UNIVERSITY OF THE AEGEAN
SCHOOL OF BUSINESS

Development of Hybrid Models of Teenager's Travel Patterns to School and to After-School Activities

by
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Submitted to the Department of Shipping, Trade and Transport in fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY
in the field of
Travel Behavior Modeling and Decision Sciences

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ΔΙΔΑΚΤΟΡΙΚΗ ΔΙΑΤΡΙΒΗ

Ανάπτυξη Υβριδικών Προτύπων για τη Διερεύνηση της Μεταφορικής Συμπεριφοράς των Εφήβων στις Σχολικές και Εξωσχολικές Δραστηριότητες

ΜΑΡΙΑ ΚΑΜΑΡΓΙΑΝΝΗ

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του Τμήματος Ναυτιλίας και Επιχειρηματικών Υπηρεσιών

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MARIA KAMARGIANNI

Submitted to the Department of Shipping, Trade and Transport in fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY
in the field of
Travel Behavior Modeling and Decision Sciences

at the University of the Aegean
February 2014

PhD Thesis Supervisor……
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Development of Hybrid Models of Teenager's Travel Patterns to School and to After-School Activities

by Maria Kamargianni

Submitted to the Department of Shipping, Trade and Transport
on February 14, 2014, in partial fulfillment of the requirements for the degree of
Doctor of Philosophy in the Field of Travel Behavior Modeling and Decision Sciences

Abstract

Substantial changes in lifestyles, urban environments and transportation systems have led to changed physical activity patterns, especially among underage people. Although we may know the demographic and economic characteristics of underage students' families and the communities where they live and attend school, we have little scientific evidence of the individual teenagers' (12 to 18 years old) activities, travel behavior and attitudes. In traditional societies there was comparatively little discrepancy between adolescents and adults because they grew up in comparable worlds. However, with rapid change and social media bringing the outside world into teenagers' lives, larger generational differences are emerging.

This thesis contributes to the understanding of various factors that affect teenagers' travel behavior. As a first step, we analyze teenagers' activity patterns and time use in school days and in Saturday and the transport mode that they use, in order to identify their travel needs. The results indicate that teenagers conduct a number of trips, especially after-school trips, without the supervision of their parents, while the mode use patterns significantly differ among the trip purposes and among distinct geographical areas.

As current teenagers spend significant amount of time on online social networking (OSN), we further analyze how much, why, and how teenagers utilize social media, and how its usage affects their travel behavior. Latent Class Poisson Regression models are developed in order to identify teenagers' trip making behavior for social purposes of various OSN usage styles, while the results indicate that those who use OSN in a rational or addictive way, conduct more social trips than those who are indifferent to OSN, thus OSN does not substitute face-to-face communication. The developed framework offers significant insights to researchers for the data required in order to model the relationship between OSN and trip making behavior.

The thesis is also concerned with investigating the effect of social influence on decision making and more specific the effect of parents' walking patterns on teenagers' attitudes towards walking and mode choice behavior. We present a methodological framework that incorporates social interaction effect into Hybrid Choice Models (HCM) and provide the required mathematical equations. The model estimation results indicate that, if the teenagers perceive that their parents are walking-lovers, then this increases their probability of loving walking too. Even though the application focus on teenagers, the framework is general and can be applied to modeling adults' behavior as well.

Moreover, this thesis contributes to the understanding of how teenagers perceive various built-environment characteristics and which of them work as constraints to active transport. We use their perceptions of built-environment characteristics, the actual built-environment characteristics of their routes from home to school and weather conditions in order to capture their effect on mode-to-school choice behavior. A latent variable model is developed for each urban environment to further investigate the differences among urban, rural and insular areas. The results show that the presence of wide pavements, greenery and traffic lights at major intersections affects positively the choice of active transport to school, while rain and bad weather conditions affect negative the choice of active transport. The most significant walkability constraint for urban teenagers seems to be the safety issue, while for rural and insular ones it is the absence of sidewalks, along with poor lighting.

For the analyses and model estimation we use data that are collected directly from teenagers. The survey took place in two countries; Greece and Cyprus, while in Greece the survey took place not only in urban, but rural and insular areas as well. The sample from Greece consists of 3,293 adolescent students, while the sample from Cyprus consists of 10,093 adolescent students, covering the 21% of the total high-school population of the country.

The contributions and innovation of this research cover several topics. First of all, to our knowledge it is the first time that such a large-scale survey on travel behavior, focusing only on teenagers, has taken place. Second, the questionnaire used for the data collection was designed specifically to investigate teenagers' perceptions of travel behavior, not only by transport engineers but also by psychologists and economists, with the aim of approaching the multidimensional nature of transportation problems in depth. Third, this thesis contributes to the modeling of social influence effect on the decision making process by proposing an extension to HCM. Fourth, the Latent Class models that are developed contribute to the understanding of the relationship between OSN and trip making behavior. The findings of this thesis offer guidelines as to the types of transport policies that could promote active transport and increase environmental consciousness. Finally, the interventions at this age could develop the desired behaviors that could be retained in adulthood.

Key words: Teenagers, Mode Choice, Active Transport, Walking, Cycling, School Transportation, Built-Environment, On-line Social Networking, Social Media, Social Interaction, Hybrid Choice Models, Latent Variables, Latent Classes.

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Acknowledgements

"The dream supervisor has the following attributes: the wisdom of Solomon; a positively delphic prescience in their pronouncements of what will matter; the communicative skills of Martin Luther King; the analytical clarity of Ada Lovelace; the patience of a saint; a pastoral touch that would make Florence Nightingale weep with envy; a breadth and depth of knowledge that could only come from omniscience; creative gifts that combine the brilliance of Leonardo da Vinci, Isaac Newton, Michelangelo and Mozart with the inspiring iconoclasm of Pablo Picasso, Einstein and the Beatles; and to cap it all, an empathic sense that must have been stolen from Mahatma Ghandi." (Marshall & Green, 2010)

Although the authors argue that the dream supervisor does not exist, I have a different opinion … the dream supervisor does exist and this is my supervisor, Amalia.

I offer my heartfelt gratitude to my supervisor Prof. **Amalia Polydoropoulou**. I feel so lucky, blessed and honored to have had the opportunity to work with her. All these years Amalia was not only my supervisor, but also my second mother. She supported me not only by providing a research assistantship, but also academically and emotionally through the rough road to finish this thesis. And during the most difficult times when writing this thesis, she gave me the moral support and the freedom I needed to move on. I also want to thank her husband, Mr. **Antulio Richetta** who was providing insightful discussions about the research and was keeping me updated about the teen tech trends.

My thesis committee guided me through all these years. I wish to thank Prof. **Moshe Ben-Akiva** for his guidance and his willingness to answer to all my questions (I had too many! Believe me). Every meeting with Moshe was like a hangover of knowledge. A special thank you to Prof. **Kostas Goulias**, who was supportive and next to me all these years. His fresh ideas, advices and input were valuable. I hope that I could be as lively, enthusiastic, and energetic as Kostas. I would also like to thank Dr. **Constantinos Antoniou** who has always made himself available to clarify my doubts and provided to me insightful material for my thesis. Thanks to Prof. **Seraphim Kapros**, I had the opportunity to anticipate situations from a different point of view. His ideas and comments were of high importance. My appreciations and a big thank you to Prof. **Nikolaos Litinas,** who initiated the idea for this thesis and provided many fruitful discussions and innovative ideas. Also thank you to Dr. **Konstantinos Panou** and Prof. **Panagiotis Papaioannou** for being part of my PhD thesis extended committee and thesis readers. I could not be prouder of my academic roots and hope that I can in turn pass on the research values and the dreams that they have given to me.

A special acknowledgement to Dr. **Athena Tsirimpa** who has been an inspiration to me. Athena was always willing to help me with my models and with great patience was explaining every single detail about discrete choice models.

The thesis would not have come to a successful completion, without the help I received from Mr. **Stelios Maistros**. I cannot find the words to describe my gratitude to him. He has spent days and nights trying to help me to upload the electronic version of the questionnaire on the servers and install the software I needed for the estimation of my models. I would also like to thank the staff of the Shipping, Trade and Transport Department, **George Pantelouks, Dimitra Rafteli, Katerina Papazi** and **Angeliki Athanasiou**. They have been

very kind to extend their help at various phases of this research, whenever I approached them.

No research is possible without research assistants. And I had the best research assistants. A big thanks to the postgraduate students **Argyro Stoupou, Georgia Daskalopoulou, Chrysa Tsalihi, Marios Vergidis** and the undergraduate students **Pantelis Kolakis, Ploumi Ilektraki, Thanasis Savvas, Tonia Chatzikonstanti, Konstantina Stafylaraki** and **Evridiki Mpolanou**. I also want to thank you my friend **Maria Petrova** whose assistance was of high importance, especially for the data collection in Alexandroupolis. My thanks also go out to the support I received from my lab buddies, **Ioanna Kourounioti, Giannis Tsouros, Nicky Krousouloudi, Evi Baxevani** and **Anna Karamigkou**.

Now is **Nikoleta**'s turn. This little creature made the impossible, possible! She was always next to me from the time we were studying in Thessaloniki till now that I finished my PhD studies. Nikoleta was responsible for everything; for organizing the data collection at schools, the road safety and active transport campaigns, for arranging the meetings, for coding the data even for organizing my relocation. Love you mikro mou!

Thank you to my friends and co-students to the Masters: **Stefanos Patsikas, Konstantina Athanasiadi, Konstantina Soulioti and Giannis Xidakis** for providing support and friendship that I needed. These acknowledgements would not be complete if I did not mention my best friend, my "sister" and my maid of honor, **Theodora Betsidou**. She has been next to me since we were 9 years old. Throughout my studies, she has been a bright light, often sending and "posting" supportive messages and phoning me to tell me of her life and asking about mine, always concerned with how stressed I might be.

My deep appreciation and love goes out to Ms. **Eleni Voutierou** and Mr. **Giannis Gkolemis**. They were my caregivers throughout my PhD studies. They were encouraging me and they always reminded me to eat!

I especially thank my mom, dad, brother, my grandparents and my uncle. My parents, Nicky and Theo, have sacrificed their lives for my brother and myself and provided unconditional love and care. They have taught me about hard work and persistence and about how to be independent. I love them so much, and I would not have made it this far without them. My brother Konstantinos has been next to me assisting with the data collection in Alexandroupolis. Thank you bro for coding the data! My grandfather (Pappoulis mou) has always supported me and inspired me to do the best. I wish my grandmother Chrysopoula, the woman who raised me, were alive to share in my joy and my achievements. I am also grateful to my grandfather Kostas, grandmother Maria and my uncle Paschalis for their support. I also want to thank you my parents-in-law, Nikos and Rea, who supported me throughout my PhD studies and they always care about me. I also want to thank you for raising such a wonderful son, my husband. I know I always have my family to count on when times are rough. And I want to thank my parents in Greek now…

Μανούλα μου και μπαμπάκα μου, σας ευχαριστώ από τα βάθη της καρδιάς μου για την αγάπη που μου χαρίζετε απλόχερα, για τις αξίες που μου έχετε εμφυσήσει, για τις βάσεις που μου δώσατε και για τις θυσίες που έχετε κάνει για εμένα και τον Κωνσταντίνο. Και επιτέλους ήρθε η ώρα να απαντήσω στην επίμονη ερώτησή σας για το πότε θα τελειώσω τις σπουδές μου ... από τη στιγμή που διαβάζετε αυτό το κείμενο, σημαίνει πως ΤΕΛΕΙΩΣΑ!!! Σας αγαπώ πολύ!

Lastly, and most importantly, I want to thank the man of my dreams, my soul-mate and future husband, Andreas. There are no words to convey how much I love him. Andreas has been a true and great supporter in every step of this thesis and has unconditionally loved me during my good and bad times. He has stayed awake many nights assisting me with the editing and proofreading of my papers and my thesis. He has faith in me and my intellect even when I felt like digging hole and crawling into one because I did not have faith in myself. These past several years have not been an easy ride, both academically and personally. I truly thank Andreas for sticking by my side, even when I was irritable and depressed. Thank you for showing me the beauty and opposite site of life and making my mind relax during the hard times of my thesis. I feel that what we both learned a lot about life and strengthened our commitment and determination to each other and to live life to the fullest. Now it is your turn to fulfill your PhD studies and my turn to encourage and assist you. Θα'σαι για πάντοτε το καλοκαίρι μου.

To the man of my dreams, Andreas,
to my parents, my brother, grandparents and parents-in-law.

Contents

List of Figures

List of Tables

List of Abbreviations

ABM = Activity Based Models
DCM = Discrete Choice Models
HCM = Hybrid Choice Models
ICT = Information and Communication Technologies
LCM = Latent Class Models
MMNL = Mixed Multinomial
MNL = Multinomial
OSN = On-line Social Networking
PTW = Powered Two Wheelers
SI = Social Interaction

Chapter 1
Introduction

The years from ages twelve to eighteen are recognized as a crucial period in a teenager's life, when initial steps towards independent adulthood are taken. The cultural icon of the "teenager" has now matured into an established market segment increasingly targeted by the marketing sector (Datz et al., 2005). However, the transport sector lags behind in recognizing the importance of this age group as a shaper of policies.

This thesis focuses on the travel behavior of this under-examined age group, the teenagers. Although there is a significant amount of research on adults' travel behavior, there is a gap in the literature about this particular age group. This chapter provides the motivation for this research and presents the objectives, methodology, innovation, contributions and organization of the thesis.

1.1 Motivation

Four main issues have motivated this thesis. First of all, substantial changes in lifestyles, urban environments and transportation systems have led to changed physical activity patterns among underage people. The reliance on passive or motorized transportation modes for trips to school has increased in recent years and schools are a significant generator of localized congestion. This fact necessitates the promotion of active transport to school, which alleviates traffic congestion and at the same time contributes to the development of healthy lifestyles.

Second, the emergence of Information and Communication Technologies (henceforth ICT) and especially social media and on-line social networking (henceforth OSN), has upended the way teenagers interact with each other and the world. There is now little room for doubt about the impact of these developments on their daily activities and, in turn, on their travel needs.

Third, recent reports show that the casualty toll rises at the point when children who had previously been accompanied or driven (escorted) to and from school begin to make their own way there and back (Mann, 2010). Hence, the urgent need for investigating teenagers as road users has emerged.

Finally, while obesity rates within this age group have increased significantly. For example, the latest OECD reports show that one in five children are affected by excess body weight across all countries; in Greece, the United States and Italy the figure is closer to one-third, whilst only in China, Korea and Turkey are 10% or less of children overweight (OECD, 2012). Greece is ranked first in the OECD list with the most overweight or obese children; 37% of girls and 45% of boys aged from 5 to 17 years old are overweight or obese (OECD, 2012).

1.1.1 Trends in School Transportation

In the past, active transportation to school and to after-school activities offered an important source of daily physical activity. Today, however, for many young and underage individuals, traditional travel patterns to school and to after-school activities have changed, and it is undoubtedly true that teenagers have become increasingly reliant on automobiles. This shift has contributed to greater congestion and decreased air quality. Schools are a significant generator of localized congestion, with morning and afternoon peaks similar to those seen in commuting behavior (McMillan, 2007). In some areas of the US, the additional school-related auto trips have generated between a 20 to 30% increase in morning traffic (Safe Routes School National Partnership & Hubsmith, 2007).

Consequently, many researchers have investigated school transportation through parental travel patterns. However, there are few surveys that use data collected directly from children or teenagers. Teenagers form a peculiar age group with special travel needs. On the one hand, their participation in activities and their mobility are constrained by parental consent and age restrictions on driving. On the other hand, their burgeoning maturity allows them to make independent decisions and spend time free from adult supervision (Clifton, 2003). Their travel behavior remains largely unrecorded and, as a result, there is increasing interest in the topic.

In addition, psychologists say that habits formed early are hard to break (Larson et al., 2002). Underage persons who mostly travel by car while growing up may continue doing so into adulthood and may, as adults, be more reluctant to travel by alternative transportation modes (Bradshaw, 2001). Also, it is believed that interventions to promote active transport and physical activity in adolescence may lead to effects that are retained in adulthood (Carlin et al., 1997).

The ability to record teenagers' trips and model their travel behavior will allow transport policy-makers to impose the appropriate measures and policies for developing environmentally friendly travel behavior among the next generation.

1.1.2 Next Generation

Social media are designed to foster social interaction in a virtual environment and millions of contemporary adolescents use them. Using OSN web sites is by far the most popular activity of today's adolescents. The root motivation is, mainly, to communicate and in particular to maintain relationships. Common usages include updating others on activities and whereabouts, sharing photos and archiving events, getting updates on friends' activities, displaying a large social network, sending messages privately, posting public testimonials and presenting an idealized persona.

This culture of innovation and rapid technological adaptation is particularly strong among the younger generations, especially the so-called New Boomers or Net Generation (born between 1983 and 2001; PRB, 2009). These "internet natives" grew up in the era of personal computing and the internet or, as Tapscott (2009) puts it, they have been "bathed in bits and bytes" since birth and easily integrate technology into their daily lives. This discourse has a wide social impact and its echoes can be found in psychology, business literature and government policy. The general claim, made in this generation's discourse, is

that this material context has led to young people developing natural aptitude and high skill levels in relation to the new technologies. In contrast, those older people who grew up in an analogue world are portrayed as being always behind, like immigrants to the new world. It is suggested that these older digital immigrants are never likely to reach the same levels of skill and fluency that have been developed naturally by those who have grown up with the new technologies (Tapscott, 2009). Hence, a generational gap is developing.

The emergence of OSN has transformed the way teenagers interact with each other and the world, and there is now little doubt about its impact on daily activities and travel needs. Against this background, in recent years a growing body of researchers has tried to investigate the kind of activities teenagers conduct using OSN, and the effects on teenagers' personalities and psychology. Alas, little is known about the extent, the reasons, and the manner in which individuals, and more specifically adolescents, utilize social media, and how this usage affects their travel behavior.

Development of a behavioral framework and investigation of the relationship between various OSN usage styles and trip making and travel behavior could act as a signal to decision makers to develop future alternative transportation policies.

1.1.3 Teenagers' Road User Behavior and Involvement in Traffic Accidents

Daily transportation to school, together with the protection of underage vulnerable road users,[1] has been the topic of several studies. Many surveys have investigated in depth the safety issues of school transportation, focusing on the infrastructure (such as accessibility and safe routes to school) and vehicles (such as safe school buses). Accordingly many interventions have taken place with regard to speed enforcement in school areas, accessibility, and the safety of school buses (Anund et al., 2011; Yannis et al., 2011; Antoniou et al., 2009). These interventions have contributed to the decrease in the number of children killed in road traffic accidents in the last decade (ETSC, 2009; DACOTA, 2012; IRTAD, 2012).

However, road safety is mainly affected by three factors: the human being, the vehicle and the infrastructure. Regarding the first factor, little work exists on students' and more specifically high school students' (twelve to eighteen years old) behavior, attitudes and perceptions as road users. Recent reports show that the casualty toll rises at the point when children who had previously been escorted to and from school begin to make their own way there and back (Mann, 2010).

Evidently, the statistics show that fourteen is the age at which the risk of death in a road traffic accident begins to rise sharply (DACOTA, 2012). Once the children reach the age of fourteen and progressively acquire access to Powered Two-Wheelers (henceforth PTW) and cars, their road mortality starts to increase dramatically (ETSC, 2009).

This phenomenon seems to be more intense in rural areas, where the transport alternatives are limited and as a result students start to drive a motorized vehicle from a young age without even having a driving license (Polydoropoulou et al., 2013). This fact intensifies the hazardous conditions for all road users, creating an imperative need to investigate the

[1] Vulnerable road users are pedestrians, cyclists and two-wheel vehicle riders (ETSC, 2009).

factors that motivate underage road users, their driving culture and style, and their involvement in illegal road usage behavior (Papaioannou, 2007). The models that are developed and estimated in this thesis provide significant insights into the factors affecting adolescents' road user behavior, and these insights can be used to promote safe transport.

1.1.4 Modeling Techniques

Over the last decade, it has been suggested that an explicit consideration of psychological factors might help us to understand people's transport decision-making processes (Anable, 2005). A growing body of research demonstrates the pertinence of a wider range of individual characteristics, including attitudes, preferences and intentions, perceptions and opinions, emotional states and motivations, subjective norms and personality traits, perceived responsibility and control, habits, lifestyle and situational variables (Diana and Pronello, 2010). Nevertheless, soft factors that had been shown to affect adult travel behavior, such as convenience, attitudes and perceptions regarding environmental protection, active transport etc. (Abou-Zeid et al., 2012; Shiftan, et al., 2008; Walker & Li, 2007; Polydoropoulou et al., 2013; Kamargianni & Polydoropoulou, 2013a) have not been examined in relation to how they affect teenagers' travel behavior.

In addition, it is well known that individuals' choices are often influenced by the presence, opinions, choices and behavior of other people (van den Bos et al., 2013; Rose and Hensher, 2004; Brock & Durlauf, 2001; Manski, 1993) or generally by the social environment of the decision-maker. In sociology and psychology, there is much empirical evidence confirming the effect of social interaction or influence. However, in discrete choice modeling there have been only a few attempts to capture this effect.

The development of modeling frameworks that include the effect of teenagers' attitudes and perceptions towards active transport on mode choice behavior could provide significant insights both to those who deal with this age group and to policy-makers. Moreover, the incorporation of social influence into hybrid choice models may boost the explanatory power of these models and potentially lead to enhanced behavioral representation in transport models.

1.2 Thesis Objectives

Taken as a whole, this research aims to understand and quantify the determinants of teenagers' travel behavior in order to enhance future transportation-related policies. The investigation will not be limited to a qualitative analysis; rather, the focus of this research is on the use of models that quantitatively represent the effects of various factors on teenagers' travel behavior. Additionally, the modeling techniques and the methodology used in this thesis could be used for modeling adults' travel behavior as well.

The thesis has four main objectives:

1. To analyze teenagers' activities, travel patterns and time use.
2. To test :
    a) data collection methodologies that involve teenagers;

b) potential variables that could capture the relationship between OSN and travel behavior;
c) the incorporation of social influence into hybrid choice models; and
d) the design of the Stated Preference (henceforth SP) scenarios used for underage persons.

3. To model:
   a) the effect of OSN usage on teenagers' trip making behavior;
   b) the effect of social influence on decision-makers' choices;
   c) the effect of actual and perceived built-environment characteristics on mode choice behavior;
   d) the factors that affect teenagers' mode choice behavior, using SP scenarios, and test the modal split under various policies.
4. To assess implications of the models' results for future transportation planning and policies.

1.2.1 Analysis

The first step taken by the thesis is to analyze the time allocation of teenagers, their activities and their travel patterns over a school day and over the weekend. These analyses provide significant insights into teenagers' activity participation and travel needs respectively. Moreover the analysis is based on the place of residence of teenagers, enabling us to identify the differences between urban, rural and insular areas.

1.2.2 Test and Measurement

This thesis provides an in-depth understanding of how to measure, select and test indicators regarding active transport and OSN usage for constructing latent variables and incorporating them in the choice process. We use various attitudes and perceptions towards walking, cycling, built-environment constraints, parental habits etc. as indicators to investigate the measurement interrelationships within each latent variable and across them. We also attempt to test and measure the social influence effect on decision-makers' choices.

1.2.3 Modeling

In this thesis, modeling frameworks for teenagers' mode choice behavior and travel patterns are developed. These modeling frameworks incorporate not only observable variables but also latent variables to assess the process of decision-making.

First, we estimate latent class models in order to capture the trip making behavior of various OSN usage styles. Second, we propose a modeling framework (an extension to HCM) that captures the effect of social influence on mode choice behavior, and we test it by using Revealed Preference (henceforth RP) data. Third, latent choice models are developed that aim to determine the effect of perceived and actual built-environment

characteristics on mode choice behaviors.

1.2.4 Implications

Using the results, we reveal how essential it is for transport planners to include this age group in transport surveys: specifically, because they conduct a significant number of trips without being escorted by their parents, thus creating extra demand for travelling. Also, by investigating the travel behavior of this age group we can predict future trends in transport demand. First, we provide methodological frameworks which contribute to the state-of-the art of all the researchers involved in studying this age group. Second, we use the model estimation results for conducting transport policy analyses in order to test the impact of various interventions on this age group. Finally, we discuss how our findings could be used to inform transportation policies.

1.3 Innovation and Contributions of the Thesis

Although we may know the demographic and economic characteristics of underage students' families and the communities where they live and attend school, we have little scientific evidence of the individual teenagers' activities, travel behavior and attitudes. Traditional travel behavior models are principally limited to the examination or prediction of adult travel behavior, which is primarily automobile dependent (McMillan, 2005). While differing in purpose, most of the research is similar in its focus on adult travel.

In traditional societies there was comparatively little discrepancy between adolescents and adults because they grew up in comparable worlds. However, with rapid change and social media bringing the outside world into teenagers' lives, larger generational differences are emerging (Axhausen, 2013; Davis et al., 2012). Nowadays, teenagers live in more complex environments and their activities, travel needs and attitudes differ from those of adults.

In recent years, a number of researchers have investigated school transportation through parental travel patterns. However, there are few surveys that use data collected directly from children or teenagers. Their travel behavior remains largely unrecorded and, as a result, there is increasing interest in the topic.

The main contribution of this thesis is methodological, with an emphasis on capturing teenagers' travel behavior. The innovation lies mainly in:

1) the focus on teenagers and in particular on gathering data about their activities and travel behavior;
2) the data collection methodology and the collected data regarding OSN usage, attitudes towards walking and cycling, and social influence;
3) the methodological frameworks that are developed for teenagers' activities and mode choice behavior;
4) the analysis, modeling and findings that offer guidelines to encourage various transport policies, to promote active transport and enhance road safety.

The questionnaire used for the data collection was designed specifically to investigate teenagers' travel behavior, not only by transport planners but also by psychologists and economists, with the aim of approaching in depth the multidimensional nature of transportation problems. Also, in order to ensure that our questionnaire captures all the possible factors that affect teenagers' travel behavior, we conducted a series of visits to high-schools in urban, rural and insular areas in order to discuss with the teenagers their transport behavior and needs. After a number of pilot surveys lasting one school year, we finalized our questionnaire. Through the questionnaire we aimed to collect data about teenagers' daily and weekend trips and activities, their time use, road using and driving behavior, perceptions and attitudes towards active transport and their relationship with parents, the opposite gender and friends. Moreover, to our knowledge this is the first time that both RP and SP data have been collected from teenagers. The questionnaire was available in both electronic and print formats, while we used all possible ways (including, for example, social media) to disseminate it among the teenagers.

An additional innovation of the data collection is its focus on the study locations. The survey took place in two countries (Greece and Cyprus). The dataset for Greece provides data from three distinct geographical areas (urban, rural and insular) with completely different transport systems, enabling us to identify the differences in travel needs across these areas. Participants in the survey in Cyprus represent 21% of the total high-school population of the country, allowing us to test various methodologies and estimate accurate models. It is worth noting that this is the first time within worldwide research that such a large-scale transport survey has taken place that has referred only to teenagers.

Although there is a significant amount of work on the effect of ICT on travel behavior, little work has been done regarding the effect of OSN on trip making. The present thesis contributes to the investigation of this relationship by providing a modeling framework within which to capture the various OSN usage styles and associated travel behavior. Also, this research provides insights into the data required to capture this relationship, which could be used both for underage persons and for adults.

Also, within this thesis, a methodological framework is proposed that captures the impact of social influence on individuals' choice behavior. The framework is based on the general HCM framework proposed by Ben-Akiva et al. (2002b). We provide the mathematical equations needed to incorporate social influence into HCM and test it using our data on the influence of parents on teenagers' attitudes and perceptions and their mode-to-school choice behavior.

Moreover, this thesis contributes to the understanding of how teenagers perceive various built-environment characteristics and which of them work as constraints to active transport. We use both their perceptions of built-environment characteristics and the actual built-environment characteristics of their routes from home to school and weather conditions in order to capture the effect of these perceived and actual characteristics on mode-to-school choice behavior. The actual built-environment characteristics of their routes have been coded for each student by using geographical information systems.

Regarding the modeling techniques, this thesis provides insights into modeling OSN usage and trip making behavior; incorporating social interaction into Hybrid Choice Models; and capturing the effect of built and actual environment characteristics on mode choice behavior.

Finally, the innovative data collection and modeling methodology could be of high importance to researchers dealing with this age group, school transportation and active transport. This thesis also generally contributes to the research in active transport and the social influence effect on decision making regardless the age group. The investigation of teenagers' travel behavior could offer significant insights to the Ministry of Transport and Ministry of Education regarding school transportation, the travel behavior of the next generation, and road safety. Also, transportation companies, and especially public transport operators, could take advantage of these results to accommodate future transport trends and at the same time to expand their market share into this age group. Organizations and Non-Governmental Organizations (NGOs) could use these results to develop campaigns for promoting active transport, fighting child obesity and improving road safety. The possible users of the results of this thesis are presented in Figure 1.2.

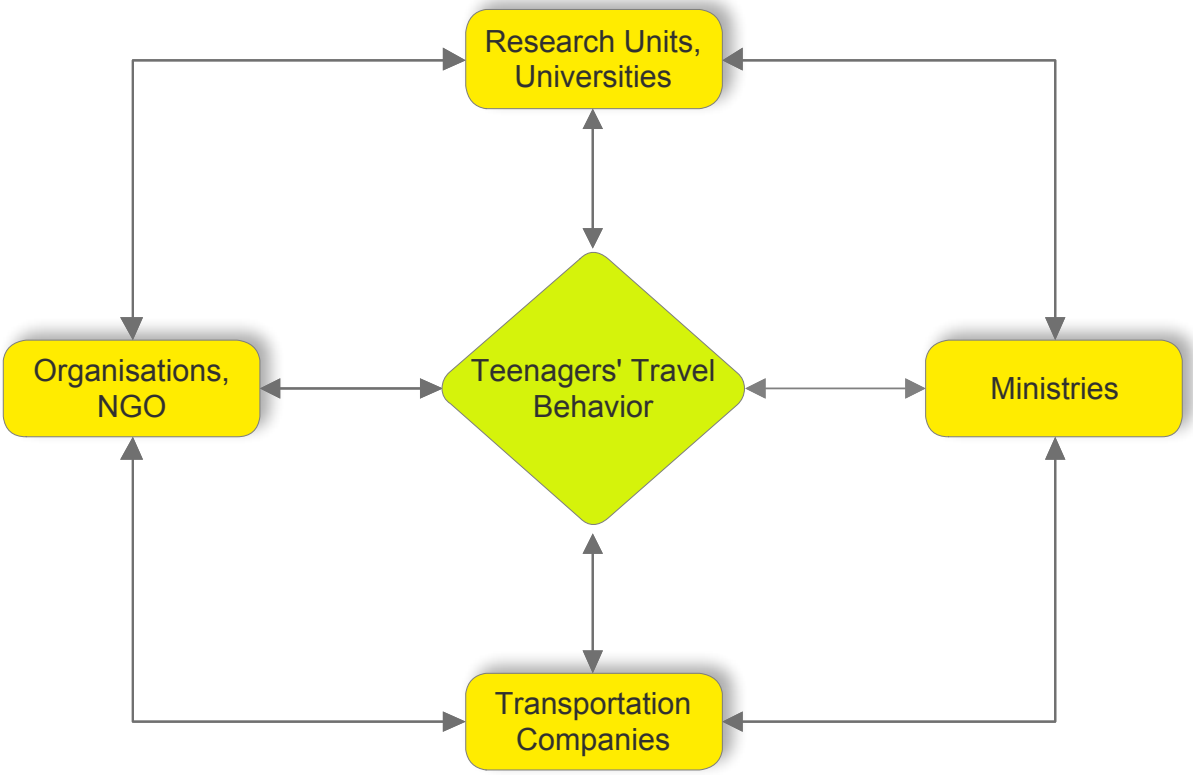


Figure 1.1: Stakeholders

1.4 Methodology

Before detailing the behavioral framework for teenagers' travel behavior, we reviewed in depth the relevant literature on school transportation and the psychology and sociology of teenagers, to highlight the way all these factors may affect their behavior and to discuss issues arising in modeling them. At the same time we designed the questionnaire for the survey, then went on to conduct the pilot surveys. Once the questionnaire was finalized, we launched the survey in Greece and in Cyprus. Following the data collection process, the datasets were carefully checked by using various statistical tests and APT for the analysis and modeling. Based on the results of the hybrid models that are estimated within this thesis, we propose various policies for promoting active transport and improving road

safety among teenagers, who as the next generation are the agents of change. The steps of the methodology are presented in Figure 1.3.

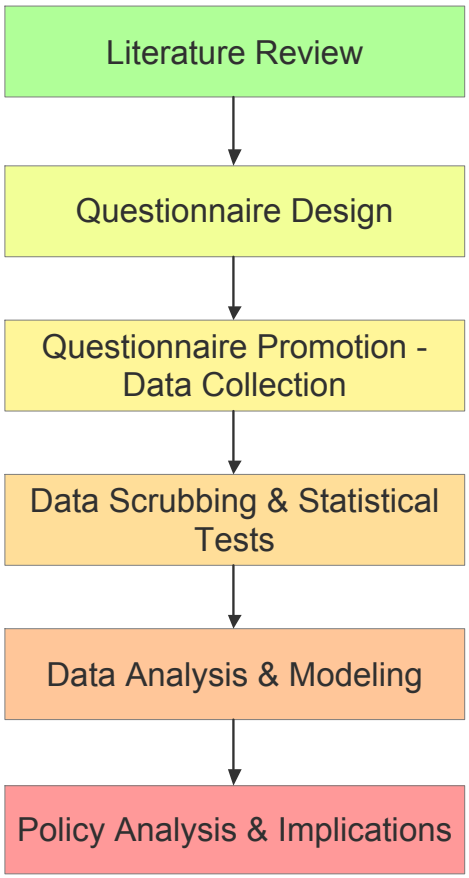


Figure 1.2: Steps of methodology of the thesis

1.4.1 Questionnaire Design

The questionnaire, which was designed especially for this research, consists of the following nine sections:

Section 1: records high school students' travel behavior and travel patterns, including transport mode(s) for their travel to school, after-school activities and Saturday activities (travel diary for one school day and Saturday);

Section 2: includes questions about time use, social networking and types of activities engaged in on a typical day and during a typical weekend;

Section 3: the questions refer to OSN usage;

Section 4: investigates the behavior of teenagers as road users;

Section 5: investigates the behavior of teenagers as drivers (this section is answered only by students who stated that they drive a motorized vehicle);

Section 6: contains questions on the attitudes and perceptions of high school students towards active transport (cycling and walking), public transport, and environmental protection;

Section 7: aims to investigate the relationships of teenagers and their social environment. More specifically, the questions refer to their parents' and friends' travel and mode use patterns;

Section 8: teenagers are presented with SP scenarios regarding their mode of transport to school;

Section 9: teenagers are asked about their personal experience of road traffic accidents, as drivers or passengers (this section is answered only by students who stated that they had been involved in a road traffic accident);

Section 10: gathers data about their socio-economic (grades, pocket money, etc.) and household characteristics (parents' education and employment, etc.).

Once the questionnaire was finalized, we held a further pilot survey in two high-schools over a period of one week, in order to ensure that the questions were clear and that the students had enough time to complete the questionnaire. We also used the feedback to prepare a manual for teachers, so that they could assist the students with any questions. The questionnaire is available in *Appendix A*.

1.4.2 Case Studies

The survey took place in two countries: Greece and the Republic of Cyprus. In Greece the pilot survey began in the school year 2009-2010. The main survey began in October 2010 and finished in May 2013 (3 consecutive school years), with 3,293 high school students participating in the survey. For the school years 2010-2011 and 2011-2012, in co-operation with the local Directors of Secondary Education, we arranged visits to high-schools to enable the students to fill in the printed questionnaires with the assistance of the researchers. In school year 2012-2013, the Ministry of Education of Greece authorized our survey and accordingly the questionnaire in electronic format was forwarded to the high-schools of 24 Greek prefectures out of 51.

The survey in the Republic of Cyprus took place in February 2012. In co-operation with the Ministry of Education and Culture (MOEC) of Cyprus, the web-based questionnaire was forwarded to all Cypriot high-schools, the sample consisting of 10,093 participants (21% of the total high-school student population). The students completed the web-questionnaire during the informatics class, while their teachers received a questionnaire-guide to enable them to answer any of the students' possible questions.

1.4.3 Models

This thesis develops latent variable and latent class models in order to investigate the teenagers' travel and mode choice behavior. In these models, various latent variables are

incorporated, such as willingness to walk, walkability constraints, and parental mode use patterns. More specifically, a latent class model is developed that investigates the effect of various OSN usage styles on trip making behavior. An HCM incorporating a social interaction effect is estimated in order to capture the effect of parents' mode use patterns on teenagers' attitudes and mode-to-school choice behavior. A latent variable model is developed that aims to capture the effect of teenagers' perceptions of walkability constraints and the effect of actual built-environment characteristics on mode choice behavior. Finally, a latent mode choice model using SP data is estimated and the estimation results are used to suggest policy implementations.

1.5 Outline of the Thesis

The remainder of this thesis is structured as follows:

Chapter 2 reviews the existing work on school transportation and the factors that have been found to affect it. It presents findings of previous surveys on teenagers' activities, social media usage and road user behavior. Also, it reviews briefly the literature on social influence and social interaction. Finally, it reviews behavioral models in the transportation field and concludes by discussing the gaps in the literature.

Chapter 3 presents descriptive statistics for the sample. Teenagers' activities, time use, and travel patterns are analysed in depth for each country and for each of the three distinct geographical areas participating in the survey (urban, rural, insular). This chapter concludes with a discussion of the findings of the statistical analyses and comparison of the findings for each distinct geographical area.

Chapter 4 studies teenagers' OSN usage styles and the trip making behavior of each OSN style. A Latent Class Poisson Regression model is developed in order to identify the trip making behavior for social purposes of each OSN usage style.

Chapter 5 presents an extension to HCM that refers to social influence. We present a methodological framework and the mathematical equations used to incorporate social interaction into HCM. The proposed modeling framework is tested within the context of a household, in terms of how parental walking habits affect teenagers' attitudes towards walking and, in turn, their mode-to-school choice behavior.

Chapter 6 presents hybrid mode-to-school choice models using RP data, while one model is estimated for each Greek geographical area, allowing us to identify the differences in travel behavior across these areas. The latent variable used in this model refers to perceived walkability constraints. Our aim is to investigate the effect of the perceived and actual built-environment characteristics on mode-to-school choice behavior.

Chapter 8 concludes the thesis. It summarizes the research objectives, approach, and findings, discusses the limitations of the survey and proposes various policies for the promotion of active and public transport. Suggestions for future research are also presented.

Chapter 2
Literature Review

As background for this thesis, in this chapter it is reviewed what is known from past research about underage people's activity patterns, mode to school and after-school choice behavior and time use. Due to the fact that in some topics there is no significant literature on adolescents' behavior, we briefly review the work on adults, in order to further understand some factors that affect travel behavior, such as the usage of Information and Communication Technologies (ICT). Then, we discuss the findings from the previous surveys identifying the gaps in the literature on teenagers' travel behavior.

2.1 Activity Patterns

Every day underage persons are making trips to school, after-school tutorial lessons, sports activities, entertainment activities, visiting friends, parks and a host of other destinations. How teenagers travel on those trips has significant environmental, economic and safety impacts on society but also short- and long-term health impacts on the teenagers (O'Brien and Gilberd, 2003). Although, there are numerous papers and reports that analyze adults' travel behavior and mode use patterns, only recently researchers have started to investigate in depth the underage persons' travel characteristics.

McDonald (2005) using data from the US National Household Travel Survey (NTHS) that conducted in 2001-2002, showed that those 18 and under make an average of 3.5 trips per day, with over 75% of these trips being in a passenger vehicle. Children spend 72 minutes traveling and cover 31 miles each day. However, when she focused only on the young teenagers (ages 13-15), she noticed that they have slightly depressed trip rate, because they make fewer automobile trips, adding that this may actually represent increased independent travelling for children. She also found out that teenagers aged from 16 to 18 years old travel more, because they have access to cars and want to travel independently. Also, high schools students are somewhat more likely to spend their afterschool time socializing with friends (5%), making serve passenger trips (5%), and shopping (4%).

Clifton (2003) analyzed the data that referred to the persons aged from 13 to 18 years old from the 1995 US Nationwide Personal Transportation Survey (NPTS finding that teenagers conduct 4.08 trips in a school-day. The majority of teenagers (71.0%) return home after school, whilst a significant portion of trips is for additional purposes. Trips for social and recreation purposes make up the majority (7.9%) of the after-school trips away from home. School-related (4.3%), personal business (3.8%), serve passenger (3.6%), dining out (3.3%), and shopping (3.0%) purposes together comprise a substantial share of trips. Also, the results showed that as students age, there is a decline in the percentage of trips made directly home and that the private automobile plays a significant role in after-school transport across all age groups.

O'Brien and Gilbert (2003) used data from the Transportation Tomorrow Survey (TTS) in Canada, finding that teenagers from 12 to 18 years old made 2.48 trips per day in 2001, while 2.30 in 1986. Also, the analysis showed that public transport trips being generally

much more common, and increasing significantly with age to become the most prevalent mode by the age of around 16. More specific, the researchers concluded that until about the age of 18, travel on schooldays is dominated by the journey to and from school; among 11 to 14 year olds, just over half of these trips are made by school bus (28%) or by car (23%).

Nevertheless, it is hard to identify other surveys that provide insights about teenagers' activity patterns. The majority of the existing surveys at underage persons' mobility focus only on the mode used for the trip to school, rather than their activity patterns and mode use for other trip purposes.

2.1.1 Modeling Activity Patterns

Although activity based models (ABM) are not developed in this thesis, a brief review of the main characteristics and principles of this kind of modeling is conducted, in order to be able to identify the activity patterns of teenagers.

The principal theories behind ABM are that demand for travel is derived from the demand for activities (Jones et al., 1990) and that an individual's multidimensional choice of a day's activities and travel consists of tours interrelated in an activity pattern (Ben-Akiva et al., 1996). The basic ingredients of an activity based approach for travel demand analysis (see Goulias, 2008) are:

a) explicit treatment of travel as derived demand (Manheim, 1979), i.e. participation in activities such as work or school, shop, and leisure motivate travel but travel could also be an activity as well (e. g., taking a drive). These activities are viewed as episodes (i. e., they are characterized by starting time, duration, and ending time) and they are arranged in a sequence forming a pattern of behavior that can be distinguished from other patterns. In addition, these events are not independent and their interdependency is accounted for in the theoretical framework;
b) the household is considered to be the fundamental social unit and the interactions among household members are explicitly modeled to capture task allocation and roles within the household, relationships at one time point and change in these relationships as households move along their life cycle stages and the individual's commitments and constraints change and these are depicted in the activity-based model (Goulias, 2008; Goulias et al., 2013); and
c) explicit consideration of constraints by the spatial, temporal, and social dimensions of the environment is given. These constraints can be explicit models of time-space prisms (Pendyala, 2003) or reflections of these constraints in the form of model parameters and/or rules in a production system format (Arentze & Timmermans, 2004).

Regarding the identification of the activities that are recorded in transport surveys, Goulias and Kitamura (1989) proposed a definition of trip chaining as a function of the numbers of trip segments by purpose, including the following factors: (a) spatial distribution of trip ends, (b) trip timing, and (c) total number of trip segments. They assumed that the number of mandatory activities influences the number of flexible and optional activities. The anchor activities are home, school or work, and the basic definition of a trip chain is then the set of trip segments between two anchor activities.

Bowman and Ben-Akiva (2001) defined a set of activity patterns called tours (trip chains).

Activity patterns contained a primary tour (travel related to primary activities) and secondary tours (involving travel for activities of lower priority to the activity in the primary tour). All activities were ranked in order of work related, school and all other purposes. Assigning higher priorities to activities of longer duration broke any ties. The advantage with this method is that it defined the number of secondary trips involved. Generally, it is assumed that individuals organize their daily travel daily in a pattern consisting of tours. The pattern is characterized by (a) the primary activity, with one alternative being to remain at home for all the day's activities, (b) the type of tour for the day's primary activity, including the number, purpose and sequence of activity stops, and (c) the number and purpose of secondary tours.

Currently, the development of transportation survey methods and especially the utilization of global positioning systems (GPS), mobile communications systems, and other new technologies enable transport planners to obtain more accurate and complete information of individuals' trajectories in time and space (Goulias & Kim, 2005), thus enhance the development of ABM.

2.2 Factors Affecting Mode Choice Behavior

This section presents and discusses the factors that have been identified to affect underage persons' mode choice behavior. For some factors that the literature on teenagers is limited, we presented the existing work on adults' travel behavior.

In recent years, increasing health problems and especially the high obesity rates among underage population in developed countries, made a vast body of researchers to investigate students' mode to school choice, and more specifically the choice of motorized versus non-motorized vehicles. In doing so, a lot of work has been produced in the health-related disciplines, but also in transportation and urban planning arena that could arguably contribute to a more active lifestyle. Indicative results show that active transport is associated with increased physical activity (Alexander et al., 2005; Cooper et al., 2005; Sirard et al., 2005; Cooper et al., 2010), and thus lower body mass index (Rosenberg et al., 2006), and higher levels of energy expenditure (Faulkner et al., 2009).

Herein, researchers have identified several factors that influence mode to school choice for children, such as distance to school, urban form, age, gender, household car availability, safety, and children's travel preferences. The results of indicative surveys are summarized in the following subsections.

2.2.1 Demographic & Socioeconomic Characteristics

Age and gender are important in determining children's travel and are included as factors in the majority of the existing surveys. Many researchers have shown that males have a higher propensity for walking and cycling to and from school (Samimi and Ermagun, 2012; McDonald, 2007; Timperio et al., 2004; Evenson et al., 2003; Black et al., 2001; Larsen et al., 2009; Bungum et al., 2009; Hume et al., 2009; Nelson et al., 2008; Nader et al., 2008; Elias & Katoshevski-Cavari, 2014; Buliung et al., 2009). Nonetheless, there are some studies in the literature that does not confirm this finding (Wilson et al., 2010; Wen et al.,

2008; Salmon et al., 2005; Martin et al., 2007; Kerr et al., 2006*)*. Regarding age, most of the studies show that older children are more likely to walk to school (Noland et al., 2010; Seraj et al., 2012; Yang & Markowitz, 2012; Larsen et al., 2012; Clifton et al., 2010), while in some studies no correlation was found between age and mode choice to school (Merom et al., 2006; Kerr et al., 2006; Dellinger and Staunton, 2002).

Socioeconomic factors such as car ownership and income have been shown to affect mode choice decisions in school trips. Income is an important constraint variable because it is correlated with the number of household vehicles which directly determine the travel options available to the household. Some studies have found that students from higher household incomes (Samimi and Ermagun, 2012; Mitra and Builing, 2012; McDonald, 2008; McMillan et al., 2006; Spalek et al., 2006*)* and those with more household cars (Makarewicz, 2013; McMillan, 2007; Yelavich et al., 2008; Copperman and Bhat, 2007*)* are less likely to use active transport for school trips. Larsen et al. (2009), on the contrary, found that there is negative correlation between active transport and household income, but only in the return trips from school back to home arguing that higher income households may have only one parent working, or more flexible working hours, which allow parents to pick up their children after school. Makarewicz (2013) also found a negative effect of vehicle ownership on escorting children to school, arguing that households with higher vehicle ownership, thus higher income, purchase homes within walking distance to schools and that for families with lower vehicle ownership sometimes is cheaper to escort their kids to school rather than paying for transit. Some other studies reported non-significant associations between household income and mode choice (Seraj et al., 2012; Martin et al., 2007; Ewing et al., 2004) and household car ownership and mode choice for school trips (Martin et al., 2007; Evenson et al., 2003*)*.

It has been also identified in some surveys that higher parental level of education affects negatively the choice of private motorized modes to school (Everson et al., 2003; Mota et al., 2006). The reason behind this positive correlation can be attributed to the fact that most of the individuals with higher education also have higher income and are thus less dispensed towards active transport. On the other hand, Makarewicz (2013) in her survey in Oakland, CA, identified negative correlations between higher parental level of education and private modes (Makarewicz, 2013). She argued that educational level is highly associated with income and that caregivers with higher education were more likely to afford a home near a good school, making it possible for their children to walk or bike.

Parents' employment status also has been identified as a factor affecting mode to school. Parent's with flexible work arrangements and schedules are more likely to be able to walk or bike with their children to and from school, while parents who have rigid work timings are more likely to chauffer their children to and from school because of schedule constraints (Seraj et al., 2012; Zhu and Lee, 2009; Yarlagadda and Srinivasan 2008).

Another sociodemographic variable, ethnicity, was tested in a number of studies as well. McDonald (2007) found that ethnic minorities often exhibit a higher tendency to commute actively. This is somewhat to the fact that vehicle ownership tends to be lower among minority and ethnic groups (Seraj et al., 2012; Samimi and Ermagun, 2012). In contrast, Makarewicz (2013) found that whites had the highest share of walking in her sample because they were the most able to choose a neighborhood for housing, school quality, and walkability, concluding that the mode choice to school was related to a variety of different factors other than race or ethnicity, including income, vehicle ownership, commute mode for the parent, marital status, work status, and the children's age and gender.

In terms of the effect of family status, once again the results vary. Some studies have identified non-significant correlation between single parenting and active transport to school (Martin et al., 2007; Timperio et al., 2006; Merom et al., 2006*)*. Few studies have stated that students in single-family homes are more likely to use active transport (Fulton et al., 2005). While few studies have identified a negative correlation between single caregivers and walking, arguing that households with two caregivers typically earned more money and therefore chose their housing near a better school; the two caregivers traded commute duties; two parent households also tended to live in neighborhoods where groups of parents knew each other and shared walk-pool duties (Makarewicz, 2013).

All the aforementioned differences among the sociodemographic variables that affect mode to school choice behavior can be indicative of each survey's different sample selection. For example, difference in age ranges and subsequently the researcher's definition of "older" for case studies has shown that some researchers are working with different age definitions such as 10-12 (Wilson et al., 2010) and 14-18 (McDonald, 2007). However, even in cases where there was no difference in definition, contradictory conclusions were still found (Kerr et al., 2006; Rodriguez & Vogt, 2009*)*. These differences can be indicative of socioeconomic, environmental or geographical factors. For example, in some countries, youths are granted the right to driving licenses from the age of 16, such as in the United States, while in Europe individuals must be at least 18 years old. This difference in minimum driving ages could be a reason for an increase in active transport for countries with higher age requirement. Methodological differences could also be a possible reason for these contradictory findings. The vast majority of the studies have assumed a similar effect of age on the propensity to choose active transport for families with different demographic, socioeconomic, and environmental characteristics. And finally, each of these surveys has been conducted in a different period of time or year and in different areas, which have their own unique built-environment characteristics. For example, the majority of the literature on this topic comes from US and Canada, while there are only few surveys from Europe and Asia. In the U.S. context, the car culture and the freedom of movement has caused greater car ownership and lower non-motorized mode usage than that in other countries (Kamargianni & Polydoropoulou, 2014; Sirard & Slater, 2008).

2.2.2 Built-Environment Characteristics

Active transportation is the missing piece in our transportation system. Walking and bicycling can improve public transportation by providing quick access to the destination. Given the availability of a safe and convenient infrastructure and the attractive built environment, more people will choose walking or bicycling for short trips. Savings in fuel costs, a smaller carbon foot-print, and it being a practical way to achieve recommended levels of physical activity are among the benefits that make active transportation an irresistible all-in-one package (ATFA, 2009). Against this background, the research on active commuting has expanded rapidly in the last decade, with researchers trying to determine which are the built-environment characteristics that favor active transport.

The distance between the students' home and school is one of the most significant environmental factors affecting the utilization of active transport. All studies regarding this subject have found negative correlation between distance and active transport (indicatively: McDonald, 2008a; McDonald, 2008b; McMillan, 2006; Wilson et al., 2010; Salmon et al., 2007; Handy, 2002). Specifically, in terms of the distance parameter, it has been found that

students who live less than 1.6 kilometers from their school have a much higher probability of utilizing active transport modes than those who live farther than 1.6km from school (McMillan, 2007). Schlossberg's et al. (2006) study has shown that in the U.S. state of Oregon, 52% of those who live less than 1.6km from their school walk to school. Another study in Belgium has identified that 83.5% of students walk to and from school when they live less than 2.0km from school (Dyck et al., 2010). Also, a number of studies have considered the effects of environmental factors such as parks, play areas, and number of trees, on the school trips and population density (Mota et al., 2007; Kerr et al., 2007; Alton et al., 2007; Evenson et al., 2006; Braza et al., 2004; Timperio et al., 2004; He, 2011; Tyrinopoulos & Antoniou, 2013).

More specific, McMillan (2007), using data from sixteen elementary schools in California, examined which factors affected students' caregivers' decisions about transport mode to school. Binomial logit regression probability models were developed to examine the likelihood of a child walking/bicycling to school versus traveling by private vehicle or neighborhood carpool. The results of the analysis support the hypothesis that urban form is important, but is not the sole factor that influences a caregiver's decision about a child's trip to school. Other factors may be equally important, such as neighborhood safety, traffic safety, household transportation options, caregiver attitudes, social/cultural norms, and socio-demographics.

Timperio et al. (2006) conducted a cross-sectional study of 235 parents of children in Melbourne aged from 5 to 6 years and 677 children aged from 10 to 12 years, in order to examine personal, family, social, and environmental correlates of active commuting to school. Parental perceptions that there were few other children in the neighborhood, and no lights or crossings for their child to use, and an objectively assessed busy road barrier en route to school were all negatively correlated with active transport. Good connectivity en route to school was negatively associated with walking or cycling to school, while children were more likely to actively commute to school if their route was less than 0.8 km.

Another survey (Larsen et al., 2009) examined the travel behavior of 614 students aged from 11 to 13 years old in London, Ontario. A geographic information system was used to link survey responses from students who lived within one mile of their school to data on the social and physical characteristics of the environment around their home and school. Logistic regression analysis was used to test the influence of environmental factors on mode of travel (motorized versus active) to and from school. The results showed that the likelihood of walking or biking to school was positively associated with shorter trips, the male gender, a greater land-use mix, and the presence of trees on the street. Active travel from school to home was also associated with lower residential densities and lower neighborhood incomes.

Mode to school choice behavior was also investigated by Mitra and Buliung (2012). The sample they examined consisted of 11-year-old children who lived within 3.2 kilometers of their schools. The data about their travel behavior were provided by their parents. A discrete-choice modeling approach was adopted to explore the correlates of four travel modes (walk, transit, school bus, car). Distance was the most important factor in explaining the mode choice for school transportation, followed by variables related to intra-household travel interactions. The built environment near the home and school, in terms of personal and traffic safety and neighborhood aesthetics/walkability, explained some of the variation in mode choice, while the effect of street connectivity on mode choice was less clear.

Schlossberg et al. (2007) examined the relationship between urban form, distance and active transportation to school by surveying the parents of 292 middle school students. The results of the multivariate models that they developed showed the independent influences of distance and urban form on walking and biking. Distance to school was highly associated with walking to and from school, with students living less than one mile away from their school the most likely to walk. Fewer street dead ends were also predictive of walking. The primary reasons parents gave for driving to or from school related to convenience: ease of dropping the child off on the way to work, the heaviness of the child's backpack, and bad weather. Neighborhood walkability concerns were expressed by some, with almost one quarter complaining of dangerous traffic conditions, high-speed vehicles and a lack of proper sidewalks.

In 2006, Kerr et al. (2006) examined the effects of objective and perceived neighborhood environmental characteristics and parent concerns regarding active commuting to school on actual active commuting to school. 259 randomly selected parents of children aged 5 to 18 years old participated in the survey. Logistic regression analyses showed that, in high-income neighborhoods, more children actively commuted in high-walkable than in low-walkable neighborhoods, but no such differences were noted in low-income neighborhoods. Parental concerns and neighborhood aesthetics were independently associated with active commuting. Perceived access to local stores and biking or walking facilities accounted for some of the effect of walkability on active commuting. Pedestrian safety, which was not related to commuting behavior, was related to parental concerns. Parental concerns about their child walking or biking to school were significantly inversely associated with residential density and neighborhood-level walkability.

Another survey, which took place in Portugal (Mota et al., 2007), tried to assess the relationships between transport to/from school (active versus passive), sedentary behaviors, measures of socioeconomic position and perceived environmental variables. The sample comprised 705 adolescent girls (mean age 14.7) who were assigned to active or passive transportation groups. No statistically significant differences were seen in terms of screen time between the travel groups. The occupational status of both the mother and the father and the father's educational level were significantly and negatively associated with active transport, while street connectivity was positively and significantly associated with active transport. Logistic regression analysis showed that the likelihood of active commuting decreased by around 50% as the father's education increased from the low to middle socioeconomic position group.

Yoon et al. (2011), using data from the 2001 post-census travel survey conducted for the Southern California Association of Governments (SCAG), investigated the propensity to escort children under 16 years old to school. Three binary logit models were estimated, the first on independent mobility, the second on active transport and the last on the father escorting the child. The estimation results show that independent mobility of children is a strong function of their socio-demographic characteristics and their family and less a function of the urban environment. Propensity to engage in active transport, however, is more strongly related to the population density and accessibility, and the escorting of children by their fathers is influenced by the relative locations of their residences and jobs.

In 2008, Grow et al. examined the factors related to two sources of physical activity for youths: active use of recreation sites and active transport to recreation sites. The sample consisted of parents of children (n = 87) and matched pairs of parents and adolescents (n = 124 pairs) from three US cities. Multivariate regression models evaluated factors associated

with youths' frequent site use and active transport to sites. Proximity to the site was associated with the frequent use of large parks and public open space. Adolescents' active transport to more sites was most positively related to higher perceived traffic safety and a better pedestrian infrastructure and negatively related to the threat of crime. Active transport was strongly associated with the use of multiple recreation sites by children and adolescents, even when accounting for proximity and demographic factors. Adolescents living in neighborhoods with better traffic safety walked/biked to more recreation sites to take part in physical activity.

Zhu and Lee (2009) identified multilevel correlates of walking to/from school. They surveyed parents of 2,695 students from nineteen elementary schools in Austin, Texas, featuring diverse socio-demographic and environmental characteristics. Among the personal and social factors, negative correlates included parents' higher level of education, higher car ownership, personal barriers and school bus availability; the positive correlates were parents' and children's positive attitudes and regular walking behavior, and supportive peer influences. Of the physical environmental factors, the strongest negative correlates were distance and safety concerns, followed by the presence of highways/freeways, convenience stores, office buildings and bus stops en route.

The results of another Australian study (Wen et al., 2008) which used a sample of 1,603 students aged from 9 to 11 years old, showed that parents' attitudes towards walking to school and their own modes of travel to work were associated with how their children traveled to and from school, as were distance from home to school and the number of cars available in the household. The fact that parents used non-motorized modes of transportation was found to influence parental attitudes and perceptions of the built environment and neighborhood safety. The parents of children who walked to school regularly perceived the built environment and neighborhood to be less dangerous than did parents whose children did not walk or cycle to school.

Seraj et al. (2012) examined the factors that influence parental attitudes towards their children walking or cycling to school. Using 1,000 observations from the California add-on sample of the 2009 National Household Travel Survey, they estimated a multivariate ordered response model using the composite marginal likelihood approach. The five-attitudinal measures were related to crime, weather, volume of traffic, speed of traffic and distance to school. The results showed that correlations were strongest between speed and volume of traffic, distance and traffic variables, and crime and traffic variables. They also showed that the proximity of a school to residential neighborhoods was critical in shaping favorable parental attitudes towards walking and cycling.

Noland et al. (2012) examined the mode choice behavior of children's travel to school based on surveys conducted at a sample of schools in New Jersey. The mode that children used to go to school was reported by their parents. Using a mixed logit model they confirmed that good connectivity, more intense residential land use, and better sidewalk infrastructure are associated with increased walking to school, while their mixed logit results indicate substantial heterogeneity in behavior associated with built environment variables.

A review of the samples and methodologies used in various surveys of school transportation and the built environment is presented in Table 2.1.

Table 2-1: Review of the literature on built environment characteristics

Reference	Sample	Modes examined	Environmental attributes examined	Methodology
McMillan, 2007	N=1128 Age=6 to 10 Reported by parents California, USA	Active transport, Private motorized vehicle	Sidewalks; houses with windows facing street; land-use mix	Binomial logit regression probability models
McDonald, 2007	N = 6,508 Age = 5 to 13 Reported by parents. NHTS survey, USA	Car, Bus/transit, Walk	Distance; Population density	Multinomial choice model
Timperio et al., 2006	N= 235 Age = 5 to 6 and N= 677 Age = 10 to 12 Reported by parents. Melbourne, Australia	Walk, Bicycle	Traffic; concern about strangers; concern about road safety; traffic lights; need to cross several roads; availability of public transport	Odds ratios
Larsen et al., 2009	N=614 Age = 11 to13 Reported by parents. London, Ontario, Canada	Walk alone, Walk accompanied, Bicycle or scooter, Skateboard/rollerblade, School bus, City bus, Driven in automobile	Street trees; distance; land-use mix	Stepwise logistic regression
Mitra and Builing, 2012	N=945 Age = 11 Data from the 2006 Transportation Tomorrow Survey. Reported by parents. Toronto, Canada	Walk, Transit, School bus, Car	Crossing a major street; ratio between network distance and straight line distance; land-use mix; number of street-blocks; proportion of 4-way street intersections; dead ends; intersections that are signalized	Multinomial choice model
Schlossberg et al., 2007	N=292 Age = 11 to 13 Reported by parents. Oregon, USA	Walk, Bicycle, Bus, Car	Distance; intersection density; dead-end density, route directness; major road en route; railroad tracks en route	Logistic regression models
Kerr et al., 2006	N=259 Age = 5 to 18 Reported by parents. Seattle, King County, USA	Active transport	Aesthetics; walking and biking facilities; street connectivity; neighborhood walkability; land-use mix; access	Logistic regression models
Grow et al., 2008	N = 87 parents of children and N = 124 matched pairs of parents and adolescents. Boston, Cincinnati, and San Diego, USA	Active transport	Land-use mix; street connectivity; pedestrian infrastructure; aesthetics; traffic safety; crime threat; city; proximity	One-way random-effects single-measure intraclass correlations

Table 2.1 - Continued				
Mota et al., 2004	N=705 (only girls) Age = 12 to 17. Aveiro District, Portugal	Active transport, Passive transport	Access to destination; connectivity of the street network; infrastructure for walking and cycling; neighborhood safety; social environment; aesthetics; recreation facilities	Logistic regression model
Reference	**Sample**	**Modes examined**	**Environmental attributes examined**	**Methodology**
Yoon et al., 2011	N = 3,483 Age = under 16 Reported by parents. 2001 post-census travel survey (SCAG). Southern California	Independent mobility, Active transport, Father escorting the child	Population density, accessibility, relative locations of parents' residences and jobs	Binary logit models (one for each alternative)
Zhu and Lee, 2009	N=2,695 Age = 6 to 10 Reported by parents. Austin, Texas, USA	Walk	Distance; safety concerns; highways/freeways; convenience stores; office buildings; bus stops en route	Multilevel correlations
Wen et al., 2008	N= 1603 Age = 9 to 11 Trips recorded by kids, socioeconomic characteristics by parents. Sydney, Australia	Walk, Car	Distance; safety	Bivariate analyses and Multiple logistic regression
Seraj et al., 2012	N=1,000 Age = under 16 Reported by parents 2009 NHTS, California, USA	Walk, Bicycle.	Distance; violence/crime rate; speed; traffic; weather.	Multivariate ordered response model
Noland et al., 2012	N=1573 Age = 5 to 13 Reported by parents. New Jersey, USA	Car, Carpool, School bus, Walk	Existence of parks; connectivity; length of sidewalks; speed limits; planting strips	Mixed logit model
Samimi and Ermagun, 2012	N=3441 Age = 12 to 17 Tehran, Iran	Walk	Population density; number of parks; road density; green spaces; mountainous vs flat	Binary logit models

2.2.3 Attitudes & Perceptions

One factor, which is not well understood yet, is how children's own attitudes, perceptions and preferences regarding travel influence their travel patterns and mode choice behavior.

The small amount of research that exists suggests that travel represents important socializing time for many youth and that this influences their travel and transport mode preferences (Gurin, 1974; Weston, 2002). Some trips appear to be undertaken purely on their merits, e.g. joyriding and cruising. This finding is at odds with the axiom that travel is a derived demand, but may relate to findings that even adults have a preferred travel time, which is not zero, and are not simply looking to minimize general travel cost (Mokhtarian and Salomon 2001). Thus, we further review the literature regarding the unobserved (latent) variables that affect travel behavior. Due to the fact that there are limited results regarding how attitudes and perceptions affect underage persons' travel patterns and mode choice behavior, we widely focus on the latent variables that have been identified to affect adults' travel behavior.

In view of the need for sustainable mobility, various studies have used attitudes and values as decisive factors in delivering a basis for measures aimed at effecting behavioral change. This is supported by significant work on understanding motivational and affective factors, and their influence on mode choice relative to instrumental variables (Steg et al., 2001; Steg et al., 2011; Steg, 2005; Gardner and Abraham, 2007; Anable and Gatersleben, 2005). The studies show that these types of variables significantly affect mode choice, sometimes even more than instrumental variables.

Many recent empirical investigations of travel mode choice have adopted latent variables about environmental consciousness or protection based on diverse indicators collected from attitudinal surveys. For example, Rieser-Schlusser and Axhausen (2012) present latent variable models that incorporate an awareness of environmental problems, a denial of environmental issues and a desire for variety in the daily routine. Initially, they carried out a factor analysis to establish the predominant attitudinal factors, which were then used as latent variables in a mode choice model. The results show that each of the three latent variables influences the mode choices of the study participants in a different way, and this could be attributed to their other socioeconomic characteristics. The data used came from a paper-and-pen mail-back survey conducted in Canton Zurich in 2010 with a total sample of 222 participants.

Atasoy et al. (2010) developed an integrated choice and latent variable model including attitude against public transport and environmental concern. Measurement equations were built using the most relevant indicators of the latent attitudes, in the form of a regression, while the indicators were treated as continuous variables in the modeling process. They used 1096 observations from the Swiss canton of Vaud and the results showed that attitude against public transport had a negative effect and environmental concern a positive one on the utility of public transport. Regarding environmental concern, the number of bikes in the household and level of education both had positive effects. Older people were found to be more concerned about environmental concepts.

Looking at travel mode choice, Johansson et al. (2006) used data from a 2001 survey of commuters from Stockholm to Upsala to construct and test the significance of five individual-specific latent variables – amongst them environmental preferences. These were used instead of mode-specific latent variables to explain choice, and the authors did not construct latent variables for non-chosen modes of travel. Individual preferences were estimated using a latent variable model and predictions regarding the effects of the latent variables on mode choice were calculated using a discrete choice model. A dataset of 1,708 observations was used for the model estimation. The results confirm that time and cost are significant determinants of modal choice and show that environmental preferences increase

the likelihood of choosing an environmentally friendly mode, (train), over a less environmentally friendly mode (bus). However, environmental preferences do not affect the choice between car and bus.

Outwater et al. (2003) expanded the mode choice model to recognize travelers' attitudes and different market segments. They use structural equation modeling (SEM) to simultaneously identify the attitudes behind travel behaviors and the causal relationships between a traveler's socioeconomic profile and their attitudes. Based on 823 observations from the San Francisco Bay Area survey in 2001, six attitudinal factors were extracted, three of which were used to partition the ferry-riding market into eight segments. These market segments were used to estimate stated preference mode choice models for 14 alternative modes. One of the surveys' conclusions was that those who are modest environmentally aware have the most need for time savings and in doing so they prefer car for their trips.

Shiftan et al. (2008) also show market segmentation to be a powerful tool for improving our understanding of travel behavior and transport services. Based on 522 records from a UTA household survey, they identify eight factors that affect travel behavior. Three of the eight factors are then used for market segmentation: sensitivity to time, a need for fixed schedules, and a willingness to use public transport. This leads to eight market segments, one of which is "green riders", a segment with high willingness to protect the environment and low sensitivity to time.

Hunecke et al. (2007) analyze the ecological impact of individual travel behavior, identifying six psychological variables as significant factors in the use of private motorized modes, and concluding that mobility-related attitudes are better predictors of travel mode choice. Regarding travel behavior changes, the relevant factors are classified into two groups: "perceived behavioral control" and "perceived mobility necessities" are variables based on subjective evaluations of the behavioral scope. Attitudes to cars and bicycles, weather resistance and ecological norms (resulting in preferences for environmentally friendly transport modes) are individual variables determining preferences for different transport modes. Regarding distance travelled, psychological variables were of minor relevance, while sociodemographic determinants such as age and employment situation were the strongest predictors.

A comprehensive study by Anable (2005) shows the motivations and constraints that relate to behavioral changes. Taking a similar approach to those of existing lifestyle studies, she utilized a set of 17 factors related to attitudes towards car use, the use of alternative transport modes, the environment, and "green behavior". Her cluster analysis of more than 600 interviews delivered a set of four car-owning and two non-car-owning groups of participants: "malcontented motorists", "complacent car addicts", "die-hard drivers", "aspiring environmentalists" (all car-owning), "car-less crusaders" and "reluctant riders" (both non-car-owning). Motivations and barriers related to changing travel behavior and using alternative modes differed widely between the groups.

Abou-Zeid et al. (2011) estimated a model in which the distribution of the value of time also depends on attitudes towards travel. They develop a hybrid choice model that incorporates a latent "car-loving" attitude as an explanatory variable influencing the cost sensitivity of travelers. The latent variable is specified so as to capture attitudes towards cars. The case study presented is based on data from a stated preferences survey conducted in Stockholm, Sweden, in 2005 among 2,400 households. The sample used for the

estimation consists of 2,216 SP responses from 554 individuals. The results show that an increasingly positive attitude reduces the cost sensitivity related to car travel. In terms of the effects of socioeconomic and demographic variables on the latent attitude, gender is insignificant, while higher income leads to a more positive attitude towards cars.

In the last decade, many attempts have been made to gain insight into individual decision-making processes and traditional choice models have been enriched with the construction of latent variables. The latent variables used for mode choice modeling have included those such as modal comfort and convenience (Morikawa et al., 2002; Polydoropoulou et al., 2010; Polydoropoulou et al., 2013), habits in mode choice (Bamberg et al., 2003; Thogersen, 2006; Diana and Mokhtarian, 2009; Tudela et al., 2011), willingness to take risks (Tsirimpa et al., 2010), the relationship between lifestyle, residential location choice and the propensity to travel (La Paix et al., 2001; Walker & Li, 2007; Bolduc et al., 2008; Vij et al., 2011; Kamargianni et al. 2012) and that between well-being and happiness (Abou-Zeid & Ben-Akiva, 2011; Polydoropoulou et al., 2010; Duarte et al., 2010). However, to date these soft factors that have been shown to affect adult travel behavior, have not been investigated if they affect teenagers' travel behavior.

2.2.4 Social Environment & Social Interaction Effect

For many years, socioeconomic factors and the attributes of transport alternatives have been the key elements considered in most models used to support stakeholder planning (Shiftan et al., 2008). However, it has been recognized that a complex interaction between several factors takes place whenever an individual makes a choice and as a consequence beliefs, values, emotions, attitudes and other personal characteristics have been incorporated into choice models (Walker & Ben-Akiva, 2002; Ben-Akiva et al., 2002a) as described in the previous subsection.

In addition, it is well-known that individuals' choice behavior is often influenced by the existence, opinions, choices and behaviors of other people (van de Bos et al., 2013; Abou-Zeid & Ben-Akiva, 2011; Rose & Hensher, 2004; Brock & Durlauf, 2001; Manski, 1993) or generally by the social environment of the decision maker. In sociology and psychology, there is much empirical evidence confirming the effect of social interaction. In terms of neighborhood influences, Crane (1991) found a relationship between both school dropout and teenage childbearing rates and the occupational composition of a community. Haveman and Wolfe (1994) presented similar findings regarding high school dropout rates. In a different context, Durlauf and Walker (1998) argued that social interaction plays a major role in explaining variations in fertility rates and the adoption of different birth control technologies.

In recent years, the effect of social interaction and social influence on individuals' decision-making has attracted attention in the transportation sector as well. In this context, Paez and Scott (2007) and Wilton et al. (2011) found that the decision of an individual to telecommute is heavily influenced by others deciding to telecommute. Social interaction effects have also been recognized in other settings, such as modal choice decisions (Kamargianni et al., 2014; Dugundji & Walker, 2005; Goetzke, 2008), leisure travel (Axhausen, 2005), participation in social activities (Carrasco & Miller, 2006), and even illicit parking behavior (Fukuda & Morichi, 2007). A guiding philosophy in these surveys is that the incorporation of social interaction variables leads to a more behaviorally realistic

representation of the choice process, and consequently to a better explanatory power.

Arguably, the utility of an individual's choice is a function of socioeconomic characteristics and psychological factors (Ben-Akiva et al., 2002b). The psychological factors are affected by the choices and behavior exhibited in the social environment of the individual, and also by the way that the individual processes or anticipates this information. McFadden (1997) argued that the most cognitive anomalies in utility theory operate through errors in perception that arise from the way information is stored, retrieved and processed, and that the empirical study of economic behavior would benefit from closer attention to how attitudes and perceptions are formed and how they influence decision-making. Currently, there is still a gap between decision-making in real life, where the influence of the social environment is extensive, and decision-making as measured in the laboratory, which is often done in the absence of any social influences (Weinberg, 2011).

Process and Context of Decision-Making

Decision-making plays a pivotal role in daily life, comprising a complex process of assessing and weighing the short-term and long-term costs and benefits of competing alternatives. The output of the decision-making process is determined by an interaction between impulsive or emotionally based systems responding to potential rewards and losses, and reflective or cognitive control systems controlling long-term goals (Visser et al., 2011). The description of choice behavior can be given more structure by describing choice behavior as a decision making process involving two dimensions: process and context (Ben-Akiva et al., 2012). Process refers to the steps involved in decision-making, while context refers to the factors affecting the process.

Individuals recognize opportunities and constraints regarding their choices. They collect and process information about the attributes of available options which, together with their attitudes and emotional states, influences their perceptions and beliefs about these options. Decision makers then focus and refine their preferences, targets and needs and form a plan for making the decision (Ben-Akiva et al., 2012). The plan can be thought of as a strategy, set of decision criteria or set of intentions. Different alternatives are evaluated and the decision is made by following the plan. Decision-making is influenced by many factors, such as gender, age, genotype, and personality, which have been extensively investigated and discussed (van den Bos et al., 2013; Homberg, 2012; Overman, 2004; Abelson & Levy, 1985). Nevertheless, relatively little attention has been paid to the crucial moderating effect of social context on decision-making.

Context refers to factors affecting the process. In real life, decisions are often strongly influenced by the person's social environment and involve direct and indirect social interactions. A valuable way to structure this is through social networks, as they affect the flow and the quality of information (Granovetter, 2005). A person's social network may affect their decision-making in numerous ways. In daily life, individuals constantly make decisions based on their personal information and experience, as well as that of others. An individual's decisions may also be indirectly influenced by their social environment, through the effect the latter can have on an individual's emotional/psychological state (van den Bos et al., 2013).

Importantly, the modulating role of the social environment is strongly affected by an individual's characteristics and personality as well as those of its group mates (Webster and

Ward, 2011). Decision makers generally belong to a number of social networks, which may be small or large and include few or many members. At this point, a distinction between tight and loose social networks is worth making. Tight social networks have few members, strong interactions between those members, and high entry and exit costs (Christakis and Fowler, 2009). Examples of tight social networks include groups defined by family relationships or close friendships. Tight social networks exhibit strategic interactions, joint constraints, and joint production. Loose social networks have low entry and exit costs. They are larger, and involve weaker interactions between members. There are many examples of loose social networks, such as friends, online networks, neighborhoods, ethnic groups, classrooms, clubs, and professional networks (e.g., close work colleagues). The size of loose social networks implies that the potential for strategic interaction is small (Golub and Jackson, 2010).

Concluding, the research community is gradually starting to appreciate the importance of factors such as interactions between decision makers, the actual processes leading to choices, and the role of subjective factors. As a result, new models are emerging that give a more realistic representation of real-world behavior, such as the Brock and Durlauf's (2001) discrete choice models with social interaction, which is in essence a static Nash equilibrium model in which a random utility framework is extended to include an effects of the expected choices of others on individual payoffs. Another model is the strategy adjustment model of Blume and Darlauf (2003), in which binary choice evolve in response to the past behavior of others via a stochastic population process. In addition, an extension to HCM has been presented by Abou-Zeid and Ben-Akiva (2011) in order to capture the indirect effect of social comparisons on travel choices through its effect on comparative happiness. They argued that social comparisons arise from exchanges of information among individuals and they postulated that the social gap resulting from comparisons is a determinant of "comparative happiness", which in turn affects subsequent behavior. They studied how perceived differences between experienced commute attributes and those communicated by others affect comparative happiness and consequently overall commute satisfaction. The incorporation of social interaction into choice process is of high significance in transportation sector, not only to understand better the travel behavior of adolescents, but adults' as well.

2.2.5 Social Media & Social Networking

Using social media web sites is among the most common activities of today's adolescents. Any web site that allows social interaction is considered a social media site, including online social networking (OSN) sites such as Facebook, MySpace, and Twitter; gaming sites and virtual worlds such as Second Life, Club Penguin, and the Sims; video sites such as YouTube; and blogs. Members use these sites for a number of purposes. The root motivation is communication and maintaining relationships. Popular activities include updating others on activities and whereabouts, sharing photos and archiving events, getting updates on friends' activities, displaying a large social network, sending messages privately, posting public testimonials and presenting an idealized persona.

While the technology underlying many of today's popular information and communication technologies (ICTs) has been available since the 1980s or 1990s, they have only started to become mainstream over the past decade, as the costs of computing and internet usage have fallen (Mans et al., 2012; Kamargianni & Polydoropoulou, 2011). High-speed internet

access, especially broadband and fiber-optic, has become much more prevalent and the number of people with internet access at home increased from 1.4 billion in 2009 to almost 1.6 billion in 2010, with 65% of these in developed countries (UNSD, 2010).

The importance of technology in our daily lives has increased, and the adoption of ICT has changed the way we live, communicate, work and entertain, and consequently how we travel. ICT provides people with alternatives to face-to-face communication and thus have the potential to substitute for physical travel. In response to this rapid expansion, a new literature has emerged to explain the potential effects of these trends on travel behavior. A vast body of researchers has been investigating the impact of ICT on transportation, examining concepts such as telecommuting/teleworking, e-commerce and time planning. Results on telecommuting and travel behavior vary, with some studies concluding that teleworking substitutes for daily travel (Walls & Safiro, 2004; Choo et al., 2004) and others that teleworking modifies the daily commute (Polydoropoulou & Tsirimpa, 2012). Also, the overall effect of e-shopping on travel behavior remains unclear, with different studies reporting contradictory and ambiguous findings, depending on the type of goods purchased (Farag et al., 2007; Dijst et al., 2008; Papola & Polydoropoulou, 2006; Mokhtarian, 2004). These studies have greatly contributed to our understanding of the possible and potential impacts of ICT on physical travel, which can be grouped into four categories (Mokhtarian, 1990; Mokhtarian, 2004; Pendyala et al., 1991; Salomon, 1986):

1. *Substitution*: usage of technology replaces a physical trip;
2. *Complementarity*: usage of technology creates additional demand for travel;
3. *Modification*: usage of technology does not affect the frequency of physical travel, but may change the characteristics of trips, such as timing and chaining;
4. *Neutrality*: usage of technology is independent of the traditional trip and has no effect on regular trip making.

Although the relationship between ICT and travel patterns has received a substantial amount of attention, not many studies focus on leisure or social travel even though it is the fastest-growing segment of travel (van de Berg et al., 2011; Mokhtarian et al., 2006; Axhausen, 2005). It is highly probable that the effect of ICT on social travel differs from its effect on travel for other purposes, such as work or shopping. Travel behavior is influenced by someone's social network characteristics, as they are relevant to his or her propensity to engage in social activities (Carrasco & Miller, 2006).

According to Mokhtarian et al. (2006), complementarity and modification are more likely than substitution in the case of social activities, because ICT-based alternatives to these activities (if available) are rarely satisfying substitutes. This is confirmed by Senbil and Kitamura (2003), who studied the relations between telecommunication and travel for the three types of activities distinguished by Chapin (1974): 1. mandatory (work and work-related) activities, 2. maintenance activities (grocery shopping, eating, household maintenance, etc.), and 3. discretionary activities (leisure, sports, hobbies, etc.). They found substitution effects for work activities; for maintenance activities, the effect appeared to be neutral, and for discretionary activities they found complementary effects. The complementary effect of ICT on social activities was also identified by Tillema et al. (2007), who found a positive correlation between frequency of face-to-face contacts and electronic communication.

However, the majority of these studies refer to adults (the Baby Boomers Generation), while there is little work, particularly produced by psychiatrists and sociologists, on how

young people and teenagers (the Net Generation, or Net Geners) use social media and how this affects their activities and travel behavior. Yet the recent explosion in online OSN sites such as Facebook, Twitter, MySpace and others has attracted considerable interest from academia, policy makers, parents and young people themselves, the repeated claim being that something new is taking place (Dwyer, 2007). Teenagers are in the vanguard of OSN practices and Facebook statistics show that, in the US, 73% of teenagers belong to a social network, the average teenager has 201 Facebook friends, and 37% send messages to friends more than once on a daily basis (Teen Facebook Statistics, 2012).

Pew Research Center (2010) published statistics showing that almost 80% of American teenagers read interactive blogs daily, leaving comments and adding links. Teenagers are multitaskers, watching TV or studying while chatting with friends and navigating the web. They are more likely than adults to use their cellphones as everything from alarm clocks to GPS devices. They see the computer as more than a tool, as a place to congregate with friends. Their safe communal spaces are not mainly in the physical world, but rather online, on OSN sites. Rather than being antisocial, Net Geners are developing an entirely new set of social skills. Also, a research of Pew (2010) showed that today's teenagers act differently in the workforce. They want to work flexibly, in terms of time and place. They want work to be fun and they expect the workplace to emphasize interpersonal relationships (even if they are virtual). Furthermore, recent clinical studies have shown that interaction with computer technology has changed Net Geners' brains (Sternberg & Preiss, 2013; Black, 2010). Net Geners' experience of using multimedia has made them more visually acute and given them better spatial awareness. Video games have benefited them in surprising ways. They have better hand-eye coordination, and are more effective decision makers and collaborators (O'Keefe & Clarke Pearson, 2011).

With this context in mind, it is crucial to study Net Geners' travel behavior as well. As the increasing popularity of social media has impacts on teenagers' lifestyles and daily lives, including aspects such as friendships, information sharing and their social lives, it is expected that it will affect their travel and trip-making behavior too.

2.3 Travel Demand Models

2.3.1 Discrete Choice Models (DCM)

Discrete Choice Models (DCM) have played a significant role in transportation modeling. DCM consider demand to be the result of several decisions made by each individual under consideration, where each decision consists of a choice made among a finite set of alternatives (Ben-Akiva and Lerman, 1985; Bierlaire, 1998). They explain choice behavior simply as a set of preferences ranking all potential outcomes, where the consumer is assumed to choose the most preferred available outcome. Under certain assumptions, consumer preferences can be represented by a utility function such that the choice is the utility maximizing outcome. These models have traditionally presented an individual's choice process as a "black box", in which the inputs are the attributes of available alternatives and the individual's characteristics, and the output is the observed choice (Ben-Akiva et al., 2002b). Behavioral researchers have stressed the importance of the cognitive workings inside the black box in determining choice behavior (Olson and Zana, 1993; Gärling et al., 1998), and a great deal of research has been conducted to uncover cognitive

anomalies that appear to violate the basic axioms of utility theory (Rabin, 1998; Johansson et al., 2006).

2.3.2 Hybrid Choice Models (HCM)

Over the last few decades, researchers have focused on enhancing DCM, and numerous improvements have been made that aim to predict realizations of the choice behavior. These methods are integrated in Hybrid Choice Models (henceforth HCM; 2). Among the numerous extensions of HCM is the explicit modeling of latent psychological factors such as attitudes and perceptions (latent variables). HCM by combining "hard information" (such as socioeconomic characteristics) with "soft information" on population heterogeneity (such as psychological characteristics), explain irrational behavior and in doing so a substantial part of the unobserved heterogeneity (Ben-Akiva et al., 2002b).

Walker and Ben-Akiva (2002) presented the extended HCM framework, where they estimated mode choice models using revealed and stated preference data, latent perceptions of comfort and taste heterogeneity in the form of random parameters and latent class segmentation. The latent factors provided for a richer behavioral representation of the choice process (although not a significant improvement in the overall fit of the model), while the inclusion of taste heterogeneity improved the explanatory power of the model. Given that the HCM framework is constructed by integrating modular components such as latent variable models, flexible disturbances, etc., its development has been catalyzed by technical developments and growing practical experience with each of the modular components (Ben-Akiva et al., 2002b).

An extension to HCM has been presented by Abou-Zeid and Ben-Akiva (2011) in order to capture the indirect effect of social comparisons on travel choices through its effect on comparative happiness. They argued that social comparisons arise from exchanges of information among individuals and they postulated that the social gap resulting from comparisons is a determinant of "comparative happiness", which in turn affects subsequent behavior. They studied how perceived differences between experienced commute attributes and those communicated by others affect comparative happiness and consequently overall commute satisfaction.

2.3.3 Latent Class Models (LCM)

The LCM for the analysis of individual heterogeneity has a history in several literatures. LCMs were introduced by Lazarsfeld (1950) and since then there have been significant contributions in terms of estimation methods, types of data and the complexity of the models, made by Goodman (1974), Haberman (1979), Hagenaars (1990), and Vermunt and Magidson (2000). Widely used in the social sciences, latent class analysis is based on the theory that individuals differ in their behaviors due to some unobservable latent trait. Social scientists are often interested in relating latent traits to some other variables, with the ultimate purpose of understanding what defines or perhaps causes the latent traits (Nagin et al., 1995).

The first aim of latent class analysis is to identify the number of classes required to explain

the associations among the observed variables, and the second is to allocate respondents/objects to latent classes. Therefore, latent class analysis has a lot of things in common with classification methods for multivariate data, such as cluster analysis, multidimensional scaling and correspondence analysis. The main difference from the aforementioned techniques is that latent class analysis is a model-based approach that can be used for any type of data and allows the appropriateness of the model to be tested statistically. The other methods are mainly based on measures of differences and similarities, and in some cases they have limited practical use.

Latent class modeling assumes that the population can be segmented into a finite number of groups, or classes, according to some combination of characteristics. The individuals within each of the groups share similar characteristics and are dissimilar from those in other groups according to those characteristics (Coogan et al., 2011). The LCM, which specifies random parameters that follow a continuous joint distribution, assumes that a discrete number of classes are sufficient to account for preference heterogeneity across classes. Therefore, the unobserved heterogeneity is captured by these latent classes in the population, each of which is associated with a different parameter vector in the corresponding utility function.

Class membership is assumed to be probabilistic so each individual can, in theory, possess characteristics of each class to varying degrees according to their class membership probabilities. Standard statistical tests can be used to determine the most appropriate number of segments that should be used to classify the population according to the characteristics selected for the segmentation. Once the classes have been defined, the members of those classes can be profiled, along with the characteristics used to define the classes as well as any other variables that are not used to define the classes.

In the last few years, LCMs have been used in various transportation-related topics (Ben-Akiva and Boccara, 1995; Gopinath, 1995). Ettema (2010), aiming to examine the effect of telecommuting on residential choice, developed latent class discrete choice models of residential relocation probability and residential area type choice, finding two classes of telecommuters. Walker and Li (2007) used LCM to examine the impact of lifestyle preferences on residential location behavior, concluding that lifestyle preferences affect residential choice. Tawfik and Rakha (2013) developed a latent class route choice model, assuming that drivers belong to different classes based on their aggressiveness in terms of route choice. LCMs have also been used for analyzing car ownership (Anowar et al., 2013) and the duration of social activities (van de Berg et al., 2011).

2.4 Conclusions

This chapter has reviewed the existing work on travel behavior, providing background for this thesis. First, we reviewed the literature regarding teenagers' activities and travel patterns, aiming to better understand the nature of teenagers' trip-making behavior. However, only a few surveys (see McDonald, 2005) have provided any information regarding underage persons' activity patterns, and the information that exists is only basic, suggesting there is a gap in the literature regarding the activities and travel patterns of teenagers. Thus, we reviewed in brief the activity-based model techniques that we are going to use in Chapter 3 to identify teenagers' activity patterns.

Then, we identified the existing work on teenagers' mode choice behavior. Over the last decade, a number of surveys have produced significant insights regarding the factors that affect students' mode-to-school choice behavior. The results indicate that socioeconomic and demographic factors, such as gender, age, household car ownership, income, and family status, affect this choice, but sometimes in different ways, depending on the survey. Built-environment characteristics, such as distance, population density, existence of green places and parks, width of sidewalks etc., also significantly affect the choice of which mode of transport students use to get to school.

Since some of the existing surveys have provided contradictory results, we further analyzed the sample in each survey and their methodologies, identifying that the majority of the surveys deal with a different age group from ours, focusing mostly on children aged from 5 to 13 years old, while only a few focus on teenagers (aged from 12 to 18 years old). Moreover, most of these surveys use data collected from the students' parents and not directly from the students. Despite the prominent role that the caregiver likely plays in the travel decision for elementary school children, teenagers typically want to avoid parental supervision by making trips that are not controlled or supervised. Thus, we need data collected directly from them in order to investigate their travel and mode choice behavior. Also, with such data, teenagers' mode choice behavior could be modeled in the utility-maximizing framework of a discrete choice model.

We also identify that all these surveys use samples from urban or metropolitan areas. Thus, there is a gap in the knowledge regarding the travel behavior of adolescents who live in rural and insular areas, which typically have completely different built-environment characteristics and probably different cultures. Also, the existing surveys only use revealed preference (RP) data for their analyses and modeling purposes, while we could identify no surveys that use stated preference (SP) experiments to investigate adolescent students' mode-to-school choice behavior.

Since it is well-known that there are other factors that affect travel behavior, we also reviewed the literature on adults' travel behavior. Attitudes and perceptions play an important role in explaining adults' behavior, and in the last decade they have been widely used in choice models as latent variables. However, in the teenagers' literature there are no models that incorporate latent variables into the mode choice process. This thesis develops mode-to-school choice models that take teenagers' attitudes and perceptions into account.

Also, it is known from the behavioral sciences that the social environment of an individual affects his/her choices. Thus, there is a growing interest in the transportation sector in modeling the social influence effect on travel behavior. Regarding modeling efforts, to date only a few works have been produced (Abou-Zeid and Ben-Akiva, 2011; Páez and Scott, 2007; Dugundji and Walker, 2005), and the most prevalent method of modeling the effect of others' actions on a focal person's actions is to incorporate others' previous actions as an additional explanatory variable in the utility of the focal person's alternatives (Abou-Zeid, 2009). Within this thesis, we propose a modeling framework that incorporates social influence effects into the HCM, and data collection techniques aimed at capturing these effects in transportation surveys.

Another factor that has been identified as affecting adults' travel behavior is the use of ICT. Since we live in the era of social media, and this is especially the case for the current teenagers, who have grown up with internet and social media, we postulate that this will

affect their travel behavior. Alas, we could identify no survey in the transportation sector that has explored the effect of social media or online social networking on daily travel behavior. Instead, we reviewed the literature regarding the effect of ICT on adults' travel behavior, and the literature produced by psychologists about teenagers and social media, in order to draw insights about the type of data that would be required in order to capture such effects. Thus, we included in our questionnaire a specific section about social media and the data collected have enabled us to estimate models regarding the effect of social networking on travel behavior.

Chapter 3
Teenagers' Travel Patterns, Activities and Time Allocation

The data used in this thesis come from a survey that took place in the Republic of Cyprus and in Greece (Figure 3.1). This chapter describes the data collection process and the descriptive statistics of the two datasets and analyses the travel patterns, activities and time allocation of the participant teenagers.

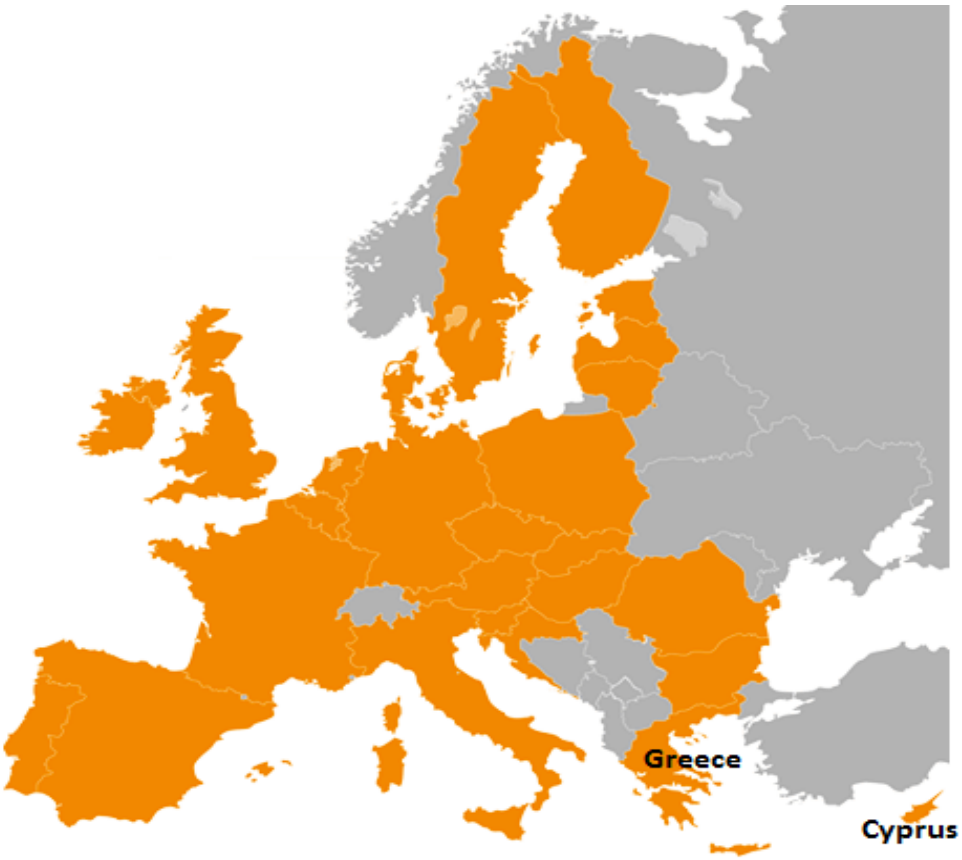


Figure 3.1: Location of Greece and Cyprus

3.1 Data Collection and Sample

This survey took place in two countries: the Republic of Cyprus and Greece. The questionnaire used for the survey was available in both paper and electronic formats. The survey began in Greece in the school year 2010-2011 and since then has been conducted every consecutive year. The majority of the data in Greece (61%) has been collected via personal interviews. The research team, which consisted of postgraduate and undergraduate university students, in cooperation with the Secondary Education Departments of each prefecture in which the survey took place, worked together closely to define the sample of schools and the grades from each school that would be asked to participate in the survey, in

order to obtain a representative sample from each area. During the data collection, the researchers visited the high schools in order to assist with any questions regarding completion of the questionnaire. In January 2013 the Ministry of Education of Greece authorized the survey and since then it has been conducted electronically during the informatics lessons in high schools. For this reason, a manual has been written to guide the teachers so that they can answer any of the students' questions about completion of the questionnaire. Also, a phone-line has been established to further assist the teachers and solve possible problems with completion of the questionnaire. From 2010 to 2013 a total of 3,293 teenagers participated in the survey. The mean completion time was 32.6 minutes.

The survey in the Republic of Cyprus took place in February 2012. In co-operation with the country's Ministry of Education (MOEC), the questionnaire was forwarded to all Cypriot high schools. The students filled in the web-questionnaire during the informatics lesson under the supervision of their teachers, who had received extra guidance to assist them with any questions about its completion. The mean completion time was 26.4 minutes. After data cleaning, the total sample used for the analyses in this thesis amounts to 10,093 observations, covering 21% of the total high-school population of the country. Table 3.1 presents the characteristics of the data collection process.

Table 3-1: Characteristics of data collection

Characteristics	Details	
Location	Cyprus (whole country)	Greece (Athens greater area, City of Alexandroupolis, Island of Chios)
Survey waves	February 2012	School year* 2010-2011, 2011-2012, 2012-2013
Questionnaire	Web-questionnaire	Print and web-questionnaire
Sampling	Adjusted to reflect high-school population of the country	Adjusted to reflect high-school population of each area
Participants	10,093 (21% of total adolescent population)	3,293
* September 20 to May 30		

3.1.1 Sample – Cyprus

The Republic of Cyprus is an island country in the Eastern Mediterranean Sea with a population of 862,100 residents (CYSTAT, 2011). It is classified by the World Bank (2012) as a high-income economy and during recent years it has developed into one of the world's more important international business centers. Cypriots are among the most prosperous people in the Mediterranean region, with a GDP per capita of 30,571€ and an average net salary of 1,656€ (IMF, 2011). The unemployment rate when the survey took place was 10.2%. Cyprus is a heavily car-dependent island and, as the standard of living rapidly progressed from an agrarian to a service-oriented economy during the past 20 years, so did the driving habits of Cypriots. Figures released by the International Road Federation (IRF) in 2007 show that Cyprus holds the highest car ownership rate in the world with 742 cars per 1,000 people. Public transport in Cyprus is limited to privately run bus services (except in the capital, Nicosia), taxis, and interurban "shared" taxi services. When the survey took place, students could use the bus without any charge by presenting their student

ID. Over the last two years bicycle lanes have been constructed in all main Cypriot cities (Nicosia, Limassol, Paphos and Larnaca). Regarding secondary education, there are 140 public and 36 private high schools and the total number of high-school students during the school year 2011-2012 was 47,615 (MOEC, 2012).

Table 3-2: Sample's characteristics - Cyprus

		Boys (45%)	Girls (55%)
Age	11 to 14 years old	41%	42%
	15 to 18 years old	59%	58%
Lived Abroad	Yes	14%	14%
	No	86%	86%
Grades (School marks)	18-20 (out of 20)	37%	43%
	16-18 (out of 20)	24%	28%
	14-16 (out of 20)	22%	18%
	9-14 (out of 20)	17%	11%
Pocket money (Euros per day)		7.37 (Std. Dev. = 2.3)	5.86 (Std. Dev. = 2.7)
Number of siblings		3.21 (Std. Dev. = 1.6)	2.28 (Std. Dev. = 1.9)
Number of one-way trips in a school-day		4.07 (Std. Dev. = 1.1)	4.15 (Std. Dev. = 1.4)
Number of one-way trips on Saturday		3.79 (Std. Dev. = 1.8)	3.98 (Std. Dev. = 2.1)
Number of one-way trips on Sunday		3.90 (Std. Dev. = 0.9)	3.14 (Std. Dev. = 1.2)
Drivers		14%	5%
Drivers with appropriate driving license		10%	3%
Owners of PTW		2%	1%
Households' Characteristics			
Income (Euros per Month)	Less than 2000€	22%	26%
	2001€ to 4000€	29%	21%
	More than 4000€	27%	27%
	Not available	22%	26%
Number of persons holding a driving license		1.9 (Std. Dev. = 0.3)	1.8 (Std. Dev. = 0.5)
Car Ownership		3.6 (Std. Dev. = 2.1)	3.0 (Std. Dev. = 1.7)
Motorcycle Ownership		1.8 (Std. Dev. = 1.4)	0.6 (Std. Dev. = 0.9)
Bicycle Ownership		1.4 (Std. Dev. = 0.9)	1.1 (Std. Dev. = 0.4)
Household size		5.8 (Std. Dev. = 1.3)	4.9 (Std. Dev. = 1.2)
Family structure	Live with parents	81%	84%
	Single parent (divorced)	16%	12%
	Single parent (one of the parents not in life)	3%	4%
Housing tenure	Owned	86%	84%
	Rent	14%	16%
Parents' Characteristics			
Mother's Level of Education	Low (Secondary education)	60%	61%
	Medium (Bachelor)	28%	30%
	High (Masters, PhD)	12%	9%
Father's Level of Education	Low (Secondary education)	66%	70%
	Medium (Bachelor)	21%	21%
	High (Masters, PhD)	13%	9%
Mother's employment status	Unemployed	13%	9%
	Housewife	16%	19%
	Public servant	33%	31%
	Private sector employee	30%	35%
	Free lancer	8%	6%
Father's employment status	Unemployed	8%	7%
	Public servant	35%	35%
	Private sector employee	30%	36%
	Freelancer	23%	22%

The sample's characteristics are presented in Table 3.2. 45% are males and 58% are between 15 to 18 years old. 14% of the participants had been living in another country in the past. 40% of the students have high school-grades (18-20 out of 20). The average pocket money teenagers receive per day is 6.5€, while the average number of siblings is 2.7. Compared to the figures in other surveys (for example O'Brien and Gilbert, 2003), the average number of trips in a school day is quite high (4.1 trips per school day). During the Saturday an average number of 3.9 trips was recorded, while on Sunday there was an average number of 3.5 trips. Regarding the characteristics of the teenagers' households, the majority have a monthly income of more than 2,000 Euros, while a significant portion of teenagers do not know exactly the monthly family income. The average household size is 5.3 persons. The household car ownership is rather high; none of the students reported zero number of cars in the household, indicating that the total sample have the option of being driven to school. The household motorcycle (PTW) ownership is 1.1.

3.1.2 Sample – Greece

The survey in Greece took place in three areas with completely different geographical and socio-economic characteristics. The three areas are: 1. Athens (urban area), 2. Alexandroupolis (rural area), and 3. Chios (insular area) and they are depicted in Figure 3.2. Table 3.3 summarizes the demographic and economic characteristics of each area.

Figure 3.2: Greek areas that participated in the survey

Table 3-3: Demographic and geographical characteristics of the Greek areas

	Athens, Peristeri (Urban)	**Alexandroupolis** (Rural)	**Chios** (Insular)
Population* (2011)	146,743	72,959	25,671
Population Density * (per km^2; 2011)	13,928	96	1,042
GDP* (in million Euro; 2010)	106,636	2,329	835
GDP per capita* (in Euro; 2010)	25,934	15,691	16,096
Unemployment Rate* (2012)	25.3%	26.9%	21.3%
Car Ownership* (cars per 1000 inhabitants; 2011)	782	356	431
Motorcycle Ownership* (motorcycles per 1000 inhabitants; 2011)	225	102	296
Urban Environment	Heavily urbanized area with many buildings per km^2. There are narrow, highly congested streets, and parked cars at a capacity that obstructs the road users' visibility.	A border coastal city surrounded by agricultural fields. The landscape consists of five-storey buildings, wide streets with low traffic levels and generally a low population density. In the city there are four main bicycle corridors that link the center of the city with the high schools.	The fifth largest of the Greek islands, situated in the Aegean Sea. It has the third highest cars per capita ownership in Greece and the highest motorcycle ownership (Hel. Stat., 2011). There are narrow streets and pavements, parked cars at a capacity that obstructs the road users' visibility.
*Source: Hellenic Statistical Authority (Hel. Stat.), Greek Census 2011			

Athens is the capital of Greece. In the greater Athens area there are 3,089,698 residents (Hel. Stat., 2011). The schools that participated in the survey are located in Peristeri area, a suburban municipality located about 5 km away from the downtown of Athens. The municipality has a population of 146,743 people. Peristeri is a heavily urbanized area (see Figure 3.3) with many buildings and narrow, highly congested streets with a lot of parked cars that obstruct the road users' visibility. In Peristeri there are a number of alternative choices for public transport: metro, train and bus, but there are no bicycle lanes. The GDP per capita is equal to 25,934€ and the unemployment rate is 25.3% (Hel. Stat., 2011). The majority of the population is employed in the services sector, both private and public. The greater Athens area (including Peristeri) has the highest car ownership rate (782 cars per 1000 inhabitants) and the second highest motorcycle ownership rate (225 motorcycles per 1000 inhabitants; Eurostat, 2011). Over the last decade the number of cars in the greater Athens area has increased dramatically, creating chaotic traffic conditions, health problems due to near-ground air pollution, and roadside traffic noise, as well as secondary environmental problems. Four public gymnasiums and six public lyceums participated in the survey. Figure 3.3 depicts the location of the gymnasiums in blue, the location of the lyceums in red and the location of the sports areas in light blue.

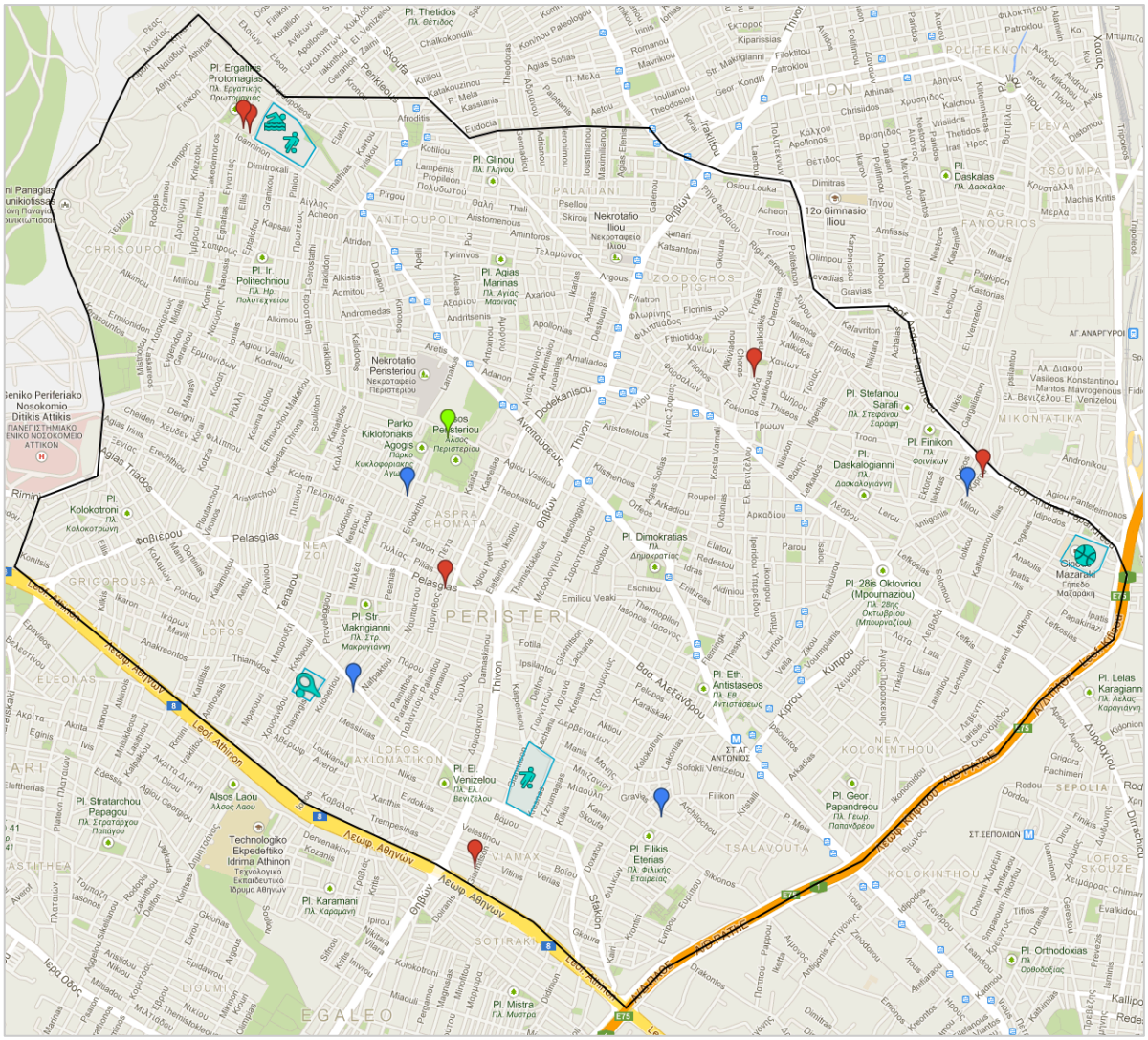


Figure 3.3: Map of Peristeri, Athens – Urban area

Alexandroupolis is a coastal border town, numbering 72,959 residents (Hel. Stat., 2011). The GDP per capita is equal to 15,691€ and the unemployment rate is 26.9% (Hel. Stat., 2011): the highest among the three studied areas. The majority of the population is employed in the public services sector. The prefecture of Evros, where Alexandroupolis belongs, holds 18th place with the highest car ownership among the 51 Greek prefectures (356 cars per 1000 residents), while the PTW ownership rate is 102 per 1000 residents. The landscape consists of four- or five-storey buildings, wide streets with low traffic levels and a generally low population density. In the city there are four main bicycle corridors (green line in Figure 3.4) that link the center of the city with the high schools. These routes are also covered by the public bus, which is the only available public transport in the city. All the high schools are situated in the southern part of the city. Generally, the schools are located in two blocks, marked in red on the map below. Three of the five gymnasiums and three of the four lyceums of Alexandroupolis participated in the survey, while no technical lyceum participated (technical lyceums are pinpointed in purple in Figure 3.4). Alexandroupolis contains only public schools. The center of the city, where most of the citizens' shopping and entertainment activities take place, is marked with yellow shapes in Figure 3.4. Also, the area where the majority of the stadiums and courts are situated is identified in light blue.

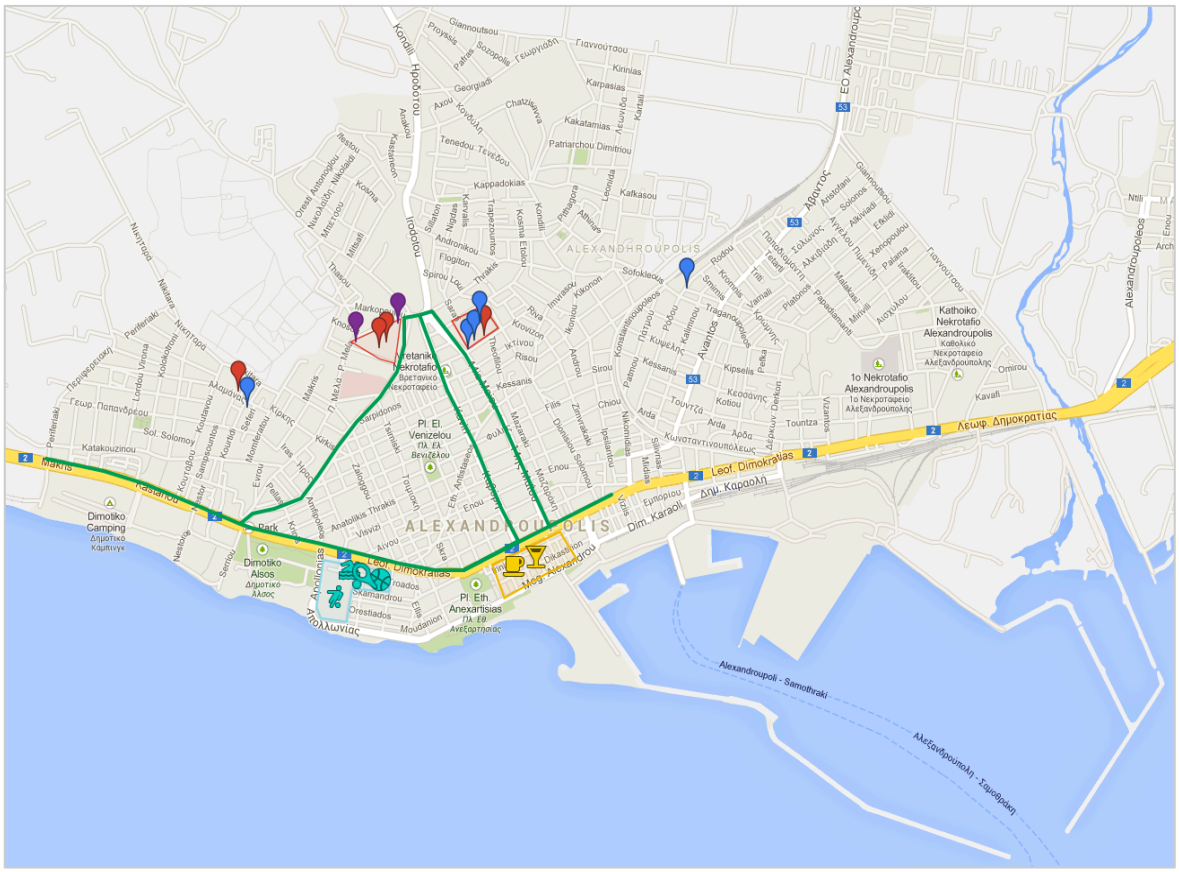


Figure 3.4: Map of Alexandroupolis – Rural area

Chios is the fifth largest of the Greek islands, situated in the Aegean Sea, with a permanent resident population of 51,930 (2011 census; Hel. Stat, 2011). The town of Chios has 25,671 residents. The GDP per capita is 835€ and the unemployment rate is 21.3% (Hel. Stat., 2011), the lowest among the three areas under study. The GDP per capita may seem low, but a significant percentage of the male residents work in the international mercantile maritime sector. Also, a percentage of the population is employed in the public services sector. Chios is the 3rd city in Greece, with the highest car ownership (431 cars per 1000 inhabitants), and the first city in Greece for motorcycle ownership, of which it has the highest rate (296 motorcycles per 1000 inhabitants). Chios town's urban environment consists of 3-storey buildings and detached houses, narrow streets and sidewalks, and is characterized by low population density. In Chios there are only public buses linking the town with the suburban areas and villages and their frequency is reduced in the afternoon. No bicycle lanes are available. The roads on which the majority of commercial and entertainment activities take place are marked with a yellow line in Figure 3.5 below. All the gymnasiums and lyceums of Chios (11 gymnasiums and 10 lyceums) participated in the survey.

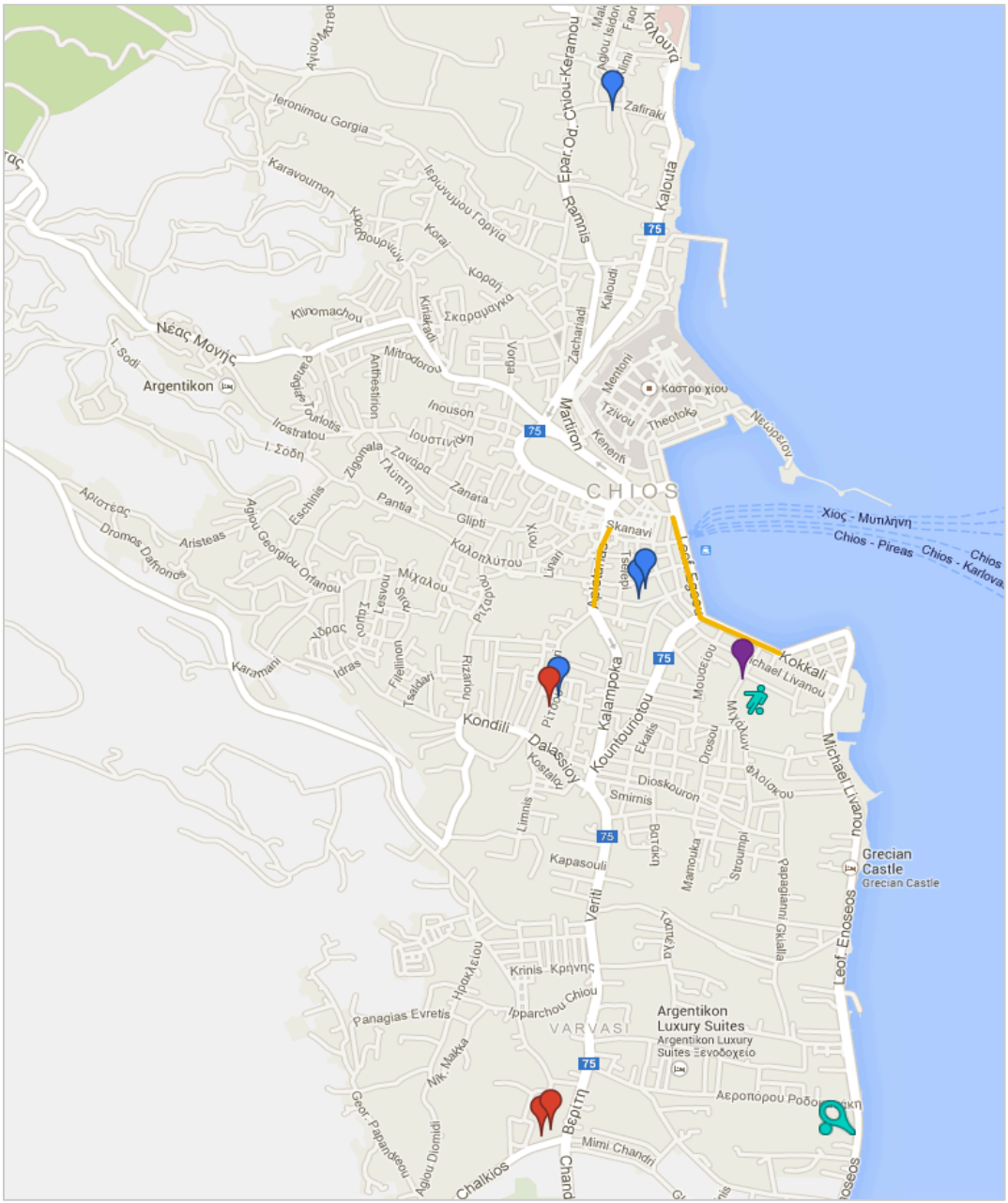


Figure 3.5: Map of Chios – Insular area

The characteristics of the participants from each area are presented in Table 3.4. The total sample consists of 3,293 public high-school students, aged between 12 and 18 years. 36% of the participants live in the urban area, 29% in the rural area and 35% in the insular area. The average age is 15.7 years old, and 52% are girls. The average number of trips in a typical school day is 4.5.

Table 3-4: Sample's characteristics - Greece

		Urban Area N= 1187	Rural Area N=954obs	Insular Area N=1152obs
Gender	Boys (Male)	56%	52%	49%
	Girls (Female)	44%	48%	51%
Age	11 to 14 years old	31%	42%	45%
	15 to 18 years old	69%	58%	55%
Lived Abroad	Yes	8%	2%	3%
	No	92%	98%	97%
Grades (School marks)	18-20 (out of 20)	30%	36%	35%
	16-18 (out of 20)	35%	28%	29%
	14-16 (out of 20)	19%	23%	20%
	9-14 (out of 20)	16%	13%	16%
Pocket money (Euros per day)		1.89 (Std. Dev. = 1.5)	2.3 (Std. Dev. = 1.9)	2.8 (Std. Dev. = 2.1)
Number of siblings		1.7 (Std. Dev. = 0.7)	1.4 (Std. Dev. = 1.1)	1.3 (Std. Dev. = 1.2)
Number of one-way trips in a school day		4.2 (Std. Dev. = 1.9)	4.4 (Std. Dev. = 1.7)	4.9 (Std. Dev. = 1.8)
Number of one-way trips on Saturday		3.7 (Std. Dev. = 1.2)	3.8 (Std. Dev. = 1.8)	4.3 (Std. Dev. = 1.9)
Number of one-way trips on Sunday		2.1 (Std. Dev. = 2.2)	2.6 (Std. Dev. = 1.9)	2.2 (Std. Dev. = 2.0)
Drivers		10%	19%	22%
Drivers with appropriate driving license		4%	9%	28%
Owners of PTW		5%	17%	20%
Households' Characteristics				
Income (Euros per Month)	Less than 2000€	38%	34%	31%
	2001€ to 4000€	24%	42%	30%
	More than 4000€	19%	8%	24%
	Not available	19%	16%	15%
Number of persons holding a driving license		1.6 (Std. Dev. = 0.6)	1.2 (Std. Dev. = 0.8)	1.4 (Std. Dev. = 0.8)
Car Ownership		2.3 (Std. Dev. = 1.3)	1.7 (Std. Dev. = 1.1)	1.8 (Std. Dev. = 1.5)
Motorcycle Ownership		0.9 (Std. Dev. = 0.4)	0.7 (Std. Dev. = 1.2)	1.4 (Std. Dev. = 1.3)
Household size		4.1 (Std. Dev. = 1.3)	4.3 (Std. Dev. = 1.5)	4.2 (Std. Dev. = 1.6)
Family structure	Live with parents	79%	86%	85%
	Single parent (divorced)	18%	10%	12%
	Single parent (one of the parents not in life)	3%	4%	3%
Housing tenure	Owned	72%	84%	91%
	Rent	28%	16%	9%
Parents' Characteristics				
Mother's Level of Education	Low (Secondary education)	24%	28%	27%
	Medium (Bachelor)	58%	63%	63%
	High (Masters, PhD)	18%	9%	10%
Father's Level of Education	Low (Secondary education)	23%	24%	29%
	Medium (Bachelor)	56%	68%	65%
	High (Masters, PhD)	21%	8%	6%
Mother's employment status	Unemployed	2%	8%	5%
	Housewife	29%	20%	46%
	Public servant	35%	40%	24%
	Private sector employee	22%	26%	12%
	Free lancer	12%	6%	13%
Father's employment status	Unemployed	7%	8%	2%
	Public servant	35%	39%	31%
	Private sector employee	22%	31%	15%
	Freelancer	31%	22%	32%
	Seafarer	5%	-	20%

3.2 Activities and Tour Types – Methodology

This subsection briefly describes the methodology followed in order to identify teenagers' activity participation and travel patterns. The principal theories are that demand for travel is derived from the demand for activities (Jones, 1977) and that an individual's multidimensional choice of a day's activities and travel consists of tours interrelated in an activity pattern (Ben-Akiva et al., 1996).

In our dataset the basic unit of the travel survey data collected is unlinked trips. The unlinked trips are the individual stages of travel, i.e. the movement between individual stops recorded in the travel survey. To create tours, these unlinked trips need to be combined. A home-based tour is a round-trip journey, that is, a sequence of trips starting at home and ending when the teenager next returns home. Once the sequence of unlinked trips forming the tour has been determined, a travel purpose for the tour is defined. This purpose is associated with the primary (main) destination of the tour. A number of methods can be used to define the primary destination. These include: a) the destination (stop) at which the person spent the most time, b) the destination which is furthest away from home (most distant), and c) the destination determined by a purpose hierarchy (Milthorpe and Daly, 2010). It is possible to include a combination of the above options as part of the definition and/or to resolve ties. For the analysis reported in this thesis, the purposes of tours have been determined using a combination of the purpose hierarchy and the stop at which the person spent the most time. For single destination journeys this is straightforward. If someone travels from home to school this is a home-based school trip. Now consider a trip chain in which someone travels from home to bakery to buy breakfast, then continues on to school, and then returns home; this was recorded as a Home-School-Home tour with one stop (HSH+). In some cases, where the tour included both tutorial lessons and participation in sports activities, which have the same hierarchical position and approximately the same duration, we use both of them as a tour purpose (denoted Tutorial and Sports).

Once the tours have been identified, we analyse the selection of modes of travel for each trip leg, and particularly the mode of transport for the outbound and the return trip leg of each tour. For example, we investigate the transport mode for the trip to school and the transport mode for the trip from school to the next activity. Generally, activity-based models include the selection of transport mode, the selection of activity location and the time of day (Bowman and Ben-Akiva, 2001). In our case we focus on the selection of transport mode, while the time of day is approximated for school days, as it is fixed that teenagers go to school in the morning and start their extracurricular activities after school (in the afternoon). The dataset does not offer details about the exact time of day that the activity took place, but as the activities are recorded by time sequence it is possible to make some assumptions about the time. Although the dataset offers details of the location of the activities, in the present thesis this information is not analyzed.

Table 3.5 describes the categorization of the activity type by purpose, primary tour type and number and purpose of secondary tours that are used in this thesis.

Table 3-5: Activity patterns alternatives

	Notation	Description
Activity Type	Home	At home all day.
	School	The activity pattern includes school activity.
	Tutorial lessons	The activity pattern includes tutorial lessons. Tutorial lessons could include foreign languages, music and school lessons tutorials.
	Sports activities	The activity pattern includes participation in sports activities.
	Entertainment	The activity pattern includes leisure and social activities. This could include hanging out in café, bar, club, cinema, internet café; excursions, watching sports etc.
	Shopping	The activity pattern includes shopping activities.
	Visiting	The activity pattern includes visiting friends' or relatives' home.
	Other	The activity pattern includes none of the aforementioned activities, but includes such as religious activities, school-based clubs etc.
Primary Tour	HSH	Simple tour from home to school and back.
	HSH+	School tour with at least one additional stop for another activity.
	HTH	Simple tour from home to tutorial lessons and back.
	HTH+	Tutorial lessons tour with at least one additional stop for another activity.
	HSpH	Simple tour from home to sports activities and back.
	HSpH+	Sports activity tour with at least one additional stop for another activity.
	HTSpH	Tour from home to tutorial lessons and sports activities and back.
	HTSpH+	Tour from home to tutorial lessons and sports activities with at least one additional stop for another activity.
	HEH	Simple tour from home to leisure activities and back.
	HEH+	Leisure activities tour with at least one additional stop for another activity.
	HE+H	Tour that includes more than one stop for leisure purposes.
	HShH	Simple tour from home to shopping area/mall and back.
	HShH+	Shopping tour with at least one additional stop for another activity.
	HOH	Simple tour with purpose other than the aforementioned.
	HOH+	Tour with purpose other than the aforementioned, with at least 1 additional stop for another activity.
Number of secondary tours	0	No secondary tours.
	1	One secondary tour.
	2	Two secondary tours.
	3+	Three or more secondary tours.

3.3 Activities, Tour Types and Time Use – Cyprus

3.3.1 Tour Types –Cyprus

The travel patterns of Cypriot teenagers are analysed and presented in this subsection. Each participant completed a trip diary for a school day and a Saturday. Note that, since we asked the respondents to describe their activity pattern for the day before the survey was conducted and for the latest Saturday, we assume that the average numbers obtained correspond to a typical day of the week and to a typical Saturday. A total number of 41,381 trips were recorded over a school day, while 39,362 trips were recorded over a Saturday.

In Table 3.6 is presented the percentage of teenagers who conduct the specific activity during a school day and during a Saturday. The most popular activities on a school day after going to school are participating in tutorial lessons and in sports activities. The most popular activities during Saturday are tutorial lessons, entertainment and sports.

Table 3-6: Activities conducted in Cyprus

Activity	% teenagers who participate in each activity – School day	% teenagers who participate in the activity – Saturday
Home	0%	4%
School	100%	0%
Tutorial lessons	78%	47%
Sports activities	68%	38%
Entertainment	16%	46%
Shopping	2%	23%
Visiting	9%	16%
Other	0%	2%

The school day in Cyprus typically runs from 07:35 to 14:00. As all teenagers go to school in the morning, we further split the school-day activities into morning (school) and afternoon (after-school) activities. No pre-school activities have been identified. In our survey, the primary activity in the morning for all the participants is school. Figure 3.6 depicts the tour types that teenagers undertake in the morning. 82% of the participants conduct simple tours from home to school and back (HSH), while the rest conduct combined or complex tours including one or more stops for activities other than school.

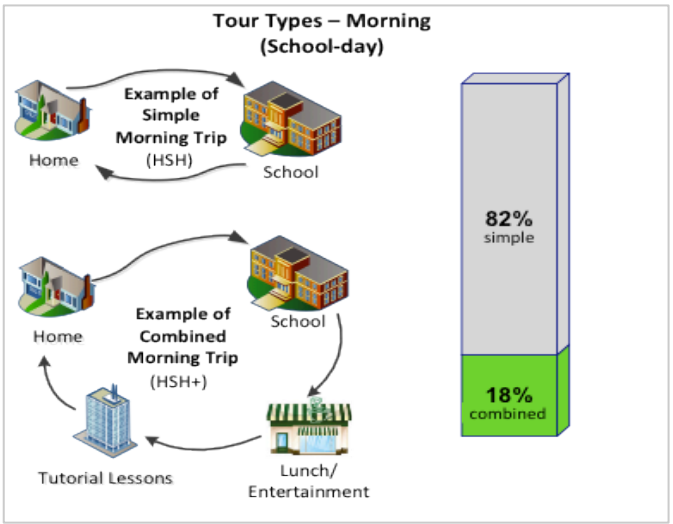


Figure 3.6: Morning tour types – School day (Cyprus)

Details of the morning combined tours are presented in Table 3.7. Overall, 7 different tour types were identified, while no home pattern was recorded. 8.3% of the tours involve tutorial lessons directly after school followed by the return home. 6.3% of the secondary activities include a visit to another's home; this activity usually consists of visiting grandparents in order to have lunch while parents are at work. In morning activity patterns, the purpose designated "other" usually includes a stop at a bakery or mini-market to buy breakfast or lunch to take to school. Other secondary activities include entertainment and participation in sports. Comparing girls to boys, girls conduct slightly more combined trips in the morning.

Table 3-7: Morning activity patterns – School day (Cyprus)

Morning Activities – School Day					
Primary Activity	Primary Tour Type	Number and Purpose of Secondary Tours	Percentages		
			Boys	Girls	Total
School	HSH	0	80.8	83.1	82
	HSH+	1 Tutorial Lessons	8.7	8.0	8.3
		1 Other	1.5	0.8	1.1
		1 Sports	2.7	1.8	2.3
		1 Visiting	1.6	2.0	1.8
		2 Entertainment & Visiting	1.9	2.0	2.0
		2 Sports & Visiting	2.8	2.3	2.5
Total			100.0	100.0	100.0

Teenagers' tour patterns are completely different in the afternoon, as the majority of teenagers (58%) undertake combined tours, while 10% stay at home (Figure 3.7). Generally, 14 different tour types are identified. Table 3.8 gives more details regarding after-school tours. 44.2% of the tours have as their primary purpose both tutorial lessons and sports (HTSpH), while in general these are the most popular activities that teenagers are involved in after school. Differences in gender are identified in HTH and HSpH tour types, with boys conducting more simple tours, from home either to tutorial lessons or sports and back. Also, girls seem to participate in more activities that have entertainment as their primary purpose.

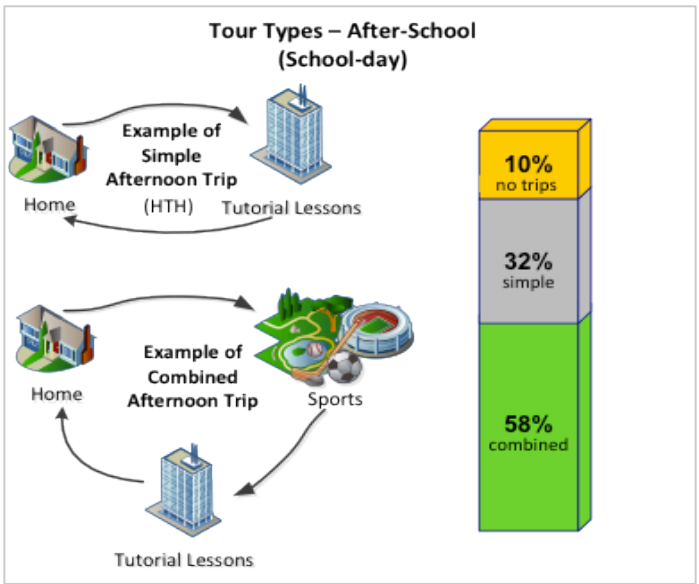


Figure 3.7: After-school tour types – School day (Cyprus)

Table 3-8: After-school activity patterns – School day (Cyprus)

After-School Activities – School-Day					
	Primary	Number and Purpose of	Percentages		
Primary Activity	Tour Type	Secondary Tours	Boys	Girls	Total
At home			11.0	9.1	10.0
Tutorial Lessons	HTH	0	19.5	17.8	18.2
	HTH+	1 Entertainment	1.4	3.1	3.6
Sports	HSpH	0	13.1	10.9	11.4
	HSpH+	1 Entertainment	1.0	1.1	1.1
		1 Visiting	1.4	1.0	1.2
		1 Shopping	1.1	1.4	1.3
		2 Entertainment & Visiting	1.0	1.1	1.1
Entertainment	HEH	0	1.5	2.8	2.4
	HEH+	1 Shopping	1	3.5	1.1
		1 Visiting	1.5	1.7	1.6
Tutorial Lessons & Sports	HTSpH	0	44.6	43.9	44.2
		1 Entertainment	1.5	2.0	1.8
		1 Visiting	0.4	0.6	1.0
Total			100.0	100.0	100

Cypriot teenagers do not attend school on Saturday or Sunday and as a result their activity patterns are different during the weekend. The collected trip data showed that 4% of the high-school students stay at home, 29% conduct simple tours and 67% conduct combined tours on Saturday (Figure 3.8).

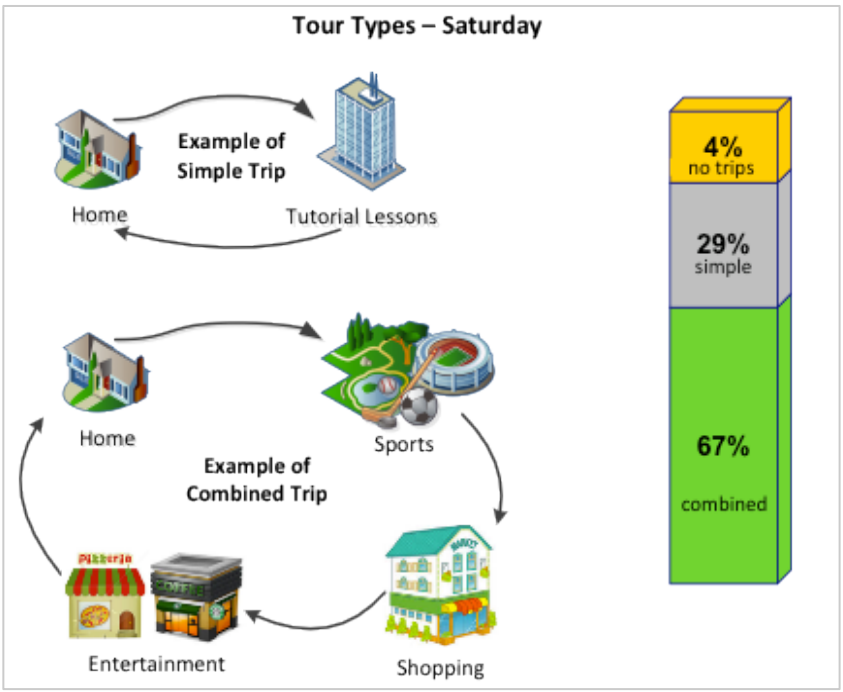


Figure 3.8: Tour types – Saturday (Cyprus)

24 different tour types were identified for Saturday activities. 13.2% of the tours are simple, with the primary activity being participation in tutorial lessons. 20.6% of the recorded tours have as a primary purpose participation in sports activities. 43.1% of the tours include

entertainment or leisure activities, while entertainment is the primary purpose for 15% of the recorded tours. Shopping is the primary activity for the 8% of the tours, while a significant percentage (15.5%) of all recorded tours includes visiting at the home of a relative or friend (Table 3.9).

Table 3-9: Activity patterns – Saturday (Cyprus)

Activities – Saturday					
	Primary	Number and Purpose of	Percentages		
Primary Activity	Tour Type	Secondary Tours	Boys	Girls	Total
At home			11.0	3.8	4.0
Tutorial Lessons	HTH	0	14.8	11.8	13.2
	HTH+	1 Entertainment	7.1	8.1	7.8
		1 Shopping	2.7	3.8	3.6
		1 Visiting	2.9	2.5	2.8
		2 Entertainment & Shopping	2.1	2.4	2.3
Sports	HSpH	0	5.7	4.8	5.3
	HSpH+	1 Entertainment	6.1	6.9	6.6
		1 Visiting	2.7	2.8	2.8
		1 Shopping	2.6	4.3	3.8
		2 Entertainment & Visiting	2.5	1.9	2.1
Entertainment	HEH	0	9.2	8.5	9.0
	HEH+	1 Shopping	4.1	8.2	7.2
		1 Visiting	1.7	1.8	1.8
Shopping	HShH	0	3.0	3.8	3.5
	HShH+	1 Entertainment	1.0	1.1	1.1
		1 Other	1.0	2.1	1.8
		2 Entertainment & Visiting	1.5	1.6	1.6
Tutorial Lessons & Sports	HTSpH	0	4.1	3.5	3.9
	HTSpH+	1 Entertainment	6.1	6.8	6.6
		1 Visiting	1.9	2.6	2.5
		1 Shopping	2.3	2.8	2.7
		2 Shopping & Visiting	1.8	1.9	1.9
Visiting	HVH	0	2.1	2.2	2.1
Total			100.0	100.0	100.0

3.3.2 Transport Mode per Activity – Cyprus

In this section the transport mode that teenagers use for each activity pattern is presented. The transport modes that teenagers use are: 1. Walking alone, 2. Walking accompanied by friends, 3. Cycling, 4. Driving a PTW, 5. Escorted by private motorized vehicle by father, 6. Escorted by private motorized vehicle by mother, and 7. Escorted by private motorized vehicle by other. Due to the fact that only a few participants (less than 1%) walked to their activities accompanied by an adult, this option is not taken into account for the analysis and this minor percentage is included in the option "Walking accompanied by friend". The options for escorted by private motorized mode include being escorted by car or PTW. The option escorted by private motorized vehicle by other includes being escorted either by a relative or by the parents of a friend. All these details are available in the dataset, but due to

space limitations they are grouped into these three categories. Initially, we analyzed the transport mode that teenagers use for their trip to school and the return trip from school to the next destination (Figure 3.9). The majority of teenagers are escorted to school by their parents, while 35% use the bus, 14% walk and only 1% cycle to school. The percentage of students escorted by private modes drops significantly for the return trip from school. While 50% of teenagers are escorted to school by private motorized vehicles, only 37% use the same mode for the return trip. The majority of boys are escorted by father, the majority of girls by mother. The most preferred mode for the return trip is bus (41%), followed by walking (20%). These results indicate that parents escort their children to school before going to work but, as the parents are not able to pick up them from school, the students use a different mode for the return trip. Regarding differences in gender, females prefer more motorized vehicles (escorted by private modes and bus). As far as active transport is concerned, teenage boys seem to walk more, while only boys (2%) stated that they use a bicycle for their trip to and from school. Moreover, both boys and girls prefer to walk accompanied by their friends rather than alone. Only 2% of male participants drive a PTW to school.

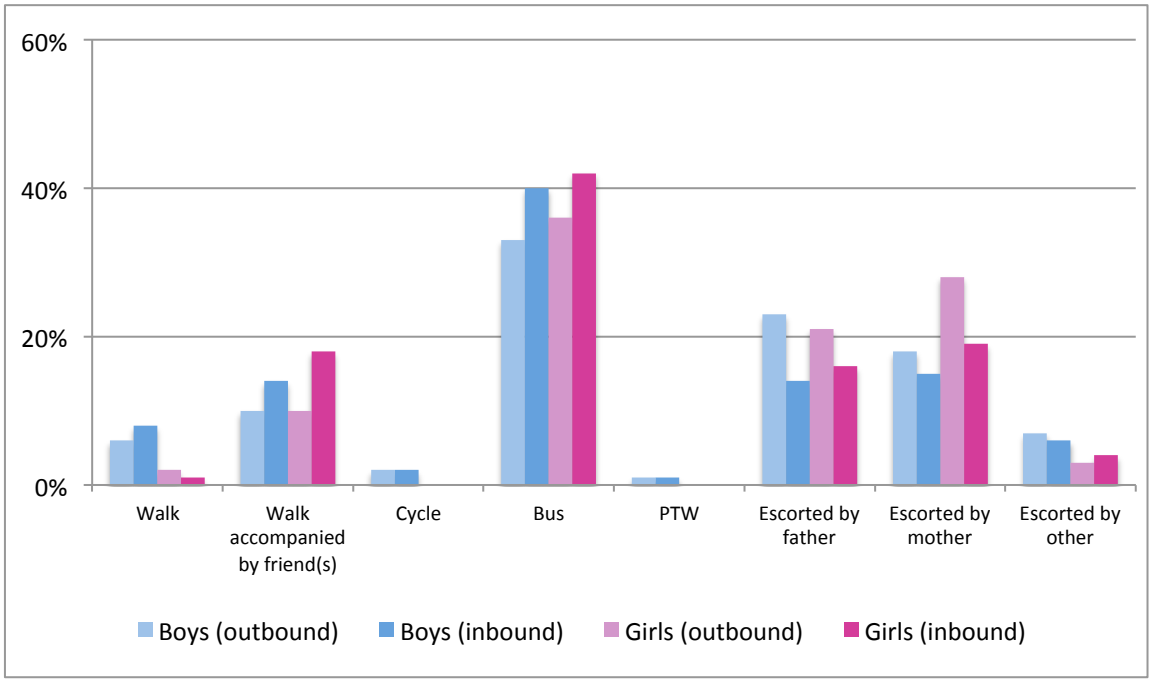


Figure 3.9: Transport mode to school and return from school – School day (Cyprus)

As the modal split between tutorial lessons and sports activities shows them as quite similar, we present the transport mode for these primary activities in one figure (Figure 3.10). Generally, it is noticed that the percentage of children who are escorted to their tutorial and sports activities increases sharply in the afternoon, while the percentage of teenagers who use the bus drops dramatically. Girls use almost the same mode in order to go to and return from their activities, while a slight difference is recorded for boys in escorted and walking patterns. Again, it is generally observed that the majority of girls are escorted by their mothers, while both boys and girls usually walk in the company of their friends.

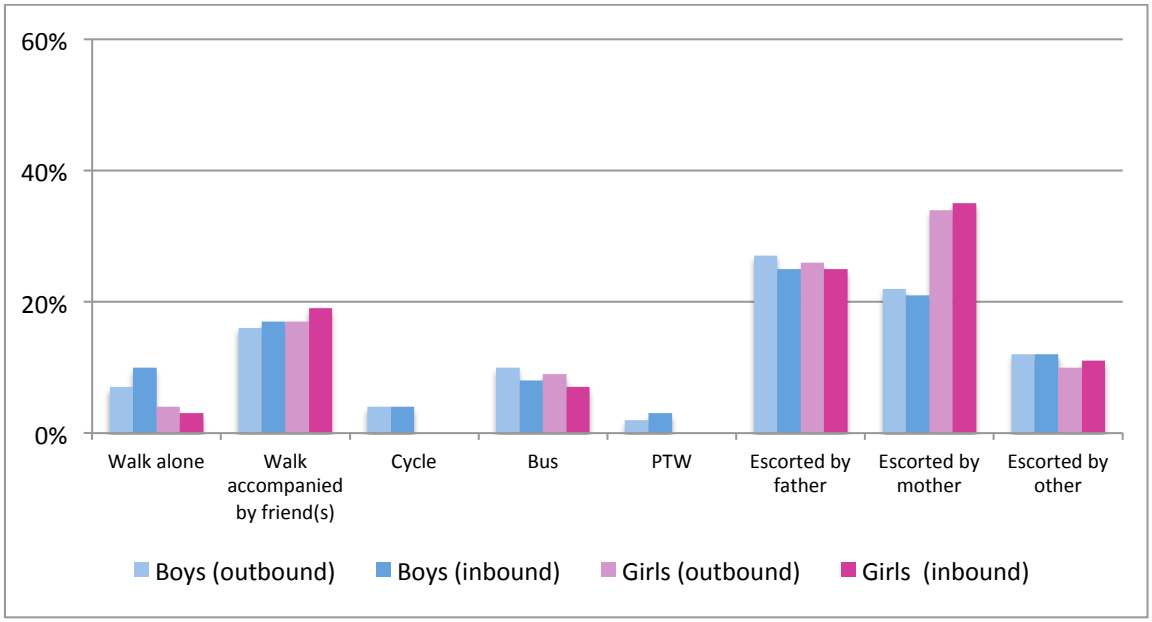


Figure 3.10: Transport mode for tutorial lessons and sports activities – School day (Cyprus)

Figure 3.11 presents the transport mode that teenagers use for activities having the primary purpose of entertainment on a school day. It is noticed that the majority of teenagers prefer active transport, with 45% choosing walking and 19% cycling. In the case of walking, 31% of the participants walk accompanied by their friends for the outbound trip, while for the inbound trip 37% walk accompanied. This fact indicates that when the purpose is entertainment or social life, teenagers prefer to go on independent trips, without being supervised by their parents; in this situation they do not prefer to be escorted by private motorized modes. PTW usage is also quite high compared to other activities, further evidence of the preference for independent mobility. Additionally, for trips having this purpose, the highest percentage of bicycle usage on a school day is recorded.

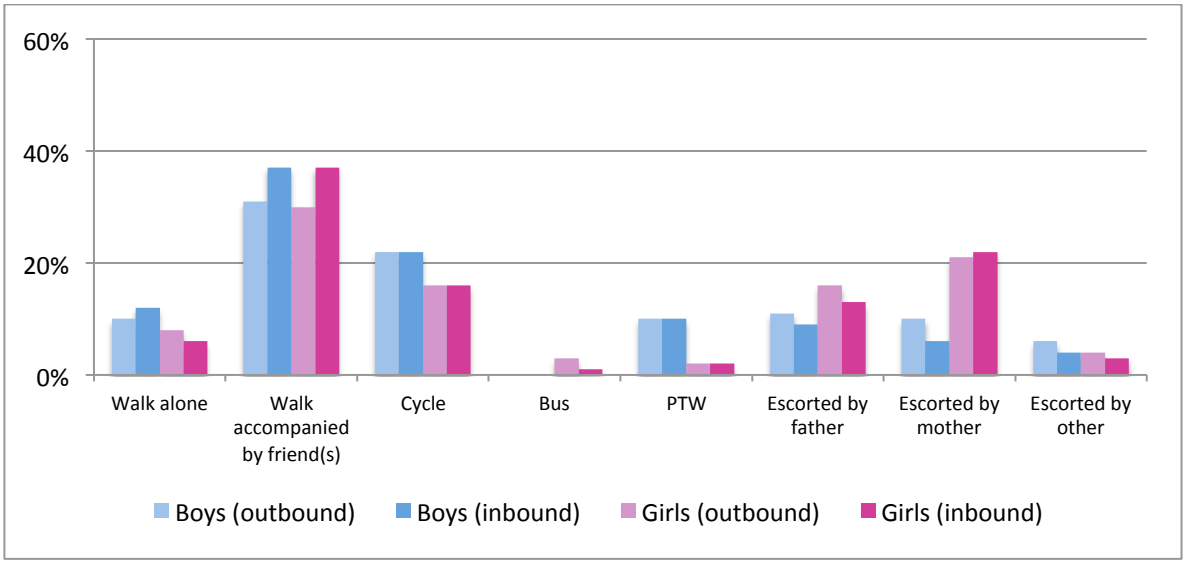


Figure 3.11: Transport mode for entertainment activities – School day (Cyprus)

Regarding tutorial lessons and sports participation on Saturday (HTH, HSpH and HTSpH), the vast majority of teenagers are escorted by private motorized modes to those activities;

more specifically, they are escorted by their fathers. A big difference is observed between girls and boys, with girls preferring to be escorted rather than to walk or cycle (Figure 3.12).

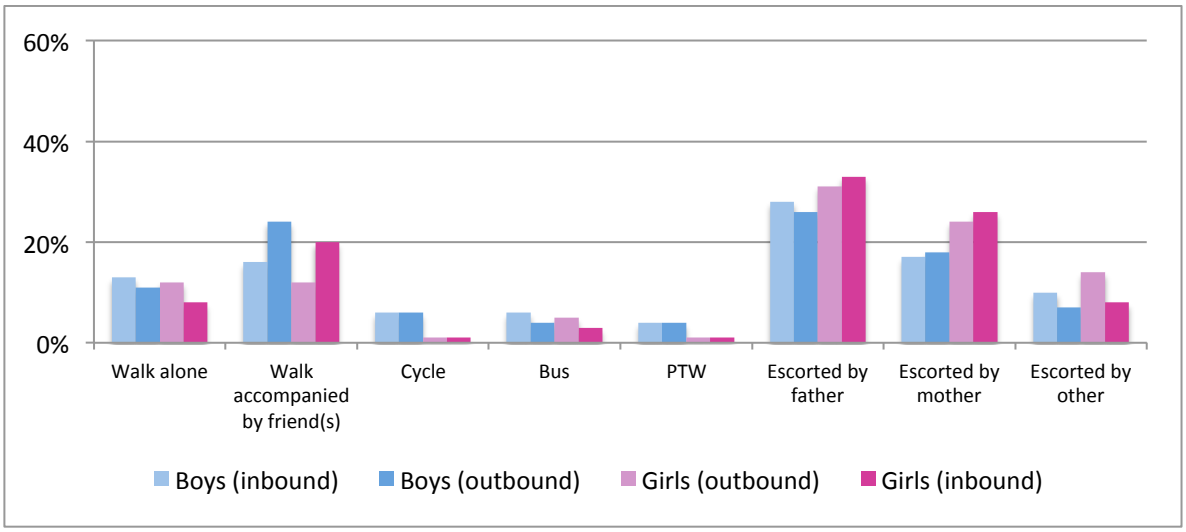


Figure 3.12: Transport mode for tutorial lessons and sports activities – Saturday (Cyprus)

Although the majority of teenagers prefer active transport for their social trips on a school day, on Saturday they prefer to be escorted by private motorized modes (Figure 3.13). We further explore the social activities that teenagers participate in on a school day and on Saturday. The results showed that the entertainment activities on a school day involve hanging out with friends in the neighborhood or the park, while Saturday entertainment activities include eating out with friends, going to the cinema, clubs or bars, and attending parties. As these activities are quite far from teenagers' homes they have to use a motorized vehicle and in doing so they prefer to be escorted by their parents, with only 3% choosing the bus.

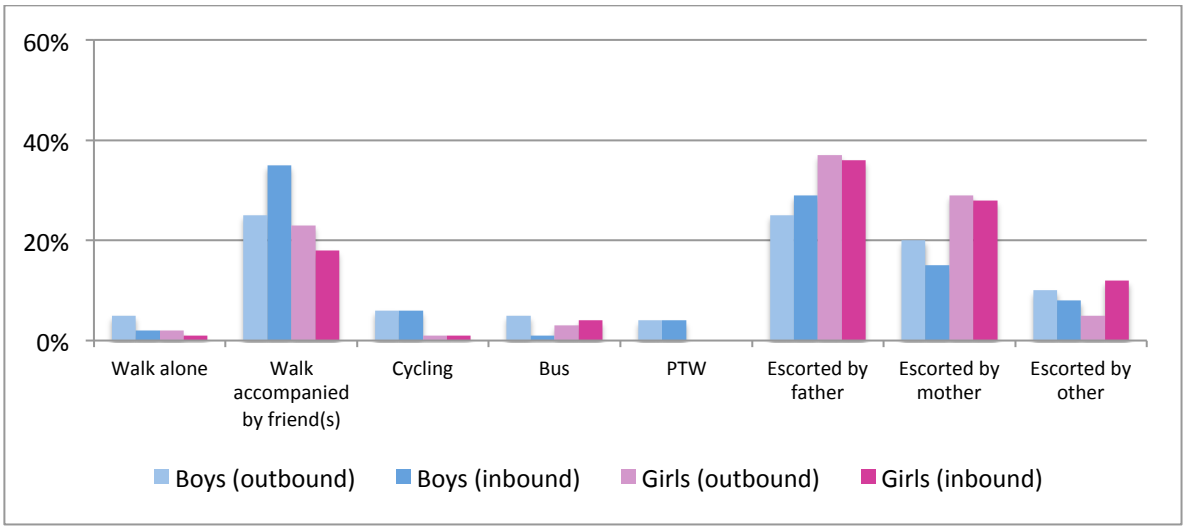


Figure 3.13: Transport mode for entertainment activities – Saturday (Cyprus)

The transport mode that teenagers use for shopping activities is presented in Figure 3.14. The analysis indicates that, generally, being escorted by private motorized vehicles is the most preferred transport mode. For the majority of shopping activities, both boys and girls

are escorted by their mothers. A significant percentage of boys choose active transport (walking and cycling), while only 1% of girls prefer the bicycle. Once again, walking accompanied by friends is more common than walking alone.

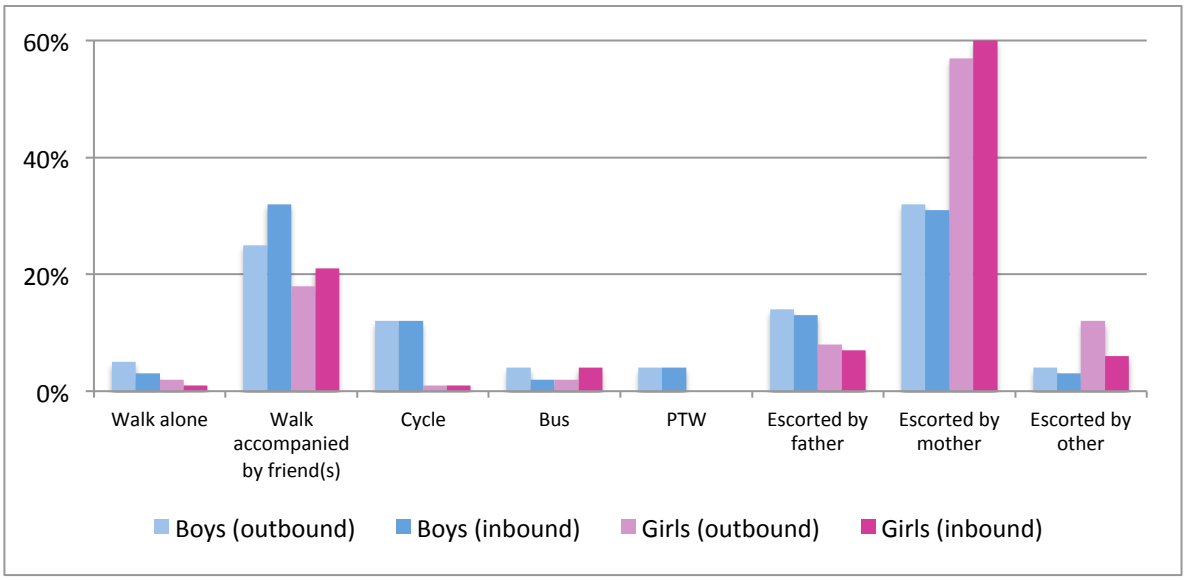


Figure 3.14: Transport mode for shopping activities – Saturday (Cyprus)

Mode use patterns for visiting tours on Saturday are quite similar to those for entertainment trips (see Figure 3.15). Being escorted by motorized vehicle is the most popular mode, followed by walking and then cycling. Being escorted by mother is more common than by father, and walking accompanied by friends is more common than walking alone. Significant differences between males and females are noticed in the escorted option, while none of the participants indicated that they use the bus for visiting purposes on Saturday.

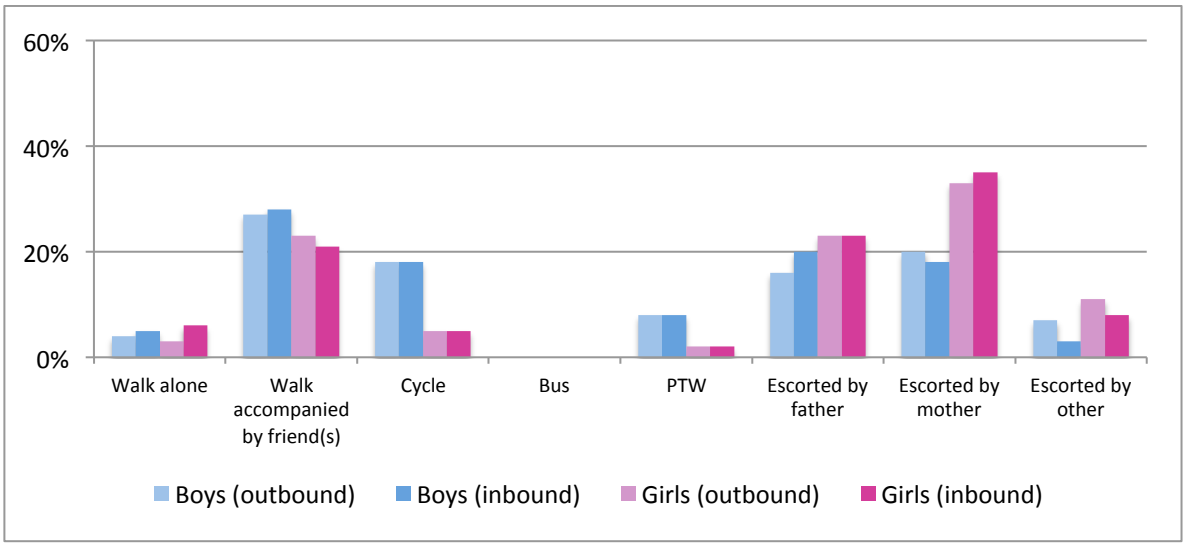


Figure 3.15: Transport mode for visiting activities – Saturday (Cyprus)

At this point it is worth investigating the average travel time for each activity. Teenagers spend 78.8 minutes in travelling to their activities on a typical school day. More specifically, the average travel time to school is 11.2 minutes, while the average travel time for the return trip from school is 12.5 minutes. They also spend 18 minutes in travelling for tutorial lessons purposes, 20.2 minutes in travelling for sports activities purposes, 14.9

minutes in travelling for entertainment purposes, 18.2 minutes in travelling for shopping purposes and 17.1 minutes in travelling for visiting purposes on a school day. The amount of time that teenagers spend in travelling for tutorial lessons and sports activities purposes on Saturday is quite similar to that on school days. However, differences are noticed in the travelling time for entertainment and shopping activities, with girls spending more time than boys in travelling for these activities. Table 3.10 presents the average travel time for each activity per gender.

Table 3-10: Average travel time for each activity (Cyprus)

(In minutes)	School Day		Saturday	
	Boys	Girls	Boys	Girls
Travelling to School	10.8	11.4	n/a	n/a
Return from School	12.1	12.7	n/a	n/a
Travelling to/from tutorial lessons	18.8	17.4	18.4	17.9
Travelling to/from sports activities	20.3	20.1	21.1	20.5
Travelling to/from entertainment/leisure purposes	15.3	14.1	24.2	26.9
Travelling to/from shopping purposes	17.5	18.7	22.4	23.6
Travelling to/from visiting purposes	16.1	17.8	17.7	18.2
Other purposes (inbound and outbound trips)	20.9	21.8	16.4	15.6
Total Travel Time	78.2	79.1	75.6	78.7

3.3.3 Activities and Time Allocation

Adolescents' time use is of great concern to both parents and policy makers. Much of the conversation about children's time use in general, and teenagers' in particular, is about whether children have too much freedom from adult supervision and whether they spend too much time engaged in leisure pursuits with little or no developmental benefit (Raley, 2006). Others argue that children may be overscheduled with commitments to a large number of organized activities that dominate family time (Lareau, 2003). Teenagers' time allocation and activity participation is also of concern to transportation planners, as they participate in a number of activities that create a demand for travel.

Our dataset provides a single-day snapshot of the previous school day's activities and previous weekend's activities. We use these data to describe a set of daily activities and focus on specific dimensions of time use that may be important for understanding teenagers' travel behavior.

Table 3.11 presents the average time that teenagers allocate to various activities on a school day, on Saturday and on Sunday. Adolescent boys seem to spend 96 minutes on a school day, 66 minutes on Saturday and 62 minutes on Sunday in studying and doing their homework, while adolescent females seem to spend considerably more time in this activity. Teenagers also spend a significant amount of time in tutorial lessons on school days, while this amount is almost halved during the weekend. Surfing the web and watching TV are among the most popular activities. Also, teenagers spend a lot of time in out-of-home activities such as sports and hanging out. Other daily activities that teenagers spend time on include playing video games and doing chores. Reading extracurricular books is not a very popular activity among teenagers, as they spend just under 30 minutes on this. Participating in the activities that we referred to in the previous subsection requires travelling and, in doing so, teenagers spend an average of 73 minutes in travelling during both school days

and Saturdays.

Table 3-11: Minutes per day teenagers spend on various activities

(In minutes)	School Day		Saturday		Sunday	
	Boys	Girls	Boys	Girls	Boys	Girls
Studying/Doing homework	96	120	66	76	62	77
Tutorial lessons	99	112	36	40	21	13
Surfing the web	150	135	216	211	209	196
Watching TV	112	116	142	159	142	147
Entertainment/Hanging out	97	83	188	226	155	156
Participating in sports activities	90	66	103	57	87	40
Reading extracurricular books	29	26	27	30	25	29
Playing video games	96	24	135	33	128	31
Chores	12	15	29	42	22	31
Travelling	71	75	71	74	n/a	n/a

Figure 3.16 depicts the three most popular activities for teenagers on a school day. Male adolescents spend an average of 150 minutes surfing the web, 152 minutes watching TV and 90 minutes engaging in sports activities. It is clear that boys spend most of their time on entertainment activities. The most popular activity for girls, too, is surfing the web, to which an average time of 135 minutes is allocated. The second most popular activity for females is studying and doing their homework (120 minutes), while watching TV follows with 116 minutes. Comparing males to females, male teenagers spend almost 30 minutes less than females in studying and preparing for school.

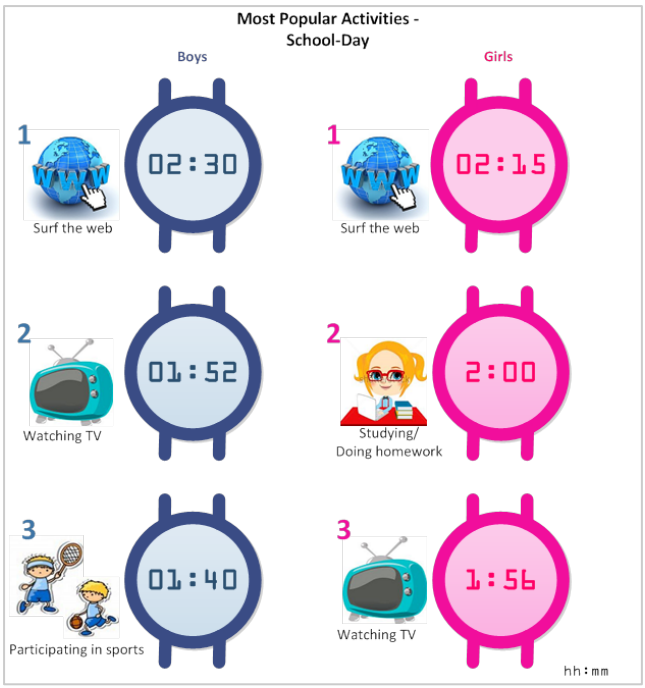


Figure 3.16: Most popular activities in a school day (Cyprus)

As can be seen in Figure 3.17, surfing the web remains the most popular activity for boys on Saturday, with an average of 216 minutes spent in this way. Girls spend an average of 211 minutes in surfing the web, but this activity is ranked at second place, as the most popular activity for girls is hanging out with friends (226 minutes). Watching TV is the third most popular activity for both girls and boys.

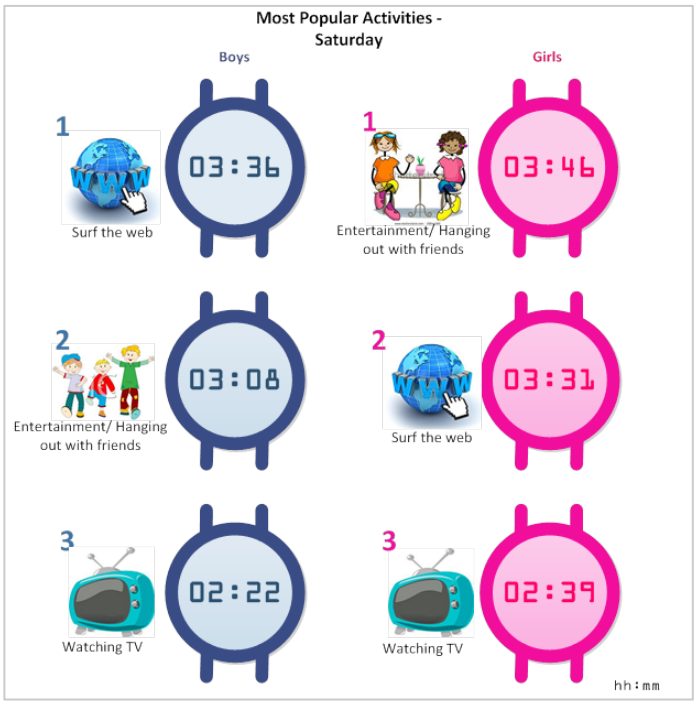


Figure 3.17: Most popular activities on Saturday (Cyprus)

The most popular activities that teenagers engage in on a Sunday are depicted in Figure 3.18. It is noticed that the ranking of the activities for both males and females is the same. The first most popular activity is surfing the web, the second is hanging out with friends and the third is watching TV.

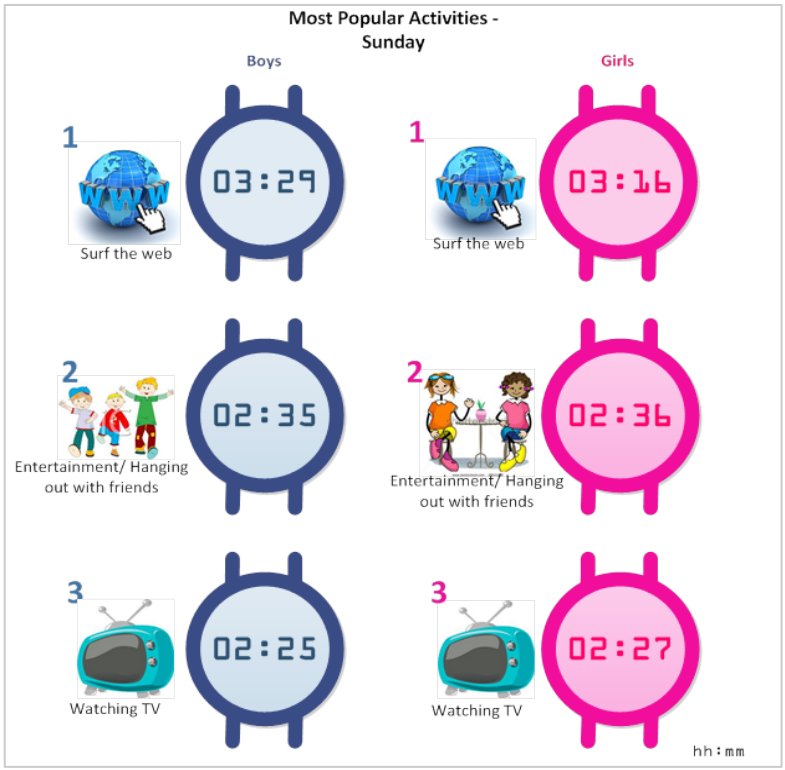


Figure 3.18: Most popular activities on Sunday (Cyprus)

3.4 Activities, Tour Types and Time Use – Greece

3.4.1 Tour Types – Greece

This subsection presents the analysis of the travel patterns of the participants in Greece. As already mentioned, the survey in Greece took place in three distinct geographical areas; thus the analysis of travel patterns is performed on the basis of the area. Similarly to the survey in Cyprus, we asked the participants to describe their activity patterns for the school day before the survey was conducted and for the latest Saturday. Therefore, it is assumed that the average numbers obtained correspond to a typical school day and a typical Saturday.

Table 3.12 presents the percentages of the activities that teenagers engage in during a school day and on a Saturday for which travelling is required. For all three areas, the most popular activities on a school day after going to school are participating in tutorial lessons and in sports activities. The most popular activity on Saturday for all areas is hanging out with friends (entertainment). This activity is pursued by 46% of urban teenagers, 57% of rural teenagers and 53% of insular teenagers. At this point it is worth mentioning that 90% of urban teenagers, 92% of rural teenagers and 93% of insular teenagers participate in tutorial lessons, but some of the tutorials take place at teenagers' homes, so no travelling is required.

Table 3-12: Activities conducted – Greece

Activity	**% teenagers who participate in each activity – School day**			**% teenagers who participate in the activity – Saturday**		
	Urban	Rural	Insular	Urban	Rural	Insular
Home	0%	0%	0%	18%	9%	8%
School	100%	100%	100%	0%	0%	0%
Tutorial lessons	64%	75%	84%	36%	43%	36%
Sports activities	39%	37%	44%	35%	29%	25%
Hanging out /Entertainment	19%	69%	60%	46%	57%	53%
Shopping	4%	4%	5%	29%	30%	30%
Visiting	5%	12%	9%	9%	12%	13%
Other	0%	4%	2%	0%	0%	1%

The school day in Greece typically runs from 08:00 to 14:10. The morning tour types for a school day by each geographical area are presented in Figure 3.19. The vast majority (88%) of urban teenagers conduct simple tours in the morning. In the rural area 58% of the morning tours are simple, in the insular area 55%. The differences in tour types between the urban area and the rural and insular areas are significant.

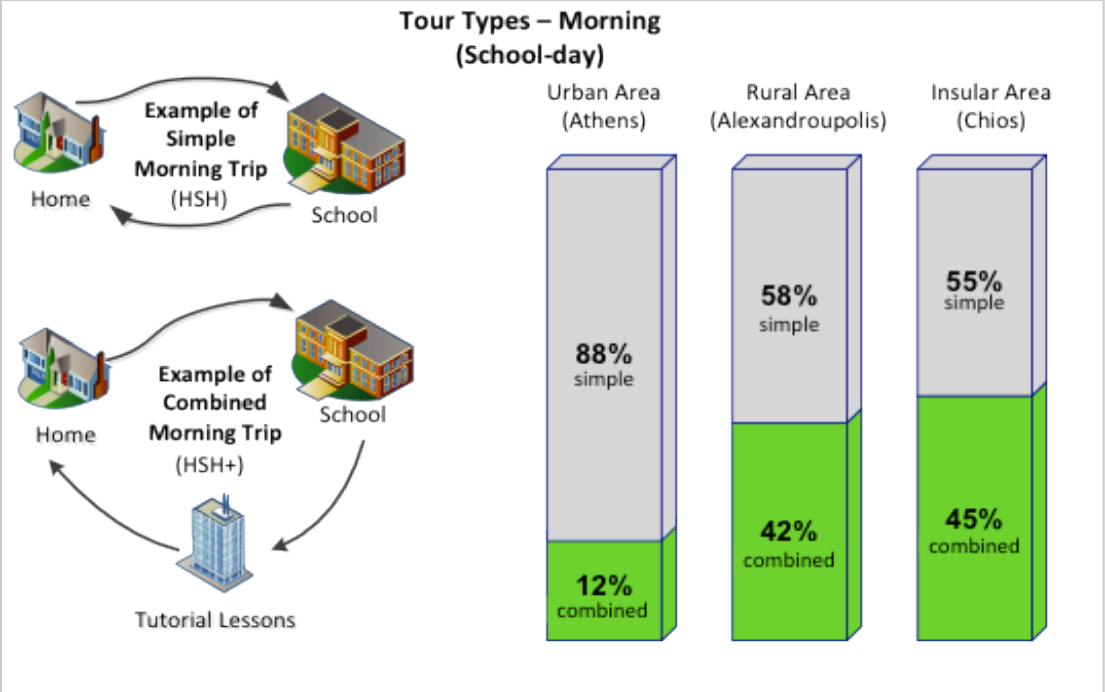


Figure 3.19: Tour types in the morning – School day (Greece)

The details of the morning tours are presented in Table 3.13. Overall, 17 different tour types were identified, while no home pattern was recorded. The majority of the combined tours in all areas have as the secondary tour purpose tutorial lessons, followed by entertainment purposes. 14.6% of the participants in the insular area stated that they went for coffee or lunch after school and then returned home, while in the rural area 10.7% of the participants reported the same activity pattern. 12.3% of the participants in the rural area, 11.7% of those in the insular area and 4.2% of those in the urban area attend tutorial lessons directly after school and then return to their home. 3.6% of the rural teenagers and 2.2% of the insular teenagers attend other activities after school, such as going to their parents' businesses in order to help them. Other secondary tour purposes include sports and visiting.

Table 3-13: Morning activity patterns – School day (Greece)

Morning Activities – School Day					
Primary Activity	Primary Tour Type	Number and Purpose of Secondary Tours	Percentages		
			Urban	Rural	Insular
School	HSH	0	88.0	58.0	55.0
	HSH+	1 Tutorial Lessons	4.2	12.3	11.7
		1 Entertainment	3.1	10.7	14.6
		1 Sports	1.2	2.5	3.6
		1 Visiting	0.8	0.9	1.9
		1 Other	0	3.6	2.2
		2 Entertainment & Tutorial Lessons	1.8	8.9	9.2
		2 Tutorial Lessons & Visiting	0.9	3.1	1.8
Total			100.0	100.0	100.0

The after-school tour types of the teenagers are presented in Figure 3.20. 24 different tour types were identified for the after-school activities. 18% of the urban, 9% of the rural and 8% of the insular teenagers stated that they had not conducted any trip in the afternoon. The

majority of the trips that urban and insular teenagers conduct in the afternoon are simple (53% and 48% accordingly).

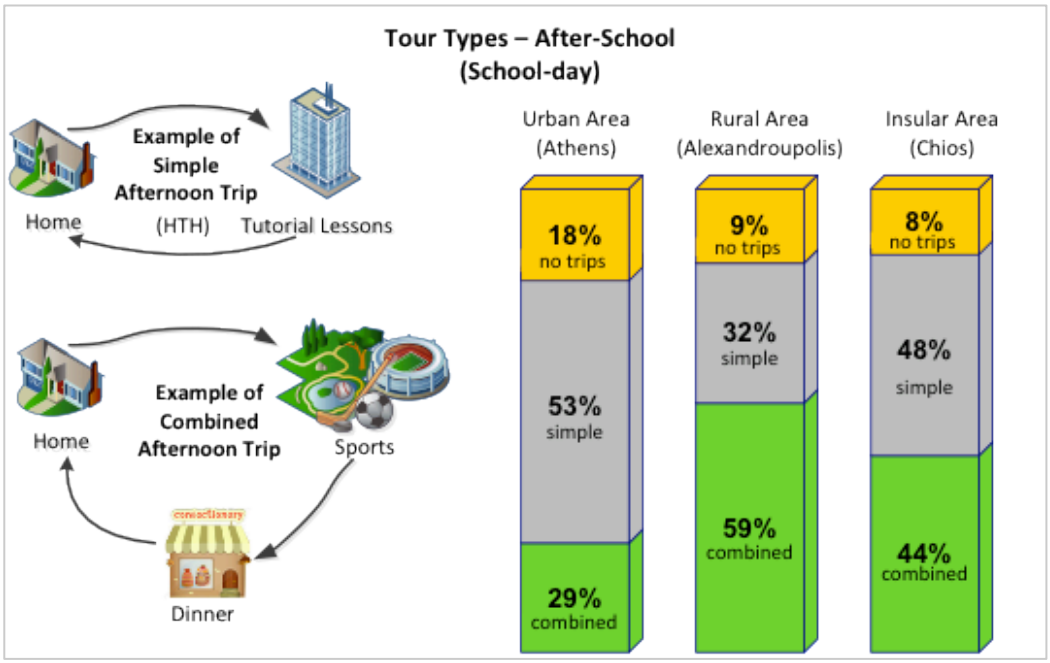


Figure 3.20: Tour types in the afternoon – School day (Greece)

The afternoon tour types per each area are presented in Table 3.14. In all areas the vast majority of simple trips have as a primary purpose participation in tutorial lessons (HTH), followed by sports activities (HSpH) and then both of these (HTSpH). Furthermore, the results of the analysis show that teenagers in rural and insular areas conduct a significant percentage of tours that include entertainment as a secondary tour purpose. However, in the urban area only a small percentage of teenagers undertake tours with a secondary purpose of entertainment.

Table 3-14: After-school activity patterns – School day (Greece)

After-School Activities – School Day					
	Primary Tour	Number and Purpose of	Percentages		
Primary Activity	Type	Secondary Tours	Urban	Rural	Insular
At home			18.0	9.0	8.0
Tutorial Lessons	HTH	0	36.4	20.4	22.2
	HTH+	1 Entertainment	1.8	19.8	21.9
Sports	HSpH	0	13.7	8.6	11.4
	HSpH+	1 Entertainment	2.2	12.5	7.3
		1 Visiting	0.6	2.6	2.2
		1 Shopping	1.2	3.4	1.5
		2 Entertainment & Visiting	1.6	2.4	0.8
Entertainment	HEH	0	2.9	3.0	2.4
	HEH+	1 Shopping	2.8	8.7	3.2
		1 Visiting	0.0	1.7	1.6
Tutorial Lessons & Sports	HTSpH	0	14.8	5.7	10.6
		1 Entertainment	2.6	1.4	6.1
		1 Visiting	1.4	0.8	0.8
Total			100.0	100.0	100

Figure 3.21 depicts the tour types that Greek teenagers in each area conduct on a Saturday. The majority of tours for all the three areas are combined, while only a small percentage of teenagers stay at home without conducting any tour.

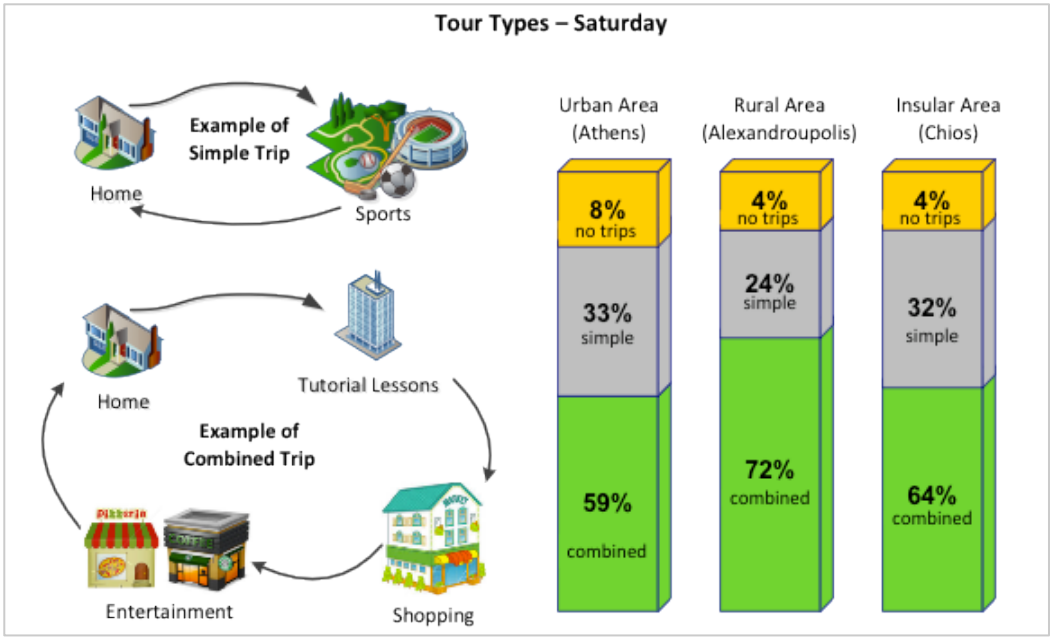


Figure 3.21: Tour types – Saturday (Greece)

The details of the Saturday tours are presented in Table 3.15. Generally, 32 different travel patterns are identified for urban teenagers, 37 for rural and 35 for insular. As can be seen, the majority of the tours conducted on Saturday include travel for entertainment purposes. More specifically, 25.7% of the tours in the urban area, 27.4% in the rural area and 32.5% in the insular area have entertainment activities as the primary tour purpose. Insular teenagers conduct more tours that have shopping activities as the primary purpose (12%). Also, it can be noticed that teenagers in urban areas conduct slightly more tours that include visiting purposes (12.9%) than rural (11.5%) and insular (11.5%) teenagers. Further analysis in relation to this finding showed that teenagers in the urban area usually make visits to their friends' homes, while the majority of rural and insular tours include visiting relatives and especially grandparents. That is due to the structure of the community. In rural and insular areas teenagers are able to have their relatives living nearby, while in urban areas the social bonds are not so tight, as teenagers usually do not have their relatives living nearby. Also, visiting a friend's home is usually a form of entertainment in urban areas (especially for younger teenagers), as it is safer than hanging out. Moreover, not only is this option safer; it is also the most cost-effective one, taking into account the economic situation in Greece. Despite taking place on Saturday, 35.8% of tours in the urban area, 42.6% in the rural area and 35.6% in the insular area have as their primary purpose participation in tutorial lessons. The majority of these tutorial lessons are for school lessons, only a small percentage being for foreign languages and music. It is very common in Greece for teenagers to attend tutorial lessons in their school subjects after school and at the weekend, a fact that creates further demand for travelling.

Table 3-15: Activity Patterns – Saturday (Greece)

Activities – Saturday					
	Primary Tour	Number and Purpose of	Percentages		
Primary Activity	Type	Secondary Tours	Urban	Rural	Insular
At home			8.0	4.0	4.0
Tutorial Lessons	HTH	0	9.2	6.3	7.4
	HTH+	1 Entertainment	4.1	11.2	8.9
		1 Shopping	3.6	7.5	4.2
		1 Visiting	0.9	1.2	2.3
		2 Entertainment & Shopping	2.4	3.1	1.6
Sports	HSpH	0	11.8	5.1	5.8
	HSpH+	1 Entertainment	6.1	3.8	2.6
		1 Visiting	0.4	1.9	1.7
		1 Shopping	1.2	3.7	2.5
		2 Entertainment & Visiting	0.0	2.2	1.2
Entertainment	HEH	0	8.7	10.1	15.3
	HEH+	1 Shopping	10.1	4.3	7.2
		1 Visiting	1.9	2.4	1.8
	HE+H	1 Entertainment	5.0	10.6	8.2
Shopping	HShH	0	3.3	2.5	4.5
	HShH+	1 Entertainment	1.8	5.3	4.2
		1 Other	0.0	0.4	1.2
		2 Entertainment & Visiting	2.1	1.1	2.1
Tutorial Lessons & Sports	HTSpH	0	5.6	6.3	5.2
	HTSpH+	1 Entertainment	4.1	2.8	1.9
		1 Visiting	1.2	0.6	1.2
		1 Shopping	2.1	1.5	1.7
		2 Shopping & Visiting	2.6	0.8	1.2
Visiting	HVH	0	3.8	1.3	2.1
Total			100.0	100.0	100.0

3.4.2 Transport Mode per Activity – Greece

In this subsection we analyse the transport mode that Greek teenagers in each area use for their activities. As in the analysis for Cyprus, walking is divided into walking alone and walking accompanied by friend(s), and being escorted by motorized vehicle is further analysed by the person who escorts the teenagers. Only a few participants (less than 1%) declared that they walk accompanied by an adult, so this minor percentage is included within the walking with friends option. Figure 3.22 depicts the transport mode that teenagers use for their trip to school and back. The majority of the adolescent students in all areas prefer to walk to school, and more specifically they walk accompanied by their friends. Differences are found between urban teenagers and rural and insular teenagers regarding bus usage, as more of the first group prefer the bus (30% for the outbound and 28% for the inbound trip). The bus network in the urban area covers a wider area, with more frequent services, than those in the other two areas, thus providing more urban teenagers with the option of using the bus. The percentages of teenagers escorted by private modes to school are approximately the same across all areas, with "escorted by father" being more common than "escorted by mother". A small difference between the outbound and inbound school trips can be observed, due to the fact that in the morning teenagers are escorted to school by their parents before the latter go to work, while after school, when

parents are not able to pick up their children, the teenagers choose either to get the bus or walk. Cycling is not a popular mode of travel to school, as only 2% in urban and insular areas and 8% in rural areas choose this mode. However, in the rural area, where there are cycle lanes linking the center of the city with the high schools, the highest cycling to school percentage is found. Also, at this point it is worth mentioning that 47% of the data for the urban area were collected in January 2012, when the average temperature in the morning was -15°C and the weather was snowy. Despite this fact, the majority of the students walk to school, while a significant percentage cycle. Differences are noted in PTW usage, with 13% of insular teenagers using it for their trip to school and back, while in urban and rural areas only 3% and 4% respectively use this mode.

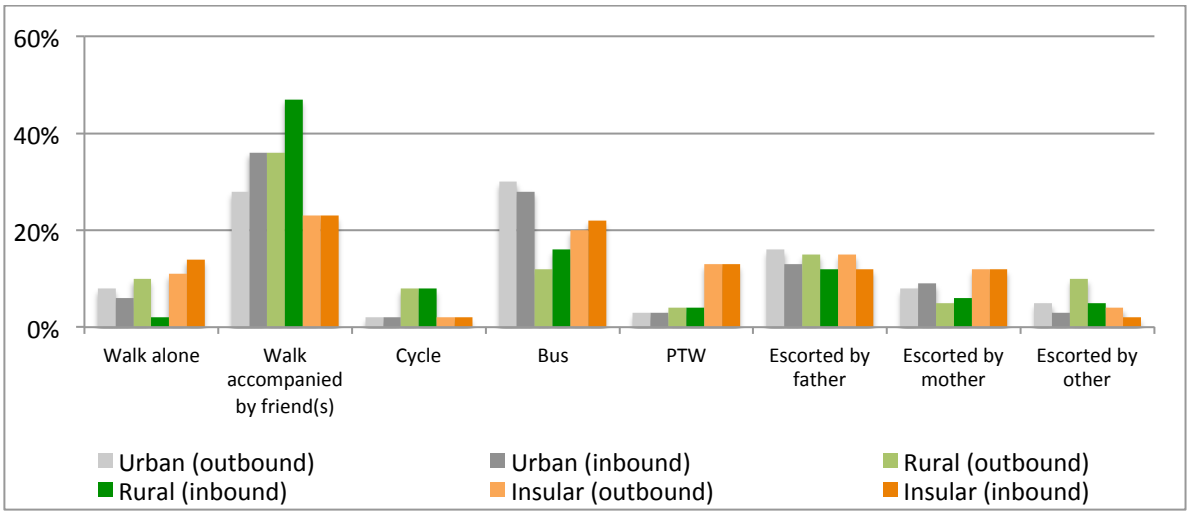


Figure 3.22: Transport mode to school and return from school - School day (Greece)

Similarly to Cyprus, no significant heterogeneity is noticed among the transport modes that teenagers use for their tutorial lessons and sports activities; thus we present these within the same figure (Figure 3.23). 38% of teenagers in the urban area use the bus to travel to these activities, while 39% use this mode for their return trip. As bus services are better in the urban area, teenagers seem to prefer this method. More teenagers in the insular area prefer to be escorted by their parents than those in the rural and urban areas. More specifically, for the majority of the trips in which teenagers are escorted, it is their father who escorts them. Also, 22% teenagers in the insular area prefer to drive their motorcycles (PTW) for these activities, while 16% in the rural area, and only 5% in the urban area, prefer this mode. A significant percentage (16%) in the rural area cycle to tutorial lessons and sports activities. Since the temperature in the rural area during the day was -10°C, the cycling percentage has been doubled. The fact that in the rural area there are bicycle lanes favors the usage of bicycles. Overall, it is noted that motorized modes are preferred to active transport in all areas, while fathers seem to undertake the duty of escorting their children to these activities.

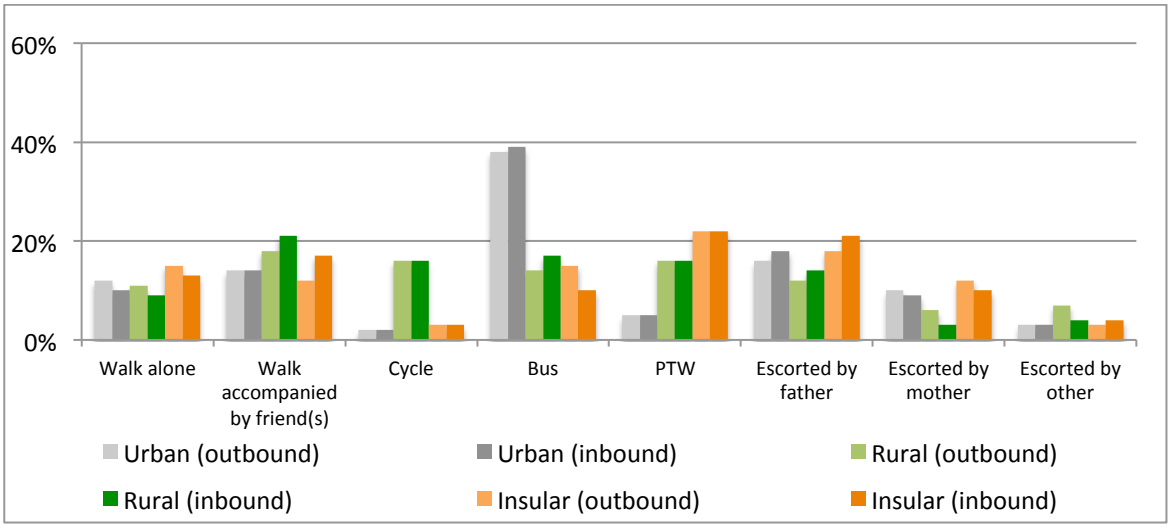


Figure 3.23: Transport mode for tutorial lessons and sports activities - School day (Greece)

The transport mode that teenagers use in each area to travel to and from their entertainment activities on a school day is presented in Figure 3.24. It is observed for all three areas that teenagers do not prefer to be escorted by an adult to their entertainment activities. They prefer to conduct trips for entertainment purposes without the supervision of their parents. Walking, and more specifically walking accompanied by their friends, is the most preferred mode for all areas. The second most preferred mode for urban teenagers is the bus (32% for the outbound trip and 35% for the inbound), for insulars it is the motorcycle (20% for both trips), while for rural teenagers it is the bicycle (21% for both trips).

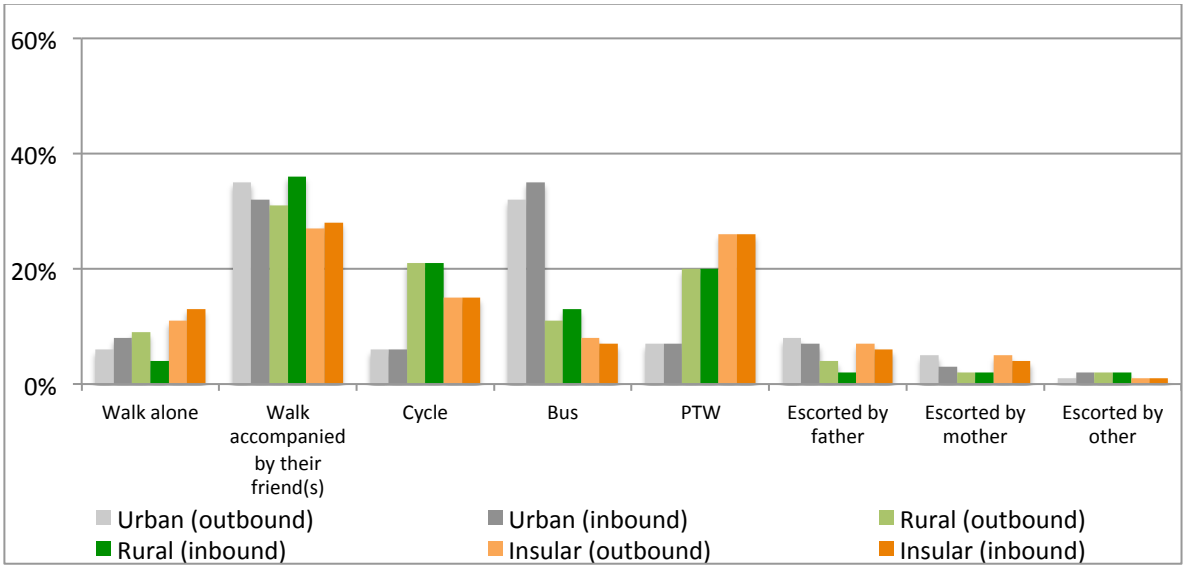


Figure 3.24: Transport mode for entertainment activities - School day (Greece)

The figures below (Figure 3.25 to 3.28) refer to Saturday tours. Figure 3.25 presents the transport mode that teenagers choose for their tutorial lessons and sports activities on Saturday. It can be seen that in the rural area teenagers generally prefer walking (33% for the outbound and 36% for the inbound tour) and especially walking accompanied by their friends (30% and 31% accordingly), while urban teenagers prefer the bus (34% for the outbound and 39% for the inbound trip). Insular teenagers' most popular transport mode for these activities is by private motorized vehicle (35% for the outbound trip and 38% for the

inbound), primarily driven by their mothers, while the second most popular is the motorcycle (22% for both trips). 12% of these tours in the rural area are conducted by bicycle, while only 5% in the urban area and 4% in the insular area choose this mode for engaging in these activities.

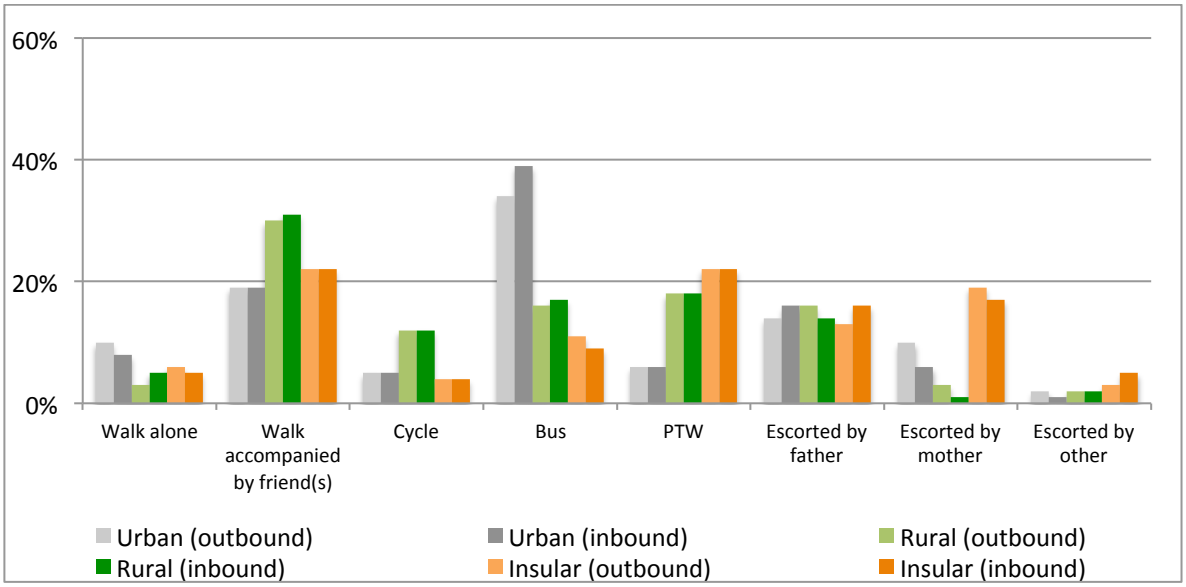


Figure 3.25: Transport mode for tutorial lessons and sports activities – Saturday (Greece)

As with Cyprus, although the majority of Greek teenagers in urban and insular areas walk to their social activities on a school day, on Saturday they prefer to be escorted by their parents (Figure 3.26). This is due to the fact that in these areas the leisure activities on a school day involve hanging out in the neighborhood or the park, while on Saturday they go to the cinema, parties, for coffee, dinner etc. On the other hand, rural teenagers still prefer walking for their entertainment activities on Saturday as well (34% for the outbound and 32% for the inbound trip). The land use of the city is distributed in such a way that the majority of the activities are within walking distance. The motorcycle is also a popular transport mode for leisure activities in the insular (26%) and rural areas (18%), while in the urban area only 4% of the participants choose it.

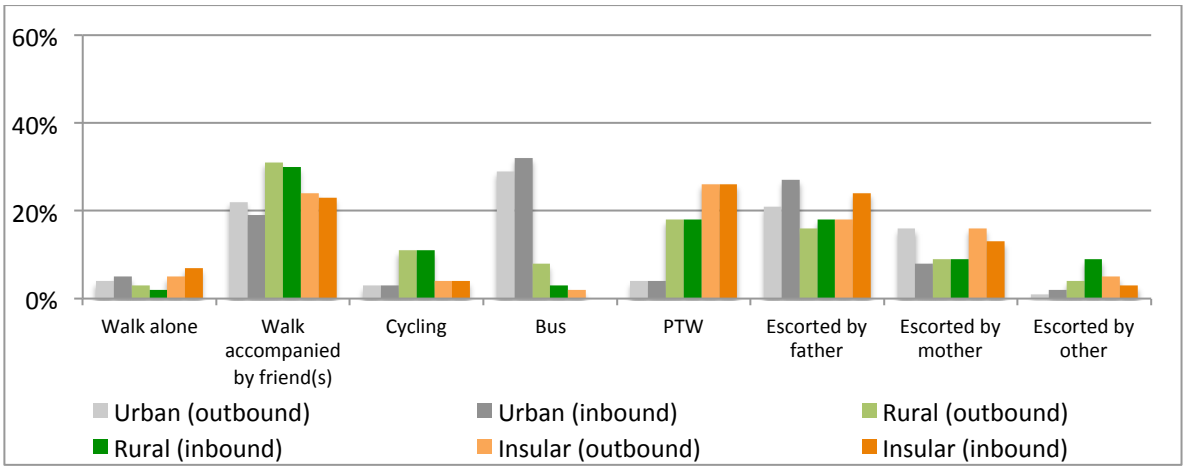


Figure 3.26: Transport mode for entertainment activities – Saturday (Greece)

As for the transport mode that teenagers use for their shopping activities, considerable differences are noticed across the three areas (Figure 3.27). Teenagers in the urban area

prefer the bus or, generally, public transport (46% for outbound and 48% for the inbound trip); teenagers in the rural area prefer to walk (51% for the outbound and 54% for the inbound trip), while teenagers in the insular area prefer to be escorted by private motorized means (42% for the outbound and 43% for the inbound trip) and especially by their mother. It seems that, for all three areas, escorting teenagers to shopping activities is a duty that women undertake. Further analysis of these results shows that teenagers in the urban area go shopping in malls, which are situated in areas other than those in which they live. Teenagers in the rural area usually conduct this activity in the shopping area, which is situated in the town center (Figure 3.4). Although the majority of teenagers in the insular area live within walking distance of the shopping area, they still prefer motorized modes of transport.

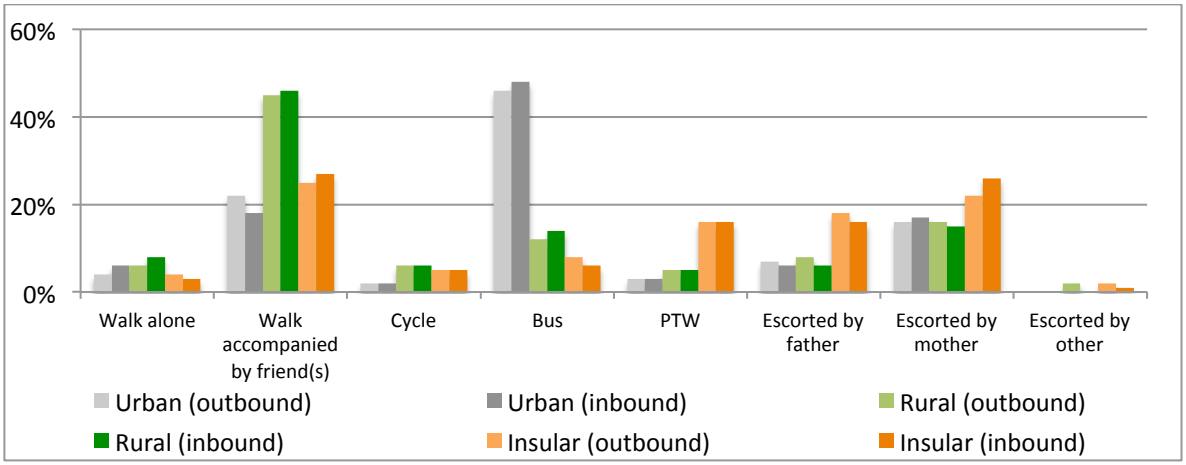


Figure 3.27: Transport mode for shopping activities – Saturday (Greece)

The majority of the tours for visiting purposes in all areas are conducted by private motorized modes (Figure 3.28). Being escorted by the father is the most common mode. Further analysis indicates that these tours usually involve a visit to grandparents or relatives who live in a village quite far from the teenager's home. In the urban area the majority (39%) of the tours that are conducted by bus usually involve a visit to a friend. In the rural area a significant percentage of these tours are also conducted by walking; these involve visits to both friends and relatives.

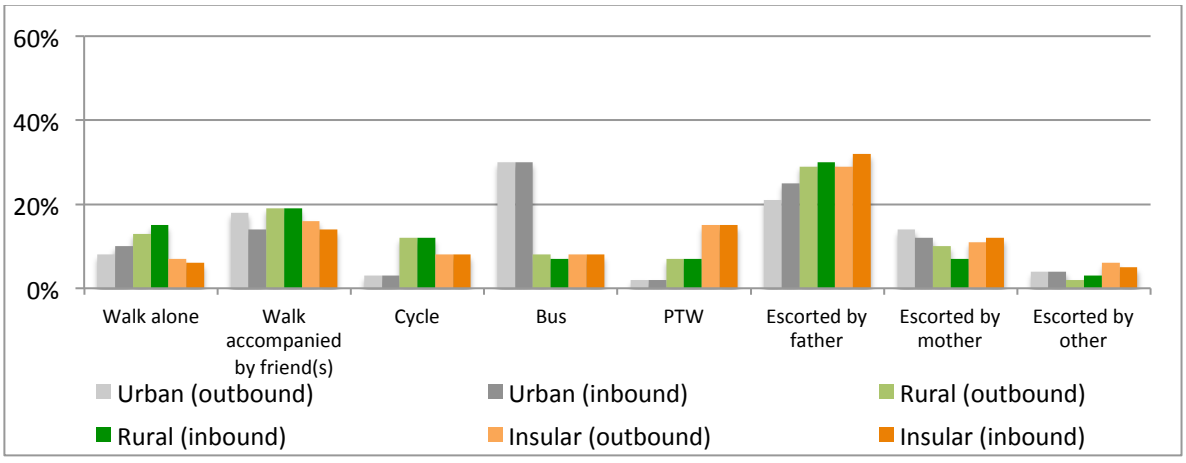


Figure 3.28: Transport mode for visiting activities – Saturday (Greece)

The analysis of the tour types and transport modes is followed by analysis of the travel time

for each activity (Table 3.16). Considerable heterogeneity is noticed in travel times among the three areas. Teenagers in the urban area travel 14.3 minutes to go to school and 17.4 minutes to return from school, while teenagers in the rural area travel 10.6 minutes to go to school and insular teenagers 11.2 minutes. There are also big differences in travel time for tutorial and sports activities. Teenagers in the rural area spend an average of 19.1 minutes on a school day and 20.3 minutes on Saturday to go to and return from their tutorial lessons, while teenagers in the urban area spend an average of 35.9 minutes on a school day and 36.8 minutes on Saturday. Moreover, urban teenagers spend considerably more time travelling for shopping purposes on Saturday (43.5 minutes) than rural (21.6 minutes) and insular (20.4 minutes) teenagers. Generally, a typical teenager spends an average of 80.2 minutes travelling in the urban area on a school day and 85.6 minutes on Saturday, while a teenager in the other two areas spends approximately 60 minutes both on a school day and on Saturday.

Table 3-16: Average travel time for each activity (Greece)

(In minutes)	School Day			Saturday		
	Urban	Rural	Insular	Urban	Rural	Insular
Travelling to School	14.3	10.6	11.2	n/a	n/a	n/a
Return from School	17.4	11.8	12.4	n/a	n/a	n/a
Travelling to/from tutorial lessons	36.7	19.1	21.2	32.2	20.3	22.6
Travelling to/from sports activities	35.9	21.3	24.6	36.8	21.7	25.3
Travelling to/from entertainment/leisure purposes	16.4	14.8	13.5	36.2	23.9	26.4
Travelling to/from shopping purposes	14.5	12.7	13.2	43.5	21.6	20.4
Travelling to/from visiting purposes	12.3	13.2	12.7	20.1	37.6	30.2
Other purposes (inbound & outbound trips)	7.9	10.4	12.3	16.4	13.6	14.3
Total Travel Time	80.2	60.3	64.6	85.6	58.7	60.9

3.4.3 Activities and Time Allocation

Table 3.17 presents the average time that teenagers allocate to various activities in a school day, on Saturday and on Sunday. Considerable heterogeneity is noted regarding the amount of time that teenagers devote to each activity in each area. Teenagers from all areas spend a significant amount of time in studying and tutorial lessons. Despite the fact that in the previous decade one of the most popular activities for teenagers was watching TV (Wight et al., 2009), nowadays they spend more time surfing the web than watching TV. Time use analysis shows that teenagers in urban areas spend an average of 63 minutes surfing the web and 51 minutes watching TV on a school day. The amount of time that teenagers spend on entertainment activities significantly differs between school days and Saturday. For teenagers in all areas, reading extracurricular books and playing video games is not such a popular activity. Compared to school days and Sunday, Saturday is the day on which teenagers allocate more time to doing chores. Finally, teenagers in the urban area spend 26 minutes more than rural teenagers and 21 minutes more than insular teenagers in travelling on a school day. Moreover, on Saturday urban teenagers spend 30 minutes more than rural teenagers and 27 minutes more than insular teenagers in travelling.

Table 3-17: Minutes per day teenagers spend on various activities – Greece

(In minutes)	School Day			Saturday			Sunday		
	Urban	Rural	Insular	Urban	Rural	Insular	Urban	Rural	Insular
Studying/Doing homework	**182**	98	155	116	57	109	200	96	114
Tutorial lessons	**145**	79	138	71	36	76	37	40	24
Surfing the web	63	68	85	127	125	157	103	105	162
Watching TV	51	64	65	92	83	127	98	88	132
Entertainment/ Hanging out	32	39	38	225	186	220	113	89	160
Participating in sports activities	67	56	72	52	50	56	47	38	40
Reading extracurricular books	15	10	18	31	15	16	27	21	17
Playing video games	14	24	29	29	62	30	20	71	29
Chores	9	16	11	21	25	18	11	12	9
Travelling	78	52	57	86	56	59	n/a	n/a	n/a

The three most popular activities for teenagers of all areas are depicted in Figure 3.29. The most popular activities are of the same type for the three areas, except for the third most popular activity for urban teenagers, which is studying and doing their homework. Urban teenagers spend approximately 3 hours per day in studying, rural teenagers spend approximately 2 and a half hours, while rural teenagers spend approximately half as much time as urban teenagers in studying (1 hour and 38 minutes). Tutorial lessons comprise the second most popular activity for all the three areas' teenagers. However, considerable heterogeneity is noted in regard to the amount of time that teenagers of each area spend in this activity. Urban teenagers spend an average of 2 hours and 25 minutes, insular teenagers spend an average of 2 hours and 18 minutes, while rural teenagers spend almost half the amount of time on this activity (1 hour and 19 minutes). The third most popular activity for rural and insular adolescents is surfing the web, on which they spend an average of 68 minutes and 85 minutes respectively. For urban teenagers the activity that comes third for the amount of time spent on it during a school day, namely an average of 78 minutes, is travelling.

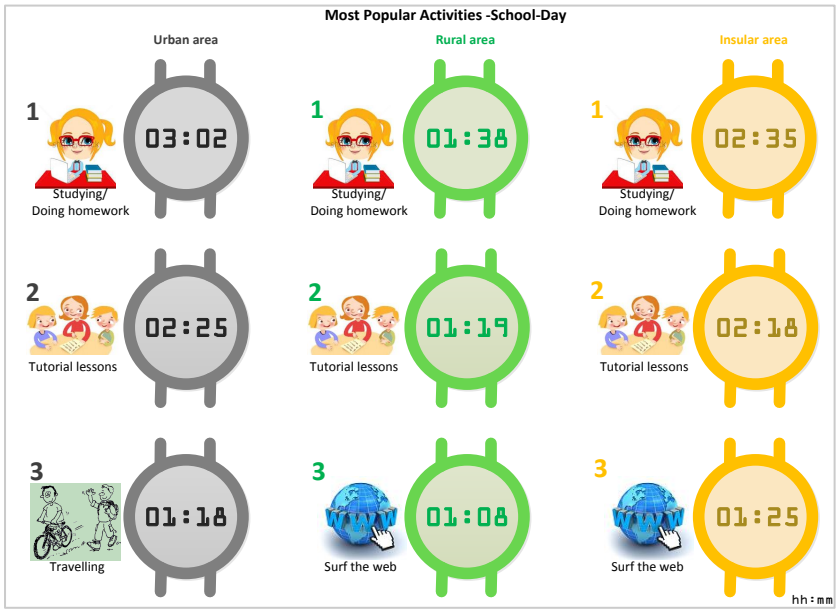


Figure 3.29: Most popular activities on a school day (Greece)

The three most popular activities on Saturday per each area are presented in Figure 3.30. Teenagers spend the most time on entertainment and leisure pursuits. Urban teenagers spend an average of 225 minutes on entertainment, rural teenagers an average of 186 minutes and insular teenagers an average of 220 minutes. Further analysis shows that entertainment purposes in Saturday include hanging out with friends and going for coffee, to clubs or to parties. The majority of the entertainment activities on Saturday are conducted with their friends. The second most popular activity for all areas' teenagers is surfing the web. Today's teenagers have grown up in the internet era and surfing the web is one of their favorite activities. Consequently, urban teenagers spend an average of 127 minutes on-line, rural teenagers spend 125 minutes, while insular teenagers seem to spend more time than the others, with an average of 157 minutes. Despite the fact that it is Saturday, studying is the third most popular activity for urban and insular teenagers, who spend an average of 116 minutes and 127 minutes respectively on it. The third most popular activity for rural teenagers is watching TV, which they do for an average of 83 minutes.

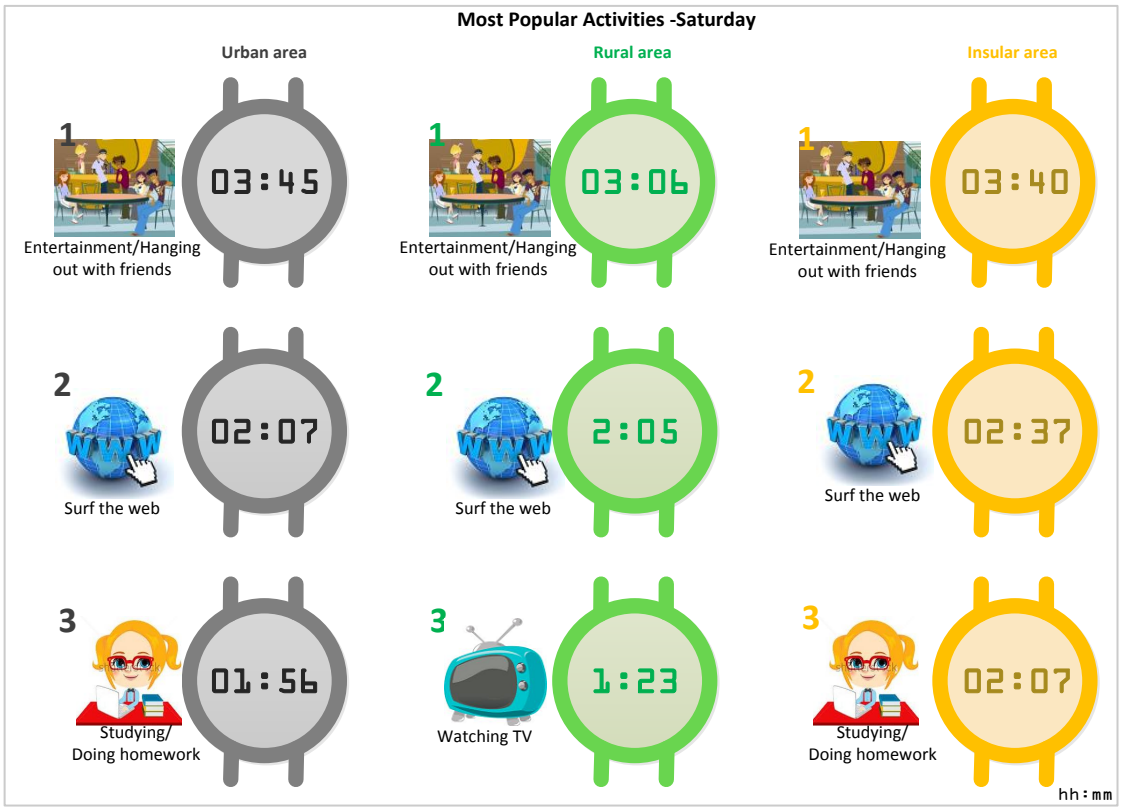


Figure 3.30: Most popular activities on Saturday (Greece)

Figure 3.31 presents the most popular activities on Sunday, which significantly differ among the three areas. Studying is the activity that urban teenagers spend the most time on (220 minutes). Entertainment is the second most popular activity for both urban and insular teenagers, who spend 113 minutes and 160 minutes respectively on it. Surfing the web is the third most popular activity for urban adolescents, who spend an average of 103 minutes on it, while for rural and insular teenagers it is the most popular activity, with 105 minutes and 162 minutes respectively devoted to it. The second most popular activity for rural teenagers is entertainment, on which they spend an average of 96 minutes; their third most popular activity is entertainment (89 minutes). The third most popular activity for insular teenagers is watching TV (132 minutes). The results show that urban teenagers spend

significant amounts of time studying on both Saturday and Sunday. Rural teenagers prefer to allocate more time on Sunday to doing their homework, and accordingly they give more time to entertainment activities on Saturday. The opposite occurs with insular teenagers, who seem to do their homework on Saturday in order to have more time for entertainment activities on Sunday. Comparing the time that teenagers allocate to surfing the web, it seems that urban and rural teenagers spend less time on Sunday than on Saturday, while insular teenagers spend approximately the same amount of time.

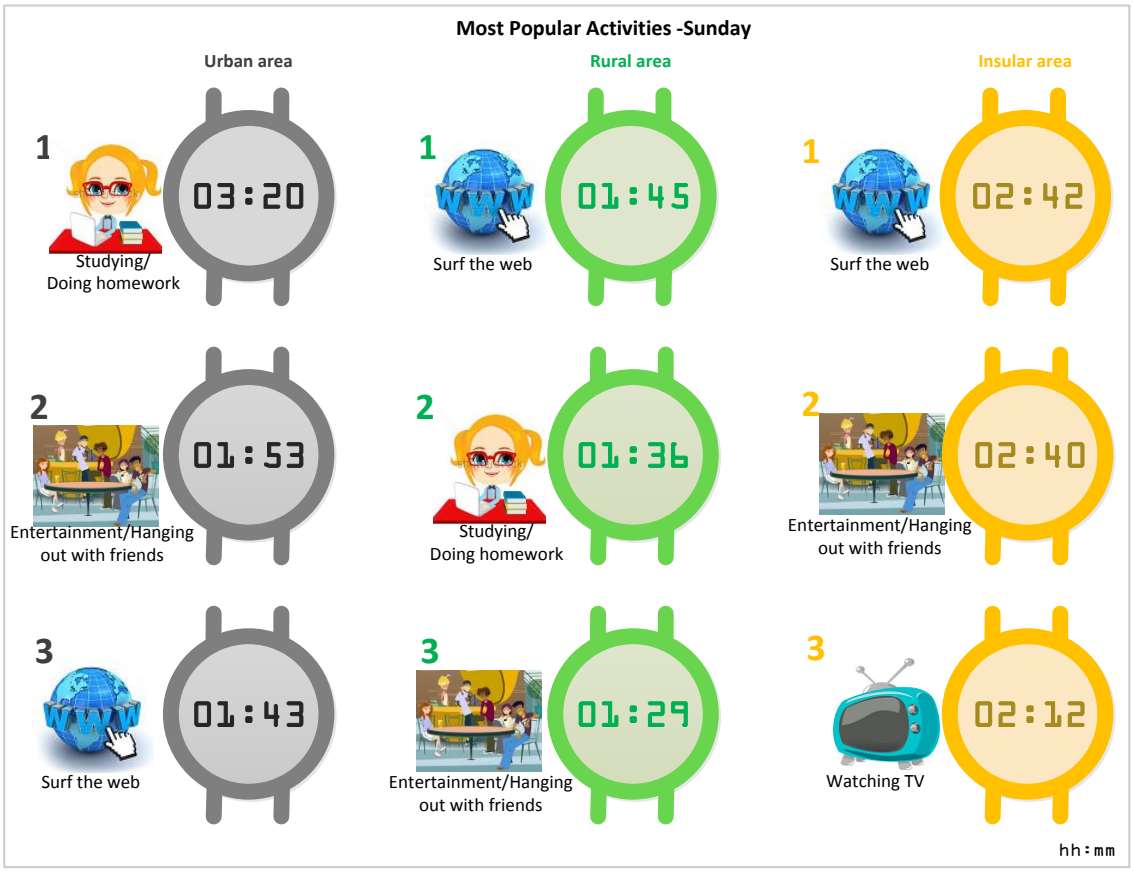


Figure 3.31: Most popular activities on Sunday (Greece)

3.5 Comparison of Activity Patterns between Cyprus and Greece

In this subsection a comparison is made between the two countries regarding the activity patterns, the transport mode and the time allocation of teenagers. Although these two countries share many common values and beliefs, their socio-economic characteristics differ a lot. The survey in Greece has been conducted since 2009, one year after the economic recession, while the survey in the Republic of Cyprus was conducted in 2012, one year before the economic recession in Cyprus. Thus, the activity patterns of Greek teenagers are quite affected by this event, while those of Cypriots are not.

The primary activity for both countries' teenagers in the morning of a weekday is going to school. The majority of the tours that Cypriot teenagers undertake in the morning are simple (18%) and are quite similar to the tours of Greek urban teenagers. Regarding

combined activity patterns in the morning, significant differences are noticed between the two countries in the purposes of the secondary tours. Greek teenagers conduct more secondary tours that include entertainment purposes. Also, the percentage of secondary morning tours that include tutorial lessons is higher for Greek adolescents.

The after-school tour types of Cypriot teenagers are quite similar to those of teenagers in the Greek rural area, with more than half of them being combined. For both countries the majority of after-school trips are conducted to participate in tutorial lessons and sports activities. Nevertheless, it is noted that Cypriot teenagers conduct more tours that have both tutorial lessons and sports activities as primary purposes. Greek adolescents seem to participate more in tutorial lessons and less in sports activities compared to Cypriots. Similarly to morning activities, Greek teenagers conduct more trips for entertainment purposes. They seem to combine their trips to tutorial lessons with hanging out with their friends.

Saturday tour types do not significantly differ between the two countries, with the majority of the tours being combined. In Cyprus 24 different tour types, and in Greece 32, were identified for Saturday. Even on Saturday a significant proportion of both countries' tours include participation in tutorial lessons. 49.4% of Cypriots' Saturday tours and 38.9% of Greeks' tours have this as their primary purpose. A significant percentage of Saturday tours include entertainment as well, but only 9% of Saturday activity patterns in Cyprus and 11.4% in Greece have entertainment activities as their primary purpose. 29.5% of the tours that Cypriot teenagers conduct on Saturday and 24.2% of the Saturday trips of Greek teenagers include shopping activities. Although this difference between the two countries is not significant, Cypriots conduct more tours that include shopping. However, we cannot report that this difference results from the economic crisis in Greece, as we do not know the kind of products they purchase and the amount they spend on this activity. 15.5% of the Cypriot adolescents' tours and 12% of Greek adolescents' tours include visiting a relative's or friend's home.

Significant differences are observed in the transport mode that teenagers from each country use in order to conduct their activities. Cyprus is a country heavily dependent on private motorized vehicles and especially on cars, while public transportation is limited to buses. Although there are cycle lanes in three out of five major Cypriot cities, they are constructed in the touristic areas of the cities, in order to cover the transport needs of tourists. The Greek urban area offers teenagers a variety of transport alternatives, as public transport includes bus, tram and metro. The only Greek area that has cycle lanes is the rural one, which is also served by public buses. The insular area's residents are also dependent on their private motorized vehicles, as the bus services are quite satisfactory in the morning, but limited in the afternoon. Bearing these facts in mind, the analysis of the transport modes that teenagers use for their activities shows that Cypriot adolescents are widely reliant on private motorized vehicles, while in Greece active transport is preferred.

The vast majority of Cypriot teenagers use a private motorized vehicle for their trip to school, usually escorted by their mother. The second most common transport mode for Cyprus is bus. In Greece the most popular transport mode to school is walking and especially walking accompanied by their friends. The second most popular mode for Greek rural and insular teenagers is being escorted by private motorized means, driven by their father, while for urban teenagers it is the bus. Also, for insular teenagers, driving a PTW to get to school is very common. For both countries, the transport mode used for the trip to

school is quite different from that used for the return trip. It is observed for both Cyprus and Greece that the percentage of teenagers driven to school is reduced for the return trip. This indicates that parents usually escort their children to school before going to work, but, as they are not able to pick up them from school, the children use a different mode for the return trip. Usually those who are escorted to school by their parents do not use the same mode for the return trip, but choose either walking with friends or bus. Furthermore, a significant percentage of insular teenagers drive a PTW to go to and return from school, while further analysis showed that 72% of these do not have the appropriate driving license, and so are illegal drivers.

For their tutorial lessons and sports activities Cypriot adolescents prefer to be escorted by private motorized modes, usually driven by their mothers. Greek urban teenagers prefer bus or generally public transport, rural teenagers prefer to walk accompanied by their friends and insular teenagers prefer to be escorted by their fathers. It is also worth referring to the fact that a significant percentage of rural teenagers cycle to these activities. Regarding the transport mode for entertainment activities, differences are noticed between weekdays and Saturday.

Cypriot teenagers choose active transport for entertainment activities on school days, as these include hanging out in the neighborhood, while they prefer to be escorted by their parents at the weekend as the places that they visit are quite far from their homes. Greek teenagers also prefer active transport on school days, while driving a PTW is also a common transport mode for these activities. These results indicate that teenagers avoid being escorted, as they do not want to be supervised by their parents. Changes on Saturday are noticed only for urban and insular teenagers, who prefer the bus and being escorted by their parents respectively. For most of the school-day and Saturday shopping activities of Cypriot teenagers they are escorted by their mothers. From this result, it is inferred that women undertake the shopping activities in the household, in the course of which they also escort their children to these activities. Urban Greek teenagers prefer public transport especially on Saturday, as the shopping areas that they visit are quite far from their homes. Rural teenagers, again, prefer active transport, while insular ones are escorted, usually by their mothers, or drive their motorcycles.

Finally, as far as the time allocation of Greek and Cypriot teenagers is concerned, Cypriots seem to spend considerably more time surfing the web both on school days and on Saturday, while Greeks spend a significant amount of time participating in tutorial lessons and studying during school days. Of high importance is the result for the Greek urban teenagers, which shows that the third activity that they spend most time on is travelling.

3.6 Conclusions

This chapter presented the activity patterns, the transport mode used for these activities and the time allocation of Cypriot and Greek teenagers on school days and on Saturdays. The activities for the school day were divided into school and after-school activities, while no pre-school activities were recorded. For each activity the transport mode that teenagers used to go to and return from this activity was presented. The identified transport modes that participant adolescents use are: 1. Walking alone, 2. Walking accompanied by friend(s), 3. Bus/Public transport, 4. Driving a PTW, 5. Escorted by private motorized mode driven by father, 6. Escorted by private motorized mode driven by mother, 7. Escorted by private motorized mode driven by other.

Generally, teenagers participate in a number of after-school activities, thus travelling is required. A significant percentage of teenagers' tours are conducted without the supervision of their parents, as they are not driven by them or any other adult. Also, in the case of Greece, especially in rural and insular areas, where the transport mode alternatives are limited, teenagers often drive a PTW even without having the appropriate driving license, a fact that creates road safety issues.

Regarding adolescents' time allocation, the results show that teenagers spend a considerable amount of time in outdoor activities and as a result in travelling. Moreover, present-day teenagers have grown up in the internet era and using social media is an activity on which they spend a lot of time both during the school day and at the weekend.

The descriptive statistics of the activity patterns, the mode use patterns and the use of social media raise many questions regarding adolescents' travel behavior. Moreover, the comparison between the two countries and especially the comparison among the three distinct Greek areas indicates that the factors that affect mode choice behavior may vary significantly from one area to another. That is the aim of this thesis. In the following sections, we are going to investigate and model the effect of social media and social networking on teenagers' trip-making behavior; the effect of social interaction on mode choice behavior; the effect of built-environment characteristics on mode-to-school choice behavior; and use of SP data to forecast modal split under various policies aiming to promote active and public transport usage.

Chapter 4
On-line Social Networking and Trip Making Behavior

"What were you doing when you were a teenager?"
The answer would be completely different from what current teenagers do.

So far in this thesis, we have provided a general motivation for investigating the effect of social media on travel behavior. We have briefly reviewed the previous literature regarding the effect of ICT usage on adults' travel behavior and we have also identified some surveys regarding teenagers and social media usage. In addition, in the previous chapter we analysed the time use of teenagers, confirming that current teenagers spend significant amounts of time on social networking on a daily basis. In this chapter, we develop two Latent Class Poisson Regression models in order to identify the effects of various On-line Social Networking (OSN) usage styles on adolescents' trip making behavior for social purposes. The first model is developed with data from the survey that took place in Cyprus. After the estimation of this model, we identified some gaps in our data. Accordingly, in the next wave of our survey in Greece in 2013, we collected more detailed data about OSN usage that are used for the estimation of the second presented model.

This chapter is organized as follows. Section 4.1 discusses in more detail the concept of social media. Section 4.2 presents our hypothesis regarding the causes and correlations of social media usage and its effect on the number of trips conducted for social purposes. Section 4.3 presents the modeling framework and the relevant mathematical equations that are used for the estimation of the Latent Class Poisson Regression models. Section 4.4 presents the first case study, using data from the survey in Cyprus, while Section 4.5 presents the second case study, using data from the Greek survey. Section 4.6 concludes the chapter.

4.1 Social Media and the Generation Gap

Social media are designed to foster social interaction in a virtual environment, and millions of contemporary teenagers use them. This culture of innovation and rapid technological adaptation is particularly strong among the younger generations, especially the New Boomers or Net Generation (born between 1983 and 2001: PRB, 2009). These so-called "internet natives" grew up in the era of personal computing and the internet or, as Tapscott (2009) puts it, they have been "bathed in bits and bytes" since birth and easily integrate technology into their daily lives. This discourse has a wide social impact and its echoes can be found in psychology, business literature and government policy. The general claim, made in this generation's discourse, is that this material context has led young people to develop natural aptitude and high levels of skill in relation to the new technologies. It is suggested that these older digital immigrants are never likely to reach the same levels of skill and fluency that were developed naturally by those who grew up with the new

technologies (Kamargianni & Polydoropoulou, 2013b; Tapscott, 2009). Thus, a generation gap is developing.

The emergence of OSN has upended the way teenagers interact with each other and the world, and there is now little room for doubt about its impact on aspects of social life such as friendships, information sharing and leisure activities. More than ever before, using social media means creating as well as receiving, with user control extending far beyond the selection of ready-made, mass-produced content. Against this background, in recent years a growing body of researchers have tried to investigate the kind of activities teenagers conduct using OSN and the effects on teenagers' personalities and psychology. However, little is known about how much, why, and how individuals, and more specifically adolescents, utilize social media, and how its usage affects their travel behavior.

4.2 Social Behavior and Face-to-Face Communication

Based on the findings discussed in the previous section, our research question in this chapter is whether social networking replaces or stimulates teenagers' trip making behavior for social purposes. Since it is difficult to find similar research in the transportation sector with which to build links between social networking and the number of trips, we use findings about the effect of ICT usage on trip making behavior and findings from the social sciences regarding virtual and face-to-face communication.

In the transportation sector, various surveys reviewed in Section 2.2.4 have shown that ICT usage either complements or modifies the number of trips that adults conduct for social purposes, as social interaction is difficult to replace by ICT (Mokhtarian et al., 2006; Tillema et al., 2007; Senbil & Kitamura, 2003). But since on-line social networking offers a wide variety of tools for communication purposes and its nature is quite different from that indicated by the broad term 'ICT', we further review the findings in the literature from the social sciences.

As adolescent on-line social networking usage grows in prevalence, so do psychologists' concerns about the effects of virtual communication on their social development. After we reviewed the research, it became obvious that there were two aspects of adolescent development and social network usage that have been most often discussed by scholars. First, there was the debate over whether on-line communication is used most by those already socially adept for additional interactions to bolster already thriving social networks, or by those adolescents who lack social skills and employ social networks as a form of social compensation (Sheldon, 2008). Second, adolescence is possibly the most essential time in a person's life for social development. In this period, teens learn to form and maintain intimate friendships, along with other essential social skills which become vital in young adulthood (Allen et al., 2010). Thus researchers want to comprehend the nature of the relationships adolescents are forming online.

Within the first debate, there is the "rich get richer" theory (Wilks, 2012). More extraverted teens who already have well-established peer groups report using the communication websites for additional peer interaction to reinforce already formed friendships and keep in touch with long-distance friends. On the other hand, less socially adept youth explain their on-line social networking as a place to anonymously self-disclose and make friends when they might otherwise be too uncomfortable to do so (Anderson-Butcher et al., 2010). There

is much debate and contradictory research as to which of these motives takes precedence, because past research (Finkelhor et al., 2002) has shown that less socially capable teens are more likely to turn to the worldwide web, while current research is showing the opposite (indicatively: Barak-Brandes & Levin, 2013; O'Keefe et al., 2011; Craig Watkins, 2009; Greenfield & Subrahmanyam, 2008).

Nevertheless, the majority of the most recent surveys verify the "rich get richer" theory. DeGroot et al. (2011) found that on-line social networking has a positive relationship with the frequency of face-to-face communication with Facebook friends and that communicating on Facebook is positively correlated with personal interactions with Facebook friends. Allen et al. (2010) found out that teens who had displayed negativity in friendships and reported symptoms of depression were less likely to possess a social networking profile, while adolescents who reported more positive intimate friendships were more likely to possess a profile. Regan and Seeves (2010) discussed the way on-line social networking could empower young people. Thus on-line social networks are able to both bridge and bond social capital by connecting large groups of people in loose networks and allowing communication that fosters relationship closeness. In their final comments on relationships, the authors suggest that on-line social networking positively affects face-to-face communication.

Since the massive popularity of social networking sites did not arise until the early 2000s, research in this field is obviously incredibly young and there is still much to be done. The studies reviewed in this article appear to indicate that, despite initial concern, on-line social networking may have more positive than negative effects on adolescents. Internet communication is an outlet for both extraverted and introverted youths. Teens most often use social networking sites to connect with friends and build communities, something they are also doing off-line.

Having all these findings in mind, we try to identify the links between adolescent virtual or on-line social networking and the number of trips they conduct for social purposes. It is obvious that teenagers use social media in order to enhance communication and social connection. Also, it is highlighted that there are groups in the total population that are affected by different ways of using social media. In doing so, we hypothesize that there are different OSN styles, which are not directly observable, and that each OSN style affects in a different way the number of trips conducted for social purposes (face-to-face communication). The modeling framework is presented in the following section.

4.3 Modeling Framework

Latent Class Models (LCM) are appropriate for our analysis, as the hypothesis is that OSN usage styles exist, that these styles are not directly observable and that they affect the number of social trips that teenagers conduct. This section describes in depth the model specification process.

The dependent variable to be dealt with is a count of the total number of trips T_i, measured in a sample of N individuals. That is, our data form a cross-section. We assume that there are X_n independent explanatory variables that affect the number of social trips. To assess the impact of the explanatory variables on the trip making, we specify a Poisson Regression model in which the intercept and the coefficients of the covariates vary across the sample

according to some distribution. This unobserved mixing distribution is assumed to be discrete, which results in a finite mixture model formulation (Weder et al., 1993). The results of Laird (1978) and Heckman and Singer (1984) show that estimates of such a finite mixture model may provide good numerical approximations even if the underlying mixing distribution is continuous. Heckman and Singer (1984) state, however, that maximum likelihood theory cannot be invoked to justify the large sample properties of the estimators in such cases. Because of the assumption of a discrete mixture distribution for the intercepts and coefficients, the point masses of this distribution can be interpreted as latent classes (see Lazarsfeld & Henry, 1968; McCutcheon, 1987; Gopinath, 1995; Green & Hensher, 2003) of subjects, which differ in terms of the relationship between the explanatory variables and the rate of occurrence of trips.

The LCM comprises two components: the class-membership model and the class-specific model, as shown in Figure 4.1.

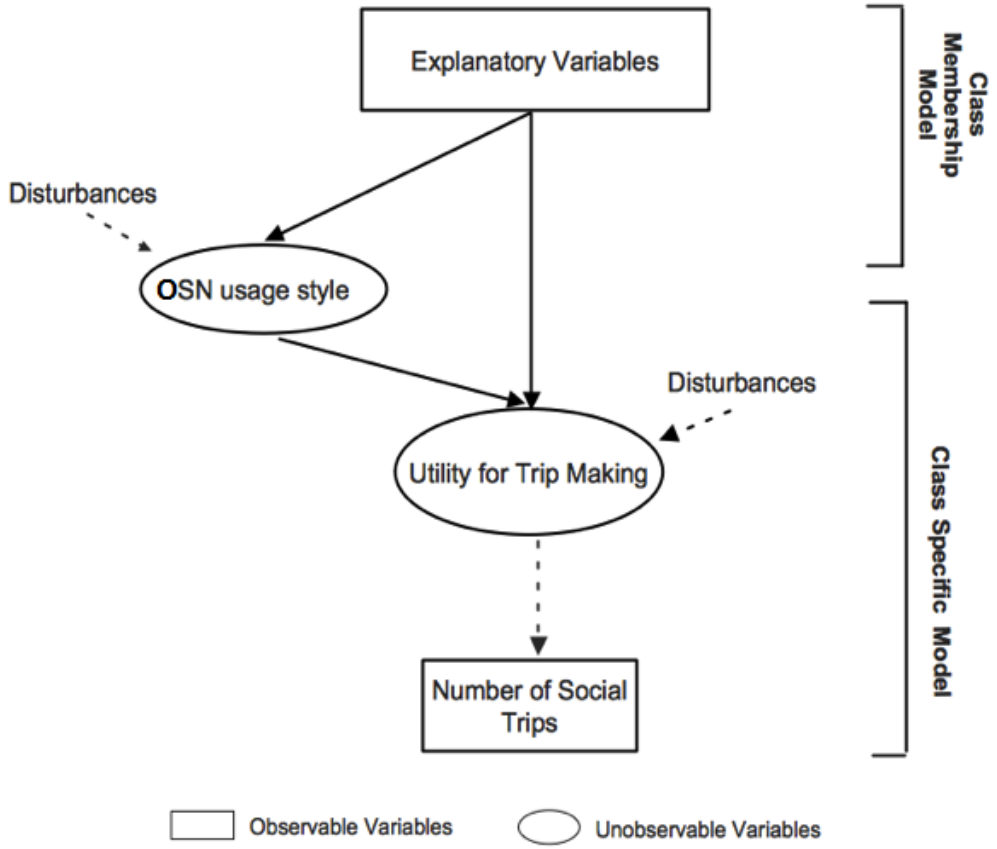


Figure 4.1: Modeling Framework

The class-specific model shows the influence of an OSN usage style and socio-economic variables on the number of trips made for social purposes.

Class-Specific Model

It is assumed that each individual belongs to one and only one class, which is not known in

advance. The class-specific model is a Poisson Regression and represents the number of trips conducted by a latent class, varying among the latent classes. The Poisson model assumes that the number of trips any individual makes in a given time period is independent and has a constant rate of occurrence (Ben-Akiva et al., 1996). It is given by:

$$P(T_i \mid s) = \begin{cases} \dfrac{e^{-\lambda_{is}}(\lambda_{is})^{(T_i)}}{(T_i)!} & for\ \lambda_i > 0 \ \text{ and T=0,1,...} \\ 0, otherwise \end{cases} \quad (4.1)$$

where T_i is the number of trips, and λ_{is} is the mean number of trips made by person i belonging to class s.

For each class s, the mean number of trips for each individual i is an exponential-linear function of the explanatory variables, as follows:

$$\lambda_{is} = \exp[a_s + X_{ik}\beta_{ks}] \quad (4.2)$$

where α is the constant of class s, and β_s depicts the impact of the X_{ik} explanatory variables on the mean number of trips in class s.

The formulation of the probability density in equation (4.1) is conditional upon individual i belonging to class s. Considering the observed frequencies T_i as arising from a mixture of S unobserved Poisson distributions (Heckman & Singer, 1984), we obtain the unconditional probability:

$$P(T_i \mid \beta_{ks}, s) = \sum_{s=1}^{S} P(T_i \mid \beta_{ks}) \quad (4.3)$$

which is the probability that individual i conducts T number of trips, conditional on the characteristics of the individual and conditional on individual i being a member of class s.

In this way, we capture heterogeneity across individuals, since: 1. a formulation is used in which the mean event rate has a discrete mixture distribution, i.e. it varies across a finite number of unobserved classes; 2. the mean trip making varies within each class, depending upon the explanatory variables.

Class-Membership Model

The class-membership model links the latent OSN usage styles to socio-demographic variables and segments all individuals into s_n classes (Swait, 1994; Hess et al., 2007; Walker & Ben-Akiva, 2011; Vij et al., 2011). While the latent class to which an individual belongs cannot be deterministically identified from the observable variables, it is presumed that the class membership probabilities can be estimated. The probability that individual i has OSN usage style s, conditional on the characteristics of that individual, X_n, is given by:

$$P(s \mid X_n) \quad (4.4)$$

LCMs simultaneously estimate class-membership functions and class-specific functions. The model simultaneously breaks down teenagers' OSN behaviors into classes and estimates the class-specific functions in a manner that maximizes model performance.

Since the class of each individual is unknown, neither of the above equations can be estimated separately. The two components are estimated simultaneously via an LCM:

$$P(T_i \mid X_{ik,} X_{in}) = \sum_{s=1}^{S} P(T_i \mid X_{ik}, s) P(s \mid X_{in}) \qquad (4.5)$$

where the probability of an individual *i* making *T* number of trips is equal to the sum over all the latent classes *s* of the class-specific membership model conditional on class $P(T_i \mid X_{ik}, s)$, multiplied by the probability of belonging to that class, $P(s \mid X_{in})$.

Likelihood Function

In writing the likelihood function, an individual's probabilities of conducting specific numbers of trips are conditionally independent, conditioned on the individual's OSN usage style (the classic latent class assumption) and on the error components. Combining the class-membership model, the class-specific choice model, the error components, and the number of social trips observed for an individual, the joint likelihood function for an individual *i* is given by:

$$L = \prod_{i=1}^{N} P(T_i \mid X_k, s) \sum_{s=1}^{S} P(s \mid X_n) \qquad (4.6)$$

Defining the number of latent classes

One of the limitations of latent class choice models is that the researcher has to decide on the number of latent classes to use. The model cannot determine this automatically. This limitation is addressed by systematically estimating LCM based on different numbers of classes and then choosing the model that performs best.

This approach requires a performance statistic that penalizes decreased model parsimony. To compare the estimated models and their goodness of fit, we use the log-likelihood, the corresponding values for the Rho-bar-squared, the Bayesian Information Criterion (BIC) and the Akaike Information Criterion (AIC). Rho-bar-squared indicates how well the model predicts class memberships. AIC and BIC differ from one another according to how much weight is applied to penalize for each additional model parameter.

The $\bar{\rho}^2$ is calculated as follows:

$$\bar{\rho}^2 = 1 - \frac{L^* - k}{L^0} \qquad (4.7)$$

The AIC is given by:

$$AIC = -2 \ln L^* + 2k \qquad (4.8)$$

The BIC imposes an additional penalty on the log-likelihood as compared to the AIC, and therefore tends to favor more parsimonious models. The equation for the BIC is:

$$BIC = -2L^{*} + \ln(N)k \quad (4.9)$$

where
k denotes the number of estimated parameters;
L^{0} is the initial log-likelihood (the log-prior) for the estimated parameters;
L^{*} is the log-likelihood calculated at the values of the fitted parameters (log-posterior);
N is the number of respondents.

The lower the values of BIC and AIC criteria, the better the model fits that number of classes. However, these criteria also fail some of the regularity conditions for a valid test under the null (Leroux, 1992). Asymptotically, the AIC is reported to be biased towards overestimating the number of preference classes, while the BIC is not, although for small sample sizes the BIC tends to favor too few classes (McLachlan & Peel, 2000). The BIC is often used with LCMs because it imposes a harsher penalty on the number of parameters than either the AIC or the log-likelihood value.

4.4 Case Study 1: Social Networking - Cyprus

The questionnaire that was used for the data collection in Cyprus contained a section regarding the usage of social media, in which the participants were asked to answer questions regarding: 1. the amount of time they allocate to social media on a school day and on Saturday, 2. on which social media they have a profile and how much time they spend on each, 3. whether they use their mobile phone for connecting to the internet and various characteristics of their mobile phones, and 4. their attitudes towards and perceptions of social media. These variables are used for the identification of the latent OSN styles in the class-membership model. The dependent variable of our model is the number of trips that teenagers conducted over a Saturday for social purposes; thus a Latent Class Poisson Regression model is estimated. All the trips that were conducted for entertainment or leisure, visiting, hanging out and having lunch/dinner/coffee purposes are counted as social trips.

4.4.1 Sample's Characteristics

For the estimation of the first Case Study's model we use a sample of 9,714 participants, who conducted a total number of 16,593 social trips. Table 4.1 presents the descriptive statistics of the sample. 55% are female and 41% are between 12 and 14 years old. 95% of the teenagers have a mobile phone, and 56% of them use their mobile phones to connect to the internet. Understanding an individual's technological environment is a vital clue to understanding how that person uses the internet, connects with others and accesses information. The average teenager owns 2.9 gadgets out of the four we asked about in our survey: cell phones (conventional or 3G/smartphones), computers (desktops and laptops), game consoles and portable gaming devices. All these gadgets increase teenagers' virtual connectivity as they provide internet access. Laptops have overtaken desktops as the most commonly owned computers. Teens are enthusiastic consumers of gaming devices, both wired and portable. In total, 80% of the teens in our sample have a game console such as a PlayStation, an Xbox or a Wii, while 59% own a portable game device such as a PSP or a Nintendo 3DS. Nowadays, game devices and consoles provide new ways for teens to go

on-line. Also, the survey indicates that the predominant purpose for which teenagers use OSN sites is for communicating with their friends. 9% of the participants indicated that they use OSN mainly for playing interactive games, while 5% use them for keeping up-to-date with various events and friends' activities.

Table 4-1: Sample descriptive statistics (Case study 1)

		Total Sample (N.Obs.=9,714)
Gender	Male	45%
	Female	55%
High School	Gymnasium (12-14 years old)	40%
	Lyceum (15-18 years old)	60%
Grades	Low (<14/20)	12%
	Medium (14-18/20)	46%
	High (18-20/20)	42%
Own a mobile phone		96%
Connect to internet via mobile		52%
Mobile contract (vs. top-up)		42%
Own a game console (PS, Xbox, Wii etc.)		79%
Own a portable gaming device (PSP, Nintendo 3DS)		50%
Own a desktop		51%
Own a laptop		82%
Own a tablet		65%
Time spent on OSN (hours per day)		1.7 (Std. Dev. = 2.30)
Internet use on a school day (hours)		1.9 (Std. Dev. = 1.80)
Internet use on Saturday (hours)		2.9 (Std. Dev. = 2.29)
Household size		4.8 (Std. Dev. = 1.34)
Siblings		2 (Std. Dev. = 0.98)
Household car ownership		2.7 (Std. Dev. = 1.22)
Household motorcycle ownership		0.4 (Std. Dev. = 1.42)
Family's monthly income	Less than 2000 Euro)	16%
	2001- 4000 Euro	27%
	More than 4000 Euro	35%
	N/A	22%
Number of social trips – school day		0.6 (Std. Dev. = 1.08)
Number of social trips – Saturday		2.1 (Std. Dev. = 1.19)

4.4.2 Model Estimation Results

The Latent Class Poisson Regression model was estimated using Latent GOLD 4.5 by Statistical Innovations Inc. In the model estimation no restrictions are imposed, since all the participant teenagers are familiar with and aware of social media and have internet access.

4.4.2.1 Defining the Number of Classes

First, we briefly summarize and present the key results for the process of defining the number of classes. A number of different model specifications with different numbers of classes and explanatory variables were tested. To determine the optimal number of latent classes for the model, the Rho-bar-squared, BIC and AIC values of models with various numbers of latent classes were estimated and the key results are presented in Table 4.2.

Table 4-2: Summary statistics of models with different numbers of latent classes (Case study 1)

Model		Number of Parameters	LL	AIC	BIC	Rho-bar-squared
1.	Model without segmentation	14	-15952.13	31932	32033	0.0363
2.	Model with two latent classes	40	-15606.83	31293	31581	0.3052
3.	Model with three latent classes	66	-15417.48	30966	31442	0.2233
4.	Model with three classes (one class predefined)	66	-16214.71	32561	33036	0.2390
5.	Model with four latent classes	92	-15216.73	30617	**31276**	0.3068
6.	Model with four classes (one class predefined)	92	-16058.28	32300	32963	**0.3255**
7.	Model with five latent classes	118	-15095.46	**30426**	31280	0.2380

1. *Model without Segmentation:* This model is based on the assumption that all teenagers' behavior is homogeneous, forming a simple latent class. The probability that a teenager *i* makes *T* number of trips is based on a single Poisson Regression model. The Rho-bar-squared is too low and AIC and BIC values are the highest compared to the other models.
2. *Model with Two Latent Classes:* This model is based on the assumption that there are two different OSN behaviors, thus two classes. A Poisson Regression model is estimated for each class. The Rho-bar-squared is improved compared to the model without segmentation; AIC and BIC values have decreased compared to the model without segmentation.
3. *Model with Three Latent Classes:* This model is based on the assumption that there are three different OSN behaviors, thus three classes. The value of the Rho-bar-squared has decreased, while the BIC and AIC have improved.
4. *Model with Three Latent Classes (one predefined*): After estimating the three latent classes model and examining the results, we decided to predefine a class as clearly indicating those who do not have an account on OSN. Compared to the previous models, the Rho-bar-squared has improved, while the BIC and AIC have increased.
5. *Model with Four Latent Classes:* This model is based on the assumption that there are four different OSN usage behaviors, thus four latent OSN usage classes. The value of the Rho-bar-squared is the second highest, while the BIC value is the lowest among the models.
6. *Model with Four Latent Classes (one predefined):* Following the estimation of the aforementioned model, we predefined a class representing those who do not have an OSN account. The Rho-bar-squared has the highest value among all the estimated models.
7. *Model with Five Latent Classes:* We estimated this model based on the assumption that there are five different OSN usage behaviors; thus five Poisson Regression models are estimated, one for each class. The Rho-bar-squared has been dropped compared to the fourth model, whereas this model has the highest AIC.

All the statistics presented in Table 4.2 indicate that a model with OSN usage segmentation is preferred over one without. The BIC suggests that the model with four latent classes is superior; the AIC indicates the model with five latent classes, while the Rho-bar-squared

suggests the model with four latent classes, one of which was predefined. Although these statistics provide a lot of information, each one indicates a different model. Thus, we examine further the estimation results of each model, with the aim of identifying the model that provides the most satisfactory behavioral interpretation regarding the OSN usage latent classes and trip making behavior (logical signs and interpretability of classes). Although Model 7 has the lowest AIC value, it is rejected because the behavioral differences among the classes are not clear and the classes are difficult to interpret. In terms of comparing Model 5 and Model 6, the first has the lowest BIC value, while the other has the highest Rho-bar-squared. We prefer Model 6 to Model 5, as availability constraints were imposed in the predefined class of the model, thus improving further the behavioral interpretation. Therefore, Model 6 delivered the best and most interpretable results and was chosen for thorough presentation below.

4.4.2.2 Model Estimation Results of Latent Class Model

The Latent Class Poisson Regression model estimation results consist of parameter estimates for the class-membership models (Tables 4.3) and the class-specific model (Table 4.5). All the parameters in these tables resulted from simultaneous estimations of the class-specific Poisson Regression and class-membership model.

Estimation results for the class-membership model

Table 4.3 provides the parameter estimates of the class-membership models that help us to identify the covariates of the latent OSN usage styles. The class-membership model is a multinomial logit model (MNL) of the probability with which each teenager belongs to one and only one of the latent classes. Class 1 represents 43% of the total sample, Class 2, 22% of the sample, Class 3, 25% of the sample and Class 4, 10% of the sample.

Variables regarding time allocation to OSN can be seen to exert a significant effect on OSN styles. In Class 1 the variable regarding time allocation that is most significant is “Allocate 1 to 2 hours on OSN” having a positive coefficient. Owning 2 to 3 out of the 4 gadgets that we asked about in the survey also has a positive sign, while high gadget ownership has a negative sign and is statistically insignificant. Connecting to the internet via mobile phone and having a mobile contract increase the probability of being in this class. Having an account on more than 3 OSN increases the probability of belonging to this class as well. Regarding Class 2, teenagers who do not allocate time to OSN daily are more likely to belong to this class. Owning only one gadget and, more specifically, owning only a mobile phone also has a positive coefficient and is statistically significant for Class 2. Regarding Class 3, spending more than 4 hours per day on OSN increases the probability of belonging to this class, while the three most statistically significant variables are owning 4 gadgets, having an account on more than 3 OSN, and going to an internet café at least once per week. Class 4 is predefined as representing those who do not have an OSN account; as a result, restrictions to variables regarding time spent on OSN are imposed.

Table 4.3 also gives the Wald statistic results. For each set of parameter estimates, the Wald statistic considers the subset associated with each class and tests the restriction that each parameter in that subset equals the corresponding parameter in the subsets associated

with each of the other classes. That is, the Wald statistic tests the equality of each set of regression effects across classes. Wald statistic results indicate that the parameters used for the class-specific model vary significantly at 95% level of confidence, indicating significant heterogeneity across the classes.

Table 4-3: Estimation results for the class-membership model (Case study 1)

	Class 1		**Class 2**		**Class 3**		**Class 4**		Wald statistic
	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	
α	2.11	5.60	1.87	5.61	-0.33	-1.57	-4.32	-7.09	71.15
Allocate no time to OSN daily	-1.26	-2.40	6.03	1.90	-1.38	-2.76	-	-	141.76
Allocate more than 4 hours daily	-1.13	-4.46	-0.78	-3.17	3.67	4.30	-	-	38.89
Allocate 1 to 2 hours daily	4.42	7.25	-0.25	-4.62	-0.69	-2.15	-	-	29.73
Own 4/4 gadgets (mobile phone, tablet, game consoles, portable game device)	-1.16	-1.80	-0.89	-1.99	2.36	7.58	-2.12	-2.61	43.51
Own tablets, 3G phones (2-3/4)	2.12	5.87	-0.13	-1.32	-0.90	-2.53	-0.53	-4.27	30.02
Own 1/4 gadgets (conventional mobile phones)	-0.48	-4.15	1.66	10.7	-0.57	-3.84	2.32	6.08	103.80
Mobile contract (v. top-up/ no contract)	1.47	3.21	-0.92	-2.43	2.12	4.21	-1.23	-2.76	82.17
Connect to internet via mobile	0.97	2.15	-0.71	-2.59	0.76	5.92	-0.99	-5.26	67.70
Going to internet café at least once per week	-0.32	-1.83	-1.49	-5.18	1.62	6.74	-0.85	-4.12	29.45
Have an account on more than 3 OSN	0.44	3.09	-1.35	-3.61	2.39	6.90	-	-	26.95
Have an account on 1 OSN	1.78	6.29	1.51	2.50	-1.30	-5.47	-	-	40.32

In order to make clearer which characteristics of each class are predominant, we rated the variables of each class of the class-membership model based on their importance. This process is determined by taking the difference between the highest and lowest value of each variable as observed in the survey and multiplying this difference by the coefficient of the variable (see Walker & Li, 2007). The absolute value of this product gives the order of potential impact.

Table 4-4: The most important values for each class (Case study 1)

	Class 1	Class 2	Class 3	Class 4
	Rational OSN usage	*Indifferent to OSN usage*	*OSN addicted*	*Non OSN users*
1	Allocate 1 to 2 hours daily	Allocate no time to OSN daily	Allocate >4 hours daily	Own 1/4 gadgets
2	Own 2-3/4 gadgets	Own 1/4 gadgets	Have an account on >3 OSN	Connect to internet via mobile
3	Have an account on 1 OSN	Have an account on 1 OSN	Own 4/4 gadgets	Mobile contract
4	Allocate no time to OSN daily	Mobile contract	Mobile contract	Going to internet café
5	Own 4/4 gadgets	Going to internet café	Going to internet café	Own 2-3/4 gadgets
6	Allocate > 4 hours daily	Have an account on >3 OSN	Have an account on 1 OSN	Own 4/4 gadgets
7	Connect to internet via mobile	Mobile contract	Allocate no time to OSN daily	
8	Own 1/4 gadgets	Own 4/4 gadgets	Own 2-3/4 gadgets	
9	Have an account on >3 OSN	Allocate >4 hours daily	Connect to internet via mobile	
10	Going to internet café	Connect to internet via mobile	Allocate 1 to 2 hours daily	

For readers' convenience, we decided to name the classes, instead of keeping to numbers. Members of latent Class 1 are more likely to spend 1 to 2 hours on a daily basis on OSN and own 2 to 3 out of 4 gadgets. Based on the literature review of other social surveys on teenagers' OSN usage behavior (O'Keeffe et al., 2011; PRC, 2010), we conclude that this is a rational amount of time, since the average time that the majority of the current teenagers spend in a typical day on OSN is 1.5 hours (Teen Facebook Statistics, 2012). Moreover, these teenagers have an account on one OSN and they connect to their account via their mobile phones. The prevalent gadgets that they use are 3G phones or smartphones and game consoles either portable or not.

The prevalent characteristics of Class 2 indicate indifference to OSN usage. Members of this group do not spend time on OSN on a daily basis, and have an account on 1 OSN. Moreover, the members of this class own only one gadget and more specifically a mobile phone, usually old-fashioned (conventional).

Class 3 indicates OSN usage addiction. Although we do not include psychological indicators in this paper to assess addiction, the results of this class indicate that its members spend more than 4 hours per day on OSN (more than average), they have all the gadgets that we asked about in our questionnaire (3G mobile phone or Smartphone, tablet, game console and portable game devices) and connect to the web via their mobile phones. In Class 4 are those who are non-users of social media, while owning 1 out of 4 gadgets is the predominant variable in this class.

Estimation results of the class-specific model

Taking into account the segmentation of the OSN usage patterns, we now continue with the class-specific model to check whether the OSN usage styles and the available socio-economic characteristics are good predictors of the trip making behavior. The estimation results for the class-specific model are shown in Table 4.5. The explanatory variables include characteristics related to gender, age, internet access at home, number of devices

with internet access in household interacting with the number of household members, monthly family income, household car ownership, parents' educational level, and residential area characteristics. All the variables used in the class-specific model are statistically significant at 95% and have significantly different effects across classes at the 95% confidence level.

Table 4-5: Estimation results for the class-specific model (Case study 1)

	Class 1 *Rational OSN usage*		**Class 2** *Indifferent to OSN usage*		**Class 3** *OSN addicted*		**Class 4** *Non OSN users*		Wald statistic
	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	
Intercept	-1.43	-4.92	-0.88	-2.98	-1.12	-3.49	-0.65	-2.37	46.88
Female	0.32	9.18	0.13	3.72	-0.95	-8.82	0.21	3.47	113.68
14 to 18 years old (vs. 12-13)	0.23	4.04	-0.40	-6.01	0.58	2.57	-0.18	-2.09	50.55
Low family income	0.26	2.77	-1.10	-10.90	0.35	3.08	-0.41	-4.90	93.20
Medium family income	0.61	1.98	0.17	3.87	-0.44	-2.89	0.35	3.31	62.57
High family income	0.26	3.91	-0.13	-1.98	-1.61	-3.61	-0.72	-7.26	73.39
Household car ownership (continuous)	0.28	2.10	0.48	2.92	0.22	6.39	0.13	1.97	30.03
Available internet access at home	0.18	3.93	-0.93	-5.56	-0.38	-7.73	-0.27	-2.31	97.61
Number of available gadgets with internet access in household divided by the number of household members	0.20	5.00	-0.15	-2.40	1.01	3.04	-0.26	-1.67	32.50
Urban (vs. suburban)	0.19	3.53	0.36	2.83	-0.96	-5.45	-0.71	-2.24	24.32
Father-Low Educational level	0.51	1.96	-0.15	-3.19	0.35	3.12	0.21	2.61	35.45
Father-High Educational level	-0.31	-1.97	0.92	2.03	0.45	3.50	-0.19	-1.98	12.60
Mother-Low Educational level	-0.37	-1.98	0.28	2.22	0.43	4.17	0.51	7.14	81.36
Mother-High Educational level	0.19	2.15	-0.28	-2.72	-0.13	-2.27	-0.13	-2.51	18.89

The mean number of social trips conducted on a typical Saturday is 1.9 for Class 1; 1.2 for Class 2; 2.4 for Class 3; and 1.0 for Class 4. The results of the class-specific model indicate that the rational OSN usage style (Class 1) is likely to lead to more social trips being conducted, having at the same time the strongest effect among the intercepts of the other four classes. OSN addicted members (Class 3) may also conduct more social trips, while those indifferent to OSN (Class 2) and non-OSN-users (Class 4) seem to conduct fewer trips for social purposes.

Demographic dummy variables are also used to explain the dependent variable. Females (girls) are more likely to belong to Class 1 and boys to Class 3, affecting negatively the number of social trips. Older teenagers, aged between 14 to 18 years, are more likely to adopt rational and addicted OSN usage styles, while through a positive sign, age strongly affects the number of social trips. All the three levels of income (the base level for this variable being Income N/A) in Class 1 affect positively the number of social trips. In Class

2, low and high family income affects negatively the number of trips, while medium family income increases the probability of trip making for social purposes. Participants with high family income are less likely to be non-OSN users (Class 4). Regarding households' car ownership, as the number of cars available in the household increases, the probability of social trip making increases across all the four classes. Despite the fact that high car-ownership could be correlated with high income, nowadays someone on a very low budget could still purchase a car, especially a second-hand one. So, low income does not necessarily mean low car-ownership. For rational and addicted OSN users, as the ratio of available gadgets with internet access in the household, divided by the number of household members, increases, the probability of making social trips increases too. For the other two classes, as this ratio increases, the possibility of conducting social trips decreases. Parents' level of education affects the dependent variable in different ways across the classes. Father's low educational level decreases the possibility of conducting social trips in Class 2, while increasing this possibility in Class 1, 3 and 4. The higher educational level of the father significantly affects the dependent variable in Class 2 and 3. Mother's higher level of education affects significantly and positively the dependent variable in Class 1.

4.4.3 Limitations

This model provided the initial insights needed to understand the relationship between the various teenagers' OSN usage styles and their trip making behavior. However, during the model specification and the estimation process we realized that there are some limitations. The variables that we use only give us information about the time that teenagers spend on ONS and their social media accounts. The fact that a teenager spends time on ONS raises more questions about what kind of activities he/she conducts through social media. Nowadays, social networks offer a variety of tools or options with which you can chat with your friends, post photos, comment on others' status, "check-in" your location, create events and invite your friends to them, etc. Thus, someone who uses social media could, for example, be informed about a number of events taking place in his/her area, a fact that could create demand for travel. Moreover, we followed the social account of 30 teenagers for a period of two weeks, in order to better understand their on-line social activities. We realized that posting photos of their daily activities was quite common. On Saturdays especially, they posted through their mobile phones photos of the places they were visiting. They also updated their status at least once per day in order to inform their friends about their thoughts, feelings, or the places that they were going to visit. Making comments to and "liking" such posts was also a frequent activity. Through this process we gained significant insights concerning the questions that our questionnaire should include so as to better approach the relationship between social media and the demand for travelling. As a result we created an updated version of the questionnaire, which was used in the next wave of our survey in Greece in 2013.

A second limitation is the fact that our dependent variable is the number of trips conducted over a Saturday. Although our survey used a two-day travel diary (the last school day and the previous Saturday), we preferred to use only the Saturday social trips, as on school days a significant percentage of the participants recorded zero social trips, indicating that their social travel behavior on school days is completely different from that on Saturdays. However, a Latent Class Zero Inflated Poisson model for the social-trip making behavior in school-days could be estimated in the future. Finally, it would be desirable to use longitudinal data for the model estimation, as they capture individuals' social networking behavior over time, thus providing better insights.

4.5 Case Study 2: Social Networking - Greece

The identification of some of the limitations discussed above impelled us to update our questionnaire so as to better capture the relationship between social networking and trip making behavior. At the same time, more papers were published regarding teenagers' social networking behavior, giving us more insights to use in creating the updated version of the questionnaire. However, due to the fact that the students had only one hour to complete the questionnaire it was impossible to collect trip data for more than two days.

In the survey that took place in Greece in 2013, we asked the participants questions about the frequency of social media usage, the frequency of posting, chatting, updating their status, "check-in" and uploading photos, the activities they conduct through social media, the kind of information they receive, the number of events attended of which they have been informed through social media, the number of their virtual friends, and profile privacy issues (see questionnaire: Appendix A). In this case study, we use this information to better specify the class membership model, and thus the OSN usage styles.

4.5.1 Sample's Characteristics

The sample for the second case study consists of 1,276 teenagers. This dataset provides information on 3,921 social trips recorded over two days: 859 trips made on a school day and 3,062 trips made on a Saturday. Once again, we shall focus only on the social trips conducted on Saturday.

Table 4.6 presents the descriptive statistics of the sample. 41% are female and 36% are between 12 and 14 years old. 94% of the teenagers have a mobile phone, and 88% of them use their mobile phones to connect to the internet. The average teenager owns 2.4 gadgets out of the four we asked about in our survey: cell phones (conventional or 3G/smartphones), computers (desktops and laptops), game consoles and portable gaming devices. 66% of the teens in our sample have a game console such as a PlayStation, an Xbox or a Wii, while 24% own a portable game device such as a PSP or a Nintendo 3DS. The most popular social medium is Facebook. Of those who have an OSN account, they all definitely have one on Facebook. The average number of Facebook friends is 408. They chat on-line 6.8 times a day and update their status 0.9 times per day, while they post on their walls 2.3 times per day. They check-in 3.2 times per week on average and upload photos 1.4 times per week. They also declared that they check-in to inform their friends about their location or simply to show their friends where they are. The photos that they upload are usually of their entertainment activities and their nightlife. Also, the survey indicates that the predominant purpose for which teenagers use OSN sites is to communicate with their friends, while the second most popular purpose is to keep up-to-date with their friends' activities and various events; they further stated that they attend an average of 4.8 events advertised on social media in a month. These events are usually parties and sports events. In addition, 58% stated that they receive all the information they want through social media (i.e. news, fashion, locations, offers, etc.). These results indicate that teenagers are informed about various events and activities through social media, a fact that creates demand for travel. Finally, 52% stated that their profile is open to the public, 39% that it is visible only to their friends and 9% that it is visible only to some of their friends. This indicates that teenagers do not hesitate to share information about themselves and do not have privacy issues.

Table 4-6: Sample descriptive statistics (Case study 2)

		Total Sample (N.Obs.=1,276)
Socio-economic Characteristics		
Gender	Male	59%
	Female	41%
High School	Gymnasium (12-14 years old)	36%
	Lyceum (15-18 years old)	64%
Grades	Low (<14/20)	21%
	Medium (14-18/20)	48%
	High (18-20/20)	31%
Household Characteristics		
Household size		4.2 (Std. Dev.=0.79)
Siblings		1.7 (Std. Dev.=0.64)
Household car ownership		1.9 (Std. Dev.=1.06)
Household motorcycle ownership		1.2 (Std. Dev.=0.96)
Family's monthly income	Less than 2000 Euro	44%
	2001-4000 Euro	36%
	More than 4000 Euro	10%
	N/A	10%
Average number of social trips – Saturday		2.4 (Std. Dev.=1.63)
Gadget Ownership		
Own a mobile phone		94%
Mobile contract (vs. top-up)		12%
Connect to internet via mobile		88%
Own an i-pad or tablet		23%
Own a game console (PS, Xbox, Wii etc.)		66%
Own a portable gaming device (PSP, Nintendo 3DS)		24%
Own a desktop		51%
Own a laptop		82%
Social Media Usage Patterns		
Have an account on social media		86%
Average time spent on chatting with friends via OSN (Saturday, in minutes)		75 (Std. Dev.=12.92)
Average number of friends		408 (Std. Dev.=7.86)
Average number of photos		112 (Std. Dev.=21.05)
Frequency of chatting on-line (per day)		6.8 (Std. Dev.=3.21)
Frequency of uploading photos (per week)		1.4 (Std. Dev.=1.03)
Frequency of updating status (per day)		0.9 (Std. Dev.=1.98)
Frequency of posting on their wall (per day)		2.3 (Std. Dev.=1.43)
Frequency of making like/comments on friends posts (per day)		3.6 (Std. Dev.=2.67)
Frequency of check-in (per week)		3.2 (Std. Dev.=2.75)
Time spent on OSN – Saturday (in hours)		3.2 (Std. Dev.=1.14)
Average number of attended events that were advertised on OSN (per month)		4.8 (Std. Dev.=2.13)
Internet use on a school day (hours)		1.9 (Std. Dev.=3.21)
Internet use on a Saturday (hours)		3.4 (Std. Dev.=2.53)
Average number of social trips – Saturday		2.4 (Std. Dev.=1.63)
Attitudes & Perceptions *(7-point Likert Scale: 1=Completely disagree,…, 7=Completely agree)*		
I use OSN to arrange hanging out with my friends		6.6 (Std. Dev. = 0.43)
I have reduced the number of trips I conduct, as I communicate with my friends via OSN		1.5 (Std. Dev. = 0.57)
I feel out of touch when I haven't logged on to social media for a while		5.7 (Std. Dev. = 0.71)
OSN is part of my daily life		5.9 (Std. Dev. = 0.65)
Mobile apps help me walk more		5.2 (Std. Dev. = 0.83)
Mobile apps help me cycle more		6.2 (Std. Dev. = 0.56)
I track my walking and cycling routes using my mobile phone		5.3 (Std. Dev. = 1.12)

As far as their attitudes and perceptions towards OSN, they almost completely agree that they use OSN to arrange hanging out with their friends. They also agree that OSN is a part of their daily life and that they feel out of touch when they have not logged on to OSN for a while. On the contrary, they disagree with the statement that their number of trips has been decreased due to OSN. Moreover, they agree that the various available mobile apps have helped them to cycle and walk more. These apps offer information about the routes, the weather and various active transport events. They also provide the opportunity to teens to truck their routes, to count their physical activity, to set goals that motivate them to walk and cycle more and share all these with their friends.

4.5.2 Model Estimation Results

Below is presented the process of defining the latent classes of the second case study's model and the results of the model estimation. This Latent Class Poisson Regression model was also estimated using Latent GOLD 4.5 by Statistical Innovations Inc. The sample used for the model's estimation consists of 1,276 Greek teenagers. In the model estimation no restrictions are imposed, since all the participant teenagers are familiar with and aware of social media and have internet access either at home or via mobile phones. Furthermore, all the data were collected in April 2013 so there is no need to impose seasonal variables in order to capture differences in trip making behavior.

4.5.2.1 Defining the Number of Classes

A number of different model specifications with different numbers of classes and explanatory variables were tested. To determine the optimal number of latent classes for the model, the Rho-bar-squared, BIC and AIC values of models with various numbers of latent classes were estimated. The key results are presented in Table 4.7.

Table 4-7: Summary statistics of models with different numbers of latent classes (Case study 2)

		Number of Parameters	AIC	BIC	Rho-bar-squared
1.	Model without segmentation	9	4560	4606	0.0141
2.	Model with two latent classes	33	4391	**4530**	0.4057
3.	Model with three latent classes	57	4355	4587	**0.4835**
4.	Model with four latent classes	81	4304	4629	0.3886
5.	Model with five latent classes	105	**4285**	4702	0.4354

1. *Model without Segmentation:* This model is based on the assumption that all teenagers' behavior is homogeneous, forming a simple latent class. The probability that a teenager *i* makes *T* number of trips is based on a single Poisson Regression model. The Rho-bar-squared is too low and the BIC value is the highest compared to the other models.
2. *Model with Two Latent Classes:* This model is based on the assumption that there are two different OSN behaviors, thus two classes. A Poisson Regression model is estimated for each class. The Rho-bar-squared is improved compared to the model without segmentation. BIC has the lowest value.
3. *Model with Three Latent Classes:* This model is based on the assumption that there are three different OSN behaviors, hence three classes. The value of the Rho-bar-squared is

the highest compared to the other estimated models. However, the BIC and AIC values of this model are not the lowest.

4. *Model with Four Latent Classes:* This model is based on the assumption that there are four different OSN usage behaviors, hence four latent OSN usage classes. The value of the Rho-bar-squared has dropped, whereas the BIC and AIC values have been increased compared to the third model.
5. *Model with Five Latent Classes:* We estimated this model based on the assumption that there are five different OSN usage behaviors, thus five Poisson Regression models are estimated, one for each class. The Rho-bar-squared is the second highest, while the AIC value is the lowest of the presented estimated models.

The statistics presented in Table 4.7 indicate that a model with OSN usage segmentation is preferred over one without. The BIC suggests that the model with two latent classes is superior; the AIC indicates the model with five latent classes, while the Rho-bar-squared suggests the model with three latent classes. Although these statistics provide a lot of information, each one indicates a different model. Thus, we examine further the estimation results of each model to identify the model that provides the most satisfactory behavioral interpretation regarding the OSN usage latent classes and trip making behavior (logical signs and interpretability of classes). Although Model 5 has the lowest AIC value, it is rejected because the behavioral differences among the classes are not clear and the classes are difficult to interpret. In terms of comparing Model 2 and Model 3, the first one has the lowest BIC value, while the other one the highest Rho-bar-squared. We prefer Model 3 to Model 2, as it provides the best and most interpretable results and so was chosen for thorough presentation below.

4.5.2.2 Model Estimation Results of Latent Class Model

The Latent Class Poisson Regression model estimation results consist of parameter estimates for the class-membership models (Tables 4.8) and the class-specific model (Table 4.10). All the parameters in these tables resulted from simultaneous estimations of the class-specific Poisson Regression and class-membership model.

Estimation results for the class-membership model

Table 4.8 provides the parameter estimates of the class-membership models that help us to identify the covariates of the latent OSN usage styles. The class-membership model is a multinomial logit model (MNL) of the probability with which each teenager belongs to one and only one of the three latent classes. Class 1 represents 48% of the total sample, Class 2, 36% of the sample, and Class 3, 16% of the sample.

Variables regarding the way teenagers use the social media can be seen to exert a significant effect on OSN styles. The variables that have a positive effect on Class 1 and are the most statistically significant are chatting on-line and making comments (like) on their friends' posts sometimes per week. Owning 2 to 3 out of the 4 gadgets that we asked about in the survey and high gadget ownership also have a positive effect, while the latter variable is statistically insignificant. Having an account or accounts on OSN and connecting to OSN via mobile phone affect positively and significantly the probability of

being in this class. Regarding Class 2, teenagers who log in to their accounts on a daily basis and post on their walls, comment on their friends' status and upload photos several times per week are more likely to belong to this class, as these variables affect this probability positively and significantly. In contrast, variables that indicate no use of OSN (e.g. never upload photos, never post on wall etc.) all affect negatively the probability of belonging to this class. Having an OSN account affects negatively and significantly the probability of a teenager belonging to this class. The most statistically significant variables that affect positively the probability of belonging to this class are "Never appear on-line", "Never posting on wall" and "Never upload photos".

Table 4.8 also gives the Wald statistic results, indicating that the parameters used for the class- specific model vary significantly at 95% level of confidence, thus showing that significant heterogeneity exists across the classes.

Table 4-8: Estimation results for the class-membership model (Case study 2)

	Class 1		**Class 2**		**Class 3**		Wald statistic
	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	
α	3.03	3.58	1.27	2.44	-4.31	-2.57	24.07
Having account(s) on OSN	0.31	3.39	1.06	4.32	-0.71	-3.02	20.85
Logging in to OSN account(s) daily	0.98	2.31	1.25	3.21	-0.85	-1.98	7.54
Logging in to OSN account(s) once/twice per week	-0.27	-1.43	-0.58	-2.31	0.68	1.97	6.32
Chatting on-line with their friends daily	0.72	2.58	1.72	4.54	-0.55	-2.75	14.82
Chatting on-line with their friends sometimes per week	1.58	5.19	-0.32	-1.85	-0.21	-2.73	6.38
Never appear on-line on chat	-0.41	-1.32	-0.78	-2.59	1.89	4.58	12.21
Posting on wall daily	0.22	1.78	2.32	3.42	-0.56	-1.09	9.54
Posting on wall sometimes per week	1.46	3.75	-0.48	-1.96	-0.18	-1.81	8.58
Never posting on wall	-0.34	-2.85	-0.65	-3.98	1.66	2.95	32.50
Like/Comment on friends' posts daily	0.82	2.85	1.45	2.12	-0.79	-3.12	23.96
Like/Comment on friends' posts sometimes per week	1.25	4.91	-0.08	-0.72	-0.31	-1.96	6.50
Like/Comment on friends' posts sometimes per three months	-0.62	-4.27	-0.32	-5.12	1.46	3.21	28.18
Upload photos on OSN 3 to 4 times per week	-0.12	0.89	1.69	4.20	-0.23	0.32	5.24
Upload photos on OSN sometimes per month	1.02	1.68	-0.92	-3.87	-0.43	2.92	18.56
Never upload photos	-0.26	-1.38	-0.81	-3.24	1.32	4.12	15.24
Own 4/4 gadgets (mobile phone, tablet, game consoles, portable game device)	0.42	1.89	2.11	5.67	-0.09	0.52	10.43
Own tablets, 3G phones (2-3/4)	1.34	4.42	1.21	2.64	-0.43	-2.51	9.19
Own 1/4 gadgets (conventional mobile phones)	-0.43	-2.51	-0.21	-1.92	1.45	4.28	7.57
Connect to OSN via mobile	2.09	3.01	3.74	3.53	-1.24	2.36	12.47

In order to make clearer the predominant characteristics of each class and in doing so to name the classes, we ranked the coefficients of the variables of each class of the class-membership model based on their importance. As described above, this process is

determined by taking the difference between the highest and lowest values of each variable as observed in the survey and multiplying this difference by the coefficient of the variable (see Walker & Li, 2007). Since the variables that are used in this model are all dummy, we ranked the coefficients of the variables. The absolute value of this product gives the order of potential impact as presented in Table 4.9.

Table 4-9: The most important values for each class

	Class 1	Class 2	Class 3
	Rational OSN usage	*OSN addicted*	*Indifferent to OSN usage*
1	Connect to OSN via mobile	Connect to OSN via mobile	Never appear on-line on chat
2	Chatting on-line with their friends sometimes per week	Posting on wall daily	Never posting on wall
3	Posting on wall sometimes per week	Own 4/4 gadgets (mobile phone, tablet, game consoles, portable game device)	Like/Comment on friends' posts sometimes per three months
4	Own tablets, 3G phones (2-3/4)	Chatting on-line with their friends daily	Own 1/4 gadgets (conventional mobile phones)
5	Like/Comment on friends' posts sometimes per week	Upload photos on OSN 3 to 4 times per week	Never upload photos
6	Having account(s) on OSN	Like/Comment on friends' posts daily	Connect to OSN via mobile
7	Upload photos on OSN sometimes per month	Logging in to OSN account(s) daily	Logging in to OSN account(s) daily
8	Logging in to OSN account(s) daily	Own tablets, 3G phones (2-3/4)	Like/Comment on friends' posts daily
9	Like/Comment on friends' posts daily	Having account(s) on OSN	Having account(s) on OSN
10	Chatting on-line with their friends daily	Upload photos on OSN sometimes per month	Logging in to OSN account(s) once/twice per week

Members of latent Class 1 (Rational OSN usage) connect to their OSN accounts via mobile phones and chat on-line with their friends sometimes per week. Posting on their walls and commenting on their friends' walls also take place sometimes per week, but logging in to their accounts is a daily activity. Members of Class 1 usually own 2 to 3 out of the four gadgets that we asked about in the survey. The main gadgets that they use are 3G phones or smartphones and game consoles either portable or not. Generally, the members of this class are informed about their friends' status, make comments, post on their walls, and upload photos on a weekly basis. Social networking is part of their life but they are not addicted to it. Based on these results, we conclude that this class represents the teenagers that use OSN rationally. More descriptive statistics for this class indicate that Facebook is their favorite social medium and that they spend an average of 1.5 hours per Saturday on OSN. They have an average number of 354.3 friends and their profile is usually open to their OSN friends only. Also, they have attended an average number of 3.8 social events that they have been informed of through Facebook in a time period of a month.

Class 2 indicates OSN usage addiction, as OSN is a part of their daily activities. Although we do not include psychological indicators in this paper to assess addiction, the results of this class indicate that its members post on their walls, comment on their friends' posts and chat on-line with their friends on a daily basis. Also, uploading photos sometimes per week is one of their favorite activities on OSN. Class 2 members usually connect to their OSN accounts via their mobile phone and own all the gadgets that we asked about in our survey (mobile phone, portable game consoles, game consoles and tablets). This class represents a

significant percentage of our sample, indicating the trends for current teenagers; OSN has invaded their daily life and it is hard for them to live without it. Other descriptive statistics of this class indicate that Class 2 members have an average number of 438.1 friends, while their profiles are usually open to everyone. They spend an average time of 3.8 hours on SN on a typical Saturday, they log in to their OSN accounts multiple times per day and have attended an average number of 5.6 events that they were informed of through OSN. Furthermore, statistics for this class show that these teenagers usually upload on their accounts/timeline photos of the events that they attend and the activities they pursue, tag themselves on the photos and check-in themselves at the locations they visit.

The prevalent characteristics of Class 3 indicate indifference to OSN usage. This class includes the teenagers that either do not have an OSN account, or rarely use it. These members do not appear on-line in order to chat with their friends, they never post on their walls or comment on their friends' posts and they never upload photos. They own only one gadget, usually a conventional mobile phone. Other statistics show that only a small percentage (12%) of these teenagers have an OSN account which is usually available for viewing by only some of their friends.

Estimation results of the class-specific model

Taking into account the segmentation of the OSN usage patterns, we now continue with the class-specific model to check whether the OSN usage styles and the available socio-economic characteristics are good predictors of the trip making behavior. The estimation results for the class-specific model are shown in Table 5. The explanatory variables include characteristics related to gender, age, internet access at home, number of devices with internet access in the household interacting with the number of household members, monthly household income, and residential area characteristics. All the variables used in the class-specific model are statistically significant at the 90% and have significantly different effects across classes at the 95% confidence level.

Table 4-10: Estimation results for the class-specific model

	Class Independent		**Class 1** *Rational OSN usage*		**Class 2** *OSN addicted*		**Class 3** *Indifferent to OSN usage*		
	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	
Household monthly income (continuous)	0.81	2.06	--	--	--	--	--	--	Wald statistic
Intercept			1.95	3.78	2.31	4.39	1.56	2.58	17.47
Female			-0.10	-2.27	0.24	1.70	-1.30	-4.87	32.78
15 to 18 years old (vs. 12-14)			0.27	4.04	0.70	2.67	-0.13	-2.87	11.41
Available internet access at home			0.38	3.93	1.93	5.56	-0.68	-1.73	8.53
Number of available gadgets with internet access in household divided by the number of household members			0.26	2.87	0.56	3.61	0.18	1.98	12.47
Urban (vs. suburban)			0.19	3.53	0.36	2.83	-0.88	-2.97	14.09

The mean number of social trips conducted on a typical Saturday is 2.6 for Class 1; 2.9 for Class 2; 1.85 for Class 3, while the mean number of trips for the total sample is 2.4. These figures indicate that Rational OSN users are more likely to conduct more social trips than the average. OSN addicted users also conduct more social trips than the average on a Saturday, while those indifferent to OSN conduct fewer social trips.

Demographic dummy variables are also used to explain the dependent variable. Females (girls) are more likely to belong to Class 2, as this variable affects positively and significantly the number of social trips. In contrast, boys are more likely to belong to Class 1 and Class 2, with the effect of conducting fewer social trips. Our results verify the fact that girls usually make more social trips and at the same time (as they belong to Class 1) upload photos of their activities on their OSN account and check-in the places that they visit. These results are similar to those of Barak-Brandes and Levin's (2013) survey. Younger teenagers, aged between 12 to 13 years, are more likely to be categorized as indifferent OSN users, having a negative sign indicating that they conduct fewer social trips. Teenagers from 15 to 18 years old seem to belong to Class 1 and Class 2 and tend to conduct more social trips. This reflects the fact that, as teenagers reach the age of 18 (adulthood), they are more involved in social networking activities and conduct more social trips. They expand the number of their on-line friends, they devote more time to chatting, and they are informed about social events through OSN, all of which results in an increase in the number of social trips. As the ratio of available gadgets with internet access in the household, divided by the number of household members, increases, the probability of making social trips increases for all the classes. Access to gadgets with internet access could be used for searching various sources of information about activities or chatting with friends, thus creating the need for travel. Teenagers who live in urban areas and belong to Classes 1 and 2 tend to conduct more social trips, while teenagers who live in rural areas seem to be indifferent to OSN and tend to conduct fewer trips for social purposes. Finally, as monthly family income increases, the number of social trips increases, while this variable is class independent.

4.6 Conclusions

4.6.1 Summary

Bearing in mind that contemporary teenagers have grown up in a completely different environment, as regards internet, social media and on-line social networking availability, from that in which middle-aged persons have grown up, we strongly believe that it is worth clarifying teenagers' travel behavior in terms of the generation gap that has emerged. Investigation of teenagers' behavior could provide policy-makers with significant insights about the trends of this generation and, in doing so, could help to develop future transportation policies.

In this chapter we explored adolescents' various OSN usage styles and their trip making behavior. The specific aim was to find out whether OSN usage replaces or stimulates teenagers' trip making behavior. At the same time, we postulated that OSN usage is not unique across the sample and that OSN usage styles exist, each one of which exhibits a different trip making behavior. Accordingly, we built a behavioral framework that captures the influence exerted by OSN usage styles on teenagers' social trips. Next, we developed a

Latent Class Poisson Regression model consisting of two parts: 1. the class-membership model, which links the latent OSN usage styles to socio-demographic variables; and 2. the class-specific choice model, which is a Poisson Regression and shows the influence of an OSN usage style and socio-economic variables on the number of trips made for social purposes.

Initially we tested this methodology with data from the survey in Cyprus, which consists of 9,714 participants who had conducted 16,593 social trips over a Saturday. After the estimation of models with various latent classes and the assessment of their goodness-of-fit, we concluded that there are four latent OSN usage styles/classes. Class 1 includes those teenagers who use OSN in a rational way. Class 2 includes those teenagers who have an account on OSN, but do not use it frequently, and hence are classed as OSN indifferent. Members of Class 3 are highly OSN oriented or, in simple words, OSN addicted. Members of Class 4 are non-OSN users. The model estimation results also showed that Class 1-Rational OSN users and Class 3-OSN addicted users conduct more social trips than Class 2-Indifferent OSN users and Class 4-non OSN users. Although Class 1 and Class 3 members spend significantly more time on OSN than the other two classes, they also conduct more trips. These teenagers usually connect to the internet via their mobile phones and have at least one account on OSN, especially on Facebook. Despite the fact that we obtained some answers from this model, more questions were raised regarding the activities that teenagers conduct via OSN and how these activities are linked to trip making behavior.

Thus, we revised our questionnaire in order to collect more data about specific OSN activities that could contribute to increased or decreased social trip making behavior. The revised questionnaire was used for the data collection in Greece in 2013, in which 1,276 students participated. The descriptive statistics gained from the new questions show that teenagers chat on-line 6.8 times per day and update their status 0.9 times per day. They check-in 3.2 times per week and upload photos 1.4 times per week, usually depicting moments from their entertainment activities and nightlife. They attend an average of 4.8 events advertised on social media in a month, usually parties and sports events. All these statistics indicate that teenagers receive significant information about their friends and social events via OSN, a fact that could contribute to an increased demand for social trips.

The results of the second case study's model indicate that the most interpretable model is the one with three latent classes. Class 1 includes those teenagers who use OSN in a rational way; they usually connect to social media via their mobile phones, they chat with their friends and upload photos sometimes per week, they like/comment on their friends' posts daily, while they usually attend an average of 3.8 social events that they have been informed of through Facebook in a month. Members of Class 2 are highly OSN oriented or OSN addicted; they also use their mobile phones and tablets to log in to their OSN accounts, they post, like and comment on their friends' posts on a daily basis, and they upload photos of their activities 3 to 4 times per week; in addition they attend an average number of 5.6 events that they were informed of through OSN. Members of Class 3 show indifference to OSN usage. The results of the class-specific model indicate that the members of Class 1-Rational OSN users and Class 2-Addicted OSN users conduct more social trips than the average, while the members of Class 3-OSN indifferent users conduct fewer social trips than the average.

The results of both case studies make clear that, in order to understand the relationship between OSN usage and trip making behavior, it is important to distinguish between

different types of OSN users. However, the first model identified that four latent OSN usage styles exist, while the second model proposed that three latent OSN classes exist. The dataset of Cyprus that used in this case study offers information for 9,714 teenagers, while the sample in Greece consists of 1,276 participants. In Cyprus we had the opportunity to predefined one class; those who do not have OSN accounts. In case study of Greece the model proposed that those who are indifferent to OSN usage seem to have the same behavior with those who do not have an OSN account. Nevertheless, since we use different variables in each case the models cannot be compared. We propose that the model of the case study in Greece captures better the frequency, the purpose and the activities that are conducted via social media and could be linked to trip making behavior.

This chapter provides insights into the rapidly growing literature investigating the effect of OSN usage on an individual's behavior. It is also a first step towards understanding the link between OSN and travel behavior. The innovative data collection used here and the variables that were tested could be of considerable importance to researchers dealing with social networking and travel behavior issues.

Finally, our findings are similar to those of the latest surveys in social sciences (Barak-Brandes and Levin, 2013; O'Keefe et al., 2012; Craig Watkins, 2009; Greenfield and Subrahmanyam, 2008). Teenagers who spend a significant amount of time on social networking are more social and conduct more trips than average teenagers. Social networking (or virtual communication) does not replace face-to-face communication. Thus, the "rich get richer" theory is verified.

In conclusion, the approach adopted here, should remain within reach of many more practitioners with standard training in maximum likelihood estimation, while still delivering more plausible and substantively different estimates than if segmentation were ignored.

4.6.2 Limitations and Extensions

The massive popularity of social networking sites only emerges in the early 2000s. Thus, research in this field is obviously incredibly young and there is still much to be done. This chapter provided preliminary support for the hypothesis about the effects of OSN on trip making behavior. It also provided significant insights into the data required in transportation surveys in order to model the effects of OSN on travel behavior. But this survey is only the first step and has a number of limitations that could be overcome by future extension.

First, in both case studies, we used as dependent variable the number of trips that teenagers conducted over a Saturday. Thus, the Latent Class Poisson Regression models that we estimated could only give us information about the various trip making behavior categories (classes) based on OSN styles, and has limited forecasting capability. The estimation of the proposed model using longitudinal data is suggested. Longitudinal data capture individuals' OSN and travel behavior over time, providing insights that contain policy implications. Second, although the class-membership model offers strong explanatory power, it could be further enhanced with the psychometric (attitudinal and perceptional) indicators regarding OSN usage that our dataset provides (see questionnaire: Appendix A). Third, we investigated the question of whether there are changes in OSN behavior across different

geographical areas (urban, rural, insular), but did not find significant differences. However, this could be further investigated by taken into account other, more specific built-environment characteristics such as the population density in the neighborhood. Finally, the dataset also offers information for a school day, which could be used for the estimation of a model, thus comparing the difference in OSN usage and trip making behavior between school days and Saturday.

4.6.3 Next Chapter

In this chapter we examined how different OSN usage styles affect trip making behavior. In the next chapter we are going to investigate how the social environment of the adolescents affects their mode-to-school choice behavior.

Chapter 5
Modeling the Social Influence Effect – How Teenagers' Social Environment Affects their Attitudes and Mode Choice Behavior

This chapter aims to identify the effect of social interaction and social influence on teenagers' attitudes and mode choice behavior. In order to investigate this effect, at the start of the chapter we introduce our general assumptions based on previous studies on decision makers, and then we test them using our dataset. Our general hypothesis is based on the latest findings of the biobehavioral sciences[2] stating that individuals' decisions are indirectly influenced by their social environment, as it affects their psychological state (van den Bos et al., 2013*;* Homberg, 2012). The individuals filter the information they receive from their social environment, so that the latter shapes their opinions towards them (Hochbaum, 1954; Hegselmann and Krause, 2002). The perceptions that individuals have regarding their environment affect their own attitudes and perceptions, and then the decision-making process. We propose an extension to hybrid choice models (HCMs) in order to incorporate the social influence effect. For the proposed model, we present the modeling framework and the relevant mathematical equations. Finally, we test it using data from the survey in Cyprus, hypothesizing that, if a teenager anticipates that his/her parents have a "Walking-lover" behavior, then this increases the probability that he/she too will have a "Walking-lover" attitude and in turn choose to walk to school.

5.1 Social Influence in the Choice Process

The utility of an individual's choice is a function of socioeconomic characteristics and psychological factors (Ben-Akiva et al., 2002b). The psychological factors are affected by the choices and behavior exhibited in the social environment of the individual, and also by the way that the individual processes or anticipates this information. McFadden (1997) argued that the most cognitive anomalies in utility theory operate through errors in perception that arise from the way information is stored, retrieved, and processed, and that the empirical study of economic behavior would benefit from closer attention to how attitudes and perceptions are formed and how they influence decision making. Currently, there is still a gap between decision making in real life, where the influence of the social environment is extensive, and decision making as measured in the laboratory, which is often done in the absence of any social influences (Weinberg and Pehlivan, 2011).

[2] Biobehavioral science is an interdisciplinary field of medicine concerned with the integration of knowledge in the biological, behavioral, psychological, and social sciences relevant to health and illness. These sciences include epidemiology, anthropology, sociology, psychology, physiology, pharmacology, nutrition, neuroanatomy, endocrinology, and immunology (Miller, 1983).

Given the above, the aim of this chapter is to develop a conceptual and methodological framework for the incorporation of social interaction into choice models, based on the previous work of Ben-Akiva et al. (2002a; 2002b; 2010; 2012) and to test it within the context of teenagers' attitudes and mode choice behavior. More specifically, the method developed provides insights useful for modeling the effect of social interaction on the formation of psychological factors (latent variables) and on the decision-making process.

The assumption of the method is based on the fact that the way the decision maker anticipates and processes information regarding the behavior and choices exhibited in her/his social environment affects her/his attitudes and perceptions, which in turn affect her/his choices (van den Bos et al., 2013; Homberg, 2012). Figure 5.1 depicts the decision maker and his/her social environment. The decision maker, in the center, receives information from his/her social environment regarding other people's behavior or choices. This information is filtered by the decision maker and he/she is able to process it in the way he/she wants. The arrows in the figure represent the information, which may be received as it is, in which case the color remains the same, or may be received slightly changed, in which case the color of the arrow changes. For example, someone could anticipate that his/her friends are fans of cycling; they may be, but they may not be. This attitude that the decision maker has shaped, affects his/her attitudes about cycling and not his/her choice directly.

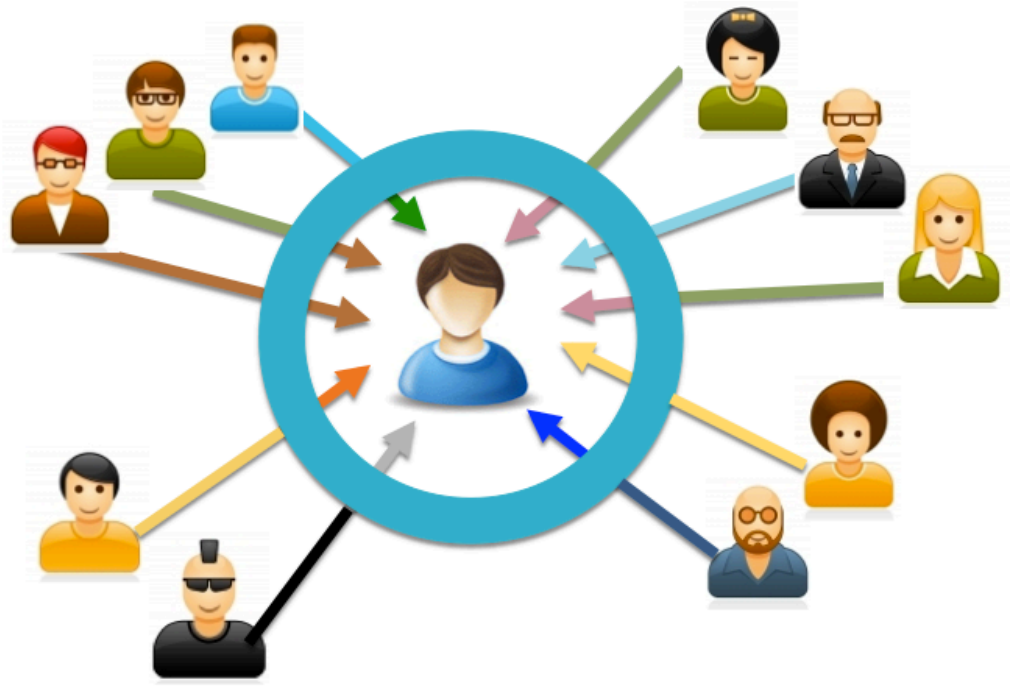


Figure 5.1: The decision maker, the social environment and the information

The proposed method is an extension to the HCM and integrates choice models with decision makers' psychological factors and latent social interaction. The model structure is simultaneously estimated, which provides an improvement over sequential methods as it provides consistent and efficient estimates of the parameters.

5.2 Modeling Framework

A starting point for the proposed methodology is the combination of a choice model with a latent variable model. That is, the framework of the HCM has been developed to enrich the behavioral realism of the DCM by accounting for latent factors such as perceptions and attitudes, and employing more flexible error structures. The framework of the HCM has been applied in various transportation contexts, such as mode choice (Johanson et al., 2006; Polydoropoulou et al., 2013; Abou-Zeid & Ben-Akiva, 2010), vehicle purchasing (Bolduc et al., 2008), and route choice (Efthimiou and Antoniou, 2014; Tsirimpa et al., 2007).

Having in mind the HCM in combination with the latest findings in psychology, neuroscience, and biobehavioral research, which state that the individual's decisions are indirectly influenced by their social environment, as it affects the individual's psychological state (van den Bos et al., 2013; Homberg, 2012), we add one more dimension to the construction of the latent variable model, that of the social environment. The choices or the behavior exhibited in the social environment are filtered by the decision maker, which in turn shapes her/his attitudes towards these choices or behaviors, or, as per Anais Nin, "we do not see things as they are, we see them as we are." Thus, the social environment is one more latent variable that represents the social interaction between the decision maker and her/his social environment, and it is added into the latent variable regarding the decision maker (Figure 5.2).

Figure 5.2 presents the modeling framework. The rectangular box in the upper right corner represents the social environment of the decision maker. The social environment has its own explanatory variables (S), that is socioeconomic characteristics, and the choices or behaviors seen in that environment are measured as psychological indicators (IS), as perceived by the decision maker. These psychological factors (IS) are used to build a latent variable (S^*) regarding the social environment of the decision maker. This latent variable (S^*) is incorporated into the formulation of the latent variable regarding the decision maker (X^*). For the construction of X^*, psychological indicators are used that refer to the decision maker's attitudes and perceptions, while X^* is affected by the explanatory variables X as well. The utility of the choice (U) is affected by the explanatory variables X and the latent variable X^*. The latent variable (X^*) and the explanatory variables (X) directly affect the choice made by the individual, while the social environment indirectly affects the utility of that choice. y represents the choice indicator.

In the social environment box, we can include as many social networks as we want, each one representing a latent variable. For example, we could introduce a latent factor regarding family, another one regarding friends or colleagues etc., or even a latent factor for each individual member of the social environment.

The integrated model is used to include latent variables regarding the decision maker and her/his social environment in choice models. The methodology incorporates indicators of the latent variables, provided by the responses to survey questions, to aid in the estimation of the model. A simultaneous estimator is used, which results in latent variables that provide the best fit to both the choice and the latent variable indicators.

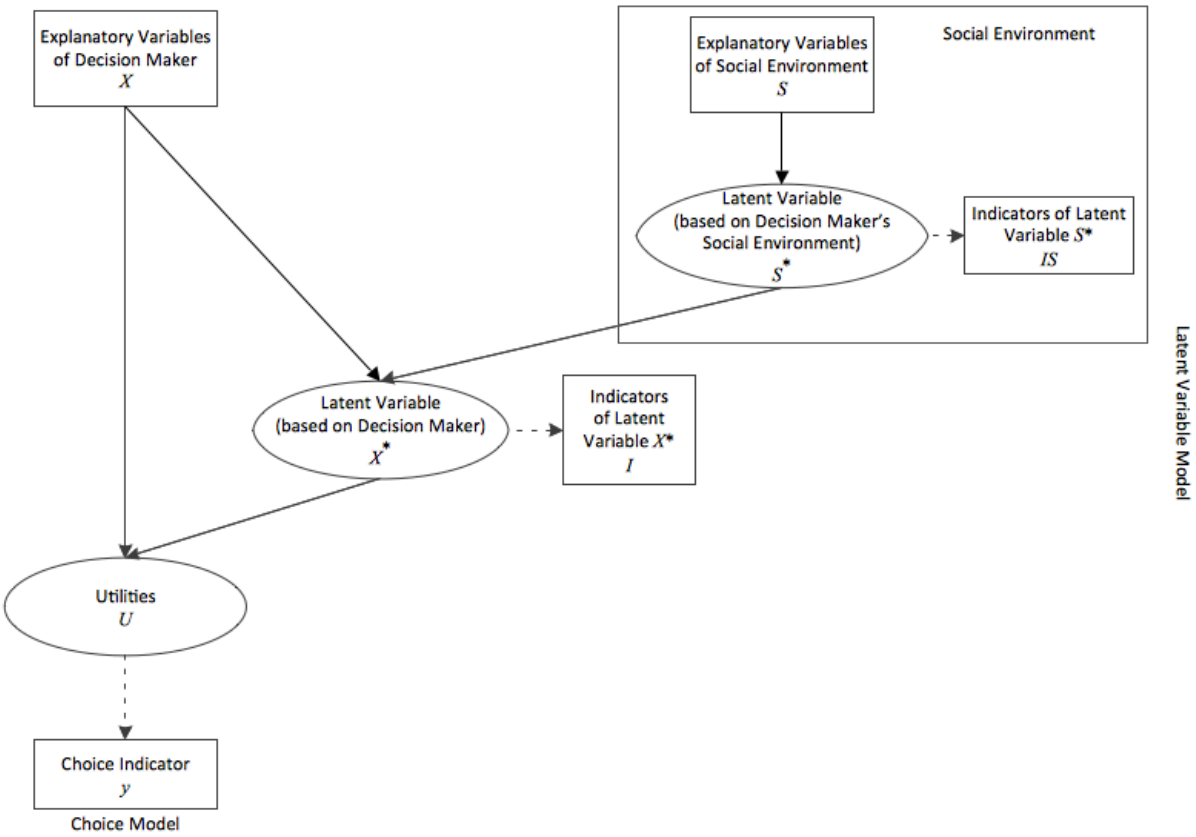


Figure 5.2: Modeling framework

5.3 Specification of the Model

Below is presented a generic formulation of the model shown in Figure 5.2. For simplicity, it is assumed that all latent variables and their indicators are continuous. The model consists of structural and measurement equations. The structural equations express the latent variables S^* (Eq. (5.1)), X^* (Eq. (5.2)) and utility U (Eq. (5.3)) using the links shown in Figure 5.2. Each of these variables is also a function of a random error term. U is a vector, whose dimensionality is equal to the number of alternatives considered (i).

Structural Model:

For the social environment of the decision maker:

$$S^* = S\xi + \eta \qquad \eta \sim N(0, \Sigma_\eta) \quad (5.1)$$

where S^* *is* the latent (unobservable) variable regarding the decision maker's social environment, S are matrices of explanatory observed variables regarding the social environment of the decision maker, ζ is a vector of unknown parameters used to describe the effect of the observable variables (S) on the latent variables, η is a vector of random disturbance terms, and Σ_η denotes the covariance of the random disturbance terms.

For the decision maker:

$$X^* = X\vartheta + S^*\xi + \omega \qquad \omega \sim \mathrm{N}(0, \Sigma_\omega) \quad (5.2)$$

where X^* is the latent (unobservable) variable based on the decision maker's attitudes or perceptions, X are the explanatory observed variables (RP) regarding the decision maker, θ is a vector of unknown parameters used to describe the effect of the observable variables (X) on the latent variable, ξ is a vector of unknown parameters used to describe the effect of the latent variable based on the decision maker's social environment (S^*) on the latent variable regarding the decision maker, ω is a vector of random disturbance terms, and Σ_ω denotes the covariance of the random disturbance terms.

Utility:

$$U = X\beta + X^*\gamma + \varepsilon \qquad \varepsilon \sim N(0, \Sigma_\varepsilon) \quad (5.3)$$

where U is a vector of utilities, β is a vector of observed variables regarding the decision maker, γ is the unknown parameter associated with the latent variable X^*, ε is a vector of random disturbance terms associated with the utility terms, and Σ_ε denotes the covariance of the random disturbance terms.

The availability of the indicators I of the latent variable regarding the decision maker and of IS, the latent variable regarding the social environment, eases the identification of the model and results in more efficient parameter estimates. These indicators can be expressed as a function of the corresponding latent variables and a random error term, as shown in the measurement equations (Eq. (5.4) and Eq. (5.5)). If we know the distributions of the error terms, then the density functions of the indicators can be derived. As a latent variable may have more than one indicator, I and IS are vectors.

Measurement model:

For the social environment of decision maker:

$$IS = a' + \lambda' S^* + \upsilon' \qquad \upsilon' \sim N(0, \Sigma_{\upsilon'}) \quad (5.4)$$

where IS corresponds to the indicators of the latent variable that is constructed for the social environment of the decision maker (S^*), α' is a vector of parameters that indicate the associations between the responses to the scale, λ' is a vector of unknown parameters that relate the latent variable S^* to the indicators, and υ' is a vector of independent error terms with unitary variance and $\Sigma_{\upsilon'}$ designates the covariance of the random disturbance terms.

For the decision maker:

$$I = a + \lambda X^* + \upsilon \qquad \upsilon \sim N(0, \Sigma_\upsilon) \quad (5.5)$$

where I corresponds to the indicators of the latent variable based on the decision maker's psychological factors (X^*), α is a vector of parameters that indicate the associations between the responses to the scale, λ is a vector of unknown parameters that relate the latent variable X^* to the indicators and υ is a vector of independent error terms, and Σ_υ designates the covariance of the random disturbance terms.

Choice model:

$$y_i = \begin{cases} 1, & if\ U_i = \max j\{U_j\} \\ 0, & otherwise \end{cases} \quad (5.6)$$

where y_i is a choice indicator, taking the value 1 if alternative i is chosen, and 0 otherwise.

The choice probability for a given observation is

$$P(y_i \mid X, X^*; \Sigma\mu) \qquad (5.7)$$

where $\Sigma\mu$ denotes all the unknown parameters in the choice model of Eq. (5.3).

The likelihood function for a given observation is the joint probability of observing the choice and the attitudinal indicators as follows:

$$f(y, I, IS \mid X, S; \delta) = \int_{X^*} \int_{S^*} P(y \mid X, X^*; \beta, \gamma, \Sigma_\varepsilon) f(I \mid X, X^*; \lambda, \Sigma_\upsilon)(IS \mid S, S^*; \lambda', \Sigma_{\upsilon'}) f(X^* \mid X; \vartheta, \xi, \Sigma_\omega)(S^* \mid S; \zeta, \Sigma_\eta) dS^* dX^* \qquad (5.8)$$

where δ designates the full set of parameters to be estimated ($\delta=\{\beta, \gamma, \lambda, \lambda', \theta, \zeta, \xi, \Sigma_\varepsilon, \Sigma_\upsilon, \Sigma_{\upsilon'}, \Sigma_\omega\}$). The first term of the integral corresponds to the choice model. The second term corresponds to the measurement equations from the latent variable models (both for the decision maker and the social environment) and the third term corresponds to the structural equations from the latent variable models (both for the decision maker and the social environment). The latent variable is only known to its distribution, and so the joint probability of y, I, IS, X^*, and S^* is integrated over the latent constructs X^* and S^*.

5.4 Model Application

5.4.1 Sample

The proposed methodology is tested using data from the survey in Cyprus. Among the other topics that the questionnaire covered, we had a section with questions asking participants to state their level of agreement or disagreement regarding (1) their attitudes and perceptions towards walking and cycling, (2) their attitudes towards their parents' travel behavior and walking, cycling and private vehicle use patterns, and (3) their attitudes towards their friends' travel behavior and walking, cycling and private vehicle use patterns. For the purposes of this chapter, we use revealed preference data regarding the following:

- the transport mode that the teenagers use for their trip to school;
- the built environment characteristics of the route between home and school;
- the attitudes of the teenagers towards walking;
- the attitudes of the teenagers towards their parents' walking behavior; and
- the socioeconomic and demographic characteristics of the teenagers and the other members of their households.

That is, the proposed methodology is tested within the context of a household and the social influence between teenagers and their parents. We mention again that we were able to use the utility maximization theory in our case, as the sample consists of teenagers and not children. Teenagers are mature enough to make their own mode choices when traveling to school (Clifton et al., 2010; Babey et al., 2009).

The sample used for the model estimation consists of 9,713 participants. The descriptive statistics of the sample used in this case study are presented in Table 5.1. 55% of the participants are females. 58% are 15 to 18 years old. 16% of the adolescents walk to school, 35% take the bus, while 49% are escorted by their parents using a private motorized vehicle. The parental level of education is quite low (secondary education). The household car ownership is rather high, and none of the students stated that there were no cars in their household, indicating that everyone in the sample has the option of being driven to school. Also, in all of the participants' households there is at least one driver. The maximum distance traveled on foot is 2.1km, while that by private motorized vehicle is 24.1km. Finally, various built environment characteristics were measured for each individual's route from home to school, after the completion of the survey, based on the travel diary completed by each participant (which are presented and discussed in depth in Chapter 6).

Table 5-1: Descriptive statistics of the sample

		Percentage (%)
Teenagers (Decision Makers)		
Gender	Female	55%
	Male	45%
Age	11 to 14 years old	42%
	15 to 18 years old	58%
Have lived abroad	Yes	14%
	No	86%
Mode to school (dependent variable)	Active transport	16%
	Bus (public transport)	35%
	Private vehicle (escorted by parents)	49%
Parents (Social Environment)		
Educational level of father	Low (secondary education)	64%
	Medium (university)	25%
	High (Master's or PhD)	11%
Educational level of mother	Low (secondary education)	60%
	Medium (university)	29%
	High (Master's or PhD)	11%
Household Characteristics		
Income (Euros per month)	Less than 2000€	25%
	2001€ to 4000€	27%
	More than 4000€	20%
	Not available	28%
Driving license	One of the parents holds a driving license	23%
	Both parents hold a driving license	77%
Car ownership		2.6
Household size		4.8
Built Environment Characteristics on the Route from Home to School		
Aesthetics: Existence of greenery (trees and flowers)		38%
Existence of cross walks		67%
Sidewalks		55%
Distance traveled on foot		Max=2.1km, Min= 0.002km, Mean=0.75km
Distance traveled by bus		Max=34.6km, Min=1.1km, Mean=11.3km
Distance traveled by private motorized vehicle		Max=24.1km, Min=0.02km, Mean=3.8km

Table 5.2 presents the responses to the attitudinal questions regarding the teenagers' willingness to walk and regarding their parents' walking habits. The answers to the statements *WL1* to *WL8* serve as attitudinal indicators of the latent variable "Walking-lover" (henceforth *WL).* The answers to the statements *PWL1* to *PWL2* are used as indicators of the latent variable *"Parents: walking-lovers"* (henceforth *PWL*). In this way, *PWL* measures how teenagers anticipate their parents' walking behavior and *WL* measures the teenagers' predisposition to walk. The response scale ranged from 1 to 7, with a response of 1 indicating that the participant completely disagreed with the statement, and 7 indicating that they completely agreed with it.

Table 5-2: Indicators of latent variables

		Mean	Std. Dev.
Indicators of Walking-lover			
I_{WL1}	I am willing to walk to school, in order to be fit	4.2	2.280
I_{WL2}	I am willing to walk to school, as it is the most cost-effective mode	3.8	2.154
I_{WL3}	I am willing to walk, in order to protect the environment	4.3	2.002
I_{WL4}	I consciously make an effort to walk instead of being escorted	4.6	2.001
I_{WL5}	I prefer walking rather than being escorted for my short-distance trips	3.8	2.192
I_{WL6}	I really enjoy walking	3.9	2.183
I_{WL7}	I am not willing to walk to school, because it is time consuming	4.0	2.233
I_{WL8}	I am not willing to walk to school alone	3.7	2.178
Indicators of the Anticipated Variable "Parents: Walking-lovers"			
SI_{PWL1}	My mother walks for her short-distance trips	4.0	1.868
SI_{PWL2}	My mother prefers walking to using the car	2.5	2.020
SI_{PWL3}	My father walks for his short-distance trips	3.2	2.039
SI_{PWL4}	My father prefers walking to using the car	2.4	2.020

5.4.2 Model Specification

A mode choice model is developed with the aim of investigating how the anticipated parental (social environment) walking behavior affects the teenagers' (the decision makers') attitudes towards walking, and how the latter affect the teenagers' mode choice behavior. We hypothesize that, when the teenager anticipates that his/her parents are walking-lovers, this has a positive effect on his/her own attitudes towards walking, increasing the probability that he/she will be a walking-lover and in turn that he/she will choose walking for the trip to school. The assumption is based on the fact that the payoff to the decision maker of choosing walking is a direct function of his/her attitudes towards walking and an indirect function of her/his attitudes towards the walking habits of her/his social environment. That is, the effect of social interaction or social influence is incorporated in the latent variable regarding the decision maker, and then this is included in the choice model. Figure 5.3 presents the modeling framework.

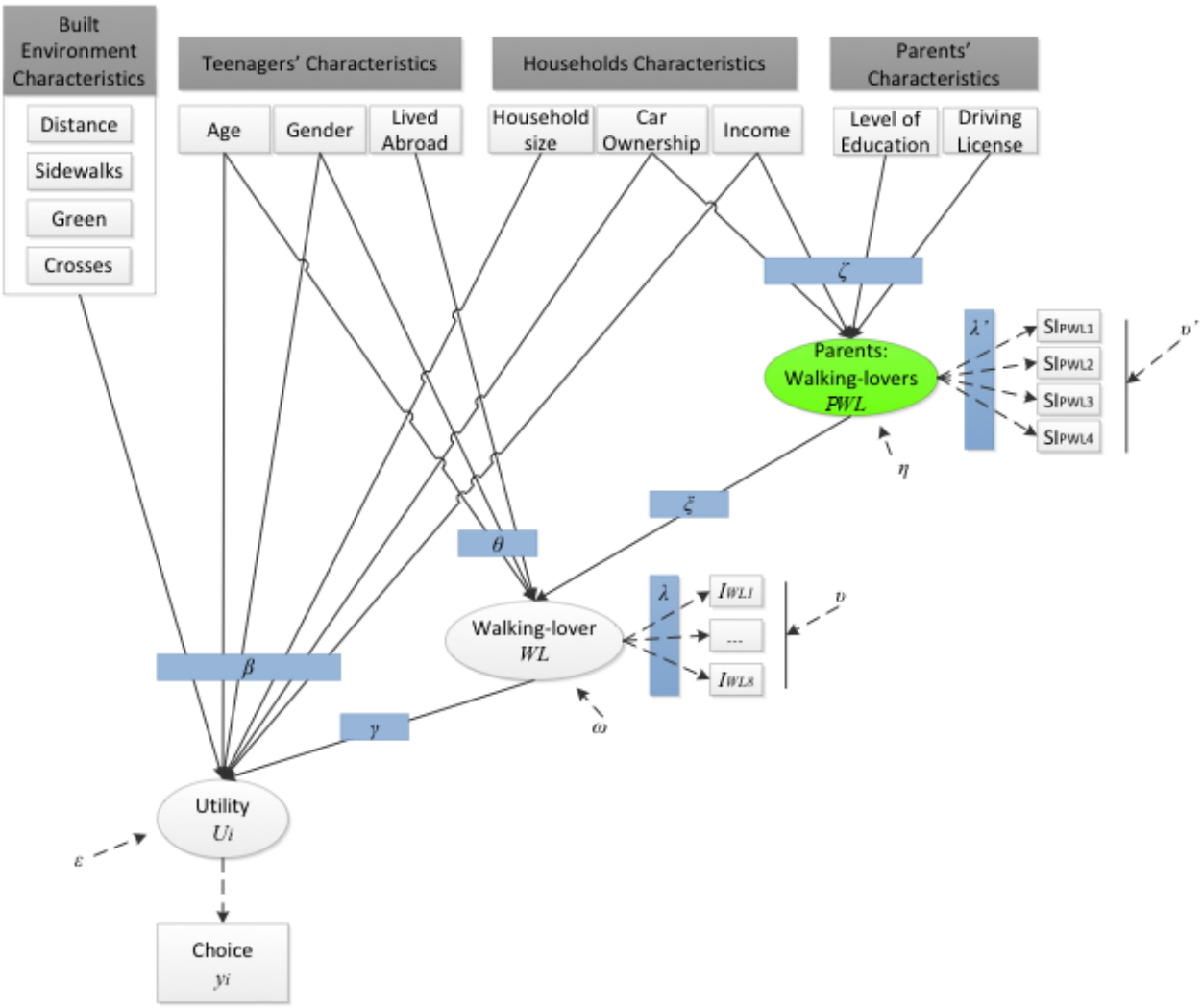


Figure 5.3: Modeling framework for teenagers (decision makers) and the social interaction effect from their parents (social environment)

5.4.2.1 Structural Model

The utility of choice is a function of socioeconomic characteristic, the urban environment characteristics and the latent variable *WL*. The deterministic utility of the alternative of walking (denoted as *WALK* – Eq. (5.9)) contains the distance from home to school, interacted with gender (as previous surveys have found that the distance that teenagers walk is affected by gender; McMillan, 2005), age, pocket money, various built environment characteristics and the latent variable *WL,* as we assume that the teenagers who are walking-lovers prefer to walk to school. The utility of *BUS* (Eq. (5.10)) includes the distance traveled from home to school. The utility of being escorted to school by an adult in a private motorized vehicle (denoted as *CAR* – Eq. (5.11)) is affected by distance interacted with gender, age, household family income and the number of motorized vehicles available in the household divided by the household size. Travel time is captured by distance per mode. Travel cost variables are not used, due to the fact that (1) students in Cyprus can use the bus free of charge, (2) teenagers do not consider the costs of traveling by car as their caregivers pay these costs. Availability constraints were inserted into the alternative *WALK*; when the distance from home to school was more than 2.1km, this

alternative was considered unavailable. Since all the participants' households owned at least one motorized vehicle, the alternative *CAR* was deemed available to all. Restrictions on parents' availability to escort their children were not imposed, as this variable was not available in the dataset. However, even if the parents were not available, the option would still be available to all the participants as someone else could escort them (e.g. the parents of a fellow student).

$$U_{WALK} = (\beta_{D1} + \beta_{G1} * FEMALE) * DIST2km + \beta_{A1} * AGE1114 + \beta_{I1} * INCOME + \beta_{G1} * GREEN + \beta_{C1} * CROSS + \gamma * WL + \varepsilon_{WALK} \quad (5.9)$$

$$U_{BUS} = \beta_{BUS} + \beta_{D2} * DIST5km + \varepsilon_{BUS} \quad (5.10)$$

$$U_{CAR} = \beta_{CAR} + (\beta_{D3} + \beta_{G3} * FEMALE) * DIST25km + \beta_{A3} * AGE1114 + \beta_{INC3} * INCOME + \beta_{CHH} * (CARHH / HHSIZE) + \varepsilon_{CAR} \quad (5.11)$$

where:
FEMALE takes the value 1 if the participant is female, 0 otherwise;
AGE1114 takes the value 1 if the participant is from 11 to 14 years old, 0 otherwise;
POCKMONEY denotes the daily pocket money in Euros, a continuous variable;
DIST2km takes the value 1 if the distance traveled between home and school is up to 2.0km, 0 otherwise;
DIST25km takes the value 1 if the distance traveled between home and school is between 2.0 and 5.0km, 0 otherwise;
DIST5km takes the value 1 if the distance traveled between home and school is more than 5.0km, 0 otherwise;
CARHH is a continuous variable representing the number of cars in the household;
HHSIZE is a continuous variable denoting the number of household members;
ε_{WALK}, ε_{BUS}, and ε_{CAR} are vectors of error terms.

The attitudes that the teenagers have regarding their parents' walking behavior are modeled as a function of their parents' socioeconomic and demographic characteristics, as shown in Eq. (5.12). Some of the explanatory variables that are used for the teenagers (decision makers) are the same as the explanatory variables used for the structural model of the parents, since they share the same household socioeconomic characteristics. The structural equation links the parents' characteristics with the latent variable *PWL* through a linear regression equation based on the parents' level of education, the family income and the number of motorized vehicles available in the household.

$$PWL = \zeta_{PWL} + \zeta_{CARHH} * (CARHH / NLICENSE) + (\zeta_{INC} + \zeta_{EDH} * EDUHIGH + \zeta_{EDL} * EDULOW) * INCOME * + \eta_{PWL} \quad (5.12)$$

where:
NLICENSE represents the number of driving license holders; it takes the value 1 when one of the parents holds a driving license and 2 when both parents have a driving license. All

the households have at least one parent who holds a driving license. Thus this variable does not take the value 0.

EDULOW takes the value 1 when the educational level of both parents is high, 0 otherwise;
EDUHIGH takes the value 1 when the educational level of both parents is low, 0 otherwise;
η_{PWL} is a random error term.

The attitudes of the teenagers regarding walking are modeled as a function of socioeconomic characteristics and the latent variable *PWL* (Eq. (5.13)). The structural equation links the teenagers' characteristics with the latent variable *WL* through a linear regression equation based on gender, age, and whether they have lived in another country, combined with household income and the latent variable *PWL*. We multiply the variable *ABROAD* by income, due to the fact that in Cyprus there are a lot of economic immigrants but also a lot of wealthy foreign residents:

$$WL = \vartheta_{WL} + \vartheta_{GWL} * FEMALE + \vartheta_{AWL} * AGE1114 + (\vartheta_{ABWL} + \vartheta_{INCWL} * INCOME) * ABROAD + \xi_{WL} * PWL + \omega_{WL} \quad (5.13)$$

where:
ABROAD takes the value 1 if the teenager has lived in a different country in the past, 0 otherwise;
ω_{WL} is a random error term.

5.4.2.2 Measurement Model

The choice between the alternatives is assumed to be based on utility maximization and can be expressed as follows:

$$y = \begin{cases} 1 & \text{if } U_i \geq U_j \quad \forall j \neq i \\ 0 & \text{otherwise} \end{cases}, \quad i = WALK, BUS, CAR \quad (5.14)$$

where y_i is the choice indicator, equal to 1 if alternative i is chosen, and 0 otherwise.

Four measures are used as indicators of the latent variable *PWL*, as shown in Eqs. (5.15) to (5.18). Eq. (5.15) is normalized by setting the intercept term to 0 and the coefficient of attitude to 1. The indicators are specified as continuous variables for simplicity.

$$SI_{PWL1} = a'_1 + \lambda'_1 * PWL + \upsilon'_1 \quad ; \alpha'_1 = 0, \ \lambda'_1 = 1 \quad (5.15)$$
$$SI_{PWL2} = a'_2 + \lambda'_2 * PWL + \upsilon'_2 \quad (5.16)$$
$$SI_{PWL3} = a'_3 + \lambda'_3 * PWL + \upsilon'_3 \quad (5.17)$$
$$SI_{PWL4} = a'_4 + \lambda'_4 * PWL + \upsilon'_4 \quad (5.18)$$

where:
$SI_{PWL1}, \ldots SI_{PWL4}$ are responses to the attitudinal questions regarding the parents (Table 2),

υ'_1, ... υ'_4 are random error terms with unitary variance, defined as $\upsilon'_1 \sim N(0,\sigma^2_{\upsilon' PWL1})$ to $\upsilon'_4 \sim N(0,\sigma^2_{\upsilon' PWL4})$, and α'_1, ... α'_4, and λ'_1, ... λ'_4 are parameters.

Eight measures are used as indicators of being a "Walking-lover" (*WL*) (Eqs. (5.19) to (5.26)). Eq. (5.19) is normalized by setting the intercept term to 0 and the coefficient of attitude to 1.

$$I_{WL1} = a_1 + \lambda_1 * WL + \upsilon_1 \quad ; \alpha_1 = 0, \quad \lambda_1 = 1 \qquad (5.19)$$
$$I_{WL2} = a_2 + \lambda_2 * WL + \upsilon_2 \qquad (5.20)$$
$$I_{WL3} = a_3 + \lambda_3 * WL + \upsilon_3 \qquad (5.21)$$
$$I_{WL4} = a_4 + \lambda_4 * WL + \upsilon_4 \qquad (5.22)$$
$$I_{WL5} = a_5 + \lambda_5 * WL + \upsilon_5 \qquad (5.23)$$
$$I_{WL6} = a_6 + \lambda_6 * WL + \upsilon_6 \qquad (5.24)$$
$$I_{WL7} = a_7 + \lambda_7 * WL + \upsilon_7 \qquad (5.25)$$
$$I_{WL8} = a_8 + \lambda_8 * WL + \upsilon_8 \qquad (5.26)$$

where:
I_{WL1}, ... I_{WL8} are the responses of the teenagers to the attitudinal questions regarding their own behavior (Table 5.2), υ_1, ... υ_8 are random error terms with unitary variance, defined as $\upsilon_1 \sim N(0,\sigma^2_{\upsilon WL1})$ to $\upsilon_8 \sim N(0,\sigma^2_{\upsilon WL8})$, and α_1, ... α_8, and λ_1, ... λ_8 are parameters.

The likelihood of a given observation is the joint probability of observing the choice, the eight indicators of the attitude *WL* and the four indicators of the attitude *PWL*, as shown in Eq. (5.27):

$$f(y, I_{WL}, IS_{PWL} \mid X, S; \delta) = \int_{WL}\int_{PWL} P(y \mid X, X^*; \beta, \gamma, \Sigma_\varepsilon) f(I_{WL} \mid X, WL; \lambda, \Sigma_\upsilon)(IS_{PWL} \mid S, PWL; \lambda', \Sigma_{\upsilon'}) f(WL \mid X; \vartheta, \xi, \Sigma_\omega)(PWL \mid S; \zeta, \Sigma_\eta) dPWL\, dWL \qquad (5.27)$$

where δ denotes the full set of parameters to be estimated ($\delta = \{\beta, \gamma, \lambda, \lambda', \theta, \zeta, \xi, \Sigma_\varepsilon, \Sigma_\upsilon, \Sigma_{\upsilon'}, \Sigma_\omega\}$).

5.4.3 Model Estimation Results

5.4.3.1 Mode Choice Model

This section presents and discusses the estimation results of the choice model (see Table 3). We first estimated a multinomial (MNL) model, which served as the base model. Afterwards, we added the latent variable *WL* to the MNL without including the social interaction latent variable *PWL*. Finally, we estimated the MNL model again with the latent variable *WL*, including the *PWL* latent variable in its structural model as a component. The models were estimated using the Pythonbiogeme software (Bierlaire & Fetiarson, 2009).

The number of draws was set to 1,000.

Overall, the estimated values of the parameters are in agreement with prior expectations. All the variables used for the estimation of the choice model are statistically significant at the 95% level. The constants in the model capture the preferences of teenagers for private motorized vehicles and buses for their trip to school.

Adolescent females prefer being escorted by their parents by car to walking to school. Teenagers aged from 11 to 14 years also prefer being escorted by car, while older teenagers aged from 15 to 18 years prefer walking. This result reflects the fact that teenagers tend to conduct more independent (unsupervised) trips once they reach the age of 18. As the household's monthly income increases, the probability of a teenager being escorted to school increases, while the probability of walking decreases. Also, with an increase in the ratio of the number of private vehicles available in the household to the number of household members, the teenagers' probability of choosing to be driven to school by their parents increases.

Table 5-3: Estimation results - choice model

	Base model		**HCM**		**HCM with social interaction**	
	Coef.	**t-stat**	**Coef.**	**t-stat**	**Coef.**	**t-stat**
β_{BUS}	1.07	5.53	3.72	14.94	3.75	15.04
β_{CAR}	2.47	12.27	5.18	20.21	5.21	20.30
Variables specific to *WALK*						
Female	-0.30	-3.51	-0.28	-3.94	-0.28	-3.98
Distance between home and school: less than 2.0km	3.53	20.46	3.67	20.84	3.67	20.34
Age 11 to 14 years old	-0.19	-2.27	-0.41	-4.36	-0.41	-4.40
Income (continuous)	-0.09	-1.97	-0.43	-1.99	-0.43	-1.99
Existence of greenery (trees/flowers)	0.434	5.35	0.42	4.78	0.42	4.78
No crosswalks for at least half of the route between home and school	-0.60	-7.86	-0.65	-7.98	-0.65	-7.62
Wide sidewalks for at least half of the route between home and school	0.29	4.04	0.27	3.39	0.27	3.41
Walking-lover (latent variable)	--	--	0.58	20.67	0.89	23.94
Variables specific to *BUS*						
Distance between home and school: more than 5.0km	5.19	10.83	5.12	10.94	5.12	10.94
Variables specific to *CAR*						
Female	0.11	1.97	0.098	1.98	0.098	1.98
Age 11 to 14 years old	0.25	4.29	0.25	4.36	0.33	8.94
Distance between home and school: 2.0 to 5.0km	1.97	4.12	1.91	3.97	1.91	3.97
Income (continuous)	0.04	4.38	0.04	4.41	0.04	4.42
Number of private vehicles in the household/ household size (continuous)	1.18	12.24	1.08	12.97	1.08	12.98

Regarding the characteristics of the built environment, the existence of wide sidewalks for at least half of the route from home to school encourages the decision to walk. The absence of crosswalks on at least half of the route between home and school decreases the probability of choosing to walk. As far as the aesthetics of the route between home and school are concerned, the existence of trees and flowers favors the choice of walking significantly. Distance plays the most significant role in the choice of mode to school, a fact that other surveys have verified as well (McDonald, 2008b; Schlossberg et al., 2006). Walking is preferred when the distance between home and school is less than 2.0km. In the

utility function for *WALK*, distance is interacted with gender and the results indicate that even if the distance is less than 2.0km, females do not prefer walking. If the distance from home to school is more than 5.0km, then the bus is preferred. For distances between 2.0 and 5.0km, teenagers prefer being escorted by private motorized vehicle.

Unsurprisingly, the incorporation of the latent variable "Walking-lover" (*WL*) enhances the explanatory power of the choice model. The latent variable enters significantly into the utility of walking, and is the most statistically significant variable. Thus, the latent variable encourages the choice of walking to school.

5.4.3.2 Structural and Measurement Latent Variable Model Estimation Results

Table 5.4 presents the estimation results of the structural and measurement models of the latent variable models. All variables used in the structural models are statistically significant at the 95% level. From the structural model, we can conclude that girls are less likely to be "walking-lovers" than boys. Being aged between 11 and 14 years has a negative impact on walking-loving behavior. The participants who have lived in a different country in the past seem to be "walking-lovers". However, when this variable is interacted with income, the results indicate that, even if they have lived abroad in the past, the more wealthy participants are not "walking-lovers". This reflects the fact that the wealthy immigrants to Cyprus do not have positive attitudes towards walking. The descriptive statistics of the sample show that the majority of the wealthy immigrants had previously lived in Russia before they came to Cyprus.

The incorporation of the latent variable, "Parents: Walking-lovers", into the latent variable "Walking-lovers" enhanced the explanatory power of the model even more. This component is the most statistically significant variable in the structural equation of *WL*, indicating the strong influence that parents have on the development of their children's attitudes towards walking. The results indicate that, when teenagers anticipate that their parents love to walk, it has a positive effect on their own attitude towards walking. However, it is not known whether their parents walk every day, and only for short trips. Since only teenagers participated in the survey, even if we had asked them about the modes that their parents used for various trips and purposes, it would be difficult to completely specify the modes used by the parents for all their activities.

The structural model of the latent variable *PWL* offers significant information about the characteristics of parents that exhibit walking-lover behavior. With respect to the educational attainment of the parents, higher levels of education for both parents are associated with greater levels of "walking-lover" behavior. In contrast, low educational levels for both parents work against such behavior. However, when the variable indicating a high educational level for the parents is interacted with income, the estimate value is -0.15. This means that, as income increases, the positive effect of a high educational level is reversed.

Table 5-4: Estimation results – Structural and Measurement models

	HCM		HCM with SI	
	Coef.	**t-stat**	**Coef.**	**t-stat**
STRUCTURAL MODEL				
Decision Maker/ Teenager – Walking-lover				
θ_{WL}	4.00	114.85	1.80	9.48
Female	-2.35	-6.35	-0.13	-6.69
Age 11 to 14 years old	-0.28	-7.57	-0.33	-8.94
Abroad	0.64	4.23	0.63	4.56
Income	-0.32	-3.95	-0.33	-3.98
PWL	--	--	0.58	11.72
σ_{WL}	1.68	78.10	1.66	77.36
Social Environment – Parents: Walking-lovers				
ζ_{PWL}	--	--	3.58	119.34
Number of private vehicles in the household/ Number of persons with a driving license in the household	--	--	0.024	4.70
Income	--	--	-0.15	-1.96
Both parents have high educational level	--	--	0.04	4.06
Both parents have low educational level	--	--	-0.23	-2.87
σ_{PWL}	--	--	0.50	20.31
MEASUREMENT MODEL				
α_1	0	--	0	--
α_2	-0.19	-3.48	-0.20	-3.60
α_3	0.09	1.48	0.08	1.35
α_4	0.22	3.74	0.21	3.60
α_5	0.42	6.97	0.43	7.04
α_6	2.27	38.10	2.28	38.26
α_7	4.93	81.17	4.93	81.11
α_8	3.91	74.87	3.93	75.07
λ_1	1	--	1	--
λ_2	0.95	72.99	0.95	72.99
λ_3	0.96	65.29	0.96	65.35
λ_4	0.96	67.28	0.96	67.34
λ_5	0.91	64.02	0.91	63.89
λ_6	0.38	27.48	0.37	27.25
λ_7	-0.19	-13.81	-0.19	-13.79
λ_8	-0.18	-14.97	-0.17	-14.68
σ_1	1.56	106.61	1.56	106.88
σ_2	1.42	102.84	1.41	102.69
σ_3	1.33	98.76	1.33	98.75
σ_4	1.27	95.81	1.27	95.73
σ_5	1.58	119.14	1.58	119.39
σ_6	2.07	137.19	2.07	137.23
σ_7	2.09	138.86	2.09	138.86
σ_8	1.86	138.79	1.86	138.81
α'_1	--	--	0	--
α'_2	--	--	-7.74	-14.89
α'_3	--	--	-2.41	-8.59
α'_4	--	--	-7.74	-14.72
λ'_1	--	--	1	--
λ'_2	--	--	2.8	19.91
λ'_3	--	--	1.46	19.27
λ'_4	--	--	2.87	19.17
σ'_1	--	--	1.88	133.92
σ'_2	--	--	1.41	72.26
σ'_3	--	--	1.81	127.43
σ'_4			1.35	64.11

Regarding the measurement model of the latent variable *WL*, several indicators were considered, linking the latent variable of psychometric "walking-lover" behavior to the responses to the attitudinal qualitative survey questions. The coefficient of the first indicator (I_{WL1}) was normalized to 1. The α parameters that indicate the associations between the responses to the scale items and the psychometric scale all have the expected signs. However, the α_2 parameter is negative, indicating that teenagers do not consider travel cost as one of the most important transport mode attributes (see I_{WL2}, Table 5.2). This is because, usually, others pay the costs. Here, we can see that a more positive attitude to walking will lead to respondents being more in agreement with the statement that they prefer walking to being escorted. Additionally, the effect of the latent variable *WL* on the indicator about environmental protection is positive, reflecting the idea that environmentally conscious teenagers perceive the idea of walking more positively because this is one of the most environmentally friendly transport modes.

For the measurement model of the latent variable *PWL,* indicators were used that linked the latent variable to the responses to the attitudinal qualitative survey questions regarding the walking behavior of the participants' parents. The coefficient of the indicator SI_{PWL1} was normalized to 1. The results indicate that the latent variable *PWL* has a positive effect on the indicators regarding the preference for walking instead of using the car, reflecting the idea that parents who enjoy walking prefer greener transport modes.

5.5 Model Performance

5.5.1 Goodness-of-fit

In this section we compute the goodness-of-fit for the overall model and for the specific model components. For the overall model, the goodness-of-fit statistics include the log-likelihood over the choice and the indicators (see Ben-Akiva and Lerman, 1985). We also assess the goodness-of-fit of the structural and measurement equations of the latent variables (specific model components).

The choice log-likelihoods of the estimated models are presented in Table 5.5. This is useful when someone wants to compare the goodness-of-fit of the HCM to that of a choice-only model without latent variables and indicators, in which case the log-likelihood (over the choice and the indicators) of the HCM cannot be directly compared to that of the choice-only model. As seen in Table 5.5, the choice log-likelihoods of the extended models are smaller than that of the standard model, indicating that the standard model fits the choice data better. This is to be expected as the standard model optimizes the likelihood over the choice, while the first extended model (HCM) optimizes the likelihood over both the choice and the latent variable regarding the decision maker and the second extended model (HCM with SI) optimizes the likelihood over the choice, the latent variable regarding the decision maker and the latent variable regarding the social environment.

Table 5-5: Log-likelihood of the standard and extended models

	MNL (Choice)	**HCM** (extended: Choice + WL)	**HCM with SI** (extended: Choice + WL + SI)
Choice log-likelihood	-6356.460	-164141.052	-243192.704

For the structural equations of the *WL* and *PWL* latent variables and for every measurement equation of the latent variables, a measure of squared multiple correlation ("pseudo" R2) can be computed as follows (Abou-Zeid & Ben-Akiva, 2013), with a higher value indicating a better fit:

$$Pseudo\ R^2 = 1 - \frac{\text{error variance}}{\text{variance of dependent variable of equation}} \quad (5.28)$$

For the measurement equations, since we have continuous indicators, the error variance is estimated from the Eqs. (5.19) to (5.26) for the *WL* latent variable and from Eqs. (5.15) to (5.18) for the *PWL* latent variable. The variance of each of the dependent variables (I_{WL1} to I_{WL8} and SI_{PWL1} to SI_{PWL4}) can be obtained from the sample data. Table 5.6 presents the variance of the indicators.

Table 5-6: Goodness-of-fit for the measurement models of *WL* and *PWL* latent variables (Pseudo R^2)

	Variance	Pseudo R^2 - HCM	Pseudo R^2 –HCM with SI
Indicators of *WL* latent variable			
I_{WL1}	5.292	0.70	0.70
I_{WL2}	4.638	0.69	0.69
I_{WL3}	4.428	0.70	0.70
I_{WL4}	4.286	0.70	0.70
I_{WL5}	4.909	0.69	0.69
I_{WL6}	4.687	0.61	0.61
I_{WL7}	4.89	0.59	0.59
I_{WL8}	4.568	0.68	0.68
Indicators of *PWL* latent variable			
SI_{PWL1}	3.774		0.59
SI_{PWL2}	3.989		0.64
SI_{PWL3}	3.811		0.61
SI_{PWL4}	3.916		0.65

The pseudo R^2 of the measurement equations can give an indication as to which of the indicators provide good measurements of the latent variable, potentially leading to the removal of "weak" indicators from the model. In our case, IWL6 and IWL7 seem to be "weakest" compared to the others. The model could be estimated again without these indicators, but we prefer to keep them, as their pseudo-R2 is not so low. All the other indicators seem to be equal "strong".

For the structural equation of the latent variables, the variance of the disturbance is also estimated or normalized, but the variance of the dependent variable (the latent variable) needs to be computed. We can compute this using one of the following ways (see Abou-Zeid & Ben-Akiva, 2013): 1. either using the measurement equations whereby the total variance of an indicator is expressed as the sum of the variance of the error term and the square of the factor loading multiplied by the variance of the latent variable; 2. or using the structural equation where the variance of the latent variable can be computed given the variances of the explanatory variables based on the sample data, the variance of the

disturbance in the structural equation, and the estimated parameters. The pseudo R^2 of the structural equation will indicate if the variables in the structural equation explain the latent variable adequately.

Table 5-7: Goodness-of-fit for the structural models of *WL* and *PWL* latent variables (Pseudo R^2)

	HCM	HCM with SI
Structural model of *WL*	0.68	0.72
Structural model of *PWL*	--	0.65

5.5.2 Efficiency

Using indicators of the latent variables in a HCM adds to the information content of the model and is expected to result in a gain in efficiency. In our case we expect that the integrated models (HCM and HCM with SI) will be more efficient than the MML model and in turn the HCM with SI will be more efficient than the HCM. There are various ways to demonstrate the efficiency of a model (see Abou-Zeid & Ben-Akiva, 2013). We choose to compare the t-statistics of the parameter estimates. If the estimated models are consistent, their parameter estimates should be close to each other; yet the more efficient model will have lower standard errors and higher t- statistics. We can see from the Table 5.3 that the HCM is more efficient, as the t- statistics of the parameter estimates that are common and significant in both models, are higher than those of the MNL model. By comparing the HCM with the HCM with SI, we can see that the differences between the t-statistics of the parameters are not so big. But generally, the t-statistics of the HCM with SI are higher than those of the HCM.

By comparing the efficiency of the structural models of the latent variable *WL* between the HCM and HCM with SI, we conclude that the t-statistics of the parameter estimates of the WL latent variable of the HCM with SI are higher than those of the HCM. Thus the structural model of the WL latent variable in the HCM with SI is more efficient than this in the HCM.

The extended framework, which incorporates social interaction (HCM with SI) leads to enhanced behavioral realism and greater efficiency.

5.6 Conclusions

5.6.1 Summary

The aim of this chapter was to identify how social influence affects teenagers' attitudes towards walking. We started by building our hypothesis based generally on the social influence effect on the decision makers. The findings from previous work that we used as a base were (1) McFadden's (1997) argument that the empirical study of economic behavior would benefit from closer attention to how attitudes and perceptions are formed and how they influence decision making, (2) Weinberg and Pehlivan's (2011) view that there is still a gap between decision making in real life and decision making as measured in the

laboratory, which is often done in the absence of any social influences, and (3) that the individual's decisions are indirectly influenced by their social environment, as it affects the individual's psychological state (van den Bos et al., 2013; Homberg, 2012). In doing so, we presented a general methodology and framework for including the social interaction effect in the HCM (Walker & Ben-Akiva, 2002; Ben-Akiva et al., 2002b)

The proposed method provides insights useful for modeling the effect of social interaction on the formation of psychological factors (latent variables) and on the decision-making process. Thus, the social environment is a latent variable that represents social interaction with the decision maker, and it is included as a component in the formation of the latent variable regarding the decision maker, which in turn is included directly in the choice model.

As an extension to the HCM, the proposed methodology requires the estimation of an integrated multi-equation model consisting of a discrete choice model, the latent variable model's structural and measurement equations regarding the decision maker, and the latent variable model's structural and measurement equations regarding the social environment. The model structure is simultaneously estimated, representing an improvement over sequential methods as it provides consistent and efficient estimates of the parameters. Maximum likelihood techniques are used to estimate the integrated model, whose likelihood function includes complex multi-dimensional integrals (one integral per latent construct). The extended model leads to enhanced behavioral realism and greater efficiency.

The methodology is tested within the context of a household, the aim being to identify the social interaction effects between teenagers and their parents regarding walking-loving behavior, and then the effect of this on mode-to-school choice behavior. The sample consists of 9,714 participants aged from 12 to 18 years old, and only revealed preference data are used. The findings from the case study indicate that, if the teenagers perceive that their parents are walking-lovers, then this increases their probability of loving walking too. The latent variable "Parents: Walking-lovers" is the most statistically significant variable in the formulation of the latent variable "Walking-lover" that refers to the decision maker. Then, the latter latent variable is incorporated directly in the utility of the alternative of walking, and positively and significantly affects the probability of choosing to walk to school. Thus, the findings from the case study are that implementation of the integrated choice, latent variable and latent social interaction model framework results in (1) improvements in the explanatory power of choice models, (2) latent variables that are statistically significant, and (3) a more real-world behavioral representation that includes the social interaction effect (similar to the HCM – see Walker, 2001). Other variables that affect the mode-to-school choice behavior are distance, income, age, gender, vehicle ownership, household size and various built environment characteristics, which are consistent with the findings of other mode-to-school choice behavior surveys (McDonald, 2008; Clifton et al., 2010).

5.6.2 Practical Findings

Due to the fact that it is difficult to collect data from all the members of an individual's social network, we propose that, in order to investigate the social influence effect, researchers should identify how the individual anticipates the behavior of his/her social

environment. The data required to apply this methodology are easier to be collected than collecting data from all the members of an individual's social environment. The main requirement is to include in the questionnaire attitudinal questions regarding the travel behavior of the social environment of the questionnaire participant. Then, these attitudinal questions may be used for the development of latent variables regarding the social environment of the participant.

One more lesson is that this integrated model (as do all HCMs) requires customized programs in order for the researcher to be able to write the source of the model. For example, Python Biogeme[3] allows the estimation of such models. The estimation programs and models tend to be complex, and therefore synthetic data should be used to confirm the program's ability to reproduce the parameters as a matter of routine. Such a test would provide assurance that the model was identified and that the likelihood was programmed correctly, but would not otherwise validate the model specification. Finally, fast computers with a lot of cores are required for the estimation, which is time-consuming. Indicatively, it took 41 days for the proposed model to be estimated on an 8-core machine (number of draws = 1000).

Finally, the discrete choice model has been criticized on the grounds that it is too simplistic to adequately explain model behavior. It can be viewed as a black box mapping observed inputs into observed choices through a function represented by the utility. The actual decision making process involves several stages, such as awareness of opportunities and attributes of alternatives, formation of perceptions and attitudes, and social interaction (McFadden, 1997; Ben-Akiva et al., 2012; Abou-Zeid & Ben-Akiva, 2013). The proposed framework leads to enhanced behavioral realism and greater efficiency and the choice model gains behavioral richness by explaining observed behavior as a function of decision maker's attitudes and social interaction effect.

5.6.3 Limitations and Extensions

Motivated by the fact that we are investigating the factors that affect teenagers' mode choice behavior, we tested the proposed methodology by using data collected directly from them. We justify our choice to use these data by the fact that previous surveys have shown teenagers to be a special age group, who make their own choices despite being underage. However, it is necessary that this model is also tested on adults' mode choice behavior.

The methodology provides researchers with the ability to specify as many latent variables for the social environment as they want. For example, different latent variables could be used for parents, siblings, friends, colleagues etc., each one representing a different social network. Moreover, this could provide insights into which social network affects the behavior of the decision maker the most, as the significance levels and signs of the coefficients could be used to identify tight and loose social networks.

Regarding the implications of this model, it is not necessary for the researcher to know the socioeconomic characteristics of the social environment in order to specify its structural equation. This model could be estimated using just the measurement model for the social

[3] Biogeme is open-source freeware designed for the estimation of discrete choice models. Python Biogeme is a more recent version, allowing the estimation of a wider variety of models. For more information, see: http://biogeme.epfl.ch.

environment. Since we tested the model within the context of a household, all the socioeconomic variables were available in order to specify the structural model. One extension of this model would be to estimate it using the perceptions of teenagers regarding their friends' walking behavior. In this case, we would not know the other characteristics of their friends, making it difficult to specify the structural model. However, as we have said, the model could be estimated using just the measurement model regarding their friends. Below is an example using perceptions that are included in our dataset but which, due to time limitations, could not be estimated for this thesis.

The perceptions that we have in our dataset regarding the participants' friends' walking behavior are presented in Table 5.5. These indicators will be used for the formulation of the latent variable "Friends: Walking-lovers".

Table 5-8: Indicators of latent variable "Friends: Walking-lovers"

		Mean	Std. Dev.
Indicators of Anticipated Variable "Friends: Walking-lovers"			
SI_{FWL1}	My friends really enjoy walking	5.7	1.81
SI_{FWL2}	My friends prefer walking to being escorted	5.4	1.71
SI_{FWL3}	My friends prefer walking in order to get physical exercise	6.0	1.64
SI_{FWL4}	My friends find walking time consuming	3.2	1.89

We keep the model specification as presented in section 5.4.2. In doing so, we have two latent variables regarding the social environment of the teenager: one for their parents and one for their friends. All the equations remain the same, but we add one more latent variable. For the reader's convenience, we present the equations again here briefly.

The utility of choice is given by:

$$U_{WALK} = (\beta_{D1} + \beta_{G1} * FEMALE) * DIST2km + \beta_{A1} * AGE1114 + \beta_{I1} * INCOME + \beta_{G1} * GREEN + \beta_{C1} * CROSS + \gamma * WL + \varepsilon_{WALK} \quad (5.9)$$

$$U_{BUS} = \beta_{BUS} + \beta_{D2} * DIST5km + \varepsilon_{BUS} \quad (5.10)$$

$$U_{CAR} = \beta_{CAR} + (\beta_{D3} + \beta_{G3} * FEMALE) * DIST25km + \beta_{A3} * AGE1114 + \beta_{INC3} * INCOME + \beta_{CHH} * (CARHH / HHSIZE) + \varepsilon_{CAR} \quad (5.11)$$

The structural model of the latent variable regarding parents' walking behavior, where the parents' socioeconomic characteristics are known, remains the same, as follows:

$$PWL = \zeta_{PWL} + \zeta_{CARHH} * (CARHH / NLICENSE) + (\zeta_{INC} + \zeta_{EDH} * EDUHIGH + \zeta_{EDL} * EDULOW) * INCOME * + \eta_{PWL} \quad (5.12)$$

The measurement model of the latent variable "Parents: Walking-lovers" is given by

$$SI_{PWL1} = a'_{P1} + \lambda'_{P1} * FWL + \upsilon'_{P1} \; ; \quad a'_{P1} = 0, \lambda'_{P1} = 1 \quad (5.29)$$

$$SI_{PWL2} = a'_{P2} + \lambda'_{P2} * PWL + \upsilon'_{P2} \quad (5.30)$$

$$SI_{PWL3} = a'_{P3} + \lambda'_{P3} * PWL + \upsilon'_{P3} \quad (5.31)$$

$$SI_{PWL4} = a'_{P4} + \lambda'_{P4} * PWL + \upsilon'_{P4} \quad (5.32)$$

where Eq. (5.29) is normalized by setting the intercept term to 0 and the coefficient of attitude to 1.

As already mentioned above, our dataset does not provide any further information regarding the socioeconomic characteristics of the teenagers' friends. Thus, we do not have a structural equation. We use the four measures presented in Table 5.5 to specify the measurement model of the latent variable "Friends: Walking-lovers" – denoted as *FWL* – as follows:

$$SI_{FWL1} = a'_{F1} + \lambda'_{F1} * FWL + \upsilon'_{F1} \; ; \quad a'_{F1} = 0, \lambda'_{F1} = 1 \quad (5.33)$$

$$SI_{FWL2} = a'_{F2} + \lambda'_{F2} * FWL + \upsilon'_{F2} \quad (5.34)$$

$$SI_{FWL3} = a'_{F3} + \lambda'_{F3} * FWL + \upsilon'_{F3} \quad (5.35)$$

$$SI_{FWL4} = a'_{F4} + \lambda'_{F4} * FWL + \upsilon'_{F4} \quad (5.36)$$

In Eq. (5.33) we normalize the intercept term to 0 and the coefficient of attitude to 1. Thus, the only unknown parameter is FWL. As a result, we have

$$SI_{FWL1} = FWL \quad (5.37)$$

We replace *FWL* by SI_{FWL1} in Eqs. (5.34) to (5.36) as presented below:

$$SI_{FWL2} = a'_{F2} + \lambda'_{F2} * SI_{FWL1} + \upsilon'_{F2} \quad (5.38)$$

$$SI_{FWL3} = a'_{F3} + \lambda'_{F3} * SI_{FWL1} + \upsilon'_{F3} \quad (5.39)$$

$$SI_{FWL4} = a'_{F4} + \lambda'_{F4} * SI_{FWL1} + \upsilon'_{F4} \quad (5.40)$$

Thus, we can estimate the latent variable regarding the teenagers' friends' walking behavior.

The latent variable "Walking-lover" for the decision maker is given by

$$WL = \vartheta_{WL} + \vartheta_{GWL} * FEMALE + \vartheta_{AWL} * AGE11114 + (\vartheta_{ABWL} + \vartheta_{INCWL} * INCOME) * ABROAD + \xi_{PWL} * PWL + \xi_{FWL} * FWL + \omega_{WL}$$

(5.41)

The choice between the alternatives is expressed as follows:

$$y = \begin{cases} 1 & \text{if } U_i \geq U_j \quad \forall j \neq i \\ 0 & \text{otherwise} \end{cases}, \quad i = WALK,\ BUS,\ CAR \quad (5.42)$$

The likelihood of a given observation is the joint probability of observing the choice, the eight indicators of the attitude "Walking-lover", the four indicators of the attitude "Parents: Walking-lovers", and the four indicators of "Friends: Walking-lovers", as shown in Eq. (5.43).

$$f(y, I_{WL}, IS_{PWL}, IS_{FWL} \mid X, S; \delta) =$$

$$\int_{WL} \int_{PWL} \int_{FWL} P(y \mid X, X^*; \beta, \gamma, \Sigma\varepsilon) f(I_{WL} \mid X, WL; \lambda, \Sigma\upsilon)(IS_{PWL} \mid S, PWL; \lambda'_{PWL}, \Sigma\upsilon'_{PWL})(IS_{FWL} \mid IS_{FWL1}; \lambda'_{FWL}, \Sigma\upsilon'_{FWL})$$

$$f(WL \mid X; \vartheta, \xi, \Sigma\omega)(PWL \mid S; \zeta, \Sigma\eta) dFWL\ dPWL\ dWL \quad (5.43)$$

where δ designates the full set of parameters to be estimated ($\delta = \{\beta, \gamma, \lambda, \lambda'_{PWL}, \lambda'_{FWL}\ \theta, \zeta, \xi, \Sigma_{\varepsilon}, \Sigma_{\upsilon}, \Sigma_{\upsilon'PWL}, \Sigma_{\upsilon'FWL}, \Sigma_{\omega}\}$).

Concluding, the proposed modeling framework could be applied, not only in the transportation sector, but also in other sectors where choice behavior and decision making are studied (e.g. marketing).

Chapter 6
The Effect of Built Environment and Weather Conditions on Mode-to-School Choice

The aim of this chapter is to investigate teenagers' mode choice behavior for the trip to school, the effect of actual and perceived built-environment characteristics on walking choice, the impact of weather and the possible differences between three distinct environments (urban, rural and insular). More specifically, a hybrid mode choice model is developed for each area, according to which the utilities of the alternative modes (active transport, public transport, escorted by adults, and driving) depend on the built environment's characteristics, weather conditions, and the teenagers' socio-economic characteristics, as well as on a latent variable referring to perceived built-environment characteristics that capture the walking constraints. The indicators of the latent variable include perceptions regarding the characteristics of the built environment, such as the presence of stray animals, poor lighting, narrow sidewalks, parked cars that obscure visibility, non-signalized intersections, the probability of an attack, and safety en route. The presented case study is based on data collected from Greece in 2011-2012, the waves consisting of 1,988 high school students aged from 12 to 18 years old.

This chapter is organized as follows. Section 6.1 presents the general model framework. Section 6.2 describes the characteristics of the sample used for estimation of the models. Section 6.3 gives the model specification. Section 6.4 shows the model estimation results, while Section 6.5 presents the goodness-of-fit tests of the model. Section 6.6 concludes.

6.1 Modeling Framework

The general model framework proposed in this chapter is an application of the Hybrid Choice Model. We construct an HCM setting in which we take perceptual indicators (I) and then define the latent variable (X^*), which enters directly into the choice process. The explanatory variables (X) are actual characteristics such as socio-economic and actual built-environment characteristics. The utility obtained by choosing a particular mode is a function of the explanatory variables, the latent variable, and the actual characteristics of the built environment. The utility is measured by the choice indicator (y). The general modeling framework is presented in Figure 6.1, where the ovals represent the latent variables, the rectangular boxes the observable variables, the dashed arrows the measurement equations and the solid arrows the structural equations.

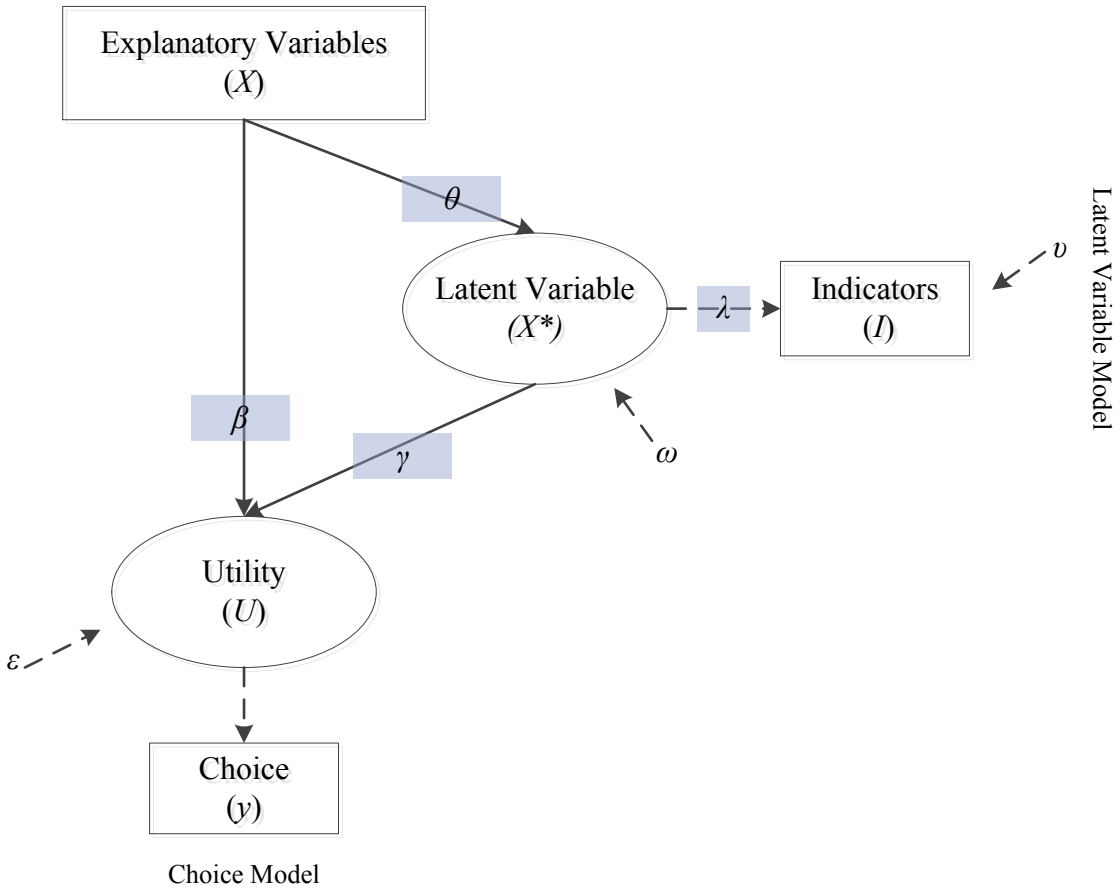


Figure 6.1: General model framework

The mathematical formulations for modeling the latent variable are given in the equations below (see Walker & Ben-Akiva, 2002).

In the latent variable model, we have the structural model (6.1) and the measurement model (6.2), as follows:

$$X^* = X_1\theta + \sigma\omega \qquad \omega \sim N(0,\Sigma_\omega) \qquad (6.1)$$

where X^* is the latent (unobservable) variable, X_1 are explanatory observed variables, θ is a vector of unknown parameters used to describe the effect of observable variables on the latent variables, ω is a vector of random disturbance terms, while Σ_ω designates the covariance of random disturbance terms.

$$I = \alpha + \lambda X^* + \upsilon \qquad \upsilon \sim N(0,\Sigma_\upsilon) \quad (6.2)$$

where I is a vector of perceptions, α is a vector of unknown parameters that indicates the associations between the responses to the scale, λ are vectors of unknown parameters that relate the latent variable to the indicators, υ is a vector of random error terms, and Σ_υ designates the covariance of the random disturbance terms.

The choice between the alternative modes is assumed to be based on maximizing one's utility. The choice model is expressed as follows:

$$U = X_2\beta + \gamma X^* + \varepsilon \qquad \varepsilon \sim N(0,\Sigma_\varepsilon) \qquad (6.3)$$

$$y_i = \begin{cases} 1, & \text{if } U_i \geq U_j \quad \forall j \neq i \\ 0, & \text{otherwise} \end{cases}, \quad i = 1,...,J \tag{6.4}$$

where U is a vector of utilities of all alternatives, X_2 comprises matrices of explanatory variables, β is a vector of unknown parameters associated with X_2, γ is a diagonal matrix of unknown parameters associated with the latent variable X^*, ε is vector of random disturbance terms associated with the utility terms, and Σ_ε designates the covariance of random disturbance terms. y_i is a choice indicator, taking the value 1 if mode i is chosen, and 0 otherwise.

The likelihood function for a given observation is the joint probability of observing the choice and the attitudinal indicators, as follows:

$$f(y_i, I \mid X; \delta) = \int_{X^*} P(y_i \mid X_2, X^*; \beta, \gamma, \Sigma_\varepsilon) f_{I_{WCon}}(I \mid X^*; \lambda, \Sigma_\upsilon) f(X^* \mid X_1; \vartheta, \Sigma_\omega) dX^* \tag{6.5}$$

where term δ designates the full set of parameters to estimate ($\delta=\{\beta, \gamma, \lambda, \theta, \Sigma_\varepsilon, \Sigma_\upsilon, \Sigma_\omega\}$), and X represents the observable variables X_1 and X_2. The first term of the integral corresponds to the choice model. The second term corresponds to the measurement equation of the latent variable model, while the third term corresponds to the structural equation of the latent variable model. The latent variable is only known to its distribution, and so the joint probability of y, I, and X^* is integrated over the vector of latent constructs X^*.

6.2 Data

For the purposes of this chapter, we use the data that were collected in Greece from September 2010 to May 2012 (school years 2010-2011 and 2011-2012). We did not use the data from the third wave (2012-2013) of the survey, as we have not coded the built-environment characteristics of teenagers' routes. The data were collected from three different environments, the characteristics of which are presented in Section 3.1.2. Ten public high-schools from the greater Athens area (urban area), seven high-schools in Alexandroupolis (a rural border city) and eight high-schools in Chios (insular area) participated.

The characteristics of the participants from each area are presented in Table 6.1. The total sample consists of 1,988 students at public high-schools, aged between 12 and 18 years old. 36% of the participants live in the urban area, 29% in the rural area and 35% in the insular area. The average age is 15.7 years old, and 52% are girls. The average number of trips in a typical school day is 4.5, and 17 different travel patterns were identified for the trip to school, with the majority of the participants conducting a simple trip from home to school and back again (HSH). The main transport mode for this type of trip is walking, with 40% of the participants walking from home to school and back again; only 3% cycle. Of those who are pedestrians, 56% walk to school with their peers. The maximum distance walked is 1.6km for the students from the urban area, 2.0km for those from the rural area and 1.0km for the insular area.

Table 6-1: Socio-economic characteristics of the sample

		Urban Area N= 716obs	Rural Area N=576obs	Insular Area N=696obs
Gender	Male (value 0)	44%	52%	49%
	Female (value 1)	56%	48%	51%
Age	(Mean)	16.4	15.0	15.6
Income	Less than €2000	44%	64%	31%
	€2000-4000	35%	46%	45%
	more than €4000	21%	37%	24%
Car ownership	(Mean)	2.3	1.7	1.8
Motorcycle ownership	(Mean)	0.9	0.7	1.4
Number of siblings	(Mean)	1.7	1.4	1.3
Mode to school (the mode that they used the day before they participated in the survey in order to go to school)	Walk	36%	50%	34%
	Cycle	2%	4%	2%
	Public transport	30%	12%	20%
	Drivers	3%	4%	13%
	Escorted by parents	29%	30%	31%
Knowledge of traffic code*	Yes	63%	45%	63%
Time period in which the survey took place	December to March (cold weather)	68%	76%**	49%
	September to November and April to May (mild weather)	32%	24%	51%

* The participants were requested to indicate whether they knew the Traffic Code. Afterwards, pictures of traffic regulations and give-way rules that apply at intersections and driveways were presented, requiring the student to choose the road user who had priority. Those who answered that they knew the Traffic Code (perceived knowledge) and also gave the right answers to the questions (actual knowledge) were recorded as being cognizant of the Traffic Code.

** It is worth mentioning that in the week when this survey took place, the highest temperature was -6°C and the lowest was -17°C. Despite the bad weather conditions, the majority of the participants still walked to school.

Table 6.2 presents the characteristics of the built environment along the route between home and school. Since the actual built-environment characteristics of the cities were not available from any other source, we examined carefully each individual's route between home and school and, by using GIS, coded the built-environment characteristics. The route characteristics in the urban area differ greatly from those in the rural and insular areas. Only 6% of the urban adolescents face poor road conditions (potholes in roads and sidewalks) on their way to school. In the urban area, no parts of the route to school are without sidewalks, while 27% of the insular adolescents were found to follow a route at least part of which has no sidewalks. 40% of the urban students follow a route with wide sidewalks, while only 9% of the insular students follow a route with this characteristic. The characteristics presented in this table are the actual characteristics of the built environment and are used in the development of the latent variables and the mode choice models below.

Table 6-2: Actual characteristics of the built environment of the route between home and school

	Urban Area N=716	Rural Area N=576	Insular Area N=696
BUILT-ENVIRONMENT RELATED ISSUES			
Poor condition of road network (potholes in roads and sidewalks)	6%	36%	41%
Traffic lights at major roads or intersections	78%	28%	18%
Part of route has no sidewalks	0%	3%	27%
More than 50% of the route has wide sidewalks	28%	40%	9%
Aesthetics (existence of greenery/trees, flowers)	3%	17%	20%

The participants were requested to indicate their level of agreement or disagreement with various statements regarding the walkability constraints of the built environment that they perceive in their route from home to school. These statements are used as indicators of the latent variable *WalkCon*. The response scale ranged from 1 to 7, with a response of 1 indicating that the participant completely disagreed with the statement, and 7 indicating that they completely agreed. The urban adolescents showed a high level of agreement with the statements about parked cars obscuring their visibility and the possibility of being attacked en route. The insular participants agreed somewhat with the statement that lack of sidewalks is a constraint on the choice of walking, while both the rural and insular students agreed that poor lighting is a constraint on the choice of walking.

Table 6-3: Indicators of the latent variable "Walkability Constraints"

Indicators of latent variable "Walkability Constraints"							
		Urban		Rural		Insular	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
I_{WCON1}	When I walk, I am afraid of stray animals	2.0	1.946	3.7	2.251	3.1	2.360
I_{WCON2}	While I walk, I feel that there is a possibility of attack	5.6	1.508	3.6	2.193	3.1	2.241
I_{WCON3}	The lighting along my walking route is poor	2.7	1.287	4.8	2.280	4.9	2.326
I_{WCON4}	There are no sidewalks along my walking routes	1.8	0.964	3.4	2.163	4.4	2.135
I_{WCON5}	There are no traffic lights at the main crossroads	2.0	1.347	3.2	2.168	3.9	2.433
I_{WCON6}	There are parked cars that obscure my visibility	5.2	2.129	2.9	2.152	3.7	1.893
7-Likert scale: 1=Completely disagree, ..., 7= Completely agree							

6.3 Model Specification

This section presents the model specification. Based on the literature review presented in Chapter 2, we hypothesize that the built-environment characteristics of the route between home and school and the socio-economic characteristics of the teenagers affect their mode choice behavior. But taking into account the fact that each individual anticipates the built-environment characteristics in a different way (sense of place; see Deutch and Goulias, 2009), we define a latent variable, namely "Walkability Constraints", which reflects the way each individual perceives the built-environment characteristics. This latent variable

incorporates indicators/perceptions about sidewalks, parked cars that obscure visibility, non-signalized intersections, the presence of stray animals, poor lighting, the probability of attack, and safety en route. The latent variable is also affected by the individual's socio-economic characteristics and the actual built-environment characteristics. Then, by developing an HCM, we ensure that the latent variable enters directly into the mode choice process.

The hybrid model setting that we considered is given in Figure 6.2, in which the complete set of structural and measurement equations is sketched, depicting the relationships between explanatory variables and each partial model. The detailed equations will be presented in the subsections below. In effect, we can distinguish the choice model, which is centered on the utility function [Eq. (6.6) to Eq. (6.9) below] and on the stated choice (Eq. 6.11); the latent variables structural model (Eq. 6.10); and the latent variables measurement model [Eq. (6.12) to Eq. (6.17)] linking the *WalkCon* with the indicators $I_{WalkCon}$.

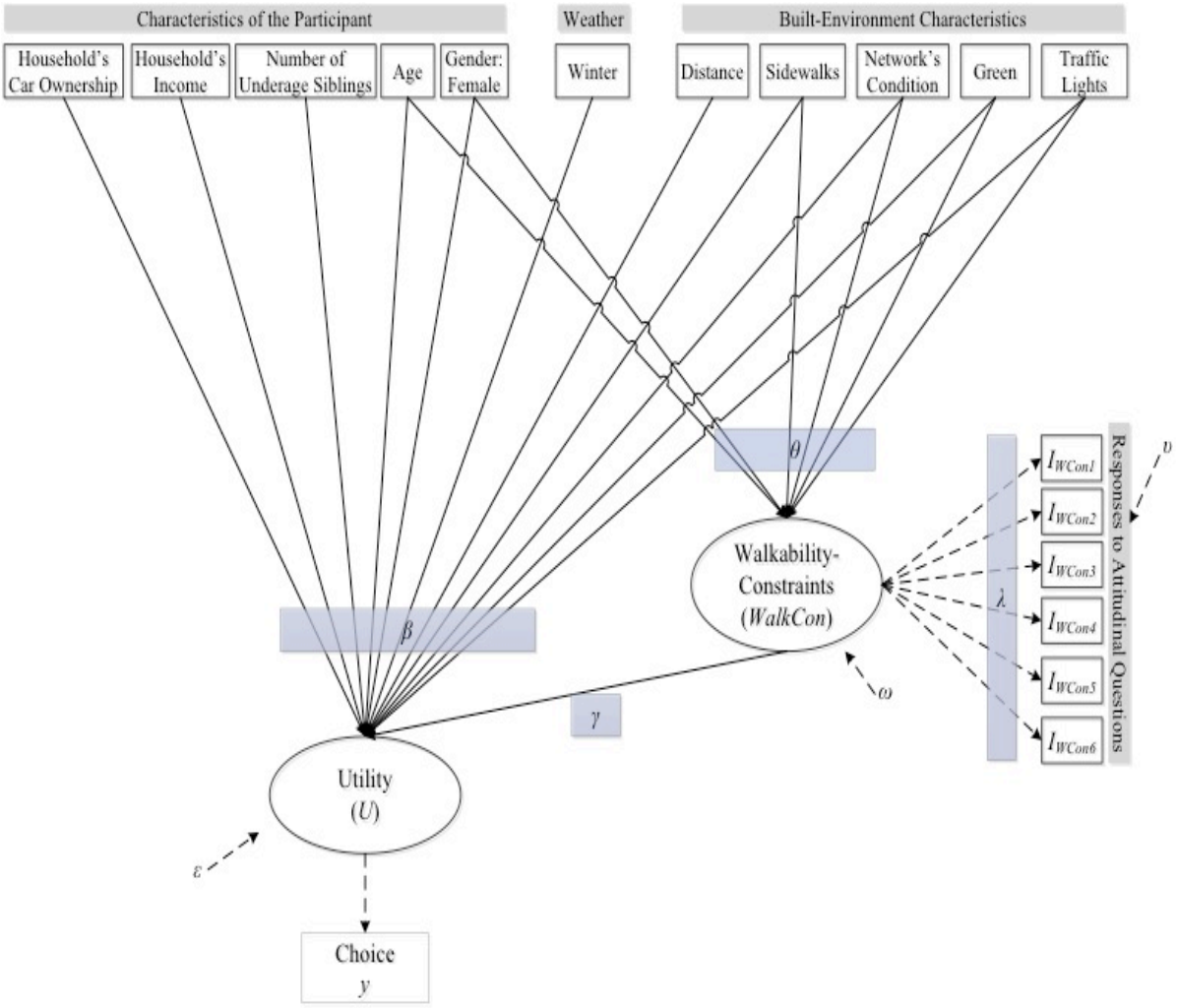


Figure 6.2: Model Structure

6.3.1 Structural Model

With the aim of investigating the effect of perceived and actual built-environment characteristics on teenagers' mode choice behavior and the differences across the three environments, we develop one mode choice model for each area. The alternatives are:

1. Active transport (*ACT*) => representing walking and cycling to school;
2. Public transport (*PT*) => representing mainly the public buses, as no school buses serve the schools that participated in our survey. Only private schools offer school-bus services in Greece;
3. Driver of motorized vehicles (*DRIVER*) => representing those who drive a PTW, as no participant stated that he/she drives a car for the trip to school;
4. Escorted (*ESC*) => representing those who are escorted to school by adults by private motorized modes. The adults who escort the participants are mainly their parents.

Because only a small percentage of the participants were found to cycle to school, we merged the walking and cycling options into one, namely active transport (*ACT*). We carefully examined and filtered the sample, in order to place constraints on the options available to certain students. For example, the option ASC was not available to students living more than 2.0 km away from their school. Similarly, to those living less than 100m from their school, the option *PT* was not available. The *ESC* option was available to all participants, as all the households owned at least one car or motorcycle and all households had at least one driver. The availability of parents to escort their children has not been checked, as there is no such information in the dataset. However, even if this information were available, we would not use it as a constraint, since the students could be escorted by other relatives or by the parents/caregivers of their co-students. We set no limits on the *DRIVER* option, having determined that some students drive motorcycles without possessing a driving license (72% of the drivers in the insular area drive unlicensed). Any availability constraint placed on *DRIVER* depended on whether or not the household owned at least one PTW vehicle.

First of all, for purposes of comparison, we estimated a multinomial logit model (MNL). At the same time, we postulated that the latent variable *WalkCon*, which reflects the perceived constraints of the built environment on the use of active transport, has a significant impact on mode choice. Specifically, we assumed that the latent variable would decrease the probability of choosing active transport (walking or cycling) and increase the probability of choosing the option *ESC*. With these factors in mind, we incorporated the latent variable *WalkCon* into the utilities of the *ACT* and *ESC* alternatives in the MNL model.

The utility of choice is a function of socio-economic and built-environment characteristics, the latent variable, and alternative specific constants for the alternatives *ACT*, *DRIVER* and *ESC*. The variable distance is interacted with income and weather variables to enable us to better interpret the estimation results. For example, distance is interacted with income, as it could be hypothesized that households with higher incomes would choose to reside near their children's school. On the other hand, it might be surmised that families with higher incomes usually live in suburban areas, and that therefore their children would not have the option of walking to school. Also, distance is interacted with weather in order to check the effect of weather on the distance travelled. The utility specification also contains the effect

of the latent variable *WalkCon*. The latent variable was not considered for the *PT* and *DRIVER* alternatives. The equation for the choice model is given below:

$$ACT = \beta_{ACT} + \beta_{GEN1} * FEMALE + \beta_{AGE1} * AGE + (\beta_{D1} + \beta_{INC1} * INCOME + \beta_{W1} * WINTER) * DISTANCE + \beta_{*WS} * WIDESIDEWALK + \beta_{NC} * NETWORKCONDITION + \beta_{TL} * TRAFFICLIGHTS + \beta_{GR} * GREEN + \gamma_{WC1} * WalkCon + \varepsilon_{ACT} \quad (6.6)$$

$$PT = \beta_{PT} + \varepsilon_{PT} \quad (6.7)$$

$$DRIVER = (\beta_{D3} + \beta_{INC3} * INCOME) * DISTANCE + \beta_{GEN} * FEMALE + \beta_{AGE3} * AGE + \varepsilon_{DRIVER} \quad (6.8)$$

$$ESC = \beta_{ESC} + \beta_{GEN4} * FEMALE + \beta_{AGE4} * AGE + (\beta_{DIST4} + \beta_{INC4} * INCOME) * DISTANCE + \beta_{CARH} * CAROWNERSHIP + \beta_{SIB} * SIBLINGS + \gamma_{W4} * WalkCon + \varepsilon_{ESC} \quad (6.9)$$

where:

FEMALE takes the value 1 if the participant is female, 0 otherwise;

AGE = the age of the participant (min. value = 12 years old, max. value =18 years old);

INCOME = the monthly family income in Euros (continuous variable);

DISTANCE = the distance between home and school (continuous variable);

WINTER takes the value 1 if the survey took place during the winter (December to March), 0 otherwise;

CAROWNERSHIP = the number of cars in the household (continuous variable);

SIBLINGS = number of siblings who are underage students (continuous variable);

WIDESIDEWALK takes the value 1 if at least 50% of the route from home to school has wide sidewalks, 0 otherwise;

NETWORKCONDITION takes the value 1 if the condition of the sidewalk network is good, 0 otherwise;

TRAFFICLIGHTS takes the value 1 if there are traffic lights at the major intersections or roads along the route from home to school, 0 otherwise;

GREEN takes the value 1 if there are trees, flowers or parks on the route from home to school, 0 otherwise;

WalkCon = latent variable "walkability constraints". A lower value indicates that the individual is more likely to choose active transport;

ε_{ACT} , ε_{PT}, ε_{DRIVER}, ε_{ESC} are vectors of error terms.

The perception of "walkability constraints" is modeled as a function of the socio-economic and built-environment characteristics. The structural equation links teenagers' characteristics with the latent variables through a linear regression equation based on the individual's gender, grades, pocket money, parents' level of education, parents' mode use patterns, household income and the characteristics of the built environment on the route

from home to school. The equation is:

$$WalkCon = \theta_{WalkCon} + \theta_{GEN} * FEMALE + \theta_{AGE} * AGE + \theta_{WSK} * WIDESIDEWALK + \theta_{NC} * NETWORKCONDITION + \theta_{G} * GREEN + \theta_{TL} * TLIGHTS + \theta_{TC} * TC + \sigma_{WalkCon}\omega \quad (6.10)$$

where:
TC takes the value 1 if the student gave the right answers to the questions about traffic regulations, 0 otherwise;
ω is a random error term.

6.3.2 Measurement Model

The choice between the alternatives is assumed to be based on utility maximization and is expressed as follows:

$$y_i = \begin{cases} 1, & \text{if } U_i \geq U_j \quad \forall j \neq i \\ 0, & \text{otherwise} \end{cases}, \quad i = ASC, PT, DRIVER, ESC \quad (6.11)$$

where y_i is the choice indicator taking the value 1 if alternative *i* is chosen, 0 otherwise.

Six measures are used as indicators of the "Walkability Constraints" perception as shown in Equations (6.12) to (6.17) below. The first equation is normalized by setting the intercept term to 0 and the coefficient of the perception to 1. The indicators are specified as continuous variables for simplicity.

$$I_{WCon1} = \alpha_1 + \lambda_1 WalkCon + \upsilon_1 \quad ; \; a_1 = 0, \; \lambda_1 = 1 \quad (6.12)$$

$$I_{WCon2} = \alpha_2 + \lambda_2 WalkCon + \upsilon_2 \quad (6.13)$$

$$I_{WCon3} = \alpha_3 + \lambda_3 WalkCon + \upsilon_3 \quad (6.14)$$

$$I_{WCon1} = \alpha_3 + \lambda_4 WalkCon + \upsilon_4 \quad (6.15)$$

$$I_{WCon5} = \alpha_5 + \lambda_5 WalkCon + \upsilon_5 \quad (6.16)$$

$$I_{WCon6} = \alpha_6 + \lambda_6 WalkCon + \upsilon_6 \quad (6.17)$$

where:
I_{WCon1}, I_{WCon2}, I_{WCon3}, I_{WCon4}, I_{WCon5}, I_{WCon6} are the responses to the perceptual questions presented in Table 6.3. α_1, α_2, α_3, α_4, α_5, α_6, λ_1, λ_2, λ_3, λ_4, λ_5, λ_6, $\sigma_{\upsilon 1}$, $\sigma_{\upsilon 2}$, $\sigma_{\upsilon 3}$, $\sigma_{\upsilon 4}$, $\sigma_{\upsilon 5}$, $\sigma_{\upsilon 6}$ are unknown parameters.

$\upsilon_1, \upsilon_2, \upsilon_3, \upsilon_4, \upsilon_5, \upsilon_6$ are random error terms with covariance $\upsilon_1 \sim N(0,\sigma^2_{\upsilon_1})$, $\upsilon_2 \sim N(0,\sigma^2_{\upsilon_2})$, $\upsilon_3 \sim N(0,\sigma^2_{\upsilon_3})$, $\upsilon_4 \sim N(0,\sigma^2_{\upsilon_4})$, $\upsilon_5 \sim N(0,\sigma^2_{\upsilon_5})$, $\upsilon_6 \sim N(0,\sigma^2_{\upsilon 6})$.

6.3.3 Likelihood Function

The likelihood of a given observation is the joint probability of observing the choice and the six indicators of the latent variable "Walkability Constraints" (*WalkCon*).

$$f(y_i, I_{WCON} \mid X;\delta) =$$

$$\int_{WalkCon} P(y_i \mid X_2, WalkCon;\beta,\gamma,\Sigma_\varepsilon) f_{I_{WCon}}(I_{WCON} \mid WalkCon;\lambda,\Sigma_\upsilon) f_{WalkCon}(WalkCon \mid X_1;\vartheta,\Sigma_\omega) dWalkCon \tag{6.18}$$

where term δ designates the full set of parameters to estimate ($\delta=\{\beta, \gamma, \lambda, \theta, \Sigma_\varepsilon, \Sigma_\upsilon, \Sigma_\omega\}$). The first term of the integral corresponds to the choice model. The second term corresponds to the measurement equation of the latent variable model, while the third term corresponds to the structural equation of the latent variable model. The latent variable is only known to its distribution, and so the joint probability of y, I_{WCon}, and *WalkCon* is integrated over the vector of latent constructs *WalkCon*.

6.4 Model Estimation Results

6.4.1 Mode Choice Model Estimation Results

This section presents and discusses the estimation results of the choice model (Table 5). As explained above, we estimated an MNL model and then an MNL with the *WalkCon* latent variable. The models were estimated using the Pythonbiogeme 2.3 software (see Bierlaire, 2003).

Table 6-4: Mode Choice Model Estimation Results

	Urban Area		Rural Area		Insular Area	
	Coef.	**t-stat.**	**Coef.**	**t-stat.**	**Coef.**	**t-stat.**
β_{ACT}	8.23	2.28	8.05	2.58	2.28	2.02
β_{PT}	12.7	4.20	*-0.29*	*-0.43*	7.43	2.92
β_{ESC}	3.59	1.08	3.63	2.73	7.20	3.11
Socio-economic						
Female - specific to ACT	-2.67	-2.81	*-1.08*	*-1.33*	*-0.83*	*-1.08*
Female - specific to DRIVE	-2.6	-3.36	-1.72	-2.65	-0.97	-2.96
Female - specific to ESC	2.22	5.25	0.94	2.30	*0.15*	*0.61*
Age - specific to ACT	0.44	2.77	0.38	1.98	1.07	2.37
Age - specific to DRIVER	0.50	3.53	*0.14*	*0.81*	0.75	4.36
Age - specific to ESC	-0.36	-3.92	-0.78	-2.65	*0.10*	*0.73*
Income - specific to ACT	*-0.15*	*-0.47*	-0.22	-1.28	-0.84	-2.25
Income - specific to DRIVE	1.32	3.80	*0.33*	*1.24*	0.27	2.97
Income - specific to ESC	3.46	10.66	-0.25	-2.46	0.08	1.16
Household Car Ownership - specific to ESC	1.00	4.04	0.85	3.38	1.08	7.54
Number of siblings who are students (<18 years old) specific to ESC	0.20	4.09	-0.34	-2.21	-0.30	-2.24
Built Environment Characteristics						
DISTANCE specific to ACT	-1.26	-7.40	-2.56	-8.22	-4.03	-5.71
DISTANCE specific to DRIVE	*-0.12*	*-1.31*	-0.46	-3.19	-0.76	-8.31
DISTANCE specific to ESC	0.33	4.76	-0.49	-5.84	-0.41	-6.09
WIDE SIDEWALKS specific to ACT	4.55	3.55	2.14	2.56	*0.54*	*0.57*
Road & sidewalk condition (1=good, 0=otherwise) specific to ACT	*0.48*	*0.39*	1.92	2.53	2.07	2.28
Existence of trees/flowers – aesthetics (1=yes, 0= otherwise)	1.28	2.30	1.91	2.36	3.78	3.71
Existence of traffic lights at major intersections/roads (1=yes, 0=otherwise) specific to ACT	4.02	4.03	*0.19*	*0.26*	*1.38*	*1.21*
WINTER specific to ACT	-0.72	-2.4	0.65	1.96	-0.34	-1.99
Latent Variable						
WalkCon (specific to ACT)	-0.52	-2.28	-091	-2.69	-1.63	-2.39
WalkCon (specific to ESC)	0.85	10.09	0.52	3.26	0.51	4.82
Number of observations		716		576		696
Number of draws		1000		1000		1000
$\bar{\rho}^2$		0.425		0.492		0.479

Females in the urban area seem to walk/cycle less, preferring to be escorted to school by their parents. These results are consistent with those of previous surveys, such as Larsen et al. (2009). Although the sign of the female variable is negative for the rural and insular

areas, the variables are not statistically significant at 95% level of confidence, indicating that there are minor differences between males and females in these areas. The possibility of driving to school increases for males of all three areas. As teenagers grow up they prefer active transport, while the possibility of being escorted decreases significantly for urban and rural teenagers. This result reflects the fact that teenagers tend to conduct more independent (unsupervised) trips while approaching the age of 18.

As income increases, the probability of choosing active transport decreases, but this variable is significant only for insular areas. Also, income affects positively the choice of driving a motorcycle for their trip to school. Teenagers from urban and insular households with higher incomes prefer being escorted to school, while the negative sign of this variable for the rural teenagers indicates a negative impact on this choice. Taking into account the fact that the average income of the examined rural area is quite low and homogeneous across the population, as the majority of the residents are public servants, this result sounds logical. On the other hand, in the other two areas studied there are residents with various types of occupation; thus income varies significantly across the population. As the number of underage siblings increases, participants in the urban area tend to be escorted to school by their parents, while in the rural and insular areas this circumstance affects this choice negatively. This means that, when parents in urban areas have more than one child who is a school-student, they tend to escort their children to school.

Regarding the characteristics of the built environment, distance plays the most significant role in mode-to-school choice, a fact that other surveys have verified as well (McMillan, 2007; Schlossberg et al., 2006). Distance affects negatively the choice of driving to school, indicating that drivers do not make long-distance trips. The maximum distance that participants cover on their motorcycles is 3.1km in insular areas, 2.8 in rural areas and 1.6 in urban areas (almost half compared to insular areas). The variable distance is interacted with income, in order to explain more clearly the location of the wealthy households. Generally the results for the urban and insular areas confirm that, as both distance and income increase, teenagers prefer to be escorted to school, preferring neither active transport nor motorcycles. This finding reflects the fact that households with high incomes choose to live in areas that may be more prestigious, despite not having a school nearby. At this point it is worth recalling the fact that all the participants in the survey go to public schools. In contrast, the negative sign of income for the rural teenagers indicates that, although in their case the income and distance increase, they do not prefer to be escorted to school. Once again, this result reflects the homogeneity in income among the residents of the rural area, the fact that in this city there are no prestigious areas to live in, and the additional fact that all the high-schools are situated in one specific location, close to each other.

The existence of wide sidewalks affects significantly the choice of active transport in urban and rural areas, while in the insular area this variable is statistically significant at 90% level. When the condition of roads and sidewalks is good, teenagers in rural and insular areas tend to prefer more active transport. However, this variable is not statistically significant at 95% level for teenagers in urban areas because there the road and sidewalk network is in better condition, with few sidewalks and roads containing potholes and obstacles. The existence of traffic lights at major intersections is significant for the choice of active transport in urban areas, while this variable does not affect this choice significantly in rural and insular areas. As the urban area is more congested and its traffic flows are higher, especially in the morning during the commute to school, traffic lights are

necessary for walking or cycling to school safely. As far as the aesthetics of the route between home and school are concerned, the existence of trees and flowers increases significantly the possibility of active transport in all areas. Bad weather (WINTER) affects significantly and negatively the choice of active transport in urban and insular areas only. These areas usually have a mild climate, so the inhabitants are not used to worsening weather conditions. As a result, they cannot stand walking in bad weather but prefer private motorized vehicles. However, this variable is not statistically significant for the rural area, as the weather in winter is usually bad and residents are used to it. Worsening weather conditions do not cause significant changes in their daily activities.

Unsurprisingly, the incorporation of the latent variable improved the explanatory power of the model, providing insights about perceived urban characteristics. The *WalkCon* enters significantly into the choice model specification. Thus, the latent variable discourages the choice of walking and cycling (*WalkCon*) to school in all areas through a negative impact on the choice of this alternative. Also, the latent variable has a positive effect on the choice of car, indicating that individuals who face walkability constraints prefer to be escorted to school by their parents. *WalkCon* has the highest effect on ESC choice in the urban area, indicating that walkability constraints affect the choice of ESC more in the urban area than in rural and insular areas.

6.4.2 Structural Model and Measurement Model Estimation Results

Table 6 presents the estimation results of the structural model. All variables used in the structural model are statistically significant at the 95% level, but some of them affect the latent variable in different ways. Females from all areas perceive the walkability constraints more strongly than males. As teenagers grow up and reach the age of 18 they tend to perceive the walkability constraints less, especially in rural and urban areas. Knowledge of the Traffic Code has a negative sign for all three areas, indicating that when teenagers know how to stay safe as road users the perceived walkability constraints decrease.

Regarding the built-environment characteristics, the existence of wide sidewalks affects significantly and negatively the perceived walkability constraints in urban and insular areas, while in rural areas this variable is statistically significant at 90% level. When the condition of roads and sidewalks is good, teenagers in rural and insular areas tend to perceive walkability constraints to a lesser extent. However, this variable is not statistically significant at 95% level for teenagers in the urban area due to the fact that in urban areas the road and sidewalk network is in better condition and there are few sidewalks and roads containing potholes and obstacles. The presence of traffic lights at major intersections affects significantly the latent variable in the urban area, while this variable does not affect this choice significantly in rural and insular areas. As the urban area is more congested and its traffic flows are higher, especially in the morning during the journey to school, traffic lights are necessary for walking or cycling to school safely. As regards the aesthetics of the route between home and school, the existence of trees and flowers reduces significantly the perceived walkability constraints in urban area.

Table 6-5: Structural Model Estimation Results

	Urban Area		Rural Area		Insular Area	
Structural Model						
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
$\theta_{WalkCon}$	5.46	7.05	4.85	13.19	3.36	10.09
$\sigma_{WalkCon}$	2.38	15.25	1.27	8.30	1.23	6.71
Female	0.64	3.29	1.10	8.34	0.43	4.12
Age	-0.17	-3.62	-0.12	-5.22	-0.25	-5.78
Knowledge of traffic code (1=yes, 0=otherwise)	-0.94	-4.86	-0.40	-3.48	-0.11	-1.96
Wide sidewalks (1=yes, 0= otherwise)	-0.48	-2.36	0.83	-1.64	-0.39	-3.07
Road & sidewalk condition (1=good, 0=otherwise)	-3.24	-1.58	-0.71	-8.20	-0.31	-2.83
Existence of trees/flowers – aesthetics (1=yes, 0= otherwise)	-0.22	-1.68	-0.56	-4.09	-0.44	-3.76
Existence of traffic lights at major intersections/roads (1=yes, 0=otherwise)	-0.53	-2.57	-0.18	-1.46	-0.15	-1.37
Measurement Model						
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
α_1	0	-	0	-	0	-
α_2	0.36	6.18	0.69	1.96	0.20	0.9
α_3	0.03	0.72	0.47	2.12	0.40	2.61
α_4	0.33	5.62	0.37	2.75	0.216	2.85
α_5	0.21	4.2	0.31	1.46	0.38	1.59
α_6	0.20	3.0	0.52	2.45	0.32	1.42
λ_1	1	-	1	-	1	-
λ_2	0.95	56.5	1.22	19.49	1.22	16.12
λ_3	0.97	78.21	1.24	18.8	1.43	17.12
λ_4	0.96	56.98	1.08	17.15	1.32	15.76
λ_5	0.96	66.19	1.09	17.32	1.39	17.54
λ_6	0.92	47.15	1.15	18.26	1.31	17.51
σ_1	0.63	26.19	1.62	31.11	1.90	35.84
σ_2	0.98	32.74	1.09	24.58	1.44	33.42
σ_3	0.60	25.65	1.2	26.48	1.18	29.43
σ_4	0.99	33.71	1.35	29.04	1.59	33.75
σ_5	0.79	30.58	1.34	28.45	0.88	25.05
σ_6	1.21	34.43	1.19	27.22	0.90	26.42

6.5 Model Performance

In this section we compare the results of the MNL model and the MNL model with the latent variable *WalkCon* in order to assess the goodness-of-fit of the estimated model. To compare the estimated models and their goodness-of-fit, we use the choice likelihood and the values for the $\bar{\rho}^2$. Table 6.6 presents the results for all three models.

Table 6-6: Goodness-of-fit

	MNL	MNL with Latent
Urban area		
Number of observations	716	716
$\bar{\rho}^2$	0.327	0.425
Rural area		
Number of observations	576	576
$\bar{\rho}^2$	0.365	0.492
Insular area		
Number of observations	676	696
$\bar{\rho}^2$	0.348	0.479

The incorporation of the latent variable in the utility of the model significantly improved the goodness-of-fit of the choice model. Note that some of this improvement in fit could probably be captured in the choice model by including in the base choice model the additional variables that are included in the latent variable structural model. The $\bar{\rho}^2$ for the model with latent attributes uses a degree-of-freedom correction involving one variable (for the satisfaction latent variable) beyond those used in the model without the latent variable, and thus this degree-of-freedom adjustment only accounts for the estimated parameters of the choice model.

6.6 Conclusions

The aim of this chapter was to investigate the effect of teenagers' perceptions of walkability constraints and actual built-environment characteristics on mode-to-school choice behavior across an urban, a rural and an insular area.

By using data collected directly from teenagers, we developed and applied an HCM to explain the effect of actual built-environment characteristics and perceived walkability constraints in a mode choice context. The HCM offers an attractive improvement in modeling mode choice behavior, due to the fact that the choice model is only part of the whole behavioral process in which we incorporate individuals' perceptions, thus yielding a more realistic model. The latent variable (*WalkCon*) enriched the choice model and provides insights into the importance of unobservable individual specific variables in modal choice, indicating that this type of model is a powerful tool for improving our understanding of travel behavior.

In general, our results indicate that each urban environment has its own characteristics which affect mode choice. The model for urban adolescents is consistent with the results of previous surveys that also took place in urban areas, such as Mitra and Buliung (2012) and Grow et al. (2008); however, individuals in rural and insular areas exhibit different behaviors. The results confirm that distance plays the most significant role in mode-to-school choice for all three areas. The presence of wide pavements, flowers/trees and traffic lights at major intersections affects positively the choice of active transport to school; hence the first two characteristics are more significant for adolescents in rural and urban areas, while the last is more important for high-school students in the urban area. Bad weather

conditions decrease the probability of choosing active transport, but this variable is not significant for rural areas.

The results of the HCM showed that teenagers' attitude towards walkability constraints is very important and significant, ensuring that unobservable variables which affect how individuals perceive the built-environment characteristics should be incorporated into the choice process in order to produce more realistic econometric models and, therefore, to implement better "cut and tailored" policies. According to our expectations, the latent variable *WalkCon* works against walking and cycling (active transportation), while affecting positively the choice of being escorted by parents.

The results of the structural model indicate that teenagers perceive the various characteristics and constraints of the built environment in different ways. The most significant walkability constraint for urban teenagers seems to be the safety issue, while for rural and insular ones it is the absence of sidewalks, along with poor lighting.

Chapter 7
Conclusion

Understanding the travel behavior of adolescents and their related factors is one of the key elements for promoting travel pattern transition in society and predicting future travel behavior. Adolescents are in the initial stages of adopting new travel patterns and developing habits, and hence they are still open to change. Nevertheless, when adolescents become increasingly car reliant, they become less responsive to policies that encourage car use reduction. Interventions at this age could develop the desired travel behaviors, which are not car-oriented, but active transport-oriented. That is the main objective of this thesis; to identify the factors that affect teenagers travel behavior and propose policies to promote active transport.

This chapter concludes the thesis. Section 7.1 summarizes the motivation, objectives contributions of the thesis and data collection processes. Section 7.2 summarizes thesis main findings. Section 7.3 considers the implications of the findings for transportation planning and policies. Section 7.4 presents directions for future research. Section 7.5 concludes.

7.1 Summary

7.1.1 Motivation, Objectives and Contributions

This thesis was motivated by a number of factors including: 1) the changes in lifestyles and urban environments that have led to car-dependency, reduced physical activity and increasing obesity rates among the adolescent group, 2) the increased traffic volumes and localized congestion around schools, which further decrease air quality, 3) the fact that this generation have grown up in the era of internet and on-line social networking, which have upended the way teenagers interact with each other and in doing so their travel needs, while a generational gap is developing, 4) the statistics showing that casualty toll rises when children start to conduct independent traveling, and 5) the fact that the majority of the existing surveys regarding underage persons focus mainly on transport to school, investigates the mode choice behavior of elementary students, and the data that they use are collected from their parents.

The main objective of this thesis was to investigate and quantify the effect of various factors that affect teenagers' travel and mode choice behavior and activity patterns, with ultimate goal to propose policies that favor active transport. Since current teenagers have no memory of a life without Web browsing, cell phones and social media, and on-line social networking is a part of their daily life, it was raised the question regarding how these affect their travel patterns and trip making behavior. The thesis was also concerned with investigating the effect of social influence on decision making and more specific the effect of parents' walking patterns on teenagers' attitudes towards walking and mode choice behavior. Another research question that we called to answer was how the perceived and

actual walkability constraints regarding the built-environment affect teenagers' mode to school choice behavior. The final objective was to develop mode choice models using SP data collected directly from adolescent students in order to forecast the modal splits under various policies that could promote active transport.

The innovation and contributions of this thesis are multifaceted. To our knowledge, it is the first time that such a large-scale transportation survey takes place, refers only to teenagers (12 to 18 years old) and collects RP and SP data directly from teenagers. The questionnaire that was used within this survey was designed not only by transport planners, but also by economists and psychologists, in order to capture the multidimensional nature of the transportation issues. The survey took place in two countries and in various cities/towns with distinct built-environment characteristics allowing us to compare the travel behavior of teenagers between the two countries and among the different urban environments (urban, rural, insular). For modeling the effect of built environment on mode choice behavior, we do not use only actual built environment characteristics, but also perceived. In addition, an innovation and contribution to the state-of-the-art is the fact that we investigate the effect of on-line social networking on trip making behavior, as the existing surveys deal generally with the effect of information and communication technologies on travel behavior. Our research offers insights on how to model this effect and on what kind of data are required for modeling purposes. This thesis also contributes to the development of a framework that incorporates the effect of social influence into hybrid choice models. The innovative data collection and modeling methodology could be of high importance to researchers who are dealing with active transport (cycling and walking), travel behavior and school transportation.

7.1.2 Data

In order to answer to answer our research questions, we needed data collected directly from teenagers covering a wide aspect of travel behavior issues. As this data was not available by any source, we designed a questionnaire and in co-operation with the Ministry of Education of Cyprus, the Ministry of Education of Greece and the Greek Directories of Secondary education we organized a large-scale survey that were addressed only to gymnasium and lyceum students (12 to 18 years old). The survey took place in Greece from 2010 to 2013. In the first two waves of our survey (2010-2011, 2011-2012) the research team where visited the schools in order to supervise the completion process of the questionnaire. In the school year 2012-2013, the Ministry of Education of Greece authorized our survey and in doing so the electronic version of the questionnaire was forwarded to the high-school of the areas that the survey had taken place the previous years. The sample of Greece consists of 3,293 adolescent students, while the 61% of the data were collected by personal interviews. In Cyprus, the electronic version of the questionnaire was forwarded to all the gymnasiums and lyceums of the country by the Ministry of Education, collecting data from 10,093 adolescent students (21% of the total high-school population of the country).

7.2 Findings

Although the past decade a significant body of researchers investigates transport to school, there is still a gap in the literature regarding teenagers' travel behavior, which identified and discussed extensively in Chapter 2. The literature review analysis showed that there is a gap in the knowledge regarding the travel behavior of adolescents, as the majority of the studies focus on elementary students' transport behavior to school. Also, these surveys investigate the mode to school choice behavior of students who live in urban areas, while the surveys that focus on rural or insular areas are limited. Also, the existing surveys use only RP data for their analyses and modeling purposes, while we could not identify any surveys that used SP experiments to investigate adolescent students' mode-to-school choice behavior.

The analysis of teenagers' travel and activity patterns in Chapter 3 verified our general assumption that teenagers conduct a number of trips without being accompanied by their parents, indicating that a number of trips in transport surveys is not recorded. Cypriot teenagers conduct an average number of 4.1 one-way trips in a school day and 3.9 in Saturday. Urban Greek teenagers conduct 4.2 one-way trips in a school day and 3.7 trips in Saturday; rural Greek teenagers conduct 4.4 one-way trips in a school day and 3.8 in Saturday; insular Greek teenagers conduct an average of 4.9 trips in a school day, while 4.3 trips in Saturday. The activity patterns of teenagers significantly differ between the two countries and among the geographical areas. Teenagers in urban areas tend to conduct simple trips from home to school and back in the morning, while rural and insular teenagers conduct combined trips. The vast majority of Cypriot teenagers are escorted by their parents to school, while the majority of Greek students walk. Although, bike lanes are available in the four out of five main Cypriot cities cycling to school is less than 1%. At this point it is worthwhile to mention, that despite the fact that the 47% of the data in the Greek rural area were collected during January, when the average temperature was -12°C and the weather was snowy, 54% use active transport to go to school, while 57% use active transport for the return trip. Also, in Greek rural area, where there are bike lanes that link the center of the city with the area where schools are located, the cycling to school rates are the highest compared to other Cypriot and Greek areas. In the afternoon, the majority of students' trips in all areas are combined. The main transport mode for the tutorial lessons and sports activities of Cypriots is escorted by private motorized modes. For Greek urban teenagers the most popular transport mode for these activities is public transport, for rural teenagers active transport and for insulars private motorized modes. The majority of after-school entertainment activities in school-days in both countries are conducted using active transport, while in Saturday car is the most popular mode for Cypriots' entertainment activities. In urban and insular areas a number of teenagers' activities, especially these involving entertainment purposes are conducted using PTW. Further analysis of the characteristics of the drivers showed that 72% of the teenagers that drive a PTW do not have the appropriate driving license; they are illegal drivers, a fact that raises safety issues. Regarding adolescents' time allocation, the results show that teenagers spend a considerable amount of time in outdoor activities and as a result in travelling. Especially, in Greek urban area travelling is the third activity that teenagers spend the most time in a school-day. Moreover, social media is an activity on which they spend a lot of time both in school days and in the weekend.

As not only the descriptive statistics of our survey, but also the statistics of social media sites (i.e. Teen Facebook Statistics, 2012), show that on-line social networking is part of

teenagers' daily life, we investigated how this affects their trip making behavior for social purposes in Chapter 4. We developed Latent Class Poison Regression models in order to investigate the trip making behavior for social purposes of various OSN usage styles. Initially we tested our methodology with data from the survey in Cyprus. The variables that we used to identify the latent OSN usage styles were referred to the time that teenagers spend on OSN, the number of OSN accounts, gadget ownership and mobile phone usage patterns. The results of the model indicated that there are four latent OSN usage styles; Class 1 includes those teenagers who use OSN in a rational way, Class 2 includes those teenagers who are OSN indifferent, Class 3 includes teenagers who are highly OSN oriented or OSN addicted, and Class 4 includes non-OSN users. The model estimation results also showed that Class 1-Rational OSN users and Class 3-OSN addicted users conduct more social trips than Class 2-Indifferent OSN users and Class 4-non OSN users. Despite the fact that we obtained answers from this model, more questions were raised regarding the activities that teenagers conduct via OSN and how these activities are linked to trip making behavior. Thus, we revised our questionnaire in order to collect more data about specific OSN activities that could contribute to increased or decreased social trip making behavior. The revised questionnaire was used for the data collection in Greece in 2013 and this sample was used to estimate again Latent Class Poison Regression models regarding the trips that are conducted for social purposes over Saturday. The variables that we used in this second case study for identifying the latent OSN usage styles in our sample concerned the frequency of conducting various activities that social media sites offer (such as "check-in", like, post etc.), the time they spend on OSN and gadget ownership. We identified three latent OSN usage styles; Class 1 includes rational OSN adolescent users, Class 2 includes OSN addicted, and Class 3 those who are indifferent to OSN. Regarding the social-trip making behavior of each class, rational and addicted OSN users conduct more social trips than the average, while the members of Class 3-OSN indifferent users conduct fewer social trips than the average. This chapter offers significant insights to researchers for the data required in order to model the relationship between OSN and trip making behavior.

It is an undoubtedly true that social environment affects individuals' decision making process and in Chapter 5 we investigated how social influence could be modeled using as an example the parental influence on teenagers mode to school choice behavior. We proposed a general methodological framework for including the social interaction effect in the HCM. We assumed that individuals develop perceptions regarding the behavior of their social environment and in turn these perceptions affect the perceptions of the individual, which affect directly the decision of the individual. Thus, the social environment is a latent variable that represents social interaction with the decision maker, and it is included as a component in the formation of the latent variable regarding the decision maker, which in turn is included directly in the choice model. The proposed framework is presented in Figure 8.1. In our case, the aim was to identify the social interaction effects between teenagers and their parents regarding walking-loving behavior, and then the effect of this on mode-to-school choice behavior. The findings indicated that, if the teenagers perceive that their parents are walking-lovers, then this increases their probability of loving walking too. The latent variable "Parents: Walking-lovers" is the most statistically significant variable in the formulation of the latent variable "Walking-lover" that refers to the decision maker/teenager. Then, the latter latent variable is incorporated directly in the utility of the alternative of walking, and positively and significantly affects the probability of choosing to walk to school. The findings from the case study are that implementation of the integrated choice, latent variable and latent social interaction model framework results in

(1) improvements in the explanatory power of choice models, (2) latent variables that are statistically significant, and (3) a more real-world behavioral representation that includes the social interaction effect. Other variables that affect the mode-to-school choice behavior are distance, income, age, gender, vehicle ownership, household size and built environment characteristics, such as existence of greenery (trees/flowers), availability of crosswalks and width of sidewalks.

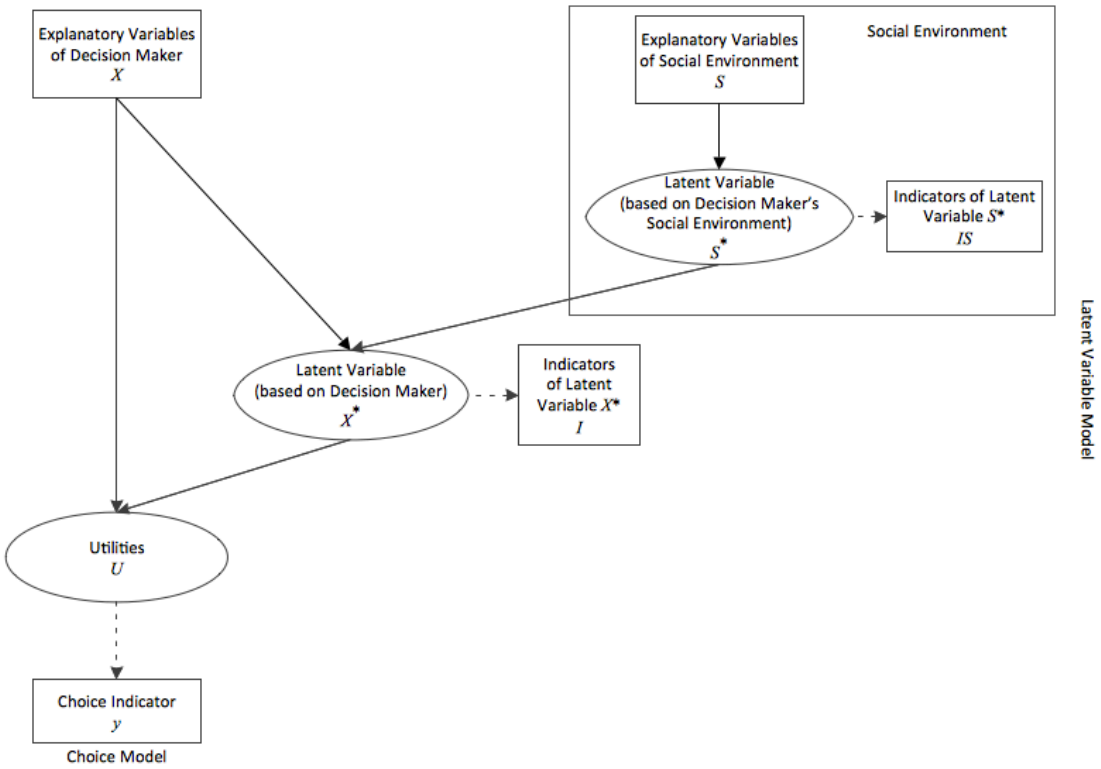


Figure 7.1: HCM with social interaction effect

In Chapter 6, we investigated in depth the actual and the perceived built-environment characteristics that could affect mode to school choice behavior and compared the results among an urban, a rural and an insular area. We developed a HCM for each area, according to which the utilities of the alternative modes (active transport, public transport, escorted by adults, and driving) depend on the actual built environment's characteristics, weather conditions, and the teenagers' socio-economic characteristics, as well as on a latent variable referring to perceived built-environment characteristics that capture the walkability constraints. The findings of the model estimation indicate that each urban environment has its own characteristics, which affect mode choice. The model for urban adolescents is consistent with the results of previous surveys that also took place in urban areas, such as Mitra and Buliung (2012) and Grow et al. (2008), but the model estimation results of rural and insular areas exhibit different behaviors. The results confirm that distance plays the most significant role in mode-to-school choice for all three areas. The presence of wide pavements, greenery and traffic lights at major intersections affects positively the choice of active transport to school; hence the first two characteristics are more significant for adolescents in rural and urban areas, while the last is more important for high-school students in the urban area. Bad weather conditions decrease the probability of choosing active transport, but this variable is not significant for rural areas, as rurals are used to low

temperature during the winter. The results of the structural model indicate that teenagers perceive the various characteristics and constraints of the built environment in different ways. The most significant walkability constraint for urban teenagers seems to be the security issue, while for rural and insular ones it is the absence of sidewalks, along with poor lighting.

7.3 Policy Implications

7.3.1 Transport Surveys - Data

Transport surveys should include the adolescent age group in their sample. First, teenagers conduct trips without the supervision of their parents, thus a number of trips remain unrecorded in travel surveys. Teenagers conduct not only trips from home to school and back, but they also conduct trips to after-school activities, while their parents are not always aware about the characteristics of these trips. Thus focus should be placed on those trips as well. Second, by collecting data regarding this age group we can identify their needs and in doing so policy makers could impose the appropriate meters and policies in order to develop "green thinking" from such a young age. It is more difficult to change the travel behavior of adults. But we have the opportunity to raise environmental conscious children, who may retain this behavior during their adulthood.

7.3.2 Information and Communication Technologies and Social Media

Information and Communication technologies and on-line social networking is a part of teenagers' daily life spending a significant amount of time on it. Policy makers could take advantage of social media and use them as a marketing tool to promote active transport. Since teenagers declared that they receive information and read the news on social media rather than by watching TV and reading newspapers, active transport campaigns, cycling events and related news could be promoted by advertisements on social media. They also give the opportunity to policy makers to promote targeted campaigns by selecting the focus groups. For example, different campaigns could be promoted to females and different to males. Due to the fact that girls agreed most that they are willing to walk in order to be fit, active transport campaigns for girls could emphasize on the physical activity and weight loss. As boys agreed most that they are not willing to walk alone, campaigns for boys could focus on how cool is to walk or cycle accompanied by friends.

In addition, policy makers could develop applications for mobile phones, in order to record the active transport activities of teenagers presenting to them not only the health benefits (i.e colories burnt), but also the environmental footprint compared to other transport alternatives. For current teenagers, who at the same time are the future adults, the visualization of the information is very important.

7.3.3 Schools

There are many actions and initiatives that a school can carry out to promote active transport not only for the trip to school but also for all students' activities. They could be short or long term actions, and could include actions for staff as well as parents.

First of all schools in co-operation with the Ministry of Education should organize educative programs and courses at schools in order to teach students how to stay safe on road both as pedestrians and cyclists, but also as passengers of motorized vehicles. These programs should mainly include audiovisual material, cycling training and practice in real road conditions. They should also aim at increasing awareness of the benefits of physical activity and to give students the confidence and motivation to walk and cycle to their activities.

Regarding the trip to school, some students live too far away from school to be able to walk; the Park & Stride scheme is a simple solution to these problems and means that students at least walk some of the way to and from school.

Active transport days or weeks could be adopted by schools. On these days, cyclist or pedestrian students could be rewarded with less homework or a free lunch. Within our survey, we implemented a three-day campaign entitled "It is really cool to walk/cycle to school" at three high-schools in Chios (insular area). During the campaign the students that use active transport to school were rewarded with a free breakfast, while the campaign closed with a party at the schoolyard, where the students that were walking or cycling to school the previous days had the opportunity to win various presents, such as bicycles, helmets and cycling safety equipment. As a result of the campaign and the incentives that we gave to students, active transport to school increased by 12% during these days. However, the impact of the incentives that are given to students in order to walk or cycle to school should be further investigate.

Schools should also provide the opportunities to students to develop and promote their own active transport to school campaigns. In any high school, there are teenagers willing to take a lead in a program to increase active transportation – especially if the program is offered as a leadership opportunity. Put to the task, the students' skills and motivations can be the means of increasing the number of their peers walking and cycling to school.

Moreover, schools could implement a tool to record the transport modes that students use. The most appropriate tool would be a mobile application. This application could track the distances that students walk or cycle and at the end of the month the students that they have traveled the longest distances either on foot or by bicycle would be awarded. Schools could also organize on their websites carpooling schemes for the students that they live far away from school and active-transport-pooling schemes for students that live in walkable or cycleable distances from school.

Particular consideration should be given to the parents. Both communities and schools could organize campaigns specifically aimed at encouraging parents to encourage their children to walk or cycle. In addition, schools could cooperate with parents by arranging "walking buses to school" (Staunton et al., 2003).

Regarding infrastructure, schools should create a more supportive to active transport school

environment. Bicycle parking places at schools are necessary, not only to encourage cyclists, but to remind the students to use their bicycles.

7.3.4 Parents

As parents play a prominent role to the development of their children's travel behavior, the proposed policies and campaigns should refer to them as well. Campaigns should target at increasing parents' awareness of the wider benefits of walking and cycling and other physically active modes of travel. For example, they should inculcate to parents that active transport can improve children movement skills, social wellbeing, self-confidence and independence, while at the same time it can help children to explore and become more familiar with their local environment staying physically active.

Contemporary society is generally perceived as risky by parents. Media reporting and a private and public culture, which emphasizes health and safety, blame and rights have made risk aversion a dominant social value. Children benefit from exposure to risks and challenges to help them develop skills and confidence. Many forms of physical activity and play (and the environments where they take place) have inherent risks. Unnecessary risk can be minimized through the use of risk-benefit assessment, safety precautions and safety equipment. Parents' and service providers' fears of injury and litigation can prevent children and young people from being physically active, even though the fear of risk may not necessarily correspond to reality. Paradoxically, in the long run, this can put children at greater risk from the conditions associated with lack of activity, such as obesity.

Children and parents can also work together to plan an interesting route and cycling together is an excellent opportunity to discuss and practice road safety rules.

7.3.5 Urban and Transportation Planning

Cities' plans should encourage more innovative types of developments, to support active transport and discourage car use. The construction of bike lanes and wider sidewalks, which cost less than constructing roads, will enhance active transport and, at the same time, improve the connectivity of walking routes (for example to the bus stop or to school). Several facilities could be implemented on sidewalks, elevating the convenience and safety for underage pedestrians and cyclists, such as bicycle parking places and priority at traffic lights.

Transport plans should aim to increase the number of adolescents who regularly walk, cycle and use other modes of physically active travel. They should also make provision for the additional needs of, or support required by, children and their parents with a disability or impaired mobility.

Furthermore, decision and policy makers should regularly organize consulting with children and parents in order to identify local factors that may increase active transport rates.

7.4 Future Research Direction

In conducting research on teenagers' transportation, it quickly becomes clear how much we do not know. Although several topics were addressed in this thesis, there are still important issues for future research. Below we discuss the future research directions regarding the data collection and modeling techniques.

7.4.1 Data Collection

A number of extensions could be considered regarding data collection.

First, as parents play an important role on teenagers travel behavior, future data collection should include parents as well. The most ideal approach consists of two phases. In the first phase focus groups should be identified. The data collection of the focus groups will give some initial insights on how to design the questionnaire in order to catch the interactions between parents and children. In the second phase the data collection will refer to all adolescent population and their parents. It is also desired in the data collection to be included other members of the social environment of teenagers, such as friends or relatives, in order researchers to able to investigate in depth the social interaction effect. The desired data from parents and teenagers' social environment should include information about the characteristics of the trips, attitudes and perceptions towards walking and cycling and socio-economic characteristics. It is also proposed the data collection to be designed based on the Traffic Analysis Zones (TAZ) of each area. This could provide the opportunity to link various socio-demographic and built-environment characteristics of the TAZ with the mode choice behavior of adolescents and their parents.

Second, future surveys could employ GPS devices or mobile applications in order to better track the characteristics of teenagers' trips and activities. Although we have all the information regarding the location of the places that teenagers conducted their activities in our survey, it was too difficult and time-consuming to handle this data and simulate the routes on the network. Additionally, by using GPS devices it is easier to identify the built environment characteristics of individuals' routes. Furthermore, calorie meters could be used in order to track the calories and the levels of teenagers' physical activity, when they walk or cycle. The ideal concept is to collect data regarding teenagers' physical activity levels, Body Mass Index (BMI) and then provide to teenagers GPS and calorie meters devices. This data could help us to identify the relationship between active transport and BMI. A future research question could be: "Do overweight teenagers walk/cycle to their activities? If no, they do not walk/cycle, because they are overweight or they put on weight due to the fact that they do not walk/cycle?" In other words what are the causal links between walking/cycling and BMI.

Third, the trip or activity diaries used in transport surveys should also collect data about the feeling of safety and security per each activity. Since the level of safety and security that someone feels in a specific urban environment significantly affects the mode choice behavior, it is important to explore this in detail per each activity or trip. Data regarding actual weather conditions should also be incorporated into transport datasets in order to be able to better explain the effect of weather on travel behavior. In our case, we faced difficulties to explain and compare the trips for shopping purposes in the two countries, as

we do not have any information about the amount of money spent on shopping. Activity diaries should also include the amount of money that was spent or the expenses made per each activity. This will allow researchers to better assess the purpose of each trip, and the origin and destination matrices.

Future surveys should also include trip or activity diaries that collect data over a certain period of time (i.e. a month). Longitudinal data will enable researchers to capture changes in teenagers' travel behavior and especially the effect of various campaigns or the effect of OSN usage on teenagers' trip making behavior.

In addition, future data collection could further investigate the kind of information that adolescents receive regarding traveling and transport modes through social media. It is also desired to collect data about the usage of mobile phone applications that offer real time travel information and how this affects their travel behavior. In the areas that our survey took place there were not available such applications, so we have not capture this aspect.

It is also desired the data collection in both countries to take place in the following years as well. Our data collection in Cyprus took place before the economic recession and it is interesting to compare at an aggregate level the travel behavior of adolescent students and their attitudes and perceptions towards walking and cycling before and after the economic recession. In Greece, since our data collection begun when the economic recession started, it would be interesting to capture at an aggregate level how the travel behavior has been changing under the economic adjustment program.

By analyzing our data we found out that a significant percentage of the adolescent participants that are drivers, they do not have the appropriate driving license. Although we have attitudinal and perceptional data about this illegal behavior, we also need data about their actual driving skills in order to assess their possibility of involving in a traffic accident or the threat to road safety. Thus, future research should also collect actual data about their driving skills by using motorcycle or car simulators.

Finally, in our survey we collected data from two countries and from different geographical areas and we identified that each country and particularly each urban environment has each own characteristics that affect travel behavior. Thus, it is desired this survey to take place in other countries as well, in order to be able to compare the adolescents' travel behavior. Launching this survey in other European countries would be ideal.

7.4.2 Modeling

A number of extensions will also be useful to support the modeling frameworks developed in this thesis.

First, we proposed a methodological framework that incorporates social influence into HCM, but we only estimated this model. Thus, further work should include the assessment of the goodness-of-fit of the proposed framework. In addition, the proposed modeling framework should be estimated by using data regarding other members of decision makers' social environment, such as friends. This thesis provides all the mathematical equations in order to estimate such a model. It is also desired this framework to be tested by using data from adults as well.

Regarding the effect of OSN usage and trip making behavior, it is desired the Latent Class Poison Regression model that estimated in this thesis to be estimated again by using longitudinal data. In doing so, we will be able to answer the question if social networking substitutes for or stimulates adolescents travel behavior, as such data allow researchers to track changes in travel behavior. In addition, it should be investigated the trip making behavior of the various OSN usage styles for school days. In our dataset, we identified a large number of participants that they had not conducted any trip for social purposes in school-days, thus a Latent Class Zero Inflated Poisson Regression model will be estimated in the future.

Future models should also include the feeling of safety and security en route, in order to better assess mode choice behavior and especially the choice of active transport. Our Latent Variable model indicated that perceptions of built environment that are related to safety & security issues significantly affect the perceived walkability constraints. Thus, a better investigation of feeling of safety and security is required. Since this data are available in our data set, future work will focus on this issue.

It is also unclear if the active transport campaigns or projects that some schools have implemented, affect teenagers mode choice behavior. Also, it is under-investigated if there is any relationship between adolescent students and their teachers' mode choice behavior. For example, if school-teachers walk or cycle to school does this affect teenagers mode to school choice as well? In the third wave of our survey in Greece, we also collected aggregate data regarding how many teachers walk or cycle to school. However, this variable has been not used in our models and we do not know if it affects students' mode choice behavior. If such a variable affects positively adolescents' mode choice behavior, then schools should also urge their staff to use active transport for their trip to work.

Abou-Zeid (2009) argued that activity patterns are chosen to maintain or enhance well-being. In our survey we used indicators regarding the level of satisfaction or happiness from the choice in the stated preference experiments. However, this has not been examined within this thesis. Future research should investigate the relationship between adolescents' mode choice behavior and travel well-being.

Finally, the models that were estimated in this thesis could be incorporated into activity based models allowing for better behavioral representation of the drivers of activities. The estimated models offer significant insights about: 1) the effect of perceived and actual built-environment characteristics on travel behavior; 2) the effect of social environment on decision maker's choices; and 3) the relationship between on-line social networking and trip making behavior. Also, the incorporation of these models into activity based models would allow transport planners and policy makers to better understand adolescents' traveling and in doing so to design the appropriate policies that will cover next generation's travel needs.

7.5 Conclusion

This thesis contributed to the understanding of teenagers travel behavior and travel needs. We analyzed their travel patterns and examined several factors that affect teenagers travel behavior, such as the effect of actual and perceived built-environment characteristics, the

effect of social influence and the effect of on-line social networking. We have outlined the policy implications of this research and directions for future research covering the aspects of data collection and modeling. We anticipate that the methods and modeling techniques developed in this research will also be appealing to those who deal with adults. Also, the developed modeling frameworks could be used in non-transportation contexts as well, especially in the marketing sector.

Concluding, this thesis focused on this special age group, as we believe that the interventions at this age could develop the desired behaviors that could be retained in adulthood. Teenagers are the next generation, the agents of change and we strongly believe that prevention is better than cure.

APPENDIX A – QUESTIONNAIRE

UNIVERSITY OF THE AEGEAN
BUSINESS SCHOOL
DEPARTMENT OF SHIPPING, TRADE & TRANSPORT

QUESTIONNAIRE

Teenagers' Travel & Driving Behavior

School:_____Class:_____

In this questionnaire you are asked to fill in the details of the trips that you conducted on the last school day and the previous Saturday. In addition, there are questions regarding your activities, your time allocation and usage of social media.

Completion of the questionnaire takes 25 to 30 minutes. There are no right or wrong answers … so do not be anxious about your answers. The data are confidential and will be used only for the purposes of this survey for the Transport and Decision Making Laboratory of the Shipping, Trade and Transport Department of the University of the Aegean.

Thank you for your time and willingness to participate in the survey!
Be cool … we start!!!

Like us on Facebook

https://www.facebook.com/groups/384098041688167/

GENERAL

Your school is:

□ Public gymnasium □ Public lyceum □ Technical lyceum
□ Private gymnasium □ Private lyceum

City/Town/Village you live in: _____ **Area**:_____**Postal Code**:_____
Prefecture: _____

1) **What time do you wake up in the morning (weekdays)?** ____:____
2) **How much time do you spend on getting ready before going to school?** _____minutes
3) **How much time do you spend on breakfast?** _____minutes □ I don't have breakfast
4) **What time do you depart from your home in order to go to school?** ____:____
5) **What time do you arrive at school?** ____:____
6) **Which transport mode do you use the most for your trip to school?** _____(scroll-down menu)

   If you walk to school accompanied by your friends, by how many friends are you usually accompanied? ____

   If you are escorted to school by private motorized vehicle, do you arrange to pick up your co-students? □ No □ Yes (If yes, how many co-students are in the vehicle? ____)

   Do you consider the bus a potential transport mode that you can use from home to school? □ No □ Yes
7) **Are there school traffic police at your school?** □ No □ Yes
8) **Are there bicycle parking spaces in your schoolyard?** □ No □ Yes
9) **How many minutes away (on foot) is the bus stop nearest to your home?** ____
10) **How many trips (one-way) did you conduct yesterday (if a school day) from the time you woke up in the morning until the time you went to sleep at night? If yesterday was not a school day, please count your trips for the last day you attended school. BE CAREFUL before you answer and count your trips carefully.** _____

    Example: If you departed from your home and went to school, then returned home, and then went to tutorial lessons, went for coffee and returned home, you conducted 5 trips:

    ____ *1st trip: Home-School*
    2nd trip: School-Home
    3rd trip: Home-Tutorial lessons
    4th trip: Tutorial lessons-Coffee shop
    5th trip: Coffee shop-Home

PART 1 - TRIPS

Remember, all the information regarding your trips will only be used for the purposes of this survey.

SCHOOL DAY

In the table below fill in the details of the ## trips that you said you conducted yesterday (school day). If today is Monday, fill in the details of the trips that you conducted on Friday or on the last day you went to school.

#	Departure Place	Address or a well-known nearby crossroads or place/monument	Arrival Place	Transport Mode	Trip Duration (min)	Trip Purpose	How safe did you feel regarding the probability of getting involved in a road traffic accident
1							
2							
….							

The choices are (drop down menu):

Departure & Arrival Place	Transport Mode	Trip Purpose	How safe did you feel regarding the probability of getting involved in a road traffic accident
Home	Walking alone	School	I felt completely unsafe
School	Walking with friends	Tutorial lessons	I felt unsafe
Tutorial for school lessons	Walking accompanied by an adult	Private tutorial lessons	Neutral
Tutorial lessons – foreign language	Bicycle	Sports	I felt safe
Music lessons	Bus	Music lessons	I felt extremely safe
Stadium/Sports center	School bus	Visit	
Dance lessons	Taxi	Lunch/Dinner	
Park	Metro/Tube	Entertainment	
Neighborhood	Tram	Play/hanging around	
Relatives' home	Motorcycle <50cc (driver)	Shopping	
Friend's home	Motorcycle >50cc (driver)	Daily shopping	
Coffee shop/Bar	Motorcycle (father driver)	Religious	
Internet café	Motorcycle (mother driver)	Work	
DVD club	Motorcycle (friend driver)	Excursion	
Restaurant/Fast food	Motorcycle (brother/sister driver)	Other	
Bakery/Kiosk	Car (father driver)		
Supermarket	Car (mother driver)		
Shopping area	Car (friend's parent driver)		
Mall	Car (driver)		
Cinema			
Farm/Forest			
Workplace			
Church			

In regard to crime, how safe do you consider your route from home to school?

Completely Unsafe Route	Unsafe Route	Neutral	Safe Route	Completely Safe Route

Below are presented some characteristics that might describe the built environment of your city/ town/village. Please check the extent to which these characteristics exist along your route from home to school.

	Not at all	1/3 of the route	2/3 of the route	Along the whole route
Wide sidewalks				
Narrow sidewalks				
Narrow sidewalks with obstacles (e.g. parked motorcycles)				
No sidewalks				
Bad condition of sidewalks' terrain (e.g. potholes)				
Bad condition of road asphalt (e.g. potholes)				
Traffic lights at the main crossroads				
Pedestrian crossings at the main crossroads				
Cycle lanes*				
Cycle ways*				
Shops				
Green (trees/ flowers)				
Coastal route				
Stray animals				

SATURDAY

How many trips (one-way) did you conduct on the previous Saturday from the time you woke up in the morning until the time you went to sleep at night? BE CAREFUL before you answer, read the example and count your trips carefully. _____

Example: If you departed from your home, went shopping, went for coffee and then returned home, you conducted 3 trips.

1st trip: Home-Shopping area/Mall

2nd trip: Shopping area-Coffee shop

3rd trip: Coffee shop-Home

Fill in the details of the ## trips that you conducted on the previous Saturday.

#	Departure Place	Address or a well-known nearby crossroads or place/monument	Arrival Place	Transport Mode	Trip Duration (min)	Trip Purpose	How safe did you feel regarding the probability of getting involved in a road traffic accident
1							
…							

If you conducted any trip for entertainment purposes with your friends, how did you arrange this? □ By telephone (call or text message) □ Through on-line social media □ Other

How many trips did you conduct the previous Sunday? ___

PART 2 – ACTIVITIES

We define as FREE TIME the hours that you have during the day to allocate to activities that you want to pursue and that you like. In the calculation of your free time do not include the hours of sleep.

1) How much Free Time (in hours) did you have on:

- the last school-day: ……. - the previous Saturday: ……. - the previous Sunday: …….

2) Below are presented some activities that you may engage in during your free time. Please, rank your 3 most favorite activities. 1 is the most favorite, …, 3 is the least favorite.

Watching TV		Sports	
Surfing the web		Reading extra-curricular books	
Hanging out with friends		Playing video games	
Listening to music		Other ……..	

3) How much time did you spend on the activities below on:

	The last school day	**The previous Saturday**	**The previous Sunday**
Studying	…….hours	…….hours	…….hours
Tutorials for school lessons	…….hours	…….hours	…….hours
Tutorial lessons for foreign languages	…….hours	…….hours	…….hours
Watching TV	…….hours	…….hours	…….hours
Surfing the web	…….hours	…….hours	…….hours
Talking/Texting (sms) on phone	…….hours	…….hours	…….hours
Going out for entertainment	…….hours	…….hours	…….hours
Sports	…….hours	…….hours	…….hours
Reading extra-curricular books	…….hours	…….hours	…….hours
Video games (PS, Xbox, i-pad, PC etc.)	…….hours	…….hours	…….hours

4) What transport mode do you use the most for the following activities? How long does your trip usually last?

	Transport Mode	**Travel Time (in minutes)**
Tutorial lessons	drop down menu	
Sports	drop down menu	
Music/Art and other extra-curricular tutorial lessons	drop down menu	
Going out for entertainment	drop down menu	
Visiting friends	drop down menu	

5) If you participate in tutorial lessons for foreign languages, please check the foreign language(s) you are learning. □ English □ French □ German □ Spanish □ Italian □ Other □ Do not participate

6) If you participate in sport activities, in which sport do you participate?

_____

7) Do you have an account (or more than one) on any on-line social networks (ONS)? □No □Yes

8) If Yes, on which ONS do you have an account?

□Facebook □msn □twitter □Instagram □Second life □Skype □OOVOO □Tango □YOUtube □Other

If No, why do you not have an OSN? □ Do not have time □ Not interested □ Do not have regular internet access □ Have never heard of OSN □ Other (specify _____)

PART 3 - ON-LINE SOCIAL NETWORKING

(This part is to be answered only by the students who have at least one OSN account)

1) How much time (in minutes) did you spend on OSN on the last school day, the previous Saturday and the previous Sunday?

OSN	Last school day	previous Saturday	previous Sunday
Here appears the OSN chosen in Part 2 – quest. 8.1	…….min/day	…….min/day	…….min/day
Here appears the OSN chosen in Part 2 – quest. 8.1	…….min/day	…….min/day	…….min/day

2) How much time did you spend ONLY FOR CHATTING with your friends via OSN?

OSN	Last school day	previous Saturday	previous Sunday
Time spent on Chatting, Video calls, Calls	…….min/day	…….min/day	…….min/day

3) Which is your favorite OSN? Here appears the OSN chosen in Part 2 – quest 8.1

4) Do you use mob apps that track walking or cycling routes? □ No □ Yes (How often? ……..)

5) Please fill in the details below regarding your favorite OSN.

OSN	Favorite OSN
How many friends do you have ?	…….
How many times per day do you communicate with your friends via OSN?	…….
How many photos (approx.) do you have on your account?	…….
How often do you "check-in" yourself?	select (drop down menu)
How often do you comment on your friends' posts/status?	select (drop down menu)
How often do you post on your wall?	select (drop down menu)
Who can see your profile?	□ Open to all □ Open only to my OSN friends □ Open only to some of my OSN friends □ No one can see my profile except me
How many events have you attended in the past month that you were informed about through OSN?	…….

6) The statements below refer to OSN usage. On a scale from 1=Completely disagree, to 7=Completely agree, fill in the level of your agreement/disagreement.

OSN	1	2	3	4	5	6	7
I use OSN in order to be informed about my friends' activities							
I use OSN for flirting							
I spend a lot of time on OSN so that my studying is delayed							
I connect to my OSN account via my mobile phone							
I use OSN to arrange hanging out with my friends							
I have reduced the number of trips I conduct, as I communicate with my friends via OSN							
Mobile apps help walk/cycle more							
I feel out of touch when I haven't logged on to Facebook for a while							
I devote part of my daily schedule to OSN							
OSN is part of my daily life							
I sign on to my account during school lessons							

PART 4 – ROAD USER BEHAVIOR

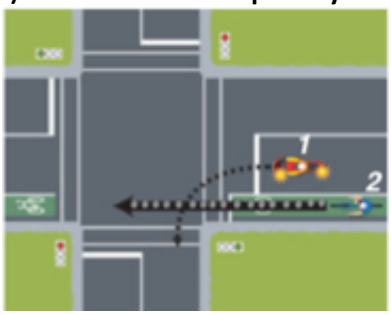
1) Do you have a bike? □ No □ Yes

If yes, how often do you use it? □ Daily □ 4-5 times per week □ 2-3 times per week □ 2-3 times per month □ 2-3 times per two months □ 2-3 times per three months □ Never

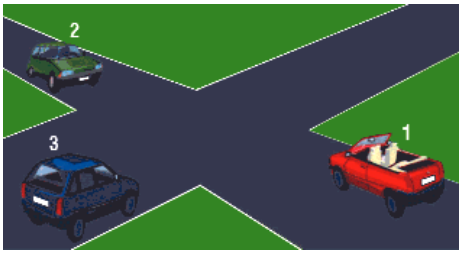
2) How often do you use public transport modes? □ Daily □ 4-5 times per week □ 2-3 times per week □2-3 times per month □ 2-3 times per two months □ 2-3 times per three months □ Never

3) Do you know the traffic law? □ No □ Yes

4) Which vehicle has priority in each picture below?



Number of vehicle ____



Number of vehicle ____

6) On a scale from 1=Completely disagree, to 7=Completely agree, indicate the level of your agreement with the statements below.

Safety culture	1	2	3	4	5	6	7	N/A
I trust unlicensed drivers								
I always use the seat belt when I am a car passenger								
I always wear a helmet when I am a PTW passenger								
I always wear a helmet when cycling								
I always wear light-colored or reflective clothing when cycling								
My bicycle has front and rear lights								
I always cross the road using the pedestrian crossings								
I use a motorcycle without my parents' knowledge								

7) On a scale from 1=Completely disagree, to 7=Completely agree, indicate the level of your agreement with the statements below.

Active transport	1	2	3	4	5	6	7
My schoolbag is too heavy for me to walk to school							
I prefer to walk to school in order to be fit							
I prefer to cycle to school in order to get physical exercise							
I am willing to walk to school as it is the most cost-effective mode							
I really enjoy walking							
I love cycling							
I prefer cycling to school as it is the most cost-effective mode							

I prefer walking to being escorted by my parents							
When I cycle, I am afraid of being hit by a car							
Walking to school is time-consuming							
Cycling to school is time-consuming							
I am willing to cycle to school if there is a cycle lane							
My parents, being afraid for my safety, do not allow me to walk							
I am willing to replace my motorized trips with active transport trips							
I consciously walk/cycle in order to reduce my environmental footprint							
I do not want to walk as I find it boring							
I wake up late, so do not have time to walk to school							
I would love to walk if I were accompanied by my friends							
I do not like walking alone							

8) With regard to your walking behavior and walking routes, on a scale from 1=Completely disagree, to 7=Completely agree, indicate the level of your agreement with the statements below.

	1	2	3	4	5	6	7
When walking, I am afraid of stray animals							
While I walk, I feel that there is a possibility of being robbed (safety)							
The lighting along my walking route is poor							
There are no sidewalks along my walking routes							
There are no traffic lights at the main crossroads							
There are parked cars that obscure my visibility							

9) With regard to walking, on a scale from 1=Completely disagree, to 7=Completely agree, indicate the level of your agreement with the statements below.

Because I'm afraid of walking alone,	1	2	3	4	5	6	7	N/A
I ask a member of my family to chauffeur me								
I ask a member of my family to escort me by motorized vehicle								
I ask my parents to buy me a motorcycle								
I follow an alternative route								
I use public transport								
I stay at home								

10) On a scale from 1=Completely disagree, to 7=Completely agree, indicate the level of your agreement with the statements below.

Public transport	1	2	3	4	5	6	7
I prefer public transport to being escorted by my parents							
I prefer public transport as it is a cost-effective option							
I check the public transport services on-line							
I am afraid of getting robbed when I use public transport							
By using public transport I am able to know the length of my trip							
I do not want to walk as I find it boring							
I wake up late, so do not have time to walk to school							
I would love to walk if I were accompanied by my friends							

11) Do you have a motorcycle in your household? □ No □ Yes

12) Do you drive a motorcycle or car? □ No □ Yes

PART 4 – DRIVER PROFILE

(This part is answered only by drivers)

1) What type of motorized vehicle do you drive? □ Motorcycle <50cc □ Motorcycle >50cc □ Car

2) Do you own a motorcycle? □ No □ Yes

3) Have you made any modifications to your motorcycle (e.g. increase hp etc.)? □ No □ Yes

If yes, what type of modifications:_____

4) With regard to the vehicle that you drive, do you have the appropriate license?

	Car	Motorcycle 50 cc	Motorcycle > 50 cc
No			
Yes			

5) How old were you when you drove for the first time? Motorcycle _____ Car_____

6) I was taught to ride a motorcycle by:□Myself □Friends □Siblings □Parents □Relatives □Driving-school

7) At what speed do you drive within residential areas? (drop down menu)

8) Have you ever received a ticket? □ No □ Yes (If yes, for what reason? _____)

9) On a scale from 1=Completely disagree, to 7=Completely agree, indicate the level of your agreement with the statements below.

I have a motorcycle, because	1	2	3	4	5	6	7
I don't want my parents to escort me							
It's a way of being free							
I feel free (independent)							
My friends own motorcycles too							
It is cool!							
It is attractive to the opposite gender							

10) On a scale from 1=Completely disagree, to 7=Completely agree, indicate the level of your agreement with the statements below.

Parental Restriction	1	2	3	4	5	6	7
My parents allow me to have my own motorcycle							
My parents allow me to drive unlicensed							
My parents trust me as a driver							
I drive without the consent of my parents							

11) On a scale from 1=Never to 7=Always, indicate the level of your agreement.

Driving Style	1	2	3	4	5	6	7
When I drive, I wear a helmet							
I participate in speed racing							
I am used to demonstrating my driving skills							
I find it exciting to drive at high speed							
I demonstrate riding skills to impress the opposite sex							
I demonstrate riding skills to impress my clique							
I bet on road racing							
I stop at crossroads to allow pedestrians to cross the road							
I yield to other drivers							
I am used to parking my motorcycle illegally							
I get nervous about other road users when I drive							
When I drive, I look around for friends							
I am used to talking on the phone when I drive							
I am used to sending text messages when I drive							
I am used to driving when I have consumed alcohol or substances							

PART 5 – SOCIAL ENVIRONMENT

1) O**n a scale from 1=Completely disagree, to 7=Completely agree, indicate the level of your agreement with the statements below.**

Parents	1	2	3	4	5	6	7
My relationships with my parents are good							
I spend a lot of time with my parents							
I discuss personal issues with my parents							
My parents are over-protective							
My parents restrict me							
My parents do not allow me to stay out late							
My parents are willing to escort me to my activities							
When my parents are not available to escort me, they arrange for someone else to do so							
My parents escort me to school before they go to work							
My mother walks for her short-distance trips							
My father walks for his short-distance trips							
My mother prefers walking to using a car							
My father prefers walking to using a car							
My parents urge me to walk/cycle							
I often have disagreements with my parents about buying me a motorcycle							
My driving style is affected by my parents' driving style							
My parents are careless drivers							
My parents do me many favors							
I am worried about my family's economic situation							
I am trying to save money							
I have reduced my participation in tutorial lessons, due to the economic crisis							

2) Please check the option that fits you best.

	Father	Mother	Both of them	Neither of them
I spend more time with				
I discuss my personal issues with				
Who has a driving license?				

3) The statements below refer to your parents' travel behavior. Please indicate the frequency with which they using the following transport modes for their trips.

Parents	**Never**	**Rarely**	**Sometimes**	**Usually**	**Always**
My mother uses her car					
My mother uses a motorcycle					
My mother uses public transport					
My mother walks					
My mother cycles					
My father uses his car					
My father uses a motorcycle					
My father uses public transport					
My father walks					
My father cycles					

4) On a scale from 1=Completely disagree, to 7=Completely agree, indicate the level of your agreement with the statements below.

Friends/ Peers	1	2	3	4	5	6	7
My friends are of great importance to me							
I want to spend more time with my friends than with my parents							
My friends love cycling							
My friends love walking							
My friends have motorcycles							
My friends prefer walking to school							
My friends prefer active transport to being escorted by their parents							

5) The statements below refer to your friends' travel behavior. Please indicate the frequency with which they use the following transport modes for their trips.

Friends	**Never**	**Rarely**	**Sometimes**	**Usually**	**Always**
My friends are escorted by motorized vehicles					
My friends use motorcycles					
My friends use public transport					
My friends walk					
My friends cycle					

6) Have you ever been involved in a traffic accident? □ No □ Yes

PART 6 – ACCIDENTS

(This part is to be answered only by students who have been involved in traffic accidents)

1) How many times? _____

2) How old were you when the most serious traffic accident occurred? _____

3) Where did the traffic accident take place? (drop down menu)

4) What caused the accident? (drop down menu)

5) Type of accident: (drop down menu)

6) You were involved as: □ Driver □ Passenger □ Pedestrian □ Cyclist

7) If you were the driver, did you have the appropriate driving license? □ No □ Yes

8) **Were you injured?** □ No □ Yes (□ Seriously injured □ Injured)

9) On a scale from -3=Completely disagree to +3=Completely agree, indicate the level of your agreement with the statements below:

	1	2	3	4	5	6	7
Since my involvement in the accident, I am more careful as a road user							
The accident affected me psychologically							
It took me a while to drive again (for those who are drivers only)							

10) Has anyone in your social environment ever been involved in a road accident? □ No □ Yes

If yes, who?_____

PART 7 – SCENARIOS FOR MOBILITY FROM HOME TO SCHOOL

	Car (escorted by adult)	PTW (motorcycle)	Bus	Bicycle	Walk
Travel time (in minutes)	5,6, 7, 8, 10, 12, 14, 15, 17, 25	5,6, 7, 8, 10, 12, 14, 15, 17	8, 10, 12, 14, 15, 17, 20, 25, 30	6, 8, 10, 12, 15, 17	5, 6, 7, 8, 10, 12, 15, 17
Travel cost (in Euros)	1, 1.5, 2, 2.5, 3	1, 1.5, 2, 2.5	0, 0.5, 1.0, 1.5	-	-
Parking place	Available, Not available	Available, Not available	-	-	Available, Not available
Walking time to the bus stop (in minutes)	-	-	2, 3, 5, 7, 10, 15	-	-
Bike path	-		-	-	- Bike Paths  - No Bike Paths 
Walkability/ Sidewalks	-	-	-	- Wide Pavements  - Narrow Pavements  - Too Narrow with obstacles 	-
Weather conditions	Sun, Rain, Snow				

How happy are you with this choice? 1=not at all, …, 7=completely happy
If you are not happy, which of the characteristics of the mode you chose dissatisfy you? (choose)
Do you believe that your parents would agree with this choice?

PART 8 – SOCIO-ECONOMIC CHARACTERISTICS

1) Age: _____

2) Gender: □ Male □ Female

3) Height: _____ **Weight:** _____

4) Grades (school marks): □ 9-11 □ 11-14 □ 14-16 □ 16-18 □ 18-20

5) Nationality: (scroll down menu)

6) Have you ever lived abroad? □ No □ Yes (Where? ____ For how many years? ____)

7) Parents' occupation:

	Father	Mother		Father	Mother
Public Section			Seafarer		
Private Section			Farmer		
Military Services			Housewife		
Businessman/woman			Unemployed		

8) Parents' level of education:

	Father	Mother		Father	Mother
Secondary education			Master's		
Technical school			PhD		
University					

9) What time does your father go to work? __:__

10) What time does your mother go to work? __:__

11) Pocket money per day: ___ Euros

12) Household's monthly income: □ <1000€ □ 1001€ –2000€ □ 2001€–3000€ □ 3001€-4000€ □ >4001€

13) Number of siblings: Total __(Brothers:__ Age: ___ | Sisters:____ Age:___)

14) Do your siblings go to the same school as you? □ No □ Yes

15) Number of members of your household: _____

16) Family status: □ I live with my parents □ I live with my _____ (my parents are divorced)
□ I live with my _____ (the other is not in my life)

17) Do you live in a: □ flat □ house

18) How many years have you lived in this home? ___

19) Your house is: □ owned □ rented

20) Number of cars in the household: _____

21) Number of motorcycles in the household: ____

22) Number of bicycles in the household: ____

23) Do you have a mobile phone? □ No □ Yes
If yes, is it 3G/smartphone? □ No □ Yes Is it: □ Contract □ Top-up Bill per month: _____
Do you connect to the web via your mobile? □ No □ Yes (Frequency: scroll down menu)

24) Do you have a tablet/i-pad? □ No □ Yes

25) Do you have a Video game console? (scroll-down menu)

26) Do you have internet access at home? □ No □ Yes

27) Do you smoke? □ No □ Yes

28) How often do you consume alcohol: □ Never □ Once per month □ 2-3 times per month □ Once per week □ Several times per week

First name: _____ Phone number: _____ or e-mail: _____

Thank you!

https://www.facebook.com/groups/38409804168816

APPENDIX B – Forecasting Teenagers' Mode Choice Behavior

In Appendix B, we develop mode-to-school choice models using stated preference data and we forecast the modal split under various policies targeting to promote active transport and bus usage for the trip to school. For the purposes of this chapter we use the data that were collected from Cypriot teenagers in 2012. The dataset consists of 10,093 teenagers aged from 12 to 18 years old, while for the model estimation a total number of 20,185 SP observations are used. The presented model is a mixed multinomial choice model, while the estimation results are used for the estimation of values of time and policy implementations.

This chapter is structured as follows. Section B.1 describes the general modeling framework. Section 7.2 presents the design of the stated preference experiments that were used in our survey. In Section 7.3 we present the modeling framework and the relevant mathematical equations. Section 7.4 describes the specification of the proposed model, while in section 7.5 are presented and discussed the model estimation results. In section 7.6 we present the modal split under various policies, and section 7.7 concludes the chapter.

B.1 Scope

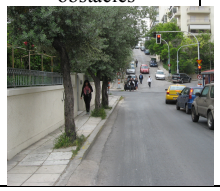
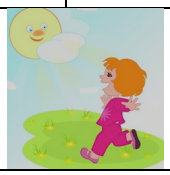
Half of the trips in developed countries and urban areas can be completed within a 20-minute bike ride, while a quarter of trips are within a 20-minute walk (ATFA, 2009). At present, the vast majority of these short trips are conducted using motorized vehicles. However, trends are changing and the latest reports show that the "future belongs to walking and cycling" (Davis et al., 2012; World Bank, 2008;Axhausen, 2013).

Although the advantages of cycling seem obvious, cycling and walking need encouragement in order to take place in urban environments - both in terms of promotion of cycling and walking as a life style as well as in terms of providing appropriate physical conditions. If the cycling and walking facilities are provided at the right places (Krizek and Roland, 2005; Tilahun et al., 2007; Winters et al., 2010; 2011; Lachance-Bernard et al., 2013), and designed in an appropriate manner teenagers will more likely decide to use them on daily bases. This is the aim of this chapter; to use stated preference scenarios in order to investigate which will be the factors that could promote cycling and walking to school and forecast the modal split under various policies aiming to promote active transport.

B.2 Stated Preference Scenarios

The SP scenarios designed in such a way in order to be clear to teenagers. After numerous pilot designs, we settled on the scenarios presented in Table B.1.

Table B-1: Stated preference scenario design

	Car (escorted by adult)	PTW (motorcycle)	Bus	Walk	Bicycle
Travel time (in minutes)	5,6, 7, 8, 10, 12, 14, 15, 17, 25	5,6, 7, 8, 10, 12, 14, 15, 17	8, 10, 12, 14, 15, 17, 20, 25, 30	6, 8, 10, 12, 15, 17	5, 6, 7, 8, 10, 12, 15, 17
Travel cost (in Euros)	1, 1.5, 2, 2.5, 3	1, 1.5, 2, 2.5	0, 0.5, 1.0, 1.5	-	-
Parking place	-	Available, Not available	-	-	Available, Not available
Walking time to the bus stop (in minutes)	-	-	2, 3, 5, 7, 10, 15	-	-
Bike lane	-		-	-	-Bike Paths  -No Bike Paths 
Walkability/ Sidewalks	-	-	-	-Wide Pavements  -Narrow Pavements  - Too Narrow with obstacles 	-
Weather conditions					

The scenarios have five alternative transport modes for the trip to school: 1.Car, 2.PTW (motorcycles), 3.Bus, 4.Walk and 5.Bicycle. The attributes of the modes are travel time (specific to all alternatives), travel cost (specific to car, PTW and bus), parking place availability (specific to PTW and bike), walking time from home to the bus stop (specific to bus), existence of bicycle lanes between home and school route (specific to bike), walkability/condition of sidewalks (specific to walk) and weather conditions.

In order to avoid misperceptions and to assure that the later three attributes are clear to all the participants we decided to use pictures of actual sidewalks and bicycle lanes' situations and weather conditions. The pictures were chosen carefully in order to make sure that they would not be contaminated with by strenuous variables (such as noise, or asphalt conditions). After the selection of the attributes and the attribute levels, we generated 600 different scenarios, in which the order of the attributes was randomized. Each participant in Cyprus was presented with two SP scenarios.

B.3 Modeling Framework

The SP data was used to estimate mode to school choice models. There are two specification issues with the collected data. The first is that logit may not be an appropriate model because of correlation of the error terms within the alternatives. The second is that each teenager in Cyprus was presented with two experiments. Thus, the responses across experiments of the same individual are likely to be correlated. These issues can be addressed by incorporating error components in a logit mixture model for panel data (see Walker et al., 2006).

In doing so the utility function, which is associated with each alternative, is:

$$U_{\text{int}} = \sum_{k=1}^{K} X_{\text{int}\,k}\beta_{kn} + \sigma_i \eta_n + \varepsilon_{\text{int}} \quad \text{(B.1)}$$

where U is the utility, i is the alternative, n is the individual, t denotes the choice experiment, X_{int} are vectors of the explanatory variables. The correlation among alternatives (nesting structure) and correlation across responses from an individual (panel effect) are captured by the error components η_n which are distributed *iid* Normal (0,1) across individuals n but remain constant within responses t from a given individual (see Train, 2003; Walker et al., 2006; Hess et al., 2011). The estimated parameters are the vectors β_{kn} and scalars σ_i.

In our case, the mode choice model has five alternatives:

1. Car (7,960 obs., 39%)
2. PTW (910 obs., 4%)
3. Bus (3,945 obs., 19%)
4. Walk (3,155 obs., 16%)
5. Bicycle (4,125 obs., 21%; denoted as *BIKE*)

The utility for each alternative is specified as follows:

$$U_{\text{nt}}^{CAR} = \beta_k X_{ntk}^{CAR} + \sigma^{PRIV}\eta_n^{PRIV} + \varepsilon_{nt}^{CAR} \quad \text{(B.2)}$$

$$U_{\text{nt}}^{PTW} = \beta_k X_{ntk}^{PTW} + \sigma^{PRIV}\eta_n^{PRIV} + \varepsilon_{nt}^{PTW} \quad \text{(B.3)}$$

$$U_{\text{nt}}^{BUS} = \beta_k X_{ntk}^{BUS} + \sigma^{BUS}\eta_n^{BUS} + \varepsilon_{nt}^{BUS} \quad \text{(B.4)}$$

$$U_{\text{nt}}^{WALK} = \beta_k X_{ntk}^{WALK} + \sigma^{ACT}\eta_n^{ACT} + \varepsilon_{nt}^{WALK} \quad \text{(B.5)}$$

$$U_{\text{nt}}^{BIKE} = \beta_k X_{ntk}^{BIKE} + \sigma^{ACT}\eta_n^{ACT} + \varepsilon_{nt}^{BIKE} \quad \text{(B.6)}$$

where n is the individual (n = 1,…,N; N=10,093), t denotes the choice experiment (t = 1,…,T; T = 2 choice experiments per participant), X_{nt} are vectors of the explanatory variables. The correlation among alternatives (nesting structure) and correlation across responses from an individual (panel effect) are captured by the error components η_n^{PRIV}, η_n^{BUS}, η_n^{ACT}, which are distributed *iid* Normal (0,1) across individuals n but remain constant within responses t from an individual. ε_{nt}^{CAR}, ε_{nt}^{PTW}, ε_{nt}^{BUS}, ε_{nt}^{WALK}, ε_{nt}^{BIKE} ~*iid* Extreme Value across all individuals n and responses t. The vectors η (η_n^{PRIV}, η_n^{BUS}, η_n^{ACT}) and ε (ε_{nt}^{CAR}, ε_{nt}^{PTW}, ε_{nt}^{BUS}, ε_{nt}^{WALK}, ε_{nt}^{BIKE}) are independent, therefore the model is a logit mixture model for panel data. X_{nt}^{CAR}, X_{nt}^{PTW}, X_{nt}^{BUS}, X_{nt}^{WALK}, X_{nt}^{BIKE} are column vectors of observable characteristics of individuals and attributes of alternatives. The estimated parameters are the vectors β_k and the scalars σ_n^{PRIV}, σ_n^{BUS}, σ_n^{ACT}.

The likelihood for the t responses of an individual i is:

$$P(i_t \mid X_n;\beta_k,\sigma_i) = \int_{\eta_n} P(i_t \mid X_{nt},\eta_n;\beta_k,\sigma_i) f(\eta_n) d\eta_n \quad \text{(B.7)}$$

each individual response i_t conditional on the unknown η_n, $P(i_t|X_{nt},\eta_n;\beta_k,\sigma_i)$ is integrated over the distribution of η_n. $f(\eta_n)$ is a 3-dimension multivariate normal with (3×1) mean vector of zeros and covariance matrix equal to a 3×3 identity matrix.

B.4 Model Specification

Figure B.1 presents the modeling framework applied to the mode to school choice experiments. The utility of each mode is a function of the scenarios' attributes and the characteristics of the participant, which are the gender, the age and the daily pocket money.

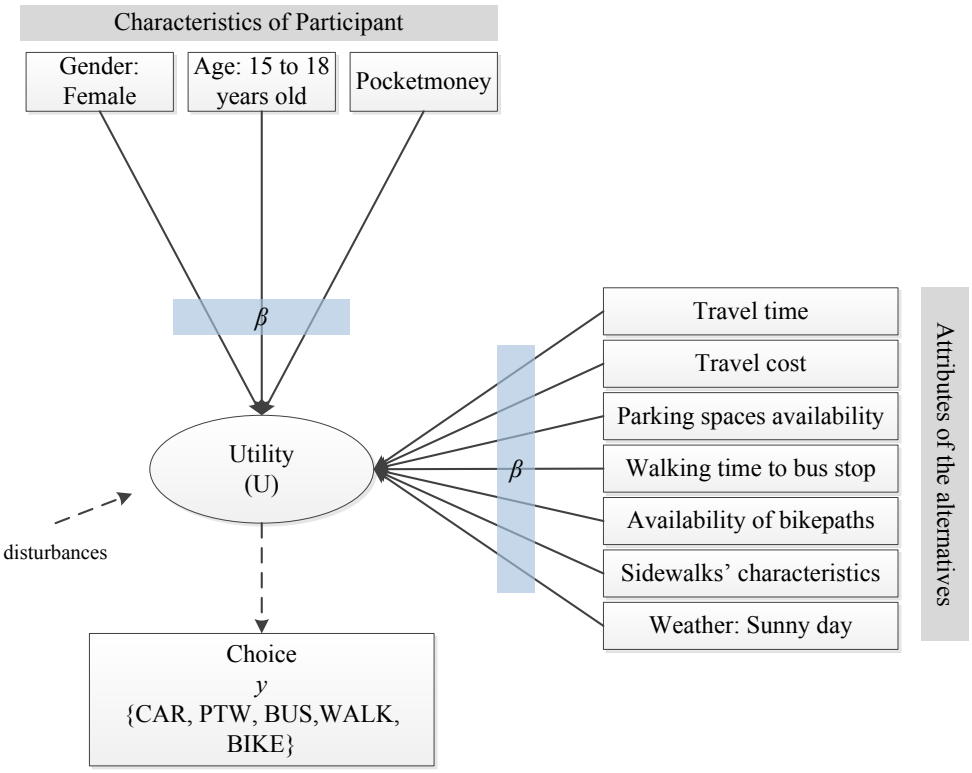


Figure B.1: Modeling framework

In our case the utilities of each alternative are specified as shown in Eq. (B.8) to (B.12). The utility of choice is a function of attributes of the alternatives. The deterministic utility contains the attributes of the experiments, the socioeconomic characteristics of the participants, as well as alternative specific constants for the alternatives *CAR*, *BUS*, *WALK* and *BIKE*. A lot of RP and SP variables and interacted terms of them were tested in order to get the final model. For example, in the place of the variable pocket money in Eq. (B.8), (B.9), (B.10) and (B.12), we also tested the variable household income. Nevertheless, due to the fact that a significant percentage of the latter variable is missing in combination with the fact that teenagers could not know their exact household income, we preferred to keep the variable pocket money, which is usually related with the family income[4].

Moreover, we carefully examined and filtered the sample, in order to put constraints on the options available to certain students. For example, students living more away than the maximum walking distance to school that identified to 2.0km, were not given the option of *WALK*. In the same way, teenagers that live more away than 1.5km from school were not given the option of selecting cycling. Alternative *CAR* is available to all students, as all the participants' households had available at least one car, all households had at least one driver (an adult with driving license) and all individuals have the opportunity to be escorted by others except by their parents/ caregivers. In Cyprus someone is authorized for a car driving license after the age of 18 years old. So the option car refers only to be escorted by car. The *PTW* alternative was available only to the teenagers that stated that they had access to a motorcycle either as drivers or passengers. Alternative *BUS* was available to all as the minimum identified distance that the bus was used was 150m.

[4] The correlation between pocket money and household income is significant at the 0.01 level.

The equations of the choice model is given below:

$$U_{nt}^{CAR} = \beta_{\text{car}} + \beta_{ttcar} * TTCAR + (\beta_{tccar} + \beta_{pm1} * POCKMONEY) * TCCAR + \beta_{age1} * AGE1518 + \beta_{gen1} * FEMALE + \sigma^{PRIV}\eta_n^{PRIV} + \varepsilon_{nt}^{CAR} \quad \text{(B.8)}$$

$$U_{nt}^{PTW} = \beta_{ttptw} * TTPTW + (\beta_{tcptw} + \beta_{pm2} * POCKMONEY) * TCPTW + \beta_{pptw} * PPTW + \beta_{gen2} * FEMALE + \sigma^{PRIV}\eta_n^{PRIV} + \varepsilon_{nt}^{PTW} \quad \text{(B.9)}$$

$$U_{nt}^{BUS} = \beta_{ttbus} * TTBUS + (\beta_{tcbus} + \beta_{pm3} * POCKMONEY) * TCBUS + (\beta_{wtbus} + \beta_{wbus} * WEATHER) * WTBUS + \sigma^{BUS}\eta_n^{BUS} + \varepsilon_{nt}^{BUS} \quad \text{(B.10)}$$

$$U_{nt}^{WALK} = \beta_{walk} + \beta_{ttwalk} * TTWALK + \beta_{nsd} * NARROWSWALKS + \beta_{wsd} * WIDEWSWALKS + (\beta_{w4} + \beta_{gen4} * FEMALE) * WEATHER + \beta_{age4} * AGE1518 + \sigma^{ACT}\eta_n^{ACT} + \varepsilon_{nt}^{WALK} \quad \text{(B.11)}$$

$$U_{nt}^{BIKE} = \beta_{bike} + \beta_{ttbike} * TTBIKE + \beta_{psb} * PSBIKE + \beta_{bpb} * BIKELANE + (\beta_{wbike} + \beta_{gen5} * FEMALE) * WEATHER + \beta_{age5} * AGE1518 + \sigma^{ACT}\eta_n^{ACT} + \varepsilon_{nt}^{BIKE} \quad \text{(B.12)}$$

where:
TTCAR = travel time by car (in minutes);
TCCAR = travel cost by car (in Euro);
TTPTW= travel time by PTW (in minutes);
TCPTW = travel cost by PTW (in Euro);
PPTW = availability of PTW parking spaces at school. It takes the value 1 if there is available parking place, 0 otherwise;
TTBUS = travel time by bus (in minutes);
TCBUS = travel cost by bus (in Euro);
WTBUS = travel time from/to bus stop (in minutes);
TTWALK= travel time on foot (in minutes);
WIDESWALKS = existence of wide sidewalks across the route between home and school. It takes the value 1 if there are wide sidewalks, 0 otherwise;
NARROWSWALKS = existence of narrow sidewalks across the route between home and school. It takes the value 1 if there are narrow sidewalks, 0 otherwise;
TTBIKE = travel time by bicycle (in minutes);
PSBIKE = availability of bicycle parking spaces at school. It takes the value 1 if there are bicycle parking places, 0 otherwise;
BIKELANE = existence of cycle lane across the route between home and school. It takes the value 1 if cycle lanes are available, 0 otherwise;
WEATHER = weather conditions. It takes the value 1 if it is a sunny day, 0 if it is a rainy day;
AGE1518 = takes the value 1 if the participant is from 15 to 18 years old, 0 otherwise;
FEMALE = takes the value 1 if the participant is female, 0 otherwise;
POCKMONEY = indicates the daily pocket money of the participants (in Euros), continuous variable;
σ^{PRIV} = parameters that account for correlation between the private motorised modes (*CAR* and *PTW*) among observations from the same individuals in the data set;

σ^{BUS} = parameter that captures the taste heterogeneity for *BUS* and the panel effect among observations from the same individuals in the data set;
σ^{ACT} = parameters that account for correlation between active transport modes (*WALK* and *BIKE*) among observations from the same individuals in the data set;

$\eta_n^{PRIV}, \eta_n^{BUS}, \eta_n^{ACT}$ are error components that capture the correlation among the alternatives (nesting structure) and the correlation across responses from the same individual (panel effect) and are distributed *iid* Normal(0,1) across individual *n*, but remain constant within responses *t*;

ε_{nt}^{CAR}, ε_{nt}^{PTW}, ε_{nt}^{BUS}, ε_{nt}^{WALK}, ε_{nt}^{BIKE} ~*iid* Extreme Value across all individuals *n* and responses *t* and are independent from $\eta_n^{PRIV}, \eta_n^{BUS}, \eta_n^{ACT}$.

B.5 Model Estimation Results

This section presents and discusses the estimation results of the mode to school choice model. We first estimated a multinomial logit (MNL) model served as base model. Due to the specification issues of the collected data that were discussed in the previous subsection, we incorporated into the MNL three error components, thus creating a mixture model. The models were estimated using the Pythonbiogeme 2.3 software (Bierlaire and Fetiarson, 2009). The sample used for the modeling process consisted of 20,185 SP responses, corresponding to 10,093 individual high school students (aged 12 to 18 years old). The estimation results are presented in Table 7.2.

Table B-2: Mode choice model estimation results

	MNL		MMNL	
	Coefficient	t-stat	Coefficient	t-stat
β_{car}	-0.73	-4.90	-1.42	-7.20
β_{bus}	-0.96	-6.13	-4.97	-12.14
β_{walk}	-1.90	-12.20	-3.78	-15.00
β_{bike}	-1.64	-10.75	-1.29	-14.00
Travel Time - Car	-0.024	-10.22	-0.069	-15.54
Travel Cost - Car	-0.117	-6.23	-0.23	-2.26
Age 15 to 18 years old - Car	-0.246	-1.71	-0.133	-0.83
Female - Car	0.458	13.25	0.616	3.39
Pocket money - Car	0.246	3.71	0.001	1.53
Travel Time – PTW	-0.165	-13.40	-0.251	-16.85
Travel Cost - PTW	-0.583	-6.01	-0.452	-3.67
Parking Place-PTW	0.146	1.93	0.101	2.12
Female-PTW	-0.26	-3.35	-0.200	-2.00
Pocket money - PTW	.019	5.26	0.015	2.24
Travel Time - Bus	-0.014	-5.88	-0.060	-9.98
Travel Cost - Bus	-0.249	-4.93	-0.461	-3.39
Walking Time to Bus Stop - Bus	-0.02	-4.77	-0.0094	-4.39
Weather - Bus	-0.009	-2.1	-0.0098	-0.45
Pocket money - Bus	-0.01	-2.52	-0.048	-3.68
Travel Time - Walk	-0.022	-6.12	-0.012	-2.81
Existence of Wide Sidewalks - Walk	0.500	9.73	0.431	7.15
Existence of Narrow Sidewalks-Walk	-0.237	-4.72	-0.328	-5.72
Weather - Walk	0.664	12.84	1.16	13.50
Female - Walk	-0.292	-4.99	-0.796	-7.36
Travel Time - Bicycle	-0.057	-10.91	-0.049	-7.35
Parking Place Availability - Bicycle	0.256	7.25	0.248	5.84
Existence of Bike Lane - Bicycle	0.353	9.96	0.336	7.91
Weather - Bicycle	0.419	8.77	0.921	11.06
Female - Bicycle	-0.109	-1.99	-0.610	-5.76
Age 15 to 18 years old - Bicycle	0.585	8.24	0.599	6.59
Parameter for Private Motorised Vehicles	--	--	3.64	21.82
Parameter for Bus	--	--	6.90	25.53
Parameter for Active Transport	--	--	3.96	15.64
Number of observations	20.185			20.185
Number of Draws	--			20,000
Init. Likelihood	-78735.14			-68668.66
Final Likelihood	-26960.55			-18653.82
$\bar{\rho}^2$	0.657			0.728

As expected, the signs for the coefficients of travel time, travel cost and walking to the bus stop time are all negative in the estimated models. These imply that increases in the values of these variables for an alternative mode reduce the utility of that mode and the probability that it will be chosen. The travel cost variables in the utility of car, PTW and bus are also interacted with the variable pocket money. The sign of the coefficient of pocket money is positive in the utility of car and PTW and negative in the utility of bus. This indicates that teenagers with higher pocket money would choose car or PTW even though the travel cost of these modes increases. On the other hand, teenagers from households with higher income would not choose bus even though the cost of bus increases. As mentioned above the pocket money of teenagers reflects the income of their household. In doing so, we assume that even the cost of car and PTW increase, teenagers from households with higher income, still prefer these modes. The opposite happens in the case of bus; even the travel cost of bus increases, students from households with higher income do not prefer it. Teenagers with higher pocket money and higher household income prefer private motorized modes even if the travel of cost increases. The coefficients of the variable female indicate that girls generally prefer car for their transport to school.

Regarding PTW, the results indicate that as travel time and travel cost increase, the participants avoid this alternative. Travel time affects negatively the choice of PTW, while it is the most statistically significant variable for this alternative. The travel time reflects the distance, thus we assume that teenagers avoid travelling with PTW when they live quite far away from school. Availability of parking place for PTW at schoolyard favors this choice. Males seem to be more likely than females to choose PTW for their trip to school.

As far as the utility of bus, travel cost is the most statistically significant variable affecting negatively the choice of bus. When the survey took place, high-school students of Cyprus had a student card that allowed them to use the bus without any charge. In our scenarios we kept this option, but we added other values to this alternative, where the students had to pay for using the bus. The reaction of students to pay for using the bus is reflected to the significance of this variable. Travel cost is also interacted with the continuous variable pocket money. The negative sign of the coefficient of pocket money variable indicates that teenagers with higher pocket money do not prefer the bus. Continuing with walking travel time to/from the bus stop to the final destination (home or school), as the value of this variable increases, teenagers seem to not prefer bus. This variable is also interacted with the dummy variable regarding weather conditions. The results show that even if the weather is sunny (good weather conditions), as walking time to/from bus stop increases, teenagers do not prefer bus. Once again, walking travel time to the bus stop reflects the distance. When the bus stop is quite away from household, the probability of choosing bus decreases.

Good weather conditions (sunny days) and the existence of wide sidewalks seem to be the most statistically significant variables and through a positive sign affect the choice of walking. As travel time increases teenagers do not choose walk to school. The existence of wide sidewalks favors the choice of walking, whilst existence of narrow pavements decreases the utility of this choice. The width of sidewalks reflects safety issues. It is probable that teenagers feel safer when wide sidewalks exist, thus the probability of choosing walking to school increases. The variable “Good weather conditions” is also interacted with the dummy variable female, in order to check the reaction of gender to weather conditions regarding walking. Females do not prefer walking even though the weather is good.

As far as the choice of bicycle, once again travel time and existence of bike lanes play the most significant role in this choice. As travel time increases, teenagers do not prefer cycling to school. In other words, as distance from home to school increases, students do not prefer cycling. Existence of bike lanes and availability of bicycle parking spaces at the schoolyard favor the choice of bicycle. Both these two attributes reflect safety issues. The first one reflects the personal safety of the teenager when he/she cycles from home to school and back; bike lanes enhances safety. Existence of bicycle parking spaces reflects safety issues regarding getting robbed. Teenagers aged from 15 to 18 years old is more likely to choose bike for their trip to school. This reflects the fact that as teenagers reach the age of 18 (adulthood), generally prefer independent traveling. Good weather conditions affect positively and significantly the choice of cycling. Similar to the alternative of walk, the weather variable is interacted with the dummy variable gender and the results are the same; female teenagers would not choose cycling to school, even if it were a sunny day.

MMNL is preferred to MNL since the former allows for taste heterogeneity across individuals as well as accommodating the correlations across choice sets that are drawn from the same individual (mixed logit with panel structure). The log-likelihood value also suggests that the model fit for MMNL is much better than for MNL. It is interesting to note that the random parameters in the MMNL are statistically significant indicating that there is a correlation between *CAR* and *PTW* (private motorized modes) and between *WALK* and *BIKE* (active transport modes).

Evidently, the results of the stated preference scenarios echo the reality and the preferences of Cypriots. That is, Cyprus is a country heavily depended on private motorized vehicles, whilst active transport is highly ignored. However, under certain policies active transport could be enhanced.

B.5.1 Value of Time

The model estimation results enabled the calculation of the value of time (VOT) in relation to car, PTW and bus. The cost sensitivity is a function of the teenager's pocket money. The VOT for each motorised transport mode is calculated using the Eq. (B.13) to (B.15).

$$VOT_{CAR} = \frac{\beta_{TTCAR}}{\beta_{TCPT} + \beta_{pm1} * POCKMONEY} \quad \text{(B.13)}$$

$$VOT_{PTW} = \frac{\beta_{PTW}}{\beta_{PTW} + \beta_{pm2} * POCKMONEY} \quad \text{(B.14)}$$

$$VOT_{BUS} = \frac{\beta_{BUS}}{\beta_{BUS} + \beta_{pm3} * POCKMONEY} \quad \text{(B.15)}$$

Table B.3 presents the average, the minimum and the maximum VOT for car, PTW and bus. It is noticed that the VOT of MMNL model is considerable higher than those of the MNL model. But since the MMNL model has better goodness-of-fit, we elaborate on the VOT of this model. The VOT for car for the adolescent participants is estimated to 18.91 Euro per hour. The VOT for PTW is 34.15 Euro per hour, while the VOT for bus is 5.20 Euro per hour. Due to the fact that we have not identified other survey referring to VOT for

teenagers, we compare our results with findings from surveys that focus on adults. The VOT for car is somewhat higher than the findings of Wardman et al. (2012), who found out that the In-Vehicle-Time (IVT) in Greece was 15.0 Euro per hour for business purposes and 12.6 Euro per hour for commuting. However, the VOT for car is not directly anticipated by teenagers, as their parents cover the car's costs. The VOT for PTW is considerably high. The travel cost of PTW in Cyprus is usually covered by teenagers' pocket money and in doing so they anticipate better the travel costs of this mode. Despite the fact that VOT is high, we assume that this indicates that teenagers are willing to pay a significant amount of money in order to drive a PTW, which reflects a way of freedom and independent traveling. The VOT for bus is quite similar to this of the adults' surveys (i.e. Polydoropoulou et al., 2013). Although the time that the survey was conducted, the students used the bus without any charge, they were willing to pay an average of 5.20 Euro per hour to use it.

Table B-3: Analysis of Value of Time (VOT)

in EURO/hour	MNL			MMNL		
	Mean	Min.	Max.	**Mean**	Min.	Max.
VOT for car	**13.69**	12.40	31.86	**18.91**	18.18	25.82
VOT for PTW	**19.96**	17.60	59.09	**34.15**	33.43	40.26
VOT for bus	**2.85**	1.17	3.36	**5.20**	1.33	7.11

B.6 Model Validation and Forecasting

In this section we use the estimation results of the mixed multinomial mode choice model in order to forecast the modal split under various policy scenarios. The base modal splits for the base model (MNL) and the mixed logit (MMNL) model are presented in Table B.4.

Table B-4: Base modal split

	MNL	**MMNL**
Probability of choosing Car	0.397	0.388
Probability of choosing PTW	0.037	0.064
Probability of choosing Bus	0.196	0.161
Probability of choosing Walk	0.158	0.164
Probability of choosing Bicycle	0.209	0.222

Table B.5 shows the policy variables presented to the respondents in the SP experiments with regard to availability of bike paths, availability of bicycle parking spaces at schoolyards, availability of wide sidewalks, and modifications to the travel cost of bus. Although we tested a number of policies and combinations of them, we present only the policies that have the most significant impact on the enhancement of active transport and public transport (bus).

Table B-5: Proposed policies

	Travel Cost for Bus (price of bus-ticket)	Sidewalks characteristics	Availability of bike lanes	Availability of bicycle parking spaces at schoolyard
Policy 1	Student Pass - Free	Wide sidewalks	Available	Available
Policy 2	50% discount (€0.50)	Wide sidewalks	Available	Available
Policy 3	No discount (€1.00)	Wide sidewalks	Available	Available
Policy 4	No discount (€1.00)	Narrow sidewalks	Non-available	Non-available
Policy 5	Increase 50% (€1.50)	Narrow sidewalks	Available	Available
Policy 6	Increase 100% (€2.00)	Wide sidewalks	Available	Available
Policy 7	-	-	Available	Available

The survey results indicate that 53% of the participants' routes from home to school have wide sidewalks, 3% have bike paths, while only 5% of the school have available bicycle parking places at their schoolyards. The forecasts here are reliant on the parameters that we take from the estimation of the MMNL model using the SP observations. Table B.6 presents the modal split under each policy that described in the above table.

Table B-6: Forecast impact

	Car	PTW	Bus	Walk	Bike
Base	38.87%	6.34%	16.14%	16.45%	22.20%
Policy 1	38.00%	**4.90%**	**17.50%**	16.80%	22.80%
Policy 2	37.75%	5.70%	16.25%	17.10%	23.20%
Policy 3	37.80%	6.70%	16.20%	16.90%	22.40%
Policy 4	42.90%	6.80%	15.70%	15.10%	19.50%
Policy 5	38.90%	6.20%	16.90%	15.50%	22.50%
Policy 6	37.82%	5.30%	16.08%	**18.10%**	22.70%
Policy 7	**37.20%**	6.80%	17.15%	15.20%	**23.70%**

The first proposed policy evaluates the impact of retaining the student pass for the bus, while at the same time all the routes between home and school have wide pavements and bike lanes, and bicycle parking places are available at all schools. It can be seen that there is an increase of 1.36% in the probability of choosing bus, an increase of 0.35% in the probability of choosing walk and 0.60% increase in the probability of cycling. The probability of choosing car and PTW decreases.

The second policy evaluates the impact of introducing a student pass with which students have 50% discount on the actual price of bus-ticket, which was €1.00 when the survey conducted. In other words, there is an increase to the travel cost by bus for the students. Also, under this policy, wide pavements, bike lanes and bicycle parking spaces at schoolyards are available. Although the travel cost by bus increases, the probability of choosing bus increases by 0.11%. However, the cost that students have to pay in this case is quite low (€0.50) and in doing so we accept this increase. The probability of walk increases

by 0.65% and the probability of cycling by 1.0%. The probability of choosing private motorized modes (car and PTW) decreases.

The third policy examines the impact of not providing discount to bus-ticket for students, but providing wide pavements, bike paths and bicycle parking spaces. The probability of choosing bicycle for their trip to school increases by 0.20%, while the probability of walking by 0.45%. The probability of choosing bus increases only by 0.06%. Similarly to Policy 2, an increase to the bus travel cost does not reduce the demand for bus. The probability of choosing car decreases by 1.07%, whilst the probability of choosing motorcycle increases by 0.36%. Although bike lanes, bicycle parking spaces and wide sidewalks are available, the increase in active transport modes is low.

Under the Policy 4, it is examined the impact of providing no incentives to students for using public transport (bus) and active transport (walk and bicycle). The forecasts seem reasonable. The demand for car increases by 4.03% and the demand for PTW increases by 0.46%. The probabilities of choosing bus, walk and bicycle decrease the most comparing to the other proposed policies (0.44%, 1.35% and 2.70% respectively).

Policy 5 examines the impact on modal split under the assumption that the bus ticket increases by 50% based on the actual price (the bus-ticket price is now €1.50), the sidewalks between home and school are narrow, while bike paths and bicycle parking spaces at schoolyards are available. Despite the fact that the provided incentives favor the choice of bicycle, the probability of choosing bicycle increases only by 0.3%. Although the bus ticket increases, the probability of choosing bus increases by 0.76%. Existence of narrow pavements decreases the probability of walking to school by 0.95%. The probability of choosing car increases by 0.03%, while the probability of choosing a PTW decreases by 0.14%.

The sixth policy examines the impact of providing to students bike paths, bicycle parking spaces and wide pavements, while at the same time the price of the bus ticket is doubled. Under this policy, we notice the biggest increase to the probability of walking to school (1.65%). The probability of choosing bicycle increases by 0.5%, while the probability of choosing a motorized mode for their trip to school decreases; the probability of choosing car decreases by 1.11%, the probability of PTW by 1.04% and the probability of bus 0.06%. This policy seems to favor the most the choice of walking to school.

Policy 7 examines the impact of improving only the bicycle facilities by providing bike paths and parking spaces at schoolyards, while the characteristics of the other modes remain as they are. This policy affects the most the choice of cycling to school, as the probability of choosing bicycle increases by 1.50%. However, at the same time it is noticed an increase (0.46%) in the probability of choosing PTW. Under this policy, it is also noticed the lowest probability of choosing car (37.2% -a decrease of 1.67%). The probability of choosing bus increases by 1.01%, while the probability of walking decreases by 1.25%.

B.6.1 Policy Evaluation

In this section we evaluate the results of the policy analysis that presented above. The forecast findings can support policies for promoting the usage of bus, walk and cycling to school. The most effective policy in order to increase the probability of choosing walking is Policy 6, which at the same time causes an increase to probability of choosing cycling and significant decrease to probability of choosing car and PTW. If policy makers envisage promoting only cycling to school Policy 7 is the most appropriate, while at the same time causes the biggest decrease in car demand. The policies that decrease the probability of choosing PTW is Policy 4 and Policy 6, while it is generally noticed that increases to the bus ticket up to €1.50, generally increase the probability of choosing bus, instead of decreasing it. However, as the increases in ticket price are low, we generally accept these results.

Table B.7 presents the evaluation of the proposed policies using colors. When an impact is evaluated with green it means that is highly recommended; orange means that the impact is the desired one and the change to the modal split is larger than 1.00%; yellow means that the impact is the desired one but the changes in the modal split are lower than 1.00%; grey means that the impact is not the desired one and in doing so the policy does not recommended. By desired impact, we mean that the probability of choosing private motorized vehicles decreases, while the probability of choosing active transport or public transport increases. In doing so, the Policy that favors the most the probability of choosing cycling is Policy 7, followed by Policy 2. Policy 3 and Policy 5 also favor the probability of choosing bike. Policy 6 favors the most the probability of choosing walking, followed by Policy 3. Policy 1 favors the most the probability of choosing bus.

Table B-7: Policy Evaluation

	Car	PTW	Bus	Walk	Bike	TOTAL
Base	38.87%	6.34%	16.14%	16.45%	22.20%	
Policy 1	38.00%	**4.90%**	**17.50%**	16.80%	22.80%	
Policy 2	37.75%	5.70%	16.25%	17.10%	23.20%	
Policy 3	37.80%	6.70%	16.20%	16.90%	22.40%	
Policy 4	42.90%	6.80%	15.70%	15.10%	19.50%	
Policy 5	38.90%	6.20%	16.90%	15.50%	22.50%	
Policy 6	37.82%	5.30%	16.08%	**18.10%**	22.70%	
Policy 7	**37.20%**	6.80%	17.15%	15.20%	**23.70%**	

■*Highly Recommended*, ■*Recommended*, ■*Recommended-Moderate*, ■ *Not Recommended*

The forecasting results indicate that by providing bike paths and bicycle parking spaces, the biggest increase in the probability of choosing bicycle is 1.5%. This increase is quite low taking into account the cost of constructing bike paths, indicating that providing only infrastructure could not affect significantly the demand. Thus, it is also necessary the policy makers and the school authorities to organize targeted campaigns in order to raise the active transport spirit.

B.7 Conclusions

The aim of this chapter was to estimate mode to school choice models using stated preference scenarios. Despite the fact that there is a growing body of researcher that deals with this issue, to our knowledge, it is the first time that mode to school choice models are estimated using SP data that are collected directly from teenagers.

We start the chapter by presenting the design of the stated preference scenarios that were used in the survey in Cyprus in 2012. The experiments have five alternatives (car, PTW, bus, walk and bicycle), while their attributes are travel time, travel cost, availability of PTW and bicycle parking spaces at schoolyard, walking time to the bus stop, the width of sidewalks and availability of bike lanes.

The mode choice model that was developed is mixed multinomial choice model (MMNL). Although a number of models (i.e. latent variable) were estimated, we decided that the MMNL was the most appropriate one with the highest goodness-of-fit. Also, the MMNL is the most appropriate as it captures the panel effect and the correlation of the error terms within the alternatives. In general, our results confirm that travel time and travel cost significantly affect teenagers' mode choice behavior, similarly to the effect on adults. Walking time from/to the bus station also has a negative effect on the decision to take a bus to school (public transportation). Active transport (walking and cycling) is preferred when there are bike lanes, bicycle parking spaces, and wide sidewalks. Weather conditions also affect mode choice: the results show that, when it is a sunny day, the participants prefer active transport, while when it is raining, motorized vehicles (car and bus) are preferred. Females seem to prefer car, even if the weather is sunny. We also used as an explanatory variable the pocket money of the participants, which was interacted with the travel cost of the alternatives car, PTW and bus. The results indicate that even if the travel costs of car and PTW increase, teenagers with higher pocket money still prefer these. The opposite happens in the case of bus; when the bus travel cost increases, teenagers with higher pocket money do not prefer this alternative for their trip to school.

The results of the model were used in order to calculate the VOT of car, PTW and bus. The estimated values show that teenagers are willing to pay a significant amount (€34.15/hour) in order to use PTW. This reflects the fact that teenagers seek for independent traveling. The VOT of car is €18.91 per hour and the VOT of bus is €5.20 per hour. Since there are no similar surveys that investigate the VOT of teenagers, we cannot compare our results. However, comparing our VOT car and bus results to adults, they seem plausible (Wardman, 2012; Polydoropoulou et al., 2012).

In addition, we further used the model estimation results in order to check the modal split under various policies. The policies that we tested mostly promote active transport and bus. Under the assumption that bike lanes and bicycle parking spaces are available, we had the highest increase in the probability of choosing bicycle. However, the results of the model implementation revealed that even if the city planners construct bike lanes and bicycle spaces, the highest increase in bicycle demand is 1.50%. This reflects the current situation in Cyprus that Cypriots are highly car-oriented. In doing so, there is an imperative need these policies that refer to infrastructure to be combined with targeted campaigns aiming to promote active transport spirit. For example, these campaigns should focus especially on female Cypriots, which seem to avoid active and public transport. Active transport days or weeks could be adopted by schools. On these days, cyclist or pedestrian students could be rewarded with less homework or a free lunch. Moreover, schools could implement a tool

similar to that used by companies, to record the transport modes that students use and reward students who are frequent users of active transport.

Generally, Cypriots cities' plans should encourage more innovative types of developments, to support active transport and discourage car use. The construction of bike paths and wider sidewalks, which cost less than constructing roads, will enhance active transport and, at the same time, improve the connectivity of walking routes (for example to the bus stop or to school). In addition, bicycle parking spaces at schools are necessary, not only to encourage cyclists, but to remind the students to use their bicycles. Nowadays, cycling is not only a healthy transport mode but also a trend among young people around the world.

Finally, it is worthwhile to refer that this school year (2013-2014) students have no discount for using the bus. They have to pay 40Euros per month in order to use the bus, which means that they pay approximately 1.82 Euros per day. Although the travel cost by bus increased, the demand for bus is the same as the previous school years, when the student pass was valid (MOEC, 2013). Our forecasting showed that when the price of the bus increases up to 1.50 Euros for the trip to school and back, the demand remains the same or slightly increases, while a slight decrease (0.06%) is noticed when the price is 2.00 Euros for the trip to school and back.

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