# Hybrid Choice Model to Investigate Effects of Teenagers' Attitudes Toward Walking and Cycling on Mode Choice Behavior

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**The scope of this paper is to develop an advanced stated preferences (SP) survey customized to capture teenagers' behaviors and to estimate models of hybrid mode choices, in which the utilities depend on both the attributes of the mode and the latent variable willingness to walk or cycle. The SP scenarios include four alternative modes for the trip to school—car (escorted by parents), bus, bicycle, and walk—while the attributes are travel time; travel cost; walking time to the bus station; availability of bike paths, sidewalks, and parking places; and weather conditions. The data are drawn from a survey that took place in all the high schools of Cyprus in 2012. The sample consists of 4,174 teenagers (ages 12 to 18) and covers 8.7% of the total high school population. For the model estimations, 8,348 SP observations are used. It was found that the existence of bike paths and wide pavements significantly affect the choice of active transport. The latent variable enters significantly into the specification of the choice model to assure that unobserved variables should be implemented in the choice process. Willingness to walk and to cycle has a positive effect on the choice of those alternatives and a negative effect on the choice of a car. Moreover, parents' level of education and mode use patterns and habits influence the development of attitudes toward mode choice. The results of the study provide insights on policies and campaigns that may help the next generation develop greener travel behavior.**

Although those in the transport planning profession may know the demographic and economic characteristics of underage students' families and the communities in which they live and attend school, those professionals have little scientific evidence of individual teenagers' activities, travel behavior, and attitudes. Traditional models of travel behavior are limited principally to the examination or prediction of adult travel behavior, which is primarily automobile dependent (*1*). While differing in purpose, most research efforts are similar in relation to their focus on adult travel (*1–5*).

In traditional societies, discrepancies between adolescents and adults were comparatively little because they grew up in comparable worlds (*6*). However, with rapid change and social media bringing the outside world into teenagers' lives, larger generational differences are emerging (*7–10*). Today, teenagers live in more complex environments, and their activities, travel needs, and attitudes differ from those of adults (*11*).

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In recent years, many researchers have investigated school transportation through parental travel patterns. However, few surveys use data collected directly from children or teenagers. Teenagers are a peculiar age group with special travel needs. On 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 allows them to make independent decisions and spend time away from adult supervision (*12*). Their travel behavior remains largely unrecorded, and, as a result, interest in the topic is increasing (*13*).

Meanwhile, some have suggested that an explicit consideration of psychological factors might help the understanding of people's transport decision-making process (*14*), and a growing body of research is demonstrating 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, and lifestyle and situational variables (*15*). Once more, however, these surveys have so far focused on adults' unobserved factors that affect travel behavior, and little work has been done on teenagers' attitudes to travel.

Moreover, habits formed early are hard to break (*6*). Underage persons who do the majority of their traveling by car while growing up may continue that behavior into adulthood and may be more reluctant to travel by alternative transportation modes as adults (*16, 17*). In addition, studies have shown that interventions to promote active transport and physical activity in adolescence may lead to effects that are retained in adulthood (*18*).

With these points as a core, this paper aims to investigate teenagers' attitudes and their effects on mode choice behavior. The case study here is based on a survey that was specifically designed to investigate teenagers' travel behavior and took place in the Republic of Cyprus in 2012. In cooperation with the Ministry of Education and Culture (MOEC) of Cyprus, the web-based questionnaire was forwarded to all Cypriot high schools, and the sample consisted of 4,147 participants (8.7% of the total student population), while 8,348 stated preference (SP) responses were available for the model estimation. Specifically, the authors constructed a hybrid choice model (HCM) in which attitudinal indicator variables about walking and cycling were surveyed and then the latent variable willingness to walk or cycle to school (ACT for active transport modes) was defined and entered directly into the choice process.

The innovation of this research covered several topics. First, to the authors' knowledge, this was the first such large-scale survey on travel behavior focusing only on teenagers (aged 12 to 18) and collecting both revealed preference (RP) and SP data. Second, the questionnaire used for the data collection was designed specifically to investigate teenagers' perceptions of travel behavior, not only by transport planners but also by psychologists and economists, with the aim of approaching the multidimensional nature of transportation problems in depth. Furthermore, the findings of this study offer guidelines about the types of transport policies that could promote active transport and increase environmental consciousness. Finally, the investigation of teenagers' travel behavior may explain many of the trends and undesired behaviors that adults adapt.

The remainder of the paper is structured as follows. The next section reviews the literature. Following that is a description of 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 attitudinal indicators of the latent variable come next, while the section after that describes the model estimation results. The paper concludes by providing a summary of the findings and implications for policy and further research.

## STATE OF THE ART

In recent years, for many young and underage individuals, traditional travel patterns to school and after-school activities have changed, and it is undoubtedly true that children have become increasingly reliant on automobiles for their mobility. 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 (*19*). It has been reported that, in some areas of the United States, the additional school-related automobile trips have generated between 20% and 30% more morning traffic (*20*).

Against this background, in the past decade, a vast body of researchers has identified and quantified the influence of demographic and socioeconomic characteristics and of the built environment on choice of school travel mode. Among the demographic variables, a child's age (*21, 22*) and gender (*13, 19, 23, 24*) have been found to influence children's choice of school travel mode significantly. In general, research has found that older children and boys are more likely to walk or cycle to school than other children. In relation to the built environment, in an extensive literature review on school transportation, He presented the barriers to using active transport to get to school that were identified by previous studies (*25*), including distance to school, motor vehicle traffic, crime and danger, and restrictive school policies, as well as neighborhood characteristics such as poor street connectivity, sloped terrain, and a lack of sidewalks (*1, 26, 27, 28*).

Furthermore, it is undeniable that mode choice behavior is affected not only by the attributes of the modes themselves but also by unobserved variables. According to cognitive psychology, preferences and behavior are affected by perceptions and attitudes (*29*). Attitude variables measure the evaluation of favor or disfavor assigned by the individual to the features of different alternatives. Attitudes determine behavioral intentions, are related to individual heterogeneity (taste variations), and reflect individual tastes, needs, values, goals, and capabilities that develop over time and are affected by knowledge, experience, and external factors such as the socioeconomic characteristics of the decision maker (*30–35*).

Recently, many studies have adopted established psychological theories of attitude–behavior relations, such as the theory of planned behavior (*36*), to predict mode choice (*14*). Parts of these surveys investigate the effect of parental attitudes on their kids' choices of school travel mode. In the case of school-going children, parents are likely to play a strong decision-making role in relation to the choice of mode for school-related travel (*26, 27, 37–40*).

McMillan, using data from 16 elementary schools in California, examined which factors affected the decisions of students' caregivers about transport to school (*19*). Binomial logit regression probability models were developed to examine the likelihood of a child walking or cycling to school versus traveling by private vehicle or neighborhood carpool. One highly significant result was the distance from home to school being greater or less than 1 mi. Meanwhile, the attitudes and perceptions of the parents about the safety and traffic situation in the neighborhood were as important as the actual attributes of the built environment in influencing the school travel mode.

Using a sample of 1,210 Australian primary school students and multivariate analyses, Timperio et al. found that many parental perceptions of the environment were associated with whether their children walked or cycled to destinations in the local neighborhood (*21*). Perceptions of limited access to public transport options and parks or sports grounds were associated with a smaller likelihood of walking or cycling, particularly among girls. More universally, parental perceptions of issues about safe pedestrian and cycling conditions were negatively associated with 10- to 12-year-old children walking or cycling to local destinations.

Zhu and Lee identified multilevel correlates of walking to and from school (*41*). They surveyed parents of 2,695 students featuring diverse sociodemographic and environmental characteristics from 19 elementary schools in Austin, Texas. Among the personal and social factors, the negative correlates included parents' education, 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, which were followed by the presence of highways and freeways, convenience stores, office buildings, and bus stops en route.

The results of another Australian study that used a sample of 1,603 students aged 9 to 11 showed that parents' attitudes toward 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 (*42*). Experience with using nonmotorized 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. examined the factors that influence parental attitudes toward their children walking or cycling to school (*43*). From 1,000 observations from the California add-on sample of the 2009 National Household Travel Survey, they estimated a multivariate ordered-response model by 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 toward walking and cycling.

The preceding review of related research shows that the vast majority of school transportation surveys focused on elementary students and their parents' attitudes. In addition, most of these surveys used data collected from the students' parents and not directly from the students. Meanwhile, little work has been done on teenagers' behavior related to transport to school and their attitudes, and surveys of transport behavior that refer to teenagers and combines SP and RP data do not exist. Moreover, no one has examined how the soft factors that have been shown to affect adult travel behavior, such as convenience, attitudes, and perceptions toward active transport, environmental protection, and others, affect teenagers' travel behavior (*44–48*).

## MODELING FRAMEWORK

HCMs are a new generation of discrete-choice models that integrate discrete-choice and latent-variables models, taking into account the impact of attitudes and perceptions on decision making (*49, 50*). The most general framework has been proposed by Ben-Akiva et al. (*51*) and Walker and Ben-Akiva (*52*), and it 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 effects of personal characteristics on the latent variables and those on other aspects of the decision.

This paper seeks to investigate the effect of teenagers' attitudes toward walking or cycling to school. In doing so, the paper constructs an HCM setting in which five attitudinal indicators about walking and cycling ($I_{ACT}$) are selected, and then the latent variable ACT is defined and entered directly into the choice process. The explanatory variables ($X$) are actual characteristics such as socioeconomic, travel, and parental mode use patterns. The utility obtained from choosing a particular mode is a function of the explanatory variables, the latent variable, and the attributes of modes, such as cost and time of travel. The utility is measured by the choice indicator ($y$). The modeling framework is presented in Figure 1, where the ovals refer to unobservable or latent variables and the rectangular boxes represent observable variables. The dashed arrows represent the measurement equations and the solid arrows represent the structural equations. In the past, the solid arrows were primarily examined, but now the dashed arrows are receiving growing attention.

The mathematical formulations for modeling the latent variable ACT are presented in the following equations [more information is available in Bolduc et al. (*31*)].

The latent-variable model consists of the structural model and the measurement model. The equations for the structural model are these:

$$\text{ACT} = X_1\theta + \omega \qquad \omega \sim N(0, \Sigma\omega) \tag{1}$$

$$U = X_2\beta + \gamma\text{ACT} + \varepsilon \qquad \varepsilon \sim N(0, \Sigma\varepsilon) \tag{2}$$

where

$X_1, X_2$ = matrices of explanatory RP variables,
$\theta$ = vector of unknown parameters used to describe effect of observable variables on latent variables,
$\omega$ = vector of random disturbance terms,
$U$ = $(4 \times 1)$ vector of utilities,
$\beta$ = vector of observed variables,
$\gamma$ = diagonal matrix of unknown parameters associated with latent variable ACT,
$\varepsilon$ = $(4 \times 1)$ vector of random disturbance terms associated with utility terms, and
$\Sigma\varepsilon$ = all unknown parameters in choice model.

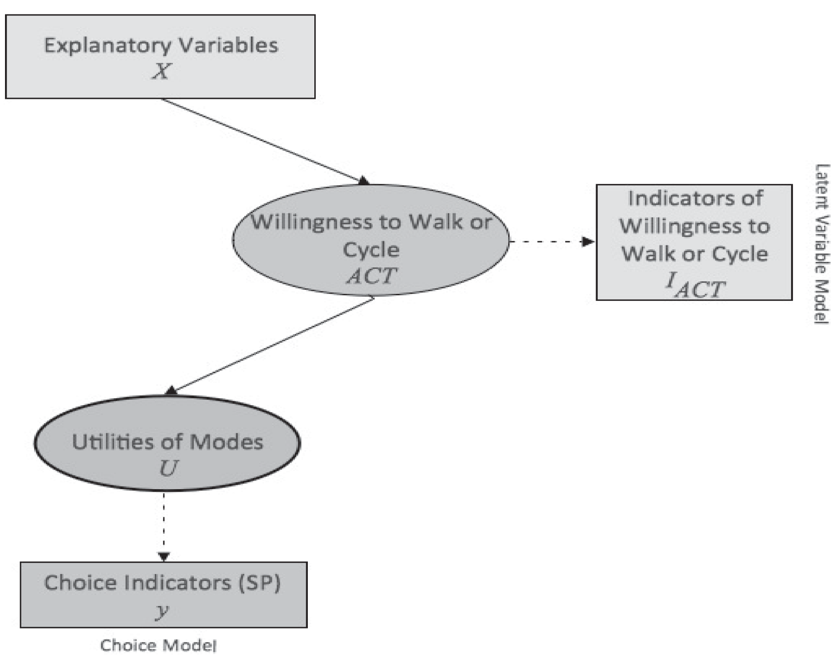


**FIGURE 1 Modeling framework.**

The equations for the measurement model are these:

$$I = \alpha + \lambda \text{ACT} + \upsilon \qquad \upsilon \sim N(0, \Sigma\upsilon) \tag{3}$$

$$y_i = \begin{cases} 1 & \text{if } U_i = \max\text{j}\{U_j\} \\ 0 & \text{otherwise} \end{cases} \qquad i = \text{escorted by car, bus, walk, bike} \tag{4}$$

where

- $I$ = vector of five indicators of latent variable ACT,
- $\alpha$ = vector of parameters that indicates associations between responses to scale,
- $\lambda$ = vectors of unknown parameters that relate latent variable to indicators,
- $\upsilon$ = random error term, and
- $y_i$ = choice indicator, taking 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:

$$f(y_i, I|X;\delta) = \int_{\text{ACT}} P(y|X, \text{ACT}; \Sigma\varepsilon) f_I(I|\text{ACT};\lambda) \times f_{\text{ACT}}(\text{ACT}|X;\vartheta)\, d\text{ACT} \tag{5}$$

where $\delta$ is the full set of parameters to estimate ($\delta = \{\lambda, \theta, \Sigma\varepsilon\}$) and $X$ is explanatory observed 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 known only to its distribution, and so the joint probability of $y$, $I_{\text{ACT}}$, and ACT is integrated over the vector of latent constructs ACT.

## CASE STUDY

### Questionnaire Design

A web questionnaire addressed only to teenagers was designed specifically for this research. Transport planners and psychologists cooperated in designing the questionnaire, with the aim of capturing the fundamentals of travel behavioral processes. The result was a questionnaire consisting of the following seven sections:

Section 1 recorded travel behavior and travel patterns of high school students, including transport modes for their travel to school, after-school activities, and weekend activities (travel diary for one school day, Saturday, and Sunday).

Section 2 included questions about time use and social networking and types of activities in which one engages on a typical day and during a typical weekend.

Section 3 investigated the behavior of teenagers as road users and drivers.

Section 4 contained questions on the attitudes and perceptions of high school students toward active transport, public transport, environmental protection, driving, their relationships with their parents and the opposite gender, and peer pressure.

Section 5 presented teenagers with SP scenarios for their mode of transport to school.

Section 6 asked teenagers about their personal experience with accidents, as drivers or passengers.

Section 7 gathered data about the teenagers' socioeconomic characteristics (grades, pocket money, etc.) and household characteristics (parents' education and employment, etc.).

The SP scenarios were designed in such a way as to be clear to teenagers. After numerous pilot designs, the scenarios presented in Table 1 were the ones chosen.

The scenarios had four alternative transport modes for the trip to school: car, bus, bike, and walk. The attributes of the modes were travel time (specific to all alternatives), travel cost (specific to car and bus), availability of a parking place (specific to car and bike), walking time from home to the bus stop (specific to bus), existence of bike paths (specific to bike), walkability–sidewalks (specific to walk), and weather conditions. To avoid misperceptions and to assure that the latter three attributes were clear to all participants, the authors decided to use pictures of actual sidewalk and bike lane situations and weather conditions. The pictures were carefully chosen to ensure that they would not be contaminated by extraneous variables (such as noise or asphalt conditions). After the selection of the attributes and the attribute levels, 600 scenarios were generated, with the order of the attributes randomized. Each participant was presented with two SP scenarios.

Once the questionnaire had been finalized, a pilot survey was conducted in two high schools over a week to ensure that the questionnaire was clear and the students had sufficient time to complete it. Feedback was used to prepare a manual for the teachers, so that they could assist the students with any questions.

This paper focuses on teenagers' behavior in relation to mode choice and the effect of the latent attitude willingness to walk or cycle on this behavior.

### Data Collection and Descriptive Statistics

The Republic of Cyprus is an island country in the eastern Mediterranean Sea, with a population of 862,100 (*53*). It is classified by the World Bank as a high-income economy, and in recent years it has been developed into one of the world's more important international business centers (*54*). Cypriots are among the most prosperous people in the Mediterranean region, with a gross domestic product (GDP) per capita of €30,571 and an average net salary of €1,656/month (*55*). Cyprus is a heavily car-dependent island, and the driving habits of Cypriots have rapidly progressed, as has the standard of living with the country's transformation from an agrarian to a service-oriented economy in the past 20 years. Figures released by the International Road Federation in 2007 showed that Cyprus had the highest car ownership rate in the world, with 742 cars per 1,000 people. Public transport in Cyprus was limited to privately run bus services (except in Nicosia, the capital), taxis, and interurban "shared" taxi services. In relation to secondary education, Cyprus had 140 public and 36 private high schools with 47,615 high school students (*56*).

In cooperation with MOEC, the survey questionnaire was forwarded to all Cypriot high schools. The students completed the web questionnaire during informatics lessons, under the supervision of their teachers who, as explained earlier, had received extra guidance to assist with any questions. For this paper, a sample of 4,174 participants

**TABLE 1 SP Scenarios Design**

| Parameter | Car (escorted by parents) | Bus | Bicycle | Walk |
|---|---|---|---|---|
| Travel time (in minutes) | 5, 6, 7, 8, 10, 12, 14, 15, 17, 25 | 8, 10, 12, 14, 15, 17, 20, 25, 30 | 5, 6, 7, 8, 10, 12, 15, 17 | 6, 8, 10, 12, 15, 17 |
| Travel cost (in Euros) | 1, 1.5, 2, 2.5, 3 | 0, 0.5, 1.0, 1.5 | na | na |
| Parking spaces | Available, not available | na | Available, not available | na |
| Walking time to the bus stop (in minutes) | na | 2, 3, 5, 7, 10, 15 | na | na |
| Bike paths | na | na |  Bike paths  No bike paths | na |
| Walkability–sidewalks | na | na | na |  Wide pavements  Narrow pavements |
| Weather conditions |   | | | |

NOTE: na = not applicable.

covering 8.7% of the total high school population of the country was used. The mean completion time was 26.4 min.

The sample characteristics are presented in Table 2, which shows that 44% were male and 42% were between the ages of 12 and 14. Parental level of education was quite low, while the majority of the households had monthly income of more than €4,000. The average pocket money teenagers received per day was €6.5. Household car ownership was rather high, and none of the students stated that their household had no cars; this information indicated that everyone in the sample had the option of being driven to school. Compared with the average number of trips in a school day in other surveys [e.g., O'Brien and Gilbert (*57*)], the average number of trips in a school day (4.1) is quite high.

Figure 2 presents the responses to the attitudinal questions regarding the teenagers' willingness to walk or cycle. The response scale ranged from −3 to +3, with a response of −3 indicating that the participant completely disagreed with the statement and +3 indicating that they completely agreed. The answers to these questions serve

**TABLE 2 Characteristics of Sample**

| Variable | Total | Male (44%) | Female (56%) |
|---|---|---|---|
| Age | | | |
| 12 to 14 years old | 42% | 43% | 40% |
| 15 to 18 years old | 58% | 57% | 60% |
| Grades | | | |
| 9–14 (of 20) | 12% | 16% | 9% |
| 14–18 (of 20) | 46% | 47% | 45% |
| 18–20 (of 20) | 42% | 37% | 46% |
| Mother's level of education | | | |
| Low (secondary education) | 59% | 57% | 60% |
| Medium (bachelor's) | 30% | 29% | 30% |
| High (master's or PhD) | 11% | 14% | 10% |
| Father's level of education | | | |
| Low (secondary education) | 67% | 65% | 69% |
| Medium (bachelor's) | 21% | 21% | 22% |
| High (master's or PhD) | 11% | 14% | 9% |
| Household's monthly income | | | |
| Less than €1,000 | 12% | 13% | 11% |
| €1,000–€2,000 | 13% | 11% | 15% |
| €2,000–€3,000 | 18% | 22% | 15% |
| €3,000–€4,000 | 17% | 17% | 18% |
| More than €4,000 | 32% | 37% | 41% |
| Father's mode use patterns | | | |
| Always uses the car for short-distance trips (response: yes) | 70% | 67% | 72% |
| Walks every day (response: yes) | 32% | 33% | 32% |
| Mother's mode use patterns | | | |
| Always uses the car for short-distance trips (response: yes) | 70% | 64% | 74% |
| Walks every day (response: yes) | 27% | 27% | 28% |
| Actual mode to school | | | |
| Motorized vehicle (escorted by parents) | 50% | 46% | 52% |
| Motorcycle (as driver) | 0.5% | 1% | 0% |
| Bus | 35% | 34% | 36% |
| Walk | 14% | 18% | 12% |
| Bicycle | 0.5% | 1% | 0% |
| Number of household members (mean) | 4.9 | 5.1 | 4.9 |
| Household's car ownership (mean) | 3.1 | 3.3 | 2.9 |
| Household's motorcycle ownership (mean) | 0.6 | 1.1 | 0.3 |
| Pocket money per day (mean) | €6.5 | €6.9 | €5.7 |
| Average number of trips in a school day | 4.1 | 4.1 | 4.2 |

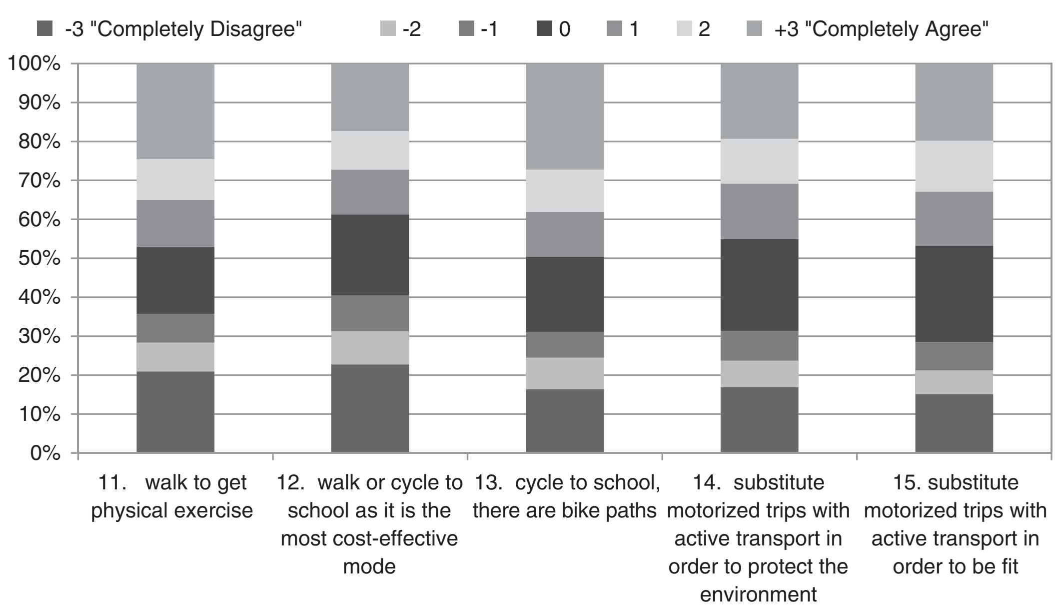


**FIGURE 2 Indicators of latent variable ACT.**

as attitudinal indicator variables, which are used for the construction of the latent variable. In this way, the latent variable ACT measures teenagers' propensity to use active means of transport and, thus, to make environmentally friendly mode choices.

As Figure 2 shows, teenagers tended to agree with the statement that, if bike paths were available, the teens would be willing to cycle. In addition, it seems that they would be willing to walk if wide sidewalks existed. Their answers indicate that the zero travel cost of active transport is not a motivation, while the desire to get more physical exercise and environmental protection could lead them to replace motorized vehicles with active transport.

## RESULTS OF MODEL SPECIFICATION AND ESTIMATION

### Model Specification

The sample used for the modeling process consisted of 8,348 SP responses, corresponding to 4,174 high school students [each participant was presented with two scenarios; more details about combined SP and RP can be found in Polydoropoulou and Ben-Akiva (*58*)]. The current authors carefully examined and filtered the sample to ensure that all participants lived within walking distance (maximum walking distance was found to be 2.1 km) of their school and that all the alternatives in the scenarios were available to them.

The mode choice model had four alternatives:

1. Car (3,600 observations, 43%),
2. Bus (1,628 observations, 19%),
3. Bicycle (1,172 observations, 14%), and
4. Walk (1,984 observations, 24%).

First, for comparison, the authors estimated a multinomial model [Ben-Akiva and Lerman (*59*)]. At the same time, they postulated that the latent variable ACT, which reflects propensity for active transport, had a significant impact on mode choice. Specifically, the authors assumed that the latent variable would increase the probability that active transport (walk and bike) would be chosen and decrease the probability that the car would be chosen. Having these assumptions in mind, the authors incorporated the latent variable ACT in the utilities of car, bus, and bike of the multinomial model.

The utility of choice is a function of attributes of the alternatives and the latent variables. The deterministic utility contains the experimental attributes travel time and cost, travel time from or to the bus station, existence of bicycle parking place and wide sidewalks, and alternative-specific constants for the alternatives bus, bike, and walk. The utility specification also contains the effect of the latent variable ACT, which was not considered for the bus alternative. The equations of the choice model are given below:

$$\boldsymbol{U}_{\mathbf{car}} = \beta_{ttcar} * \mathrm{TTCAR} + \beta_{tccar} * \mathrm{TCCAR} + \beta_{weather1} * \mathrm{WEATHER} + \beta_{ACT1} * \mathrm{ACT} + \varepsilon_{car} \quad (6)$$

$$\boldsymbol{U}_{\mathbf{bus}} = \beta_{bus} + \beta_{ttbus} * \mathrm{TTBUS} + \beta_{tcbus} * \mathrm{TCBUS} + \beta_{wtbus} * \mathrm{WTBUS} + \beta_{weather2} * \mathrm{WEATHER} + \varepsilon_{bus} \quad (7)$$

$$\boldsymbol{U}_{\mathbf{bicycle}} = \beta_{bicycle} + \beta_{ttbike} * \mathrm{TTBIKE} + \beta_{ppbike} * \mathrm{PPBIKE} + \beta_{bikepath} * \mathrm{BIKEPATH} + \beta_{ACT2} * \mathrm{ACT} + \varepsilon_{bike} \quad (8)$$

$$\boldsymbol{U}_{\mathbf{walk}} = \beta_{walk} + \beta_{ttwalk} * \mathrm{TTWALK} + \beta_{sidewide} * \mathrm{SIDEWIDE} + \beta_{weather3} * \mathrm{WEATHER} + \beta_{act3} * \mathrm{ACT} + \varepsilon_{walk} \quad (9)$$

where

TTCAR = travel time by car (min),
TCCAR = travel cost by car (€),
WEATHER = weather conditions (value = 1 if the day is sunny, 0 if it is rainy),
TTBUS = travel time by bus (in min),
TCBUS = travel cost by bus (€),
WTBUS = travel time to or from bus stop (min),
TTBIKE = travel time by bicycle (min),
PPBIKE = availability of bicycle parking place at school (value = 1 if parking place, 0 otherwise),
BIKEPATH = existence of bike path (value = 1 if bike path, 0 otherwise),
TTWALK = travel time on foot (min),
SIDEWIDE = dummy variable (value = 1 if wide sidewalks, 0 otherwise), and
$\varepsilon_{car}$, $\varepsilon_{bus}$, $\varepsilon_{bike}$, $\varepsilon_{walk}$ = vectors of error terms.

A higher value of ACT indicates that the individual is more willing to walk or cycle. The attitudes are modeled as a function of socioeconomic and demographic characteristics. The structural equation links teenagers' characteristics with the latent variables through a linear regression equation that is based on the individual's gender, grades, pocket money, parents' level of education, parents' mode use patterns, and household income. The equation is

$$\mathrm{ACT} = \theta_{ACT} + \theta_{female} * \mathrm{FEMALE} + \theta_{grade1} * \mathrm{GRADES18\text{–}20} + \theta_{grade2} * \mathrm{GRADES9\text{–}14} + \theta_{medu1} * \mathrm{MEDUUNIV} + \theta_{medu2} * \mathrm{MEDUSEC} + \theta_{fedu} * \mathrm{FEDUMSC} + \theta_{inc} * \mathrm{INC{>}4000} + \theta_{fwalk} * \mathrm{FWALK} + \theta_{fcar} * \mathrm{FCAR} + \theta_{mcar} * \mathrm{MCAR} + \theta_{mwalk} * \mathrm{MWALK} + \theta_{pock} * \mathrm{POCKMONEY} + \sigma_{ACT\varpi} \quad (10)$$

where

FEMALE = 1 if participant is female, 0 otherwise;
GRADES18–20 = 1 if participant's grades are between 18 and 20 (out of 20), 0 otherwise;
GRADES9–14 = 1 if participant's grades are between 9 and 14 (out of 20), 0 otherwise;
MEDUUNIV = 1 when mother is university graduate, 0 otherwise;
MEDUSEC = 1 when mother's education level is basic (secondary education), 0 otherwise;
FEDUMSC = 1 when father has master's level education, 0 otherwise;
INC>4000 = 1 when monthly family income is more than €4,000, 0 otherwise;
FWALK = 1 when father walks on a daily basis, 0 otherwise;
FCAR = 1 when father uses car for short-distance trips, 0 otherwise;
MWALK = 1 when mother walks on daily basis, 0 otherwise;
MCAR = 1 when mother uses car for short-distance trips, 0 otherwise;

POCKMONEY = pocket money per day (continuous variable); and

ω = random error term.

## Mode Choice Model

This section presents and discusses the estimation results of the choice model (Table 3). As explained earlier, the authors estimated a multinomial model and then a multinomial model with the latent variable ACT. The models were estimated by using the Python Biogeme software (*60, 61*). The number of draws was set to 1,000.

As expected, travel time, travel cost, and walking time from or to the bus station had negative signs. In relation to weather conditions, teenagers' preferred active transport (walk and bicycle) on a sunny day and motorized vehicles (car and bike) during rain. The existence of bike paths and a bicycle parking area at school significantly affected the choice to use a bicycle, while wide sidewalks increased the likelihood of choosing to walk. These results indicate that the urban form has a strong relationship with the choice to use active means of transport.

Unsurprisingly, the incorporation of the latent variable improved the explanatory power of the model. The willingness to use active transport (cycle or walk) entered significantly into the choice model specification. Thus, the latent variable encouraged the choice of walk and cycle to school through a positive impact in the choice of those alternatives. ACT had the highest effect on bicycle choice, followed by the walk choice. In addition, the latent variable had a negative effect on the choice of car, indicating that individuals who were less willing to walk and cycle preferred the car for their trip to school.

**TABLE 3 Mode Choice Model Estimation Results**

| Variable | MNL Coefficient | MNL *t*-Stat. | Latent Variable Model Coefficient | Latent Variable Model *t*-Stat. |
|---|---|---|---|---|
| $\beta_{bus}$ | 0.158 | 1.29 | –0.013 | –0.09 |
| $\beta_{bike}$ | –1.61 | –12.35 | –3.62 | –19.95 |
| $\beta_{walk}$ | –1.04 | –10.03 | –2.52 | –18.03 |
| Travel time, car | –0.0122 | –3.58 | –0.0123 | –3.49 |
| Travel cost, car | –0.0709 | –2.7 | –0.0626 | –2.32 |
| Weather, car | –0.165 | –2.41 | –0.157 | –2.22 |
| Travel time, bus | –0.0289 | –7.64 | –0.0282 | –7.42 |
| Travel cost, bus | –0.664 | –9.68 | –0.673 | –9.77 |
| Walking time to bus station, bus | –0.0377 | –5.77 | –0.0377 | –5.75 |
| Weather, bus | –0.269 | –3.42 | –0.263 | –3.28 |
| Travel time, bicycle | –0.0826 | –7.71 | –0.0766 | –7.08 |
| Parking place availability, bicycle | 0.32 | 4.91 | 0.317 | 4.76 |
| Existence of bikepath | 1.03 | 14.85 | 1.05 | 14.8 |
| Travel time, walk | –0.0309 | –6.02 | –0.0302 | –5.77 |
| Existence of wide sidewalks, walk | 0.825 | 14.63 | 0.829 | 14.4 |
| Weather, walk | 0.343 | 4.48 | 0.339 | 4.4 |
| ACT (specific to car) | — | — | –0.0456 | –2.28 |
| ACT (specific to bike) | — | — | 0.403 | 14.17 |
| ACT (specific to walk) | — | — | 0.303 | 12.66 |

NOTE: MNL = multinomial model; *t*-stat = *t*-statistic.

## Estimation Results from Structural Model and Measurement Model

Table 4 presents the estimation results from the structural and measurement models. All the variables used in the structural model are statistically significant at the 95% level. The structural model allows the conclusion that boys were more willing to walk or cycle to school than girls. Furthermore, students who got high grades (18 to 20 of 20) were more willing to use active transport, while those who got low grades (9 to 14 of 20) were less likely to do so. Teenagers from households with a high monthly income (more than €4,000) were less willing to walk or cycle, and, as daily pocket money increased, the possibility of choosing an active transport mode decreased.

With respect to the educational attainment of parents, higher levels of education for both the mother (bachelor's) and the father (master's)

**TABLE 4 Structural Model and Measurement Model Estimation Results**

| | Coefficient | *t*-Stat. |
|---|---|---|
| Structural Model | | |
| $\theta_{ACT}$ | 4.09 | 6.2 |
| Female (gender) | –0.225 | –5.49 |
| Grades 18–20 (out of 20) | 0.177 | 4.09 |
| Grades 9–14 (out of 20) | –0.207 | –3.17 |
| Mother's level of education: university | 0.426 | 9.41 |
| Mother's level of education: high school | –0.199 | –3.13 |
| Father's level of education: university | 0.235 | 3.65 |
| Income more than €4,000 | –0.332 | –5.15 |
| Father always uses the car for short-distance trips | –0.101 | –2.18 |
| Father walks every day | 0.137 | 3.04 |
| Mother walks every day | 0.22 | 5.29 |
| Mother always uses the car for short-distance trips | –0.108 | –2.43 |
| Pocket money | –0.00302 | –1.96 |
| $\sigma_{ACT}$ | 1.66 | 7.89 |
| Measurement Model | | |
| $\alpha_1$ | 0 | na |
| $\alpha_2$ | –0.0793 | –1.96 |
| $\alpha_3$ | 0.85 | 12.11 |
| $\alpha_4$ | 0.614 | 8.43 |
| $\alpha_5$ | 0.642 | 9.15 |
| Walk to get physical exercise ($\lambda_1$) | 1 | na |
| Walk or cycle to school as it is most cost-effective mode ($\lambda_2$) | 0.941 | 51.14 |
| Cycle to school, if there are bike paths ($\lambda_3$) | 0.85 | 53.88 |
| Substitute motorized trips with active transport to protect environment ($\lambda_4$) | 0.85 | 66.85 |
| Substitute motorized trips with active transport to be fit ($\lambda_5$) | 0.879 | 55.19 |
| $\sigma_1$ | 1.47 | 88.39 |
| $\sigma_2$ | 1.44 | 90.34 |
| $\sigma_3$ | 1.63 | 110.9 |
| $\sigma_4$ | 1.45 | 94.77 |
| $\sigma_5$ | 1.36 | 91.01 |

were associated with greater levels of willingness among the teenagers to walk or cycle. Moreover, the results were in line with the results of other surveys showing that patterns of parental mode use and parental habits significantly affect the kids' behavior in mode choice (*41, 42*). When both parents walked on a daily basis, then the teenagers too were more likely to walk or cycle to school. In contrast, parents always using their cars for short-distance trips had a negative effect on the teenagers' willingness to use active transport.

Several indicators were considered in the latent variable measurement model, which linked the latent variable of psychometric willingness to walk or cycle to the responses to the attitudinal qualitative questions of the survey. The coefficient of the first indicator (I1) was normalized to 1. The $\alpha$ parameters that indicate the associations between the responses to the scale items and the psychometric scale all have the expected signs. Here, a more positive attitude to walking or cycling will lead to respondents being more in agreement with the statements about fitness and physical activity. In addition, the effect of the latent variable ACT on the indicator about environmental protection is positive, reflecting the idea that environmentally conscious teenagers perceived the idea of walking or cycling more positively because each is a greener transport mode.

## CONCLUSIONS

This paper has investigated the effects of teenagers' attitudes toward walking and cycling on their choices of mode of transport to school. In cooperation with MOEC in Cyprus, the authors forwarded a web questionnaire to all high schools in the country, and 4,147 students (corresponding to 8.7% of the total high school population) participated in the survey. To the authors' knowledge, this is the first such large-scale survey about travel behavior focusing only on teenagers and collecting both RP and SP data.

Using these data, the authors developed and applied HCM to explain willingness to walk or cycle in a mode choice context. The specification used here was consistent with the new trend in discrete-choice modeling toward incorporating unobservable (perceptual and attitudinal) factors into the behavioral representation of the decision process. HCM offers an attractive improvement in modeling of behavior in mode choice because that the choice model is only a part of the whole behavioral process, in which individuals' attitudes are incorporated to thus yield a more realistic model. On several counts, the latent variable–enriched choice model outperforms the traditional choice model. It provides insights into the importance of unobservable, individual-specific variables to modal choice, indicating that this type of model is a powerful tool for improving the transport planning profession's understanding of travel behavior.

In general, the current results confirm that travel time and travel cost significantly affect teenagers' mode choice behavior, similarly to the effect on adults. Walking time to and from the bus station also has a negative effect on the decision to take a bus (public transportation) to school. Active transport (walking and cycling) is preferred when bike paths, bicycle parking places, and wide sidewalks are available. Weather conditions also affect mode choice: the results show that, on a sunny day, participants prefer active transport, while during rain, motorized vehicles (car and bus) are preferred. Moreover, comparison of (*a*) the actual choice of transport mode to school (RP) with (*b*) the choice in the SP shows the significant increase in the percentage of those who would use active transport if facilities for bicycles and appropriate facilities for pedestrians were available.

The results of HCM show that teenagers' attitudes toward walking and cycling are quite important and significant and imply that unobservable variables should be implemented in the choice process to create more realistic econometric models and in so doing implement better cut-and-tailored policies. As the authors expected, the latent variable ACT works in favor of walking and cycling and against traveling by car.

The results of the structural model indicate that teenagers who get higher grades at school are more willing to use active transport modes than those who get low grades. Teenagers from households with high incomes (more than €4,000/month) are less likely to be willing to walk or cycle. Similarly, as teenagers' pocket money increases, the propensity to walk or cycle decreases. Moreover, the results assert that family is undoubtedly the most important institution in shaping adolescents' travel behavior. A high level of education (bachelor's degree) attained by the mother has the highest effect on a teenager's willingness to walk or cycle. Parental mode use patterns and habits also significantly affect the latent variable ACT. Both the mother's and the father's addiction to using a car will discourage teenagers from walking or cycling to school, while, when parents walk on a daily basis, the teenagers tend to adopt a more positive attitude to active transport. These findings are similar to the results of other surveys about the role parents play in their children's transport behavior (*41–43*).

These results would lack any meaning if they could not be translated into policies and measures. 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 (e.g., to the bus stop or to school). Several facilities could be implemented on sidewalks, elevating the convenience and safety for pedestrians and cyclists, such as bicycle parking places and priority at traffic lights. In addition, bicycle parking places at schools are necessary, not only to encourage cyclists but also to remind students to use their bicycles. Today, cycling is not only a healthy transport mode but also a trend among young people. Cities should take the needs of the new generation into consideration and rearrange their plans accordingly.

Moreover, particular consideration should be given to parents. The findings indicate that targeting parents of lower educational level to adopt active transport alternatives could strongly influence future transport outcomes. Both communities and schools could organize campaigns specifically aimed at urging parents to encourage their children to walk or cycle. Schools could cooperate with parents by arranging "walking buses to school" or websites along similar lines to carpooling for active transport to school (active "transpooling") (*62*). 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 businesses) to record the transport modes that students use and reward those who are frequent users of active transport.

The innovative data collection and modeling methodology used here could be highly important to researchers dealing with this age group and the topic of school transportation. Moreover, the investigation of teenagers' travel behavior could provide significant findings for policies, strategies, and campaigns aimed at shaping desired travel behaviors that may be retained into adulthood.

Future surveys will be redesigned to take into account the percentage of trips with an available bike path or a wide sidewalk. Moreover, future work will investigate more teenagers' attitudes toward travel and behavior in mode choice. Perceptions and attitudes toward sports activities, ecological awareness, relationships with parents, parental guidance, and involvement with peers will be examined. Further research should also include the investigation of how perceptions toward information and communication technologies, social networking, and virtual traveling affect the new generation's travel behavior.

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