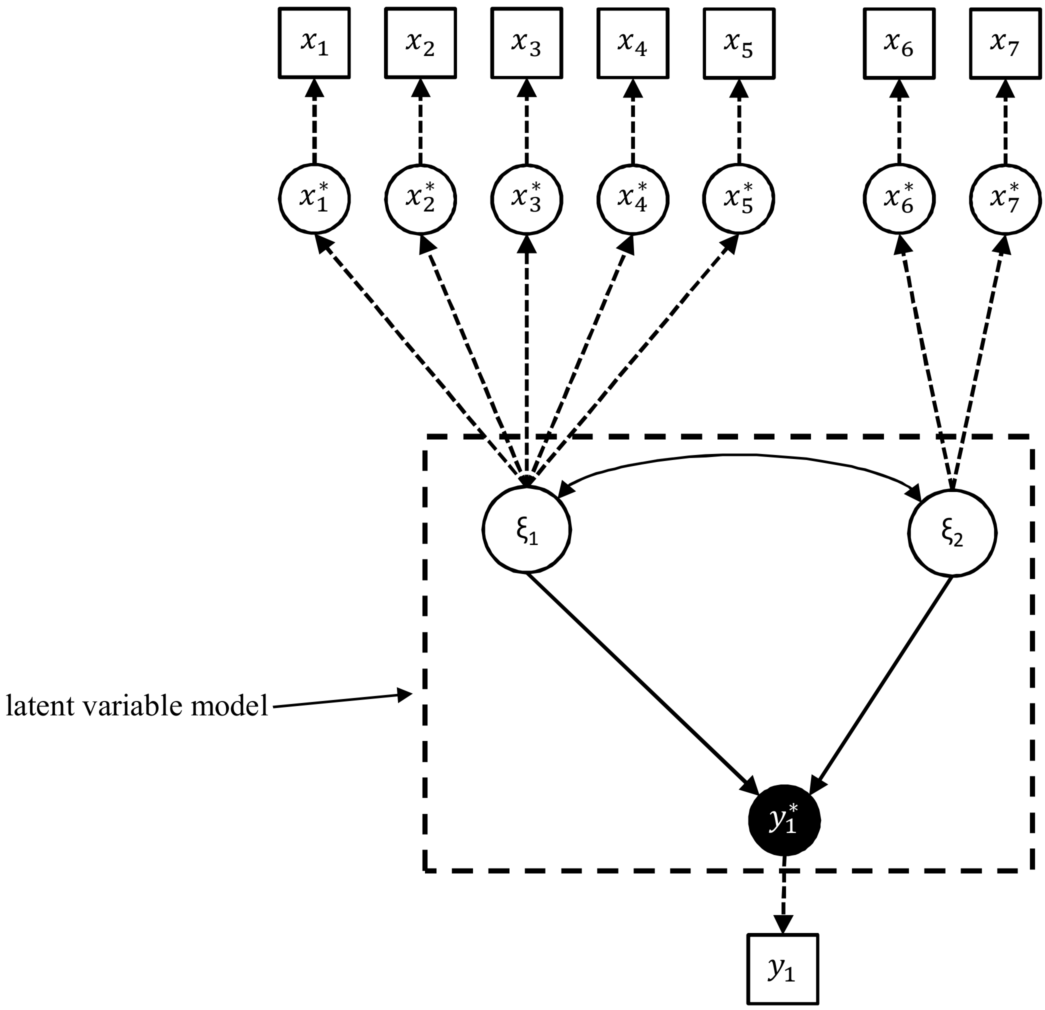

Figure 3a: SEM Example (Latent Variable Model)

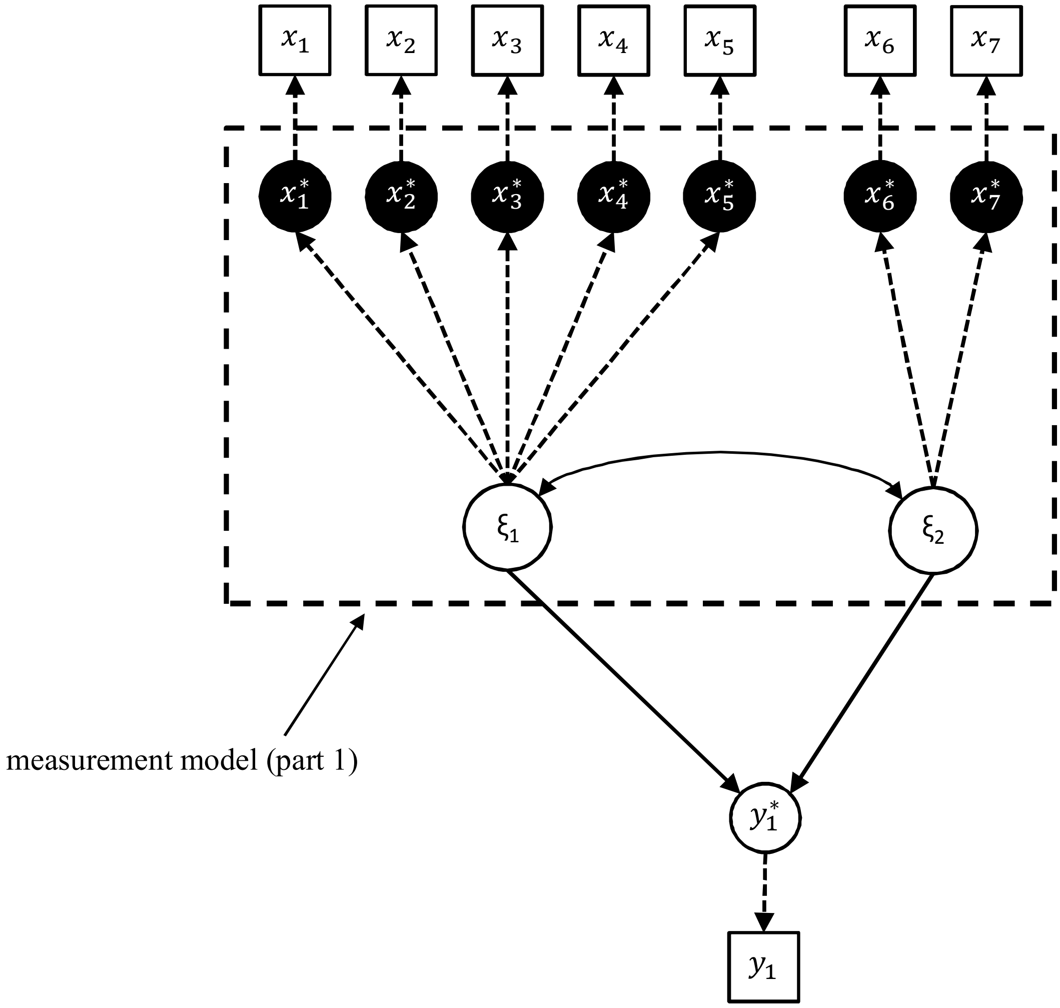

Figure 3b: SEM Example (Measurement Model – Part 1)

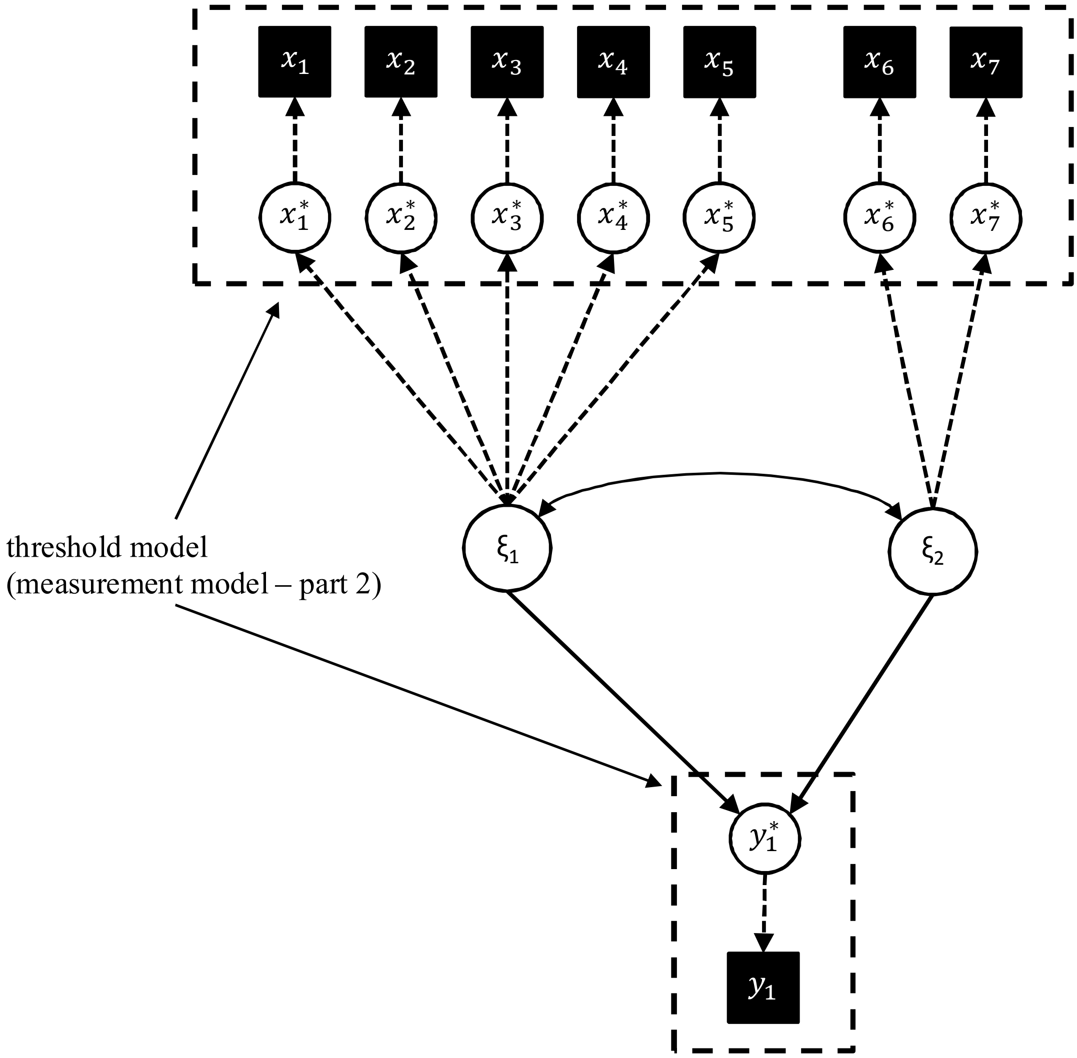

Figure 3c: SEM Example (Measurement Model – Part 2: Threshold Model)

The latter parts are then all used simultaneously in order to construct a system of equations and unknowns based on equating the implied covariance matrix of the elements in the structural equation model to the observed variance-covariance matrix of the collected data.

Given the mathematically heavy nature of the following sections within this chapter, it is recommended for the casual reader to continue reading from Chapter 5 onwards; a brief overview of the SEM used specifically in this study is presented in Chapter 7.

4.2. Structural Equation Model with Continuous Dependent Variables

Below is the latent variable model for variables in *deviations from the means* form (as will be the case for all equations in this chapter) (Bollen, 1989),

$$\eta = \mathrm{B} * \eta + \Gamma * \xi + \zeta \tag{1}$$

The following is a table describing the above variables and parameters in equation (1) (Bollen, 1989).

Table 2: Latent Variable Model Variables and Parameters

Variable/ Parameter	Dimension	Description
η	m x 1	vector of endogenous latent variables
ξ	n x 1	vector of exogenous latent variables
B	m x m	matrix of coefficients (β) capturing the effect of the endogenous latent variables on one another
Γ	m x n	matrix of coefficients (γ) capturing the effect of the exogenous latent variables on the endogenous latent variables
ζ	m x 1	disturbance vector which is assumed to have an expected value of zero and to be uncorrelated with the exogenous latent variables

The measurement model follows (Bollen, 1989),

$$x = \Lambda_x \xi + \delta \tag{2}$$

$$y = \Lambda_y \eta + \epsilon \tag{3}$$

Table 3 describes the variables and parameters of the measurement model.

Table 3: Measurement Model Variables and Parameters

Variable/ Parameter	Dimension	Description
x	q x 1	vector of observed variables which are indicators of the exogenous latent variables
y	p x 1	vector of observed variables which are indicators of the endogenous latent variables
Λ_x	q x n	matrix of coefficients (λ_x) showing the relation of x to ξ
Λ_y	p x m	matrix of coefficients (λ_y) showing the relation of y to η
δ	q x 1	errors of measurement for x which are assumed to be uncorrelated with ξ
ϵ	p x 1	errors of measurement for y which are assumed to be uncorrelated with η

Note that a restriction here is that the measurement errors of x and y, i.e. δ and ϵ, are uncorrelated.

Given the latter sub-models (the latent variable model and the measurement model) and a non-singular matrix $(I - \mathrm{B})$, the implied covariance matrix is given as (Bollen, 1989; Everitt, 1984),

$$\Sigma(\theta) = \begin{bmatrix} \Sigma_{yy}(\theta) & \Sigma_{yx}(\theta) \\ \Sigma_{xy}(\theta) & \Sigma_{xx}(\theta) \end{bmatrix} = \begin{bmatrix} \Lambda_y(I - \mathrm{B})^{-1}(\Gamma\Phi\Gamma' + \Psi)[(I - \mathrm{B})^{-1}]'\Lambda_y' + \Theta_\epsilon & \Lambda_y(I - \mathrm{B})^{-1}\Gamma\Phi\Lambda_x' \\ \Lambda_x\Phi\Gamma'[(I - \mathrm{B})^{-1}]'\Lambda_y' & \Lambda_x\Phi\Lambda_x' + \Theta_\delta \end{bmatrix} \quad (4)$$

where the parameters and matrices for the above equation are defined in the table below.

Table 4: Implied Covariance Matrix Parameters and Other Matrices

Parameter/ Matrix	Dimension	Description
$\Sigma(\theta)$	(q + p) x (q + p)	implied covariance matrix written as a function of the unknown model parameters θ
$\Sigma_{yy}(\theta)$	p x p	covariances of y written as a function of the unknown model parameters θ
$\Sigma_{yx}(\theta)$	p x q	covariances of y with x written as a function of the unknown model parameters θ
$\Sigma_{xy}(\theta)$	q x p	covariances of x with y written as a function of the unknown model parameters θ
$\Sigma_{xx}(\theta)$	q x q	covariances of x written as a function of the unknown model parameters θ
Φ	n x n	covariance matrix of ξ
Ψ	m x m	covariance matrix of ζ
Θ_ϵ	p x p	covariance matrix of ϵ
Θ_δ	q x q	covariance matrix of δ
I	m x m	identity matrix

Ideally, the unknown parameters in the model are estimated by equating the implied covariance matrix to the population covariance matrix of observed variables (Σ) (Bollen, 1989; Everitt, 1984),

$$\Sigma(\theta) = \Sigma \tag{5}$$

As discussed earlier, the reasoning behind this approach is that the population covariance matrix should be exactly reproduced by the model given a correct model (Bollen, 1989). The objective of the estimation process is therefore minimizing the difference between the implied covariance matrix and the observed covariance matrix (Bollen, 1989).

Given a large enough sample of the population, the parameters are estimated by solving the following (Bollen, 1989),

$$\Sigma(\theta) = \mathrm{S} \tag{6}$$

where S is the sample covariance matrix of observed variables.

4.3. Structural Equation Model with Ordinal Dependent Variables

In the case of ordinal dependent variables, whereas the latent variable model remains unchanged as displayed in equation (1), the measurement equations need to be modified (Skrondal, 2005). Essentially, instead of specifying the measurement model for the observed variables x and y as is the case in equations (2) and (3), the measurement model is specified for the continuous latent response variables x^* and y^* which are related to the observed ordinal variables x and y through a threshold model (Skrondal, 2005).

Accordingly, the measurement equation becomes (Muthén, 1984; Bollen, 1989),

$$x^* = \Lambda_x \xi + \delta \tag{7}$$

$$y^* = \Lambda_y \eta + \epsilon \tag{8}$$

where the newly introduced variables x^* and y^* are defined in the table below.

Table 5: Measurement Model Variables for SEM with Ordinal Observed Variables

Variable	Dimension	Description
x^*	q x 1	vector of latent response variables
y^*	p x 1	vector of latent response variables

For the ordinal observed variables, a threshold model is established as shown below (Muthén, 1984; Bollen, 1989; Skrondal, 2005),

$$x_i = \begin{cases} z_1 & if \quad x_i^* \leq \tau_{x_i,1} \\ z_2 & if \quad \tau_{x_i,1} < x_i^* \leq \tau_{x_i,2} \\ \vdots & \vdots \quad \vdots \\ z_{u-1} & if \quad \tau_{x_i,u-2} < x_i^* \leq \tau_{x_i,u-1} \\ z_{u_i} & if \quad \tau_{x_i,u-1} < x_i^* \end{cases} \quad (9)$$

where i = 1, … , q. The measurement model parameters and categories in equation (9) are defined below in Table 6.

Table 6: Measurement Model Parameters and Categories for SEM with Ordinal Observed Variables

Parameter/ Categories	Description
Z_i	vector of ordinal categories for indicator x_i
T_{x_i}	category threshold vector of parameters (τ_{x_i}) relating x_i to x_i^*
u_i	number of categories for a given variable x_i, i.e. the dimension of vector Z_i

A similar threshold model is established for the vector y relating it to y^*.

Here, the unknown parameters in the model are no longer estimated by equating the implied covariance matrix to the population covariance matrix of observed variables (Σ) but to that of the latent response variables (Σ^*) (Bollen, 1989),

$$\Sigma(\theta) = \Sigma^* \quad (10)$$

Given a large enough sample of the population, the parameters are estimated by solving the following (Bollen, 1989),

$$\Sigma(\theta) = \mathrm{S}^* \quad (11)$$

where S^* is the sample covariance matrix of response variables.

4.4. Estimation

4.4.1. Threshold Model Estimation

Typically, thresholds are estimated by assuming that x^* and y^* are multinormally distributed. The latter assumption does not, however, assume normality for the observed ordinal variables, which in turn allows these variables to have kurtosis or skew (Bollen, 1989). Accordingly, the thresholds are estimated as (Bollen, 1989),

$$\tau_k = \Phi^{-1}\left(\sum_{j=1}^{k}\frac{N_j}{N}\right), \qquad k = 1, 2, 3, \dots, u-1 \tag{12}$$

where $\Phi^{-1}(.)$ is the inverse of the standardized, normal cumulative distribution function, N_j the number of observations in the jth category and N the total number of observations.

4.4.2. Polychoric Correlations

S* is estimated given the assumption that x^* and y^* are multinormally distributed (Bollen, 1989). Given the case of ordinal observed variables, the estimated correlations between the continuous latent response variables are called *polychoric* (Bollen, 1989). The main notion behind polychoric correlations is that ordinal variables are envisioned as discretized continuous variables (Ekström, 2011a). If the latter assumptions are true, whereby ordinal variables can be truly represented by discretized multinormally distributed continuous variables, then the polychoric coefficient is, in Ekström's words,

> the parameter value for which the volumes of the discretized bivariate standard normal distribution equal the joint probabilities of the contingency table, i.e. the parameter value for which the probability measures, as induced by the bivariate standard normal distribution, of the rectangles resulting from the discretization equal the joint probabilities of the contingency table (Ekström, 2011b).

The contingency table is a matrix-form representation of ordinal data whereby each variable represents a dimension and each cell represents the proportion of observations falling under different categories of paired variables. For instance, if two raters (R1 and R2) are to evaluate entries as passing or failing, a 2x2 contingency table would look as follows.

Table 7: 2x2 Example Contingency Table

	R1, fail	R1, pass
R2, fail	a	b
R2, pass	c	d

where a, b, c and d are values representing the proportion of observations belonging to each cell.

Using the latter 2x2 contingency table as example, polychoric correlation can be defined in simpler words. In reality, in a 2x2 case, the correlation becomes *tetrachoric*, which is a special case of polychoric. The joint distribution between the continuous latent response variables can be represented as an ellipse as represented below.

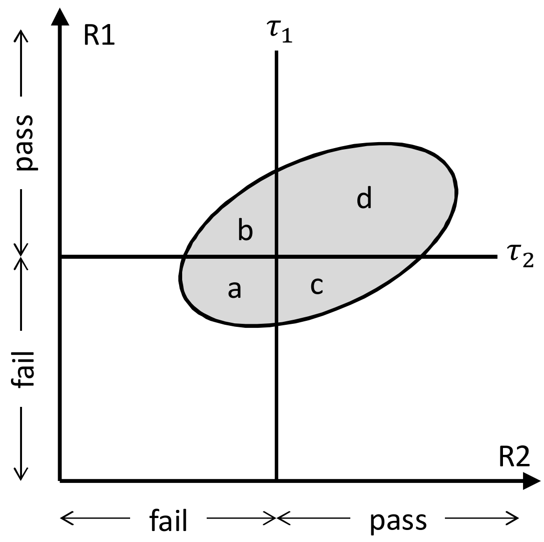

Figure 4: Ellipse Representation of the Joint Distribution between Two Continuous Latent Response Variables

Similarly to the contingency table, the values a, b, c and d are the proportions of observations falling under each region. τ_1 and τ_2 are the discretizing thresholds between failing and passing criteria for each of the two raters. The correlation is then accordingly iteratively estimated as the parameter determining the *fatness* of the ellipse which best fits the contingency table given the estimated discretizing thresholds (Uebersax, 2006).

Note that in other cases, where not all observed variables are ordinal, correlations would be *Pearson* between two continuous indicators, *polyserial* between a continuous and an ordinal indicator or, as indicated earlier, *tetrachoric* between two dichotomous (binary) indicators.

4.4.3. Overall Model Estimation

Although the estimation can be conducted using *maximum likelihood* estimation, using the latter may lead to incorrect standard errors, t-tests, chi-square and other significance tests in situations where data is not normal or has excessive kurtosis (Bollen, 1989). Accordingly, a better choice is using *weighted least square* estimation (WLS), where the objective function to minimize is given by (Bollen, 1989),

$$F_{WLS} = [s - \sigma(\theta)]' W^{-1} [s - \sigma(\theta)] \tag{13}$$

Table 8 describes the above vectors and matrices (Bollen, 1989).

Table 8: WLS Estimator Vectors and Matrices

Vectors/ Matrices	Dimension	Description
s	½(p+q)(p+q+1) x 1	vector of polychoric correlation coefficients for the nonredundant correlations between all pairs of x^* and y^*
$\sigma(\theta)$	½(p+q)(p+q+1) x 1	corresponding vector for the implied covariance matrix
W	½(p+q)(p+q+1) x ½(p+q)(p+q+1)	consistent estimator of the asymptotic covariance matrix of s

Accordingly, θ is estimated so as to minimize the weighted sum of squared deviations of s from $\sigma(\theta)$ (Bollen, 1989). The asymptotic covariance matrix of s is given below (Bollen, 1989),

$$N^{-1}\left[\left(\frac{d\sigma(\theta)}{d\theta}\right)\Sigma_{ss}^{-1}\left(\frac{d\sigma(\theta)}{d\theta}\right)\right] \tag{14}$$

where Σ_{ss} is the covariance matrix of the limiting distribution of $\sqrt{N}s$.

Although several matrices could be chosen for W "without destroying the consistency of the weighted least square regression estimator," the ideal selection is the covariance matrix of the sample covariances (Bollen, 1989). Consequently, the asymptotic covariance of s_{ij} with s_{gh} is,

$$cov(s_{ij}, s_{gh}) = N^{-1}(\sigma_{ijgh} - \sigma_{ij}\sigma_{gh}) \tag{15}$$

where σ_{ijgh} is the fourth-order moment around the mean as displayed below,

$$\sigma_{ijgh} = E(x_i - \mu_i)(x_j - \mu_j)(x_g - \mu_g)(x_h - \mu_h) \tag{16}$$

and σ_{ij} and σ_{gh} are the population covariances of x_i with x_j and x_g with x_h, respectively, and s_{ij} and s_{gh} their respective sample counterparts (Bollen, 1989).

Equation (15) is suitable under any condition requiring no specific distribution provided that the eighth-order moments of the observed variables' distribution are finite (Bollen, 1989). However, in the case of multinormally distributed variables, equation (15) simplifies to (Bollen, 1989),

$$cov(s_{ij}, s_{gh}) = N^{-1}(\sigma_{ig}\sigma_{jh} + \sigma_{ih}\sigma_{jg}) \tag{17}$$

Here, the expression no longer involves the fourth-order moment expression but instead only the product of covariances. Accordingly, the ideal weight matrix W would consist of products of covariances in the form of the latter equation. Moreover, F_{WLS} can be simplified to (Bollen, 1989),

$$F_{WLS} = \frac{1}{2} tr\{[S - \Sigma(\theta)]V^{-1}\}^2 \tag{18}$$

where V is a weight matrix similar to W. The weight matrix here is denoted differently however due to its different dimension being (p+q) x (p+q). In its latter form, the *weighted least squares* function is a generalization of other fitting functions being the *generalized least squares*, *maximum likelihood* and *unweighted least squares* functions (Bollen, 1989).

For more details on the estimator W and the asymptotic covariance matrix see Muthén (1984) and Bollen (1989).

4.5. Identification

The parameters θ in a model are identified if, given two parameter vectors θ_1 and θ_2, $\Sigma(\theta_1) = \Sigma(\theta_2)$ if and only if $\theta_1 = \theta_2$ (Everitt, 1984). Without any restrictions on the parameters in a structural equation model, the model is underidentified (Bollen, 1989). While there are various approaches for achieving proper identification of latent variables, two of such approaches stand out given that they provide scale to the latent variables as well. The first approach is setting one of the λ coefficients for each of the exogenous latent variables ξ to 1. Accordingly, the scale of each ξ will be similar to that of the respective λ for which the coefficient has been set to 1 (Bollen, 1989). However, note that this scale is not a one-unit to one-unit relation due to the presence of measurement errors δ. The second approach is setting the variance of every exogenous latent variable ξ to a fixed value, typically 1. Other less typical constraints would be setting specific parameters to zero in presence of particular hypotheses (such as setting the off-diagonal elements of Θ_δ to zero if the measurement errors are believed to be uncorrelated) (Bollen, 1989).

Furthermore, in the case of ordinal dependent variables, variance values for latent response variables need to be set to a fixed value, typically 1, for identification.

4.5.1. Conditions for Identification

In terms of tests and rules, there are no necessary and sufficient conditions for identification; some rules exist that provide either necessary or sufficient conditions for identification, but not both simultaneously (Everitt, 1984). Of such rules are the *t-rule* which provides necessary conditions for identification and the *two-step rule* which provides sufficient conditions for identification. Below a summary of these two tests are provided. For greater details, the reader is referred to Bollen (1989).

Note that the parameters for the threshold model are not part of these identification tests, as the latter are automatically identified provided sufficient information is available in the sample through sufficient number of observations in each category of an indicator.

4.5.1.1. t-rule

The t-rule requires that the number of parameters to be estimated is less than the number of non-redundant equations (Bollen, 1989, Everitt, 1984). Given that the matrices $\Sigma(\theta)$ and S are symmetrical, the number of equations provided by the model is $(p+q)(p+q+1)/2$ (Bollen, 1989, Everitt, 1984). Denoting t as the number of unknown parameters, the following becomes a necessary condition for identification (not sufficient, however),

$$t \leq (p+q)(p+q+1)/2 \qquad (19)$$

4.5.1.2. Two-step rule

The two step rule, a sufficient yet not necessary rule for identification, requires breaking the model down to two parts (Bollen, 1989). The first step of the two-step rule entails reformulating the model as a measurement model and establishing identification for the latter (Bollen, 1989). Consequently, Β, Γ and Ψ are eliminated (Bollen, 1989). The second step entails reformulating the model as a latent variable model "as if latent variables [are] observed with no measurement error" (Bollen, 1989). At this stage, one must determine whether Β, Γ and Ψ are identified. If identification is achieved in both stages, then the model is identified. However, failure to meet the requirements of this test does not eliminate the chance of the model being identified.

4.6. Illustration

4.6.1. Model

An illustration of a structural equation model with ordinal observed variables is provided below. Assume the following model.

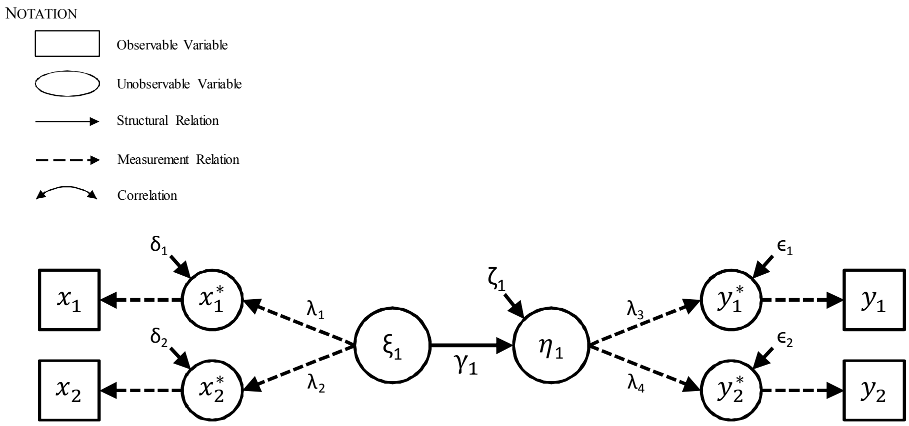

Figure 5: Example SEM

Also, assume that the ordinal variables x_1, x_2, y_1 and y_2 are measured on a 3-point Likert scale.

The latent variable for the above SEM model is as follows,

$$[\eta_1] = [0][\eta_1] + [\gamma_1][\xi_1] + [\zeta_1] \tag{20}$$

followed by the measurement model below,

$$\begin{bmatrix} x_1^* \\ x_2^* \end{bmatrix} = \begin{bmatrix} \lambda_1 \\ \lambda_2 \end{bmatrix} [\xi_1] + \begin{bmatrix} \delta_1 \\ \delta_2 \end{bmatrix} \tag{21}$$

$$\begin{bmatrix} y_1^* \\ y_2^* \end{bmatrix} = \begin{bmatrix} \lambda_3 \\ \lambda_4 \end{bmatrix} [\eta_1] + \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \end{bmatrix} \tag{22}$$

Here, Φ, Ψ, Θ_δ and Θ_ϵ are all diagonal covariance matrices. Whereas Ψ needs to have its diagonal elements estimated, Φ is a 1 x 1 matrix with a variance set to 1 as a scale – and to allow proper identification of the model. Similarly, Θ_δ and Θ_ϵ have their diagonal elements set to fixed value. Subsequently, the implied covariance matrix can be simplified to,

$$\begin{aligned} \Sigma(\theta) &= \begin{bmatrix} \Sigma_{yy}(\theta) & \Sigma_{yx}(\theta) \\ \Sigma_{xy}(\theta) & \Sigma_{xx}(\theta) \end{bmatrix} \\ &= \begin{bmatrix} \Lambda_y(\Gamma\Gamma' + \Psi)\Lambda_y' + \Theta_\epsilon & \Lambda_y\Gamma\Lambda_x' \\ \Lambda_x\Gamma'\Lambda_y' & \Lambda_x\Lambda_x' + \Theta_\delta \end{bmatrix} \end{aligned} \tag{23}$$

The expanded form of the symmetrical matrix is, accordingly,

$$\Sigma(\theta) = \begin{bmatrix} \lambda_3^2(\gamma_1^2 + var(\zeta_1)) + var(\epsilon_1) & & & \\ \lambda_3\lambda_4(\gamma_1^2 + var(\zeta_1)) & \lambda_4^2(\gamma_1^2 + var(\zeta_1)) + var(\epsilon_2) & & \\ \lambda_1\lambda_3\gamma_1 & \lambda_1\lambda_4\gamma_1 & \lambda_1^2 + var(\delta_1) & \\ \lambda_2\lambda_3\gamma_1 & \lambda_2\lambda_4\gamma_1 & \lambda_1\lambda_2 & \lambda_2^2 + var(\delta_2) \end{bmatrix} \quad (24)$$

The threshold model for the ordinal variables is,

$$x_1 = \begin{cases} 1 & if \quad x_1^* \leq \tau_{x_1,1} \\ 2 & if \quad \tau_{x_1,1} < x_1^* \leq \tau_{x_1,2} \\ 3 & if \quad \tau_{x_1,2} < x_1^* \end{cases} \quad (25)$$

$$x_2 = \begin{cases} 1 & if \quad x_2^* \leq \tau_{x_2,1} \\ 2 & if \quad \tau_{x_2,1} < x_2^* \leq \tau_{x_2,2} \\ 3 & if \quad \tau_{x_2,2} < x_2^* \end{cases} \quad (26)$$

$$y_1 = \begin{cases} 1 & if \quad y_1^* \leq \tau_{y_1,1} \\ 2 & if \quad \tau_{y_1,1} < y_1^* \leq \tau_{y_1,2} \\ 3 & if \quad \tau_{y_1,2} < y_1^* \end{cases} \quad (27)$$

$$y_2 = \begin{cases} 1 & if \quad y_2^* \leq \tau_{y_2,1} \\ 2 & if \quad \tau_{y_2,1} < y_2^* \leq \tau_{y_2,2} \\ 3 & if \quad \tau_{y_2,2} < y_2^* \end{cases} \quad (28)$$

Assuming that x_1^*, x_2^*, y_1^* and y_2^* are multinormally distributed, the thresholds can be then estimated using equation (12) given the total number of observations and observations in each category for each of the four observed variables. The model can then be estimated using the *weighted least squares* function provided in equation (18).

4.6.2. Identification

The following is a demonstration of identification tests on the sample model.

First, the *t-rule* is applied as a necessary test for identification. Here, t is equal to 10;

$$\theta = [\lambda_1 \quad \lambda_2 \quad \lambda_3 \quad \lambda_4 \quad \gamma_1 \quad var(\epsilon_1) \quad var(\epsilon_2) \quad var(\delta_1) \quad var(\delta_1) \quad var(\zeta_1)] \quad (29)$$

p and q are equal to 2 each. Accordingly, $(p+q)(p+q+1)/2$ is equal to 10. t is equal to $(p+q)(p+q+1)/2$ which satisfies a necessary condition for identification.

As for the *two-step rule*, the model is divided into sub-models as displayed,

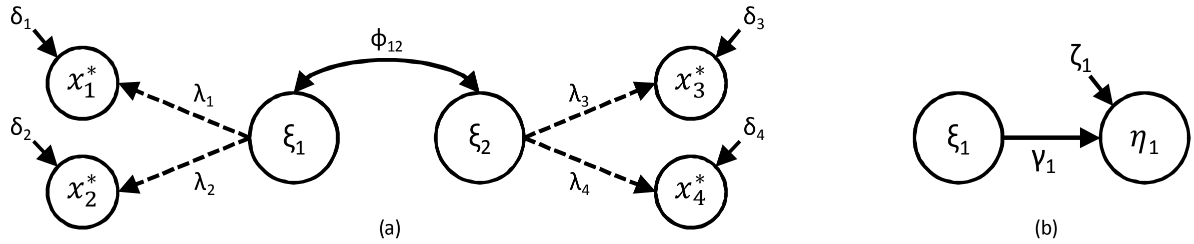

Figure 6: (a) Measurement Model for Two-Step Rule and (b) Latent Variables Model for Two-Step Rule

In part (a) of Figure 6, ξ_2, x_3, x_4, δ_3 and δ_4 are redefinitions of η_1, y_1, y_2, ϵ_1 and ϵ_2, respectively. Similarly to the assumption in Section 4.6.1, the diagonal elements of Φ are equal to 1.

For the measurement model, identification is checked manually by equating the implied covariance matrix to the covariance matrix of the latent response variables,

$$\begin{bmatrix} \lambda_1^2 + var(\delta_1) & & & \\ \lambda_1\lambda_2 & \lambda_2^2 + var(\delta_2) & & \\ \lambda_1\lambda_3\phi_{12} & \lambda_2\lambda_3\phi_{12} & \lambda_3^2 + var(\delta_3) & \\ \lambda_1\lambda_4\phi_{12} & \lambda_2\lambda_4\phi_{12} & \lambda_3\lambda_4 & \lambda_4^2 + var(\delta_4) \end{bmatrix} = \begin{bmatrix} var(x_1^*) & & & \\ cov(x_1^*, x_2^*) & var(x_2^*) & & \\ cov(x_1^*, x_3^*) & cov(x_2^*, x_3^*) & var(x_3^*) & \\ cov(x_1^*, x_4^*) & cov(x_2^*, x_4^*) & cov(x_3^*, x_4^*) & var(x_4^*) \end{bmatrix} \quad (30)$$

The above system of equations is over-identified with 10 equations and 9 unknowns. Solving the system of equations and unknowns, the above results are determinant given that the ratio $\frac{cov(x_1^*,x_3^*)}{cov(x_1^*,x_4^*)}$ is equal to $\frac{cov(x_2^*,x_3^*)}{cov(x_2^*,x_4^*)}$.

As for the latent variable model in part (b) of Figure 6, it is identified based on the *Null B Rule*. According to the *Null B Rule*, if B is equal to zero, then a structural equation model with observed variables is identified (Bollen, 1989); as earlier discussed in Section 4.5.1.2, the latent variable model in part (b) of Figure 6 is treated as a structural equation model with observed variables under the *two-step rule*.

With both sub-models identified, sufficient conditions for model identification are met according to the *two-step rule*.

CHAPTER 5

STUDY AREA

The study area targeted in this thesis is the neighborhood of the American University of Beirut (AUB). AUB is located in Ras Beirut overviewing the Mediterranean Sea (Myntti, 2013). To the south of the campus is the Hamra/Ras Beirut region, including two vibrant streets, Bliss and Hamra streets, which contain a rich array of amenities, including restaurants, services, galleries, theatres, etc. (American University of Beirut, a, b). Streets in the neighborhood are local streets serving low-speed traffic.

In terms of walkability, infrastructure is relatively substandard, consisting of low-quality narrow sidewalks with a multitude of obstacles, including but not limited to parking meters, large trash bins, electricity poles, encroachment by construction sites and shops, etc. Consequently, an individual is forced at several instances to cross the road to the sidewalk on the opposite side of the road or even walk on the side of the road rather than on the sidewalk given the poor sidewalk conditions.

The streets investigated in this study are: Bliss, Omar Bin Abdul Aziz, Jeanne d'Arc, Mahatma Gandhi and Sadat. Below is a map of the neighborhood and the latter streets. While other streets in the neighborhood could have been added, given the multitude of streets in the neighborhood, the indicated streets have been selected in the case study for being the main pathways to AUB (based on the author’s experience and the survey results).

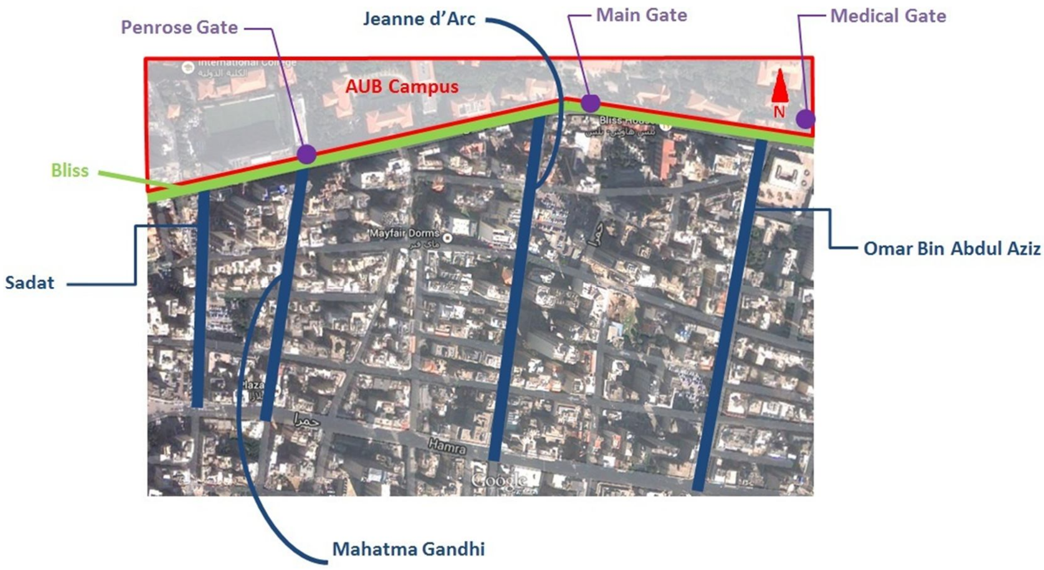

Figure 7: Birdseye View of the Neighborhood of AUB

A general description of the characteristics of each street is provided in the following section. Appendix A provides a numerical summary of sidewalk data, being the minimum sidewalk width along the street, average sidewalk width, maximum sidewalk width (Table 13) and percentage of sidewalk area occupied by different obstacles (Table 14). Original data used in such calculations are retrieved from Jamaleddin's *Assessing Walkability and Pedestrian Mobility in the AUB Neighborhood* (2013). The data has been collected during the months of July and August of the year 2013.

5.1. Street Characteristics

5.1.1. Bliss Street

Being the street that connects all the latter streets to AUB, Bliss Street is a major street in this study. The street serves traffic in the east-to-west direction and is bordered by the university to the north (right with respect to traffic direction) and commercial buildings housing restaurants, cafés, bookstores, etc. to the south (left with respect to traffic direction).

While sidewalks are wider than those on other streets in this study, ranging between 1.6 and 3.5 meters with an average of about 2.5 meters, pedestrian traffic is highly impeded on the southern sidewalk due to infringement by shops and the high number of standing pedestrians waiting to be served by many of the restaurants and cafés on the sidewalk that don't provide seating space. The northern sidewalk, however, provides better pedestrian flow with only occasional disruptions resulting from large trash bins adjacent to the sidewalk, electricity poles and trees.

5.1.2. Omar Bin Abdul Aziz Street

Bounded by numerous commercial shops, medical facilities and the American University of Beirut Medical Center, which has a 600-bed capacity and serves around 360,000 patients a year (American University of Beirut Medical Center), Omar Bin Abdul Aziz Street witnesses relatively heavy traffic, whether vehicular or pedestrian.

Pedestrian traffic on Omar Bin Abdul Aziz Street is typically impeded by the conflicting pedestrian traffic (pedestrian traffic in the opposite direction) due to the narrowness of the sidewalks at certain instances (as narrow as 0.7 meters), static obstacles and vehicles parked on the corners of intersections. Furthermore, during the timeline of this study (2013 to 2014), the expansion of the American University of Beirut Medical Complex led to stretches of the eastern sidewalk being almost totally unavailable and encroached by the construction site.

5.1.3. Jeanne d'Arc Street

Jeanne d'Arc Street serves as a connecting street from Hamra (one of the major and most active streets in the neighborhood) to AUB's Main Gate on Bliss Street. Accordingly, this street is highly utilized by students walking from Hamra to AUB or vice versa as well as for visiting bookstores and printing centers.

Pedestrian flow on Jeanne d'Arc Street is generally obstructed by the numerous construction sites along the street and occasionally by shop encroachment on the sidewalk, both occupying more than 13% of the sidewalk area. Therefore, pedestrians may be forced to change sidewalks when interrupted by these construction sites (or walk on the side of the street rather than on the sidewalk).

Nonetheless, as previously discussed in Section 1.1, pending plans exist for reconfiguring Jeanne d'Arc Street's sidewalks into barrier-free walkways with wider unobstructed sidewalks, improved pedestrian crossings and sidewalk furnishings including seating, proper lighting and greenery (Myntti, 2014).

5.1.4. Gandhi Street

Gandhi Street, serving south-to-north traffic from Hamra Street to Bliss Street, is mostly characterized with its narrow sidewalks. These narrow sidewalks, as narrow as 1.0 meter, impede pedestrian traffic by allowing one or, at most, two people to walk side by side without the need to walk on the street instead.

Gandhi Street provides a variety of commercial services, including restaurants, mini-markets and others.

5.1.5. Sadat

Sadat Street serves vehicular traffic in the north-to-south direction connecting the end of Bliss Street to the end of Hamra Street. Sidewalks on this street are generally narrow, similarly to

Gandhi Street. Therefore, although pedestrian traffic isn't generally impeded on this street, one may encounter fitful stretches where a combination of narrow sidewalk and obstructions is hindering.

Commercial services provided on this street include a range of grocery shopping, photography services, music shops, etc.

CHAPTER 6

DATA AND DESCRIPTIVE FINDINGS

As part of the Neighborhood Initiative at the American University of Beirut, a survey was launched in November 2013 to collect data on the daily commute of students to and from the university, the potential for switching to a new taxi sharing service, the students' walking patterns in the neighborhood of AUB and their satisfaction with the neighborhood walkability.

6.1. The Survey

The survey was web-based and all university students were invited to participate through e-mail. The survey remained active for three weeks within which students were sent two reminders to complete the survey.

Out of 7920 current students (then), 2291 started the survey (28.93% of the student population). Only 1393 students (17.59% of the student population, 60.80% of respondents) completed the survey whereas the remaining 898 only submitted partial responses.

6.1.1. Walkability Questions

The questions targeted in the *walkability* section of the survey are mainly divided into the following categories: questions targeting the walkability at a neighborhood level, questions targeting walkability on Bliss street which borders the university from the southern side, questions targeting walkability on a chosen street – based on which street the respondent uses most frequently to conduct his or her commute or daily walking trips, respondent's suggested interventions, respondent's level of agreement with given statements regarding walking in the neighborhood of AUB and respondent's on-foot trips on the last day he or she came to AUB.

At the neighborhood level, an initial question inquires about the respondent's satisfaction with the walking environment in the neighborhood of AUB. The respondent is then inquired about his or her satisfaction with attributes of the walking environment – at a neighborhood level – on a 7-point Likert scale ranging from *very dissatisfied* to *very satisfied*. Similarly, at the level of separate streets, whether Bliss street or the chosen street, the respondent is asked to rate his or her satisfaction with given attributes of the walking environment along the street on a 7-point Likert scale ranging from *very dissatisfied* to *very satisfied* as well. The respondent is also asked to rate how bothered he or she is by another set of attributes, also on a 7-point Likert scale which ranges, however, from *not at all* to *very much*. All such attributes are listed in Table 9.

In the section assigned for suggestions and suggested interventions, respondents answer two questions. The first question is to choose from a list of 14 suggested interventions the 3 they believe would improve their walking experience the most. The second is an open-ended question allowing the respondent to type in his or her suggestions.

Several attitudinal statements about walking in the neighborhood of AUB are also presented to the respondent for him or her to indicate their level of agreement with such statements on a 7-point Likert scale. An example of such statements is "I don't mind the absence of greenery as long as the majority of the sidewalk is shaded during daytime."

Table 9: Attributes of the Walking Environment Inquired about in the Survey

Satisfaction Attributes (neighborhood level)	ease of pedestrian crossing sidewalk blockage cleanliness of the sidewalk vehicular traffic on the streets traffic noise traffic fumes motorcycles going against traffic on one-way streets
Satisfaction Attributes (street level)	sidewalk width sidewalk surface quality and evenness diversity of activities trees and greenery proportion of shadowed sidewalk
Bother Attributes (street level)	buildings with entrance door access to the sidewalk parking access across the sidewalk (to building garage or parking lot) bollards on the sidewalk parking meters on the sidewalk sign posts on the sidewalk cars and motorcycles parked on the sidewalk sidewalk infringement by shops electricity poles on the sidewalk large trash bins

Finally, within the walkability section of the survey, respondents are asked to list the places visited on foot during their last day at AUB – if any – and the time at which these trips were conducted.

Besides the questions included in the walkability section of the survey, respondents are asked about their socio-economic characteristics, including gender, year of university education, major area of study and corresponding faculty, household income and others. Also, all respondents are asked about their satisfaction with their current commute at the beginning of the survey.

6.2. Data Cleaning

Given that not all questions in the survey are mandatory in addition to 39.20% of the responses being incomplete, data cleaning is necessary prior to utilizing the data. Note that data from incomplete responses is used as well – when possible.

Out of the 2291 responses (complete and incomplete), 889 (38.80%) include responses to walkability questions. Of the 889 responses, 687 (29.99 % of the 2291 responses) are used in the modeling process; other responses missing information crucial to the model are discarded.

The cleaned data itself is segregated into two groups: those who commute to AUB on foot (on-foot commuters: OFC) (248 responses out of 687) and those who don't (non-foot commuters: NFC) (439 responses out of 687). Satisfaction with the walking environment is then modeled for both groups.

Note that, satisfaction with walking on a "chosen street" is assumed to influence satisfaction with the walking environment. The chosen street is the street used for commuting for those who commute to AUB on foot, while for those who don't commute to AUB on foot the chosen street is a street used most frequently for daily non-commute walking trips.

6.3. Data Description

Taking the cleaned data as a whole, excluding the 16 observations that did not indicate their gender, the sample consists of 358 female and 313 male students (53.35% and 46.65% of sample, respectively). This distribution between females and males is representative of the AUB student population (52.30% and 47.70%, respectively). Furthermore, the population is also well-represented by the sample in terms of faculties under which students are majoring with the largest deviation from the population being 2.60% for the Suliman Olayan School of Business.

The average household income in the sample is 7,560,000 Lebanese Pounds (LBP) per month (or $5,040/month) with a median of 5,000,000LBP/month (or $3,330/month). Respondents are given the choice of not indicating their household income; accordingly, the above value is representative as an average for 54.29% of the sample.

As for the responses to the attitudinal statements, the mean ($\bar{x}$) and standard deviation (s) for each is summarized in Table 10.

By referring to the table, the average value for the satisfaction with the walking environment is similar for on-foot commuters and non-foot commuters, being 4.02 for on-foot commuters (s = 1.76) and 4.05 for the commuters of other modes (s = 1.60) (on a scale from 1 to 7, 1 being *very dissatisfied*, 4 being *neutral* and 7 being *very satisfied*).

However, on-foot commuters display a higher average level of satisfaction with their commute when compared to commuters of other modes. For on-foot commuters, the average level of satisfaction with the commute is 5.60 (s = 1.33), whereas for commuters of other modes the average is 3.95 (s = 1.85).

As for the indicators (or attributes), the average ratings are generally close between the two samples, with the average absolute difference between indicators being equal to 0.17. One apparent relatively large difference is that for the level of satisfaction with *ease of pedestrian crossing* (equal to 1.04). Note that, out of the 43 indicators presented in the table, only the population distributions for the satisfaction indicator for *vehicular traffic on street* and for the bother indicator for *large trash bins* on other (or chosen) street are identical between the two samples, OFC and NFC, according to the Mann-Whitney-Wilcoxon Test at 0.05 significance level.

Looking at average levels of satisfaction, the lowest rating is 1.88 for *motorcycles going against traffic on one-way streets* for OFC, whereas the highest is 5.25 for *diversity of activities* for NFC. On the other hand, the lowest average bother rating (on a scale from 1 to 7, 1 being *not bothered at all* and *7* being *very much*) is 2.42 for *buildings with entrance door access to the sidewalk* for OFC, while the highest rating (5.53), belongs to the bother indicator *cars and motorcycles parked on the sidewalk* for NFC.

Table 10: Attitudinal Responses Summary

		OFC		NFC	
		$\bar{x}$	s	$\bar{x}$	s
Level of Satisfaction	with walking environment	4.02	1.76	4.05	1.60
	with commute	5.60	1.33	3.95	1.85
Satisfaction Indicators	ease of pedestrian crossing	2.67	1.52	3.71	1.64
	sidewalk blockage	3.20	1.57	2.66	1.48
	cleanliness of the sidewalk	2.93	1.45	3.10	1.58
	vehicular traffic on the streets	2.43	1.34	2.55	1.35
	traffic noise	2.39	1.29	2.35	1.32
	traffic fumes	2.67	1.52	2.30	1.30
	motorcycles going against traffic on one-way streets	1.88	1.21	2.00	1.38

		OFC Bliss		OFC Other		NFC Bliss		NFC Other	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Satisfaction Indicators	sidewalk width	3.67	1.59	3.06	1.53	3.80	1.69	3.10	1.60
	sidewalk surface quality and evenness	3.67	1.59	3.08	1.56	3.62	1.59	3.19	1.50
	diversity of activities	5.06	1.43	4.34	1.46	5.25	1.43	4.35	1.50
	trees and greenery	3.31	1.78	3.00	1.54	3.46	1.64	3.05	1.44
	proportion of shadowed sidewalk	3.38	1.61	3.40	1.59	3.56	1.41	3.45	1.44
Bother Indicators	buildings with entrance door access to the sidewalk	2.42	1.52	2.63	1.79	2.48	1.64	2.72	1.73
	parking access across the sidewalk	3.48	1.89	3.37	1.88	3.29	1.87	3.17	1.85
	bollards on the sidewalk	3.43	1.89	3.27	1.87	3.32	1.82	3.17	1.82
	parking meters on the sidewalk	3.00	1.83	2.95	1.85	2.89	1.88	2.89	1.84
	sign posts on the sidewalk	2.54	1.65	2.78	1.77	2.54	1.67	2.65	1.71
	cars and motorcycles parked on the sidewalk	5.53	1.83	5.11	2.06	5.45	1.81	5.13	2.01
	sidewalk infringement by shops	4.15	1.95	3.71	2.06	4.27	1.96	3.88	2.04
	electricity poles on the sidewalk	3.28	1.79	3.10	1.86	3.39	1.91	3.36	2.02
	large trash bins	4.80	2.04	4.42	2.13	5.09	1.98	4.78	2.11

CHAPTER 7

STRUCTURAL EQUATION MODELING: OFC AND NFC MODELS

Structural equation modeling (SEM) is utilized for estimating the causal relations between the level of satisfaction with the attributes of the walking environment and the level of satisfaction with the walking environment overall. Two models are estimated, one for the on-foot commuters and one for the non-foot commuters.

Initially, exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) are implemented in order to, respectively, identify and confirm the underlying relationships between the variables (attitudinal indicators) and the latent factors.

7.1. Exploratory and Confirmatory Factor Analysis

Exploratory factor analysis is conducted on the attributes of the walking environment separately for each of the two samples. The rotation method utilized is oblique rotation (otherwise known as *promax*) which allows for correlations between the latent factors. The number of latent factors (initially equal to 7) has been determined based on non-graphical solutions to the scree test, including parallel analysis, optimal coordinates and acceleration factors, in addition to common sense and a priori hypothesis in order to determine which result from the several tests is most sensible.

While several runs of exploratory factor analysis have been conducted, the results for which the number of factors has been specified to 7 is displayed in Table 15 and Table 16.

Subsequent to EFA, alterations to the resulting relationships from EFA between the attitudinal indicators and latent factors are implemented in order to add intuition to the model. Altered models are then tested for how well the measured variables represent the construct using CFA.

Originally, 7 latent factors have been identified through this analysis. The 7 factors have been labeled as, 1: *neighborhood attributes*; 2: *bother with sidewalk obstacles*; 3: *sidewalk width and quality on Bliss Street*; 4: *sidewalk width and quality on chosen street*; 5: *diversity of activities*; 6: *greenery and cleanliness;* and 7: *sidewalk blockage and infringement.* All of the factors, with the exception of 2 and 7, denote levels of satisfaction with a set of attributes of the walking environment; 2 and 7 denote levels of bother towards their respective attributes.

These factors, along with their respective indicators, are shown in Table 11. The separate and complete results for EFA and CFA are displayed in Table 15 and Table 16 in Appendix B.

Table 11: Identified Factors and Respective Indicators

Factors Denoting Levels of Satisfaction	Factors Denoting Levels of Bother
Neighborhood attributes	**Bother with sidewalk obstacles**
ease of pedestrian crossing	buildings with entrance door access [1,2]
sidewalk blockage	parking access across the sidewalk [1,2]
cleanliness of the sidewalk	bollards on the sidewalk [1,2]
vehicular traffic on streets	parking meters on the sidewalk [1,2]
traffic noise	public phones on the sidewalk [1,2]
traffic fumes	sign posts on the sidewalk [1,2]
motorcycles going against traffic on one-way streets	electricity poles on the sidewalk [1,2]
	Sidewalk blockage and infringement
Sidewalk width and quality on Bliss Street	sidewalk blockage
sidewalk width [1]	cars parked on or blocking the sidewalk [1,2]
sidewalk quality and evenness [1]	sidewalk infringement by shops [1,2]
	large trash bins [1,2]
Sidewalk width and quality on chosen street	
sidewalk width [2]	
sidewalk quality and evenness [2]	
Diversity of activities	
diversity of activities [1,2]	
Greenery and cleanliness	
cleanliness of the sidewalk	
trees and greenery [1,2]	
proportion of shadowed sidewalk [1,2]	

[1] on Bliss street
[2] on chosen street

This analysis is used as a basis to develop the structural equation model which is described next.

7.2. Model Specification

Using EFA and CFA results as a base model, the model is further developed through SEM in order to model the *level of satisfaction with the walking environment* as a function of covariates. For on-foot commuters, the *level of satisfaction with the commute* is modeled simultaneously with *level of satisfaction with the walking environment* given their hypothesized correlation. That is not the case for non-foot commuters given that the *level of satisfaction with the commute* for non-foot commuters is associated withmodes other than walking. Correlations are allowed between factors and identification is ensured through normalizing the variances of all exogenous latent variables. Furthermore, all observed variables (with the exception of *travel time to AUB*) are input into the model as ordinal data in *deviations from the means* form; *travel time to AUB* is input in *deviations from the means* form as well, but as a continuous observed variable. The estimation method utilized is *diagonally weighted least squares with robust standard errors and mean and variance adjusted test statistic* (Muthén, 2004; Rosseel, 2012). The utilization of a robust approach and adjusted test statistics is mainly to accommodate for the non-normality of the data. The SEM is then improved iteratively by removing insignificant factors and variables.

7.2.1. Notation and Path Diagram

The following is a path diagram of the structural equation model specific to the OFC sample including *level of satisfaction with the commute*.

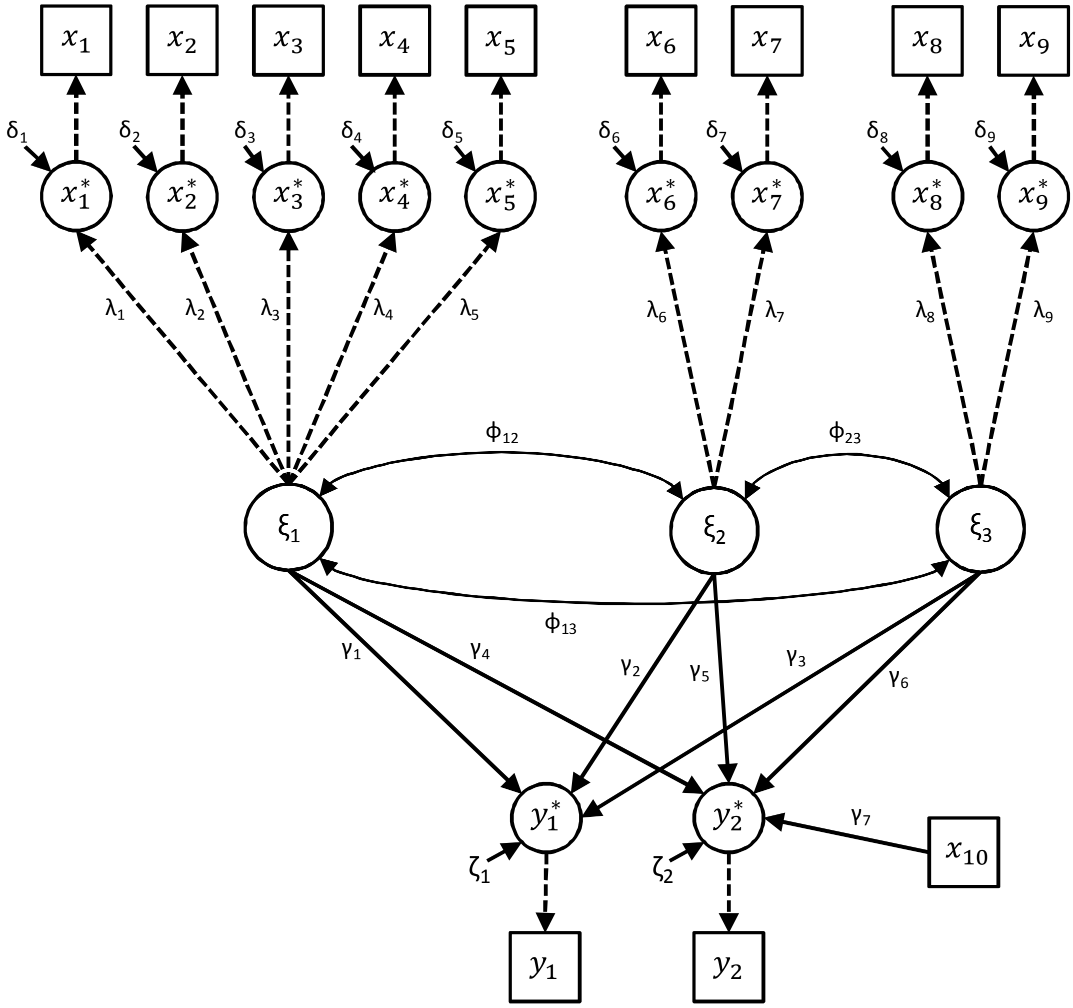

Figure 8: SEM Path Diagram

Each of the above observed and latent variables are defined below,

Table 12: Description of Latent and Observed Variable Parameters

Parameter	Description
x^*	vector of latent response variables
x_1	level of satisfaction with ease of pedestrian crossing (observed)
x_2	level of satisfaction with sidewalk blockage (observed)
x_3	level of satisfaction with cleanliness of the sidewalk (observed)
x_4	level of satisfaction with vehicular traffic on the streets (observed)
x_5	level of satisfaction with motorcycles going against traffic on one-way streets (observed)
x_6	level of satisfaction with sidewalk width on chosen street (observed)

Table 12 (cont'd): Description of Latent and Observed Variable Parameters

Parameter	Description
x_7	level of satisfaction with sidewalk quality on chosen street (observed)
x_8	level of satisfaction with diversity of activities on Bliss Street (observed)
x_9	level of satisfaction with diversity of activities on chosen street (observed)
x_{10}	travel time to campus (in minutes) (observed)
ξ_1	level of satisfaction with overall neighborhood attributes (latent)
ξ_2	level of satisfaction with sidewalk width and quality on chosen street (latent)
ξ_3	level of satisfaction with diversity of activities (latent)
y_1	level of satisfaction with the walking environment (observed)
y_2	level of satisfaction with the commute (observed)
y^*	vector of latent response variables

7.2.2. Formulation

The model specified above is a special case of the general structural equation model. Here, every endogenous latent variable (η) is a latent response variable of the ordinal observed variables and is therefore equal to and denoted as y^*. Also, Ψ is diagonal since disturbances ζ are uncorrelated, Θ_δ is diagonal as well since the errors δ are uncorrelated and $\mathrm{B} = 0$ since none of the latent response variables y^* affect one another directly. The latent variable model becomes,

$$y^* = \Gamma * \xi + \zeta \tag{31}$$

Following is the measurement equation,

$$x^* = \Lambda_{x^*}\xi + \delta \tag{32}$$

$$y^* = \eta \tag{33}$$

and the implied covariance matrix,

$$\Sigma(\theta) = \begin{bmatrix} \Sigma_{y^*y^*}(\theta) & \Sigma_{y^*x^*}(\theta) \\ \Sigma_{x^*y^*}(\theta) & \Sigma_{x^*x^*}(\theta) \end{bmatrix} = \begin{bmatrix} \Gamma\Phi\Gamma' + \Psi & \Gamma\Phi\Lambda'_{x^*} \\ \Lambda_{x^*}\Phi\Gamma' & \Lambda_{x^*}\Phi\Lambda'_{x^*} + \Theta_\delta \end{bmatrix} \tag{34}$$

In expanded form, the above latent variable and measurement models become,

$$\begin{bmatrix} y_1^* \\ y_2^* \end{bmatrix} = \begin{bmatrix} \gamma_1 & \gamma_2 & \gamma_3 \\ \gamma_4 & \gamma_5 & \gamma_6 \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \\ \xi_3 \end{bmatrix} + \begin{bmatrix} 0 \\ \gamma_7 \end{bmatrix} [x_{10}] + \begin{bmatrix} \zeta_1 \\ \zeta_2 \end{bmatrix} \tag{35}$$

$$\begin{bmatrix} x_1^* \\ x_2^* \\ x_3^* \\ x_4^* \\ x_5^* \\ x_6^* \\ x_7^* \\ x_8^* \\ x_9^* \end{bmatrix} = \begin{bmatrix} \lambda_1 & 0 & 0 \\ \lambda_2 & 0 & 0 \\ \lambda_3 & 0 & 0 \\ \lambda_4 & 0 & 0 \\ \lambda_5 & 0 & 0 \\ 0 & \lambda_6 & 0 \\ 0 & \lambda_7 & 0 \\ 0 & 0 & \lambda_8 \\ 0 & 0 & \lambda_9 \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \\ \xi_3 \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \\ \delta_7 \\ \delta_8 \\ \delta_9 \end{bmatrix} \tag{36}$$

Note that x_{10} is a special case of the exogenous variables being observed instead of latent.

The covariance matrix of ξ is represented below,

$$\Phi = \begin{bmatrix} 1 & \phi_{12} & \phi_{13} \\ \phi_{12} & 1 & \phi_{23} \\ \phi_{13} & \phi_{23} & 1 \end{bmatrix} \tag{37}$$

The diagonal elements of Φ are set to 1 as scale for the exogenous latent variables. The latter assumption also allows for model identification.

The threshold model is constructed based on the material discussed in Chapter 4 (refer to Section 4.6.1 for an illustration). A sample of the overall threshold model is given below for the latent response variable x_1^*,

$$\mathrm{x}_1 = \begin{cases} 1 & if \quad x_1^* \le \tau_{x_1,1} \\ 2 & if \quad \tau_{x_1,1} < x_1^* \le \tau_{x_1,2} \\ 3 & if \quad \tau_{x_1,2} < x_1^* \le \tau_{x_1,3} \\ 4 & if \quad \tau_{x_1,3} < x_1^* \le \tau_{x_1,4} \\ 5 & if \quad \tau_{x_1,4} < x_1^* \le \tau_{x_1,5} \\ 6 & if \quad \tau_{x_1,5} < x_1^* \le \tau_{x_1,6} \\ 7 & if \quad \tau_{x_1,6} \le x_1^* \end{cases} \tag{38}$$

The model construct for the NFC sample is similar to that for OFC, with the two differences being the absence of the *level of satisfaction with the commute* in the model as discussed earlier and *travel time to AUB* which loads on the latter.

7.3. Model Results

Model estimation is then conducted using the *weighted least squares* (WLS) estimation as discussed in Section 4.4. Estimation is conducted in *R* (version 3.0.3) (R: A language and environment for statistical computing, 2014) through the package *lavaan* (version 0.5-15) (Rosseel, 2012). Figure 9 and Figure 10 display the two models, for OFC and NFC, with the estimated parameters as well as the respective p-values (between parentheses). Results are also presented in Appendix B in Table 19 and Table 20. Note that in the following figures, neither variances nor the threshold model are displayed for clarity.

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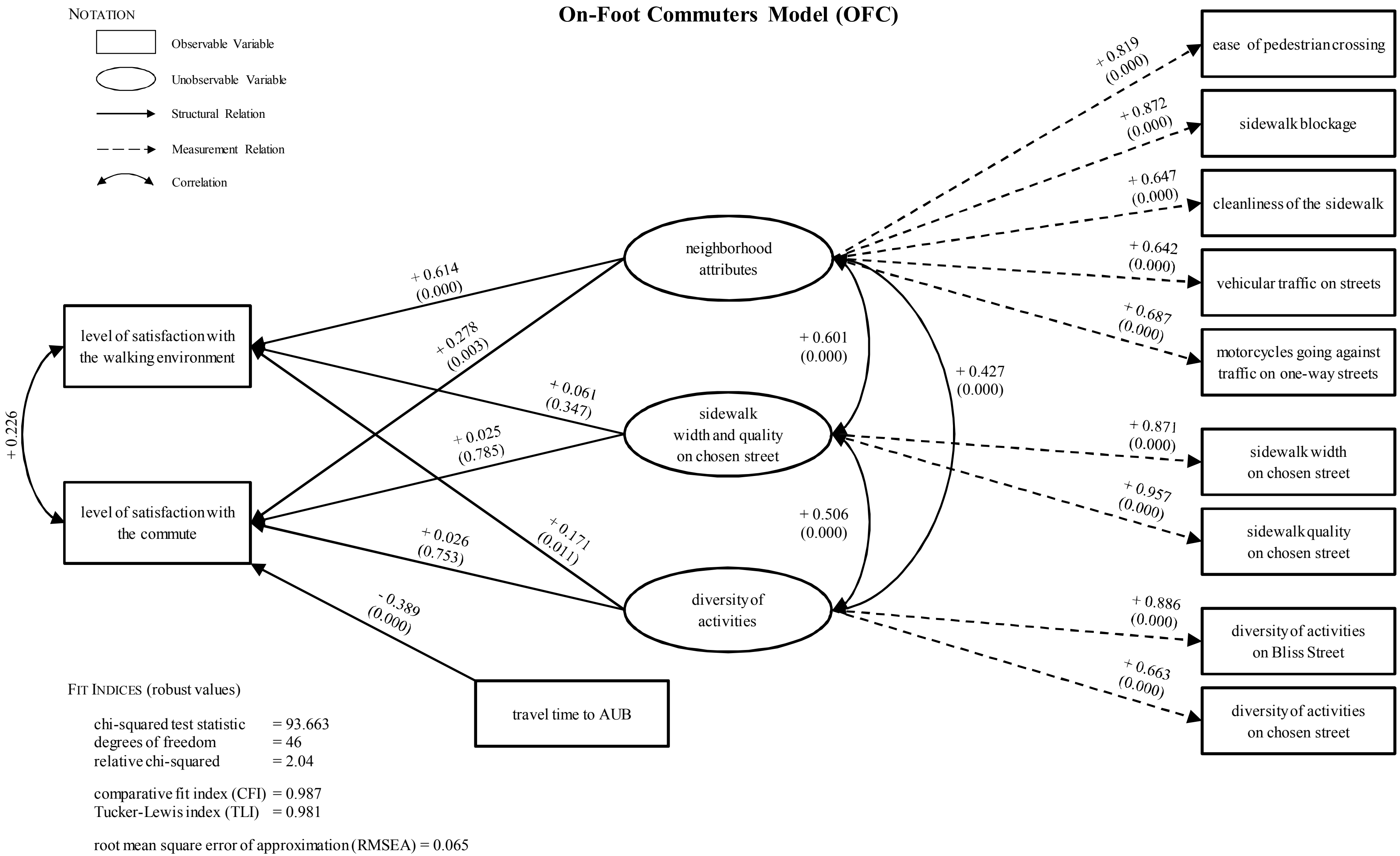

Figure 9: Results for the On-Foot Commuters (OFC) Model
(parameter estimates; p-values in parentheses)

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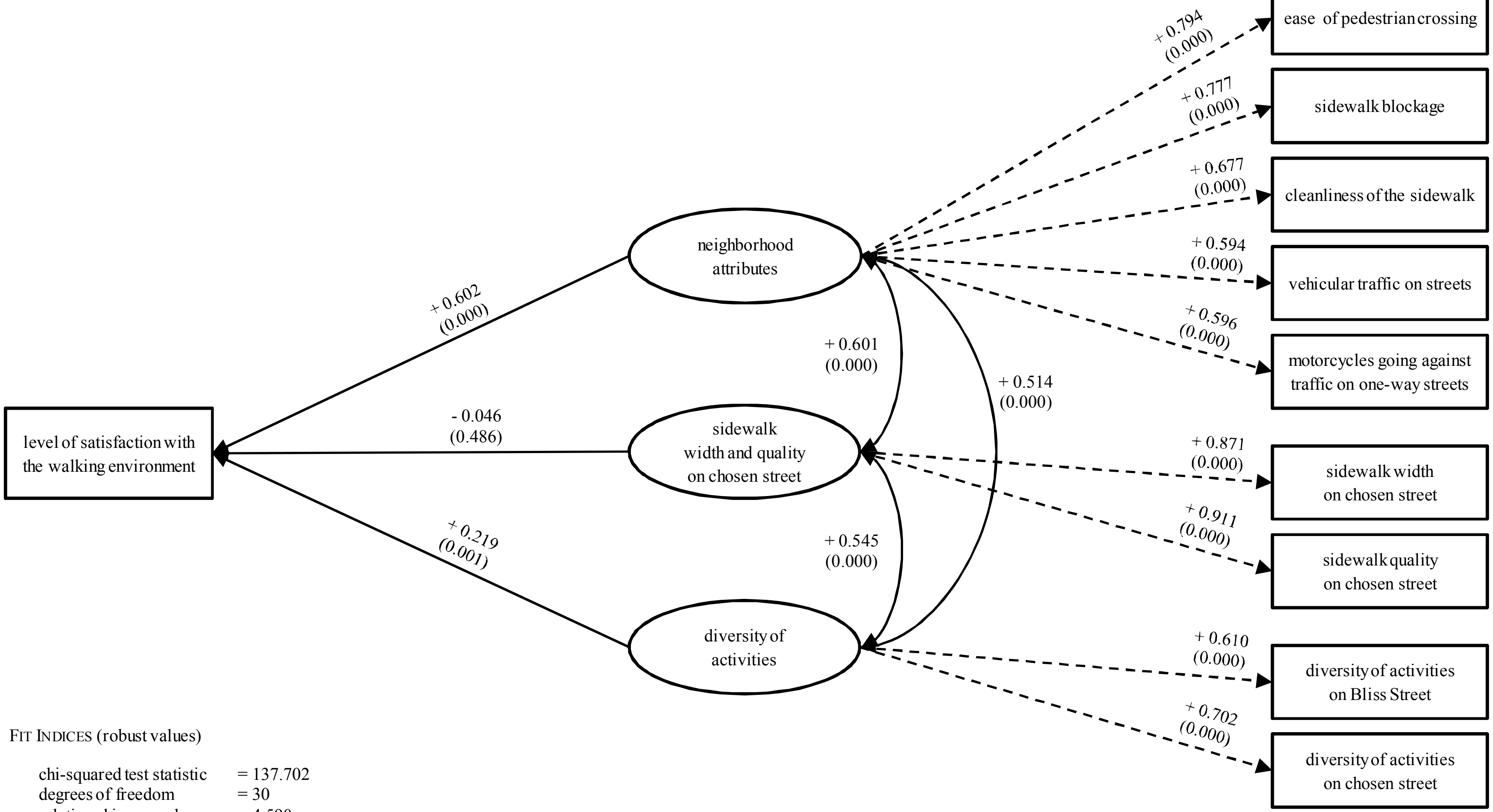
Non-Foot Commuters Model (NFC)



FIT INDICES (robust values)

chi-squared test statistic = 137.702
degrees of freedom = 30
relative chi-squared = 4.590

comparative fit index (CFI) = 0.972
Tucker-Lewis index (TLI) = 0.958

root mean square error of approximation (RMSEA) = 0.091

Figure 10: Results for the Non-Foot Commuters (NFC) Model
(parameter estimates; p-values in parentheses)

7.3.1. Fit Indices

For a good fit, the ratio between the chi-squared statistic and the degrees of freedom should be less than 5 (Martínez, 2014); however, Ullman suggests a lower ratio, being less than 2, as an indicator of a good fit (Moss, 2008). Here, the the null hypothesis is that the model fits perfectly in the population (Hoyle, 2012). Furthermore, based on a study by Hu and Bentler, it has been suggested that the RMSEA (Root Mean Square Error of Approximation) be less than 0.06 and that the CFI (Comparative Fit Index) and TLI (Tucker Lewis Index) be each greater than 0.95 (Hoyle, 2012).

By referring to Figure 9 and Figure 10, most of the fit indices suggest a good or acceptable fit with the exception of the RMSEA. Both the CFI and TLI values indicate a good fit being greater than 0.95 for each model. As for the relative chi-squared, though Ullman suggests a ratio of 2, the values for the latter two models are acceptable for the relative chi-squared threshold of 5. In fact, for the OFC model, the relative chi-squared ratio is almost 2, being equal to 2.04, whereas the value is equal to 4.59 for the NFC model. The two models have RMSEA values greater than the suggested guideline of 0.06; however, whereas that of the NFC model is noticeably higher than the suggested guideline at 0.091, that of the OFC model is close to the guideline, being 0.065.

The better fit indices for the OFC model over the NFC model may be attributed to the additional information provided by the inclusion of *level of satisfaction with the commute* in the OFC model.

7.3.2. Interpretation of Model Results

7.3.2.1. OFC Model

Regarding the OFC model, all estimates for the measurement relations are significant at α = 0.01, where α is the level of significance. Furthermore, measurement equation coefficients are relatively high with values as high as 0.957 for the case of the latent variable *sidewalk width and quality on chosen street* loading on satisfaction with *sidewalk quality on chosen street*. This is indicative of the large effect of the latent variable on the indicator. Lower values are in the range of 0.642 and 0.647 for the indicators *vehicular traffic on streets* and *cleanliness of the sidewalk*.

As for the structural equation explaining the *level of satisfaction with the walking environment*, the latent variables *neighborhood attributes* (coef. = 0.614) and *diversity of activities* (coef. = 0.171) are significant at α = 0.01 and 0.05, respectively, whereas *sidewalk width and quality on chosen street* is insignificant at α = 0.05. While insignificant, *sidewalk width and quality on chosen street* still retains a correct coefficient sign based on the hypothesis that higher level of satisfaction with *sidewalk width and quality on chosen street* affects the *level of satisfaction with the walking environment* positively. Accordingly, the *level of satisfaction with the walking environment* for on-foot commuters is most influenced by *neighborhood attributes* and *diversity of activities*.

As for the part of the structural equation explaining the *level of satisfaction with the commute*, both, the latent variable *neighborhood attributes* (coef. = 0.278) and *travel time to AUB* (coef. = -0.389) are significant at α = 0.01. The other latent variables, *sidewalk width and quality on chosen street* and *diversity of activities* are both insignificant at α = 0.05.

Moreover, the three latent variables are fairly correlated with correlation values varying from 0.427 to 0.601.

Given that all observed and latent variables reflect satisfaction levels with the exception of *travel time to AUB*, it is hypothesized that all such factors and correlations are positive in value, with the exception of *travel time to AUB*, which is the case as presented in Figure 9.

7.3.2.2. NFC Model

Similarly, all estimates for the measurement relations in the NFC model are significant at $\alpha = 0.01$. *Sidewalk width and quality with chosen street* has, likewise, the highest loading coefficient amongst measurement equations with a value of 0.911 on satisfaction with *sidewalk quality on chosen street*. The lowest coefficient is that for the latent variable *neighborhood attributes*' loading on *vehicular traffic on streets* (0.594).

Explaining the *level of satisfaction with the walking environment*, the latent variables *neighborhood attributes* (coef. = 0.602) and *diversity of activities* (coef. = 0.219) are significant at $\alpha = 0.01$, whereas *sidewalk width and quality on chosen street* is insignificant at $\alpha = 0.05$. Therefore, similarly to the OFC model, the *level of satisfaction with the walking environment* for non-foot commuters is most influenced by *neighborhood attributes* and *diversity of activities*.

Also, the latent variables are fairly correlated with correlation values varying from 0.514 to 0.601.

As in the OFC case, parameter signs are hypothesized to be positive. This is the case for all factors and correlations with the exception of *sidewalk width and quality on chosen street*'s effect on the *level of satisfaction with the walking environment*. However, the latter variable is insignificant and, therefore, its coefficient is statistically equal to zero.

CHAPTER 8

DISCUSSION AND POLICY ANALYSIS

This chapter is a discussion of the results from the previous chapter, which involves discussing the results of the two latter models and comparing them as well as conducting policy analysis and proposing policy interventions.

8.1. Model Discussion

In the case of both, on-foot commuters and non-foot commuters, their *level of satisfaction with the walking environment* is most influenced by their satisfaction with *neighborhood attributes* followed by their satisfaction with *diversity of activities*. In addition, in the model for on-foot commuters, a correlation exists between the *level of satisfaction with the walking environment* and the *level of satisfaction with the commute*, where the latter is most influenced by the commuters' *travel time to AUB* and satisfaction with *neighborhood attributes*.

Given the difference in magnitudes, the *level of satisfaction with the walking environment* is more sensitive to the *neighborhood attributes* than it is to the other significant latent variables (whether for OFC or NFC). This indicates that, regardless of trip purpose, walkers of the neighborhood of AUB are highly sensitive to changes in the general aspects of the walking environment.

Level of satisfaction with the walking environment is affected by satisfaction with *diversity of activities* as well for both models, but to a lesser extent. In the model for on-foot commuters, the coefficient for the influence of *diversity of activities* on the *level of satisfaction with the walking* *environment* is 9.93% that of *neighborhood attributes* and 36.38% of the latter for non-foot commuters.

Contrary to the a priori hypothesis, however, the influence of satisfaction with *sidewalk width and quality on chosen street* on the *level of satisfaction with the walking environment* is insignificant. Normally, one would expect the physical aspects of the sidewalk, being the sidewalk width and quality, to be of high priority to pedestrians, whether on-foot commuters or non-foot commuters. Given the strong hypothesis regarding the significance of the latter influence and that sidewalk width and quality is a very important aspect of the walking environment to be overlooked, the latent variable for the satisfaction with *sidewalk width and quality on chosen street* was not excluded from the model. The fact that *sidewalk quality and width on chosen street* is insignificant may be explained by the reality that walking on sidewalks in Lebanon is an option rather than an obligation; walking on the sides of the road rather than the sidewalk is a norm to avoiding low-quality and narrow sidewalks. Another possible reason is the standing low expectations of younger Lebanese adults with regard to the quality of the infrastructure.

Additionally, previous versions of the model tested for the effect of gender on the *level of satisfaction with the walking environment* through the inclusion of *gender* dummy variables. Such dummy variables were later excluded from the model due to their insignificance. It is important to indicate, however, that the students are asked about their day-time trips. Therefore, the two models are representative of trips that are conducted during naturally lit and relatively crowded times of the day; concerns with safety are minimal, which may explain the insignificance of *gender*.

All in all, while the influence of different latent factors on *level of satisfaction with the walking environment* differs to a certain extent, the only major difference between the two models is the inclusion of the *level of satisfaction with the commute* for on-foot commuters as another dependent variable. However, looking solely at the *level of satisfaction with the walking environment*, the two models are fairly similar in that regard.

8.2. Policy Analysis

Given the fact that the exact values of latent variables are unknown, policy analysis is conducted based on deviations from the sample means of such variables. For instance, one can analyze the shift of *level of satisfaction with the walking environment* as a function of the satisfaction with *neighborhood attributes* and *diversity of activities*. The analysis would then allow studying the impact of the shift in either of the latter two on the *level of satisfaction with the walking environment*.

To more easily understand the shifts in these latent factors, one can think of the influence of such shifts on the observed variables. Looking at the latent factor for satisfaction with *diversity of activities* (denoted by *Act**) in the OFC model, the following are the measurement equations for the latent response variables depicting the level of satisfaction with *diversity of activities on Bliss Street* (act_B^*) and *diversity of activities on chosen street* (act_c^*). The errors of measurement are accordingly denoted as δ_{act_B} and δ_{act_c} and have a mean of zero.

$$\begin{bmatrix} act_B^* \\ act_c^* \end{bmatrix} = \begin{bmatrix} 0.886 \\ 0.664 \end{bmatrix} [Act^*] + \begin{bmatrix} \delta_{act_B} \\ \delta_{act_c} \end{bmatrix} \tag{39}$$

Accordingly, any 1 unit change in satisfaction with *diversity of activities* for an individual results in a change of 0.886 in the latent response variable depicting satisfaction with *diversity of* *activities on Bliss Street* and 0.664 in that depicting satisfaction with *diversity of activities on chosen street* for that individual.

While acknowledging the 7-point Likert scale used to measure satisfaction in this study (1 being *very dissatisfied*, 4 being *neutral* and 7 being *very satisfied*), one can get a sense of the meaning of the values assigned to the latent variables. For instance, having a specific value for the latent variable depicting satisfaction with *diversity of activities* and a drawn value for the respective error of measurement for *diversity of activities on Bliss Street*, equation (39) can be used to calculate the latent response variable for satisfaction with *diversity of activities on Bliss Street*. Equation (38) from Section 7.2.2 is then used to retrieve the observed level of satisfaction with *diversity of activities on Bliss Street* corresponding to the specified latent satisfaction with *diversity of activities*. Accordingly, for example, values in the range from -1.43 to -0.48 for the latent satisfaction with *diversity of activities* result in an average value of 4.00 for the satisfaction with *diversity of activities on Bliss Street* (Figure 19 in Appendix C-1). With 4.00 being the equivalent of a neutral level of satisfaction, values for the latent satisfaction with *diversity of activities* ranging from -1.43 and -0.48 can be explained as the values that coincide with *neutral* average level of satisfaction with *diversity of activities on Bliss Street*. Similarly values in the range from –0.96 to 0.18 for the latent satisfaction with *diversity of activities* coincide with a neutral value of 4.00 for the satisfaction with *diversity of activities on chosen street* (Figure 20 in Appendix C-1). Note that, to retrieve such values, errors of measurements are assumed to be equal to zero given that they theoretically converge to zero after sufficient draws. The variation of indicators as a function of the latent factors is represented graphically in Appendix C-1 (for OFC) and Appendix C-2 (for OMC).

It is important to point out that where the range of the latent variable is small for a given category of the observed variable, such as the case of a level of satisfaction equal to 3 for *diversity of activities on Bliss Street* in Figure 19 in Appendix C-1, then the observed variable is more sensitive to a change in the latent variable in that region given that the individual's satisfaction can more easily change from that level to another as a result of a shift in the latent variable. The opposite is true for larger ranges.

8.2.1. On-Foot Commuters

Figure 11 depicts the predicted *level of satisfaction with the walking environment* as a function of satisfaction with *neighborhood attributes* and *diversity of activities* for on-foot commuters.

Given the slope of the boundaries between every two categories for the *level of satisfaction with the walking environment*, it is apparent that the latter is more sensitive to changes in the satisfaction towards *neighborhood attributes* than *diversity of activities*. Similarly to the variation of indicators as a function of latent variables, as in the previous section, smaller ranges for a given *level of satisfaction with the walking environment* (or the Euclidean distance between the two boundaries of that level of satisfaction) entail higher sensitivity, at that level of satisfaction, towards changes in the latent variables as compared to other values for *level of satisfaction with the walking environment* with broader ranges.

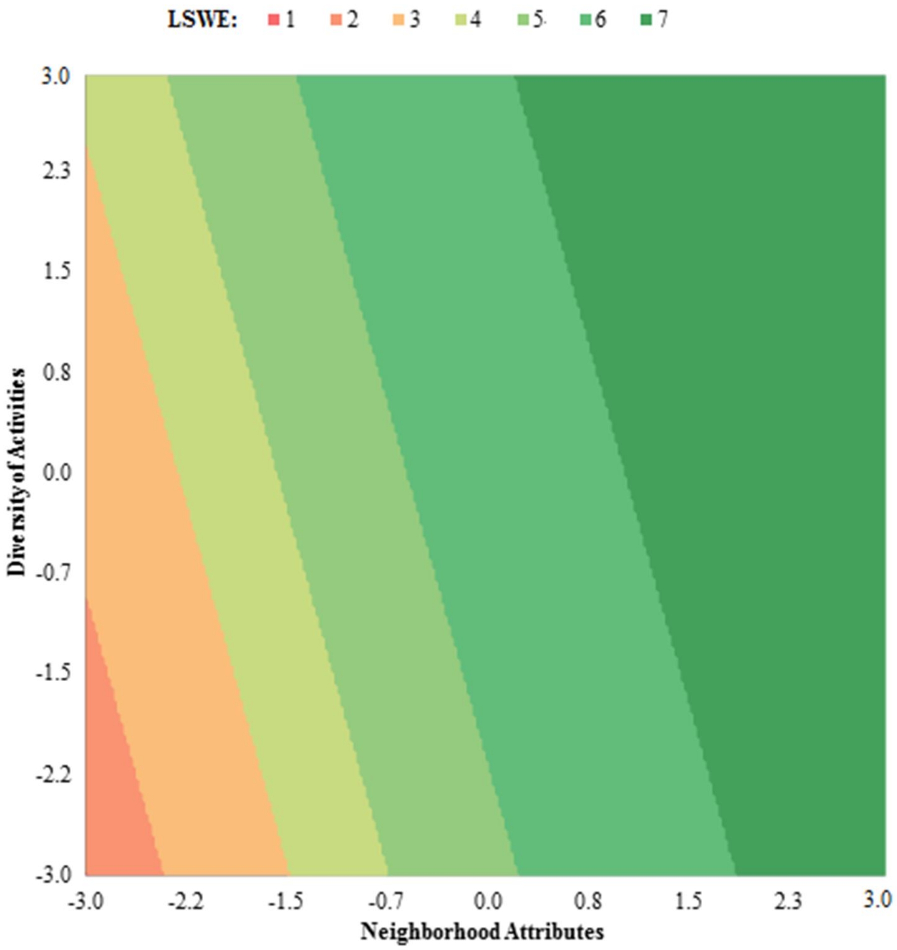


Figure 11: ***Level of Satisfaction with the Walking Environment*** **as a Function of Satisfaction with** ***Neighborhood Attributes*** **and** ***Diversity of Activities*** **for On-Foot Commuters**

For instance, in the above figure, the range for the *level of satisfaction with the walking environment* being equal to 4 is the narrowest. Accordingly, at that level of satisfaction, an individual is most sensitive to changes in satisfaction with *neighborhood attributes* and satisfaction with *diversity of activities*; that individual's *level of satisfaction with the walking environment* can, consequently, easily change from that level to another. The opposite is true for broader ranges.

For the case of on-foot commuters, the shift in *level of satisfaction with commute* can be observed similarly. Below is a plot of *level of satisfaction with commute* as a function of the significant factors in the model, *travel time to AUB* and satisfaction with *neighborhood attributes*.

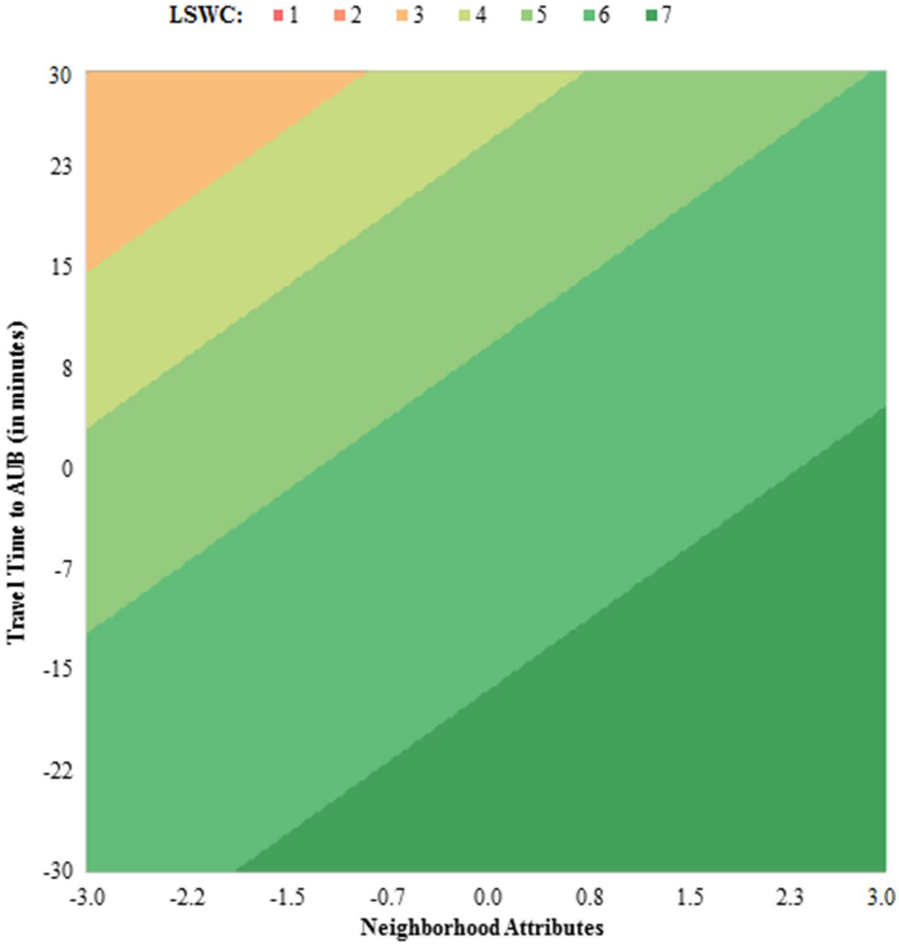


Figure 12: ***Level of Satisfaction with the Commute*** **as a Function of Satisfaction with N*eighborhood Attributes*** **and** ***Travel Time to AUB*** **for On-Foot Commuters**

The different units and scales for the two axes render a straightforward analysis based purely on boundary slope difficult. Furthermore, note that the values for travel time to AUB can be negative given that, as previously mentioned, travel time is included in the model in *deviations from the means* form. One notices, however, that the *level of satisfaction with commute* is generally high for on-foot commuters as previously indicated, only dropping below the neutral satisfaction value of 4 at extreme values of *travel time to AUB* and satisfaction with *neighborhood attributes*. Taking the boundaries of the neutral satisfaction level as an example, a shift of 1.63 units is required in satisfaction with *neighborhood attributes* to move from the upper boundary of the neutral *level of satisfaction with commute* to the lower boundary. As for the *travel time to AUB*, the latter is better thought of as a constant for every individual rather than a shifting value due to its dependence on location of residence and low variability given that such commutes are conducted on foot. However, looking at two different individuals while still taking the neutral *level of satisfaction with the commute* as an example, a 11.3 minute difference in commute travel time, all else constant, is present between the upper and lower boundaries of the *level of satisfaction with the commute*.

8.2.2. Non-Foot Commuters

The plot for the variation in *level of satisfaction with the walking environment* for non-foot commuters as a function of satisfaction with *neighborhood attributes* and *diversity of activities* for non-foot commuters is similar to that for on-foot commuters. The plot is shown in Figure 13.

Similarly to the case of on-foot commuters, *level of satisfaction with the walking environment* is more sensitive to changes in satisfaction with *neighborhood attributes* than it is to changes in satisfaction with *diversity of activities*. In the case of non-foot commuters, individuals are more sensitive to their satisfaction with *diversity of activities* as compared to on-foot commuters (Figure 11); for individuals who generally conduct on-foot trips for purposes other than commute (such as for shopping, eating, personal business, etc.), the diversity of activities becomes more of an important factor given the activity-oriented nature of these trips.

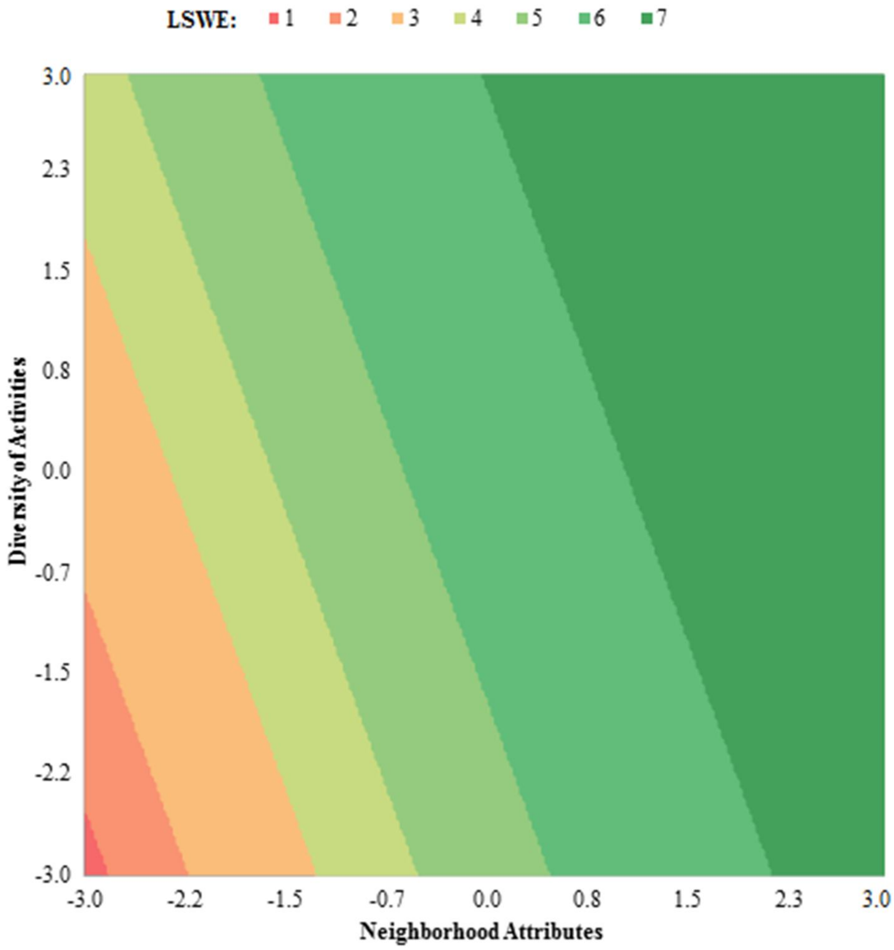


Figure 13: ***Level of Satisfaction with the Walking Environment*** **as a Function of Satisfaction with** ***Neighborhood Attributes*** **and** ***Diversity of Activities*** **for Non-Foot Commuters**

8.2.3. Policy Recommendations

Policy recommendations are based on the model results and policy analysis. Any form of intervention in order to improve the *level of satisfaction with the walking environment* and, accordingly, walkability needs to target either pedestrians who conduct their trips for commuting purposes (such as reaching AUB), pedestrians conducting day-time trips for other purposes or both at once. Interventions to improve the *level of satisfaction with the commute* target on-foot commuters.

8.2.3.1. Improving the Level of Satisfaction with the Walking Environment

Generally, given the high influence of *neighborhood attributes* on the *level of satisfaction with the walking environment* for both models, it is important to target the underlying elements of the latter latent variable in order to attain the greatest increase in satisfaction for both pedestrian populations. Furthermore, the magnitude of the factor loadings of *neighborhood attributes* on its indicators (refer to Figure 9 and Figure 10) suggests the extent to which changing these attributes would impact the *level of satisfaction with the walking environment* (even though the causality goes from the latent variables to their indicators, the latent variables can be extracted given the factor loadings; the higher the factor loading, the higher the association between a latent variable and the given indicator). For instance, in the case of OFC, improving the pedestrians' satisfaction with the condition of the sidewalk in terms of sidewalk blockage – intuitively, by decreasing sidewalk blockage – would lead to the greatest impact on their satisfaction with the walking environment whereas in the case of NFC, the highest loading is on the indicator *ease of pedestrian crossing*.

It is important to note, however, that adjusting some elements comes at more ease and lower costs than others. For instance, the *level of satisfaction with the walking environment* can be improved by improving both *ease of pedestrian crossing* and *cleanliness of the sidewalk*. Although improving the *ease of pedestrian crossing* would have a greater overall impact on the *level of satisfaction with the walking environment*, targeting *cleanliness of the sidewalk* would be an easier task returning positive results at lower costs. Such improvement, for instance, may be achieved through enhanced municipal supervision of the outsourced waste management company responsible for sidewalk cleanliness. Strictly banning motorcycles from driving against traffic – and enforcing this ban – would positively impact walkability at low costs as well by requiring basic traffic law enforcement.

Interventions targeting the diversity of activities in the neighborhood would, as well, impact the satisfaction with the walking environment for students who commute to AUB on foot and those who walk in the neighborhood for other trip purposes. Nonetheless, the impact would be small compared to interventions targeting *neighborhood attributes*. However, increase in satisfaction with *diversity of activities* can be achieved through the regulation and consolidation of activities, commercial and non-commercial, in the neighborhood.

As for interventions targeting the sidewalk quality or width, they do not have a significant impact on either of the two student populations as shown in Figure 9 and Figure 10. However, while acknowledging the insignificance of the latent variable, interventions targeting sidewalk quality and width are essential for enhancing the walking environment and are required in the long-run in order to accommodate increased pedestrian traffic resulting from a more walkable environment. However, given the context of the neighborhood of AUB, which mainly consists of narrow one-way streets and limited right-of-way and faces shortage of parking spaces, it may be too costly and not feasible to widen sidewalks along all street sections in the region. As such, interventions targeting *neighborhood attributes* need to be considered and may have the desired impact. Of such interventions, decreasing *sidewalk blockage*, which has a positive impact on the *level of satisfaction with the walking environment*, is the closest in nature to widening sidewalks by providing a larger effective sidewalk width without changing the overall width.

8.2.3.2. Improving the Level of Satisfaction with the Commute for On-Foot Commuters

In terms of *level of satisfaction with the commute* for on-foot commuters, the two significant variables are the latent level of satisfaction with *neighborhood attributes* and the observed *travel time to AUB*. Out of the two latter variables, only the first, level of satisfaction with *neighborhood attributes*, is controllable, whereas the second, *travel time to AUB*, is mainly dependent on place of residence and individual's walking speed with very little available room for improvement; even adjustment of signal timing at intersections will have very little impact as pedestrians tend to not abide by pedestrian crossing lights.

Accordingly, similarly to the *level of satisfaction with the walking environment*, the underlying elements of the level of satisfaction with the *neighborhood attributes* need to be targeted in order to attain an increase in satisfaction with the commute for on-foot commuters. The resulting improvement in satisfaction with the commute will be an automatic result of the policy recommendations targeting the *level of satisfaction with the walking environment* (as indicated in the previous section) by targeting the level of satisfaction with *neighborhood attributes*. This makes targeting level of satisfaction with *neighborhood attributes* an attractive policy recommendation given its major effect on the *level of satisfaction with the walking environment* for all pedestrians (OFC and NFC) as well as its effect on *level of satisfaction with the commute* for on-foot commuters.

The other latent variables, level of satisfaction with *sidewalk width and quality on chosen street* and with *diversity of activities*, have an insignificant impact on the *level of satisfaction with the commute*. However, while the area of study is quite diverse in activities, it is important to target sidewalk width and quality in the long-term regardless of its insignificant impact (as shown in

Figure 9 and Figure 10) in order to enhance the walking environment and accommodate any increase in pedestrian traffic.

CHAPTER 9

CONCLUSION

The topic of *walkability* has been of great interest to transportation and urban planning researchers due to the numerous benefits accrued as a result of increasing the share of trips conducted on foot. Such benefits not only span health benefits, but also social, environmental and economic benefits (Blaga, 2013).

This thesis provides a suitable framework, utilizing structural equation models, for studying and analyzing the latent elements affecting and influencing the level of satisfaction of pedestrians with different elements of the walking environment and their overall satisfaction with the walking environment. This thesis also examines, as a case study, the level of satisfaction of students with the walking environment in the neighborhood of the American University of Beirut (AUB) in the capital of Lebanon, Beirut. Given the generally poor walking conditions of the neighborhood, including but not limited to poor quality sidewalks and sidewalk infringement by shops, construction sites, large garbage bins and parked vehicles, there is a vital need to identify the most efficient intervention in order to increase people's level of satisfaction with the walking environment, which, in turn, would increase the rate of trips conducted on foot.

Based on data collected through a survey distributed to students of AUB, two structural equation models (SEM) have been developed to identify the elements of the walking environment with greatest impacts on the level of satisfaction with the walking environment. The first SEM targets frequent on-foot commuters while the second targets those who typically commute on foot for purposes other than commuting.

The study identifies that, for both, the first group and the second, general aspects of the walking environment, being the ease of pedestrian crossing, sidewalk blockage, cleanliness of sidewalk, vehicular traffic on streets and motorcycles going against traffic on one-way streets, have an apparent impact on the level of satisfaction with the walking environment. The latter, general aspects of the walking environment, also has a significant impact on the *level of satisfaction with the commute* for on-foot commuters. Diversifying activities along the streets serving the neighborhood has a positive impact on the *level of satisfaction with the walking environment* for both groups. As for sidewalk width and quality of streets leading to the university, they have an insignificant impact on the *level of satisfaction with the walking environment* for either group; nonetheless, it is important to target sidewalk width and quality in order to provide the suitable pedestrian infrastructure.

All in all, while acknowledging the elevated satisfaction of on-foot commuters with their commute compared to commuters of other modes, their satisfaction with the walking environment is close to neutral, indicating room for improvement. Improvements to the walking environment would not only target the current on-foot commuters, but also encourage additional walking trips overall, for on-foot commuters and non-commuters alike. Suggested policy interventions are therefore of great importance and priority to responsible and interested entities, being the government, municipality, planners or NGOs (non-governmental organizations) and to the population overall.

Accordingly, the following objectives have been accomplished in this study:

- quantifying the overall level of satisfaction with the walking environment based on the satisfaction with attributes of the walking environment

- identifying which of these attributes have an effect on the perceived overall satisfaction with the walking environment and to what extent
- using the model to get insights about prioritizing planning interventions to improve walkability

This study has several contributions. The first is adding to the literature of the yet developing topic of walkability. Furthermore, this paper contributes by providing results and a framework that can be extended to other locations and contexts. This study also contributes to literature on walkability specific to Lebanese context, which is close to absent. Qualitatively, the results of this study can be extended to different regions of Lebanon and cities of similar urban texture in developing countries, while quantitatively the results can be extended to neighborhoods in Lebanon and in developing countries as long as similarities in both, neighborhood nature and population characteristics, with AUB's neighborhood exist. As for the framework, given its flexible nature, it can be extended freely to any area of interest.

As for study limitations and extensions, one of the limitations is that some attributes of the walking environment have not been included as part of the study, such as sidewalk connectivity, block length, pedestrian volume, etc. This study is also mainly representative of the perception of young adults (university students) towards the walking environment and only of day-time trips.

Several future extensions to this study are possible. It is desirable to construct a model which is not only limited to subjective perceptions of the physical aspects of the walking environment, but one that also includes physical network measurements in the model alongside subjective perceptions. However, that would require greater variability in the physical network data as compared to the available data in this study, requiring that data collection be conducted on a larger number of streets and areas (as compared to a couple of streets in the Hamra area). Another extension is linking walkability and satisfaction with walkability to mode choice modeling in the context of either, commute or leisure trips. Furthermore, given the limitation that this study is mainly representative of students' perceptions, a follow up study could look into the perception of different population groups other than students.

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APPENDIX A

Table 13: Minimum, Maximum, Average and Average Effective Sidewalk Widths (in meters) (July and August, 2013)

Street	Min. Width	Max. Width	Avg. Width	Avg. Effective Width
Bliss St.	1.6	3.5	2.5	2.4
Omar Bin-Abdul Aziz St.	0.7	6.0	2.4	2.3
Jeanne d'Arc St.	1.1	7.0	2.3	1.8
Gandhi St.	1.0	5.4	2.0	1.8
Sadat St.	1.0	4.0	2.0	1.8

Table 14: Percent of Sidewalk Area Blocked by Obstacles (July and August, 2013)

Obstacle Type	Bliss St.	Omar Bin-Abdul Aziz St.	Jeanne d'Arc St.	Gandhi St.	Sadat St.
Bollards	2.60%	0.59%	3.04%	4.88%	3.35%
Electricity Poles	0.45%	0.53%	0.21%	0.38%	0.30%
Parking Meters	0.17%	0.20%	0.42%	0.15%	0.20%
Sign Posts	0.35%	0.82%	1.08%	0.64%	1.12%
Public Telephones	0.07%	0.06%	0.06%	0.00%	0.16%
Construction Site Infringement	0.49%	1.08%	11.16%	0.00%	0.00%
Shop Infringement	1.39%	0.51%	2.03%	4.39%	1.07%
Trash Bins	0.11%	0.14%	0.13%	0.03%	0.00%
Trees	0.09%	0.21%	0.00%	0.39%	0.27%
Other (Non-Permanent Obstacles)	0.70%	1.71%	0.49%	0.81%	1.83%
Other (Permanent Obstacles)	0.16%	0.98%	1.58%	0.34%	0.80%
Total	**6.57%**	**6.82%**	**20.20%**	**12.01%**	**9.10%**

APPENDIX B

Table 15: Exploratory Factor Analysis with Seven Factors for On-Foot Commuters

Indicator	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
ease of pedestrian crossing [s,0]	-0.164	0.283		0.405		0.183	
sidewalk blockage [s,0]		0.144	-0.390	0.228		0.196	-0.210
cleanliness of the sidewalk [s,0]		0.305	-0.145	0.215			
vehicular traffic on streets [s,0]	-0.130			0.854			
traffic noise [s,0]			0.109	0.987			0.127
traffic fumes [s,0]	0.104			0.833		-0.151	0.108
motorcycles going against traffic on one-way streets [s,0]			-0.155	0.465			
sidewalk width[s,1]	0.105	0.370		0.130			-0.267
sidewalk quality and evenness [s,1]	0.149	0.429		0.136	0.128		-0.293
diversity of activities [s,1]		0.460	0.104			-0.156	
trees and greenery [s,1]		0.968			-0.197	0.187	
proportion of shadowed sidewalk [s,1]		0.797			-0.101		
buildings with entrance door access [b,1]	0.247		-0.152			0.558	0.102
parking access across the sidewalk [b,1]		0.144		-0.110		0.593	0.272
bollards on the sidewalk [b,1]	0.159		0.178	0.108	0.181	0.292	0.591
parking meters on the sidewalk [b,1]	0.786		-0.148	0.142	-0.109	-0.118	0.531
public phones on the sidewalk [b,1]	0.632		-0.299			0.151	0.309
sign posts on the sidewalk [b,1]	0.430	0.108				0.311	0.392
cars parked on or blocking the sidewalk [b,1]	-0.177		0.765	0.109			0.334
sidewalk infringement by shops [b,1]			0.472	0.103	-0.104	0.239	0.143
electricity poles on the sidewalk [b,1]	0.475	-0.114	0.207		0.134	0.163	
large trash bins [b,1]		-0.245	0.460	0.129		0.107	

[s] indicator of satisfaction level
[b] indicator of bother level
[0] at a neighborhood level
[1] on Bliss street
[2] on chosen street

Table 15 (cond't): Exploratory Factor Analysis with Seven Factors for On-Foot Commuters

Indicator	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
sidewalk width[s,2]			-0.101		0.868		0.101
sidewalk quality and evenness [s,2]					0.826		
diversity of activities [s,2]		0.493	0.220	-0.157	0.243	-0.242	
trees and greenery [s,2]		0.832					0.171
proportion of shadowed sidewalk [s,2]		0.704			0.130		
buildings with entrance door access [b,2]	0.543					0.277	-0.123
parking access across the sidewalk [b,2]	0.432	0.123		-0.117		0.307	
bollards on the sidewalk [b,2]	0.660		0.206				0.126
parking meters on the sidewalk [b,2]	1.05					-0.354	0.195
public phones on the sidewalk [b,2]	0.940		-0.115			-0.152	
sign posts on the sidewalk [b,2]	0.789						
cars parked on or blocking the sidewalk [b,2]		0.165	0.888			-0.168	
sidewalk infringement by shops [b,2]	0.259	0.103	0.570		-0.163		-0.182
electricity poles on the sidewalk [b,2]	0.703	-0.118	0.267				-0.210
large trash bins [b,2]	0.144		0.611		0.126		

[s] indicator of satisfaction level
[b] indicator of bother level
[0] at a neighborhood level
[1] on Bliss street
[2] on chosen street

Table 16: Exploratory Factor Analysis with Seven Factors for Non-Foot Commuters

Indicator	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
ease of pedestrian crossing [s,0]			0.294	0.299	0.205		
sidewalk blockage [s,0]		-0.221	0.370	0.220	0.219	-0.117	
cleanliness of the sidewalk [s,0]			0.299	0.192	0.250		
vehicular traffic on streets [s,0]			0.758				
traffic noise [s,0]			0.953	-0.105			
traffic fumes [s,0]	-0.127		0.875	-0.105			
motorcycles going against traffic on one-way streets [s,0]		-0.254	0.558				

[s] indicator of satisfaction level
[b] indicator of bother level
[0] at a neighborhood level
[1] on Bliss street
[2] on chosen street

Table 16 (cond't): Exploratory Factor Analysis with Seven Factors for Nn-Foot Commuters

Indicator	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
sidewalk width^{s,1}	0.116		-0.107	0.928			
sidewalk quality and evenness ^{s,1}				0.831	0.112		
diversity of activities ^{s,1}	-0.222	0.196		0.341		0.238	
trees and greenery ^{s,1}	0.146		0.134	0.265	-0.221	0.614	
proportion of shadowed sidewalk ^{s,1}				0.332	-0.266	0.610	
buildings with entrance door access ^{b,1}	0.253	-0.111			0.108		0.578
parking access across the sidewalk ^{b,1}		0.133					0.726
bollards on the sidewalk ^{b,1}	0.506	0.135					0.193
parking meters on the sidewalk ^{b,1}	0.637	-0.102			0.101	-0.139	0.159
public phones on the sidewalk ^{b,1}	0.806	-0.200					0.101
sign posts on the sidewalk ^{b,1}	0.783	-0.102					
cars parked on or blocking the sidewalk ^{b,1}	-0.285	0.831					0.141
sidewalk infringement by shops ^{b,1}		0.522					0.102
electricity poles on the sidewalk ^{b,1}	0.483	0.293		-0.105			
large trash bins ^{b,1}		0.578				-0.112	
sidewalk widths,2			-0.131	0.107	0.865		
sidewalk quality and evenness s,2					0.818		
diversity of activities s,2		0.224		0.108	0.368	0.168	
trees and greenery s,2				-0.277	0.365	0.664	
proportion of shadowed sidewalk s,2				-0.148	0.272	0.608	
buildings with entrance door access b,2	0.455						0.384
parking access across the sidewalk b,2	0.239	0.182					0.546
bollards on the sidewalk b,2	0.680						
parking meters on the sidewalk b,2	0.806						
public phones on the sidewalk b,2	0.931	-0.116				0.144	
sign posts on the sidewalk b,2	0.944					0.111	-0.180
cars parked on or blocking the sidewalk b,2	-0.124	0.862					
sidewalk infringement by shops b,2	0.180	0.522					
electricity poles on the sidewalk b,2	0.581	0.343		-0.176			-0.190
large trash bins b,2	0.160	0.596	0.121			-0.111	

[s] indicator of satisfaction level
[b] indicator of bother level
[0] at a neighborhood level
[1] on Bliss street
[2] on chosen street

Table 17: Confirmatory Factor Analysis Model for On-Foot Commuters (OFC)

Fit Indices (robust):				
chi-squared test statistic	1683.282			
degrees of freedom	643			
relative chi-squared	2.62			
comparative fit index (CFI)	0.783			
Tucker-Lewis Index (TLI)	0.775			
root mean square error of approximation (RMSEA)	0.081			

Measurement Model:	Estimate	Std.err	Z-value	P(>|z|)
neighborhood attributes →				
ease of pedestrian crossing	1.10	0.0834	13.227	0.000
sidewalk blockage	0.772	0.0886	8.714	0.000
cleanliness of the sidewalk	0.590	0.119	4.974	0.000
vehicular traffic on streets	1.11	0.0815	13.681	0.000
traffic noise	1.05	0.0795	13.162	0.000
traffic fumes	0.989	0.0806	12.269	0.000
motorcycles going against traffic on one-way streets	0.765	0.0860	8.888	0.000
sidewalk width and quality on Bliss street →				
sidewalk width on Bliss street	1.28	0.0767	16.652	0.000
sidewalk quality on Bliss street	1.50	0.0686	21.822	0.000
sidewalk width and quality on chosen street →				
sidewalk width on chosen street	0.871	0.0305	28.603	0.000
sidewalk quality on chosen street	0.957	0.0286	33.503	0.000
diversity of activities →				
diversity of activities on Bliss Street	0.886	0.0540	16.426	0.000
diversity of activities on chosen street	0.663	0.0509	13.022	0.000
greenery and cleanliness →				
cleanliness of the sidewalk	0.492	0.114	4.300	0.000
trees and greenery on Bliss Street	1.31	0.0869	15.087	0.000
proportion of shadowed sidewalk on Bliss Street	1.28	0.0781	16.355	0.000
trees and greenery on chosen street	1.15	0.0802	14.323	0.000
proportion of shadowed sidewalk on chosen street	1.16	0.0850	13.621	0.000

Table 15 (cont'd): Confirmatory Factor Analysis Model for On-Foot Commuters (OFC)

Measurement Model:	Estimate	Std.err	Z-value	P(>|z|)
bother with sidewalk obstacles →				
buildings with entrance door access on Bliss Street	0.813	0.102	7.995	0.000
parking access across the sidewalk on Bliss Street	1.00	0.109	9.209	0.000
bollards on the sidewalk on Bliss Street	0.934	0.111	8.441	0.000
parking meters on the sidewalk on Bliss Street	1.22	0.101	12.111	0.000
public phones on the sidewalk on Bliss Street	0.931	0.106	8.810	0.000
sign posts on the sidewalk on Bliss Street	1.10	0.0970	11.331	0.000
electricity poles on the sidewalk on Bliss Street	1.21	0.0893	13.530	0.000
buildings with entrance door access on chosen street	1.22	0.117	10.453	0.000
parking access across the sidewalk on chosen street	1.28	0.0993	12.846	0.000
bollards on the sidewalk on chosen street	1.35	0.0973	13.905	0.000
parking meters on the sidewalk on chosen street	1.55	0.0834	18.560	0.000
public phones on the sidewalk on chosen street	1.23	0.103	11.962	0.000
sign posts on the sidewalk on chosen street	1.51	0.0814	18.565	0.000
electricity poles on the sidewalk on chosen street	1.37	0.0942	14.571	0.000
sidewalk blockage and infringement →				
sidewalk blockage	-0.521	0.100	-5.193	0.000
cars parked on or blocking the sidewalk on Bliss Street	1.18	0.108	10.912	0.000
sidewalk infringement by shops on Bliss Street	1.26	0.102	12.353	0.000
large trash bins on Bliss Street	1.12	0.113	9.877	0.000
cars parked on or blocking the sidewalk on chosen street	1.47	0.106	13.866	0.000
sidewalk infringement by shops on chosen street	1.45	0.0995	14.557	0.000
large trash bins on chosen street	1.37	0.107	12.793	0.000

Covariances:	Estimate	Std.err	Z-value	P(>|z|)
neighborhood attributes ↔				
sidewalk width and quality on Bliss street	0.593	0.0490	12.089	0.000
sidewalk width and quality on chosen street	0.485	0.0685	7.076	0.000
diversity of activities	0.341	0.0721	4.735	0.000
greenery and cleanliness	0.532	0.0621	8.557	0.000
bother with sidewalk obstacles	-0.254	0.0645	-3.938	0.000
sidewalk blockage and infringement	-0.466	0.0638	-7.311	0.000
sidewalk width and quality on Bliss street ↔				
sidewalk width and quality on chosen street	0.547	0.0656	8.344	0.000
diversity of activities	0.507	0.0719	7.059	0.000
greenery and cleanliness	0.637	0.0550	11.577	0.000
bother with sidewalk obstacles	-0.136	0.0775	-1.757	0.079
sidewalk blockage and infringement	-0.391	0.0680	-5.757	0.000

Table 15 (cont'd): Confirmatory Factor Analysis Model for On-Foot Commuters (OFC)

Covariances:	Estimate	Std.err	Z-value	P(>|z|)
sidewalk width and quality on chosen street ↔				
diversity of activities	0.500	0.0716	6.986	0.000
greenery and cleanliness	0.588	0.0690	8.521	0.000
bother with sidewalk obstacles	-0.252	0.0718	-3.510	0.000
sidewalk blockage and infringement	-0.498	0.0601	-8.284	0.000
diversity of activities ↔				
greenery and cleanliness	0.593	0.0691	8.577	0.000
bother with sidewalk obstacles	-0.307	0.0800	-3.839	0.000
sidewalk blockage and infringement	-0.356	0.0756	-4.706	0.000
greenery and cleanliness ↔				
bother with sidewalk obstacles	-0.194	0.0790	-2.458	0.014
sidewalk blockage and infringement	-0.464	0.0668	-6.950	0.000
bother with sidewalk obstacles ↔				
sidewalk blockage and infringement	0.520	0.0548	9.485	0.000

Variances:	Estimate	Std.err	Z-value	P(>|z|)
Latent Variables				
neighborhood attributes	1.00	-	-	-
sidewalk width and quality on Bliss street	1.00	-	-	-
sidewalk width and quality on chosen street	1.00	-	-	-
diversity of activities	1.00	-	-	-
greenery and cleanliness	1.00	-	-	-
bother with sidewalk obstacles	1.00	-	-	-
sidewalk blockage and infringement	1.00	-	-	-

Table 15 (cont'd): Confirmatory Factor Analysis Model for On-Foot Commuters (OFC)

Variances:	Estimate	Std.err	Z-value	P(>|z|)
Observed Variables				
ease of pedestrian crossing	1.54	0.154	10.003	0.000
sidewalk blockage	1.06	0.113	9.406	0.000
cleanliness of the sidewalk	1.57	0.157	10.008	0.000
vehicular traffic on streets	0.862	0.113	7.652	0.000
traffic noise	0.684	0.0938	7.287	0.000
traffic fumes	0.671	0.134	5.023	0.000
motorcycles going against traffic on one-way streets	0.868	0.158	5.482	0.000
sidewalk width on Bliss street	0.872	0.133	6.567	0.000
sidewalk quality on Bliss street	0.286	0.131	2.185	0.029
sidewalk width on chosen street	0.593	0.182	3.264	0.001
sidewalk quality on chosen street	0.367	0.133	2.767	0.006
diversity of activities on Bliss Street	0.858	0.176	4.865	0.000
diversity of activities on chosen street	1.11	0.179	6.211	0.000
trees and greenery on Bliss Street	1.43	0.195	7.331	0.000
proportion of shadowed sidewalk on Bliss Street	0.958	0.124	7.716	0.000
trees and greenery on chosen street	1.05	0.128	8.194	0.000
proportion of shadowed sidewalk on chosen street	1.18	0.169	6.965	0.000
buildings with entrance door access on Bliss Street	1.64	0.159	10.365	0.000
parking access across the sidewalk on Bliss Street	2.57	0.245	10.481	0.000
bollards on the sidewalk on Bliss Street	2.68	0.252	10.625	0.000
parking meters on the sidewalk on Bliss Street	1.86	0.260	7.145	0.000
public phones on the sidewalk on Bliss Street	1.32	0.145	9.073	0.000
sign posts on the sidewalk on Bliss Street	1.49	0.226	6.603	0.000
electricity poles on the sidewalk on Bliss Street	1.74	0.193	9.032	0.000
buildings with entrance door access on chosen street	1.71	0.229	7.444	0.000
parking access across the sidewalk on chosen street	1.91	0.233	8.161	0.000
bollards on the sidewalk on chosen street	1.66	0.244	6.804	0.000
parking meters on the sidewalk on chosen street	1.00	0.186	5.368	0.000
public phones on the sidewalk on chosen street	1.04	0.172	6.044	0.000
sign posts on the sidewalk on chosen street	0.825	0.133	6.186	0.000
electricity poles on the sidewalk on chosen street	1.57	0.195	8.078	0.000
cars parked on or blocking the sidewalk on Bliss Street	1.95	0.236	8.260	0.000
sidewalk infringement by shops on Bliss Street	2.21	0.223	9.915	0.000
large trash bins on Bliss Street	2.90	0.267	10.872	0.000
cars parked on or blocking the sidewalk on chosen street	2.05	0.254	8.087	0.000
sidewalk infringement by shops on chosen street	2.11	0.215	9.832	0.000
large trash bins on chosen street	2.63	0.268	9.805	0.000

Table 18: Confirmatory Factor Analysis Model for On-Foot Commuters (OFC)

Fit Indices (robust):				
chi-squared test statistic	2774.315			
degrees of freedom	643			
relative chi-squared	4.31			
comparative fit index (CFI)	0.745			
Tucker-Lewis Index (TLI)	0.735			
root mean square error of approximation (RMSEA)	0.087			
Measurement Model:	Estimate	Std.err	Z-value	P(>|z|)
neighborhood attributes →				
ease of pedestrian crossing	0.905	0.0649	13.962	0.000
sidewalk blockage	0.831	0.0767	10.834	0.000
cleanliness of the sidewalk	0.680	0.0973	6.984	0.000
vehicular traffic on streets	0.947	0.0622	15.218	0.000
traffic noise	1.10	0.0608	18.061	0.000
traffic fumes	1.08	0.0582	18.631	0.000
motorcycles going against traffic on one-way streets	0.890	0.0740	12.020	0.000
sidewalk width and quality on Bliss street →				
sidewalk width on Bliss street	1.36	0.0585	23.256	0.000
sidewalk quality on Bliss street	1.46	0.0522	27.959	0.000
sidewalk width and quality on chosen street →				
sidewalk width on chosen street	1.34	0.0707	18.922	0.000
sidewalk quality on chosen street	1.34	0.0630	21.220	0.000
diversity of activities →				
diversity of activities on Bliss Street	0.955	0.0958	9.968	0.000
diversity of activities on chosen street	0.902	0.0749	12.052	0.000
greenery and cleanliness →				
cleanliness of the sidewalk	0.339	0.102	3.321	0.001
trees and greenery on Bliss Street	1.26	0.0639	19.660	0.000
proportion of shadowed sidewalk on Bliss Street	1.02	0.0646	15.787	0.000
trees and greenery on chosen street	0.824	0.0680	12.121	0.000
proportion of shadowed sidewalk on chosen street	0.766	0.0683	11.214	0.000

Table 15 (cont'd): Confirmatory Factor Analysis Model for On-Foot Commuters (OFC)

Measurement Model:	Estimate	Std.err	Z-value	P(>|z|)
bother with sidewalk obstacles →				
buildings with entrance door access on Bliss Street	0.947	0.0764	12.400	0.000
parking access across the sidewalk on Bliss Street	1.07	0.0750	14.216	0.000
bollards on the sidewalk on Bliss Street	1.26	0.0675	18.649	0.000
parking meters on the sidewalk on Bliss Street	1.31	0.0705	18.636	0.000
public phones on the sidewalk on Bliss Street	1.21	0.0721	16.732	0.000
sign posts on the sidewalk on Bliss Street	1.19	0.0711	16.660	0.000
electricity poles on the sidewalk on Bliss Street	1.11	0.0788	14.120	0.000
buildings with entrance door access on chosen street	1.22	0.0695	17.476	0.000
parking access across the sidewalk on chosen street	1.23	0.0706	17.403	0.000
bollards on the sidewalk on chosen street	1.40	0.0624	22.403	0.000
parking meters on the sidewalk on chosen street	1.46	0.0607	24.099	0.000
public phones on the sidewalk on chosen street	1.32	0.0730	18.050	0.000
sign posts on the sidewalk on chosen street	1.31	0.0673	19.396	0.000
electricity poles on the sidewalk on chosen street	1.26	0.0771	16.404	0.000
sidewalk blockage and infringement →				
sidewalk blockage	-0.266	0.0688	-3.867	0.000
cars parked on or blocking the sidewalk on Bliss Street	1.36	0.0810	16.848	0.000
sidewalk infringement by shops on Bliss Street	1.28	0.0780	16.371	0.000
large trash bins on Bliss Street	1.06	0.0957	11.112	0.000
cars parked on or blocking the sidewalk on chosen street	1.60	0.0713	22.398	0.000
sidewalk infringement by shops on chosen street	1.41	0.0712	19.858	0.000
large trash bins on chosen street	1.15	0.100	11.480	0.000

Covariances:	Estimate	Std.err	Z-value	P(>|z|)
neighborhood attributes ↔				
sidewalk width and quality on Bliss street	0.532	0.0425	12.518	0.000
sidewalk width and quality on chosen street	0.427	0.0506	8.443	0.000
diversity of activities	0.371	0.0613	6.047	0.000
greenery and cleanliness	0.525	0.0520	10.097	0.000
bother with sidewalk obstacles	-0.259	0.0500	-5.192	0.000
sidewalk blockage and infringement	-0.437	0.0556	-7.858	0.000
sidewalk width and quality on Bliss street ↔				
sidewalk width and quality on chosen street	0.552	0.0458	12.071	0.000
diversity of activities	0.590	0.0582	10.143	0.000
greenery and cleanliness	0.636	0.0477	13.343	0.000
bother with sidewalk obstacles	-0.216	0.0522	-4.133	0.000
sidewalk blockage and infringement	-0.314	0.0540	-5.819	0.000

Table 15 (cont'd): Confirmatory Factor Analysis Model for On-Foot Commuters (OFC)

Covariances:	Estimate	Std.err	Z-value	P(>|z|)
sidewalk width and quality on chosen street ↔				
diversity of activities	0.505	0.0575	8.780	0.000
greenery and cleanliness	0.423	0.0545	7.762	0.000
bother with sidewalk obstacles	-0.168	0.0593	-2.842	0.004
sidewalk blockage and infringement	-0.315	0.0570	-5.527	0.000
diversity of activities ↔				
greenery and cleanliness	0.590	0.0651	9.055	0.000
bother with sidewalk obstacles	-0.251	0.0733	-3.420	0.001
sidewalk blockage and infringement	-0.0970	0.0768	-1.263	0.207
greenery and cleanliness ↔				
bother with sidewalk obstacles	-0.128	0.0614	-2.080	0.037
sidewalk blockage and infringement	-0.333	0.0584	-5.696	0.000
bother with sidewalk obstacles ↔				
sidewalk blockage and infringement	0.448	0.0429	10.449	0.000
Variances:	Estimate	Std.err	Z-value	P(>|z|)
Latent Variables				
neighborhood attributes	1.00	-	-	-
sidewalk width and quality on Bliss street	1.00	-	-	-
sidewalk width and quality on chosen street	1.00	-	-	-
diversity of activities	1.00	-	-	-
greenery and cleanliness	1.00	-	-	-
bother with sidewalk obstacles	1.00	-	-	-
sidewalk blockage and infringement	1.00	-	-	-

Table 15 (cont'd): Confirmatory Factor Analysis Model for On-Foot Commuters (OFC)

Variances:	Estimate	Std.err	Z-value	P(>|z|)
Observed Variables				
ease of pedestrian crossing	1.88	0.115	16.402	0.000
sidewalk blockage	1.24	0.110	11.343	0.000
cleanliness of the sidewalk	1.66	0.122	13.557	0.000
vehicular traffic on streets	0.913	0.0892	10.238	0.000
traffic noise	0.541	0.0649	8.326	0.000
traffic fumes	0.516	0.0687	7.504	0.000
motorcycles going against traffic on one-way streets	1.10	0.121	9.041	0.000
sidewalk width on Bliss street	1.01	0.120	8.411	0.000
sidewalk quality on Bliss street	0.400	0.0962	4.161	0.000
sidewalk width on chosen street	0.775	0.143	5.412	0.000
sidewalk quality on chosen street	0.458	0.104	4.403	0.000
diversity of activities on Bliss Street	1.12	0.153	7.336	0.000
diversity of activities on chosen street	1.43	0.133	10.761	0.000
trees and greenery on Bliss Street	1.12	0.122	9.154	0.000
proportion of shadowed sidewalk on Bliss Street	0.938	0.0875	10.720	0.000
trees and greenery on chosen street	1.40	0.126	11.091	0.000
proportion of shadowed sidewalk on chosen street	1.48	0.113	13.038	0.000
buildings with entrance door access on Bliss Street	1.79	0.162	11.109	0.000
parking access across the sidewalk on Bliss Street	2.36	0.168	14.048	0.000
bollards on the sidewalk on Bliss Street	1.73	0.141	12.212	0.000
parking meters on the sidewalk on Bliss Street	1.78	0.182	9.761	0.000
public phones on the sidewalk on Bliss Street	1.08	0.102	10.600	0.000
sign posts on the sidewalk on Bliss Street	1.36	0.151	9.024	0.000
electricity poles on the sidewalk on Bliss Street	2.38	0.193	12.324	0.000
buildings with entrance door access on chosen street	1.53	0.159	9.575	0.000
parking access across the sidewalk on chosen street	1.92	0.153	12.587	0.000
bollards on the sidewalk on chosen street	1.36	0.133	10.243	0.000
parking meters on the sidewalk on chosen street	1.23	0.137	8.983	0.000
public phones on the sidewalk on chosen street	1.08	0.123	8.797	0.000
sign posts on the sidewalk on chosen street	1.21	0.134	8.984	0.000
electricity poles on the sidewalk on chosen street	2.47	0.216	11.463	0.000
cars parked on or blocking the sidewalk on Bliss Street	1.41	0.141	10.025	0.000
sidewalk infringement by shops on Bliss Street	2.22	0.175	12.697	0.000
large trash bins on Bliss Street	2.79	0.210	13.306	0.000
cars parked on or blocking the sidewalk on chosen street	1.50	0.140	10.696	0.000
sidewalk infringement by shops on chosen street	2.17	0.164	13.182	0.000
large trash bins on chosen street	3.10	0.241	12.907	0.000

Table 19: Final Structural Equation Model for On-Foot Commuters (OFC)

	Estimate	Std.err	Z-value	P(>|z|)
Fit Indices (robust):				
chi-squared test statistic	93.663			
degrees of freedom	46			
relative chi-squared	2.04			
comparative fit index (CFI)	0.987			
Tucker-Lewis Index (TLI)	0.981			
root mean square error of approximation (RMSEA)	0.065			
Measurement Model:	Estimate	Std.err	Z-value	P(>|z|)
neighborhood attributes →				
ease of pedestrian crossing	0.819	0.0268	30.560	0.000
sidewalk blockage	0.871	0.0244	35.673	0.000
cleanliness of the sidewalk	0.647	0.0384	16.869	0.000
vehicular traffic on streets	0.642	0.0371	17.309	0.000
motorcycles going against traffic on one-way streets	0.687	0.0411	16.690	0.000
sidewalk width and quality on chosen street →				
sidewalk width on chosen street	0.871	0.0305	28.603	0.000
sidewalk quality on chosen street	0.957	0.0286	33.503	0.000
diversity of activities →				
diversity of activities on Bliss Street	0.886	0.0540	16.426	0.000
diversity of activities on chosen street	0.663	0.0509	13.022	0.000
Structural Model:	Estimate	Std.err	Z-value	P(>|z|)
level of satisfaction with the walking environment ←				
neighborhood attributes	0.614	0.0601	10.228	0.000
sidewalk width and quality on chosen street	0.0608	0.0647	0.940	0.347
diversity of activities	0.171	0.0671	2.545	0.011
level of satisfaction with the commute ←				
neighborhood attributes	0.278	0.0939	2.961	0.003
sidewalk width and quality on chosen street	0.0247	0.0905	0.273	0.785
diversity of activities	0.0255	0.0812	0.314	0.753
travel time to AUB	-0.389	0.0623	-6.233	0.000

Table 15 (cont'd): Final Structural Equation Model for On-Foot Commuters (OFC)

Covariances:	Estimate	Std.err	Z-value	P(>|z|)
neighborhood attributes ↔				
sidewalk width and quality on chosen street	0.601	0.0405	14.857	0.000
diversity of activities	0.427	0.0569	7.510	0.000
sidewalk width and quality on chosen street ↔				
diversity of activities	0.506	0.0486	10.408	0.000
level of satisfaction with the walking environment ↔				
level of satisfaction with the commute	0.226	-	-	-
Variances:	Estimate	Std.err	Z-value	P(>|z|)
Latent Variables				
neighborhood attributes	1.00	-	-	-
sidewalk width and quality on chosen street	1.00	-	-	-
diversity of activities	1.00	-	-	-
Observed Variables				
level of satisfaction with walking environment	0.445	-	-	-
level of satisfaction with commute	0.906	-	-	-
ease of pedestrian crossing	0.329	-	-	-
sidewalk blockage	0.241	-	-	-
cleanliness of the sidewalk	0.581	-	-	-
vehicular traffic on streets	0.588	-	-	-
motorcycles going against traffic on one-way streets	0.529	-	-	-
sidewalk width on chosen street	0.241	-	-	-
sidewalk quality on chosen street	0.0844	-	-	-
diversity of activities on Bliss Street	0.214	-	-	-
diversity of activities on chosen street	0.560	-	-	-
Threshold Model:	Estimate	Std.err	Z-value	P(>|z|)
level of satisfaction with walking environment				
τ_1	-1.33	0.111	-12.010	0.000
τ_2	-0.744	0.0886	-8.401	0.000
τ_3	-0.162	0.0807	-2.007	0.045
τ_4	0.0729	0.0799	0.913	0.361
τ_5	0.615	0.0852	7.224	0.000
τ_6	1.75	0.147	11.896	0.000

Table 15 (cont'd): Final Structural Equation Model for On-Foot Commuters (OFC)

Threshold Model:	Estimate	Std.err	Z-value	P(>|z|)
level of satisfaction with commute				
τ_1	-2.36	0.215	-10.950	0.000
τ_2	-2.00	0.170	-11.806	0.000
τ_3	-1.42	0.116	-12.213	0.000
τ_4	-0.964	0.0928	-10.387	0.000
τ_5	-0.367	0.0833	-4.398	0.000
τ_6	0.636	0.0903	7.040	0.000
ease of pedestrian crossing				
τ_1	-1.13	0.103	-11.035	0.000
τ_2	-0.528	0.0839	-6.296	0.000
τ_3	0.0728	0.0800	0.910	0.363
τ_4	0.407	0.0818	4.974	0.000
τ_5	0.990	0.0957	10.346	0.000
τ_6	2.26	0.221	10.216	0.000
sidewalk blockage				
τ_1	-0.553	0.0844	-6.549	0.000
τ_2	0.0201	0.0798	0.251	0.802
τ_3	0.713	0.0876	8.142	0.000
τ_4	0.957	0.0948	10.086	0.000
τ_5	1.62	0.134	12.152	0.000
τ_6	2.65	0.353	7.515	0.000
cleanliness of the sidewalk				
τ_1	-1.06	0.0984	-10.747	0.000
τ_2	-0.287	0.081	-3.544	0.000
τ_3	0.276	0.0809	3.418	0.001
τ_4	0.753	0.0885	8.502	0.000
τ_5	1.28	0.111	11.526	0.000
τ_6	2.14	0.202	10.604	0.000
vehicular traffic on streets				
τ_1	-0.867	0.0919	-9.424	0.000
τ_2	-0.193	0.0804	-2.397	0.017
τ_3	0.363	0.0816	4.447	0.000
τ_4	1.21	0.105	11.551	0.000
τ_5	1.52	0.124	12.265	0.000
τ_6	2.26	0.227	9.972	0.000

Table 15 (cont'd): Final Structural Equation Model for On-Foot Commuters (OFC)

Threshold Model:	Estimate	Std.err	Z-value	P(>|z|)
motorcycles going against traffic on one-way streets				
τ_1	0.0926	0.0806	1.150	0.250
τ_2	0.644	0.0862	7.470	0.000
τ_3	1.36	0.113	12.008	0.000
τ_4	1.81	0.148	12.194	0.000
τ_5	2.15	0.198	10.883	0.000
τ_6	2.26	0.220	10.281	0.000
sidewalk width on chosen street				
τ_1	-0.958	0.0951	-10.071	0.000
τ_2	-0.174	0.0806	-2.155	0.031
τ_3	0.319	0.0815	3.916	0.000
τ_4	0.795	0.0895	8.881	0.000
τ_5	1.43	0.118	12.100	0.000
sidewalk quality on chosen street				
τ_1	-0.881	0.0922	-9.559	0.000
τ_2	-0.224	0.0807	-2.774	0.006
τ_3	0.299	0.0811	3.686	0.000
τ_4	0.809	0.0898	9.005	0.000
τ_5	1.37	0.114	12.047	0.000
diversity of activities on Bliss Street				
τ_1	-1.92	0.162	-11.847	0.000
τ_2	-1.57	0.126	-12.405	0.000
τ_3	-1.27	0.106	-11.965	0.000
τ_4	-0.422	0.0834	-5.068	0.000
τ_5	0.114	0.0807	1.410	0.159
τ_6	1.09	0.0996	10.925	0.000
diversity of activities on chosen street				
τ_1	-1.62	0.133	-12.226	0.000
τ_2	-1.23	0.106	-11.605	0.000
τ_3	-0.753	0.0885	-8.504	0.000
τ_4	0.162	0.0802	2.024	0.043
τ_5	0.753	0.0885	8.506	0.000
τ_6	1.52	0.124	12.223	0.000

Table 20: Final Structural Equation Model for Non-Foot Commuters (NFC)

	Estimate	Std.err	Z-value	P(>|z|)
Fit Indices (robust):				
chi-squared test statistic	137.702			
degrees of freedom	30			
relative chi-squared	4.590			
comparative fit index (CFI)	0.972			
Tucker-Lewis Index (TLI)	0.958			
root mean square error of approximation (RMSEA)	0.091			
Measurement Model:	Estimate	Std.err	Z-value	P(>|z|)
neighborhood attributes →				
ease of pedestrian crossing	0.794	0.0224	35.537	0.000
sidewalk blockage	0.777	0.0231	33.684	0.000
cleanliness of the sidewalk	0.677	0.0295	22.961	0.000
vehicular traffic on streets	0.594	0.0320	18.553	0.000
motorcycles going against traffic on one-way streets	0.596	0.0391	15.246	0.000
sidewalk width and quality on chosen street →				
sidewalk width on chosen street	0.871	0.0270	32.220	0.000
sidewalk quality on chosen street	0.911	0.0268	34.050	0.000
diversity of activities →				
diversity of activities on Bliss Street	0.610	0.0477	12.768	0.000
diversity of activities on chosen street	0.702	0.0441	15.914	0.000
Structural Model:	Estimate	Std.err	Z-value	P(>|z|)
level of satisfaction with the walking environment ←				
neighborhood attributes	0.602	0.0560	10.754	0.000
sidewalk width and quality on chosen street	-0.0463	0.0664	-0.697	0.486
diversity of activities	0.219	0.0638	3.439	0.001
Covariances:	Estimate	Std.err	Z-value	P(>|z|)
neighborhood attributes ↔				
sidewalk width and quality on chosen street	0.601	0.0341	17.635	0.000
diversity of activities	0.514	0.0503	10.209	0.000
sidewalk width and quality on chosen street ↔				
diversity of activities	0.545	0.0460	11.861	0.000

Table 16 (cont'd): Final Structural Equation Model for Non-Foot Commuters (NFC)

Variances:	Estimate	Std.err	Z-value	P(>|z|)
Latent Variables				
neighborhood attributes	1.00	-	-	-
sidewalk width and quality on chosen street	1.00	-	-	-
diversity of activities	1.00	-	-	-
Observed Variables				
level of satisfaction with walking environment	0.497	-	-	-
ease of pedestrian crossing	0.369	-	-	-
sidewalk blockage	0.397	-	-	-
cleanliness of the sidewalk	0.542	-	-	-
vehicular traffic on streets	0.647	-	-	-
motorcycles going against traffic on one-way streets	0.645	-	-	-
sidewalk width on chosen street	0.241	-	-	-
sidewalk quality on chosen street	0.169	-	-	-
diversity of activities on Bliss Street	0.628	-	-	-
diversity of activities on chosen street	0.508	-	-	-

Threshold Model:	Estimate	Std.err	Z-value	P(>|z|)
level of satisfaction with walking environment				
τ_1	-1.60	0.0981	-16.320	0.000
τ_2	-0.856	0.0686	-12.485	0.000
τ_3	-0.257	0.0606	-4.238	0.000
τ_4	0.140	0.0601	2.335	0.020
τ_5	0.769	0.0668	11.514	0.000
τ_6	1.77	0.110	16.075	0.000
ease of pedestrian crossing				
τ_1	-1.23	0.0796	-15.445	0.000
τ_2	-0.616	0.0642	-9.601	0.000
τ_3	-0.0600	0.0599	-1.001	0.317
τ_4	0.310	0.0609	5.093	0.000
τ_5	0.942	0.0706	13.339	0.000
τ_6	2.28	0.170	13.406	0.000
sidewalk blockage				
τ_1	-0.687	0.0653	-10.519	0.000
τ_2	0.123	0.0601	2.049	0.040
τ_3	0.658	0.0649	10.153	0.000
τ_4	1.12	0.0756	14.761	0.000
τ_5	1.54	0.0945	16.317	0.000
τ_6	2.36	0.185	12.777	0.000

Table 16 (cont'd): Final Structural Equation Model for Non-Foot Commuters (NFC)

Threshold Model:	Estimate	Std.err	Z-value	P(>|z|)
cleanliness of the sidewalk				
τ_1	-0.873	0.069	-12.658	0.000
τ_2	-0.269	0.0607	-4.428	0.000
τ_3	0.316	0.0610	5.188	0.000
τ_4	0.754	0.0665	11.334	0.000
τ_5	1.42	0.088	16.155	0.000
τ_6	2.28	0.170	13.406	0.000
vehicular traffic on streets				
τ_1	-0.658	0.0649	-10.153	0.000
τ_2	0.169	0.0602	2.811	0.005
τ_3	0.673	0.0651	10.337	0.000
τ_4	1.35	0.0845	15.947	0.000
τ_5	1.89	0.120	15.678	0.000
τ_6	2.84	0.319	8.885	0.000
motorcycles going against traffic on one-way streets				
τ_1	0.0886	0.0600	1.478	0.139
τ_2	0.616	0.0642	9.601	0.000
τ_3	0.969	0.0713	13.587	0.000
τ_4	1.56	0.0957	16.323	0.000
τ_5	1.89	0.120	15.678	0.000
τ_6	2.36	0.185	12.777	0.000
sidewalk width on chosen street				
τ_1	-0.907	0.0698	-13.001	0.000
τ_2	-0.175	0.0602	-2.907	0.004
τ_3	0.292	0.0608	4.808	0.000
τ_4	0.731	0.0661	11.064	0.000
τ_5	1.42	0.088	16.155	0.000
	2.09	0.143	14.642	0.000
sidewalk quality on chosen street				
τ_1	-1.16	0.0771	-15.047	0.000
τ_2	-0.292	0.0608	-4.808	0.000
τ_3	0.251	0.0606	4.143	0.000
τ_4	0.848	0.0684	12.398	0.000
τ_5	1.33	0.0839	15.898	0.000
τ_6	2.28	0.170	13.406	0.000

Table 16 (cont'd): Final Structural Equation Model for Non-Foot Commuters (NFC)

Threshold Model:	Estimate	Std.err	Z-value	P(>|z|)
diversity of activities on Bliss Street				
τ_1	-1.89	0.120	-15.678	0.000
τ_2	-1.47	0.0906	-16.247	0.000
τ_3	-1.28	0.0816	-15.684	0.000
τ_4	-0.724	0.0659	-10.974	0.000
τ_5	-0.0657	0.0599	-1.096	0.273
τ_6	1.01	0.0723	13.913	0.000
diversity of activities on chosen street				
τ_1	-1.71	0.106	-16.191	0.000
τ_2	-1.15	0.0767	-14.977	0.000
τ_3	-0.680	0.0652	-10.428	0.000
τ_4	0.129	0.0601	2.145	0.032
τ_5	0.680	0.0652	10.428	0.000
τ_6	1.51	0.0924	16.290	0.000

APPENDIX C-1 **(OFC)**

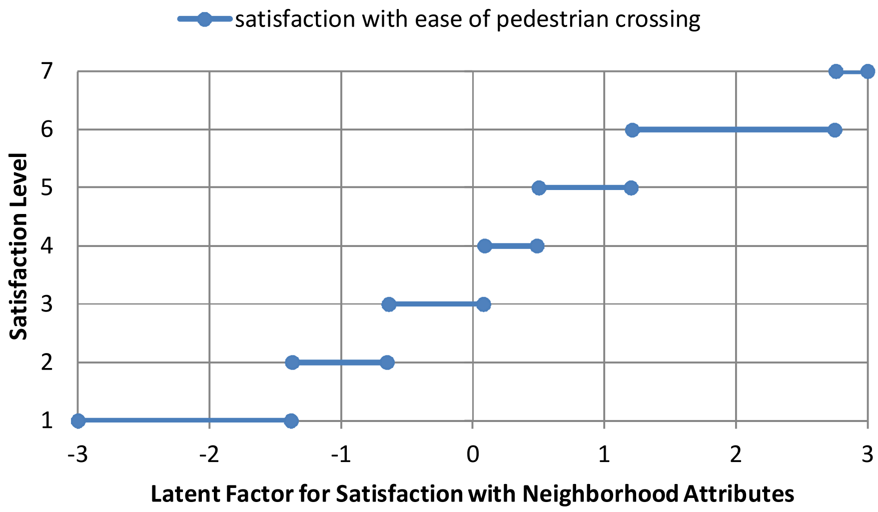

Figure 14: Variation of Satisfaction with *Ease of Pedestrian Crossing* as a Function of the Latent Factor for the Satisfaction with *Neighborhood Attributes* for On-Foot Commuters

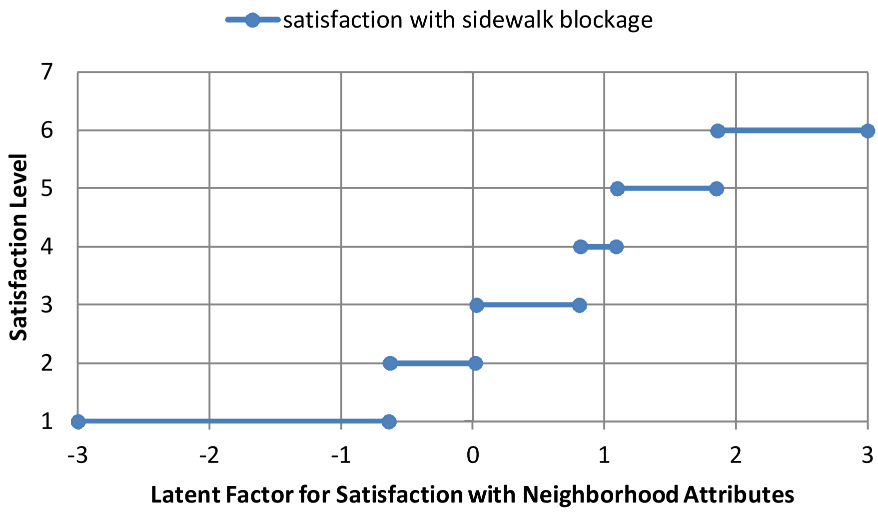

Figure 15: Variation of Satisfaction with *Sidewalk Blockage* as a Function of the Latent Factor for the Satisfaction with *Neighborhood Attributes* for On-Foot Commuters

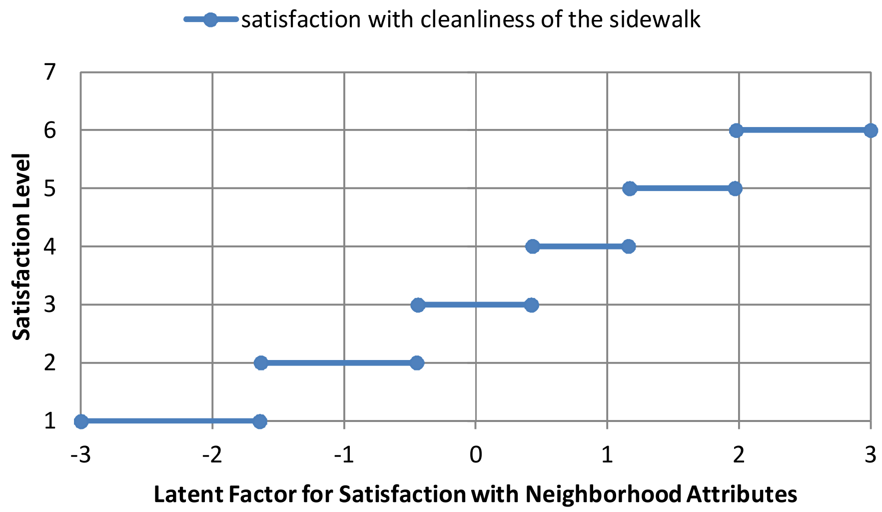

Figure 16: Variation of Satisfaction with *Cleanliness of the Sidewalk* as a Function of the Latent Factor for the Satisfaction with *Neighborhood Attributes* for On-Foot Commuters

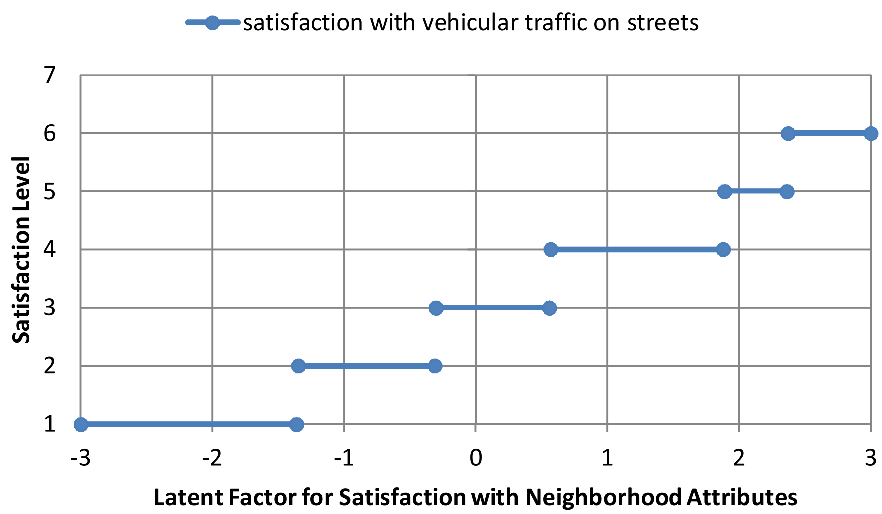

Figure 17: Variation of Satisfaction with *Vehicular Traffic on Streets* as a Function of the Latent Factor for the Satisfaction with *Neighborhood Attributes* for On-Foot Commuters

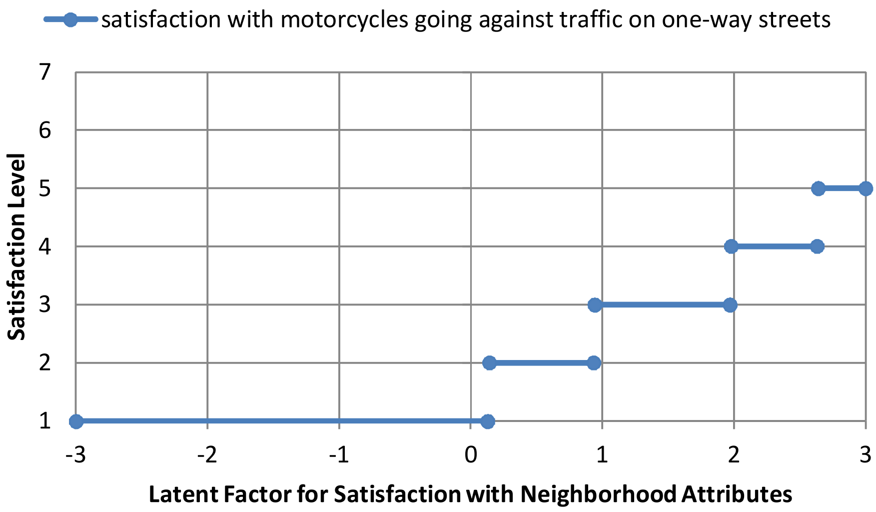

Figure 18 Variation of Satisfaction with *Motorcycles Going against Traffic on One-Way Streets* as a Function of the Latent Factor for the Satisfaction with *Neighborhood Attributes* for On-Foot Commuters

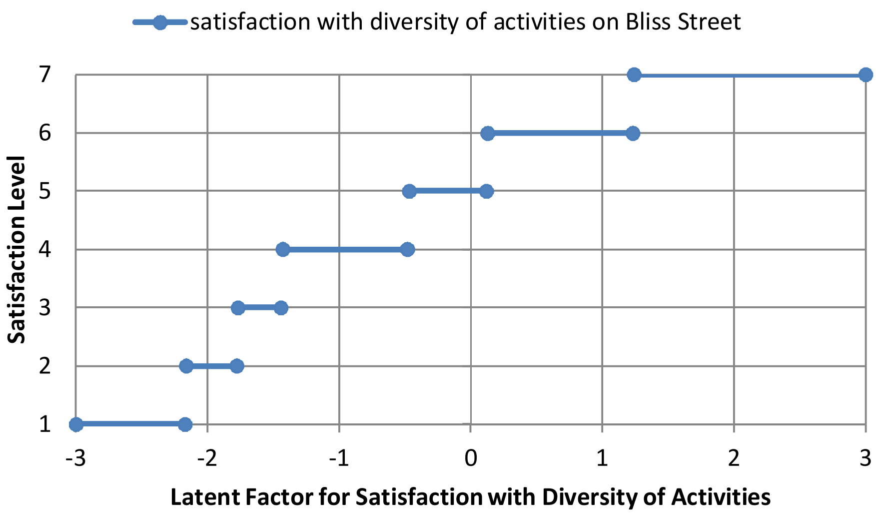

Figure 19: Variation of Satisfaction with *Diversity of Activities on Bliss Street* as a Function of the Latent Factor for the Satisfaction with *Diversity of Activities* for On-Foot Commuters

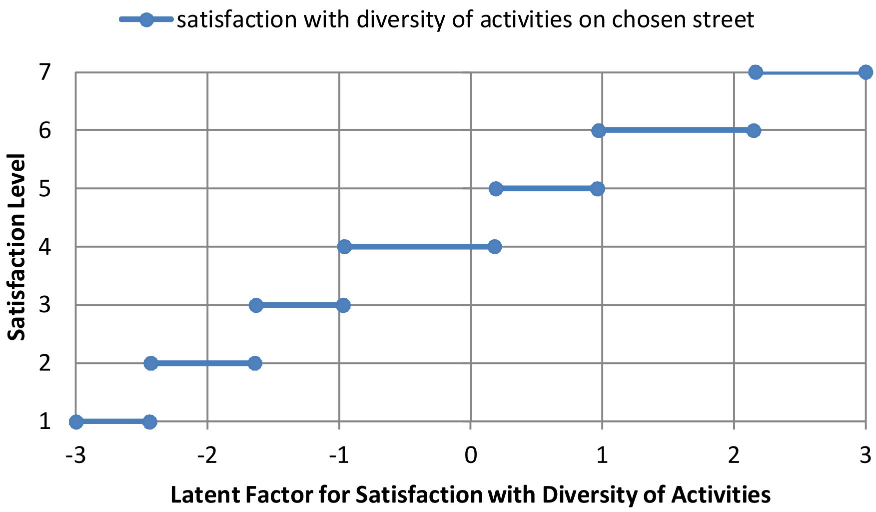

Figure 20: Variation of Satisfaction with *Diversity of Activities on Chosen Street* as a Function of the Latent Factor for the Satisfaction with *Diversity of Activities* for On-Foot Commuters

APPENDIX C-2 (**OMC)**

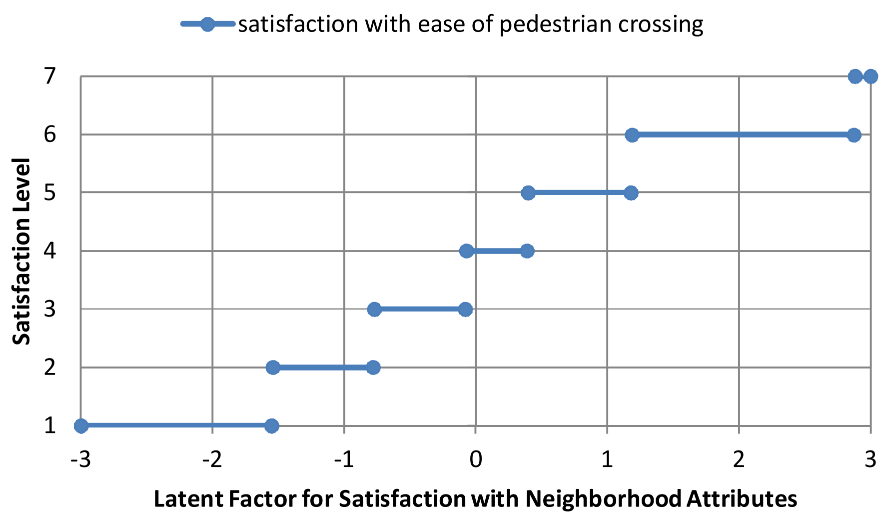

Figure 21: Variation of Satisfaction with *Ease of Pedestrian Crossing* as a Function of the Latent Factor for the Satisfaction with *Neighborhood Attributes* for Non-Foot Commuters

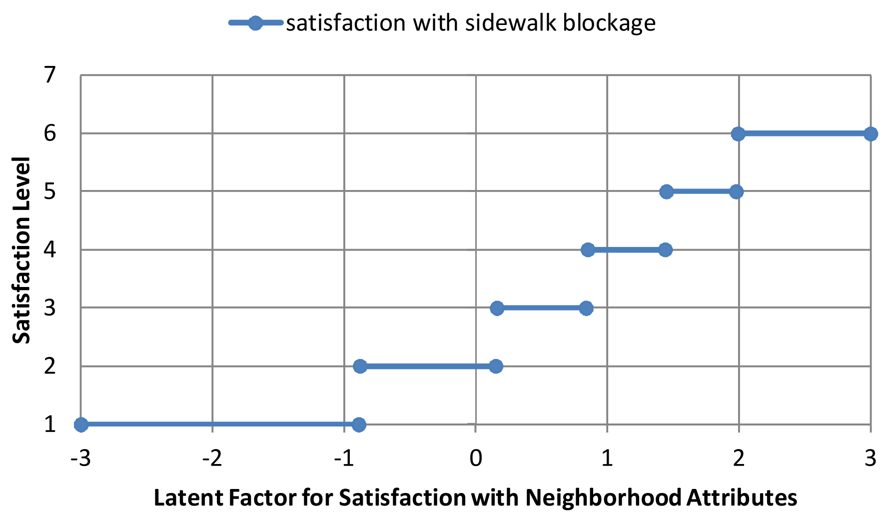

Figure 22: Variation of Satisfaction with *Sidewalk Blockage* as a Function of the Latent Factor for the Satisfaction with *Neighborhood Attributes* for Non-Foot Commuters

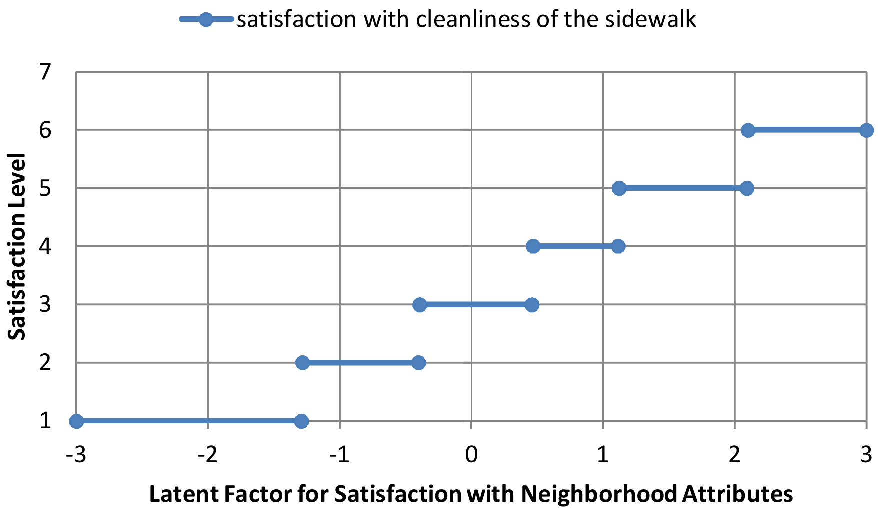

Figure 23: Variation of Satisfaction with *Cleanliness of the Sidewalk* as a Function of the Latent Factor for the Satisfaction with *Neighborhood Attributes* for On-Foot Commuters

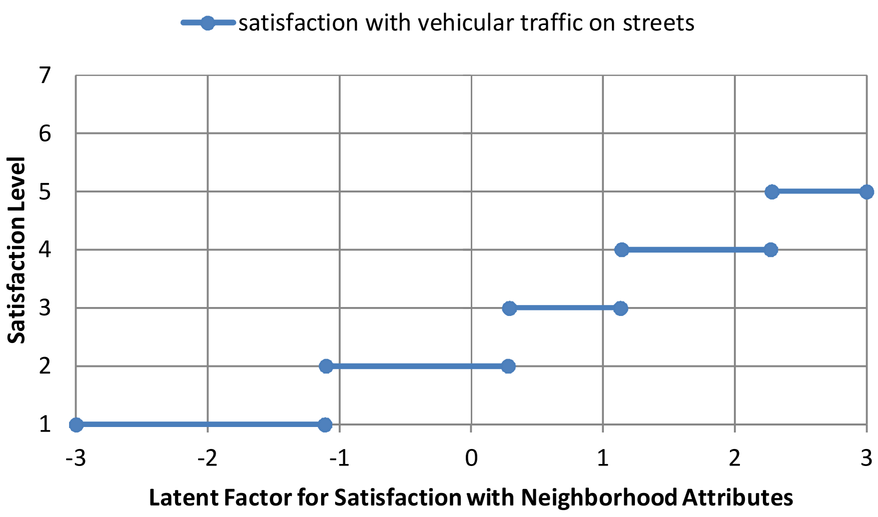

Figure 24: Variation of Satisfaction with *Vehicular Traffic on Streets* as a Function of the Latent Factor for the Satisfaction with *Neighborhood Attributes* for Non-Foot Commuters

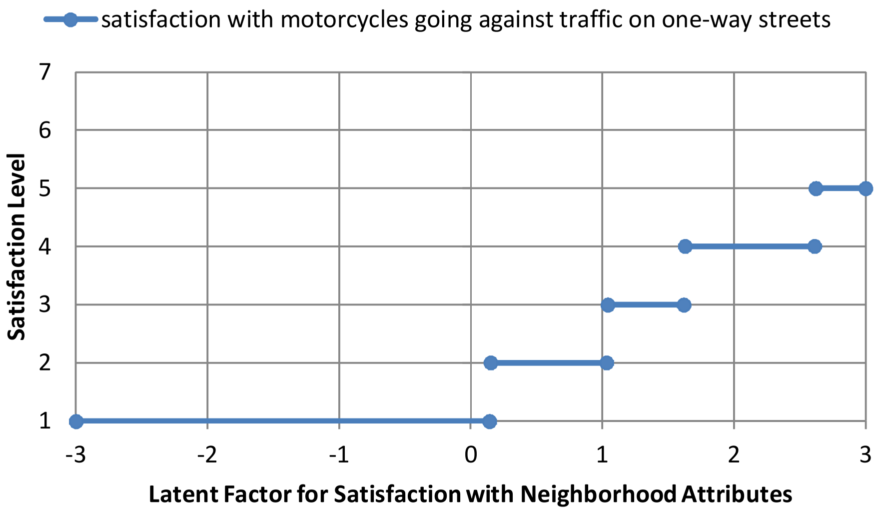

Figure 25: Variation of Satisfaction with *Motorcycles Going against Traffic on One-Way Streets* as a Function of the Latent Factor for the Satisfaction with *Neighborhood Attributes* for Non-Foot Commuters

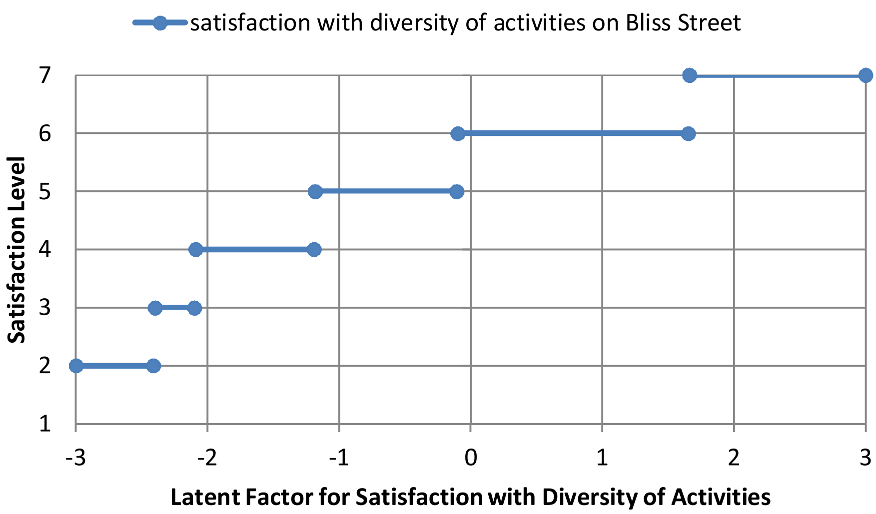

Figure 26: Variation of Satisfaction with *Diversity of Activities on Bliss Street* as a Function of the Latent Factor for the Satisfaction with *Diversity of Activities* for Non-Foot Commuters

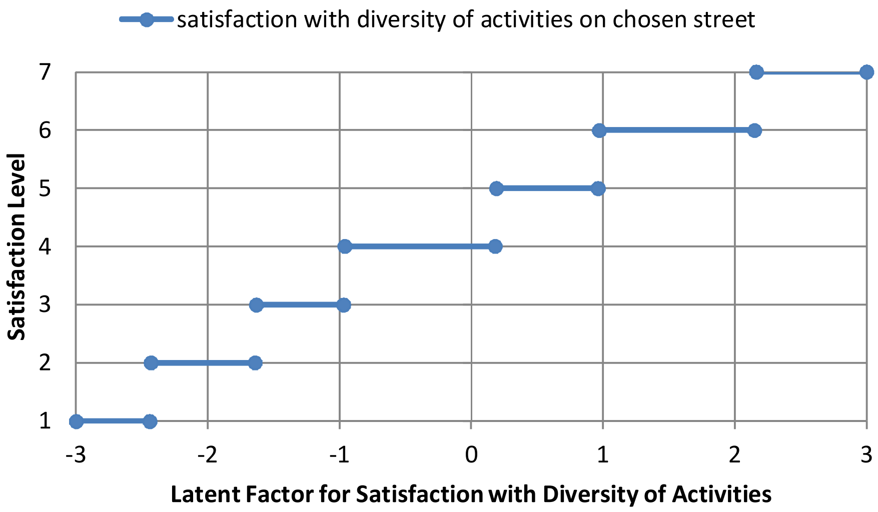

Figure 27: Variation of Satisfaction with *Diversity of Activities on Chosen Street* as a Function of the Latent Factor for the Satisfaction with *Diversity of Activities* for Non-Foot Commuters