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Determinants of Pro-Environmental Activity-Travel Behavior Using GPS-Based Application and SEM Approach

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Abstract

Technological advancement in automobile and infrastructure sector encourages more and longer distance travel and the way people travel to perform their daily tasks creates environmental problems. Activity-travel behavior of individual have a significant potential to be influenced to reduce environmental issues, however, the underlying factors need to be investigated. This paper investigates pro-environmental activity-travel behavior using recorded GPS-based travel-activity diaries and individual personal traits using online questionnaire and estimating a structure equation model borrowed from theory of planned behavior. The results of the study verified that individual mobility decisions were highly influenced by the attitude one has about specific travel behavior. The results are helpful in devising effective behavioral intervention.

Keywords: Activity-travel; GPS-based application; Personal traits; Structural Equation Model; Theory of planned behavior

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1. Introduction

In developed countries, the technological advancement in automobile and infrastructure sector encourages more and longer distance travel and the way people travel to perform their daily tasks creates environmental problems [1]. Transport sector contributed 23 percent of the total CO_2 emissions which is the 2nd highest in Europe in 2015. Further it has increased its contribution significantly since 1990 [2]. This highlights the importance of encouraging sustainable and environmentally friendly transportation in urban settings. Along with other measures, it is important to investigate activity-travel behavior of individuals and develop understanding on the determinants of pro-environmental elements within this behavior.

Activity-travel behavior of an individual can be found by tracking the travel choices one makes to perform any activity and the environmental impact of personal travel is assessed in terms of the number of out-of-home trips, distance traveled, and the mode choice, such as walking, cycling, car and public transport usage [3]. A more pro-environmental activity travel behavior is for example traveling shorter distances to a perform a particular activity by using public transport, cycling/walking instead of taking the car. It is important to investigate what are the underlying factors that influence individual to have pro-environmental and sustainable travel behavior. Therefore, The overall aim of this study was to investigate determinants that have possible positive and negative effects on the pro-environmental activity travel behavior in an urban setting. Different approaches have used such as recorded GPS data and prompted recall web survey to identify mobility pattern, online questionnaire and use of structural equation modelling (SEM) approach to get the intended objectives.

The rest of the paper is organized in the following way. In section 2 we give a brief overview of the theory of planned Behavior and discuss its extension in the context of pro-environmental activity travel behavior. Section 3 describes in detail participant selection, adopted methods and data collection. The functionality and implementation of variance-based structural equation models (PLS-SEMs) are explained in section 4. The results of statistical analysis based on PLS- SEM approach is presented, and further interpretation of estimated path model is described in section 5. This paper ends with a discussion on results, along with their application in designing the effective behavioral intervention studies.

2. Theory of Planned Behavior

The theory of planned behavior (TPB) proposes a generic socio-cognitive model of behavior which can measure how human actions are guided [4]. It has been applied successfully to explain various human behaviors related to Health, sustainable transport, recycling, traffic safety and green environment [5]. Three main determinants of TPB are subjective norms, attitude and perceived behavioral control which predict behavioral intention, which is the immediate precursor of behavior itself. Intentions are assumed to capture the motivational factors that influence a behavior; they are indications of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behavior. It can be hypothesized that the stronger the intention one have in performing a behavior, the more chance it is that the individual will behave in that specific way [6, 7, 8]. Based on TPB, authors assumed that pro-environmental travel behavior (PEATB) is influenced by attitude. The second predictor is a social factor (i.e. subjective norm); it refers individual's perceived social pressure whether he or she should or should not perform particular behavior. If somebody is encouraged by peers, friends and family to adopt environmental friendly mode of transport then it's more likely to behave in a sustainable way by him. The third factor influencing intention is the degree of perceived behavioral control (PBC) which is the perceived ease or difficulty of performing the eco-friendly travel behavior. It is assumed in the model that PBC has not only the indirect link via intentions but also have a direct link to behavior.

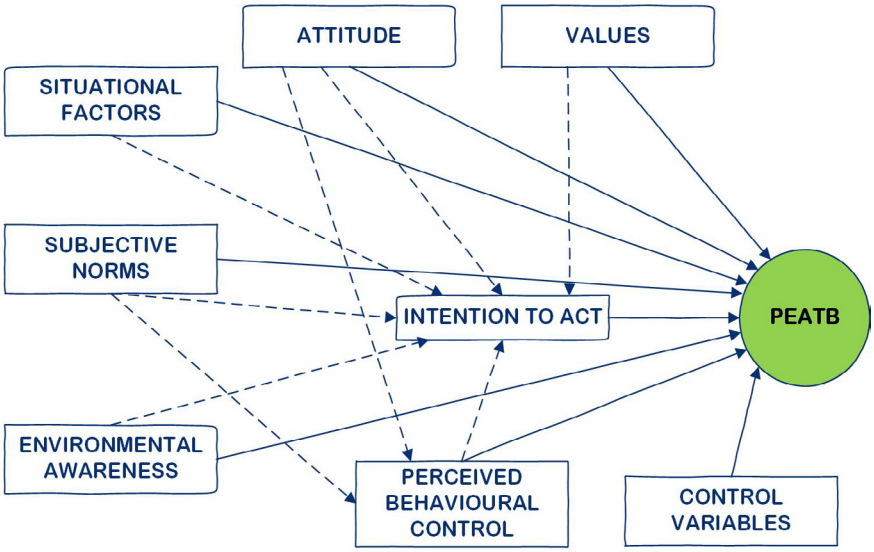

Fig. 1. Hypothetical Model to investigate determinants of PEATB

It has been found from previous studies that some intentions and behaviors related to mobility are influenced by domain specific factors that are not present in the TPB model [9,10, 11]. In a mobility and environment related context three constructs i.e. values, environmental awareness and situational conditions have been identified that might have a significant influence on the pro-environmental travel behavior. To check the effect of socio-economic aspect on the PEATB, income is selected as a control variable and included in the hypothetical TPB model as shown in Fig. 1. Higher income urges one to go for more expensive travel mode choice i.e. individual motorized vehicle that results in less sustainable mobility behavior. The impact of income on the sustainable travel behavior is considered direct in the hypothetical TPB model.

3. Methodology

The methodology is developed with the aim to investigate key determinants of pro-environmental activity-travel behavior that is prevalent among citizens. Based on past studies conducted on similar lines, different aspects related to cognitive, environmental, socio demographic and contextual were incorporated in extended TPB model. Multiple methods that are supplementing each other were applied to measure these constructs accurately. Initially an online questionnaire is designed to get information based on socio-demographic and socio-cognitive factors. PEATB is recorded by tracking individual daily activity travel patterns using GPS-based android application coupled with prompted recall web survey. Details of this methodological approach is presented below in section 3.2 and 3.3.

3.1. Study Area and Sample Characteristics

The study was conducted in Hasselt Arrondissement from June to July 2018. Hasselt is one of the urbanized Arrondissement in Limburg province with an area of 906.15 square km and population of about 0.45 million. It has an average density of about 460 people/sq. Km. The non-probability sample consisted of *55 participants* ranging in the age from 25 to 69 years (Mean = 41, SD =14) who completed the study successfully. 65 % male and 35 % female took part in the survey. The inclusion criterion was the minimum of 18 years of age i.e. eligibility criterion for driving license in Belgium. So subjects having driving license were 78 %. Majority of participants have education status equivalent to bachelor's degree or above (i.e.87%), however, income distribution seemed more uniform. Around 65%

of citizens have ownership of 1 or more cars, but at the same time it is also noted that considerable citizens (i.e. 91%) have bicycle ownership. Formal approval was taken from the Social Societal Ethics Committee (SSEC) of Hasselt University before the commencement of the study. Further, online informed consent was obtained from each participant prior to the studies.

3.2. Online Questionnaire

The information regarding socioeconomic attributes and various personal traits such as attitude, values, perception and environmental awareness associated with travel behaviors is collected through a survey questionnaire. The survey questionnaire is designed by using "Qualtrics" in Dutch and English versions. The survey is distributed by sending an anonymous link to participants via email. As target population is the citizens of Hasselt Arrondissement, so Questionnaire is designed keeping in mind the problems related to environment and mobility in the locality. The web-based survey questionnaire consists of four major sections. In the first section respondents, socio-economic, personal and transport related information is gathered. Questions related to environmental awareness, perceived behavior control, subjective norms and transport facilities are asked in the second section. In the third section, questions are designed based on human values. Respondents attitudes towards Pro-environmental behavior is recorded in the fourth section. The information gathered from the questionnaire is used to predict different independent variables that have some association with the PEATB.

3.3. SPARROWS – GPS based smartphone application

Global Positioning System (GPS) is a promising technology to detect the individual mobility patterns accurately with respect to time and space. Recording individual travel behavior using GPS sensors is becoming easier with time [9, 12] but there are still some practical problems such as cost, participant burden, battery life, memory limitations associated with GPS data collection. In order to overcome these limitations to some extent, GPS based smartphone application SPARROWS has been developed by Transportation Research Institute (IMOB). It can easily be installed in the smartphone that has Android mobile operating system 3 or later and is available free on the Google Play Store. Recorded GPS traces give a description of movements, through series of spatial locations that are collected after every 3 seconds, leading to a detailed spatiotemporal representation of movement. GPS data were stored locally in small and encrypted files on the participant's smartphone. SPARROWS uploaded the data recorded in the smartphone once in 12-h to our server. Upon availability of internet connection SPARROWS uploads data more frequently.

3.4. Prompted Recall Web Survey

Based on the prompted recall concept, web survey was designed based on the individual trip and stops generated by algorithm using recorded individual GPS traces by SPARROWS. Prompted recall survey has been conducted in the past to get the information from GPS recordings. In Prompted Recall survey, respondent is asked to annotate the recorded trips and stops by showing them on the map. The map that shows the recorded travel patterns act as a memory prompt to the respondent thus allows the individual to respond to the asked questions without any difficulty [12]. Based on the concept of Prompted Recall survey explained above, a web-based application has been designed that has a potential to get the information from the participants necessary for our study. In prompted recall application, an individual can see his stops ad trips on a map with the timestamps by logging into his account as shown in Fig. 2. For each selected stop, individual will have to answer two main Questions (i.e. about activity purpose and travel mode).

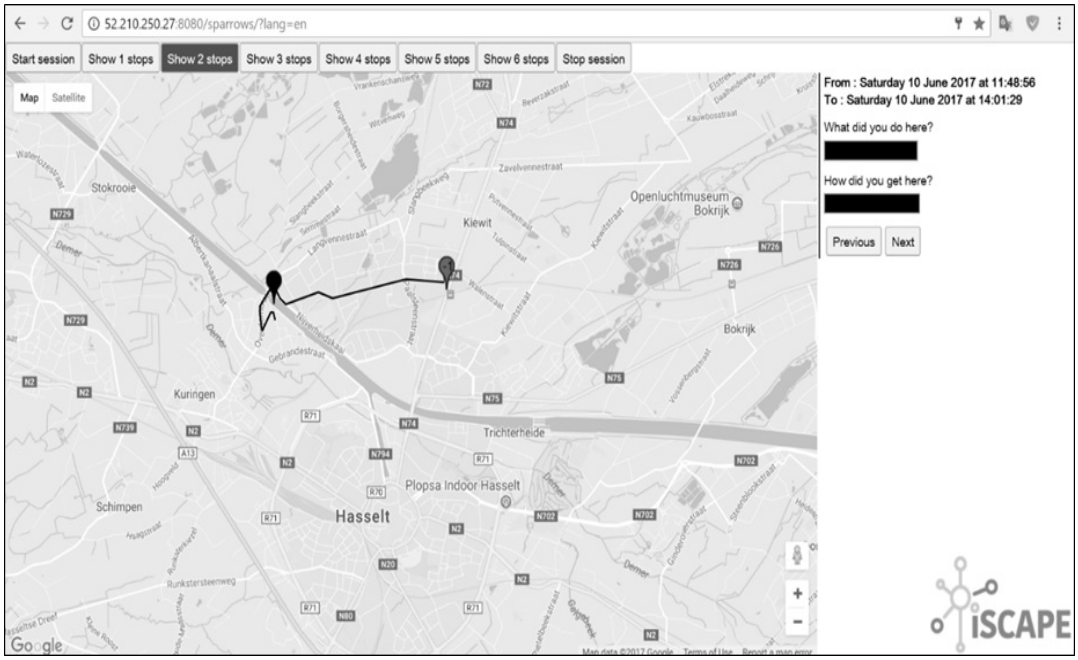

Fig. 2. User interface of our Prompted Recall application

3.5. Implementation Process

The first phase in the study was to recruit citizens of Hasselt. A news was floated via print, electronic and social media in start of May 2018 regarding the study with the message that interested citizen can contact directly to get more practical knowledge of the study. The whole methodology of the study is designed in such a way that it can be remotely managed, without the requirement of physical contact, therefore it is necessary that citizens who are participating in the study are an active user of the smartphone and have sufficient knowledge of e-mail based communication. The participants are provided with detail information and schedule of various activities of the study. At the same time, each participant has obtained a consent form. The recruitment of the citizens is confirmed when the consent form was returned by the individual. In total, 55 citizens were recruited for this study. The detail information regarding each step was provided to each participant when that particular activity was about to start. Each participant was treated individually, and at every activity start and also during that activity, help using telephonic and e-mail communication medium was provided, if the citizen has requested. A complete set of instructions regarding each step is also sent via e-mail to each participant.

Data collection period was started in the month of June 2018. First of all, socio-demographic attributes and other traits as mentioned in hypothetical model was recorded by sending a link of online web based questionnaire to each participant via email and asked to give your responses with in prescribed time period. The most distinctive method adopted in this study was the evaluation of pro-environmental activity travel behavior. Studies mainly consider self-reported behavioral action from the respondents, however, in our methodology this is an output from the GPS-based activity-travel routine, that is more appropriate and consistent approach. For this purpose, participants were asked to install GPS based application in their smartphones. Trial period was given to the participants in which they learnt how to run SPARROWS and to upload the data successfully. Individual GPS-based travel patterns were recorded for the period of one week. A set of stop and trip detection algorithm was applied to these individual recorded GPS traces to detect trips and stops with associated time stamp, speed and location.

The information collected was not sufficient for determination of the pro-environmental activity travel behavior. In order to get more insights about individual travel behavior, Prompted recall survey was used. Prompted recall survey is web based survey in which individual trips are uploaded in a chronological order and displayed on google maps. In this study mobility patterns were presented to each participant in a password protective way. Different questions were asked related to mode used, trip purpose etc. in a prompted recall survey which were important in assessing individual travel behavior.

4. Structural Equation Modelling

To examine the effect of different latent constructs on PEATB as mentioned in the extended TPB model, structural equation modelling (SEM) technique has been selected. SEM has been implemented successfully in various travel behavior studies [4,5]. This modelling technique greatly help researchers to understand the relation and effect of latent variables on each other by analyzing several direct and in-direct paths in a single statistical model. These paths are depicted in extended TPB model as shown in Fig. 1. A variance based approach i.e. PLS (partial least square) SEM was selected as it can be applied to small sample size. PLS-SEM was conducted using smartPLS version 3. PLS algorithm was run on conceptual model for simulating the effects of various latent variables on PEATB. The explanatory power and the significance of individual path in the model was determined by assessing structural relations. Structural relationship model is well explained from calculated squared multiple correlations (R2) and path co-efficient (β) of each path. Finally, Global validity and explaining power of the model was evaluated to explain Goodness of fit (GoF) index. All latent variables except PEATB were predicted via online Questionnaire. The respondents were asked to agree/disagree with five statements. The responses were judged on the scale from 1= strongly disagree to 5 = strongly disagree.

Internal factors were explained by subjective norms, environmental awareness, intention to act, perceived behavior control, human values and attitude toward PEATB. Subjective norms measure the expectation of others to behave pro-environmentally in relation to activity-travel behavior. Three statements were provided with the scale from 1 being strongly disagree to 5 strongly agree. Environmental awareness gives the indication of how much someone has knowledge about air quality, pollutant concentration levels, causes of pollution etc. the respondents were asked to indicate whether they agree or disagree with 8 statements on the same scale as used for subjective norms. Intention to act and perceived behavior control were based on TPB are measured with a scale ranging from 1 = strongly disagree to 5 = strongly agree. Values were measured by scale -1 = Opposed to my values, 0 = not important, 1 = Important, 2 = Very Important and 3 = Supremely Important. Attitude indicates the level one act in a positive or negative way in relation to pro-environment activity-travel behavior was measured by 9 different statements on the scale 1 = Yes always, 2 = Yes, 3 = Very seldom, 4 = No and 5 = I don't know.

The variable PEATB was predicted based on the recorded activity patterns (one week) using GPS based smart phone application. This is the distinction in our study the way we recorded individual behavior. All the items explaining PEATB construct were obtained from the daily travel activity patterns and therefore mapped the behavior in most realistic way. The following are used as indicators of PEATB construct.

- From the travel mode information for each trip for an entire week, car dependency is determined using a percentage of distance travelled by car. The percentage from 0-100 is then divided into 5 equidistant categories, representing very low to very high car dependency. Based on the measured percentage of car dependency, an individual is assigned a particular category.
- Similar to Car dependency measure, this indicator is determined using a percentage of distance travelled by public transport (bus, train or tram, etc.) and then a measured percentage is assigned to a particular equidistant category.

- This indicator is incorporated to give weightage to individual involvement in physical activity within PEATB. Active travel modes (walking and cycling), are usually used for the short distant trip (5 km or lesser), therefore it is measured as a percentage of distance travelled using active travel modes in comparison to other modes only for short distance trips. The measured percentage is assigned to a particular equidistant category.

5. Results and Discussion

PLS simulation of the conceptual model to assess PEATB is based on estimating various parameters in a two step process. In step one, i.e. evaluation of measurement model is done by investigating the reliability and consistency of the latent variables involved. Discriminant validity and composite reliability factors indicate the quality of the model. In step two, testing of the structural model is conducted by estimating the path coefficients and R2 values of the endogenous constructs. We presented the results below based on the outcomes of 2 step process. In the end overall fitness of the model is discussed.

In order to check the reliability and validity of constructs within the model, evaluation of measurement model has been done. For this purpose, Composite reliability scores (CR) and Average variance extracted (AVE) of the latent variables has been determined. Composite reliability is calculated by using the factor loadings extracted from the model. For composite reliability suggest 0.7 as a threshold value. All the constructs were greater than the threshold value as mentioned in Table 1. Average variance extracted (AVE) is used to measure internal consistency of the construct by calculating the amount of variance that latent variable captures from its measurement items relative to the amount of variance due to measurement errors. Literature findings stated that AVE should be higher than 0.5. AVE score of all the constructs are greater than 0.5 as shown in Table 1.This means that at least 50% of measurement variance is captured by the latent variables. In order to evaluate the Goodness of Fit for PLS-SEM models, recommended to calculate the standardized root mean square residual (SRMR). SRMR values close to or less than 0.10 was mentioned as a good fit [13]. The SRMR (of the composite factor model) in our model was 0.12, thus showing a good model fit.

Table 1: Construct reliability and validity scores

Variable	CR	AVE
Attitude	0.88	0.66
Subjective Norms	1.00	1.00
Values	0.77	0.52
PBC	1.00	1.00
Env. Awareness	0.84	0.56
Situational Factors	0.87	0.68
Intention	1.00	1.00
PEATB	0.75	0.51

The estimated structural model indicating path coefficients with explained variances in the model are presented in Fig. 3.

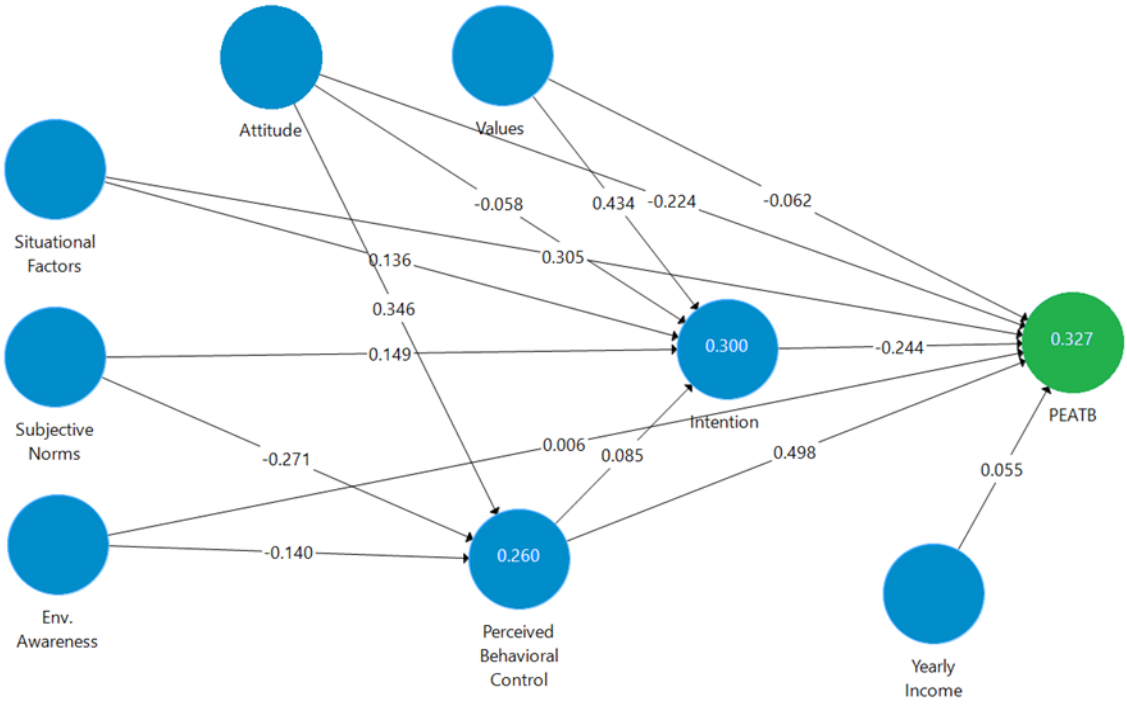

Fig. 3. Estimation of Structural Model showing Factors loadings and Path coefficients

Values (β = 0.43), subjective norms (β = 0.15) and situational factors (β = 0.13) have influenced an individual's intention to behave in a pro-environmental way. Model demonstrated that values strongly and significantly influenced one's intention to practice more PEATB. This shows the more a person conscious about the environment, the more he will intend to use the public and active mode of transportation. Perceived behavior control (β = 0.50), Situational factors (β = 0.31), Intention to perform a PEATB (β = - 0.25) are all found to have considerable influence on PEATB. It was determined from estimation that Perceived Behavior Control (PBC) have a significant and strongest effect on PEATB. It can be concluded that the more one perceives to act in pro-environmentally easy the more he will behave in a pro-environmental way. In summary we can say that the path that starts from attitude and ends on PEATB via PBC has strongest and significant effect on pro environmental activity travel behavior of an individual. Ajzen [7] in TPB states more favorable the attitude with respect to a behavior, and the greater the perceived behavioral control, the stronger should be an individual's intention to perform the behavior under consideration. This study further supports this statement. 26 percent of the variance was explained by PBC in our model which further increased to 30 and 33 percent by Intention and PEATB. Hence developed model has substantial explanatory power regarding all three endogenous constructs. In contrary to various studies conducted in the past, our structural model could not justify the relationship between intention to act and actual performance of sustainable travel. The reason behind the lack of relationship between intention and behavior has been described by Ghasemzadeh et al suggesting that in routine or habitual behaviors, behavior or performance is not likely related to a rational statement of intentions that further studies are needed to investigate how habitual or routine behaviors are affected by social norms or individual beliefs in the communities [13]. The travel behavior of the community greatly depend on the situational factors as well. One approach to reduce car use and encourage sustainable travelling is by improving the infrastructure and services related to the active and public modes of transport. Higher availability of PT or fully/partially dedicated lanes for non-motorized vehicular traffic leads to reduce obstacles in the way of sustainable mobility.

6. Conclusion

The results of the study verified that individual mobility decisions were highly influenced by the attitude one has about specific travel behavior. People having positive belief in preserving their surroundings and having more preference to travel by using public and active transport were perceived to be more easy for them to improve their mobility patterns in a pro-environmental way. This perceived easiness encouraged them to actually travel in a sustainable and pro-environmental way. These results are helpful in developing an effective behavioral intervention study.

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