To Walk or not to Walk? Teenagers' Travel Behavior and Perceptions Towards Walkability Constraints

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ABSTRACT

The aim of this paper is to investigate the interrelationship between urban environment and walking to school, and how teenagers' perceptions towards walkability constraints affect their mode choice. An advanced hybrid mode choice model is developed, where the utilities of the alternative modes depend on the modes' characteristics, teenagers' socioeconomic characteristics, as well as a latent variable, referring to walking constraints. The indicators of the latent variable include perceptions regarding the existence of stray animals, poor lighting, narrow sidewalks, parked cars that obscure visibility, non-signalized intersections, and probability of attack and safety en route. A case study is presented based on a questionnaire survey that took place at high schools of three distinct geographic Greek areas (an urban area, a rural and an insular area) during 2011-2012. 1,988 high-school students, aged between 12 to 18 years old participated in the survey. Adolescents in rural areas walk greater distance than urban and insular adolescents. Model estimation results show that teenagers from each geographical area perceive in different ways the built environment, indicating how significant is the sense of place. The incorporation of the latent variable improved the overall goodness-of-fit of the model and its explanatory power. The results of the study provide insights on policies and campaigns that may help the next generation to develop a greener travel behavior.

Key words: Hybrid Choice Model (HCM), Teenagers/ Adolescents, Walking, Walkability Constraints, Mode Choice to School,

1. Introduction

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. At present, the vast majority of these short trips are conducted using motorized vehicles (ATFA, 2009). However, trends are changing and the latest reports show that the "future belongs to walking and cycling" (COST, 2010; World Bank, 2008) with young people (14 to 30 years old) consciously choosing active transport and avoiding obtaining driving licenses (Davis et al., 2012).

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 right 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, 2008). Due to the fact that transportation is a routine in which we all engage, active transportation has great potential to increase our levels of physical activity and help reverse current obesity trends, especially amongst children (Strong et al., 2005; Polydoropoulou and Kamargianni, 2012).

Against this background, the research on active commuting has expanded rapidly in the last decade, with researchers trying to determine which factors affect this behavior. Some of the identified factors are socioeconomic characteristics (e.g. gender, age, income etc.), attitudes and perceptions towards ecological issues, car addiction and the built environment (Leslie et al., 2007; Mokhatarian et al., 2001; Handy et al., 2002; Abou-Zeid et al., 2011; Polydoropoulou et al., 2012). Narrowing the scope down to children (5 to 11 years old), a growing body of researchers is trying to identify school transportation mode choice behavior and, having largely drawn its variables from studies of adults, has suggested that neighborhood factors such as distance to school, land-use mix, parental perceptions, and the characteristics of the built environment may influence this (Mitra et al., 2012, Kamargianni and Polydoropoulou, 2013).

However, the majority of these surveys refer to elementary students, leaving the adolescent age group's travel behavior under-examined. Teenagers are a special age group with peculiar travel behavior and special travel needs. On the one hand, their participation in activities and mobility are constrained by parental consent and age restrictions on driving. On the other hand, their burgeoning maturity enables them to make independent decisions and spend time without adults' supervision (Clifton, 2003). Additionally, the propensity of an individual to choose a specific transport mode is highly subjective as different people perceive the built environment in different ways. Thus, a number of unobserved variables regarding the built environment affect this choice (Deutsch and Goulias, 2008). The existing work on minors' travel behavior focuses on urban areas; little work has focused on rural and especially insular areas, where the built environment is completely different.

With these points in mind, the aim of this paper is to investigate teenagers' mode choice behavior for the trip to school, the effect of actual and perceived built environment characteristics on this behavior, and the possible differences between three distinct environments (urban, rural and insular). More specifically, an advanced hybrid mode choice model is developed for each area, where the utilities of the alternative modes (active transport, public transport, escorted by parents, and driving) depend on the built environment's characteristics, the teenagers' socioeconomic characteristics and on a latent variable referring to walking constraints. The indicators of the latent variable include perceptions regarding the existence of stray animals, poor lighting, narrow sidewalks, parked cars that obscure visibility, non-signalized intersections, the probability of an attack, safety en route and parental prohibitions.

The presented case study is based on a questionnaire survey specifically designed for teenagers, which took place in three distinct areas in Greece (one urban, one rural and one insular) in 2012. The sample consists of 1,988 high school students aged from 12 to 18 years old.

While many pieces of research have been conducted on school transportation, the innovativeness of this work relies on several topics. First of all, to our knowledge, only a few school transportation surveys focus on teenagers, with the majority focusing on elementary students. Secondly, this survey tries to investigate the students' behavior by using data that come from the teenagers and not from their parents. The questionnaire used for data collection was designed specifically to investigate teenagers' perceptions of travel behavior. It was designed jointly, not only by transport planners but also by psychologists and economists, with the aim of approaching the multidimensional nature of transportation problems in depth. Moreover, herein we examine the travel behavior of teenagers and compare the effects of effects of actual and perceived built environment characteristics on active transport in three distinct geographical areas.

The remainder of the paper is structured as follows. Section 2 reviews the literature. Section 3 describes the modeling framework and associated mathematical formulations for incorporating the attitudes into the choice process. The case study, the sample's descriptive statistics and the indicators of the latent variable, "Walkability Constraints" (henceforth WalkCon), are presented in section 4, while section 5 gives the model estimation results. Section 6 concludes the paper by providing a summary of the findings, implications for policy and suggestions for further research.

2. LITERATURE REVIEW

Nowadays, the traditional travel patterns to school and after-school activities have changed and it is true that children have become reliant on automobiles for their trips (He, 2011). This shift has contributed to greater congestion and decreased the quality of life, while depriving children of the noted health benefits of physical activity. Schools are also a significant generator of localized congestion, with morning and afternoon peaks similar to those seen in commuting behavior (McMillan, 2007). Driven largely by this situation, research on children's active commuting to school has expanded rapidly during the last few years, and has indicated that distance between home and school is the most important variable in determining the mode of travel to school, and that the built and social environments also play an important role in the choice of travel mode.

For example, 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.

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 et al. (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, even when the distance traveled and the household activity-travel relationships were taken into account, while the effect of street connectivity on mode choice was less clear.

In 2006, Kerr et al. 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.

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.

Another survey, which took place in Portugal in 2004 (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.

As mentioned above, the majority of these studies focus on young children and only few look at adolescents. At the same time, the majority use data on students' travel behavior as reported by their parents and not collected directly from the students. However, 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 without being controlled or supervised. Also, most of these studies were conducted in urban areas and little is known about the travel behavior of rural or insular adolescents. Finally, soft factors that have been shown to affect adult travel behavior, such as convenience, attitudes and perceptions towards active transport, environmental protection and others (Abou-Zeid et al., 2012; Shiftan, et al., 2008; Walker and Li, 2007; Polydoropoulou et al., 2012; Polydoropoulou and Kamargianni, 2012), have not been examined in relation to teenagers' travel behavior. A review of the samples and methodologies used in various surveys of school transportation and the built environment is presented in Table 1.

Table 1: Review of the Literature

Reference	Sample	Modes examined	Environmental attributes examined	Methodology

McMillan (2007)	N=1128 elementary students. Reported by parents. California, USA	Active transport, private motorized vehicle	Sidewalks; bouses with windows facing street; land-use mix	Binomial logit regression probability models
Timperio et al. (2006)	N= 235 students 5-6 years old and 677 students 10 to 12. Reported by parents. Melbourne, Australia	Walk, cycle	Traffic; concern about strangers; concern about road safety; traffic lights; need to cross several roads; availability of public transport	Odds of walking or cycling to school
Larsen et al. (2009)	N=614 students aged between 11-13 years old. London, Ontario, Canada	Walking alone, walking accompanied, bike or scooter, skateboard/rollerblade, school bus, city bus, driven in automobile	Street trees; distance; land-use mix	Stepwise logistic regression
Mitra et al. (2012)	N=945 11-year-old students. 2006 Transportation Tomorrow Survey. Reported by parents	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 logit model (MNL)
Schlossberg et al. (2007)	N=292 middle school students. Reported by parents. Oregon, USA	Walk, bike, 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 students between 5 to 18 years old. 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)	Parents of children (N = 87) and matched pairs of parents and adolescents (N = 124 pairs). 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
Mota et. al (2004)	N=705 adolescent girls. 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
Kamargianni and Polydoropoulou (2013)	N= 4,147 high-school students, aged from 12 to 18 years old. Cyprus	Walk, bike, public transport, private motorized modes	Sidewalks; existence of bike lanes; distance	Hybrid Choice Model (HCM) with stated preference (SP) data

3. Modeling Framework

Based on the literature review and our hypothesis about the effect of the perceived characteristics of the built environment on travel behavior, we define the latent variable "walkability constraints", which incorporates indicators/perceptions about sidewalks, bike lanes, parked cars that obscure visibility, non-signalized intersections, the existence of stray animals, poor lighting, and the probability of attack and safety en route. By developing a Hybrid Choice Model (HCM), we ensure that the latent variable enters directly into the mode choice process.

HCM are a new generation of discrete-choice models that integrate discrete-choice and latent variable models, taking into account the impact of attitudes and perceptions on the decision process (McFadden, 1986; Ben-Akiva et al., 2002a). The most general framework was proposed by Ben-Akiva et al. (2002b) and Walker and Ben-Akiva (2002) and consists of two components: The measurement model describes the relationship between the indicators and the psychological factors, while the structural model explains the psychological factors with the help of personal characteristics and, thus, allows the analyst to distinguish between the influence personal characteristics have on the latent variables and their effects on other aspects of the decision.

In this paper, we seek to investigate the effect of teenagers' perceptions towards walkability constraints on their choice of mode of travel to school. To do so, we construct an HCM setting where we take indicators about built environment characteristics ($I_{WalkCon}$) and then define the latent variable "walkability constraints" ($WalkCon$), which enters directly into the choice process. The explanatory variables (X_n) are actual characteristics such as socioeconomic, time use, travel patterns and actual built environment characteristics. The utility obtained from 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_n). The modeling framework is presented in Figure 1, where the ovals represent the latent variables, and the rectangular boxes the observable variables, the dashed arrows the measurement equations and the solid arrows the structural equations. To our knowledge, this is the first time that a HCM has been developed in order to investigate teenagers' travel behavior.

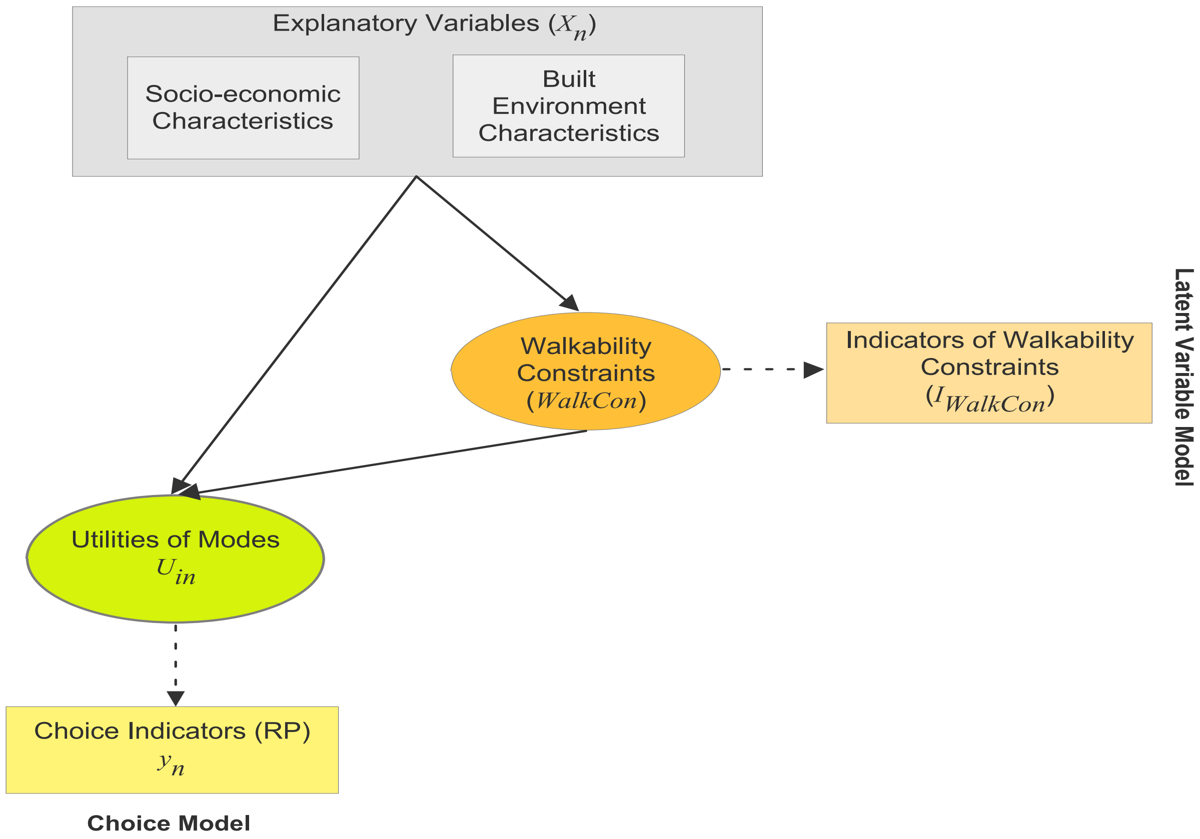


Figure 1: Modeling Framework

The mathematical formulations for modeling the latent variable are presented in the equations below (for more information see Walker and Ben-Akiva, 2001).

In the latent variable model, we have the structural model (1) and the measurement model (2) as follows:

$$WalkCon = X_n\theta + \sigma\omega \qquad \omega \sim N(0,1) \quad (1)$$

where *WalkCon* is the latent (unobservable) variable, X_n are matrices of explanatory observed variables (RP), θ is a vector of unknown parameters used to describe the effect of observable variables on the latent variables and ω is a vector of random disturbance terms.

$$I_{WalkCon} = \alpha + \lambda WalkCon + \upsilon \qquad \upsilon \sim N(0, \Sigma\upsilon) \quad (2)$$

where $I_{WalkCon}$ corresponds to a vector of 6 indicators of the latent variable $WalkCon$, α is a vector of 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 and υ is random error term.

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

$$U = X_n\beta + \gamma WalkCon + \varepsilon \qquad \varepsilon \sim N(0, \Sigma\varepsilon) \qquad (3)$$

$$y_i = \begin{cases} 1, & \text{if } U_i = \max j\{U_j\} \\ 0, & \text{otherwise} \end{cases} \quad , \quad i = \text{ACT, PT, DRIVER, ESC} \qquad (4)$$

where U is a (4x1) vector of utilities, β is a vector of observed variables, γ is a diagonal matrix of unknown parameters associated with the latent variable $WalkCon$, ε (4x1) is vector of random disturbance terms associated with the utility terms and $\Sigma\varepsilon$ designates all the unknown parameters in the choice model. 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:

$$f(y_i, I \mid X; \delta) = \int_{WalkCon} P(y \mid X, WalkCon; \Sigma\varepsilon) f_I(I \mid WalkCon; \lambda) f_{WalkCon}(WalkCon \mid X; \vartheta)\, dWalkCon \qquad (5)$$

where term δ designates the full set of parameters to estimate ($\delta=\{\lambda, \theta, \Sigma\varepsilon\}$). 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, $I_{WalkCon}$, and $WalkCon$ is integrated over the vector of latent constructs $WalkCon$.

4. Case Study

4.1 Survey Design and Data Collection

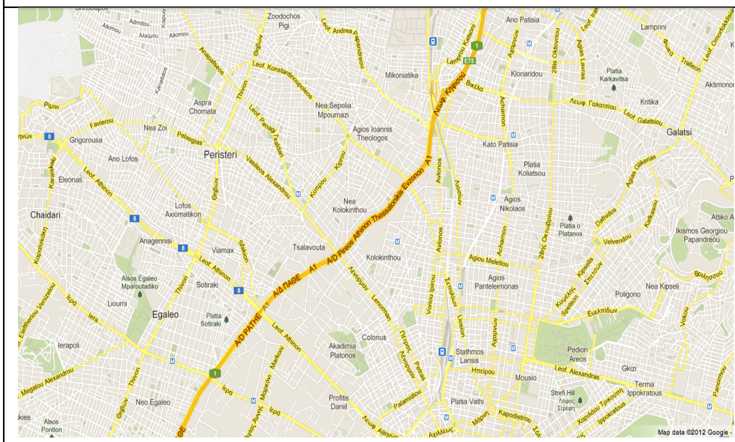
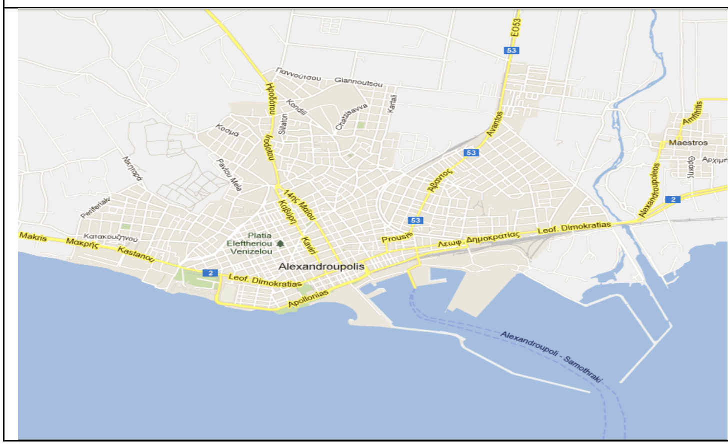
As explained above, the primary aim of this research is to investigate the travel behavior of adolescents and the effect of perceived built environment characteristics on this behavior. For this purpose, a questionnaire that takes into account the special needs of this age group was designed by transport planners, psychologists and economists. The questionnaire consists of seven sections and aims to explore in general the travel patterns, activities, time allocation, road-user behavior and social networking of teenagers (for more information see Kamargianni and Polydoropoulou, 2013).

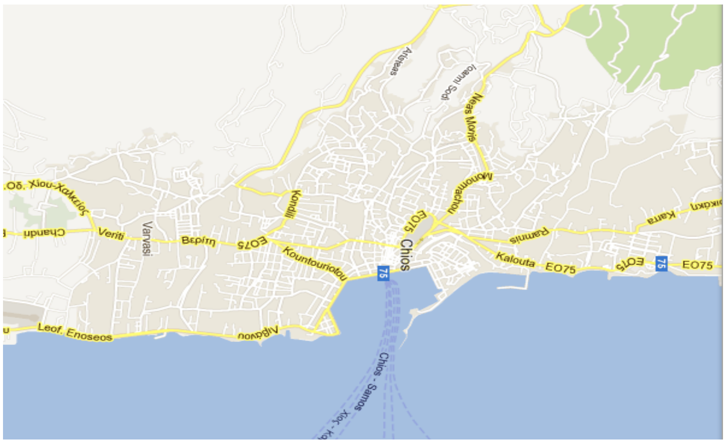
The data collection took place from September 2011 to May 2012 (academic year 2011-2012). The research team, in cooperation with the Secondary Education Departments of each area, worked together closely to define the sample of schools and the grades (years) from each school that would be asked to participate in the survey, in order to obtain a representative sample of each area. During the data collection, the researchers visited the high schools in order to assist with any questions regarding the completion of the questionnaire. The questionnaire was available in both paper and web formats. If the high school gave the research team access to the informatics classroom, the online version was used, otherwise we used the paper questionnaire.

Data were collected from three different environments (see Table 2). Eight public high schools from the greater Athens area (capital city of Greece; urban area), six high schools in Alexandroupolis (a rural border city) and eight high schools in Chios (an insular border area) participated. Of the schools in the Athens area, four are in the Korydallos neighborhood and four in the Peristeri neighborhood (from now on, we will refer to this area as Athens).

These three areas are completely different in terms of their local culture and built environment. Table 2 presents the characteristics of each area.

Table 2: Characteristics of the sampled areas

Area	Characteristics
	Urban area: Korydalos and Peristeri are located within the greater Athens area, 12 km southwest of Athens' city center. They are in a 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. Population density: 7,361/km^2 (high)
	Rural area: Alexandroupolis is 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. Population density: 35.21/km^2 (low)



Insular area: Chios is the fifth largest of the Greek islands, situated in the Aegean Sea. The quality of life is relatively high, as it is the fourth Greek county in terms of savings, with €16,570 per capita and has the third highest cars per capita ownership in Greece and the highest motorcycle ownership (Hel. Stat., 2011). Population density: 59.06/km^2 (low)

Students in all of the above areas can use cars, motorcycles, public transport, bikes or walking as their means of transport to school. The difference between the urban and rural areas is that, in Athens, there are a number of alternative public transport choices, such as tram, metro, train and bus, while in rural areas only buses are available, and their frequency is reduced in the afternoon.

4.2 Sample Characteristics

The characteristics of the participants from each area are presented in Table 3. The total sample consists of 1,988 students of 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 3: Socioeconomic characteristics of the sample

		Urban Area N= 716	Rural Area N=576obs	Insular Area N=696obs
GENDER (dummy variable)	Male (value 0)	44%	52%	49%
	Female (value 1)	56%	48%	51%
AGE	(Mean, String variable)	16.4	15.0	15.6
GRADES	Low (9-14 out of 20)	0%	13%	13%
	Medium (14-18 out of 20)	70%	49%	55%
	High (18-20 out of 20)	30%	38%	32%
POCKET MONEY	Low (less than €3)	44%	64%	31%
	Medium (€3-5)	35%	46%	45%
	High (more than €6)	21%	37%	24%
CAR OWNERSHIP (string variable)	(Mean)	2.3	1.7	1.8
MOTORCYCLE OWNERSHIP (string variable)	(Mean)	0.9	0.7	1.4
NUMBER OF SIBLINGS (string variable)	(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%
NUMBER OF TRIPS	Morning	2.3	2.1	2.2
	Total	4.2	4.4	4.9
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, two pictures about 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 -17°C. Despite the bad weather conditions, the majority of the participants still walked to school.

Table 4 presents the characteristics of the built environment along the route between home and school. 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 on which at least a part 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 variable models and the mode choice model below.

Table 4: 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. 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 a 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 a lack of sidewalks is a constraint on the choice to walk, while both the rural and insular students agreed that poor lighting is a constraint on the choice to walk.

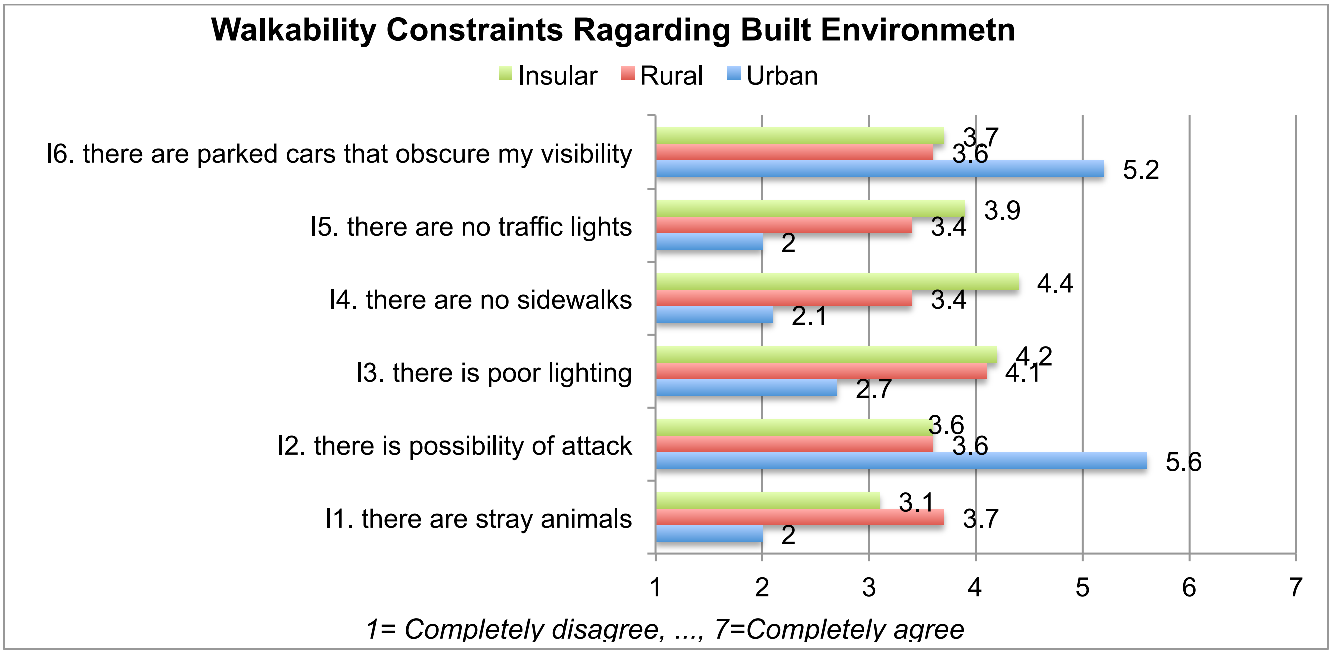


Figure 2: Indicators of the Latent Variable "Walkability Constraints" (*WalkCon*)

5. Model Specification and Estimation Results

5.1 Model Specification

Aiming to investigate the mode choice behavior of teenagers and the differences between the three environments, we develop one mode choice model for each area. The mode choice model has four alternatives:

1. Active transport (ACT)
2. Public transport (PT)
3. Driver of motorized vehicles (DRIVER)
4. Escorted by parents (ESC)

Due to the fact that only a small percentage of the participants were found to cycle to school, we merged the walking and cycling options into one, active transport (ACT). We carefully examined and filtered the sample, in order to put constraints on the options available to certain students. For example, students living more than 2.0 km away from their school were not given the option of selecting ACT. The car option was available to all participants, as all of the households owned at least one car or motorcycle. Regarding the option DRIVER, we set no age limits due to the fact that we identified that some students drive motorcycles without having a driving license (72% of the drivers in the insular area drive unlicensed).

First of all, for comparison reasons, we estimated a multinomial model (MNL) (see Ben-Akiva and Lerman, 1985). At the same time, we postulate that the latent variable *WalkCon*, which reflects the constraints of the built environment and parental prohibitions on the use of active transport, has a significant impact on mode choice. Specifically, we assume that the latent variable will decrease the probability of choosing active transport (walking or cycling) and increase the probability of choosing the option ESC. Having these elements in mind, we incorporated the latent variable WC into the utilities of the ACT and ESC options in the MNL model.

The utility of choice is a function of attributes of the alternatives and the latent variables. The deterministic utility contains the socioeconomic characteristics and the characteristics of the built environment, as well as alternative specific constants for the alternatives ACT, DRIVER and ESC. The utility specification also contains the effect of the latent variable WC. The latent variable was not considered for the PT and DRIVER alternatives. The equation for the choice model is given below:

$$\mathbf{ACT} = \beta_{ACT} + \beta_{GEN1} * FEMALE + \beta_{AGE1} * AGE + \beta_{INCLOW} * INCOMELOW + \beta_{DIST1} * DISTANCE + \beta_{WIN} * WINTER + \beta_{WC1} * WalkCon + \varepsilon_{ACT} \quad (6)$$

$$\mathbf{PT} = \beta_{PT} + \varepsilon_{PT} \quad (7)$$

$$\mathbf{DRIVER} = \beta_{DIST3} * DISTANCE + \beta_{GEN3} * FEMALE + \beta_{AGE3} * AGE + \varepsilon_{DRIVER} \quad (8)$$

$$\mathbf{ESC} = \beta_{ESC} + \beta_{GEN4} * FEMALE + \beta_{AGE4} * AGE + \beta_{INCHIGH} * INCOMEHIGH + \beta_{CARH} * CAROWN + \beta_{SIB} * SIBLINGS + \beta_{DIST4} * DISTANCE + \beta_{WC1} * WalkCon + \varepsilon_{ESC} \quad (9)$$

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);
INCOMELOW takes the value 1 if the monthly family income is up to €1000, 0 otherwise;
INCOMEHIGH takes the value 1 if the monthly family income is more than €1000, 0 otherwise;
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;
CAROWN = the number of cars in the household (continuous variable);
SIBLINGS = number of siblings that are underage students (continuous variable);
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 available indicators may refer to walkability constraints regarding safety, aesthetics or other type of constraints. Based on this fact, one may assume that different latent variables could be included in model estimations. At the beginning of the modeling effort, a factor analysis model was estimated using the indicators presented in Figure 2. The factor analysis gave as a result only one component; thus in all further modeling one latent factor was used, named as "Walkability Constraints".

The perception of "walkability constraints" is modeled as a function of the socioeconomic 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, parent's level of education, parent's mode use patterns, household income and the characteristics of the built environment that exist on the route from home to school. The equation is:

$$\mathbf{WalkCon} = \theta_{WalkCon} + \theta_{GEN} * FEMALE + \theta_{AGEL} * AGE + \theta_{WSK} * WIDESWALK + \theta_{NC} * NETCOND + \theta_{G} * GREEN + \theta_{TLIGHTS} * TLIGHTS + \theta_{TC} * TC + \omega_{WalkCon} \quad (10)$$

where:
WIDESWALK takes the value 1 if at least 50% of the route from home to school has wide sidewalks, 0 otherwise;
NETCOND takes the value 1 if the conditions of the road and sidewalk network are good, 0 otherwise;
TLIGHTS 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;
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.

5.2 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. Due to space limitations, herein we only present the results of the MNL with the latent variable (HCM). The models were estimated using the Pythonbiogeme software (see Bierlaire, 2003; Bierlaire and Fetiarison, 2009). The number of draws was set to 1000.

Table 5: Mode Choice Model Estimation Results

	Urban Area		Rural Area		Insular Area	
	Coef.	**t-stat.**	**Coef.**	**t-stat.**	**Coef.**	**t-stat.**
β_{ACT}	12.4	3.68	7.12	2.52	10.0	2.08
β_{PT}	11.1	3.58	-1.23	-0.43	6.27	2.46
β_{ESC}	10.3	3.15	8.63	2.73	5.63	2.14
Socio-economic						
FEMALE specific to ACT	-1.63	-2.94	-0.29	-0.45	-0.80	-1.11
FEMALE specific to DRIVE	-2.6	-3.36	-1.78	-2.71	-0.98	-3.02
FEMALE specific to ESC	2.22	5.25	0.75	1.72	0.02	0.15
AGE specific to ACT	0.28	2.21	0.38	1.98	0.61	2.06
AGE specific to DRIVER	0.62	3.73	0.14	0.81	0.71	4.08
AGE specific to ESC	-0.34	-4.13	-0.58	-4.16	0.10	0.70
INCOME LOW specific to ACT	0.26	-0.47	1.56	2.65	2.16	1.27
HOUSEHOLD CAR OWNERSHIP specific to ESC	1.00	4.04	0.73	2.72	1.03	7.04
INCOME HIGH specific to ESC	0.53	2.03	1.94	3.78	-0.89	-3.37
NUMBER OF SIBLINGS THAT ARE STUDENTS (<18 years old) specific to ESC	0.20	4.09	-0.34	-2.21	-0.30	-2.24
DISTANCE						
DISTANCE specific to ACT	-1.19	--9.94	-2.56	-8.22	-3.66	-7.90
DISTANCE specific to DRIVE	-0.14	-1.57	-0.57	-3.57	-0.74	-8.07
DISTANCE specific to ESC	-0.11	-1.65	-0.47	-5.31	0.41	-6.03
WINTER specific to ACT	-0.72	-2.4	0.65	1.86	-0.342	-1.99
Latent Variable						
WalkCon (specific to active transport)	-0.42	-1.99	-091	-2.69	-1.63	-2.39
WalkCon (specific to Escorted)	0.85	10.09	0.52	3.26	0.513	4.82
Number of observations		716		576		696
Number of draws		1000		1000		1000
R Squared		0.225		0.292		0.279

Females in urban area seem to walk/cycle less, while they prefer to being escorted by their parents to school. These results are consistent with the results of previous surveys, such as Larsen et al. (2009). Although the sign of the female variable is negative for the rural and insular area, 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 significant for urban and rural teenagers. This result reflects the fact that teenagers tend to conduct more independent (unsupervised) trips while they reach the age of 18. Low income affects significant the choice of active transport only in rural area. In accordance with other surveys (Mitra et al., 2012) that have taken place in urban areas high income affects significantly the choice of being escorted to school. However, in rural and insular areas the situation seems to be completely different as high income affects negatively this choice. As number of underage siblings increases the participants in urban area tend to being escorted by their parents to school, while in rural and insular area this fact affects negatively this choice.

Regarding the characteristics of 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., 2007). As distance between home and school increases teenagers from all areas tend to being escorted to school by their parents. Distance affects negatively the choice of driving to school, indicating that drivers do not make long distance trips. The maximum distance that participants cover by their motorcycles is 3.1km in insular areas, 2.8 in rural area and 1.6 in urban area (almost the half comparing to insular areas). Bad weather (WINTER) affects significantly and negatively the choice of active transport in urban and insular area.

Unsurprisingly, the incorporation of the latent variable improved the overall goodness of fit of the model. The $WalkCon$ enters significantly into the choice model specification. Thus, the latent variable discourages the choice of walk and cycle ($WalkCon$) to school in all areas through a negative impact in 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 being escorted by their parents to school. $WalkCon$ has the highest effect on ESC choice in urban area, indicating that walkability constraints affect more the choice of ESC in urban area than in rural and insular area.

5.3 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 in different ways the latent variable. Females from all areas perceive the walkability constraints more strongly than males. As teenagers grow up and reach the age of 18 tend to perceive less the walkability constraints, especially in rural and urban areas. The knowledge of traffic code has a negative sign for all the three areas, indicating that when teenagers know how to stay safe as road users the perceived walkability constraints decrease.

Regarding the built environment characteristics, existence of wide sidewalks affects significantly and negative the perceived walkability constraints in urban and insular area. While in rural 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 perceive less walkability constraints. However, this variable is not statistically significant at 95% level for teenagers in 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 with potholes and obstacles. Existence of traffic lights at major intersections affects significantly the latent variable in urban area, while this variable does not affect significantly this choice in rural and insular area. As urban area is more congested and the traffic flows are higher, especially in the morning during the commuting to school, traffic lights are necessary for walking or cycling with safety to school. As far as 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: Structural Model Estimation Results

	Urban Area		Rural Area		Insular Area	
	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	0.645	3.29	1.10	8.34	0.436	4.12
AGE	-0.172	-3.62	-0.125	-5.22	-0.259	-5.78
KNOWLEDGE OF TRAFFIC CODE (1=yes, 0=otherwise)	-0.946	-4.86	-0.409	-3.48	-0.11	-1.96
WIDE SIDEWALKS (1=yes, 0= otherwise)	-0.486	-2.36	0.835	-1.64	-0.39	-3.07
ROAD & SIDEWALK CONDITION (1=good, 0=otherwise)	-3.24	-1.58	-0.715	-8.20	-0.316	-2.83
EXISTENCE of TREES/FLOWERS – AESTHETICS (1=yes, 0= otherwise)	-0.22	-1.68	-0.569	-4.09	-0.44	-3.76
EXISTENCE of TRAFFIC LIGHTS at MAJOR INTRSECTIONS/ROADS (1=yes, 0=otherwise)	-0.532	-2.57	-0.189	-1.46	-0.159	-1.37

Regarding the measurement model, which results are presented in Table 7, several indicators (Figure 2) were considered in the latent variable measurement model, which links the latent psychometric walkability constraints to answers to attitudinal qualitative survey questions.

Table 7: Measurement Model Estimation Results

	Urban Area		Rural Area		Insular Area	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
α_1	0	-	0	-	0	-
α_2	0.362	6.18	0.694	1.96	0.207	0.9
α_3	0.0315	0.72	0.475	2.12	0.406	2.61
α_4	0.331	5.62	0.375	2.75	0.216	2.85
α_5	0.213	4.2	0.311	1.46	0.38	1.59
α_6	0.203	3.0	0.522	2.45	0.321	1.42
λ_1	1	-	1	-	1	-
λ_2	0.954	56.5	1.22	19.49	1.22	16.12
λ_3	0.975	78.21	1.24	18.8	1.43	17.12
λ_4	0.963	56.98	1.08	17.15	1.32	15.76
λ_5	0.965	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	0.632	26.19	1.62	31.11	1.9	35.84
σ_2	0.985	32.74	1.09	24.58	1.44	33.42
σ_3	0.603	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	0.794	30.58	1.34	28.45	0.889	25.05
σ_6	1.21	34.43	1.19	27.22	0.9	26.42

The coefficient of the first indicator ($I_{WalkCon1}$) equation is being normalized to 1. The α parameters that indicate the association between the response to the scale item and the psychometric scale have all the expected signs (see equation 2). Here, we can see that an increasingly negative attitude towards walkability constraints will lead to respondents being more in agreement with the statements (indicators). The effect of the latent variable *WalkCon* on the indicators varies amongst the three geographical areas. The most significant walkability constraint for urban teenagers seems to be the safety issues, while for rural and insular ones the absence of sidewalks and poor lighting. Although these two indicators are the most significant for those who live in rural and insular area, they are not statistically significant for those who live in urban area. Absence of traffic lights at major intersections is also important for urban adolescents, while they are less significant for those in rural and insular areas.

6. Conclusions and Further Research

The aim of this paper is to investigate the effect of teenagers' perceptions towards walkability constraints on mode to school choice behavior amongst an urban, a rural and an insular area. To our knowledge, it is the first time that such a survey regarding travel behavior to school takes place, focuses only on teenagers and compares the effect of characteristics of different urban forms on mode to school choice.

By using data that collected directly from teenagers we developed and applied a Hybrid Choice Model (HCM) to explain the effect of perceived walkability constraints in a mode choice context. Our specification is consistent with the new trend in discrete choice modeling toward incorporating unobservable (perceptual and attitudinal) factors into the behavioral representation of the decision process. The HCM offers an attractive improvement in modeling mode choice behavior, due to the fact that the choice model is only a part of the whole behavioral process in which we incorporate individual's perceptions, thus yielding a more realistic model. On several accounts the latent variable (*WalkCon*) enriched choice model outperforms a traditional 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 of the model for urban adolescents are in consistence with the results of previous surveys that also took place in urban areas, such as Mitra et al. (2012), Grow et al. (2008. Our results confirm that distance plays the most significant role in mode to school choice for all the three areas. Existence of wide pavements, flowers/trees and traffic lights at major intersections affect positive the choice of active transport to school, thus the two first characteristics are more significant for adolescents in rural and urban area, while the last one is more important for high-school students in urban area.

The results of the HCM showed that teenagers' attitude towards walkability constraints is very important and significant, assuring that unobservable variables should be implemented in the choice process in order to have more realistic econometric models and in doing so to implement better "cut and tailored" policies. According to our expectation the latent variable *WalkCon* works against walk and cycle (active transportation), while affects the choice of being escorted by their parents positively.

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

These results would be without any meaning, if they could not be translated into policies and measures. Cities' plans should encourage more innovative types of developments, which support active transport and discourage car use. Construction of wider sidewalks and bike lanes, which costs less than roads construction, will enhance active transport and at the same time will improve the connectivity of walking routes (for example to the bus stop or to school). Several facilities could be implemented at the sidewalks elevating the convenience and safety of the pedestrians and cyclists, such as better lighting, more parking restrictions across the roads, bicycle parking places and priorities at traffic lights or intersections. Cities should take into consideration the needs of the new generation and rearrange their plans accordingly.

Moreover, both community and schools could organize campaigns especially for parents in order to shift their attitudes favorably towards walking and bicycling for their children. Active transport days or weeks could be adopted by schools. During these days the cyclist or pedestrian students could be awarded with less homework or a free lunch.

The innovative data collection and modeling methodology could be of high importance to researchers who are dealing with this age group and school transportation. Moreover, the investigation of teenagers' travel behavior could provide significant findings for policies, strategies and campaigns in order to shape the desired travel behaviors, which may be retained in the adulthood.

Future work includes the estimation of mode choice models which will incorporate the indicators of the latent variable *WalkCon* as constraints to the choice set (latent choice sets). Furthermore, more teenagers' perceptions and attitudes towards travel and mode choice behavior will be investigated. Also, further research includes the investigation of how perceptions' towards ICTs, social networking and virtual travelling affect the new generation's travel behavior.

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