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# Assessing the Relationships Between Young Adults' Travel and Use of the Internet Over Time

**Guoqiang Wu**[1]

Lecturer (Urban Planning)

School of Architecture and Urban Planning, Chongqing University

174 Shazheng Ave., Shapingba District, Chongqing, China 400044

Email: wu.guoqiang@cqu.edu.cn; Tel: + 86 023 651 20700

**Jinhyun Hong**

Lecturer (Urban Studies)

School of Social and Political Sciences, University of Glasgow

7 Lilybank Gardens, University of Glasgow, Glasgow, UK G12 8RZ

Email: Jinhyun.Hong@glasgow.ac.uk; Tel: +44 (0) 141 330 7652

**Piyushimita (Vonu) Thakuriah**

Professor and Dean

Edward J Bloustein School of Planning and Public Policy, Rutgers University

33 Livingston Ave., New Brunswick, New Jersey 08901, USA

Email: p.thakuriah@rutgers.edu; Tel: +1 848 932 2714

[1] Corresponding author

**ABSTRACT**

Although young people's mobility behaviors and their association with information and communications technologies (ICT) usage have been extensively researched, few studies have considered the relationship between changes in the use of ICT over time and young people's travel patterns. This paper explores how use of the Internet during adolescence/late childhood and the degree of change while transitioning from late childhood to adulthood is related to sustainable travel patterns in young adults. We are particularly interested in the mediating role that attitudes towards the environment have on the relationship between early age Internet use and sustainable travel in young adults. The use of rich, longitudinal datasets, the 2004 British Household Panel Survey (BHPS) and the Understanding Society Survey (Wave 4, 2012/14), allow an investigation of these attitudes and relationships for the same people from childhood to adulthood. We use structural equation modeling (SEM) to examine the complex interrelationships between young adults' Internet use over time, their travel modes and attitudes towards the environment, and other related behaviors. Our key finding is that consistently high levels of Internet use between adolescence and young adulthood is associated with the formation of environmental attitudes. While other factors not considered in this study might also have an effect, we find that these attitudes are indirectly but significantly associated with young adults' sustainable travel patterns and behaviors.

Keywords: *young adults; Internet use; attitude; travel mode use; pro-environmental behavior; structural equation modeling*

## 1. INTRODUCTION

Millennials (i.e. people born between 1981 and 1996 according to the Pew Research Center, 2018) have been the focus of much research across various fields. They are reported to have different attitudes, behaviors, consumption patterns, and lifestyles compared to earlier generations at the same life stage. In transportation research, millennials are reported to have lower rates of driver's license and car ownership (Delbosc & Currie, 2013; Dutzik et al., 2014; Thakuriah et al., 2010), drive less (Frändberg & Vilhelmson, 2013; McDonald, 2015; Kuhnimhof et al., 2012), use alternative modes more often (Blumenberg et al., 2012; Dutzik et al., 2014; Garikapati et al., 2016), and generally undertake fewer trips and travel fewer miles on a daily basis (McDonald, 2015; Polzin et al., 2014). Dramatic socioeconomic changes, such as delayed marriages and transitions into adulthood have contributed to sustainable mobility patterns, e.g. bicycling or walking (Delbosc & Currie, 2013; Dutzik et al., 2014). Furthermore, people born after 1980 have been exposed to digital technologies from a young age and have used such technologies to a much greater degree in their everyday lives compared with earlier generations (Thakuriah & Geers, 2013). This heavy reliance on information and communications technologies (ICT) in daily life has largely reshaped their transportation needs and travel behaviors (Hong & Mcarthur, 2017; Lyons, 2015). Aside from these longer term societal patterns, disruptive economic conditions like the global economic recession may have led to millennials' lower rates of car usage by causing an increase in the cost of car ownership and car insurance rates for younger people (Allstate, 2011; Thakuriah & Mallon-Keita, 2014).

Many studies have considered the impact of ICT on human travel/activity, particularly the potential of substituting physical travel with virtual activities (e.g. teleworking, e-shopping, online socializing, etc.). In addition, the application of ICT in the transportation sector has brought about various technology-enabled transportation services and tools, such as real-time information provision, car-sharing apps, and on-board Wi-Fi, which make public transit, cycling, ridesharing, and other modes more attractive to travelers and reduces car use (Dutzik et al., 2013; Dutzik et al., 2014; Martin et al., 2010). Millennials seem to be more susceptible to such ICT-induced effects as they are "digital natives" (i.e. born and raised in the digital era) and are more tech-savvy than earlier generations (Circella et al., 2016; Circella et al., 2017; Dutzik et al., 2014; van Wee, 2015).

Attitude may also mediate the ICT-induced impact on travel behavior. Much of the research on millennials' mobility patterns and travel choices has considered their environmental attitudes and concerns (Circella et al., 2016; Circella et al., 2017; Dutzik et al., 2014; Sakaria & Stehfest, 2013). These studies generally conclude that a pro-environment attitude correlates to millennials' sustainable travel behavior (including less car use and greater use of other modes of transportation). This conclusion is consistent with classical behavioral theories, such as the theory of planned behavior, the norm-activation theory, and the value-belief-norm theory. All these theories highlight the link between attitudinal factors and behavior and have been widely applied to explain human travel behavior, particularly travel-choice behavior (Adjei & Behrens, 2012; Gehlert et al., 2013).

Based on attitude-behavior relationships, scholars have researched how behaviors can be changed to more sustainable patterns by influencing attitudes and ICT was found to be effective in exerting such an influence. For example, as an information repository, the Internet can increase people's environmental consciousness and awareness by spreading information and knowledge (Good, 2006; Nistor, 2010; Stokols & Montero, 2002). Additionally, researchers have looked at how the Internet can be a tool for environmental activism and organization and have highlighted its potential to enhance environmental activism and governance (Pickerill, 2003; Stokols & Montero, 2002; Zelwietro, 1998). In millennial studies, Allen, Wicks, and Schulte (2013) revealed that young citizens tend to use online social networks to convince their peers to be more environmentally friendly and that this peer persuasion can generate subjective norms that may ultimately influence behavior (Allen et al., 2013). This finding seems to reinforce the emerging theory of *captology* (i.e. the study of computers as persuasive technologies), which highlights ICT's role in changing people's attitudes and behavior (Fogg, 2003).

The relationships between the use of ICT and behavior and between attitudes and behavior have been widely studied to better understand millennials. The association between the use of ICT and the attitudes of millennials and how the latter mediates the relationship between use of ICT and observed behavior has received little attention, however. Therefore, this study attempts to address this gap in the literature by exploring both the direct and indirect associations between young people's use of the Internet, their pro-environmental attitudes, and sustainable travel behavior, and the relationships between their attitudes and behavior.

Another important issue that is often overlooked in research on millennials' mobility and ICT is the effect of changes in ICT usage over time on current behavior. The theoretical underpinnings of the reliance of behavior on past history can be conceptualized as hysteresis in behavior (Georgescu-Roegen, 1971), which implies that current preferences are relative to a history of behavioral choices (Elster, 1976). Inadequacy in the research of such dynamic effects is largely attributed to the unavailability of data sources, as longitudinal analysis is always required. Nevertheless, a few studies have presented some enlightening findings.

Based on the Puget Sound Transportation Panel (PSTP) data, Kim and Goulias (2004) modeled the relationships between time allocation to daily activities and travel, modal split, and changes in ICT ownership and availability between the years 1997 and 2000. They found that the consequences of changes in ICT use depended on the location of the technology used (i.e. home or workplace). For example, new computer users at work tended to spend more time on subsistence activities and less time on leisure, while users at home generally spent more time on all activities and tended to use public transportation more often.

In the context of millennial studies, Thulin and Vilhelmson (2006) used the Swedish National Communication Survey data (1997–2001) to explore the impact of young people's changing ICT use on their in-home and out-of-home activity participation. Their results revealed that while increased computer use had no significant impact on young people's out-of-home activity engagement, it substantially displaced other in-home activities.

Despite these valuable discoveries, however, past studies have not considered how changes in the use of ICT relate to people's attitudes, which indirectly shape behavior. In addition, the periods during which the changes took place in these studies were generally short and may not fully explain the long-term interactions between ICT use and mobility behavior.

To address the research gaps identified above, this study uses structural equation modeling (SEM) to explore the complex relationships between Internet use from adolescence/late childhood to adulthood, young adults' environmental attitudes, and travel behavior. The degree of young adults' pro-environmental behavior in terms of energy use and shopping is also modeled to assess the overall sustainability levels of millennials' lifestyles. The data used for this longitudinal study are samples of young teenagers and young adults from the 2004 British Household Panel Survey (BHPS) and the Understanding Society survey (2012/14, Wave 4). . The primary question that this study attempts to answer is: how does use of the Internet and changes in Internet usage patterns over time relate to the environmental

attitudes, choice of travel mode, and pro-environmental behavior of young adults? While other unobserved factors not considered in this study such as changes in residential location, lifestyles, and education may also explain changes in attitudes and travel behavior, our objective, by answering this question, is to analyze young people's experience with using ICT alongside their attitude formation and development and their connections with daily behavior and mobility patterns.

## 2. DATA AND VARIABLES

This study is based on datasets from two nationwide longitudinal household surveys: the British Household Panel Survey (BHPS) and Understanding Society (the UK Household Longitudinal Study) survey. Started in 1991, the BHPS followed the same representative sample of individuals over a period of years and was carried out annually by the Institute for Social and Economic Research (ISER) to understand social and economic changes at household and individual levels across the UK. In 2009, Wave 19 of the BHPS became part of the new Understanding Society survey (from Wave 2 onwards), which contains a larger sample of households and individuals and more diverse topics. Each of the BHPS sample members was therefore issued a unique identifier within the Understanding Society datasets to allow users to match BHPS data to Understanding Society Wave 2 data onwards.

The survey consists of three questionnaires: (a) the *household survey*, which investigates households' composition and socioeconomic situations; (b) the *individual survey*, which collects the socio-demographic status, behavior, and attitudes (including Internet usage, travel mode use, pro-environmental attitudes, and behavior) of every adult (aged 16 years and above) in selected households; and (c) the *youth survey*, which looks at the behavior and attitudes of young people (aged 10–15 years) in households, including their Internet usage.

As this study focuses on the temporal changes in ICT usage, young adults' past use of the Internet needs to be linked to their current Internet-use patterns, attitudes, and behaviors. Therefore, the youth sample contained in the youth survey of an early BHPS is first tracked in the individual survey dataset of a later Understanding Society survey according to the unique identifiers. This creates a comprehensive dataset containing information for each young person in both adolescence and adulthood. Considering their inclusion of key variables and appropriate time span, the 2004 BHPS and the 2012–14 (Wave 4) Understanding Society

survey were selected as the data sources for this study. The initial sample size after data merging was 1,306.

As one of the key variables in this study, young people's Internet use is recorded in terms of frequency of accessing the Internet in both adolescence and adulthood. Respondents indicated their level of Internet use for personal reasons by placing themselves into one of the following bands: "never use", "less than once a month", "at least once a month", "at least once a week", and "every day." Based on the usage frequency information, we identified two groups: *light Internet users* and *heavy Internet users*.

A heavy Internet user is defined as a person who uses the Internet every day, whereas a person who does not use it daily is defined as a light Internet user. After removing all the cases with missing information regarding Internet use and behavior, the sample size was reduced to 792. In 2004, only 24.95% of the sampled youths were heavy Internet users, but in 2012–14, this figure significantly increased to 83.39% for young adults. To reflect the changes in Internet use over time, indicator variables for four groups were created based on past and current Internet-use patterns:

- *New heavy users*: people who were light Internet users in 2004 but are now heavy users (61.37%)
- *Past heavy users*: people who were heavy Internet users in 2004 but are now light users (2.93%)
- *Experienced heavy users*: people who were heavy Internet users in 2004 and still are (22.02%)
- *Persistent light users*: people who were light Internet users in 2004 and still are (13.68%)

The effects of socio-demographics and their changes are also controlled in this study. Table 1 presents descriptive statistics for the socio-demographics of the sampled young adults in 2012/14. The statistics reveal that there are more females than males, with the former accounting for over 53% of the total sample. The ages of the sampled young adults range from 18 to 24 years, with an average of 20 to 21. The average number of children is generally less than one per household and the average number of adults is 3–4.

**TABLE 1. Descriptive statistics of young adults' socio-demographics and Internet use and changes over time as measured in 2012/14 (N=792).**

| Variable Name | Descriptions | Mean | Min. | Max. |
|---|---|---|---|---|
| ***Socio-demographics in 2012/14*** | | | | |
| Female | Gender: Male='0', female='1' | 53.50% | 0 | 1 |
| Age | Age of respondent | 20.47 | 18 | 24 |
| Kid0_4 | Number of kids aged 0–4 years in household | .11 | 0 | 2 |
| Kid5_15 | Number of kids aged 5–15 years in household | .28 | 0 | 4 |
| Adults | Number of adults in household | 3.29 | 1 | 7 |
| Income | Monthly household income (thousands of British Pounds) | 3.39 | .27 | 20.00 |
| Parent_living | Living with parents or not (Living='1') | 77.17% | 0 | 1 |
| Employment_status | Employment status | — | 1 | 3 |
| *Unemployed (reference)* | Employment status: unemployed (reference) | 13.07% | 0 | 1 |
| *Employed* | Employment status: employed | 37.34% | 0 | 1 |
| *Student* | Employment status: student | 49.59% | 0 | 1 |
| Highest_qualification | The highest educational level in 2015/17 (Wave 7) | 3.55 | 1 | 5 |
| | *1: Below GCSE or no qualifications* | 4.54% | 0 | 1 |
| | *2: GCSE or equivalents* | 16.29% | 0 | 1 |
| | *3: A-Level or equivalents* | 32.45% | 0 | 1 |
| | *4: Diploma, teaching, and nursing qualifications etc.* | 11.49% | 0 | 1 |
| | *5: 1st and higher degree (BSc, BA, MSc, MA, PhD, etc.)* | 35.23% | 0 | 1 |
| Driving_license | Holding driving license or not (Holding='1') | 50.61% | 0 | 1 |
| ***Residential location in 2012/14*** | | | | |
| Urban | Living in urban areas or not (urban ='1', rural='0') | 71.78% | 0 | 1 |
| ***Changes in (household) socio-demographics over time*** | | | | |
| Change_income | Changes in monthly household income (based on the 2004 British Pound values) | -.46 | -30.69 | 11.13 |
| Change_kid0_4 | Change in the number of kids aged 0–4 years in household | — | 1 | 3 |
| *No_change_kid0_4 (reference)* | No change in the number of kids aged 0–4 years (reference) | 84.15% | 0 | 1 |
| *Decrease_kid0_4* | A decrease in the number of kids aged 0–4 years in household | 6.31% | 0 | 1 |
| *Increase_kid0_4* | An increase in the number of kids aged 0–4 years in household | 9.54% | 0 | 1 |
| Change_kid5_15 | Changes in the number of kids aged 5–15 years in household | — | 1 | 3 |
| *No_change_kid5_15 (reference)* | No change in the number of kids aged 5–15 years (reference) | 3.41% | 0 | 1 |
| *Decrease_kid5_15* | A decrease in the number of kids aged 5–15 years in household | 94.95% | 0 | 1 |
| *Increase_kid5_15* | An increase in the number of kids aged 5–15 years | 1.64% | 0 | 1 |
| ***Internet usage in 2012/14*** | | | | |
| Internet_use | Frequency of using the Internet | — | 1 | 5 |
| *Internet_freq1 (reference)* | Never use (reference) | 0.49% | 0 | 1 |
| *Internet_freq2* | Use less than once/month | 0.16% | 0 | 1 |
| *Internet_freq3* | Use at least once/month | 3.42% | 0 | 1 |
| *Internet_freq4* | Use at least once/week | 12.54% | 0 | 1 |
| *Internet_freq5* | Use every day (i.e. heavy users) | 83.39% | 0 | 1 |
| ***Changes in the Internet usage over time*** | | | | |
| Change_Internet | Changes in Internet usage over time | — | 1 | 4 |
| *Persistent (reference)* | Persistent light users (reference) | 13.68% | 0 | 1 |
| *New* | New heavy users | 61.37% | 0 | 1 |
| *Experienced* | Experienced heavy users | 22.02% | 0 | 1 |
| *Past* | Past heavy users | 2.93% | 0 | 1 |

*(Note: dummy variables developed from the multi-level categorical variables are list in italics)*

Regarding household income, the average level in 2012/14 was £3,390 per month. Among the sampled young adults, 77% live with their parents, which is not surprising given the low rate of employment (37%) and that nearly 50% are students. As half of them were still studying at schools or universities/colleges in 2012/14, the highest educational level these young people would reach at the later period of the Understanding Society survey (Wave 7, 2015/17) is used to reflect their eventual educational attainments. This is because college students would normally graduate with a degree/diploma after three waves of the survey. According to the 2015/17 information, over one third of the young adults have or are expecting a first degree or above from universities/colleges. Moreover, half of them hold a valid driving license and over 70% of them live in urban areas.

As for changes in household characteristics over time, household income generally reveals a decrease after adjusting the current income values to 2004 British Pound values according to the UK Consumer Prices Index. In terms of changes in household composition, while the number of children aged 0–4 years remains stable over time for most families, the number of older children (aged 5–15 years) shows a decrease in almost 95% of the households. As the sampled young people completed the transition from adolescents in 2004 to adults in 2012/14, it is unsurprising that the majority of families have fewer children aged 5–15 years in 2012/14.

Apart from socio-demographics, indicator variables of Internet use and changes in usage are also presented in Table 1. Most of the young adults (over 60%) behave as new heavy users of the Internet and less than 3% of them drop the habit of using the Internet daily when they leave adolescence or late childhood. In addition, almost a quarter of them have been heavy users since a young age, and the remaining have never used the Internet daily (persistent light users).

In terms of young adults' attitudes and behavior, which are considered as the endogenous variables in the study model, these were recorded as a set of ordinal variables in the dataset. People's travel behavior is represented by their frequencies of traveling by car, bus, train, and bike; from "less than once a year" to "at least once a day." Frequency of carpooling was measured on a scale from "never" to "always." The same frequency scale was applied to describe young adults' pro-environmental behavior and the scale from "never" to "always" generally implies an increasingly pro-environmental pattern. As for environmental attitudes, six attitudinal variables in the dataset were selected and measured at either four or five-point

**TABLE 2. Distributions of behavioral and attitudinal variables used (N=792).**

| Categories | Variable Name/Description | Frequency or Attitude Scales (% of total sample) | | | | |
|---|---|---|---|---|---|---|
| ***Travel Mode Used*** | | ***1. Less than once/year*** | ***2. At least once/year*** | ***3. At least once/month*** | ***4. At least once/week*** | ***5. At least once/day*** |
| | **Car**/Frequency of travelling by private car/van | 2.2% | 2.9% | 9.0% | 31.0% | 54.9% |
| | **Bus**/Frequency of travelling by bus | 27.9% | 15.7% | 19.6% | 23.8% | 13.0% |
| | **Train**/Frequency of travelling by train | 25.8% | 32.2% | 26.5% | 10.2% | 5.3% |
| | **Cycling**/Frequency of travelling by bike | 62.2% | 15.5% | 7.9% | 9.3% | 5.1% |
| | | ***1. Never*** | ***2. Not very often*** | ***3. Quite often*** | ***4. Very often*** | ***5. Always*** |
| | **Carpooling**/Frequency of travelling by carpooling | 52.7% | 10.2% | 18.2% | 11.8% | 7.1% |
| ***Environmental Behavior*** | **Light**/Switching off lights | 2.5% | 7.5% | 14.3% | 23.9% | 51.9% |
| | **Water**/Turn off the tap while you brush your teeth | 11.1% | 13.3% | 16.8% | 19.9% | 39.0% |
| | **Heating**/Put more clothes on when you feel cold rather than relying on heating | 12.7% | 12.4% | 20.0% | 28.4% | 26.5% |
| | **Recycled**/Buy recycled paper products | 47.0% | 22.3% | 17.1% | 8.1% | 5.5% |
| | **Bag**/Take your own shopping bag when shopping | 40.2% | 14.1% | 12.0% | 13.1% | 20.5% |
| ***Attitudes & Perceptions*** | | ***1. Do nothing env. friendly*** | ***2. 1/2 things env. friendly*** | ***3. Few things env. friendly*** | ***4. Mostly env. friendly*** | ***5. Everything env. friendly*** |
| | **Life_feel**/Current lifestyle environmentally friendly | 10.7% | 43.6% | 31.7% | 10.5% | 3.5% |
| | | ***1. Disagree strongly*** | ***2. Disagree*** | | ***3. Agree*** | ***4. Agree strongly*** |
| | **Being_green**/Being green is an alternative lifestyle for the majority | 5.0% | 25.8% | | 53.3% | 15.9% |
| | | ***1. Disagree strongly*** | ***2. Tend to disagree*** | ***3. Neither agree nor disagree*** | ***4. Tend to agree*** | ***5. Agree strongly*** |
| | **Life_change**/Help environment with changes fitting with lifestyle | 3.2% | 9.1% | 26.4% | 45.4% | 15.9% |
| | **Crisis_feel**/Environmental crisis has been exaggerated | 19.1% | 39.5% | 26.4% | 9.6% | 5.4% |
| | **Climate_worry**/Climate change too far in future to worry | 21.2% | 43.6% | 22.5% | 8.8% | 3.9% |
| | **Change_worth**/Not worth making changes if others do not do the same | 16.7% | 40.8% | 27.4% | 9.1% | 6.0% |

Likert scales that represented the level of agreement or disagreement regarding an environmental statement (except individuals' perception of current lifestyle). All behavioral and attitudinal variables used in this study are summarized in Table 2.

According to Table 2, private cars/vans are still the most popular travel mode for young adults, with around 55% using them daily. In contrast, cycling is the least popular mode, with over 62% of young people using it less than once a year. As for the use of public transit, buses are used more frequently for young people's daily travel than trains, with about 37% using buses more than once per week or every day. In terms of environmental behavior, young adults generally do well in the rational use of resources, as most of them consume energy (electricity, water, and gas) conservatively.

Their purchasing behavior seems to be less environmentally friendly, however, as almost half never buy recycled paper products or take their own bags when shopping. Regarding their attitudes, young people are generally pro-environmental. Although less than 15% of them feel that their current lifestyles are environmentally friendly in most or all aspects, nearly 70% agree that "being green" is an alternative lifestyle for the majority and over 60% would like to help the environment by making changes that fit with their lifestyles. Additionally, over half of these young adults tend to see environmental crises and climate change as serious issues and value their own actions in making changes.

## 3. METHOD AND MODEL

We applied SEM to reveal the complex interactions between Internet use, environmental attitudes, travel, and pro-environmental behavior. The strength of SEM is its ability to simultaneously estimate the complex relationships within a set of latent and observed variables based on a specified model (Kaplan, 2000). Our context certainly involves multiple relationships, for example, we could hypothesize that attitudes affect both mode use and pro-environmental behavior and in turn are affected by them, and that usage and behavior each affect each other. Moreover, apart from the direct effect of one variable on another, SEM is also able to detect the indirect relationship between two variables as mediated by other intervening variables. The total effect therefore consists of a direct effect and one or more indirect effects. This technique is appropriate for our study as we seek to explore the

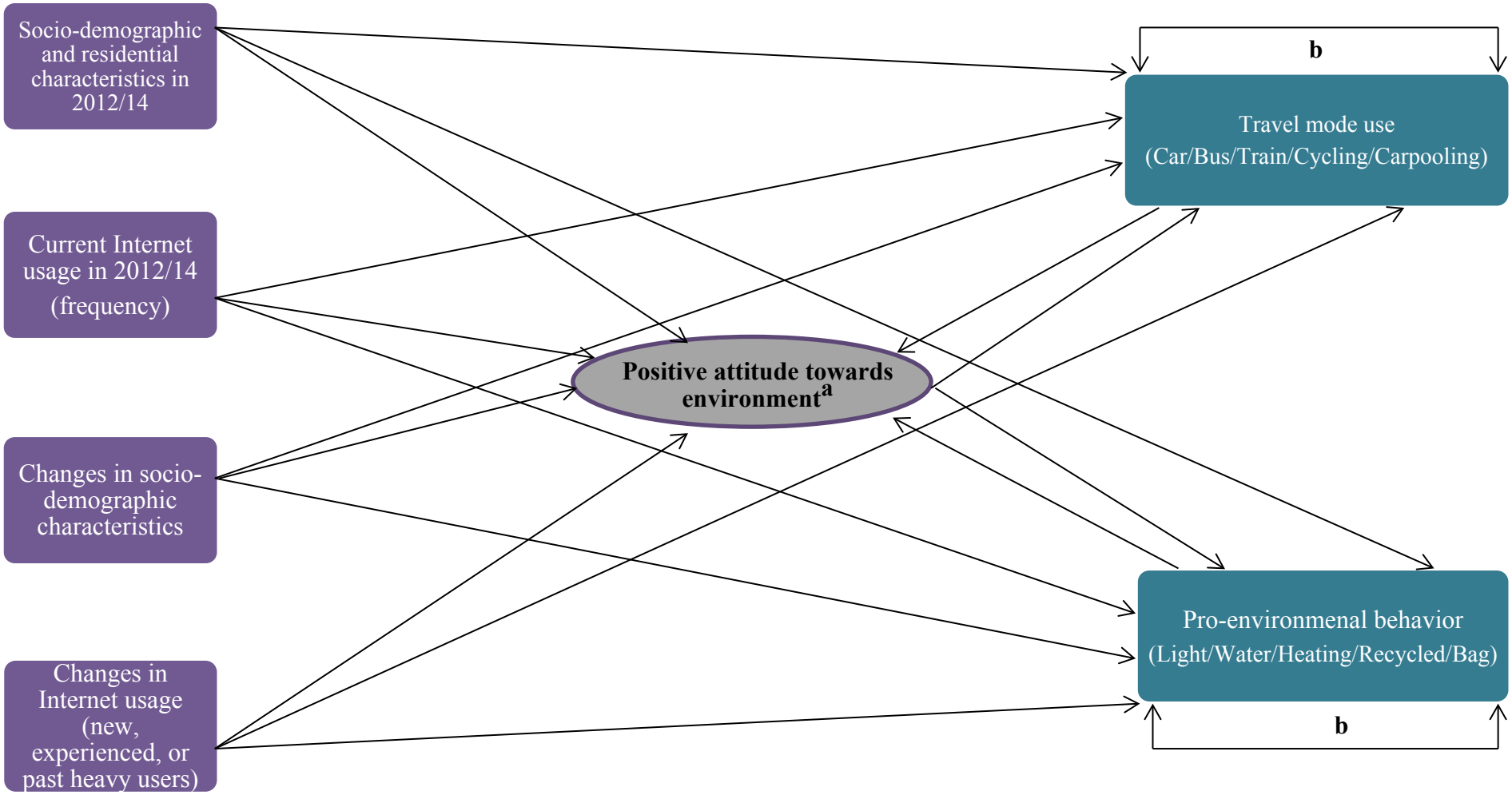
mediating role environmental attitudes play in the relationship between Internet use and behavior.

A traditional SEM analysis consists of two parts: a measurement model and a structural model. The measurement model specifies how latent variables are explained by the observed variables, whereas the structural model specifies the relationships between the latent variables and captures the influence of exogenous variables on endogenous variables and the associations among endogenous variables.

Based on SEM techniques and the data and variables used, we developed a modeling framework that illustrates the complicated relationships examined in this study. As shown in Figure 1, young adults' socio-demographics, current usage of the Internet (frequency of use), and changes in socio-demographics and Internet-use patterns were treated as exogenous variables. For changes in Internet usage, three indicator variables: *new, experienced* and *past heavy Internet users*, were included, with one indicator of *persistent light users* referenced and omitted. The remaining attitudinal and behavioral variables were considered as endogenous variables. Although some studies have suggested that individuals' travel choices may influence their use of the Internet or other ICT in reverse (e.g. Kwan et al., 2007; Mokhtarian, 1990), we did not find any reverse effects to be significant when the bi-directional relationships between use of the Internet and travel were tested. Therefore, we only considered the unidirectional relationships in our final model framework.

Moreover, to simplify the model structure and to clearly represent the attitude-related relationships, a latent variable of *positive attitude towards environment* was created based on the six observed attitudinal variables in the dataset.[2] In addition to the influence of attitude on travel and pro-environmental behavior, the potential influence of behavior on attitude was also assumed in the model as some behavioral theories, such as the self-perception theory, imply that behavior may shape and precede attitudes (Bem, 1972). Besides, correlations between travel mode use and between pro-environmental behavior were modeled. The model was run in the Mplus environment and the WLSMV (weighted least squares means-and-variance-adjusted) estimator was used as all the dependent variables modeled were ordered categorical variables with non-normal distributions.

[2] Confirmatory factor analysis was performed to determine the factor structure.




*Notes: a. a latent construct created based on the six observed attitudinal variables.*

*b. correlations among mode use/pro-environmental behavior.*

*Oval represents the latent variable, rectangles represent the observed variables.*

**FIGURE 1. Modeling framework depicting the hypothesized relationships in the structural model of SEM**

A variety of goodness-of-fit measures have been developed to assess the appropriateness of a structural equation model. The indices provided by Mplus usually include the chi-square ($\chi^2$) statistics, the Tucker–Lewis index (TLI), the comparative fit index (CFI), the root mean square error of approximation (RMSEA), and the standardized/weighted root mean square residual (SRMR/WRMR).

## 4. RESULTS

The goodness-of-fit indices presented in Table 3 show that the model performs reasonably well. Although the chi-square is significant at the 0.05 level, the other indices indicate a good

**TABLE 3. Parameter estimates of factor analysis and model goodness-of–fit indices (N=792).**

| Factor | Observed Variables | Standardized Parameter Estimate |
|---|---|---|
| *Positive attitude towards environment* | Life_feel | .416** |
| | Being_green | .342** |
| | Life_change | .369** |
| | Crisis_feel | -.635** |
| | Climate_worry | -.654** |
| | Change_worth | -.568** |
| *Goodness-of–fit indices* | Chi-square=371.546 (d.f.=170, p-value=.000)<br>Chi-square/d.f.=2.186<br>TLI=0.915<br>CFI=0.942<br>RMSEA=0.042, Pro.(RMSEA<=.05)=0.980<br>WRMR=0.091 | |

*(Note: ** significant at the 5% level)*

fit. For instance, both the TLI and the CFI are over 0.90, the RMSEA is less than 0.05, and the WRMR is less than 1.0. Table 3 also shows the standardized parameter estimates of the

six observed attitudinal indicators used for constructing the latent variable. All the observed variables can be significantly explained by the factor *positive attitude towards environment* and the magnitude of the factor loadings is generally acceptable. Young people with a positive attitude towards the environment are more likely to feel that their current lifestyles are environmentally friendly and less likely to neglect environmental problems and the importance of their own actions. Besides, they are more willing to change their behavior or lifestyle if this would improve the environment.

Tables 4, 5, 6, and 7 show the influence of exogenous variables on endogenous variables and that of endogenous variables upon each other. Tables 4 and 5 present the relationships between endogenous variables, i.e. the attitudinal and behavioral variables. According to Table 4, attitude (i.e. positive attitude towards the environment) positively relates to young adults' sustainable travel patterns, including less frequent car use and more frequent use of public transportation and bicycles. In addition, pro-environmental behavior (e.g. energy saving and eco-friendly purchasing) is also positively influenced by attitude.

In terms of the relationships between behavior and attitude, although travel and pro-environmental behavior are not generally found to shape environmental attitude, less car use, more cycling, and more frequent purchasing of recycled products significantly contribute to people's positive attitudes towards the environment. As for the interactions among different travel modes, car use is negatively correlated with taking public transportation and cycling (see Table 5). In contrast, traveling by train is positively correlated with travelling by bus and cycling. Moreover, most pro-environmental behaviors are positively related to each other. Tables 6 and 7 present both the direct and the total influence of the exogenous variables on the endogenous behavioral variables and attitudinal construct in the model.

### 4.1. Relationships Between Socio-Demographics and Behavior/Attitude

Most of the socio-demographic characteristics show significant correlations with travel mode use, pro-environmental behavior, and attitude (see Table 6). For instance, compared to males, young females tend to use cars less, take public transit more often, and be more environmentally friendly in general. They also have a more positive environmental attitude. The number of children aged 5–15 years in a household is positively associated with young

**TABLE 4. Standardized coefficients of the interactions between attitude and travel/pro-environmental behavior (N=792).**

| | Travel Behavior (mode use) | | | | | Pro-Environmental Behavior | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Car | Bus | Train | Cycling | Carpooling | Light | Water | Heating | Recycled | Bag |
| Positive attitude towards environment *(attitude -> behavior)* | -.185** | .229** | .208** | .111** | .094 | .088** | .219* | .420** | .349** | .204* |
| Positive attitude towards environment *(behavior -> attitude)* | -.201** | .048 | .233 | .113** | .047 | .002 | .074 | .318 | .136** | .030 |

**TABLE 5. Standardized correlations among mode use/pro-environmental behaviors (N=792).**

| | **Car** | **Bus** | **Train** | **Cycling** | **Carpooling** | **Light** | **Water** | **Heating** | **Recycled** | **Bag** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Car** | n.a. | -.233** | -.065* | -.141** | .077 | n.m. | n.m. | n.m. | n.m. | n.m. |
| **Bus** | -.233** | n.a. | .219** | .062 | .023* | n.m. | n.m. | n.m. | n.m. | n.m. |
| **Train** | -.065* | .219** | n.a. | .103** | .015 | n.m. | n.m. | n.m. | n.m. | n.m. |
| **Cycling** | -.141** | .062 | .103** | n.a. | .003 | n.m. | n.m. | n.m. | n.m. | n.m. |
| **Carpooling** | .077 | .023* | .015 | .003 | n.a. | n.m. | n.m. | n.m. | n.m. | n.m. |
| **Light** | n.m. | n.m. | n.m. | n.m. | n.m. | n.a. | .219** | .374** | .120** | .023 |
| **Water** | n.m. | n.m. | n.m. | n.m. | n.m. | .219** | n.a. | .159** | .007* | .002 |
| **Heating** | n.m. | n.m. | n.m. | n.m. | n.m. | .374** | .159** | n.a. | .158* | .040 |
| **Recycled** | n.m. | n.m. | n.m. | n.m. | n.m. | .120** | .007* | .158* | n.a. | .142** |
| **Bag** | n.m. | n.m. | n.m. | n.m. | n.m. | .023 | .002 | .040 | .142** | n.a. |

*(Note: n.a. = not applicable; n.m. = not modeled; *significant at the 0.10 level; ** significant at the 0.05 level)*

**TABLE 6. Standardized coefficients of the direct and total influence of socio-demographic variables on endogenous variables (N=792).**

| **Exogenous Variables (*Socio-demographics and their changes*)** | | **Endogenous Variables** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Travel Mode Use** | | | | | **Pro-Environmental Behavior** | | | | | **Positive Attitude Towards Environment** |
| | | **Car** | **Bus** | **Train** | **Cycling** | **Carpooling** | **Light** | **Water** | **Heating** | **Recycled** | **Bag** | |
| ***Socio-demographics*** | | | | | | | | | | | | |
| Female | direct | -.170** | .055** | .037* | – | – | .097* | .226* | .044* | .247** | .402** | .107* |
| | total | -.182** | .057** | .038* | – | – | .111* | .230* | .041 | .261** | .403** | .117** |
| Age | direct | .076** | -.112* | – | – | – | – | – | – | – | – | – |
| | total | .076** | -.120* | – | – | – | – | – | – | – | – | – |
| Kid0_4 | direct | – | – | – | – | -.057* | – | – | -.245* | – | – | – |
| | total | – | – | – | – | -.054 | – | – | -.317* | – | – | – |
| Kid5_15 | direct | – | – | .211* | – | – | – | – | – | – | – | – |
| | total | – | – | .211* | – | – | – | – | – | – | – | – |
| Adults | direct | -.133** | .177** | – | – | .114** | – | – | – | – | – | – |
| | total | -.130** | .181** | – | – | .116** | – | – | – | – | – | – |
| Income | direct | .404** | .102** | .105** | .007 | – | -.008** | -.003 | -.086** | – | – | .012* |
| | total | .452** | .107** | .112** | .016* | – | -.004* | -.008* | -.077** | – | – | .009 |
| Parent_living *(Living with parent)* | direct | -.220** | .178* | – | – | .351** | -.263** | -.070** | -.287** | – | -.015* | -.120** |
| | total | -.267** | .212** | – | – | .368** | -.263** | -.072** | -.335** | – | -.013* | -.107* |
| Employed | direct | .231** | .164* | .160* | .288* | – | -.107* | – | – | – | – | – |
| | total | .243** | .175** | .209* | .287* | – | -.126* | – | – | – | – | – |
| Student | direct | – | .073* | .517** | .216** | .112* | .027 | .010 | – | – | – | .392** |
| | total | – | .098** | .486** | .241** | .128** | .094* | .114* | – | – | – | .513** |
| Highest_qualification | direct | .114** | – | .007* | – | .064** | – | – | – | .037* | – | .227** |
| | total | .117** | – | .003 | – | .065** | – | – | – | .048** | – | .229** |
| Driving_license | direct | .312** | -.201** | -.108* | – | -.164** | – | – | – | – | – | -.028* |
| | total | .312** | -.207** | -.096* | – | -.162** | – | – | – | – | – | -.013 |
| Urban *(Living in urban areas)* | direct | -.155** | – | -.147** | .080** | – | – | – | – | – | – | .114** |
| | total | -.140** | – | -.162** | .095** | – | – | – | – | – | – | .230** |
| ***Changes in socio-demographics*** | | | | | | | | | | | | |
| Change_income | direct | .116** | .079* | .056* | – | – | – | – | -.103** | – | – | – |
| | total | .119** | .104** | .077* | – | – | – | – | -.104** | – | – | – |
| Change_kid0_4 (reference: no_change_kid0_4) | | | | | | | | | | | | |
| Decrease_kid0_4 | direct | – | – | – | .046* | – | – | – | – | – | – | – |
| | total | – | – | – | .027 | – | – | – | – | – | – | – |
| Increase_kid0_4 | direct | .100** | – | – | – | -.039 | – | – | -.098 | – | – | – |
| | total | .093* | – | – | – | -.070* | – | – | -.114* | – | – | – |
| Change_kid5_15 (reference: no_change_kid5_15) | | | | | | | | | | | | |
| Decrease_kid5_15 | direct | – | -.050* | – | – | – | – | – | – | – | – | – |
| | total | – | -.022 | – | – | – | – | – | – | – | – | – |
| Increase_kid5_15 | direct | – | – | – | – | – | – | -.061* | – | – | – | – |
| | total | – | – | – | – | – | – | -.034 | – | – | – | – |

*(Note: dash (–) = no significant direct or total effect detected; *significant at the 0.10 level; ** significant at the 0.05 level)*

**TABLE 7. Standardized coefficients of the direct and total influences of internet-use variables on endogenous variables (N=792).**

| **Exogenous Variables** (***Internet usage and its changes***) | | **Endogenous Variables** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Travel Mode Use** | | | | | **Pro-Environmental Behavior** | | | | | **Positive Attitude Towards Environment** |
| | | **Car** | **Bus** | **Train** | **Cycling** | **Carpooling** | **Light** | **Water** | **Heating** | **Recycled** | **Bag** | |
| ***Internet Usage (reference: Internet_freq1 [never use])*** | | | | | | | | | | | | |
| Internet_freq2 | direct | – | – | .041 | – | – | – | – | – | – | – | – |
| *(Use less than once/month)* | total | – | – | .048* | – | – | – | – | – | – | – | – |
| Internet_freq3 | direct | .097 | .127* | .114* | – | – | – | .011 | .020 | – | – | .130* |
| *(Use at least once/month)* | total | .112* | .129** | .118* | – | – | – | .120* | .135** | – | – | .138* |
| Internet_freq4 | direct | -.261* | .308** | .287** | -.190* | .009 | .068* | .102* | -.033 | -.008 | .011* | .187** |
| *(Use at least once/week)* | total | -.279** | .326** | .323** | -.221** | .013* | .261* | .241** | .189** | .276** | .252** | .232** |
| Internet_freq5 | direct | -.439** | .557** | .406** | -.214** | .047* | .115* | .114** | .112* | .060* | .071 | .350** |
| *(Use every day)* | total | -.462** | .572** | .433** | -.216** | .053** | .423** | .472** | .385** | .377** | .312** | .363** |
| ***Changes in the Internet usage (reference: Persistent)*** | | | | | | | | | | | | |
| New | direct | – | .168** | .113** | – | .101 | – | .023 | -.002 | – | – | .163* |
| | total | – | .180** | .113** | – | .105* | – | .197* | .078* | – | – | .188* |
| Experienced | direct | -.072* | .109** | .110** | .055 | .092* | .042 | – | .054* | .106** | .071* | .304** |
| | total | -.222** | .277** | .264** | .163** | .221* | .173* | – | .152** | .259** | .220** | .375** |
| Past | direct | – | – | – | – | – | -.003 | – | – | – | .008 | – |
| | total | – | – | – | – | – | .009* | – | – | – | -.002* | – |

*(Note: dash (–) = no significant direct or total effect detected; *significant at the 0.10 level; ** significant at the 0.05 level)*

people's train use and those from households with more adults travel by car less frequently but travel by bus and carpool more often. As car ownership per capita in household is negatively related to the number of adults, which is suggested by a further correlation analysis with a coefficient of -0.184, young people from the households with more adults would have lower access to private cars. Higher household income generally brings about more physical travel for young people, both by car and by public transportation, and is negatively correlated to energy saving.

Compared to people living by themselves, those living with their parents tend to travel by car less, but by bus and by carpooling more often. They are also less likely to save energy or to have an environmentally friendly attitude. It seems that their behavior and attitude are greatly influenced by parental involvement in their lives. Both workers and students travel more frequently than unemployed people. While employed people tend to use the car more often, students are more likely to share cars with others. Moreover, students show a more positive attitude towards the environment compared to employed and unemployed individuals.

In terms of the associations between young adults' educational backgrounds and their travel behavior, the higher the educational level they achieve in 2015/17, the more likely they are to travel by car and carpool. Educational attainment is also positively correlated with young people's pro-environmental attitude and their purchase of recycled products. Possession of a driver's license is positively related to frequent car use but is negatively related to the use of other modes of travel. Compared to those living in rural areas, urban dwellers are inclined to use cars and take trains less, but cycle more often. They are also more environmentally friendly in their attitudes.

In addition, changes in some of these characteristics over time are significantly associated with behavioral and attitudinal factors. For example, a change in household income, as measured by comparing the inflation-adjusted 2012/14 and the actual 2004 income values is positively correlated with the use of car and public transit (i.e. bus and train). This implies that the more income increases, the more often young people travel using these modes.

### 4.2. Relationships Between Current Internet Usage and Behavior/Attitude

Table 7 suggests significant correlations between young adults' Internet-use patterns and

their travel mode use, pro-environmental behavior, and attitude. In general, people with high Internet usage tend to travel by car and by bike less frequently and take public transportation more often. The negative correlation between Internet use and car use and cycling is only significantly identified for medium-to-heavy Internet users. Frequent Internet users may have more access to (and greater reliance on) technology-enabled transportation services in public transportation systems, such as real-time bus information and on-board Wi-Fi. Therefore, they are more likely to choose bus and train as travel modes. Additionally, heavy Internet users tend to share vehicles with others more often compared to light users. Greater access to smart technologies like car-sharing apps could explain this.

High Internet usage is also positively related to both environmentally friendly behavior and a positive attitude towards the environment. Notably, in the relationship between Internet use and pro-environmental behavior, the indirect influences of Internet usage, which are channeled through the attitude construct, account for most of the total influence. In other words, use of the Internet relates to young adults' pro-environmental behavior primarily via their environmental attitude. As suggested by the literature (e.g. Allen et al., 2013; Good, 2006; Nistor, 2010), the Internet may play an important role in the formation of people's environmental awareness and attitudes, especially among young people who rely heavily on ICT in their daily lives. It is therefore possible that use of the Internet has indirect associations with users' environmental behaviors through the attitude–behavior link.

### 4.3. Relationships Between Changes in Internet Usage and Behavior/Attitude

Table 7 further reveals that young adults' travel and pro-environmental behavior and their positive attitude towards the environment are also related to changes in their Internet use over time. Compared with the persistent light users, who have never used the Internet daily, new heavy users (i.e. those who recently started to use the Internet every day) tend to take public transportation and carpool more often. As mentioned before, such results could be ascribed to access to technologies.

The same Internet-travel interaction can also be found for experienced heavy users (i.e. those who have been using the Internet daily since they were teenagers) and they tend to have more sustainable travel patterns as they use cars less and cycle more often. As for the past heavy users who decreased the degree to which they use the Internet (i.e. dropped the habit of using

the Internet daily), no significant distinction is detected between their travel behavior and that of persistent light users as they both have low access to technologies in their current lives.

Attention therefore needs to be paid to experienced heavy users and the distinction between new and experienced heavy users, although changes in other factors (e.g. residential locations, lifestyles, education) over time might also correlate with their travel behavior (e.g. De Paepe et al., 2018; De Vos et al., 2012; Handy et al., 2004). Similar to the relationship between Internet use and pro-environmental behavior, the overall associations between sustained daily Internet usage and young adults' travel patterns are largely explained by their indirect correlations mediated by a positive attitude towards the environment. This result is underpinned by the fact that such habit-keeping has a positive correlation with the environmental attitude construct, which is more significant with a larger regression coefficient compared to the correlation between starting the habit of heavy use and a positive attitude towards the environment.

Although the travel behavior for both heavy user groups is associated with Internet use, the mechanisms of the interactions differ. While Internet use has associations with new heavy users' traveling by public transportation and by carpooling, such Internet-travel relationships tend to be stronger and significantly mediated by environmental attitude for experienced heavy users. Different from new heavy users, experienced heavy users have been exposed to the Internet since adolescence or late childhood. The long-term exposure to the Internet starting from an early age not only directly correlates with their behavior patterns but, more importantly, shapes their attitude towards the environment. As a result, attitude indirectly but significantly contributes to the Internet-travel interactions. This indirect association via environmental attitude also significantly accounts for the relationship between consistent heavy use of the Internet and pro-environmental behavior. The result shows that experienced heavy users generally have more sustainable lifestyles in terms of energy consuming and shopping compared with other user groups.

## 5. SUMMARY AND CONCLUSIONS

This study empirically examines both the direct and indirect associations between young adults' Internet usage over time, their travel mode use, pro-environmental attitude and sustainable behavior. The focus is on the intermediary role that attitudes play on the

relationship between travel and the Internet, and how young people's use of the Internet and changes in use over time are related to their travel and pro-environmental behavior. We use data from the British Household Panel Survey (BHPS) and the Understanding Society survey, which are uniquely suited for this purpose, as these datasets record individuals' behavior, attitudes, and lifestyles at different ages.

By merging the data from both the surveys, we created a comprehensive dataset containing information about young people during both adolescence and adulthood. Aside from the multiple socio-demographic, attitudinal, and behavioral variables considered, a set of "experience" variables were created to represent changes in the use of the Internet over time. By investigating the associations between the use of the Internet and the use of different travel modes, this study aims to enrich the empirical literature on ICT-travel relationships and young people's travel behavior.

We used structural equation modeling (SEM) to explore the complex relationships among the variables considered. A latent variable representing a positive attitude towards the environment was constructed first, based on six observed attitudinal variables in the dataset. This construct was found to positively correlate with young adults' sustainable travel patterns, including less frequent car use and more frequent use of public transportation and cycling, and a greater degree of pro-environmental behavior (energy saving and eco-friendly purchasing). Although positive attitude towards the environment was not generally shaped by choice of travel mode and travel behavior, it was significantly associated with Internet usage. The use of the Internet (as measured by frequency of accessing the Internet) was found to be positively related to the environmental attitude construct and more importantly, such attitude acted as a mediator in the correlation between Internet use and pro-environmental behavior, thereby indirectly but significantly framing the Internet-behavior relationship.

In addition, the study differentiates between the travel outcomes of young adults who are heavy users of the Internet (defined as those who used the Internet on a daily basis) from those who do not use the Internet heavily. We find that the frequency with which the Internet was used by young adults is positively related to their sustainable travel behavior. Young people who used the Internet heavily over time in a sustained manner resulted in having a long-term and intensive exposure to the Internet, which may have played an important role in the formation of their environmental attitudes and awareness. Such attitude significantly

influences their travel patterns, which makes their travel behavior distinct from that of other young adults, who did not consistently use the Internet heavily over time.

We also considered those who recently started using the Internet daily. We call this group as new heavy users. Although new heavy users are inclined to use bus, train, and car-sharing modes frequently, such Internet-travel interactions tend to be immediate and direct as they are not additionally mediated by the travelers' positive attitude towards the environment. For experienced heavy users, however, their long-term exposure to the Internet results in an even stronger interaction between ICT and travel, which is greatly mediated and supported by their pro-environmental attitude. As a result, they have more sustainable travel patterns with even lower levels of car use and more cycling.

As conceptualized by Salomon (1986) and Mokhtarian (1990), the ICT-travel interactions for the new heavy users are likely to be "first-order" interactions that only involve the direct influence of either element on each other, whereas for the experienced heavy users, such interactions are "higher-order" ones, which usually take place at a more profound level through attitudes and perceptions, location choices and urban form, lifestyles, and other factors and over a long period (e.g. Audirac, 2005; Hjorthol, 2008; Sivak & Schoettle, 2012). Overall, the findings suggest that the duration of Internet use over the lifetime of young adults has a discernable effect on the degree of differences in the use of sustainable modes of transportation.

The paper has several limitations. First, the variables measuring the use of the Internet measure the frequency of accessing the Internet. The different purposes, contents or forms of usage are not specified. The relationship between degree and duration of Internet use, travel behavior, and attitudes could be drawn out more richly, if information on the specific use of the Internet and the types of online content that adolescents and young adults access could be introduced into the study. Second, environmental attitudes and behavior as used in the model are self-reported by respondents, potentially leading to an overestimation of the correlations between actual attitudes and behavior. This may occur if respondents self-report responses that are more socially desirable, thereby overestimating pro-environmental tendency. Future data collection practices may need to pay greater attention to these issues. Finally, although Internet-use patterns and changes in these patterns over time are important personal choices, especially for young people, there may be other personal or life stage factors (e.g. lifestyles, residential relocation, transition to higher education) that are correlated with individuals'

travel behavior or attitudes. Improvements therefore could be made in the future by additionally including such factors in model, so as to examine Internet-travel relationships more accurately.

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