iSCAPE

Environmental Effects of Behavioural Actions

D4.1

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Short Description	*The report presented a comprehensive methodological framework for WP 4, and based on that identified the data requirements that can be combined with activities planned for task 4.1. Task 4.1 is re-oriented in the shape of informational-based behavioural intervention for the Hasselt Living Lab, to provide meaningful utilization of the GPS-based activity-travel routine and its analysis. Several survey instruments and tools are developed to facilitate the required data. Sparrows Mobile application, Web-based surveys, material for informational intervention and Stated choice experiments are developed. Design of the intervention is primarily based on analysis of activity-travel data of individuals in four different dimension such as 1) Exposure analysis, 2)*

	GHG emissions, 3) Involvement in the physical activity and 4) Hot and cold starts of car engines. Rule-based algorithms are developed not only to estimate individual's own contribution in these four dimensions but at the same time they are providing information about what could be possibly changed in the activity-travel routine to minimize the negative impacts of these four dimensions. Citizens of Hasselt are recruited with the help of Stad Hasselt support and by disseminating the study news in various forums. 40% of study participants have shown commitment to change their behaviour.		
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DoW	Description of work
PBC	Perceived behavioural control
PEATB	Pro-Environmental Activity Travel Behaviour
PT	Public Transport
TPB	Theory of Planned Behaviour
SP	Stated Preference
VKT	Vehicle Kilometres Travelled

1 Executive Summary

This deliverable presents the coherent methodological framework for achieving the objectives of WP 4 of iSCAPE project. The methodological framework outlined in the deliverable comprise to address three major aspects which are as follows:

1) Key determinants of behavior especially pro-environmental activity-travel behavior that is prevalent among citizens.
2) Effect of information that encourages pro-environmental activity-travel behavior and its evaluation
3) Upgradation of the policy models for capturing both-ways effect of policies (i.e. effect on environment and effect on behavioral actions in a coherent manner).

The above-mentioned aspects are able to address several tasks outlined in WP 4 (i.e. 4.1 and 4.2, 4.3 and 4.4.) but at the same time supports the Living Lab framework and its aligning activities for Hasselt city as part of WP 2. To work along these aspects, data requirements and survey tools and instruments are developed within the scope of this deliverable (more details on this can be seen in section 5 of this deliverable). These are; a web-based questionnaire asking details of socio-demographics characteristics and individual perception, attitude and subjective norms in relation to pro-environment travel behaviour (i.e. lesser use of cars and more use of active travel modes), android-based smart phone application along with prompted-recall tool for collecting data regarding individual activity-travel routine and hypothetical scenario-based questionnaire to investigate effect of air quality information on travel mode choices. Based on these survey instruments, an informational based behavioral intervention is designed. The design of this intervention is primarily based on analysis of activity-travel data of individuals in four different dimension such as 1) Exposure analysis, 2) GHG emissions, 3) Involvement in the physical activity and 4) Hot and cold starts of car engines. Rule-based algorithms are developed not only to estimate individual's own contribution in these four dimensions but at the same time they are providing information about what could be possibly changed in the activity-travel routine to minimize the negative impacts of these four dimensions. In this regard, focus was more towards changing only those aspects of travel behaviour which are relatively easier e.g. short trips through active travel mode, use of public transport when it is easily available and also reasonable in terms of travel time, chaining of flexible and non-mandatory activities in a main tour to reduce number of trips and cold starts. Results of this analysis were disseminated as a customized information pack, that describes the impact of activity-travel behaviour of an individual and also provide information in relation to small changes in his/her behaviour along with quantification of its impact (more details on this can be seen in section 4 of this deliverable).

The behavioural intervention study was conducted for the citizens of Hasselt in the same methodological framework. Citizens are recruited with the help of Stad Hasselt support and by disseminating the study news in various forums. Study starts with 53 citizens; however, some participants were dropped in between. Results of the information based behavioural intervention indicated that around 40% of individuals have shown commitment to change their behaviour. Other citizens have indicated the increase in their awareness of their activity travel routine and its impact on environment. Additionally, statistical analysis of control and treatment group activity-travel behaviour from data collected before and after the intervention suggest that there is significant reduction in car use for short trips, which in turn causes significant increase in use of active travel modes (more details on this can be seen in section 6 of this deliverable).

2 Introduction

This section defines the background and contextual information under which task 4.1 is perceived within the objective of WP 4. Further, based on this information and illustrations that are given in the DoW for task 4.1, focus and scope of the work is defined for the deliverable 4.1. This is required to make working methodology more consistent and coherent to achieve the objectives of WP 4.

Given the overall objectives of WP 4 (page 37 of the DoW), within which an activity-based travel behaviour model will be utilized to forecast the road emissions. Furthermore, coupling this information with atmospheric dispersion model to ascertain population exposure and consequent health impacts under different policy scenarios.

The specific models within an activity-based microsimulation framework depict individual behavioural decisions towards different travel choices e.g. travel mode, activity destination choices and overall daily activity pattern (such as participation in which type of activities in a day) given certain information such as road network performance indicators. Usually, network performance indicators are represented using time-dependent travel time (in-vehicle travel time, waiting times, access and egress times) and travel cost (tolls, fares and any other taxes such as congestion pricing). During the task 1.3 of WP 1 (literature review on behavioural intervention), it has been found that at present these models are not able to depict travel behavioural decision considering changes in air quality conditions. This means that effect of travel decisions on the environment can be simulated, however, the effect of changed conditions of air quality cannot be simulated on travel behaviour. In other words, a feedback loop does not exist, therefore, the effect of policies and environmental regulations on travel behaviour cannot be captured. Nowadays, information in relation to air quality is readily available to individuals, such as availability of air quality information through several dedicated websites and also from the advent of portable pollution sensing devices which can be easily coupled with smartphones. This information may cause a significant effect on individual activity-travel behaviour. *Therefore, these policy models required to be upgraded in these aspects to capture environment effects of behavioural actions in a feedback loop mechanism to obtain a more appropriate assessment of policies* (task 4.2 and 4.3).

In addition to the above line of thoughts, the description of task 4.1 in the DoW suggested that a methodological framework needs to formulated, through which a GPS trajectories data from the citizens of each iSCAPE city are to be analysed. The analysis needs to be done in the context of finding the potential impact of current behavioural actions on the environment and also, what can be possibly changed in the behaviour to improve air quality. Apparently, this analysis seems disjointed with the overall objectives of WP 4. Therefore, within this deliverable, we present a comprehensive methodological framework that not only fulfill the commitments made in task 4.1 but also supports the future tasks within WP 4. Additionally, given the time frame of task 4.1 (i.e. 6 months), it is not possible to carry out all tasks within which a methodological framework need to be designed along with collecting such a sensitive personal data (trajectories) from all iSCAPE cities and then perform its analysis. *Therefore, we focus on the more important aspects e.g. 1) development of a comprehensive methodological framework comprising objective of WP 4, 2) development of the necessary tools and survey instruments for employing that methodology, , and 3) finally implementation of the methodology in at least one iSCAPE city to illustrate the advantages and effectiveness of the methodological framework.* Additionally, we propose a plan to carry out similar implementation in other iSCAPE cities, which will help generate significant data to improve the analysis and also upgradation of the policy model required for tasks 4.2 and 4.3.

2.1 Defining task in relation with WP 4 objectives

2.1.1 Methodological Framework

To develop a comprehensive methodological framework considering key objectives of WP4, we have taken into account the possible and effective engagement of citizens, as they are the main source of generating the required behavioural data. Some key guidelines based on deliverable 1.3 are also considered. Furthermore, we set the following key aspects, that should be fulfilled through the methodology.

1) Key determinants of behavior especially pro-environmental activity-travel behavior that is prevalent among citizens.
2) Effect of information that encourages pro-environmental activity-travel behavior and its evaluation
3) Upgradation of the policy models for capturing both-ways effect of policies (i.e. effect on environment and effect on behavioral actions in a coherent manner).

These aspects are comprehensive in a manner that they necessitate the incorporation of all major propositions mentioned in the DoW in defining task 4.1, 4.2, 4.3 and 4.4. Further at the same time due to the involvement of citizens, it makes the framework generalized so that it can be incorporated in all iSCAPE cities with limited adjustments. The details of the methodological framework are provided in section 4.

2.1.2 Data Requirements

There are several data requirements for such a comprehensive framework, these are vital and need to be collected with a proper design of survey tools and instruments. Few data items are directly concerning to the citizens and therefore required to be collected at once, as engaging citizens for each data item separately is time-consuming and also costly in terms of financial resources.

As illustrated in the proposal, for task 4.1 data required from the citizens of all iSCAPE cities are basically their GPS based trajectories. However, in accomplishing task 4.2 and 4.3, it is required to have individuals' preference data (their decisions in relation to travel behaviour choices) given air quality information. Additionally, the literature review carried out in D 3.1 show a strong correlation between individual's attitudes/values and perception with pro-environmental behaviour, therefore, for the effective design of behavioural intervention as part of the requirement for living lab in Hasselt such data need to be gathered from citizens. Since collection of the data from citizens of all iSCAPE cities is a very cumbersome task to manage even once, it is therefore, not feasible to organize this on a task basis. *This is also one of the major reasons to make a more coherent approach in terms of methodology, and therefore all the required data can be collected in one go.* The required data from the citizens are as follows:

1) Individual's socio-economic attributes, their attitudes/values, awareness and perceptions
2) Individual's activity-travel habits in detail
3) Reaction to information, both revealed and stated preference

Additional data, such as air quality condition (in the form of air pollutant concentration maps), transport network (generally available via open street maps) and details of policies that may be implemented in future and required to be tested.

2.1.3 Development of survey tools and instruments

This is also a vital aspect of the WP 4. Collection of activity-travel habits in detail entails that complete activity-travel diary is required. Furthermore, locations of the individuals in different times should be as precise as possible, which is required for appropriate exposure analysis. Along with that to ascertain reaction to information, it is required to have this activity-travel diary for at least a week for properly analyze the effects. It is therefore decided to capture the activity-travel diary before and after the provision of information. In relation to this, the following are developed as a tool and instruments to obtain the required information from the citizens.

1) Tracking individual through the mobile application and further asking individuals to annotate data regarding activity purposes, travel mode, and flexibility of activities. Transportation Research Institute (IMOB) of UH has already developed a research-based mobile application that could able to provide an activity-travel diary of individuals with appropriate accuracy. However, some developmental efforts were made to bring efficiency in the mobile application. Further, significant adjustments are made to translate the GPS traces into an activity-travel diary data; where the outputs of the stop-detection algorithm are presented to the user for annotating/labeling them with appropriate travel and activity characteristics.
2) Development of survey questionnaire to collect information regarding socio-economic attributes and also the personal traits in the form of attitude, perceptions, and awareness towards environment preservation in relation to travel behavior. The questionnaire was web-based and sent online to citizens to facilitate easy digitization.
3) Development of a stated-preference questionnaire, within which an individual is presented a hypothetical scenario about a particular transport choice (e.g. travel mode choice). The individual considers the details of the hypothetical scenario and select particular option. The challenging task was to develop details of those hypothetical scenarios which may influence individual choice. A complete set of attributes levels were found along with air quality information levels and then based on the fractional factorial design methodology, a set of hypothetical scenarios were developed. To bring a contextual and local information with the experiments, we developed those hypothetical scenarios in close relation with the activity-travel diary routine of each individual. This was again a web-based instrument and sent online to citizens for their responses.

2.2 Scope of the work

In relation to the discussion in subsection 2.1, for the deliverable 4.1, this sub-section presents the focus and scope of the work considering commitments in task 4.1 and also to support the overall objectives of WP 4.

The main focus remains on to the development of a comprehensive methodological framework that will guide throughout WP 4. Along with that focus also remains onto the development of tools and survey instruments for collection of the required data. In addition, to fulfil the commitments made in task 4.1 to a significant extent, implementing the developed methodological framework in Hasselt with a collection of required data and its analysis. The analysis of the data collected from Hasselt study is limited to present the key findings in the form of descriptive statistics, and development of the path model using the theory of planned behaviour[*Forward, 2004*]. The model currently may have large standard errors because of a limited sample, however, once the data is available from other iSCAPE cities, this can be re-estimated. In addition to this, an attempt has also been made to measure the effectiveness of

the information based intervention in changing travel behaviour. The major analysis such as upgrading of the policy models is not part of this deliverable as this required collection of data from all iSCAPE cities and also an important outcome of task 4.2, which will be presented in subsequent deliverables.

2.3 Layout of the Report

The report is structured into various key sections. Section 3 presents a review of the literature from methodological and analysis aspects about determining key factors that are helpful in understanding/investigating individual behaviour. Further, it also highlights how effectiveness can be measured for information-based interventions in light of travel behaviour. Section 4 presents methodological framework considering the scope of work for deliverable 4.1 and also a coherent approach employed to achieve the objectives of WP 4. Section 5 presents the efforts made in the development of tools and survey instruments and also pinpoints some novel concepts incorporated to bring more consistency in obtaining the appropriate data. Section 6 discusses the implementation of concepts and developed tools for conducting the case study in Hasselt, with a discussion on recruitment and engagement of citizens. Furthermore, collected data is analysed and key findings are presented. Section 7 highlights the time frame for implementing the similar experiment in other iSCAPE cities to strengthen the data and its analysis. Section 8 concludes the deliverable.

3 Environment and Travel Behaviour

The deliverable 1.3 presents the comprehensive account of the relationship between the environment and travel behaviour. Therefore, the focus here is to only provide discussion on the aspects that help in the fulfilment of the required tasks lay out in section 2.2. This section presents the key lessons learned from the existing literature and building on that mention the key approaches that are useful for quantifying and investigating the effect on the environment due to individual activity-travel routine.

3.1 Lessons from Existing Literature

This section highlights key findings from the existing literature on aspects through which individual behaviour is determined and how changes can be influenced.

1) Psychographic variables (that consider attitudes, interests, and opinions), societal context and awareness about impacts of actions on the environment are stronger predictors of sustainable behaviour than demographic variables [*Uren et al., 2015, Straughan and Roberts, 1999*].
2) Soft strategies such as informational based strategies/interventions can influence change in behaviour which is relatively easier and has high benefits. In terms of travel behaviour, travel for non-mandatory activities can be influenced by such interventions [*Schultz, 2014*].
3) Informational based strategies should use a method such as feedback, and are designed in consistent with existing beliefs and attitudes are found to work well for influencing changes in behaviour that are easier to do and have high benefits (as mentioned in point 2) [*Schultz, 2014, Osbaldiston and Schott, 2012*].
4) Policy models (forecasting the effect of policies on individual behaviour) are effective tools, however, their application in terms of investigating the effect of policies on the environment is rather limited [*Shiftan and Suhrbier, 2002, Dons et al., 2014*]. Furthermore, these models are not able to forecast the effect of changes in the environment in travel behaviour (i.e. only one-way effect can be determined).
5) Information nowadays regarding the environment and air quality is readily available to individuals. Portable low cost sensors and real-time updates regarding air quality on many websites are realities now, and in near future integration of these with smart phone apps are inevitable. This can make this information more reliable and easier to access. This information can play a significant role in influencing individual's activity-travel routine [*Int Panis et al., 2016, De Nazelle et al., 2013*].
6) Regarding travel behaviour, it has been established that dynamic consideration of individual movement in space and time can produce more appropriate exposure estimates [*Beckx et al., 2009a, Hatzopoulou and Miller, 2010*]. Along with this, in few studies it has been observed that exposure to air pollutant can be different in relation to travel modes (individuals travelling in car are exposed to higher level of concentration than those travelling in bicycle and public transport) [*de Nazelle et al., 2016, Int Panis et al., 2016*]. Furthermore, activities performed indoor and outdoor are also cause changes in exposure levels [*Kornartit et al., 2010, Dias and Tchepel, 2014, Gerharz et al., 2009, Lee et al., 2000*].
7) CO_2 emission measurement has been given considerable attention in the literature, and its emission is directly proportional to car use and the fuel a particular vehicle is consuming [*Beckx and Denys, 2016, Reichert et al., 2016*]. The decrease in car use is important for improving air quality and reducing the greenhouse effect.

8) Hot and cold starts for car-related trips are also important to consider as both these conditions of the engine have been observed to emit significantly different levels of air pollutant such as CO, HCs and NOx. It is reported in the literature that trips following a parking duration in the range of 3-8 hours contain a cold start [*Martin Weiss et al., 2017, Reiter and Kockelman, 2016*].
9) Literature also emphasised use and encouragement of active travel modes (such as cycling, walking and public transport). The advantages are twofold, such as health benefits for individuals and at the same time causing improvement of air quality. Hard strategies (such as instructional strategies) are vital to cause such a behavior change, however, at the same time, informational strategies may help make these changes more sustainable [*Clark et al., 2011, Hong et al., 2016, Panter et al., 2016*]. For a particular individual, it is recommended to spend at least 30 minutes of intermediate level exercise on a daily basis. This can also be achieved by choosing active travel modes [*ALR, 2016*].

3.2 Quantification and assessment approaches

This section highlights key findings from the existing literature on methodological aspects through which individual behaviour is determined and which intervention methods are used to influence behaviour.

3.2.1 Theory of planned behaviour and estimation of paths models

The Theory of Planned Behaviour (TPB) proposes a generic socio-cognitive model of behaviour, which can measure how human actions are guided. It was first proposed by Icek Ajzen in 1985, however, later it was improved further and the element of behaviour controls are added [*Ali et al., 2011*]. It has been applied successfully to explain various human behaviours related to health, recycling, energy conservation, traffic safety and green environment [*Miafodzyeva and Brandt, 2013, Steg and Vlek, 2009, Schmidt, 2016, Karlin et al., 2014, Dwyer et al., 1993*]. For explaining travel behaviour, the application of this theory is rather limited. There are three main determinants of TPB namely subjective norms, attitude and perceived behavioural control which predict behavioural intention, which is the immediate precursor of behaviour itself. Intentions are assumed to capture the motivational factors that influence a behaviour; 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 behaviour.

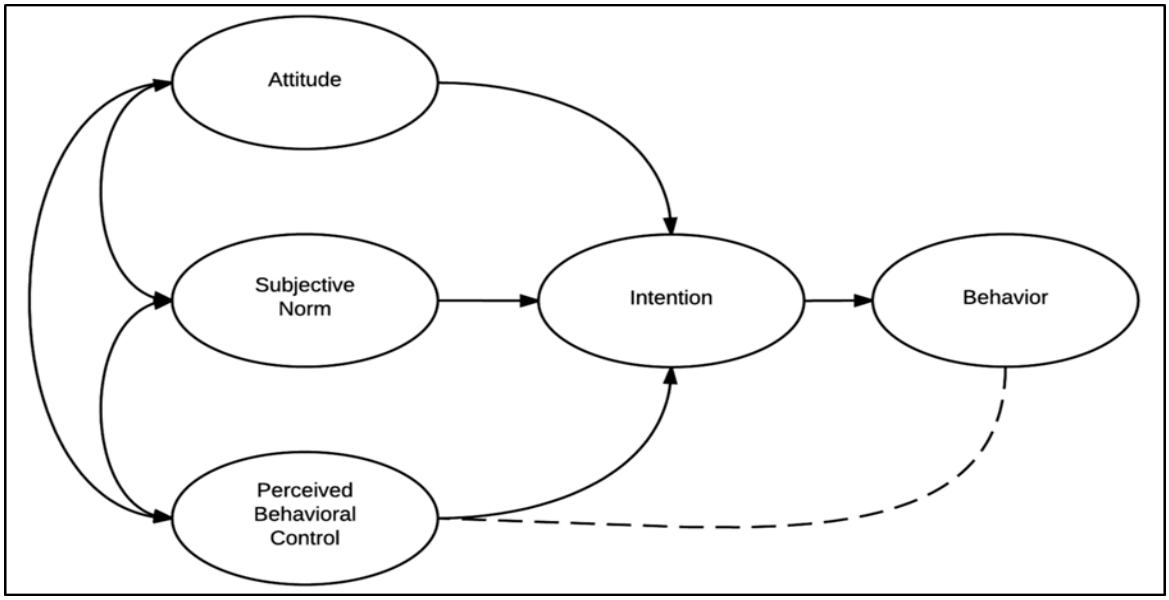


Figure 1: Conceptual Framework of the Theory of Planned Behaviour.

The first determinant "Attitude" indicates one's positive or negative evaluation of a particular behaviour. The main idea is the extent to which performance of behaviour in question is valued as positive or negative. The second predictor is a social factor named as subjective norm; it refers individual's perceived social pressure whether he or she should or should not perform a particular behaviour. The third antecedent of intention is the degree of perceived behavioural control which relates to the perceived ease or difficulty of performing the behaviour and it depends on a lot on the self believe and self-confidence to behave in a specific way. As a general rule, the more favourable the attitude and subjective norm with respect to a behaviour, and the greater the perceived behavioural control, the stronger should be an individual's intention to perform the behaviour under consideration. The relative importance of attitude, subjective norm, and perceived behavioural control in the prediction of intention is expected to vary across behaviours and situations. Thus, in some applications, it may be found that only attitudes have a significant impact on intentions, in others that attitudes and perceived behavioural control are sufficient to account for intentions, and in still others that all three predictors make independent contributions. The application of this theory is based on formulating self-reported survey questions that are indicators of individuals attitudes, perceptions and beliefs. Conformity analysis and structural equation modelling tools help in estimating the path models. In this way, the effect of various indicators of behaviour is quantified [*Ali et al., 2011*].

This theory provides a comprehensive framework to determine to what extent various attitudes, perceptions, and beliefs can influence pro-environmental activity-travel behaviour (PEATB) (for example, use of bicycle and public transport for shorter trips). The results could provide a way forward to design an effective behavioural intervention especially an informational based intervention which could be used as a part of living lab activities for the fulfilment of objectives of WP 4 and WP 2.

3.2.2 Informational intervention: methods and assessment

Travel behaviour and habits related to it are hard to influence, and often require hard and systematic interventions to guide individual actions. Informational strategies, however, considered important to support hard intervention to achieve more optimal and desirable change in behaviours. Literature emphasis on various methods for provision of information to individuals. For influencing changes in behaviour along with the determinants factors from

the path models, various methods are discussed in details and examined in terms of their effectiveness [*Osbaldiston and Schott, 2012*]. Based on the review, the following are found more appropriate in relation to influence change in non-mandatory level travel behaviour.

1) **Feedback:** monitoring individuals, and then provided a feedback regarding their travel behaviour such as how much is their exposure to air pollutant for their activity-travel routine.
2) **Justification:** Reasons can be provided about the recommendation of a particular change in behaviour such as if short trips are made via active travel modes then what are their benefits.
3) **Cognitive dissonance:** Information is provided which are consistent with existing beliefs and attitude, this can mainly be done by making the information as much customized as possible (i.e. individual specific). Furthermore, it is required to have results of the path model to be known as how much attitude and beliefs are important in describing PEATB.
4) **Commitment:** Asking a commitment from an individual after giving them the necessary awareness about consequence and advantages of following a particular activity-travel routine.

The effectiveness of the intervention is usually assessed by using some metrics that is representative of behaviour before and after implementation of the intervention. In order to make the experiment more rigorous and to counter for variation in behaviour due to some external means, a control group and treatment group methodology is used. The control group subjects are not part of the intervention programme; however, their behaviour is noted before and after the intervention. In terms of travel behaviour, which is an entire day activity-travel routine and comprise of several dimensions such as travel mode, departure time for activities, activity durations, activity chaining patterns, activity location it is, therefore, a challenging task to develop such a metric that measures variation before and after the intervention. Literature within activity-based approach provides such measure that estimate changes in activity-travel routine, however, most of them are just based on single dimension such as inserting and deletion of activities to match a pattern and weigh the effort required to do that without considering mode, duration and other dimensions of entire day activity schedule. In this situation, a heuristic based algorithms that can consider a variety of activity scheduling dimension which is proposed by [*Joh et al., 2001*], and then further adapted by [*Kwan et al., 2014*] can be beneficial. Some simple metrics can also be developed that relates to PEATB such as more use of active travel modes and public transport, lesser car use, lesser outdoor activities and therefore lesser number of trips etc.

3.2.3 Measurements of environmental effects from GPS data

In task 4.1 it is indicated that environmental effect will be measured using GPS trajectories. However, a more rational approach to convert GPS trajectories first in activity-travel routine and then measure their environmental effect more concretely. If the data is available regarding air pollutant concentrations in time and space along with GPS-based activity-travel routine then following can be measured according to the literature.

1) Exposure to air pollutants in time and space, i.e. duration of time individual is exposed to a particular concentration level of a specific air pollutant. Usually, literature focused on measuring population exposure and often maps are created as an output [*Beckx et al., 2009*].

2) When the GPS based trajectories are translated into activity-travel routine, it is simpler to identify activities that are usually performed indoor and outdoor microenvironments. Therefore, exposure can be differentiated in these aspects given there are factors available to measure air pollutants concentration in these microenvironments. For NO_2, Ozone, PM_{10} and $PM_{2.5}$ there is considerable literature available where these factors can be obtained.
3) Exposure estimate can be further corrected based on travel mode if GPS based trajectories can provide an idea about travel mode with certainty. In different microenvironments of travel mode, pollutant concentration can be different. Factors for each mode are described in the literature and can be obtained.
4) CO_2 emission can be measured if along with activity-travel routine information about car fuel type, model, and other details are obtained. There are a variety of formulation presented in the literature, where CO_2 emission is considered as a function of distance, fuel, vehicle models and manufacturing year. Some simple formulation is also available in the literature which is just based on distance.
5) Along with CO_2, some other pollutant emission can also be measured such as NOx, CO and PM_{10} and $PM_{2.5}$.
6) Details of activity-travel routine can also provide an idea about the involvement of physical activity level. Activity purpose, if available can include specific activity types along with a duration such as time spent in exercise activity.
7) Identification of hot and cold start of vehicles, based on the preceding activity duration.

Based on the measurement of these environmental effects, an exploratory analysis could also be done by combining some of the measures from travel-related characteristics. For example, examining a number of short distance trips that can be replaceable by walk, bicycle and how much it can offer in terms of improving air quality. How many cold starts can be avoided if activities can be chained together more effectively. Reduction of few non-mandatory outdoor activities and their advantages in terms of reduction in exposure. Which bicycle and walking route are more appropriate for causing lesser level of air pollutant exposure. This analysis as part of task 4.1, could help in the development of an effective customized informational package, where the environmental effect of individual travel-activity routine can be explained with its quantification. Furthermore, some suggestions can be put forwarded to make their activity-travel routine more pro-environmental within the framework of feedback, justification, cognitive dissonance and commitments. Additionally, information regarding peers can be illustrated within the informational pack if the study is planned for an entire group simultaneously.

4 Methodological Framework

This chapter presents a detailed account of the methodology developed for formulating and deployment of a location-based framework required to be implemented in WP 4. The methodological framework present here is based on the discussion formulated in section 3. The methodology is based on three major aspects; 1) investigating determinants of behavioural actions in relation with PEATB, 2) Design, implementation, and effectiveness of informational based behavioural intervention and 3) updating the policy model to capture two-way effects for testing policies appropriately. The methodological framework is such that it can be applicable in all iSCAPE cities, provided that data requirements are fulfilled. Furthermore, the methodological framework provides flexibility in terms of fulfilling the commitments made for task 4.1 (as mentioned in section 3.2.3). In figure 2, it is shown that methodological framework based on three major aspects in overall fulfills the objectives of WP 4, however, at the same time, it provides the flexibility of including the tasks in relation

with WP 2, where living lab activity in the form of behavioural intervention is carried out. More details on figure 2 are described in next three sub-sections, where three major aspects are discussed along with the comments on methods and required data, especially from the citizens.

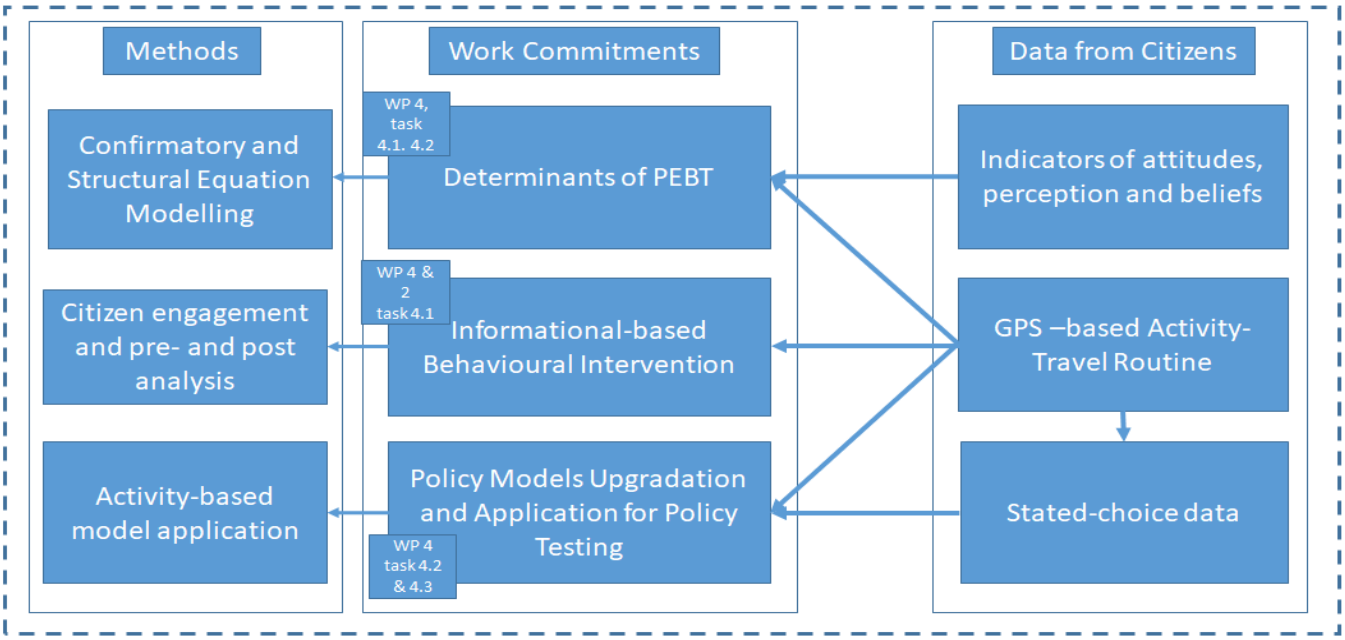


Figure 2: Methodological Framework for WP 4.

4.1 Behavioural actions and its determinants

Investigation of the determinants of behavioural action of individuals is important, as it highlights the key factors that are guiding a particular action of an individual. These key factors are need to be considered in designing an intervention and informational campaigns to influence change in individual behaviour. As explained in section 3.2.1, TPB and its realization through estimation of path model using exploratory and confirmatory analysis techniques provides a more comprehensive framework to distinguish factors on which individual behaviour is based. Literature, in relation to energy conservation and recycling behaviour often utilised TPB to investigate their determinants, however, within travel behaviour research application of TPB is scarce. However, it has been established that in terms of mode choice, TPB is an effective tool to explain intentions and behavioural actions. Perceived behavioural control (PBC) has been found more significant compared to attitudes and subjective norms [*Forward, 2004*]. At the same time Habits, which in theory considered as part of PBC found more significant than PBC. This could only be tested once the data is available. Behavioural studies [*Ghasemzadeh et al., 2017, Ambak et al., 2016*] emphasize consideration of other context specific factors that are not part of the TPB framework shown in figure 1. These factors are as follows:

- ***Perceived Consumer Efficacy:*** it shows that when people perceive their actions as effectively changing the situation then they are more motivated to change behaviours
- ***Environmental awareness***; knowledge of issues especially related to environment have been found in some studies as important in predicting behaviour, it is therefore required to considered separately.
- ***Situational factors***; it is defined as availability or non-availability of the facilities that directly or indirectly assist individuals to behave in a particular way.

TPB has been extended to include the above mentioned factors, it is therefore used in our methodology, to determine the significance of each factors on explaining the PEATB. It is to note that important distinction in our case will be the way behaviour/actions are determined. Studies mainly consider self-reported behavioural 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. This is indicated via directed arrow in figure 2. However, the task here is to define PEATB using activity-travel routine information. The following are used as indicators of PEATB

1) *Car dependency*: 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.
2) *Use of Public transport:* 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.
3) *Use of active travel mode:* 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. Again, that measured percentage is assigned to a particular equidistant category.
4) *Exposure level:* Exposure level is measured as maximum time an individual is exposed to a particular Air Quality Index category[*WAQI, 2016*]. This index is measured for each source of pollutant and the final score is the highest of all the source pollutant. The index may have a value ranging from 0 to more than 300 and is categorised in ten different non-linear levels. Each category is comprised of 50 units of AQI index. Low scores representing the less polluted environment, and a score of more than 300 is regarded as hazardous to health. For each category of AQI, time an individual exposed is calculated. An individual is assigned to a particular category based on the maximum of time an individual is exposed to that category.

Along with the 4 indicators described above to represent PEATB, some control variables that represents a socio-economic class of an individual are also included e.g. Household yearly income. This has been found immensely in the literature to effect travel behaviour of an individual. To represent variables within TPB, a web-based online questionnaire that asked various indictors from the individuals is designed, and share with experts from T6 (partners in iSCAPE), for its further improvement. More details on the questionnaire are described in section 5.2. The analysis based on the collected data will be useful to suggest more effective interventions and specific considerations that should be taken into account. Therefore, it is considered as the first activity within the whole methodological framework implementation. Figure 3 represents the final conceptual path model comprising all the factors that will be tested via collected data. Solid arrows indicate a direct effect on the PEATB, and broken arrows indicate an indirect effect on PEATB via intentions or other factors considered.

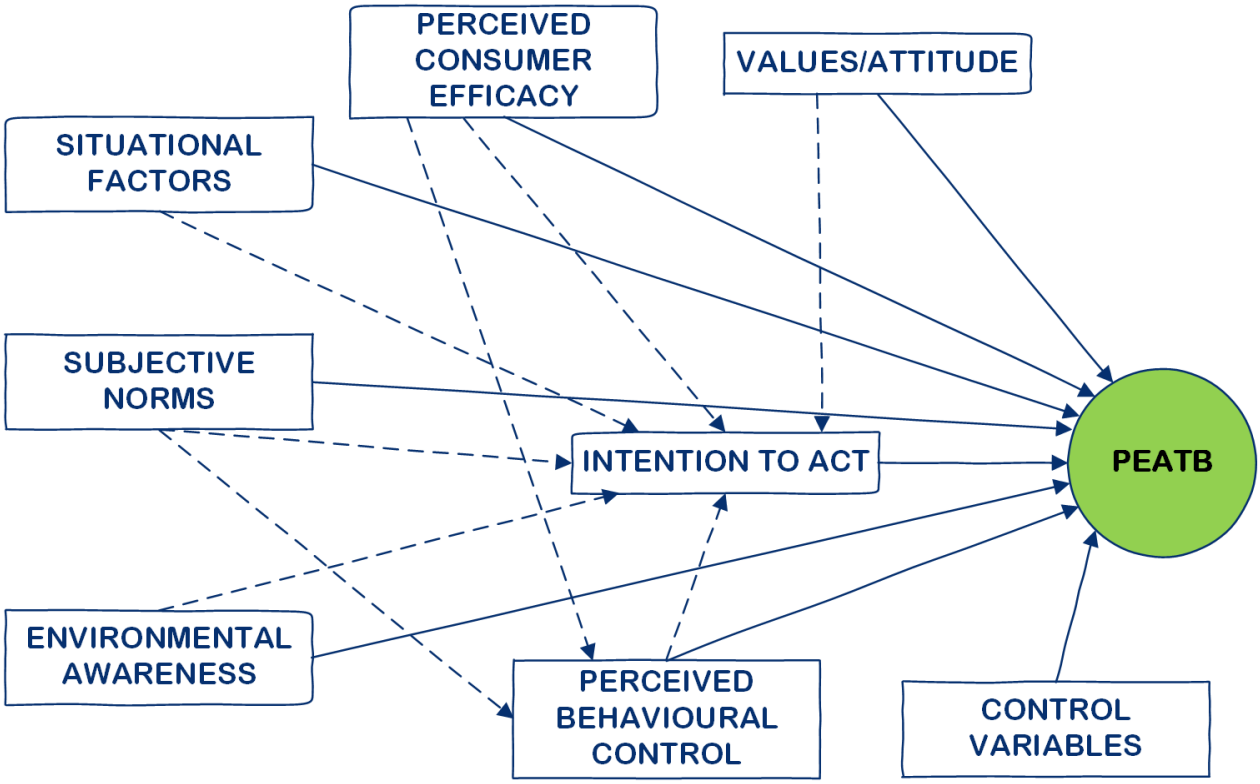


Figure 3: Conceptual Path Model to investigate determinants of PEATB.

4.2 Behavioural Intervention – Design, Implementation, and Effectiveness

This section presents the details of informational-based behavioural intervention conceived as a part of living lab activities for WP 2, and also for partial fulfillment of objectives of WP 4. The section first presents the details related to its design, and then focus on how it needs to be implemented followed by a discussion on assessing its effectiveness.

4.2.1 Informational-based Intervention: Design

The design of the information-based intervention is following the four methods suggested in section 3.2.2 (i.e. Feedback, Justification, Cognitive dissonance, and Commitments). Customized information is provided to each individual in four different aspects.

1) Exposure to air pollutant,
2) Contribution in CO_2 emission (only if an individual used a car)
3) The extent to physical activity level.
4) Hot and cold start of car (only if an individual used a car)

Each participant will receive their informational pack that comprises 4 sections based on the 4 aspects mentioned above; each section of this information contains three fundamental elements. These are as follows:

- A brief information to increase the awareness of participant regarding a particular aspect, which is easy to understand and digest.
- Feedback in terms of a quantitative measure of their behaviour on each aspect and description of its effect.
- Some recommended suggestions on how to change travel behaviour to decrease the effects along with its quantification. These suggestions are designed considering the ease in change for a particular participant (i.e. a consideration based on perceived behavioural control).

Some optional elements can also be included based on the results of the path model, e.g. more information to increase the awareness regarding each aspect and to inculcate positive attitudes and beliefs. Quantification information about peers (How other persons in the study are behaving compared to a single participant), which relate to the subjective norms. Along with the above, at the end of information pack, individuals are asked to give their commitments for some of the suggestions put forwarded in the 4 sections of the information pack. Also, a flexibility is provided to give the commitments on their own. Annexure-II provides an example of the information pack given to a particular individual in the Hasselt study.

In order to develop a customized information pack, the background analysis is required to be performed considering an activity-travel routine of each participant and other data. This background analysis is part of task 4.1 in WP 4. Specific details of this can be found in section 6, however, some generalized details are provided here, which improve the overall understanding regarding the design of this intervention. This background analysis can be divided into two parts, in the first part quantification is made regarding the four aspects and in the second part, suggestions are drawn along with the effect on the four aspects. Key

highlights of this background analysis are presented below under sections 4.2.1.1, 4.2.1.2 and 4.2.1.3.

4.2.1.1 Exposure Analysis

Given the availability of activity-travel routine from GPS-based trajectories and pollutant concentrations, this analysis can provide the duration an individual is exposed to a particular concentration level of a specific air pollutant. Additionally, with the availability of microenvironments factors (travel mode and indoor/outdoor factors) regarding specific pollutant, the exposed duration can be further improved. This analysis is not robust, as data regarding pollutant concentration will not be available in a fine resolution of space and time compared to GPS-based activity-travel routine, which is possible only when portable sensors are available and provided to each citizen. Furthermore, microenvironment factors used in the analysis is based on the literature and studied elsewhere. In order to provide suggestions to an individual, the following is considered.

- For each trip duration, exposure to pollutant concentration is measured considering the mode of travel. If the trip is performed by car and it is a long distance trip the replacement is considered for the travel mode by public transport in consideration of the following: 1) availability of public transport option for specific origin and destination of the trip, 2) travel time reasonableness (i.e. the difference is within 30 minutes compared to car trip) and both access[1] and egress[2] travel can be done via walking (i.e. Total distance is within 1-km) and 3) flexibility of end time of previous activity and start time of the activity for which the trip is made. After identification of all such trip in an entire week, exposure is estimated for each trip considering the public transport route (as car and public transport route may differ for some trips) by application of factor for public transport. The suggestion is prepared in a way that if 50% of such car trips are replaced by public transport, this much exposure is reduced for each category of pollutant concentration level. The algorithm is developed to identify such cases.
- Among all the activities, indoor and outdoor activities durations are taken and exposures are estimated considering the available factors. Non-mandatory outdoor activities (such as leisure, social and other) are replaced from indoor activity, and exposure is re-estimated. If the non-mandatory outdoor activities are performed in a simple home-based or Work-based tour, both inward and outward trips are also reduced. If the non-mandatory outdoor activity is part of the complex pattern (e.g. making a stop way back to home after work activity), then the trips are not reduced, and it is considered as a single long trip without that non-mandatory activity and route is also considered the same. The duration of next indoor activity was increased the same amount as of replaced non-mandatory outdoor activity. The suggestion is then prepared in a way that if 50% of such non-mandatory activities are replaced by indoor activities, this much exposure is reduced for each category of pollutant concentration level. The algorithm as described above is developed to identify such cases from the activity-travel routine.
- Short distant trips, i.e. trips within 1-km and 3-km are identified from the weekly activity-travel routine and travel mode is checked for each trip along with measurement of the exposure level of these trips based on the travel mode

[1] Access: it indicates travel from current activity location to Public transport stop/station
[2] Egress: it indicates travel after alighting from public transport stop/station to the next activity location.

microenvironment factors. Trips within 1-km distance is considered to replace with walking and within 3-km by bicycle. Exposure is re-estimated considering walk and bicycle route of those trips along with consideration of microenvironment factors. This is a more conservative approach as literature suggested up to 5km range of distance as short trips. Suggestions are then prepared as follows:

- For trips within 1-km, it is suggested that all such trips are replaced by walking and the reduced exposure is mentioned for each category of pollutant concentration level.
- For trips within 3-km, it is suggested that if 50% of such trips are replaced by bicycle, this much exposure is reduced for each category of pollutant concentration level.

4.2.1.2 GHG Emission Analysis

Based on the activity-travel routine information, an individual car use is determined and it is measured that within a week, how much vehicle-km are travelled using the car. Use of Taxi is also considered within car use. In addition to that use of motorcycles and moped are also considered in this analysis. Trips made using public transport are not considered as a contribution of an individual in GHG emissions.

As suggested by [*Zahabi et al., 2016*], we used the similar formulation for measurement of GHG (CO_2) emissions.

$$GHG_{Ajt} = \left(\sum_{i=1}^{N}\left(SP_{ijt} \times D_{Aij}\right)\right) \times \left(\frac{EF_{Af}}{R_{Aj}}\right) \quad (1)$$

Where *A* – Auto
i – Link (*i* = 1,..., N links used by trip *j*)
j – Trip
t – Departure time
GHG_{Ajt}= GHGs for automobile trip *j* (in kg of CO2) departing at time *t*.
D_{Aij} = Travel distance for automobile on segment (link in network) *i*.
SP_{ijt} = Speed correction factor for segment *i* of trip *j* departing at time *t*. Since fuel consumption also depends upon speed, therefore they are also used. These factors were produced on the basis of link speed[*Brzezinski et al., 2001*] Link speed was matched with its corresponding speed correction factor.
EF_{Af} = Average emission of CO_2 in g/km based on the fuel type *f* of auto *A*, taken from [*Beckx and Denys, 2016*] for Belgian fleet. For motorcycle and moped we have assumed the value of
R_{Aj} = Number of passengers in trip *j*, including the driver. Taken from activity-travel routine to facilitate the appropriate calculation of contribution of each individual. If the information is not available for a particular trip, we have considered this as unity.
If the trip is performed via taxi, fuel type is not available, we, therefore, assumed the fuel type as diesel, because most of the taxi fleet is based on diesel due to its high efficiency of mileage compared to gasoline.

Further analysis is based on the use of a car for long distance and its replacement by public transport, given that few conditions are satisfied. These are similar as described for exposure analysis in section 4.2.1.1, such as; previous activity end time and the next activity start time is flexible, public transport option is available with reasonable travel time compared to the travel time for the trip performed by car. An algorithm is developed to identify such cases from the activity-travel routine. The suggestion is prepared in a way that if 50% of such car trips are replaced by public transport then how much reduction is observed in CO_2 emission from an individual. Along with that, short trips (i.e. trip within 3 km) if performed using car are

also considered to be replaced from walk and bicycle, and suggestions are mentioned in similar way as mentioned within exposure analysis. Such as in case of within 1-km, all trips are replaced by walk and within 3-km, 50 % of trips are replaced by bicycle. In both cases reduction is noted for CO_2 emission and mentioned.

4.2.1.3 Physical Activity Level Analysis

For analysing physical activity levels, we considered individual involvement in walking and bicycling for outdoor trips. Furthermore, time spent in activity purpose (i.e. exercise) is also considered as an indication of involvement of an individual in a physical activity. This time can be spent at home location or some specific location outside the home. For assessing individual involvement in physical activities, we use the threshold limit of 150 minutes per week or 30-minutes of daily limit (for at least five days of the week) as recommended by WHO. According to [*WHO, 2010*], to improve cardiorespiratory and muscular fitness, bone health, reduce the risk of non-communicable diseases and depression, adults (19-64) should aim for at least 150 minutes of moderate-intensity aerobic physical activity in a week.

Further analysis is based on the replacement of car, taxi, car passenger based trips into public transport, if the trip is for long distance (i.e. a distance greater than 3 km). Again, few conditions are required to be met, i.e. public transport is available with reasonable travel time, flexibility in the end time of previous activity and start time of the next activity and reasonable access and egress times (i.e. that can be travelled via walk). The suggestion is mentioned in terms of replacing 50% of such car trips by car and increase in physical activity duration (due to access an egress walk) is noted and mentioned in a manner that this much goal can be achieved with such change in behaviour. Other suggestions are based on the conversion of car-based short trips into walk and bicycle in the same manner as mentioned for GHG emissions and exposure analysis.

4.2.1.4 Hot and Cold Start Analysis

Hot and Cold start are noted for individual who are travelling by car and driving themselves. Except for the first cold start in the morning (a person going to work) and a cold start after the work activity, other cold starts are considered in the analysis and we called it as an excess cold start (as few of them could be avoided). Cold start is determined by a simple rule, i.e. when an activity preceding the car trip is of duration longer than 3 hours.

In terms of preparing suggestions, car trips if replaced from public transport, walk and bicycle (based on the rules defined above for longer and shorter trips), reduction in cold starts are noted and mentioned. In addition to that, presence of activities, after reaching home with a gap of 3 hours and longer are noted, and suggested that if 50 % of such activities are performed in trip chains (performed before reaching home or work locations) or with a gap of less than 3 hours, this much number of cold starts can be avoided.

4.2.2Informational-based Intervention: Implementation

The informational-based intervention is designed in such a way that it can be easily managed remotely, and therefore can be implemented in other iSCAPE cities. An informational pack is a web-based tool, along with the information and suggestion on each section as mentioned in the design section, various questions are asked from each section in order to gauge the understanding of the participant and also to ensure that individual has read all the information and remembered few key things. It can be seen in the example information pack given in Annexure-II. Additionally, the following key points are also taken into account for implementation of this intervention.

1) Recruitment of citizens for the long-term (for at most 5-6 weeks): As the intervention is based on the processing of GPS-based activity-travel routine data, therefore, the processing time is considered as minimum as possible. Most of the algorithms for analysis are rule-based and can be easily programmed, therefore, before the implementation stage these algorithms are already developed and tested with pilot data which was collected from few students from the Hasselt university. Furthermore, citizens at the recruitment stage are provided a complete schedule of activities of this intervention, and periodically, during the study, they are reminded about those once the particular step is due.
2) The information pack contains a variety of information, help from designers are taken to make that information as readable as possible and provide the look and feel of the information pack to make it attractive to read. Help from graphical illustrations and symbols are taken in this regard.
3) In order to facilitate the effectiveness of the informational intervention, participants are required to be divided into two groups, i.e. Control and Treatment group. Control group activity-travel routine is required to be measured twice, however they are not provided with any information. For the treatment group, they are also required to provide their behavioural information twice, i.e. pre and post-intervention along with the provision of the informational pack in between.

4.2.3Informational-based Intervention: Effectiveness

This is an important aspect of the intervention, which measures how much change in behaviour is influenced by the intervention. We have limited our scope to measure only short-term changes. In order to measure effectiveness, there are a variety of ways from which this can be assessed. Additionally, the implementation of the intervention and collection of data from pre and post phases, will ease in formulating appropriate effectiveness assessing methodology. Few of the effectiveness assessing method are discussed as follows:

1) Estimating PEATB before and after the informational intervention and compare the results, on disaggregate and aggregate level for control and treatment groups. The differences can be statistically ascertained by applying some statistical tests. The PEATB as defined in section 4.1, provide meaningful indicators regarding pro-environmental activity-travel behaviour and therefore plausible in assessing the effectiveness of the intervention.
2) There are some questions designed to asked from the respondents regarding the intervention during the final feedback step. These questions are open-ended question and individuals are flexible to provide their opinions on various aspects of the study along with influence on their travel behaviour. Compilation of these answer can also support examination of the effectiveness of the intervention. Additionally, combining process mentioned in point 1) with these responses can also provide more comprehensive assessments regarding intervention effectiveness. These questions will also help in WP 5 where, a complete methodology for social impact assessment has been formulated for each intervention within iSCAPE project.
3) Application of Sequence alignment algorithms considering multi-dimensions of activity-travel routine to determine the required effort to match individual pattern before and after the intervention can also act as a useful method for measuring effectiveness. The signification differences in the measure would entail that intervention is effective in influencing the travel behaviour. This analysis can be more authentic as it is based on the previous research on a comparison of activity-travel routine. However, translating the algorithm as a programming code is an added effort.

Furthermore, the effectiveness analysis can be more comprehensive if it incorporates all the three methods described here.

4.3 Policy Models - Data Requirements and model development

Policy models that measure the effects of policy on various activity-travel scheduling dimensions are discussed in length in deliverable 1.3, under the comprehensive review of integrated models. These integrated models are a chain of different models, in which output of the one model is an input for the next. Models are sophisticated and require a large amount of data and able to simulate the effect for an entire population in the region. As mentioned earlier, studies are scarce for application of these models for certain policy measures, and in the current setting, these models can only determine the one way effect of any policy on activity schedule and in turn on the environment and air quality. However, the effect of changes in air quality on the activity-travel schedule cannot be predicted. Information on air quality can be readily available, and it may influence change in travel behaviour. Therefore, it is required to upgrade these models and then apply them to test the effect of few policies (task 4.2 and 4.3 of WP 4). In order to fulfill these requirements, data regarding the influence of air quality and other environment changes on travel decisions is required.

Usually, travel behaviour data do not possess information regarding air quality and other environment variables and therefore individual decision are not correlated with these variables in traditional models. In such situation, travel demand modelling literature suggest a collection of stated preference (SP) data, where individuals are provided with some hypothetical situation with the required information, and then asked to choose a particular alternative (such as travel mode, route, activity pattern etc.). However, to conduct such studies, a comprehensive experimental design is required to capture the effect of those new variables in travel decision-making. Once the data is obtained, models from the family of discrete choice modelling framework are estimated to predict travel decision choices of individuals. These models can be integrated within the activity-based modelling framework to test the effect of policies in a more appropriate manner.

As in task 4.2 and 4.3, the application of such models need to be shown, therefore it is important that required data from the citizens and the experimental design process can be ascertained. Engagement of citizens for the data collection is required to obtained GPS-based activity travel routine, therefore, it is more appropriate to obtain SP data as well. Therefore, effort has been devoted to developing an experimental design to develop SP scenarios to obtain such data. Section 5.3 describes this process in detail, and also provide glimpses of scenario developed for obtaining this data. More details on how to utilise such data in model development are not the subject of this deliverable, therefore, it is not discussed here.

5 Development of Study Instruments

5.1 Sparrow- Mobile application

Transportation experts need activity travel habits in order to assess the mobility behaviour of individuals. One approach to do this is by asking participants to fill in a diary. Methods linked with such approach are very expensive and also not very accurate. E.g. An individual mentioned that he went to shopping from 11:30 to 12:00 while actual starting and ending time associated with that activity was from 11:22 to 11:56 or an individual forget to report

some activities and trips performed by him during the day. These problems are solved by automatically detecting the spatial and temporal details associated with individuals' movements using GPS technology. The recorded GPS points using smartphone application are successfully sent to the server where stop detection algorithm detects the stops and trips. The detected stops and trips are uploaded to web-based application where participant annotate the data by answering the questions related to activity purposes, travel mode and flexibility of activities. The tools required in above-mentioned approach is discussed in detail below.

Global Positioning System (GPS) is a promising technology to detect the position of an individual accurately with respect to time and space. Based on this concept, GPS based smartphone application SPARROWS has been developed by Transportation Research Institute (IMOB) at UHASSELT. 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. Figure 4 shows the SPARROWS user interface before and after installation.

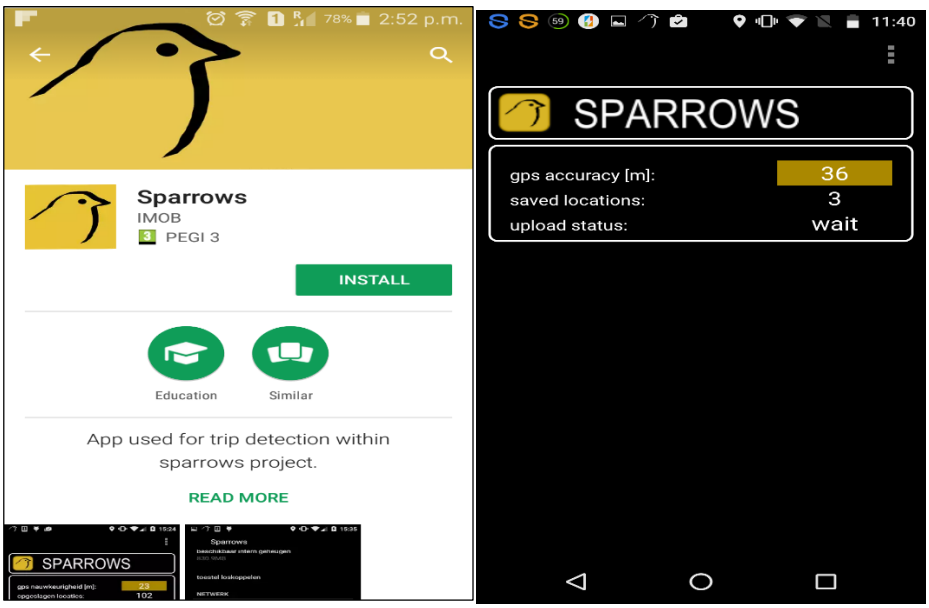


Figure 4: SPARROWS user interface before and after installation.

The main idea behind the development of SPARROWS is to efficiently record the GPS traces of an individual's activities and trips performed during the day. 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. These traces were collected as geo coordinate–time data points consisting of latitude, longitude, date (mm:dd:yy), and time (hh:mm:ss). 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 the server. Upon availability of internet connection SPARROWS uploads data automatically.

5.1.1SPARROWS- Installation and Activation

Following are the steps for the installation and activation of the SPARROWS:

- Download the SPARROWS application from the Google Play Store (https://play.google.com/store /apps/details?id=be.uhasselt.imob.sparrows).
- The next step after successful installation is to scan the QR code (send via email). The application will ask this when it is opening for the first time.

- If you don't have QR code scanner app on your phone then you have to download any of the free QR code scanner app available on Google Play Store. E.g. Barcode scanner
- Scan the QR code that is located in the upper right corner of the document provided via email.
- Initially, the screen that will be displayed after scanning the QR code is showing no saved locations. When you will start moving, GPS will start tracking you and you will see the similar screen with different no of saved locations as shown in figure 5.
- GPS (location) should be activated all the time on your smartphone for the complete recording of your all-day trips and activities locations.
- For sending the saved GPS points from your phone to the server you have to be connected to the internet not more than 5 minutes in a day.

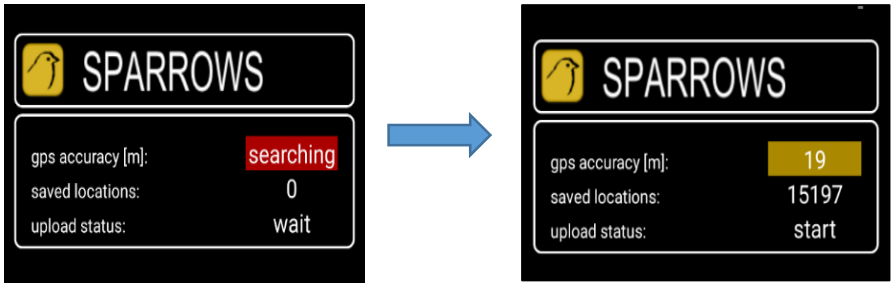


Figure 5: Interfaces with and without saved locations

5.1.2 Stop and Trip Detector

The GPS traces recorded via SPARROWS as Personal traces are available in the form of mixed sequences of walking, cycling, public transport and car movements. It is very important and crucial to identify stops and trips accurately from Personal traces. Stop are the locations where people stay for some time period to perform a particular activity and trips are connecting these stops spatially and temporally. The aim is to find out the regions in time-space that corresponds to a single stop (contrary to usually visited locations that correspond to a region in space). A stop is specified by an area, time period and a purpose. The purpose of a particular stop cannot be identified by the GPS trace but it is found out in a step i.e. Prompted Recall Survey that follows the stop detection as shown in Figure 8. It is a web-based application (explained in section 3) on which stops and trips are presented and the individual is asked about purpose and mode used to visit that particular location. So, it is necessary to detect the stops accurately in order not to present false positives to the respondent. To meet the objectives mentioned above following tools have been developed:

- **STOP detector** based on identification of spatial clusters of GPS coordinates
- **TRIP detector** that tries to identify sequences of GPS recordings corresponding to movements.

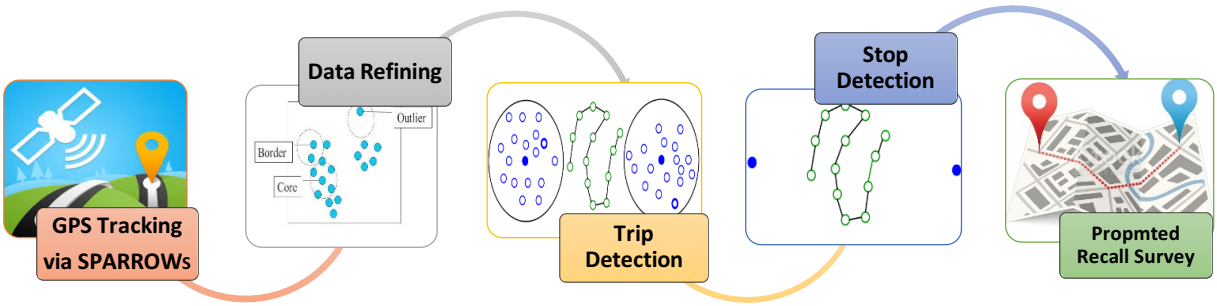


Figure 6: Schematic Diagram representing *steps involved in Data collection to annotation*

The tool depends primarily on the STOP/TRIP detection algorithm that can operate with minimal information i.e. GPS coordinates with a timestamp. The development of this algorithm is based on the work reported by *Yan and Spaccapietra* [*2009*]. Their algorithm uses five steps, namely “preparation”, “data pre-processing”, “trajectory segmentation”, “stop identification” and “semantic enrichment”. An application of Stop detection algorithm is discussed in section 5.1.2.1 in which we attempt to find stop clusters. Stop cluster is identified as a group of GPS points which are close to each other spatially and temporally. In Section 5.1.2.2 trip detection algorithm is explained which finds stops by using the speeds between the GPS points.

5.1.2.1 Stop Detection

GPS records are processed by stop detector in two runs. The algorithm examines the last few recorded GPS points and performs spatial clustering. The first run tries to find stops and trips by associating every GPS record either as stop member or trip member and further by allotting it the number of the stop or trip it belongs to. This can be done by detecting the clusters of points that are significantly close to each other as shown in Figure 7a. GPS Points are defined by longitude, latitude and time stamp and expressed as (x,y,t). In the second run, the process of cleaning of stops and trips are to be done and the set of points representing a stop is replaced by single representative point (Figure 7b). The attributes (x,y,t) of that point is calculated by averaging all points of a particular cluster.

When the Stop detection algorithm identifies two consecutive stops, it will evaluate the distance between them with respect to time and space. Spatial and chronological distance are measured between the last point belong to the first cluster and the centre of the second cluster. If the measured distance is found significantly small, both clusters are combined as one cluster. This scenario is well depicted in Figure 7 (c,d). The last step is the cleaning of both trips and stops. In the process of trip cleaning, we calculate the average speed between the point and its successor (speed is calculated from exactly two GPS recordings). If the average speed between 2 consecutive points let say A and B is very high, we exclude point B from the trip. This is how we can detect the malfunctioning of GPS where a GPS point B appears thousands of kilometres away from the chronological predecessor A while the successor of B is again near to A as shown in Figure 7(e). The stop cleaning process is same as trip cleaning. All stops are observed and if the difference between the average speed of two consecutive stops e.g. A and B is too high, we delete point B. This case is illustrated in Figure 7(f). Both trips and stop cleaning problems can be solved with outlier GPS points.

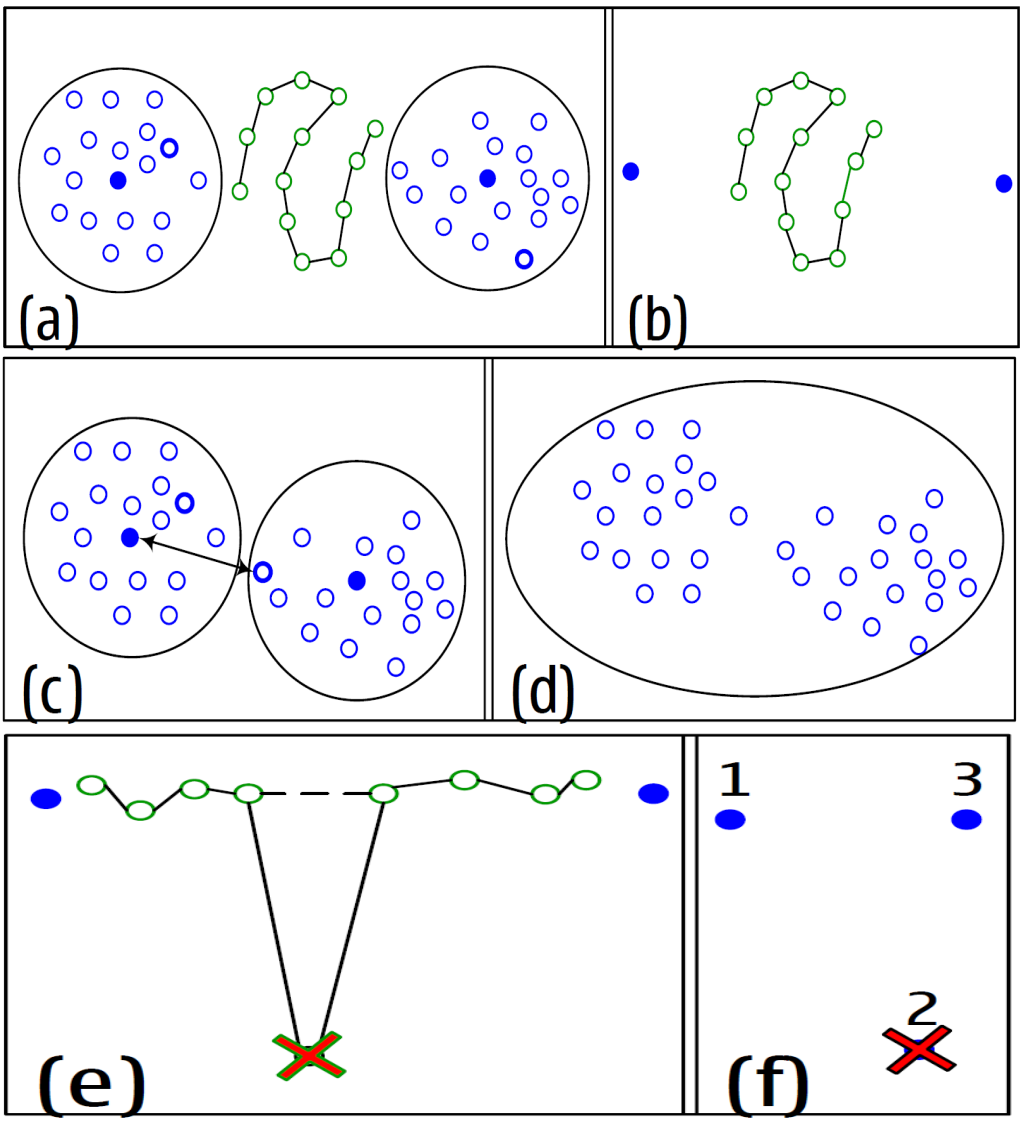


Figure 7: Stop Detection algorithm (a) Stop detection with two stop clusters and one trip. (b) Stop detection with combined stop clusters. (c) Two stop clusters separated by a small distance. (d) A merge of the two stop clusters shown in (c). (e) Trip cleaning. (f) Stop cleaning

5.1.2.2 Trip Detection

In trip detection, the following situations in which (a) the travelled distance is quite large (same as for stop detection), (b) speed ranges from zero to some value and again drop to zero and (c) no large gaps due to missed recordings are found is considered to constitute a trip. Sequences in which zero speed is observed is considered as stops and the remaining recorded GPS points are considered as junk.

The TRIP detector scans the GPS records and maintains a variable size sliding window containing the last records seen. Those records have not yet been finally qualified as stop, trip or junk. Each time a record is read, several quantities are evaluated: instantaneous and smoothed speed and acceleration, window size and period etc. Specific changes in the evaluated quantities lead to event firing. The events are fed to the finite state machine (FSM) that controls the qualification of the subsequence contained in the window. Definitely qualified records are dropped from the window. The speed condition is required because part of the traces to be processed by the TRIP detector was recorded using devices that can be turned on/ off by the respondents while driving. Plausible evolution of speed and lack of large

gaps caused by missed recordings were required to assure the extraction of complete trips (as opposed to junk parts). A state corresponds to a provisional qualification of the GPS records contained in the window being processed i.e. the tail of the sequence of GPS records inspected but not yet finally qualified. Such records cannot be qualified individually: the qualification collectively applies to all records.

5.1.3 Prompted Recall Tool- Web Application

The trips and stops generated by applying Stop and Trip detector do not give the information related to travel modes, trip purposes, and activity flexibility. These attributes are required by in assessing individual travel behaviour and further in designing various transport policies and interventions. Prompted recall survey has been conducted in the past to get the information from GPS recordings [*Doherty et al., 2006, Li and Shalaby, 2008*]. 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 [*Stopher et al., 2010*]. 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 figure 8. For each selected stop, individual will have to answer two main Questions.

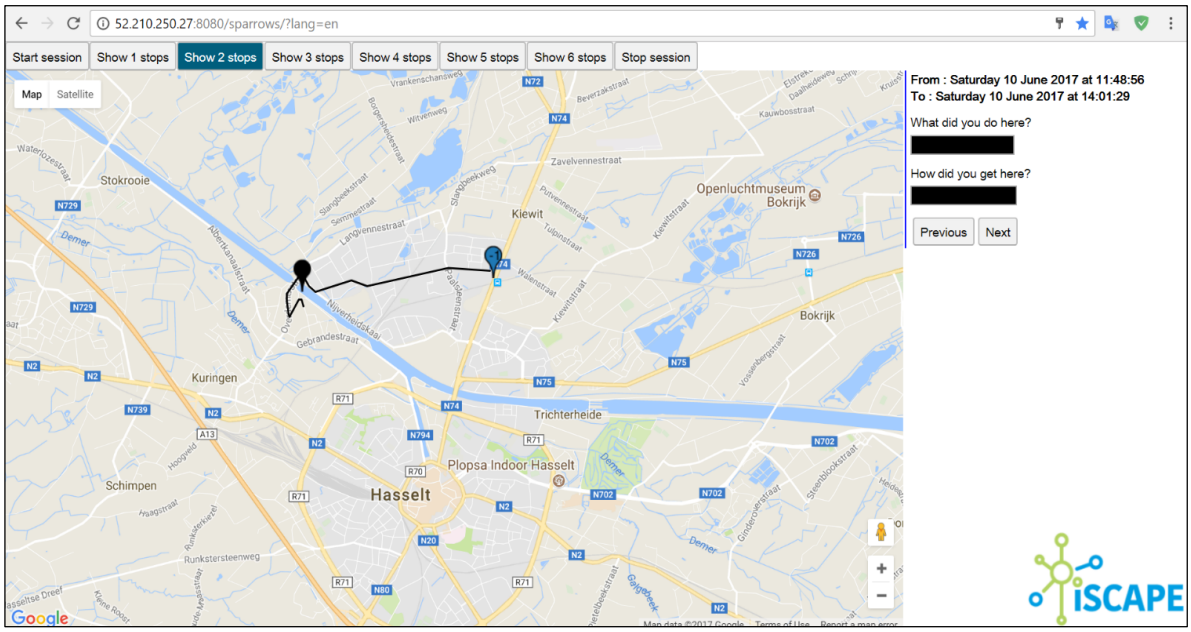


Figure 8: User interface of our Prompted Recall application

In this application, two screens have been developed i.e. for before login and after login.

1) **Login Screen:** The login screen was designed to provide just basic functionality. The user needs to enter his username and password for login. It provides the login functionality, with correct error messages when a wrong user name or password is entered. It is capable to remember the login name (and/or password) of a user. Hence, a user does not need to enter his username all the time.
2) **Prompted Recall Screen:** Prompted Recall screen was designed in such a way that an individual sees the map (based on Google Maps API) with some buttons on the top and Annotation window on the right of the screen. The purpose and functions of buttons and Annotation window are explained in below subsections.

5.1.3.1 Prompted Recall Screen: Buttons

Start Session: Starts the session, which means that all the not-yet-annotated episodes (combination of a trip and a stop) are loaded from the database and prepared to be shown in the application.

Show 1 stop: Shows the current episode.

Show 2 stops: Shows the current episode and the previous stop.

Show 3 stops: Shows the current episode and the previous and next stop.

Show 4 stops: Shows the current episode and the previous and next 2 stops.

Show 5 stops: Shows the current episode and the previous and next 3 stops.

Show 6 stops: Shows the current episode and the previous and next 4 stops.

End session: Closes the session and saves information which is not yet saved

The stop that has already annotated is shown with -1 and the selected stop that needs to be annotated is marked with 0.

5.1.3.2 Prompted Recall Screen: Annotation Window

When a user log in and start the session, he/she can see the annotation window on the right side of the screen. It shows the timestamp and annotation options associated with the stop blinking on the screen in black colour as shown in Figure 9.

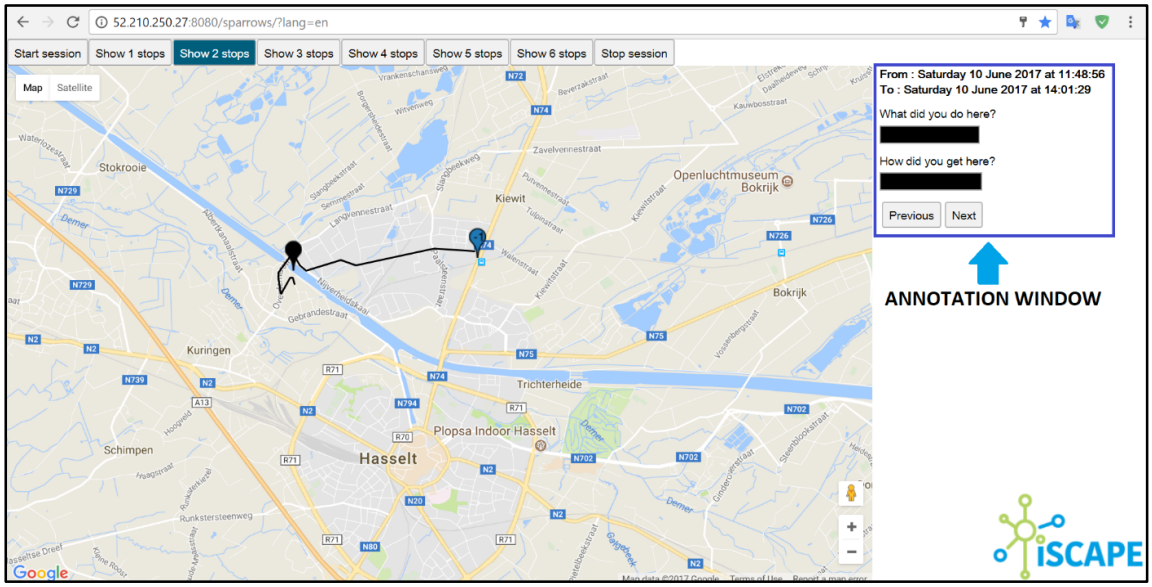


Figure 9: Annotation window (top right) showing timestamp and annotation options.

The questions shown in the data annotation windows are described as below.

- The purpose of the trip is explained by the question “what did you do here?”. The options given are none, home, work, business, bring/get, shopping, leisure, social, transfer/waiting, parking and services.
- Indoor\outdoor nature of the activity.
- Details about activity flexibility are recorded by selecting YES/NO. Beginning/ending of activity flexible means activity can start/finish early or later by half hour
- The travel mode is asked the question “How did you get here”. The options given are on foot, bike, moped, car (as a driver), bus, train, metro/tram, car (as a passenger), motor and taxi.

- If car (as a driver) or car (as a passenger) is selected as the mode of travel, fuel type will also be asked as shown in figure 10.
- If Bus or Train is selected as the mode of travel, Access or Egress modes will also be asked as shown in figure 11.

After giving responses to all the questions asked one can proceed further by clicking the "Next" button. There is also an option to go back to previous stop and change the response by clicking the "Previous" Button available in the Annotation windows.

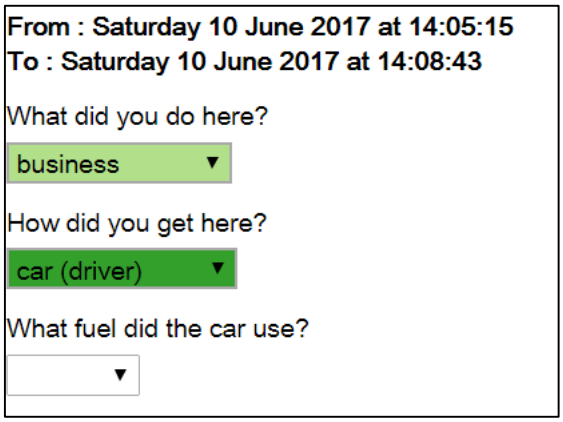


Figure 10: Annotation window showing question related to Fuel used

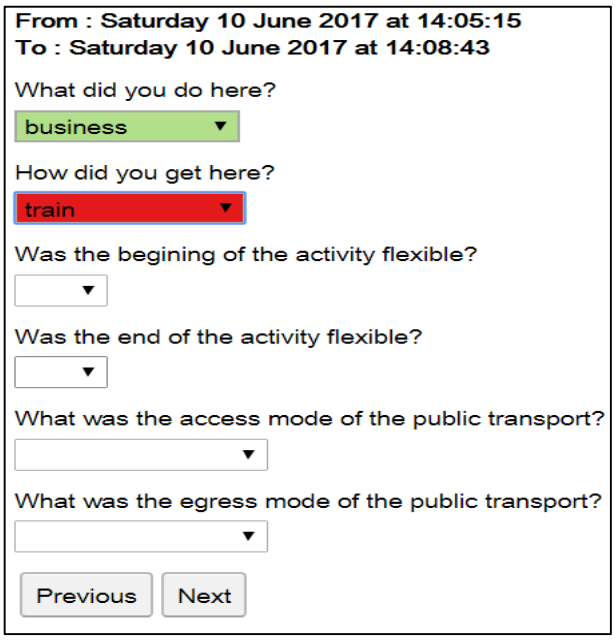


Figure 11: Annotation window showing questions related to access and egress mode used

5.2 Survey Questionnaire

The information regarding socioeconomic attributes and various personal traits such as attitude/values, perception and environmental awareness associated with travel behaviours is collected through a survey questionnaire. This method is considered appropriate for the study due to the expected large number of participants from different countries of Europe and UK. So, it is not feasible to collect required information by interviews or observations. 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. In 1st phase,

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 behaviour control, subjective norms and transport facilities are asked in the second section. In the third section, questions are designed based on human values and attitudes. Respondents PCE towards Pro-environmental behaviour 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 dependent variable. Independent variables (factors) are explained in section 5.2.1 with their operationalization. The questionnaire can be seen in Annexure-I.

5.2.1Independent Variables

Independent variables are categorized as socio-demographic factors, transport-related factors, external factors and internal factors. These factors are determined by certain indicators are explained below.

5.2.1.1 Socio-Demographic Factors

The socio-demographic factors selected in our study are Age, Gender, Nationality, Place of living, Employment status, Education, Income and household composition. Respondents are asked to mention their age in years and indicate their gender as male or female. Place of living is recorded by using two questions that are current address and how long the respondent is living at the current address. The education level is indicated on the scale from lower than secondary education to the doctorate. Employment status is noted by giving multiple choices question. Information regarding total household income per year is gathered by giving options ranging from less than 10,000 to 200,000 and up. Respondents are also answered the questions related to household size and composition. Operationalization of the concept " Socio-demographic factors" is expressed in Table 1.

5.2.1.2 Transport Related Factors

The factors explaining transport are driving behaviour, car ownership, in use car details and bike ownership. Driving behaviour is assessed by asking about possession of driving license or not and year of obtaining it. Respondents are asked to mention the number of cars from the scale of 0 to 4 and more. Furthermore, brand, model and fuel type of in use car by the respondent is acquired. Bike ownership is obtained by giving options of Yes and No.

Determinative Factor	Indicator/Measure	Questions	Scale
Socio-Demographical Factors	Age in years	Age?	Male Female
	Gender of the respondent	Gender?	Fill in the blank number
	Nationality	Nationality?	Fill in the blank response
	Place of living	Current Address? How long have you been living at the above address?	Fill in the blank response
	Present status of employment	Employment status Are you currently...?	Employed for wages Out of work but not currently looking for work Military Self-employed

			A homemaker Retired Out of work and looking for work Student Unable to work
	Level of education	What is the highest degree or level of degree you have completed?	Lower than secondary education Academic bachelor Secondary education or equivalent Academic Master Higher professional education Doctorate
	Income	What was your total household income before taxes during the past 12 months?	Less than 10,000 Euros 10,000 to 24,999 Euros 25,000 to 49,999 Euros 50,000 to 74,999 Euros 75,000 to 99,999 Euros 100,000 to 149,999 Euros 150,000 to 199,999 Euros 200,000 and up Euros Prefer not to answer
	Family setup and composition	Select one that describes your family setup best Your Family composition: Please provide no of person in the household	Single adult without children Couple with children Couple without children Other with children Single adult with children Other without children
Transport Related Factors	Driving behaviour	Driving License? When did you obtain a driving license?	Yes No Fill in the blank number
	No of cars	Number of Cars in your house? Car details (mostly) in your personal use: Brand Car details (mostly) in your personal use: model Car details (mostly) in your personal use: fuel type	0,1,2,3,4+ Fill in the blank Fill in the blank Diesel Liquid Petroleum Gas Compressed Natural Gas Diesel plugin Hybrid Petrol Petrol plugin Hybrid Electric Vehicle Hydrogen Vehicle
	Bike	Do you have a bike?	Yes No

Table 1: Operationalizing the concept " Socio-demographic and transport related factors" as independent variables

5.2.1.3 External Factors

The external factors are epitomised by situational factors as facilities and infrastructure accessible for performing Pro-environmental activity Travel Behaviour. These factors measure conditions and services available for behaving pro-environmentally. The respondents are asked to agree/disagree with five statements. The responses are judged on the scale from 1= strongly disagree to 5 = strongly disagree. Operationalization of the concept " External factors" is expressed in Table 2.

5.2.1.4 Internal Factors

Internal factors are explained by subjective norms, environmental awareness, intention to act, perceived behaviour control, human values and attitude and PCE toward PEATB.

Subjective norms measure the expectation of others to behave pro-environmentally in relation to activity-travel behaviour. 3 statements are provided with the scale of 1 being strongly disagreed to 5 strongly agreeing. Environmental awareness gives the indication of how much someone has knowledge about air quality, pollutant concentration levels, causes of pollution etc. the respondents are 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 behaviour control were based on TPB are measured with a scale ranging from 1 = strongly disagree to 5 = strongly agree.

Values/attitudes were categorized in 5 distinct groups as shown in table 2 and 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 behaviour. Perceived consumer efficacy is measured by 9 different statements on the scale 1 = Yes always, 2 = Yes, 3 = Very seldom, 4 = No and 5 = I don't know. .Operationalization of the concept " Internal factors" is expressed in Table 2.

Determinative Factor	Indicator/Measure	Questions	Scale
External Factors	Situational Factors Availability of facilities to act more pro-environmentally	1. There are opportunities available to change your daily routine which could lead to lesser exposure to pollution (e.g. change in activity location, flexibility in opening hours of shops) 2. Public transport (buses frequency, bus stop locations) in your area is good and you are satisfied with it. 3. Bicycle facilities (e.g. bike share programs, bike parking availability, safe and segregated bicycle paths) in your area is good and you are satisfied with it. 4. Pedestrians facilities (e.g. Footpaths, restricted traffic zones, zebra crossings, pelican signals, traffic observing priority to pedestrians) in your area is good and you are satisfied with it. 5. There should be more restrictions on the use of car in your area (e.g. speed control, Car free zones, increase in parking cost, increase of taxes etc.)	1= Strongly disagree 2 = Disagree 3 = Neutral 4= Agree 5= Strongly Agree
Internal Factors	Subjective norm regarding environment problem and solutions	1. Environment Pollution is a society problem, and everyone has to take part in it to resolve it. 2. The process of designing programs/activities/events for encouraging pro-environmental behavior also involve citizens. 3. I will be more inclined to behave pro-environmentally when peers/people in my neighborhood are also engaged in that behavior.	1= Strongly disagree 2 = Disagree 3 = Neutral 4= Agree 5= Strongly Agree
	Environmental awareness (Level of personal awareness)	1. Environmental Pollution is a problem in Hasselt (your area of residency) 2. Environmental pollution may affect your health 3. The environment is deteriorating, it is clearly notable and visible 4. Environment issues need to be considered properly, people who do not take this into account are escaping their responsibility 5. Humans have the right to modify the natural environment to suit their needs.	1= Strongly disagree 2 = Disagree 3 = Neutral 4= Agree 5= Strongly Agree

		6. Mankind is severely abusing the environment. 7. When humans interfere with nature, it often produces disastrous consequences. 8. We are approaching the limit of the number of people the earth can support	
	Intention to act (assessing intention to act pro-environmentally)	1. Given the opportunity, I would like to take action that is in line with pro-environmental behavior.	1= Strongly disagree 2 = Disagree 3 = Neutral 4= Agree 5= Strongly Agree
	Perceived Behaviour Control (measuring people's perception of their ability to perform PEB)	1. Whether I perform pro environmentally is entirely up to me. 2. It is worthless for the individual consumer to do anything about pollution.	1= Strongly disagree 2 = Disagree 3 = Neutral 4= Agree 5= Strongly Agree
	Human Values and attitudes (measuring Feelings and emotions attached to human nature)	Please rate to what extent these values are guiding principles in your life **Self-transcendence – Altruistic** 1. Social justice (Correcting Injustice, Care for the weak) 2. Equity (Equal Opportunity for all) 3. A world of peace (no wars, no conflict) **Self-transcendence – Altruistic – Environmentalism** 4. Protecting the environment (preserving nature) 5. Preventing pollution (conserving the natural resources) **Conservatism** 6. Self-discipline (resistance to temptations) 7. Family security (Safety for loved ones) **Self-Interest (Self-enhancement)** 8. Influential (Having an impact on people and events) 9. Wealth (material possessions, money) 10. Authority (the right to lead or command) **Openness to change** 11. Curious (interested in everything, exploring) 12. A varied life (filled with challenges, novelty, and changes 13. An exciting life (stimulating experiences)	-1= Opposed to my values 0 = not important 1 = Important 2 = Very Important 3 = Supremely Important
	Perceived Consumer Efficacy (measuring people's perception of their positive belief in their pro-environmental actions)	1. When I buy products, I try to consider how my use of them will affect the environment and other consumers 2. I try only to buy products that can be recycled. 3. When there is a choice, I always choose that product which contributes to the least amount of pollution. 4. To save energy, I drive my car as little as possible. 5. I try to buy energy efficient household appliances 6. If I understand the potential damage to the environment that some products can cause, I don't purchase these products	1 = Yes always, 2 = Yes 3 = Very seldom 4 = No 5 = I don't know

		7. I buy high-efficiency light bulbs to save energy 8. I usually purchase the lowest price products, regardless of its impact on society. 9. I have convinced members of my family or friends not to buy some products which are harmful to the environment.	

Table 2: Operationalizing the concept " External and internal factors" as independent variables

5.3 Stated-preference Instrument

This instrument primarily depends on the stated preference technique, commonly applied in the areas of marketing and travel demand modelling. It is an effective way to analyse individual evaluation of products and services having multiple attributes, especially when there are hypothetical choice alternatives and new attributes are considered[*Yang et al., 2009*]. In this method, discrete combinations of attributes and their levels are produced, that respondents evaluate in the choice questions. In our study, we want to assess the effect of air quality on the travel behaviour of an individual based on multiple attributes. So, keeping in view the applicability, SP method is best suited to get the desired objectives.

The designing of SP Preference instrument consists of a selection of attributes with appropriate levels and creation of scenarios from them. There are four modes of transport i.e. car, PT, walk, and bike under consideration. So, in each choice set, there is maximum of four possible alternatives based on the context. Further, the attributes attached with each alternative is not same (e.g. access and egress mode are applicable to PT modes only, physical activity level is associated with a walk and bike modes etc.). therefore it is a very challenging task to develop this tool keeping in view the different attributes associated with four alternatives. Our approach is to select one work and shopping trip randomly from the participant recorded movements and based on the context, different scenarios are given to him/her. The challenge behind this is to accommodate the availability of modes (not all modes are available for that particular trip) and the base value of attributes for a certain mode (which are context dependent). Further, the success of this tool is to present the scenarios realistically so that potential biases in the data are minimized. The procedure of attributes selection with appropriate levels and development of scenarios for each alternative is discussed in detail in the following section.

5.3.1Selection of Attributes and Levels

The common context based attributes associated with alternatives are Travel time, Travel cost, Departure Time and Arrival time. The effect of departure and arrival time with travel duration and cost is self-evident in the selection of travel mode form the different studies in the past. As mentioned above one trip related to work and shopping is selected from individual activity-travel dairy. The selected trip is then examined in the Google maps at the same time of the day when that trip was actually performed and different travelling options have been recorded. Based on these contextual and other attributes as mentioned in table 3, scenarios are created using fractional factorial design, within which some higher order interaction among attributes levels are ignored. Annexure-III presents the complete SP survey designed for a particular participant for your ready reference.

Attributes	**Levels**			
	Car	**PT**	**Bike**	**Walk**
Arrival Time	Context-based			
Departure Time	Context-based			
In vehicle Travel Time	Context-based			

Travel Cost	Context-based		-	-
Access time	-	Context-based	-	-
Egress time	-	Context-based	-	-
Segregated bike lanes	-		None, Half, Full	-
Air pollutant level	Low, medium, high			
CO_2 emissions	Context based	-	-	-
Physical activity level	-	Context-based	Context-based	Context-based
Temperature	-	0°C, 10°C,20°C	0°C, 10°C,20°C	0°C,10°C,20°C
Rainfall	-	Yes, No	Yes, No	

Table 3: Attributes and their levels for SP Experiment

6 Hasselt Case Study

This section presents the detailed process of the study conducted as part of Hasselt Living Lab activities. Through this study the required data has been collected and also a behavioural intervention study is being tested by active engagement of Hasselt citizens. Before carrying out this study with Hasselt citizens, a pilot study has been conducted with the Hasselt University students to ascertain consistency of various tools and information provided in the intervention pack. Considerable revisions are made in the survey instruments and also in information material to make them easy to understand. The following sections describe the various steps of the study and analysis of collected data.

6.1 Citizens Recruitment Process

The first step towards implementing the study is to recruit citizens of Hasselt. For this purpose, help from the key stakeholder for the Hasselt living lab i.e. Stad Hasselt (Hasselt City) was sought. A brain storming meeting was held with the stakeholder representative to formulate the ways to recruit citizens. It has been decided to float the news regarding the study on various forums used by communication department of Stad Hasselt. A news was afloat in the Monthly magazine “Hasselar” of May 2017 regarding the study with the message that interested citizen can contact directly to get more practical knowledge of the study. This monthly magazine is very popular among the residents of Hasselt and it is distributed free to each household within Hasselt containing important announcements, news about the activities planned in the coming months and also some features and articles that increase the knowledge base of the citizens. Some interesting achievements of the Hasselt citizens are also shared with the community. Figure 12 presents the snapshot of the page of the magazine, where the announcement of the study has been published. In addition to this, more details of the study are also published on the Stad Hasselt website (www.hasselt.be/iscape). It is important to note that all the information provided to the citizen is in their local language i.e. Dutch.

Additionally, the same news was floated on other environment monitoring forums and volunteer organizations utilising the contacts of Hasselt University. A study brochure was also designed and prepared to distribute to these organization. The brochure can be seen in Annexure-IV. As per the news, the target audience is the adult citizens of Hasselt, who have Android-based smart phones and are willing to take part in the month-long study, planned to start in the month of June. We did not restrict the participation of citizens on any other demographic characteristic. 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 smart phone and have sufficient knowledge of e-mail based communication. Due to the same

reason, the recruitment process was designed in such a way that interested individuals are required to contact us via e-mail. In the month of May, we received about more than 70 e-mails from the interested citizens and they were provided further details of the study. As a plan B for recruitment of citizen, it is planned to participate in one of the Stad Hasselt programme where citizens are invited, and using this forum to recruit citizens by explaining them the study details at the same time. However, it was not materialized, as the response from the first strategy was overwhelming.


de nieuwe Hasselaar
#4 – mei 2017 – jg 42
STADSMAGAZINE HASSELT
NIEUWS
Halt aan fijn stof
Wist je dat je levensverwachting met twee jaar verkort als je in een stad woont? Het fijn stof dat veroorzaakt wordt door gemotoriseerd verkeer, is de belangrijkste boosdoener. Hoog tijd voor actie dus! En jij kan je steentje bijdragen. UHasselt is op zoek naar Hasselaren die willen deelnemen aan het Europese iSCAPE-project. De bedoeling is om via individuele coaching je verplaatsingsgedrag bij te sturen én zo 'jouw' persoonlijke luchtvervuiling terug te dringen. Interesse? Je moet enkel beschikken over een Androidsmartphone, waarmee je jouw verplaatsingen registreert, én genoeg motivatie om het experiment minstens drie weken vol te houden. Alle deelnemers worden beloond. Doe je mee?
www.hasselt.be/iscape
iscape@uhasselt.be

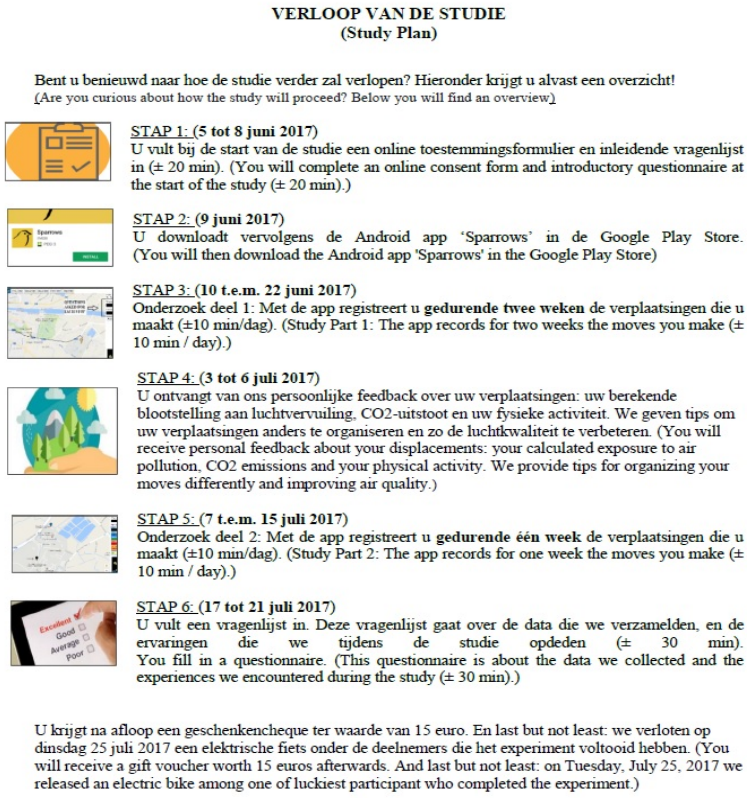
Figure 12: Snapshot of the Hasselt Monthly Magazine where news about the study is published (Stadsmagazine Hasselt 2017, pp: 5).

6.2 Implementing behavioural intervention study

Interested participants in the study 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 study was also approved by the Ethical Commission of the Hasselt University, as it uses personalized data of the citizens. The recruitment of the citizens is confirmed when the consent form is returned by the individual. The consent form indicated a clear message to the citizens that all data will strictly use for research purposes, and it will be anonymised in various aspects so that citizen identity is intact. The schedule of activities that each participant received also contains an announcement that at the end of the study each citizen

will receive a gift voucher of 20 Euros, along with that they are part of the lucky draw, which gives them the opportunity to win an Electric Bike. This schedule can be viewed from figure 13. In total, 53 citizens were recruited for this study.

The study plan described in Figure 13 is very concise, the detail information regarding each step is provided to each participant when that particular activity is 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 is provided, if the citizen has requested. A complete set of instructions regarding each step is also sent via e-mail to each participant. It is noted that most of the help is requested during the annotation phase for the recorded activity-travel routine. In addition to this, out of those 53 participants, we have randomly chosen 15 participant's to be part of a control group. These control group participants were not received any information pack (i.e. step 4 of figure 13), they are provided a slightly different study plan compared to the one shown in Figure 13. i.e. In their study plan, step 4 is missing.



VERLOOP VAN DE STUDIE
(Study Plan)

Bent u benieuwd naar hoe de studie verder zal verlopen? Hieronder krijgt u alvast een overzicht!
(Are you curious about how the study will proceed? Below you will find an overview)

STAP 1: **(5 tot 8 juni 2017)**
U vult bij de start van de studie een online toestemmingsformulier en inleidende vragenlijst in (± 20 min). (You will complete an online consent form and introductory questionnaire at the start of the study (± 20 min).)

STAP 2: **(9 juni 2017)**
U downloadt vervolgens de Android app 'Sparrows' in de Google Play Store. (You will then download the Android app 'Sparrows' in the Google Play Store)

STAP 3: **(10 t.e.m. 22 juni 2017)**
Onderzoek deel 1: Met de app registreert u **gedurende twee weken** de verplaatsingen die u maakt (±10 min/dag). (Study Part 1: The app records for two weeks the moves you make (± 10 min / day).)

STAP 4: **(3 tot 6 juli 2017)**
U ontvangt van ons persoonlijke feedback over uw verplaatsingen: uw berekende blootstelling aan luchtvervuiling, CO2-uitstoot en uw fysieke activiteit. We geven tips om uw verplaatsingen anders te organiseren en zo de luchtkwaliteit te verbeteren. (You will receive personal feedback about your displacements: your calculated exposure to air pollution, CO2 emissions and your physical activity. We provide tips for organizing your moves differently and improving air quality.)

STAP 5: **(7 t.e.m. 15 juli 2017)**
Onderzoek deel 2: Met de app registreert u **gedurende één week** de verplaatsingen die u maakt (±10 min/dag). (Study Part 2: The app records for one week the moves you make (± 10 min / day).)

STAP 6: **(17 tot 21 juli 2017)**
U vult een vragenlijst in. Deze vragenlijst gaat over de data die we verzamelden, en de ervaringen die we tijdens de studie opdeden (± 30 min). You fill in a questionnaire. (This questionnaire is about the data we collected and the experiences we encountered during the study (± 30 min).)

U krijgt na afloop een geschenkencheque ter waarde van 15 euro. En last but not least: we verloten op dinsdag 25 juli 2017 een elektrische fiets onder de deelnemers die het experiment voltooid hebben. (You will receive a gift voucher worth 15 euros afterwards. And last but not least: on Tuesday, July 25, 2017 we released an electric bike among one of luckiest participant who completed the experiment.)

Figure 13: Study Plan (English translation is provided in bracket)

6.2.1 Available data for Analysis

This section presents the other available data that is used for analysis, mainly for producing customized informational pack for the participants. Along with the emission factors and factors related to different microenvironments for estimating appropriate exposure estimates, the major data regarding pollutant concentrations are obtained from open source data available on www.irceline.be. For the four pollutants such as PM_{10}, $PM_{2.5}$, O_3 and NO_2 concentration data in $\mu g/m^3$ at a resolution of 1x1 km grids for entire Belgium region and for each hour of the day is extracted from the given application program interface (API). According to the website, these concentration maps are developed using coupled RIO-IFDM model. This model couples the land use regression model RIO, the road emissions model MIMOSA4 (taking into account COPERT4 emission functions, vehicle fleet and vehicle

counts), and the Gaussian plume model IFDM. The latter is used to include large concentration variations near the major air pollution sources, such as roads and point sources. The model has been validated extensively for the discussed region [*Lefebvre and Vranckx, 2013*]. An example, of the GIS-based maps available from the API is shown in Figure 14.

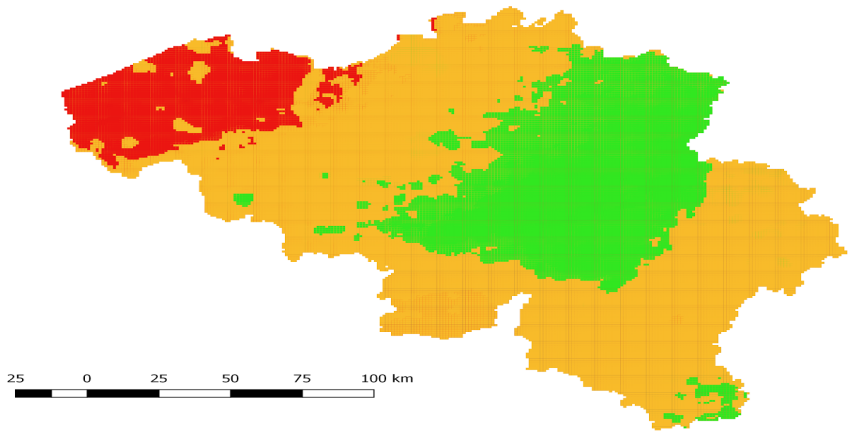


Figure 14: Spatial distribution of hourly concentration of O_3 (source: www.irceline.be)

The exposure is estimated by assigning each GPS co-ordinate with the nearest 1X1 km grid cell pollutant concentration. As GPS data contains exact time-stamp to the nearest second, for an entire hour of these time-stamp we have assigned a single value of concentration because pollutant data is available for each hour. Similar data has been used by [*Dewulf et al., 2016*], where dynamic exposure has been estimated using data from the mobile phone networks. The methodology can be refined further if more finer resolution data is available both in terms of time and space.

6.3 Analysis and Key Findings

This section highlights the main findings from the study implemented in Hasselt. Analysis of different data sets collected during the study is presented in detail. Along with the descriptive and qualitative analysis of the data, path model is also estimated that provide key results on which information intervention study is based. Effectiveness of informational based behavioural intervention is also presented.

6.3.1Descriptive Analysis

This section highlights key socio-demographics characteristics and views of the study participants on various internal and external factors. Some of these key characteristics will be correlated with PEATB, and also used in discrete choice model estimation for task 4.2. Table 4 and 5 presents the distribution of socio-demographic characteristics.

Variables/ Characteristics	Description and Statistics
Gender	• Male 65% • Females 35%
Age (in years)	No of participants expressed in percentage with respect to age group is summarized as below:

	• Less than 18 years 00 % • B/W 18-30 years 35 % • B/W 31-44 years 32 % • Greater than 44 years 33 %
Nationality	Majority of the people (72%) who participated in the survey are from Belgium. 28% of participants were non-European. The participants from Europe other than Belgium who took part in the survey are 2%.
Employment status	• Employed for wages 56 % • Out of work & looking for work 0.2 % • Retired 11 % • Self-employed 0.4 % • Student 26 % • Unable to work 0.2 %
Education status	• Secondary Education 13% • Bachelor 17% • Academic bachelor 15% • Academic Master 51% • Doctorate 02% • Higher Professional Education 02%
Household Income	Participants are categorized in percentage w.r.t total household income before taxes during past 12 months as: • less than 10,000 € 04% • 10,000 to 24,999 € 26% • 25,000 to 49,999 € 20% • 50,000 to 74,999 € 11% • 75,000 to 99,999 € 15% • 1,00,000 to 1,49,999 € 07% * People who didn't prefer to answer are 17%.
Family Setup	46% respondents are living with children and 54% without children. Further breakdown are as follows: • Couple with children 31% • Couple without children 28% • Other with children 0.6% • Other without children 0.2% • Single adult with children 0.9% • Single adult without children 24%
Total Family Members	Participants are grouped with respect to family size (expressed in numbers) as: • 01 member 33% • 02 members 33% • 03 members 0.6% • 04 members 20% • 05 members 0.4% • 06 members 0.2% • 07 members 0.2%

Table 4: Socio-Demographic characteristics distribution of study Participants

Table 4 provides an interesting detail, it can be noted that around similar % of citizens in terms of the 3 age groups have participated in the study. However, female participation is at the lower side compared to males. Majority of participants have education status equivalent to bachelor's degree or above (i.e.87%), however, income distribution seems more uniform. Table 5 also presents some key interesting statistics regarding the study participants, which may influence their travel habits. 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. Majority of the car are based on Diesel fuel, which is cheaper and is considered more efficient in terms of mileage compared to Petrol. In the next section, some of these key characteristics are co-related with their travel behaviour.

Variables/ Characteristics	**Description and Statistics**
Driving License	Most of the people (78%) had a driver license and substantial number (22%) did not have it.
Car ownership	35% participants do not have ownership of car. 33% of the respondents have their own car. People having 2 or more cars are 32%.
In use Car model	Only 3% participants have car models built before 2005. Respondents having car models between 2005 – 2010 and 2015 - 2015 are 40% and 34% respectively. 23% subjects own car models later than 2015.
In use car fuel type	Participants are grouped in percentage based on the fuel type of the car in use. • Diesel 63% • Petrol 34% • Petrol hybrid 03% • Diesel Hybrid 00% • Electric 00% • Compressed Natural Gas 00% • Liquid Petroleum Gas 00% • Hydrogen 00%
Bike ownership	91% of the respondents have bicycle and around 9% in comparison did not have any cycle.

Table 5: Travel related characteristics distribution of study Participants

Figure 15, 16, 17, 18, 19, and 20 presents the distribution of responses of individuals in relation to internal and external factors as described in table 2. In Figure 15, where indicators of environmental awareness are gathered and distribution of individual responses are shown, indicate that majority of the respondents have understanding of the environmental issues (such as Q.26, Q.27, Q.32) and also have an opinion that humans should take responsibility to improve the environmental condition (Q. 28, Q.29). However, it is noted around 60% of the citizens are agree that environment pollution is a problem in Hasselt and only 10% are disagree with the statement.

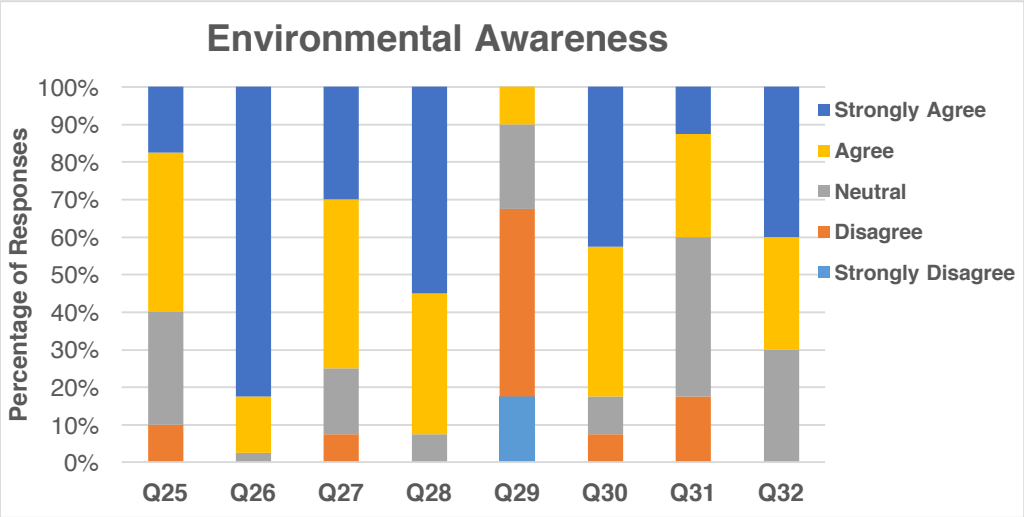


Figure 15: Distribution of responses on indictors of Environmental Awareness

Figure 16 highlights the opinion of individuals in relation to those indicators that are gathered under situational factors (can be considered as an external factors). Respondents showed mixed views about the facilities available to adopt more pro-environmental travel behaviour options, such as public transport, bicycle and pedestrian facilities (Q. 40, Q.41, Q.42, and Q.43). Respondents also have an opinion that car use should be more restricted by taking some hard policy measures, however, 30% respondents have shown disagreement on this. This clearly depict the situation that there is more room to improve the facilities that encourage pro-environmental travel behaviour among individuals in Hasselt. Figure 17, indicates that how strongly individuals feels about resolving the environmental issues together (as a society). Furthermore, 60% of the individuals indicated that they may be more inclined to behave pro-environmentally, if their peers are also involved in such actions. This clearly suggests that subjective norms (especially social norms) are important to be considered intervention programs.

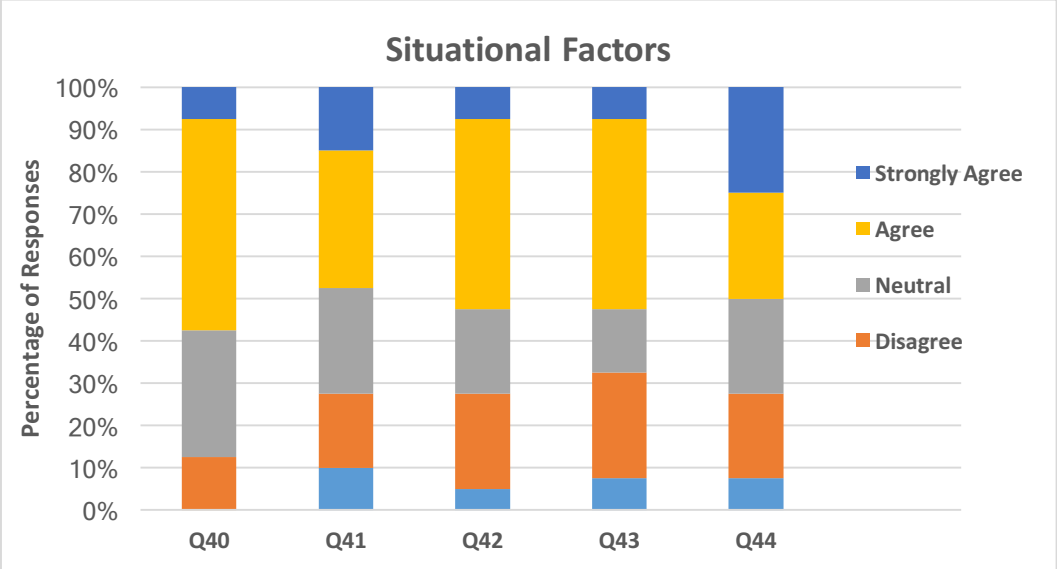


Figure 16: Distribution of responses on indictors of Situational Factors

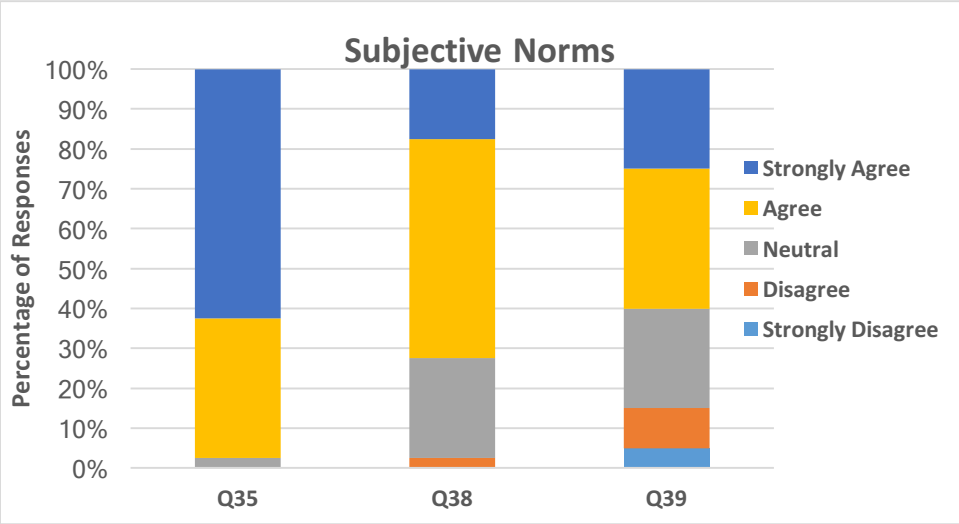


Figure 17: Distribution of responses on indictors of Subjective norms

Figure 18 presents individual's responses about indicators representing perception about ability to perform pro-environmental behaviour (i.e. PBC). Response distribution of Q.36 shows that individuals have strong belief that their contribution in terms of behavioural change can bring positive change and such an action can be easily be done.

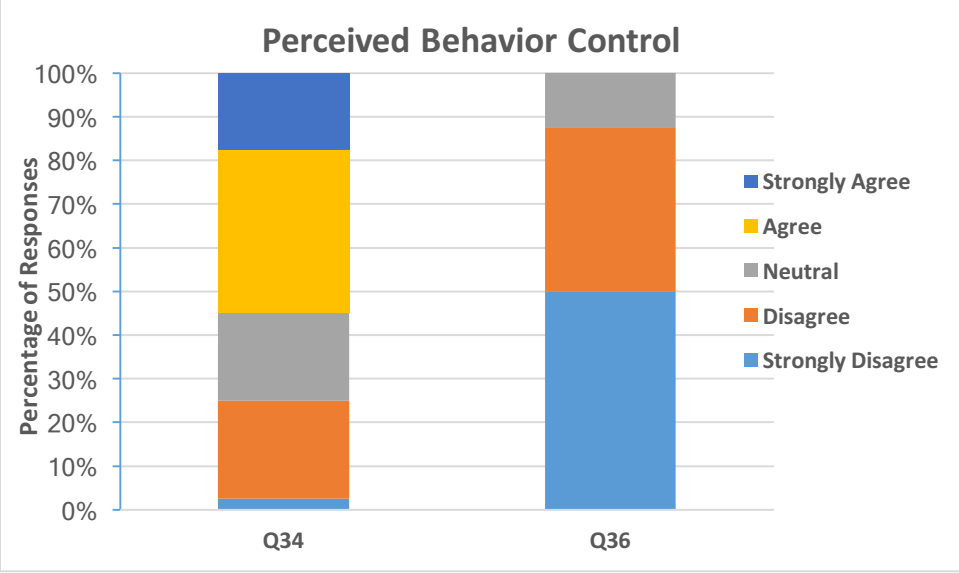


Figure 18: Distribution of responses on indictors of Perceived behavioural control

Human values and attitudes related indicators response distribution is shown in Figure 19. Respondents seems so to be more altruistic (Q.45, 46, 47, 48,49) and less around themselves (Q.50, 51, 52, 53, 54). Furthermore, they are also more open for adaptation (Q.55, 56) but the variation should not be very extreme (Q.57). In Figure 20, responses for indicators on PCE are gathered. Majority of the respondents carried out environmental conservation behaviour in relation to buying various consumable products, which indicates that individuals are positive in regard to that and believe that their actions bring positive change in environment. The path model estimated using this data may be more useful to see which factors are important in explain PEATB.

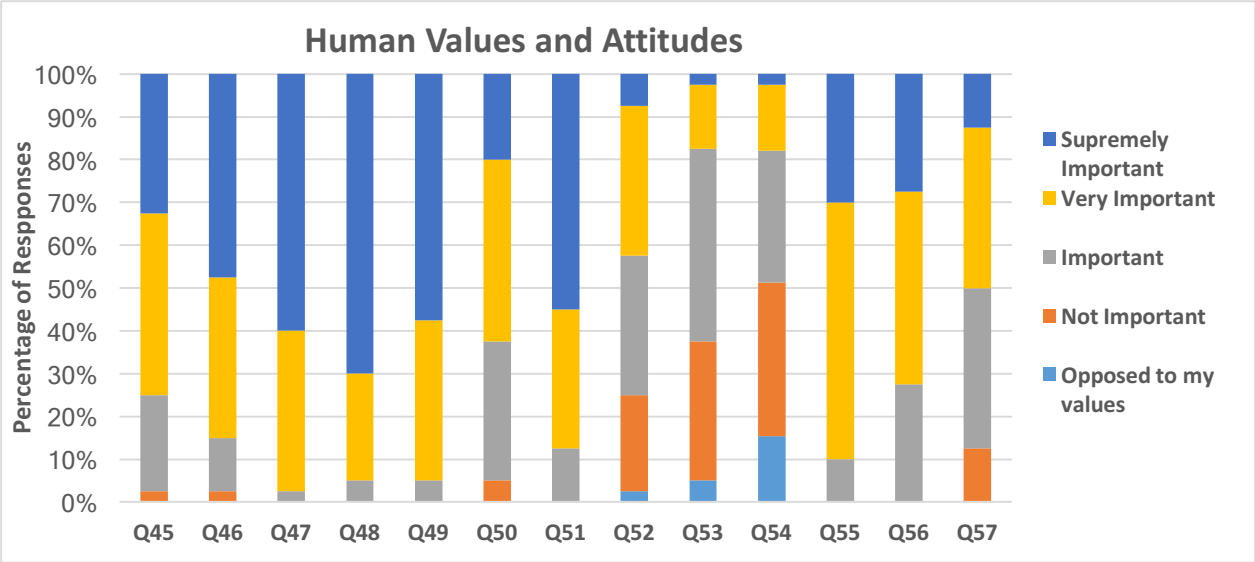


Figure 19: Distribution of responses on indictors of Values and Attitudes

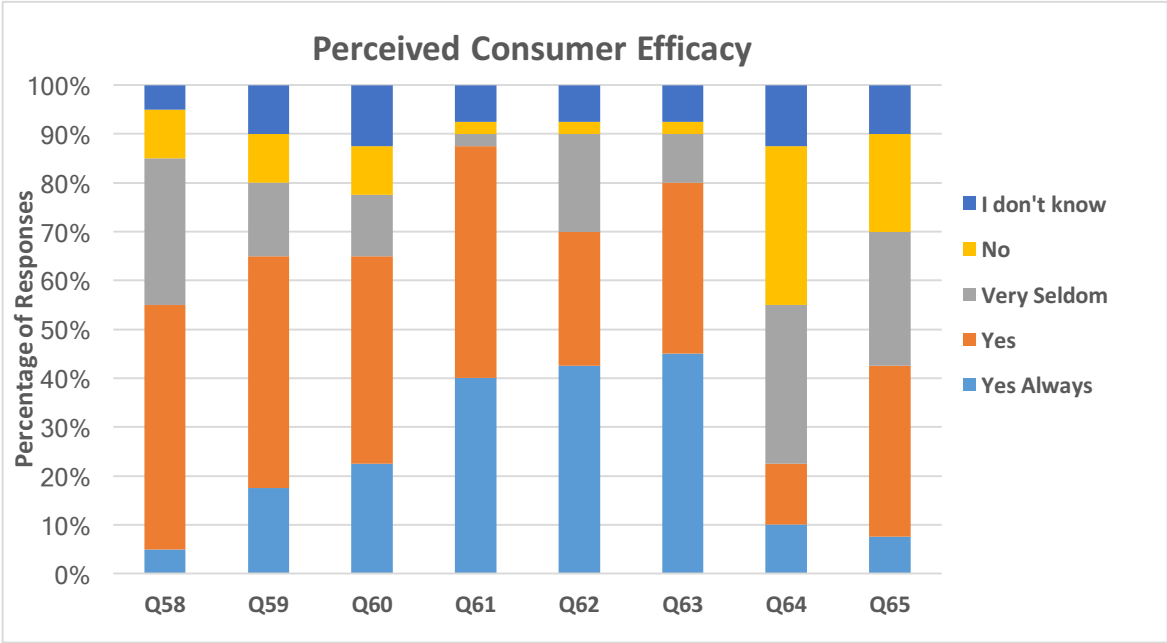


Figure 20: Distribution of responses on indictors of PCE

6.3.2Estimation of Path Model

Based on the general conceptual Path model of PEATB discussed in Section 4.1, Path model for Hasselt study has been developed by incorporating the context based information in the model which better indicates the relationship of identified factors and determinants with PEATB. Estimation of the model is done using Partial Least Square –Structural Equation Modelling (PLS-SEM) method considering exploratory factor analysis. SmartPLS software has been used in predicting the strength of each factor influencing PEATB, which is also used in many studies such as [*Schoenau and Müller, 2017, Wong, 2013*] . The estimated model showing the factor loadings to a particular latent construct, path co-efficients and R^2 values are presented in Figure 21.

In order to test the consistency of the path model, it is first required to see the result of the association of factors with the latent variables (For example, how good the indicators considered to represent Attitude, are relevant to this latent variable). There are various measures for this, such as Cronbach's alpha (Alpha), Composite reliability scores (CR) and Average variance extracted (AVE) of the latent variables. Values higher than 0.5 are representing good association. Table 6 presents these values for the path model presented in figure 15. All measures have values 0.5, therefore, latent variables and factors chosen to present them have good association. In addition to this, cross loadings are also observed, i.e. association of a particular factors with other latent variables. It has been found that no factors have a high correlation with other latent variable than the variable with which it is already associated as shown in figure 15. So, the discriminant validity of the constructs is confirmed. Global validity and explaining power of the model is assessed to explain Goodness of fit (GoF) index. The equation to measure GoF index as:

$$GoF = \sqrt{(\text{Avg. AVE x } R^2)}$$

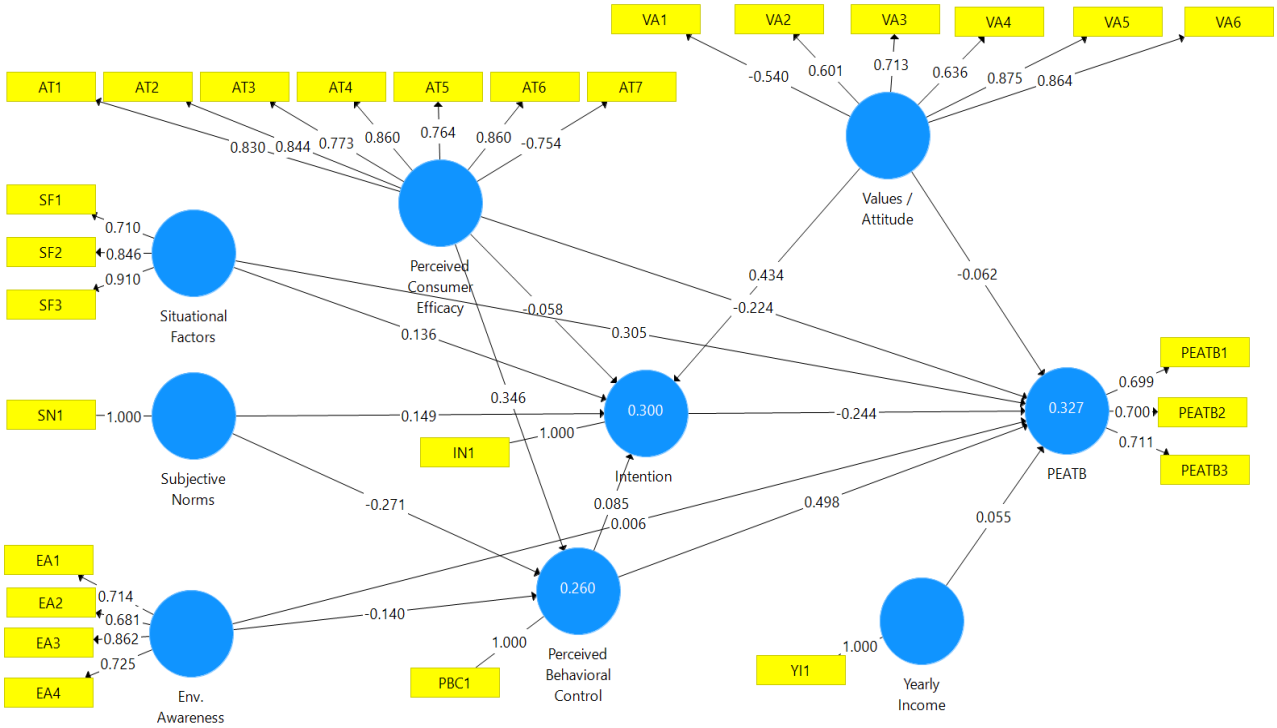


Figure 21: Path Model Estimation Results, Factors loading, Path co-efficient and R^2 Values

Latent Variable	Alpha	CR	AVE
Attitude	0.74	0.88	0.661
Subjective Norms	1.00	1.00	1.00
Values	0.66	0.77	0.52
PBC	1.00	1.00	1.00
Env. Awareness	0.75	0.84	0.56
Situational Factors	0.78	0.87	0.68
Intention	1.00	1.00	1.00
PEATB	0.65	0.75	0.51

Table 6: Latent Variable and Factors Association

R^2 for the estimated path model is 0.327, and Avg. AVE is around 0.74, So, GoF is estimated to have a value of 0.49. This value is higher than 0.36, which is the cut-off value for the substantial model [Wong, 2013]. This confirms that estimated path model is substantial in explaining the PEATB.

Perceived behaviour control (PBC), Situational factors, Intention to perform a PEATB are all found to have stronger impact on PEATB. The path starting from PCE to PBC and then to PEATB is the strongest among all paths. This is consistent with the findings of previous studies. It is therefore, vital that behavioural intervention should consider notions of PCE and PBC. Behaviours should be easy for individual and also individual should have belief that his actions improve the environmental conditions. Attitudes/values have +ve effect on intentions for PAETB, which is certainly need to address in informational campaigns. Increasing fact based knowledge may provide meaningful impact in this regard. Subjective norms have +ve impact on intentions, therefore it is required to include this aspect in designing informational strategy. Other relationships are found insignificant in the path model.

Keeping the above-mentioned results, attempt have been made to address PCE and PBC, along with providing fact based knowledge and awareness regarding individual owns action in terms of their effect on environment. Additionally, information related to peers are also provided to include aspects of subjective norms in the informational strategy.

6.3.3Results on Environmental effects of Behavioural Actions

This section presents the results of various analysis performed on the activity-travel routine to develop an individual oriented information pack as a behavioural intervention. Some collective results of those analysis are presented here.

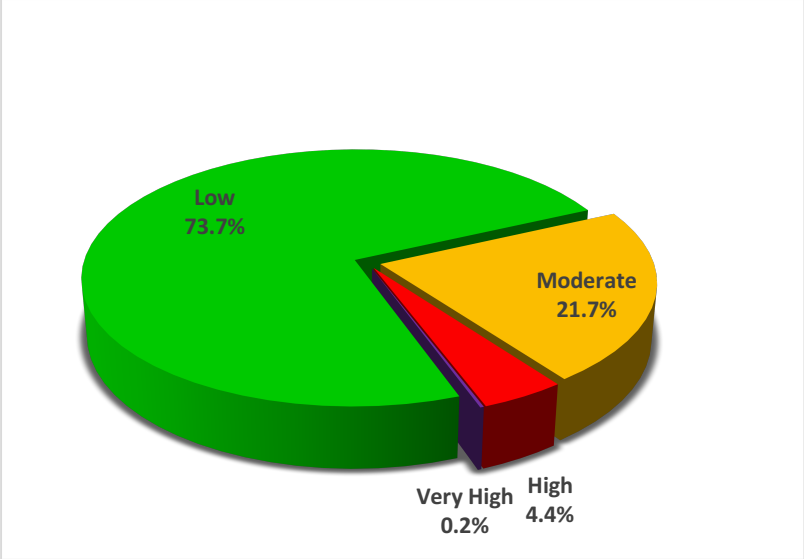


Figure 22: Exposure distribution of all participant during the study period – Before intervention stage

Figure 22 presents the exposure distribution in 4 different categories of pollutant concentration based on cumulative hours of an entire week data for all participants of the study (in percentage). During the study period, Ozone concentration level was found more severe than other pollutant considered (based on their threshold limits), therefore results are only shown for Ozone only. 4 different levels of pollutant concentration as indicated in other studies. Such as low, moderate, high and very high (These are combination of 10 different levels proposed in terms of AQI). It can be seen that majority of the cumulative hours are exposed to low and moderate level of pollutant concentration, however, for only few hours (i.e. 4.6% of the total) some citizens of Hasselt are exposed to high and very high category of

ozone concentration levels. The results are also compiled in terms of descriptive statistics measure for all participants of the study. These are shown in table 7.

Statistics	Exposure Levels			
	Low	Medium	High	Very high
Mean	58.70	17.48	3.14	0.16
Median	61.43	17.27	1.73	0
SD	21.24	8.1	4.01	0.28
Range	75.68	38	18.38	1.17
Minimum	9.35	0.1	0.1	0
Maximum	85.03	38.1	18.48	1.17

Table 7: Descriptive statistics of hours exposed for different exposure levels

These descriptive statistics measures provide more idea of the distribution of hours in different exposure levels. The mean values for low and medium exposure levels are considerably higher compared to high and very high. Figure 23, presents the details of exposure for each participant in the study based on which table 7 was derived. The variation in each levels of exposure can be explained by each participant movements in space and time.

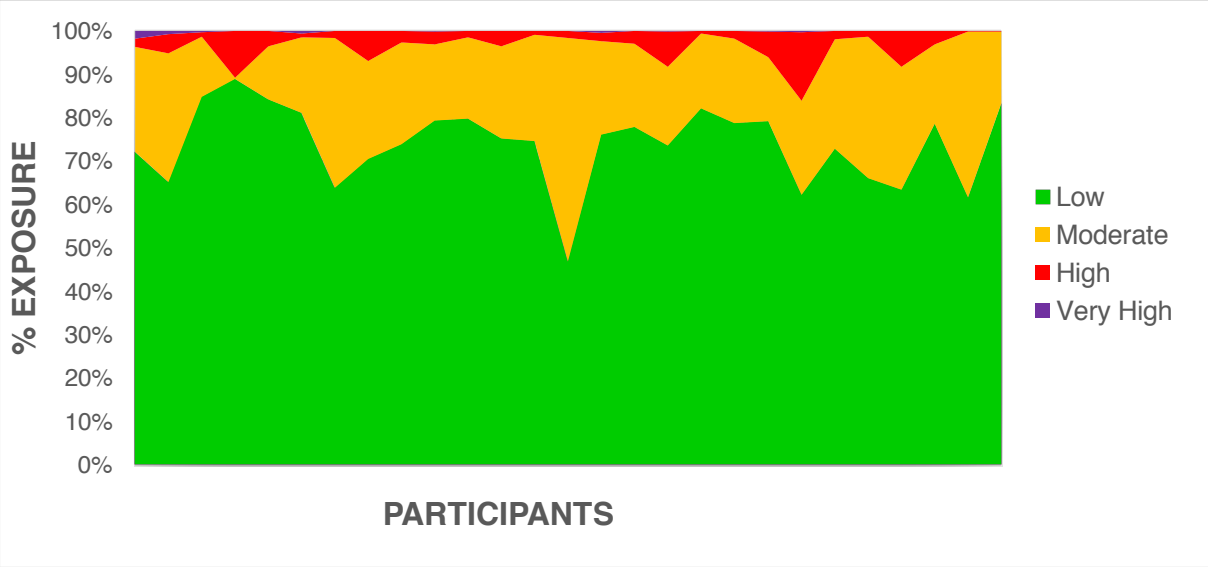


Figure 23: Exposure distribution of all participants during the study period – Before intervention stage

In terms of Physical activity level, table 8 presents some descriptive statistics measure of overall involvement of all study participants in walking and cycling in minutes. Cycling is being found more popular among citizens of Hasselt compared to their involvement in Walking. However, the zero-minimum value in both active travel mode, show that there are individuals for which there are no trips recorded using these modes. Figure 24, shows per participant involvement of physical activity in minutes, where it can be seen that there are two participants who are not involved in physical activity (both active travel modes lines are touching zero axis twice).

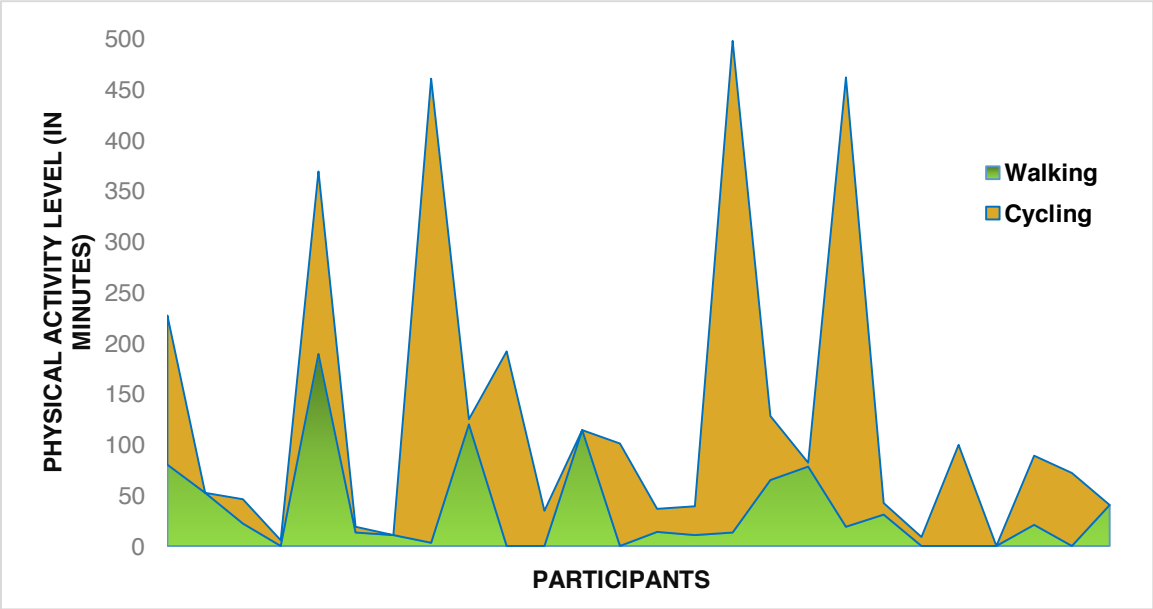


Figure 24: Physical activity involvement of all participants during the study period – Before intervention stage

Statistics	Walking (min)	Cycling (min)	Total
Mean	34.50	94.58	129.07
SD	47.43	146.43	150.04
Range	189	485	498
Minimum	0	0	0
Maximum	189	485	498

Table 8: Descriptive statistics of participant involvement in Physical activity for an entire week – Before intervention

Participant car use in terms of their contribution to CO_2 emission is also estimated and some descriptive measure in terms of all study participants and participants who have used car at least once for their trips during the study period. These results are shown in table 9. It can be noted that mean value is different for both cases because some participants did not use Car entirely in the study period. It can be seen that minimum value of CO_2 emission is 396 grams, which entails that few participants may use Car only to a limited extent. Table 9 also presents an estimation of a number of cold starts from all participants, it does not include cold starts involved in the first trip of the day and also the cold start after the mandatory work activity. The mean value is more than 4 for car users, and therefore there is a potential to reduce some of them.

Statistics	CO2_emissions (grams) (All Participant)	CO2_emissions (grams) (Car Users)	Number of Cold Starts (All Participants)	Number of Cold Starts (Car Users)
Mean	8285	11967	3.19	4.61
SD	10809	10872	3.31	2.94
Range	39925	39529	9	8
Minimum	0	396	0	1
Maximum	39925	39925	9	9

Table 9: Descriptive statistics of participant Contribution in CO_2 and number of Cold Starts for an entire week – Before intervention

Based on these results, it can be seen that there is a significant potential in terms of encouraging the individual to perform their travel behaviour which is more pro-environmental. Therefore, above measures are correlated with travel behaviour to draw some meaningful suggestions for citizens of Hasselt. Table 10 provides the summary statistics of Car usage for all participants of the study.

Statistics	Car Trips Composition					
	Trips Within 1 km	Trips Within 1 km replaced by walk	Trips Within 3 km	50 % Trips Within 3 km replaced by bike	Total trips	50 % Total Trips replaced by PT
Sum	0	0	82	44	192	80
Mean	0	0	3.28	1.76	7.68	3
Std. Deviation	0	0	4.53	2.27	9.86	4.91
Variance	0	0	20.54	5.27	96.73	24.08
Range	0	0	13	7	30	10
Minimum	0	0	0	0	0	0
Maximum	0	0	13	7	30	10

Table 10: Descriptive statistics of participant Car Usage characteristics and its replaceable potential

Table 10 provides some interesting insights in order to provide suggestion to citizens. It should be noted that citizens are not using Car for the trips which are limited to 1km or less, perhaps the availability of Car creates a tendency to involve in trips which are of distance greater than 1 km. Furthermore, it is noted that a considerable number of trips are performed within 1- 3 km range, and there is a potential to replace them by bike. Similarly, Car trips can be replaced by Public transport, the numbers reported in the last column is based on the availability of this mode, considering the flexibility options of the consequent activities and reasonableness of travel time. 50% of those replaceable trips are shown. This table shows that there is a significant potential in terms of environmental benefits if individuals are encouraged to change their behaviour. Impacts of changing behaviour are also estimated in terms of reduction of their exposure to higher categories CO_2 emission and a number of cold starts and increase their physical activity levels. These are reported to individuals in the information pack. Table 11 presents the current use of Public transport among citizens of Hasselt, the analysis provides an opportunity to re-consider some their public transport trips in order to create the balance between the physical activity level.

Statistics	Public Transport Trips Composition			
	Trips Within 1 km	Trips Within 1 km replaced by walk	Trips Within 3 km	50 % Trips Within 3 km replaced by bike
Sum	5	5	35	22
Mean	0.16	0.16	0.61	0.32
Std. Deviation	0.82	0.82	3.04	1.61
Variance	0.67	0.69	9.24	2.61
Range	4	4	13	7
Minimum	0	0	0	0
Maximum	4	4	13	7

Table 11: Descriptive statistics of participant Public Transport Usage characteristics and its replaceable potential

Additionally, we conducted similar analyses to see the potential of chaining of trips in order to avoid cold starts of the Cars and also for reducing non-mandatory participation in outdoor activities. Few participants provided suggestions based on that along with their impacts.

We also considered to perform analysis including changing in the departure times of few flexible activities, however, due to the lesser resolution of pollutant concentration data in terms of time (time resolution is one hour for pollutant concentration data), we did not see any significant impacts of suggesting such change. Additionally, due to non-availability of detailed locational data of various key facilities and also non-availability of their opening and closing times, the analysis in terms of estimating the potential of changing activity locations is not performed.

6.3.4Behavioural Intervention Effectiveness

In this section, some insights of the effectiveness of the implemented behavioural interventions are provided. The effectiveness is measured based on the self-reported feedback of the citizens of Hasselt, and on quantitative measures such as PEATB before and after the intervention. Due to the time limitations, the details of activity-travel routine comparison based on multi-dimension sequential alignment methods are not performed. It should be noted that the study started with 53 individuals, with 15 individuals are part of the control group. However, during the course of the study, some participants from both groups dropped. The study finished with the active involvement of 25 participants from the treatment group and around 9 participants from the control group, i.e. 34 participants in total. Majority of the participants left the study due to their other commitments in the holiday season (especially in the month of July), however, at the start of the study they were given the complete study timeline, and we have obtained their commitment.

6.3.4.1 Participant Feedback

This effectiveness can be measured based on the responses on the feedback questionnaire at the end of the study from the participants belong to the treatment group. The feedback questionnaire asked the participants the following questions.

- Upon participating to the study, did you change your transport routine? If you select YES, then please explain why?
- What have you learned from your participation in the study?
- Please shortly describe what you like most during the study and what you found less interesting or difficult to understand?

Around **40%** of the individual mentioned **YES**, as the response to the first question. The participants replied positively have the intention to use the car as less as possible by increasing cycle trips. Some participants have the intention to use the car by completing different activities in a single loop and by doing so they want to decrease car use. A couple of respondents have the opinion to perform the short trips by bike keeping in view the severity of the weather. It should be noted that this is self-reported measure, and therefore, care should be taken to consider this as a measure of the effectiveness of the intervention. Furthermore, from this question, it is not clear how much change these individuals have brought into their activity-travel behaviour routines. The responses to the second question are important to analyse, especially from the participants who responded NO to the first question. These responses are encouraging as some of them reported that participation in the study increases their knowledge base. Few of these responses are provided as it is

> *''I have an opportunity to learn the daily carbon emissions related to my travel and how much I am exposed to air pollutant''.*

> *''That there are still more possibilities/alternatives when moving than seems, at first sight, to act in a more pro-environmental way''.*

> ''Quality of air, daily effort (bicycle) contributes to the achievement of min.30 minutes a day!. How much CO2 emissions are even for small workloads!.
> Small changes in my daily pattern can have a big impact on the battle against the warming of the beautiful blue planet! Provided that a larger number of cohabitants want to participate. Every little effort counts. What about big players?

In addition to the above, we have obtained two responses that are slightly negative about the study. These are individuals who are already considering environmental at their top priority and therefore, acting pro-environmentally. For example;

> "Actually, I do all my travel with the bike, and therefore, did not observe many advantages of the study. Maybe it is interesting for others."

> ''I do a lot of my movements in a good way, mostly with the bike! The use of the car is very limited. Practical limitations (groceries, weather conditions, etc.) make me use car''.

6.3.4.2 Assessing Effectiveness using PEATB

For quantitative assessment of intervention effectiveness, use of PEATB indicator is used. Furthermore, Control group is very important here as it provides the flexibility to measure the changes in PEATB due to some external factors. As the study is conducted, in the month of June and July. Activity-travel behaviour can be considerably different due to a variety of reasons, e.g. in the month of July schools are closed due to the summer vacation. Presence of children in homes may cause a considerable shift in activity-travel routine.

Table 12 provides the PEATB measures in Control group and treatment group. We considered 4 measures to describe PEATB, car use in VKT and Cold starts, activity travel mode involvement and PT usage. It is important, that the numbers mentioned in table 12 are properly understood. This is as follows for Car VKT (VKT for Car trips within 3 km). In the pre-intervention phase for each participant based on the VKT travel in the car mode are estimated in % based on the total VKT in an entire week. Based on the estimated % an equi-distant rank from 1 to 5 is assigned to each participant in control and treatment group. A similar approach is adopted in the post-intervention phase. As the ranks are equidistant, a simple difference is taken for pre and post-intervention phase, and this difference is then summed over all participants in control group and treatment group. Table 12 presents this sum measured for each indicator of PEATB. There is a considerable difference noted in the sum for each group and for each measure, which depicts that informational strategy has some influence on the travel behaviour routine of individuals.

Groups	PEATB Measures			
	Car VKT (≤ 3km)	Cold Starts	Active Mobility	PT Use
Control	-1	3	-16	-7
Treatment	11	9	-33	-3

Table 12: PEATB Measure Summary, Pre and Post intervention Phase for Control and Treatment Groups

As the data for each PEATB measure is based on ordinal rank, therefore we used an analysis based on Wilcoxon signed-rank test for both groups, and the results are mentioned as below in table 13. The Wilcoxon signed-rank test compares the two ranks sample data of the same population and tests whether the two-rank data have any difference statistically. The results are reported as significant (S) and Non-significant (NS) in table 13. It is clear from the table 13 that in the control group, the paired rank differences among individual are not significant for Car VKT, and Active mobility involvement, However, in the treatment group the differences are significant. This signifies the fact that informational strategy was able to cause some significant differences in the travel behaviour.

Groups	PEATB Measures			
	Car VKT (≤ 3km)	Cold Starts	Active Mobility	PT Use
Control	NS	NS	NS	NS
Treatment	S	NS	S	NS

Table 13: Wilcoxon Signed-rank test significance results for Control and Treatment Groups (measures at significance level of 0.05)

6.3.5Study Limitations

The study has some limitations as mentioned at various places in this report. This section highlights the key limitations of the study. These are as follows:

1) The exposure analysis is limited in this study as pollutant concentration data is available on very low resolution compared to the GPS based activity-travel routine. This can be improved by providing portable sensors to the individual in order to know the exact level of pollutant inhalation and exposure to individuals. The availability of such precise information may render develop a more appropriate and comprehensive informational strategy which certainly have more effect on influencing individual behaviour.
2) Some details on travel movement have been asked at the annotation stage. However, it is required to ask more details on it, which may provide ideas in relation to other constraints of travel movement. For example, information about accompanying persons for car trips, information about shopping trips based on the amount of luggage. The knowledge of these constraints will result in the more appropriate algorithm to obtain a replaceable number of trips.
3) Implementing the study with a large number of citizens, it has been noted that Control group sample after the dropped participants is quite lower to perform statistical analysis with greater confidence.
4) GPS-connectivity and smartphone issues due to which continuous activity and travel episodes are not appropriately obtained. To improve the continuity of the data, additional step by asking participants manually to fill the missing and undetected stops and trips. This will provide much confidence to participants that there travel movements are recorded with utmost accuracy. It will also increase the accuracy of information extracted from individual activity-travel routine.
5) Availability of activity-travel routine data for different months or season, in order to assess the effect of external factors on travel behaviour. This knowledge can be utilised for appropriate effectiveness analysis for intervention.

6) The effectiveness of the intervention is measured using ad-hoc indicators of PAETB, a more comprehensive analysis on effectiveness should be based on the entire daily activity-travel routine, which should be based on multi-dimension sequential alignment measure.
7) The literature on indoor and outdoor air quality indicated that sometimes indoor air quality can be more worse compared to out-door air pollutant concentration levels, as there are other pollutant sources, which causes deteriorated air quality for indoor microenvironment. This study, however, does not consider any other pollutant source for determining air quality for microenvironments.

Some of these limitations can be addressed in similar experiments planned for other iSCAPE cities, e.g. limitations mentioned in 2), 3) and 4), however, it is not possible to address all limitation due to the limited time and budget.

7 Planning for other iSCAPE Cities

This section presents the planning activities details to repeat the similar experiments in other iSCAPE cities for the fulfillment of the required objectives of WP 4. This planning is being made with mutual agreements of other iSCAPE living lab activities in order to make an effective strategy for citizens engagement. Living lab representative are consulted regarding the planning. Table 14 shed the lights on these plans.

iSCAPE City	Citizen Recruitment Strategy	Implementation of the Study
Dublin	In Dublin's living lab, activities of citizens engagements are starting from mid-September till October 2017 for the LL activities planned for Dublin city. At about same time, citizens will be recruited for the behavioural intervention study	In November, Behavioural intervention study will be implemented, so that it can finish the holiday season in December 2017.
Bottrop	In Bottrop, citizen recruitment activities will start from November and it will be carried out in December as well. It has been planned to use social media to recruit citizen for LL activities of Bottrop. Similar, strategy will be used to recruit citizens for behavioural intervention.	The behavioural study is planned to conduct in January 2018. Bottrop's LL representative is providing help in translation of necessary materials required to conduct an experiment in Bottrop.
Bologna	In Bologna, citizen recruitment starts from January, 2018. For a busy Street, workers and residents will be engaged for air quality monitoring. Same individuals will be used for the behavrioual intervention study.	The behavioural study is planned to conduct in January/February 2018. Bologna's LL representative is providing help in translation of necessary materials required to conduct an experiment.
Guilford	In Guilford, some sessions with the	The study can be started in

	stakeholder will be arranged in the month of October, and at the same time planning will be done regarding citizen engagement for LL activities. Behavioural intervention study will benefit from such arrangement and may also take part in some workshop organized in this regard. .	the month of February, 2018.

Table 14: Planning to conduct similar experiments in other iSCAPE Cities

8 Conclusions

The report presented a comprehensive methodological framework for WP 4, and based on that identified the data requires that can be combined with activities planned for task 4.1. This combination is important because data collection is a difficult task and require the engagement of citizens. Task 4.1 is re-oriented in the shape of informational-based behavioural intervention for Hasselt living lab, to provide meaningful utilization of the GPS-based activity-travel routine and its analysis required to fulfill the commitment made in task 4.1.

During the last 6 months, along with the development of a comprehensive methodological framework for WP 4, several survey instruments and tools are developed to facilitate the required data. Sparrows Mobile application, Web-based surveys, material for informational intervention and Stated choice experiments are developed. To conduct the Hasselt study, the citizen is recruited, and the study is implemented in the month of June and July 2017.

The report presents several findings of the Hasselt study. Path models are estimated utilizing the theory of planned behaviour by estimating structural equation modelling approach. Results show that path formulated from perceived consumer efficacy (PCE) to perceived behaviour control (PBC) to PEATB is strongest among all other paths, which shows the for any intervention study factors related to PCE, PBC is of prime importance for influencing travel behaviour of individuals.

The behavioural intervention is designed by analysing GPS-based activity travel routine in various aspect by correlating it with specific air pollutants under different micro-environments for estimating exposure. Additionally, Car use in terms of contribution to CO_2 emission and Cold starts of the engine is determined. Furthermore, level of individual involvement in physical activity is also assessed considering their use of active travel mode. The informational intervention is designed considering the effective methods such as Feedback, Justification, cognitive dissonance and commitments while keeping in mind the result of the estimated path model. Attempts have been made to make the informational strategies as simple as possible for easy understanding of the common individual. Results of the analysis to provide suggestion for changing in behavioural actions indicated that there is a significant potential in individual activity-travel routine to make it more pro-environmental. Furthermore, it has been noted that informational strategy is not only increasing the awareness of individuals but at the same time influencing some individuals to change those aspects of travel behaviour which are relatively easier.

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10 Annexures

10.1 Annexure-I: Study Introductory Questionnaire

Behavioural Intervention: Pilot Study Introductory Questionnaire

Participant please read:

You are welcome as participant of the behavioural intervention study to improve air quality of Hasselt as a part of EU Project iSCAPE. Please note that data collected during this study will be used solely for research purpose. Participants of the study has a right to quit from the study at any point in time by a written request. Participants can refuse to give any information as they desired.

Consent Form

I hereby confirm that I have been informed about the study and have received complete information about various activities that will perform in the study. I have read and understood the information. In this context, I declare the following:

• I understand that I am free to end my participation in this study at any time, without this leading to any disadvantage.

• I agree to the collection, processing and use of my data, (the trip data is digitally stored in encrypted form and only the researchers involved have access to this data).

• I agree with the anonymous transfer and the anonymous processing of my data in partner countries involved in the project.

• I agree to the use by the client of this encrypted data for other research purposes

• I completely voluntarily take part in this study

• I give permission to be contacted in the future with regard to a follow-up study

- ○ **I AGREE**
- •
- ○ **I DISAGREE**

Introductory Questionnaire:

Section I : Socio- Demographic and Personal details

Age	_____(years)
Gender	Male ☐ Female ☐
Nationality	
Current Address (only Street name and Town)	
How long you have been living at the above address?	_____(Years)
Employment Status: Are you currently…?	• Employed for wages • Self-employed • Out of work and looking for work • Out of work but not currently looking for work • A homemaker • A student • Military • Retired • Unable to work
What is the highest degree or level of school you have completed? If currently enrolled, highest degree received.	• Less than high school degree • High school graduate, diploma or the equivalent • Trade/technical/vocational training • Associate degree • Bachelor's degree • Master's degree • Professional degree • Doctorate degree •
What was your total household income before taxes during the past 12 months?	• Less than 10,000 Euros • 10,000 to 24,999 Euros • 25,000 to 49,999 Euros • 50,000 to 74,999 Euros • 75,000 to 99,999 Euros • 100,000 to 149,999 Euros • 150,000 to 199,999 Euros • 200,000 and up • Prefer not to answer

Select one that describes your family setup best.	Single Adult without children ☐ Couple without children ☐ Single Adult with children ☐ Couple with children ☐ Other with Children ☐ Other without children ☐
Persons living with you (your family composition)	Please provide number of persons in the household _____ Adults (above 18 years) _____ Teenagers (12 -18 years) _____ Children (6- 12 years) _____ Children (below 6 years)
Driving License	Yes ☐ No ☐
When did you obtain driving license ?	_____(e.g 2010)
Number of Cars in the house	No Car ☐ 1 ☐ 2 ☐ 3 ☐ 4+ ☐
Car details (mostly) in your personal use	Brand: _____ Model year: _____ ; Fuel type: Diesel ☐ ☐ Petrol ☐ CNG Electric ☐
Do you have a bicycle?	Yes ☐ No ☐
Contact Number (Mobile)	
E-mail:	

Section II : Environmental Issues, Human values and Interests

We are asking few questions regarding environmental problems and issues, along with your opinion about human values. You need to give your opinion in the form of degree to which you agree or disagree to the statements shown below:

(a) Questions in relation to Environmental issues/concern

Please indicate how much you agree /disagree with the following statements. **1= Strongly disagree, 2 = Disagree, 3 = Neutral, 4= Agree, 5= Strongly Agree**
Environment Pollution is a problem in Hasselt (your area of residency). ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
Environmental pollution may affect your health. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
The environment is deteriorating, it is clearly notable and visible ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
Environmental issues need to be considered properly. People who do not take this into account are escaping their responsibilities ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
Humans have the right to modify the natural environment to suit their needs. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
Mankind is severely abusing the environment. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
When humans interfere with nature, it often produces disastrous consequences. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
We are approaching the limit of the number of people the earth can support.

○ 1 ○ 2 ○ 3 ○ 4 ○ 5
Given the opportunity, you would like to take action that are in-line with pro-environmental behaviour ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
Whether I perform pro-environmentally is entirely up to me ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
Environmental Pollution is a society problem, and everyone has to take part in it to resolve it. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
It is worthless for the individual consumer to do anything about pollution. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
When I buy products, I try to consider how my use of them will affect the environment and other consumers. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
Process of designing programs/activities/events for encouraging pro-environmental behaviour also involve citizens ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
I will be more inclined to behave pro-environmentally when *peers/people in my neighbourhood* are also engaged in that behaviour ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
There are opportunities available to change your daily routine which could lead to lesser exposure to pollution (e.g. change in activity location, flexibility in opening hours of shops) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
Public transport (buses frequency, bus stop locations) in your area is good and you are satisfied with it. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

Bicycle facilities (e.g. bike share programs, bike parking availability, safe and segregated bicycle paths) in your area are good and you are satisfied with it. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
Pedestrians facilities (e.g. Footpaths, restricted traffic zones, zebra crossings, pelican signals, traffic observing priority to pedestrians) in your area are good and you are satisfied with it. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
There should be more restrictions on the use of car in your area (e.g. speed control, Car free zones, increase in parking cost, increase of taxes etc.) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

(b) Questions related to Human values

Please rate to what extent these values are guiding principles in your life **-1= Opposed to my values, 0= not important, 1= Important, 2 = Very Important, 3 = Supremely Important**
Social justice (Correcting Injustice, Care for the weak) ○ -1 ○ 0 ○ 1 ○ 2 ○ 3
Equity (Equal Opportunity for all) ○ -1 ○ 0 ○ 1 ○ 2 ○ 3
A world of peace (no wars, no conflict) ○ -1 ○ 0 ○ 1 ○ 2 ○ 3
Protecting the environment (preserving nature) ○ -1 ○ 0 ○ 1 ○ 2 ○ 3
Preventing pollution (conserving the natural resources) ○ -1 ○ 0 ○ 1 ○ 2 ○ 3
Self-discipline (resistance to temptations) ○ -1 ○ 0 ○ 1 ○ 2 ○ 3

Family security (Safety for loved ones) ○ -1 ○ 0 ○ 1 ○ 2 ○ 3
Influential (Having an impact on people and events) ○ -1 ○ 0 ○ 1 ○ 2 ○ 3
Wealth (material possessions, money) ○ -1 ○ 0 ○ 1 ○ 2 ○ 3
Authority (the right to lead or command) ○ -1 ○ 0 ○ 1 ○ 2 ○ 3
Curious (interested in everything, exploring) ○ -1 ○ 0 ○ 1 ○ 2 ○ 3
A varied life (filled with challenges, novelty and changes) ○ -1 ○ 0 ○ 1 ○ 2 ○ 3
An exciting life (stimulating experiences) ○ -1 ○ 0 ○ 1 ○ 2 ○ 3

c) Questions related to ecological behaviours

Please indicate to what extent you observe the following behaviours **1= Yes Always, 2 = Yes, 3 = Very Seldom, 4= No, 5= I don't know**
I try only to buy products that can be recycled. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
When there is a choice, I always choose that product which contributes to the least amount of pollution. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
To save energy, I drive my car as little as possible. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

I try to buy energy efficient household appliances ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
If I understand the potential damage to the environment that some products can cause, I don't purchase these products ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
I buy high efficiency light bulbs to save energy ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
I usually purchase the lowest price products, regardless of its impact on society. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
I have convinced members of my family or friends not to buy some products which are harmful to the environment. ○ 1 ○ 2 ○ 3 ○ 4 ○ 5
If you were awarded with 1000 euro to be spent in transport-related goods/services, how would you spend them? Buying a bicycle : _____ Buying an eBike : _____ Public transport tickers/pass : _____ Car maintenance and gasoline : _____ Others : _____ Total : _____
If you spend money on "Others", Please explain "Others":

10.2 Annexure-II: Information Pack

INFORMATION PACKAGE WITH COMMITMENT SHEET

HOW PRO-ENVIRONMENTAL IS YOUR TRAVEL BEHAVIOUR?

Dear Participant

We kindly thank you for actively participating in our study and are glad to provide you with your personal results.

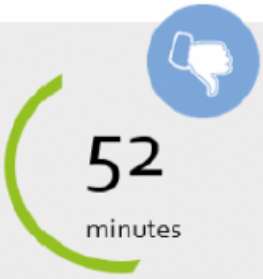
The results presented here are based on the analysis of the data we collected from you personally. We are presenting the results in 3 different sections: your active mobility, your car use behaviour and your exposure to pollutants. We hope that this information can convince you to consider more pro-environmental transportation behaviour in the future!

SECTION I : YOUR INVOLVEMENT IN WALKING & CYCLING

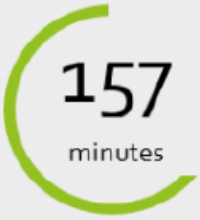
*Physical inactivity is identified by WHO as the fourth leading **risk factor** for **global mortality.** To **improving** cardiorespiratory and muscular fitness, bone health, reduce the risk of non-communicable diseases and depression, adults (19-64) should aim for at least **150 minutes** of moderate-intensity aerobic physical activity in a week.*

*We measured your **Physical Activity Level** as your use of active modes of travel such as walk and cycling from your appropriate travel records collected during this study period. We compared the outcomes with average level of other individuals and recommended level.*

RECOMMENDED



YOUR'S:
52 minutes walking
00 minutes cycling



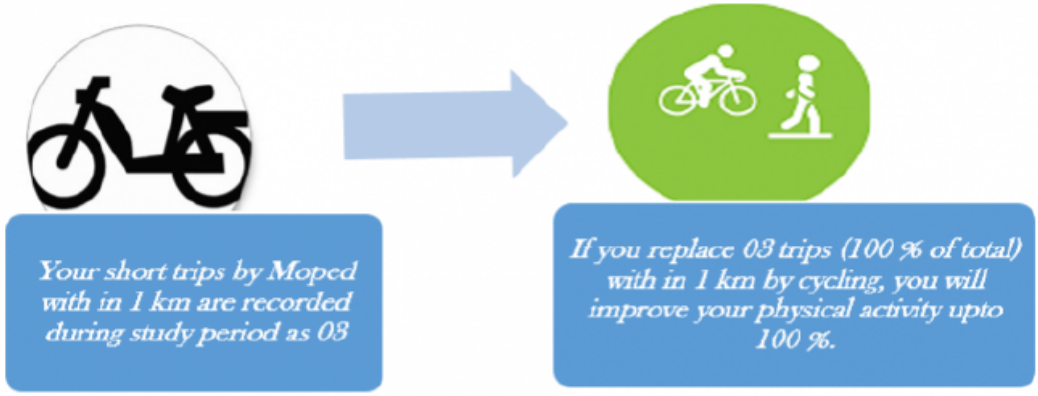
OTHER INDIVIDUALS (AVERAGE) :
50 minutes walking
107 minutes cycling

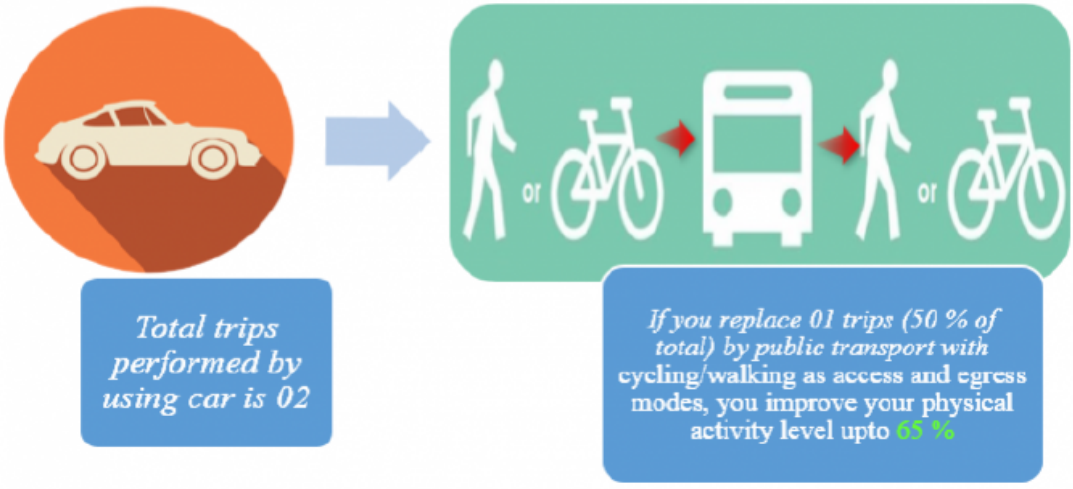
Can you understand the information provided above?

Yes ○ No ○

HOW YOU WILL IMRVOVE YOUR PHYSICAL ACTIVITY LEVEL:

*By doing the recommended physical activity level, Life expectancy can be **enhanced** by **3.4 years** but what you need to do to meet the recommended activity level?*





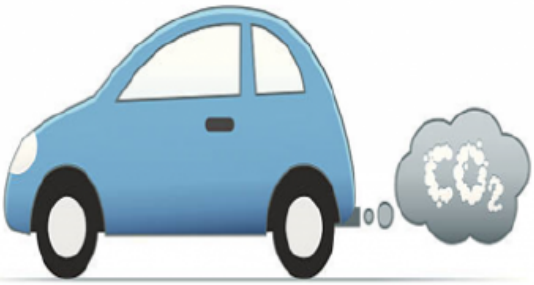
Can you understand the information provided above?

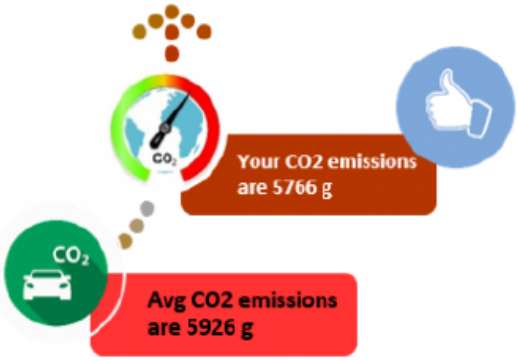
Yes ○ No ○

SECTION II : YOUR CAR USE BEHAVIOUR

*Cars are responsible for around **12%** of total EU emissions of carbon dioxide (CO2) causing **global warming, acid rain, and harming the environment and human health**.*

*A typical passenger vehicle emits about **4.7 metric tons of carbon dioxide** per year. By limiting our personal car use, we contribute to a **better air quality***

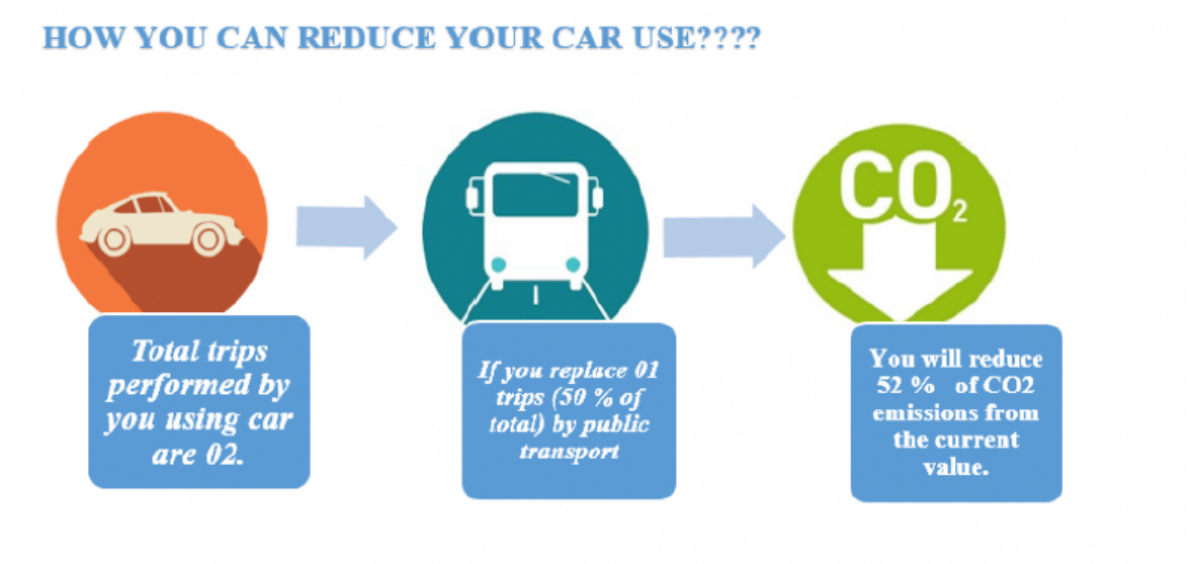




Use of your Car and taxi is expressed in CO2 emissions during the study period. We Compared your CO2 emissions to these of an average participant in this study.

Can you understand the information provided above?

Yes	No
○	○



Can you understand the information provided above?

Yes ○ No ○

SECTION III : YOUR EXPOSURE TO ENVIRONMENTAL POLLUTANTS

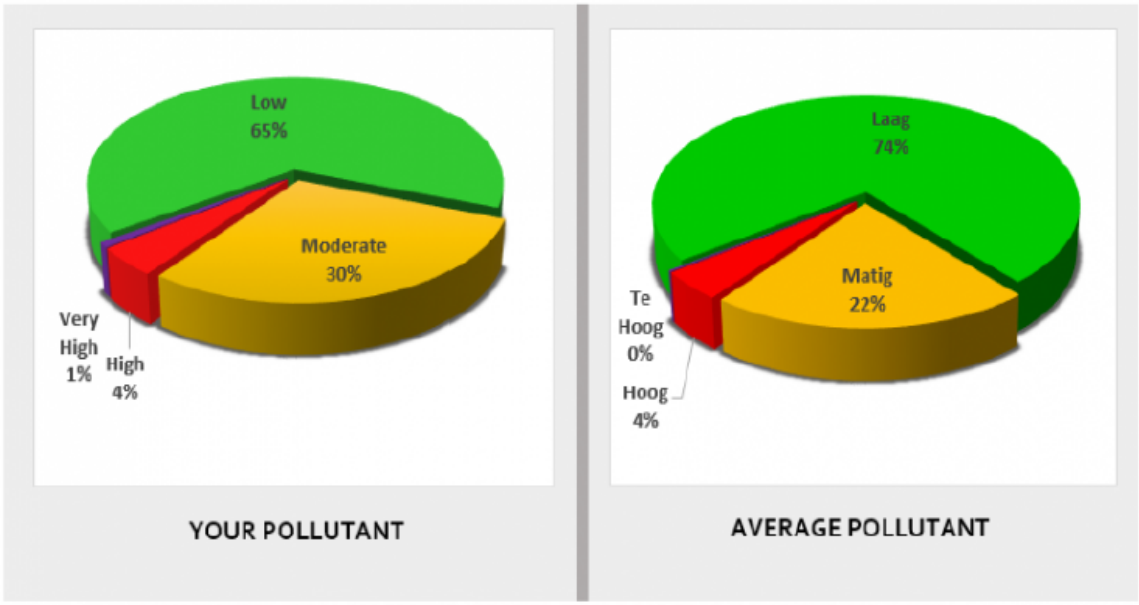
Exposure *indicates your contact with the environmental pollution. We measured the amount of* ***time*** *you were exposed to a particular* ***level of pollutant concentration*** *while performing* ***any trip or activity.*** *Air pollutant (Ozone , NOx, PM10, PM2.5) concentrations range from* ***Low*** *to* ***Very High*** *where all type of outdoor activities have bad impact on health as shown below in table.*

Air pollutant Levels	Health messages for General population
Low	Enjoy your usual outdoor activities.
Moderate	Enjoy your usual outdoor activities. (avoid strenuous activities by sensitive group)
High	Anyone experiencing discomfort such as sore eyes, cough or sore throat should consider reducing activity, particularly outdoors.
Very High	Reduce physical exertion, particularly outdoors, especially if you experience symptoms such as cough or sore throat.

Can you understand the information provided above?

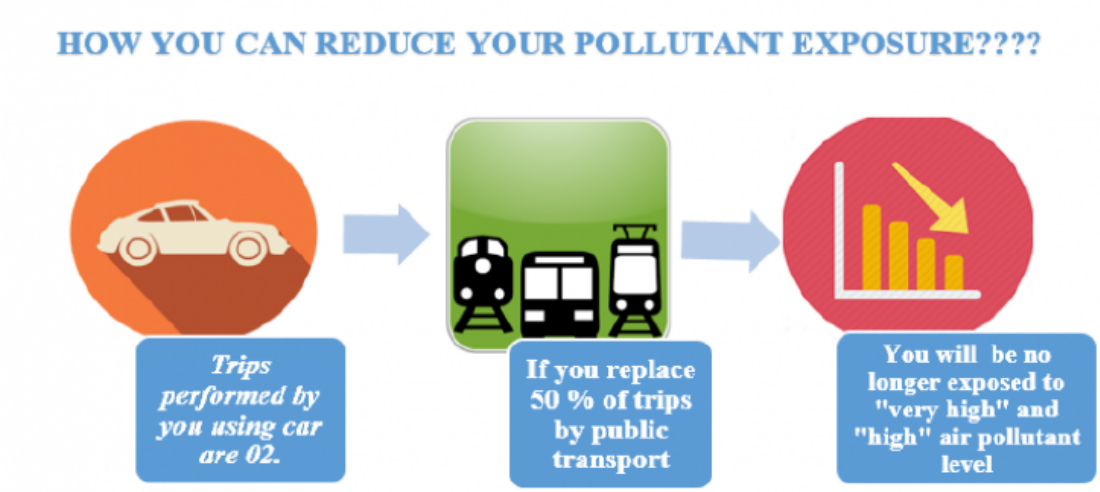
Yes ○ No ○

Total exposure *is calculated by taking summation of the exposure of your all trips and activities during study period and is represented here by a* ***PIE CHART.*** *You can interpret the chart as percentage of time you are exposed to a particular AIR POLLUTANT LEVEL*



Can you understand the information provided above?

Yes ○ No ○



Can you understand the information provided above?

Yes	No
○	○

QUESTIONNAIRE

SECTION IV. **We are now going to ask some questions in relation to the information provided to you based on recorded movements and air quality in Hasselt.**

Q 1. How much in % you are exposed to **LOW AIR POLLUTANT LEVEL** during study period?

Q 2. Your exposure to pollutant during study period is more than average pollutant exposure in **MODERATE AIR POLLUTANT LEVEL**

Yes ○ No ○

Q 3. Your CO2 emissions is less than average value during study period?

Yes ○ No ○

Q 4. How many trips you performed with in 3 km using public transport?

less than 5 ○ 5 - 10 ○ 11 - 15 ○ more than 15 ○

Q 5. As per WHO recommendations one should involve in physical activity _____ minutes per week

30 ○ 70 ○ 100 ○ 150 ○

COMMITMENT SHEET

SECTION V. **We are now taking some commitments (customized based on examination of your patterns) from you in relation to behavioural changes. You should choose the best possible option after learning from the given information:**

C 01. How much you are willing to decrease your non mandatory out door activities?

- ◯ 0 %
- ◯ 10 %
- ◯ 20 %
- ◯ 40 %
- ◯ 60 %
- ◯ 80 % or more

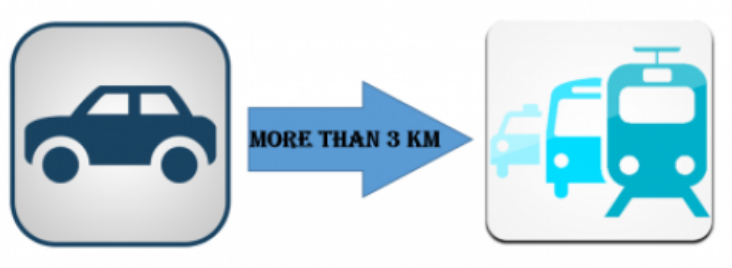
C 02. How much you are willing to change your car/bus trips within 01 km by walk?

I am already doing it | 25 % | 50 % | 75 % | 100 %

C 03. How much you are willing to change your car/bus trips within 03 km by walk/cycling ?

I am already doing it | 25 % | 50 % | 75 % | 100 %

C 04. How much you are willing to change your car trips more than 03 km by public transport ?



I am already doing it	25 %	50 %	75 %	100 %
◯	◯	◯	◯	◯

. Please mention below if you want to commit for any other behavioural change

C 05	
C 06	
C 07	
C 08	

10.3 Annexure-III: SP Choice Experiments

Behavioral Intervention Study: Stated Preference Survey

Introduction

We have devised a questionnaire to obtain your preferences of travel modes by slightly changing the existing circumstances. We have selected most frequent trip purposes from your obtained travel records and providing you a full view of circumstances using a map based illustration. This will remind you about your current preference of travel mode under the illustrated conditions.

From this survey, we wanted to know that if few things will change (for example change in weather, air pollutant level, physical activity level, travel time and travel cost), whether you will prefer any other travel mode compared to what you have selected previously for similar trip.

For further clarification, we are reminding you about the different terms, so that you can state your choice more appropriately. Please read the following text carefully.

Explanation of technical terms used in the survey

Air Pollutant Level

According to sources, air pollutant (Ozone , NOx, PM10, PM2.5) concentrations ranges are defined in terms of their impact on human health. They vary from Low to Very high. Low air pollutant level is ideal and very high air pollutant level require to refrain from outdoor activities. Further details are shown in the table.

Air pollutant Banding	Health messages for General population
Low	Enjoy your usual outdoor activities.
Moderate	Enjoy your usual outdoor activities. (avoid strenuous activities by sensitive group)
High	Anyone experiencing discomfort such as sore eyes, cough or sore throat should consider reducing activity, particularly outdoors.
Very High	Reduce physical exertion, particularly outdoors, especially if you experience symptoms such as cough or sore throat.

Physical Activity Level

As per WHO, Adults (19-65) should aim for 30 mins of moderate intensity aerobic activity such as walking and cycling in a day. Your physical activity level while performing any trip is expressed as percentage of the total physical activity you needed in a day

Access and Egress mode

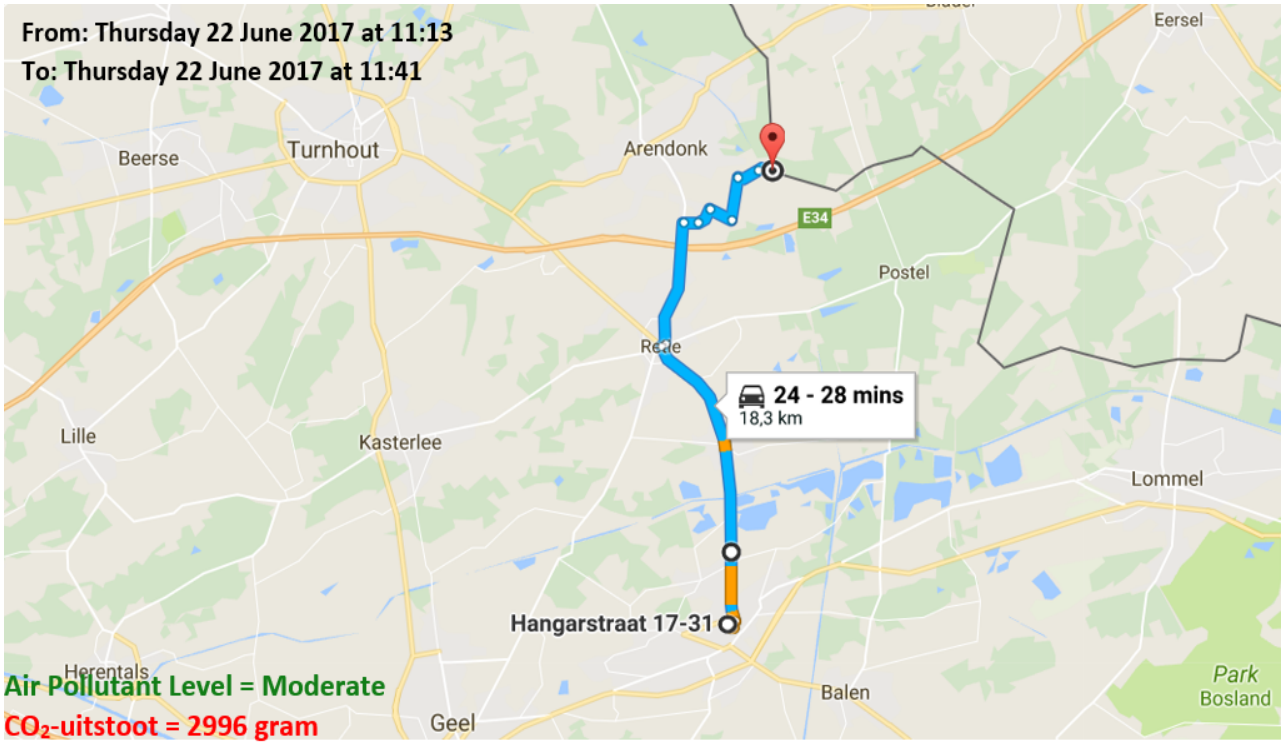
A mode used to get from a trip origin to a main mode (bus, metro, tram) is called access mode and a mode used to get from the main mode to the trip destination is called egress mode.

Segregated Bike Lanes

A reserved lane on the verge of the roadway that is often used by the bicyclists is called Segregated bike lane as shown below. Depending upon the situation these lanes are available throughout or halfway while performing any trip.

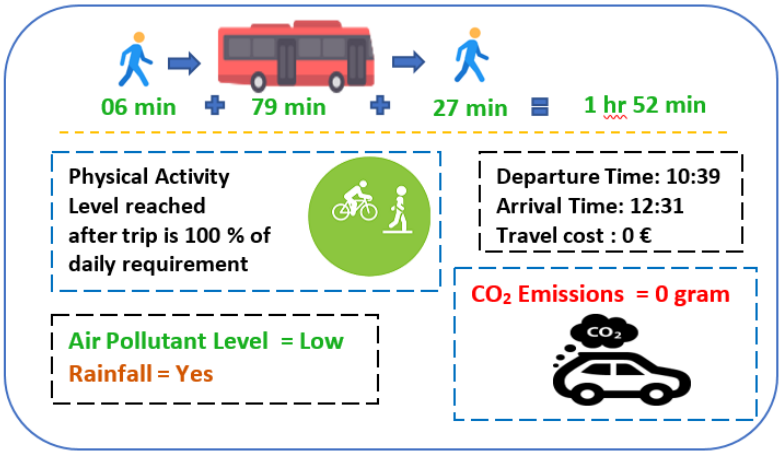
Work Trip based Stated Preference Questions

We have selected your work based trip from your recorded moves as shown on map below.

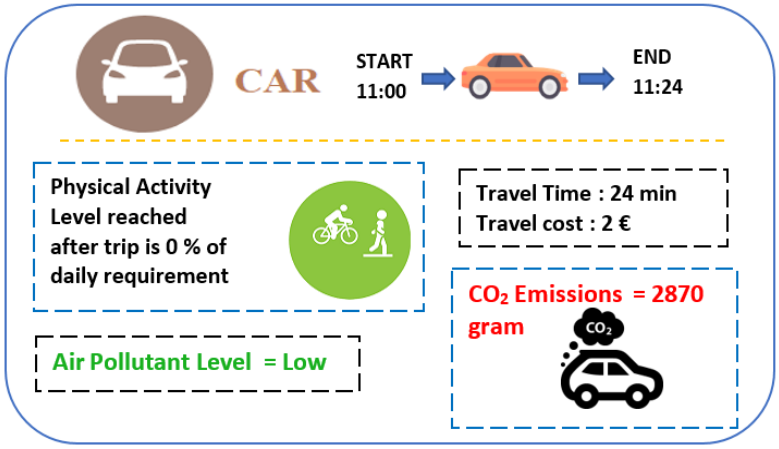


Suppose you have to perform same trip in the future. We have designed few hypothetical scenario to get your response on selection of choice of travel mode in slightly different circumstances. You need to select travel mode considering a particular hypothetical scenario as you may face in real life situation.

Q1 If you have to perform similar work trip as shown above. Which travel model you will select. Please select one option

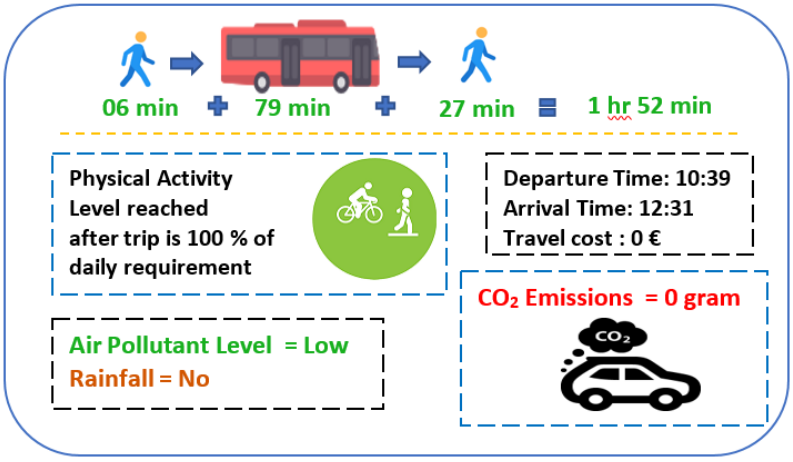


o OPTION 1 OF 2

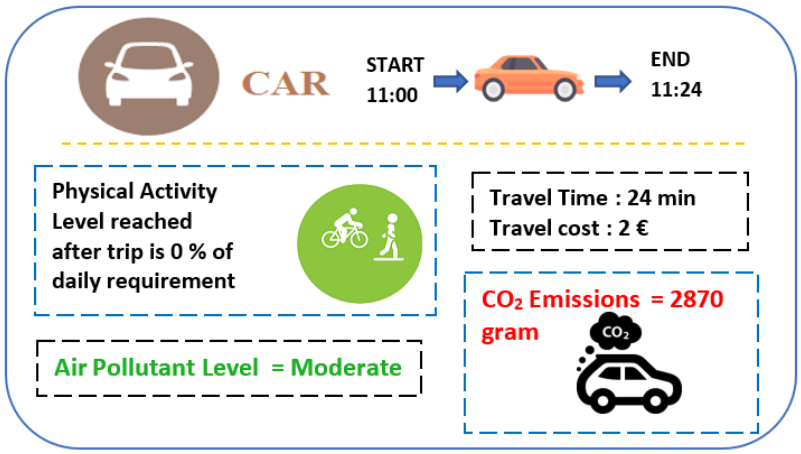


o OPTION 2 OF 2

Q2 If you have to perform similar work trip as shown above. Which travel model you will select. Please select one option

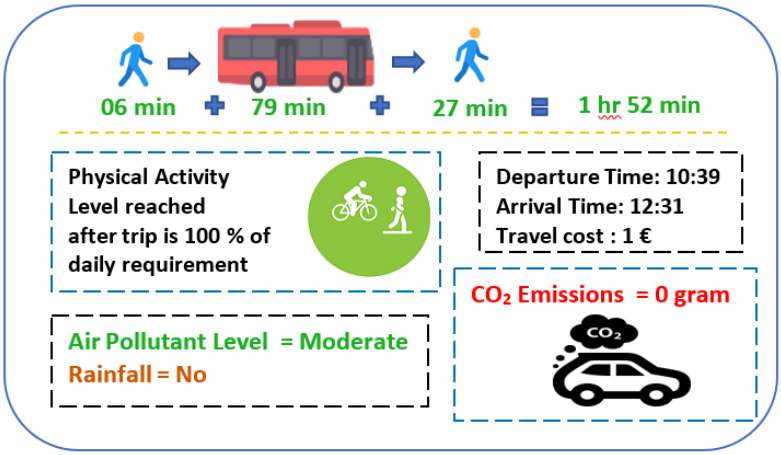


o OPTION 1 OF 2

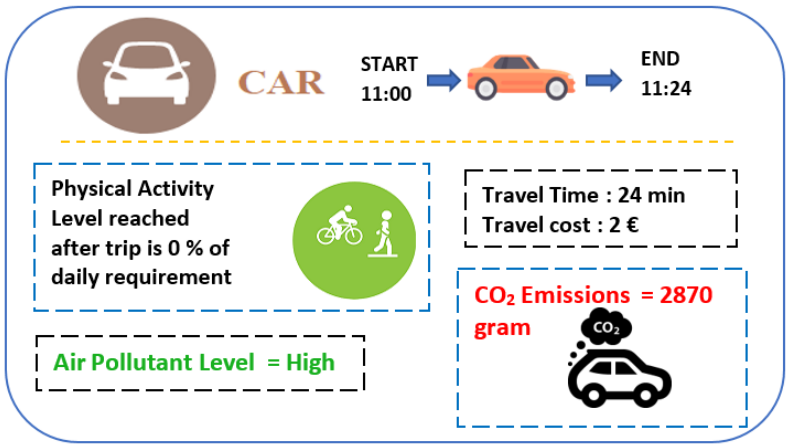
o 

OPTION 2 OF 2

Q3 If you have to perform similar work trip as shown above. Which travel model you will select. Please select one option

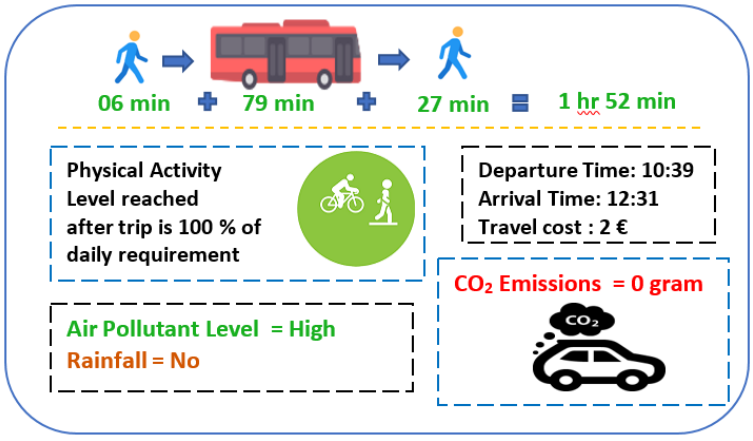
o 

OPTION 1 OF 2

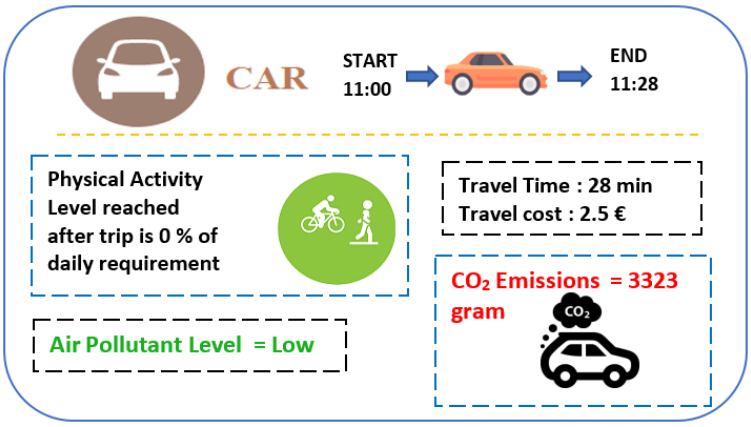


o OPTION 2 OF 2

Q4 If you have to perform similar work trip as shown above. Which travel model you will select. Please select one option

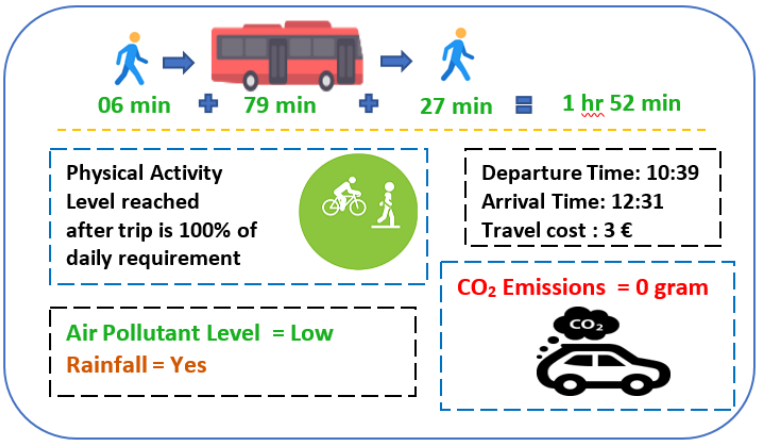


o OPTION 1 OF 2

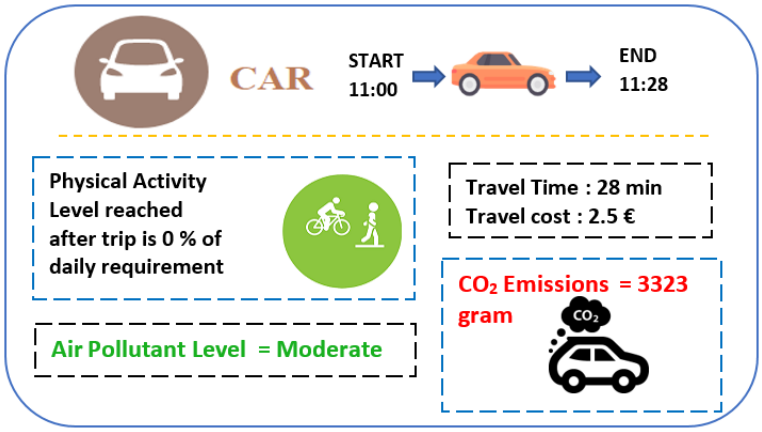


o OPTION 2 OF 2

Q5 If you have to perform similar work trip as shown above. Which travel model you will select. Please select one option

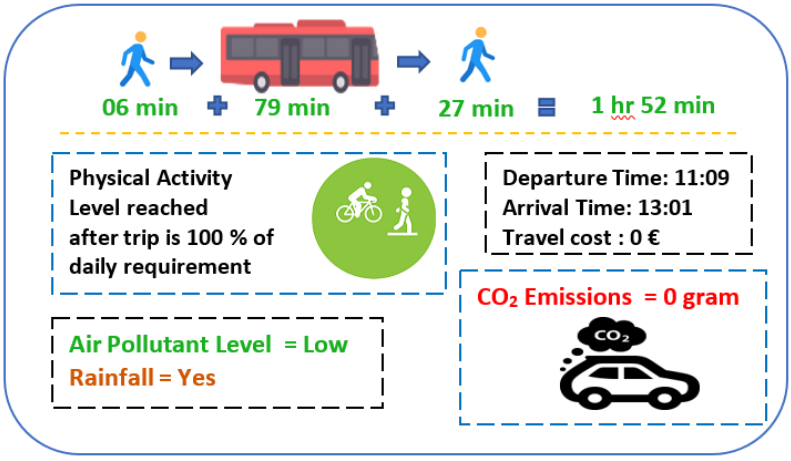


o OPTION 1 OF 2

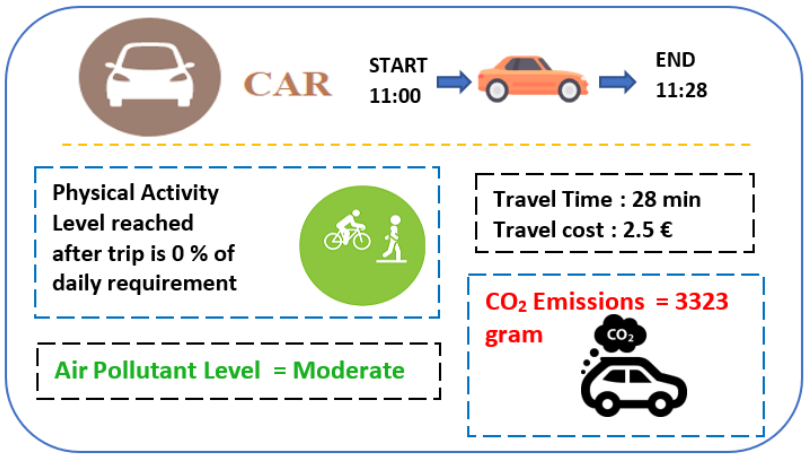


o OPTION 2 OF 2

Q6 If you have to perform similar work trip as shown above. Which travel model you will select. Please select one option

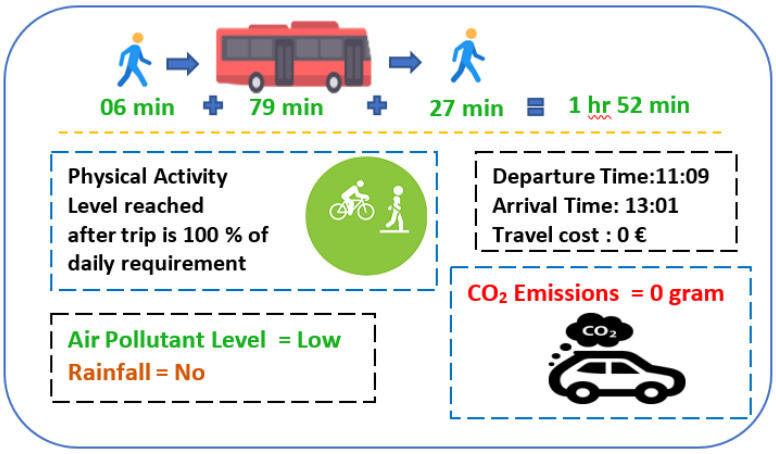


o OPTION 1 OF 2

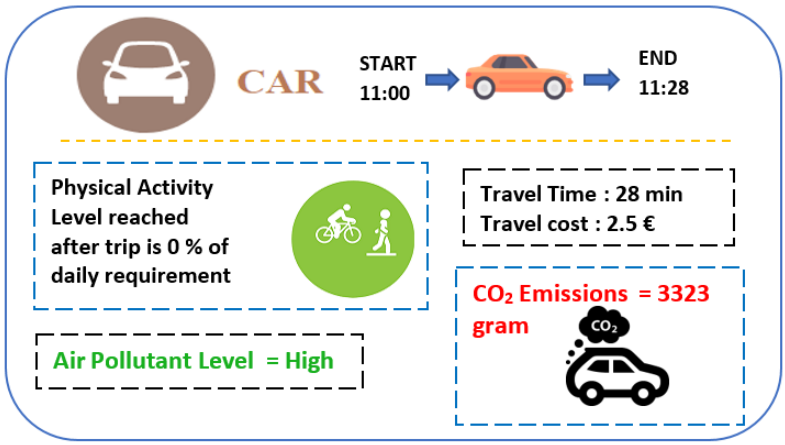


o OPTION 2 OF 2

Q7 If you have to perform similar work trip as shown above. Which travel model you will select. Please select one option

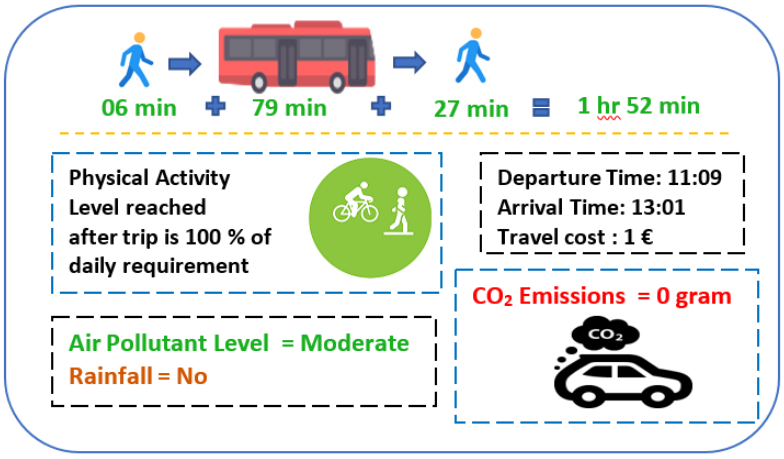


o OPTION 1 OF 2

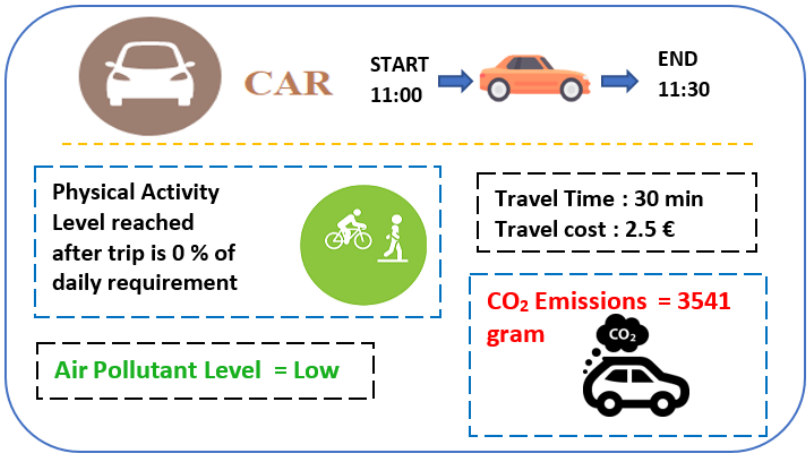


o OPTION 2 OF 2

Q8 If you have to perform similar work trip as shown above. Which travel model you will select. Please select one option

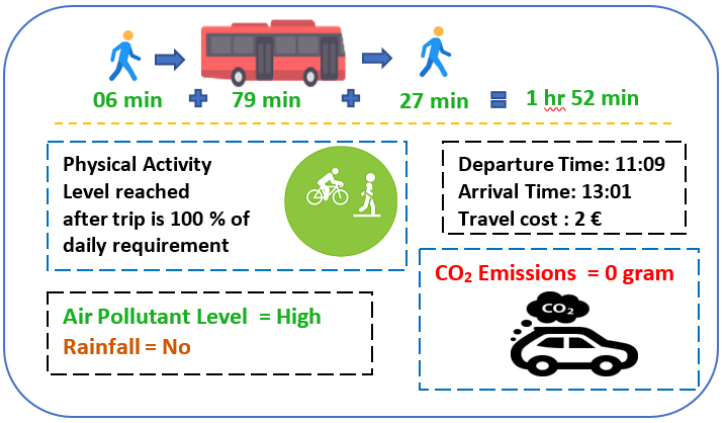


o OPTION 1 OF 2

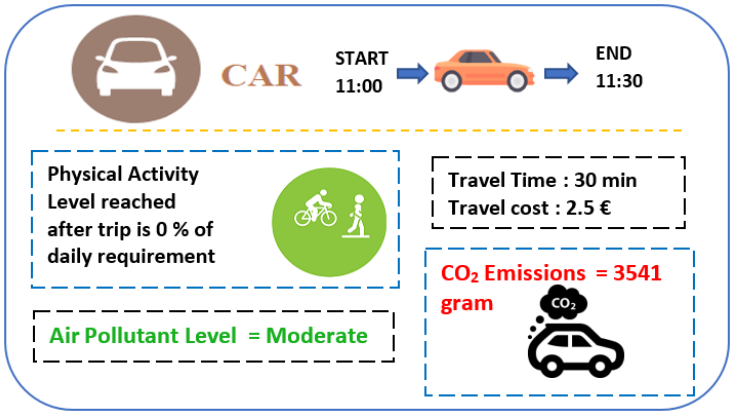


o OPTION 2 OF 2

Q9 If you have to perform similar work trip as shown above. Which travel model you will select. Please select one option

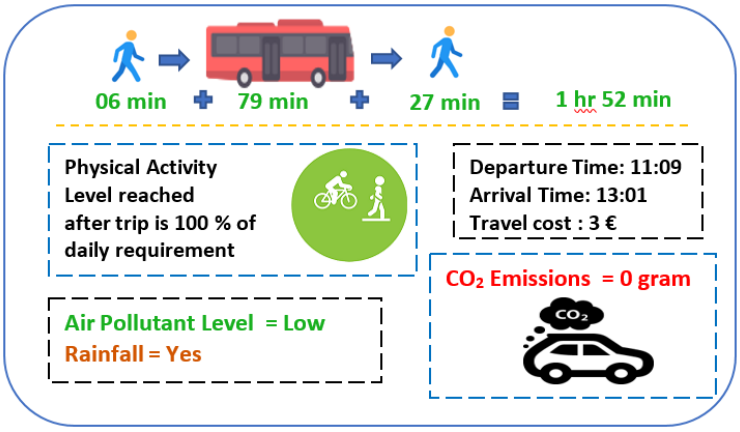


o OPTION 1 OF 2



o OPTION 2 OF 2

Q10 If you have to perform similar work trip as shown above. Which travel model you will select. Please select one option



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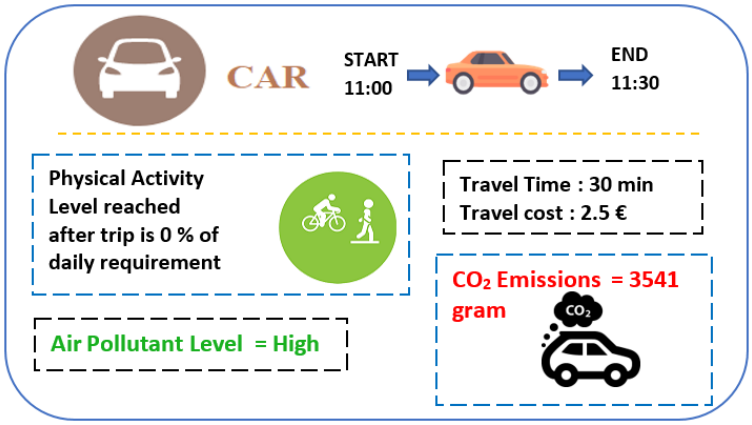
o 

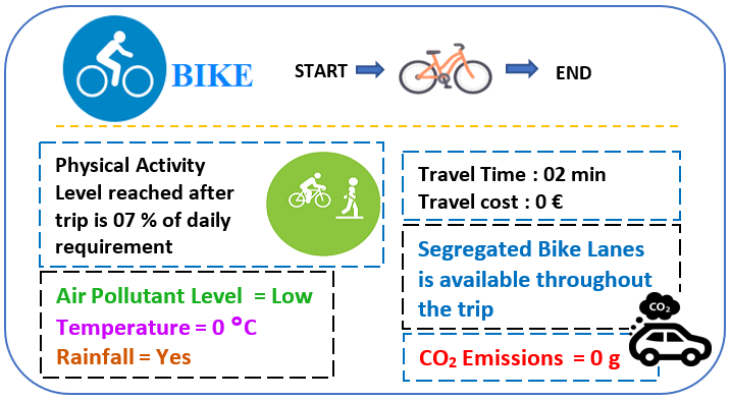
OPTION 2 OF 2

Shopping Trip based Stated Preference Questions

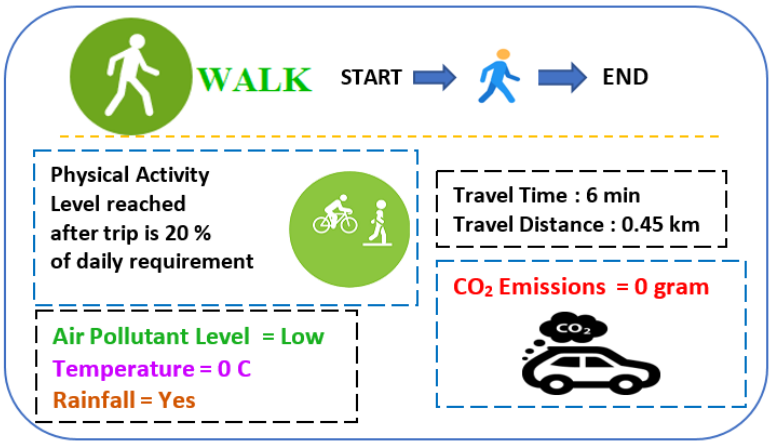
We have selected your shopping based trip from your recorded moves as shown on map below.

Suppose you have to perform same trip in the future. We have designed few hypothetical scenario to get your response on selection of choice of travel mode in slightly different circumstances. You need to select travel mode considering a particular hypothetical scenario as you may face in real life situation.

Q11 If you have to perform similar shopping trip as shown above. Which travel model you will select. Please select one option

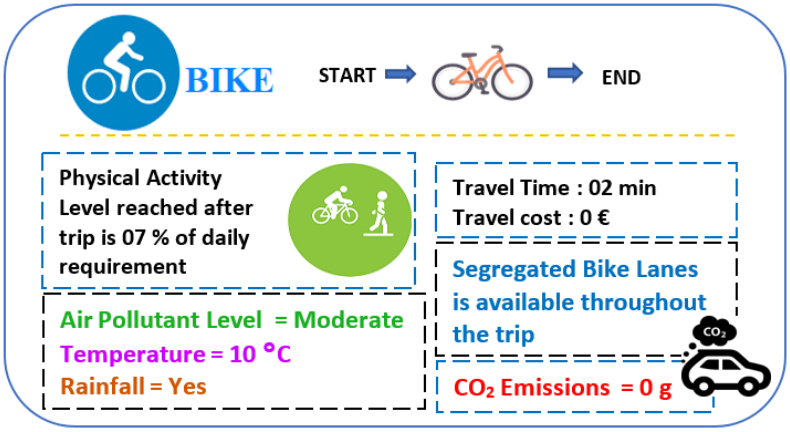


o OPTION 1 OF 2

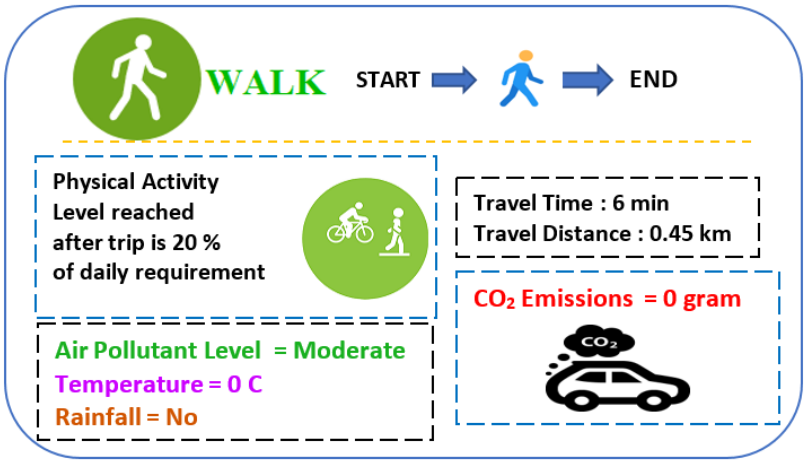


o OPTION 2 OF 2

Q12 If you have to perform similar shopping trip as shown above. Which travel model you will select. Please select one option

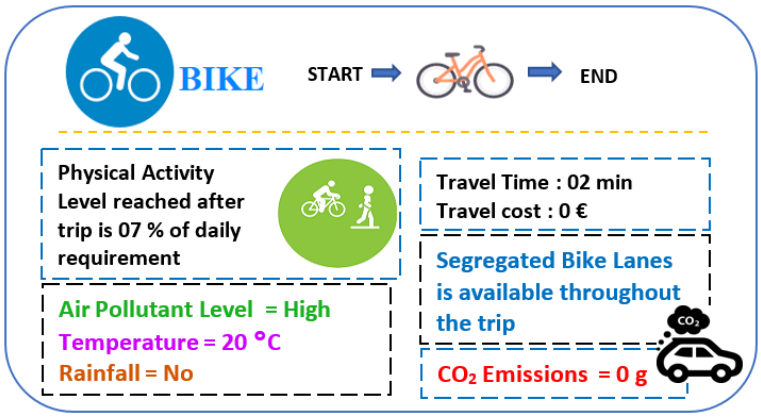


o OPTION 1 OF 2

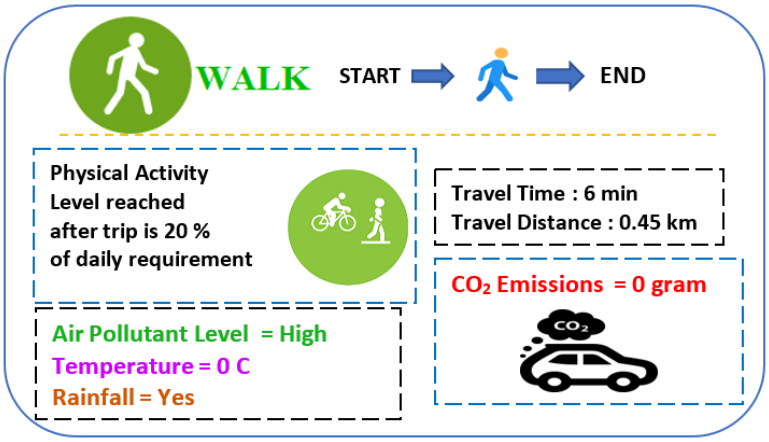


o OPTION 2 OF 2

Q13 If you have to perform similar shopping trip as shown above. Which travel model you will select. Please select one option

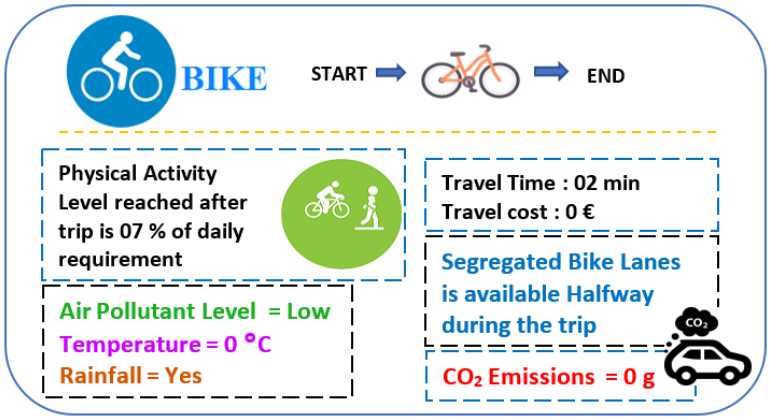


o OPTION 1 OF 2

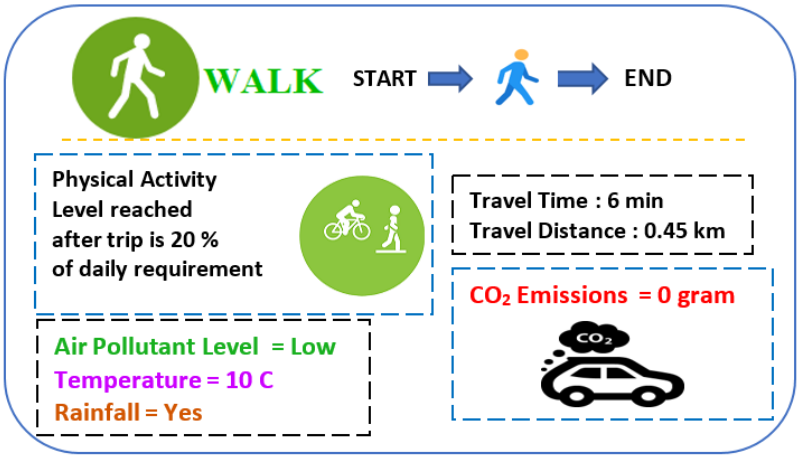


o OPTION 2 OF 2

Q14 If you have to perform similar shopping trip as shown above. Which travel model you will select. Please select one option

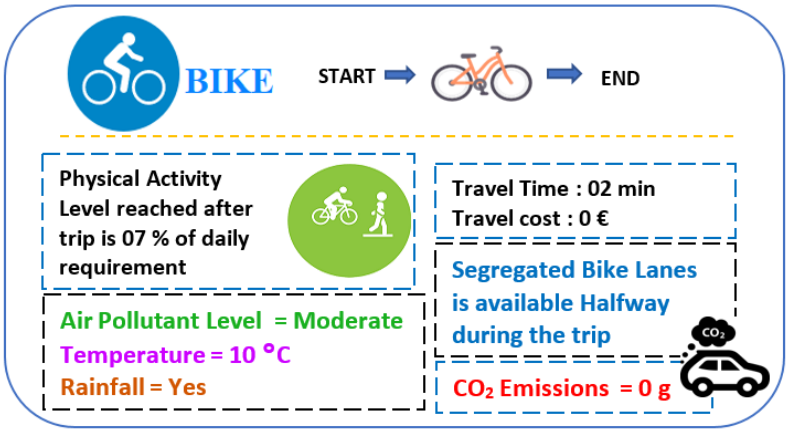


o OPTION 1 OF 2

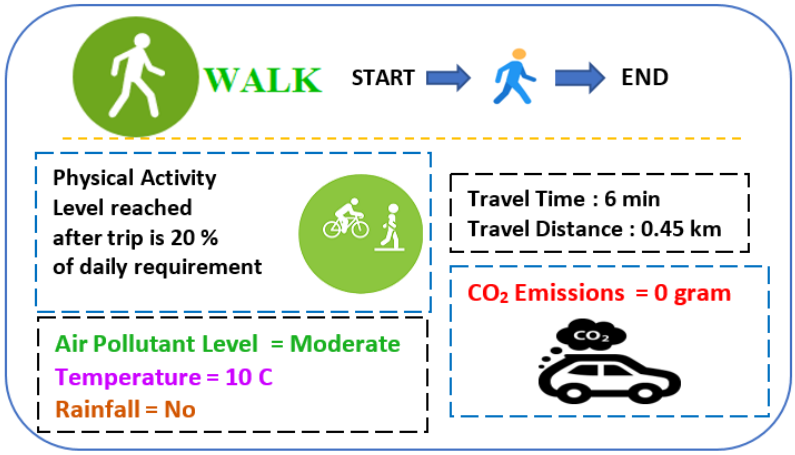


o OPTION 2 OF 2

Q15 If you have to perform similar shopping trip as shown above. Which travel model you will select. Please select one option

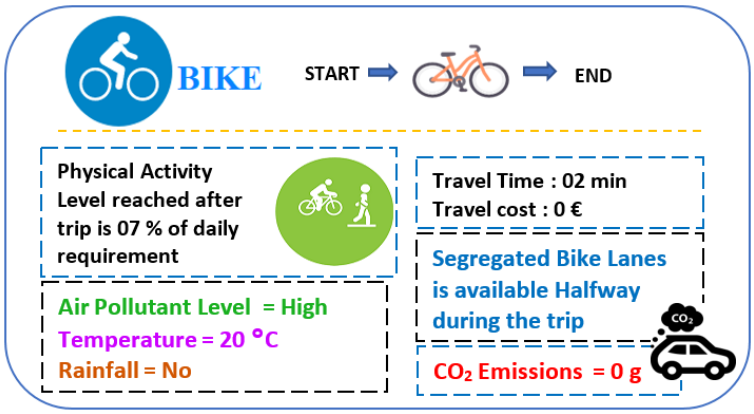


o OPTION 1 OF 2

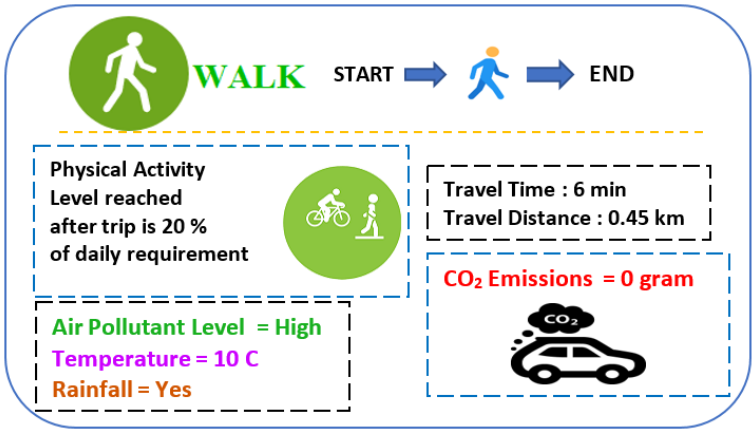


o OPTION 2 OF 2

Q16 If you have to perform similar shopping trip as shown above. Which travel model you will select. Please select one option

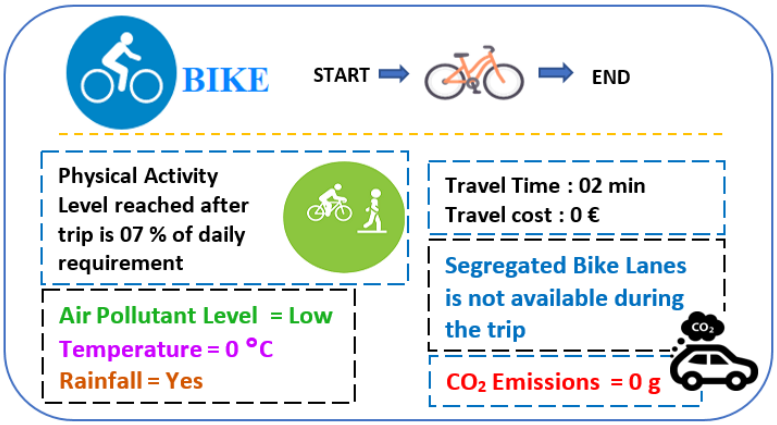


o OPTION 1 OF 2

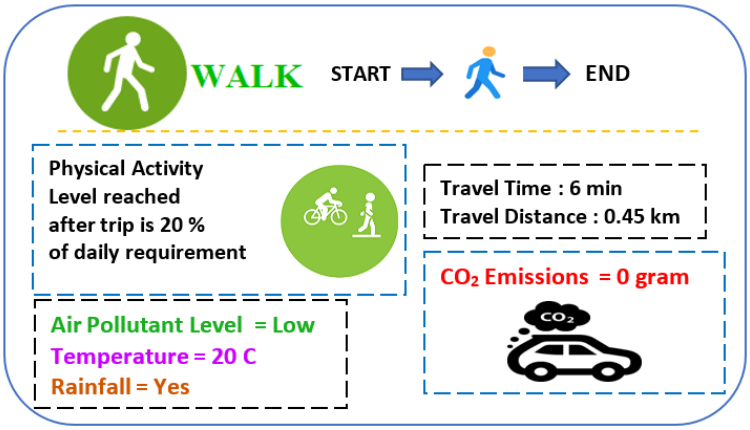


o OPTION 2 OF 2

Q17 If you have to perform similar shopping trip as shown above. Which travel model you will select. Please select one option

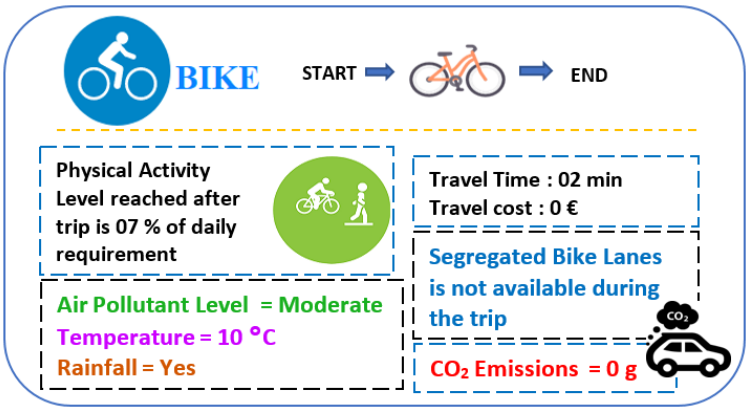


o OPTION 1 OF 2

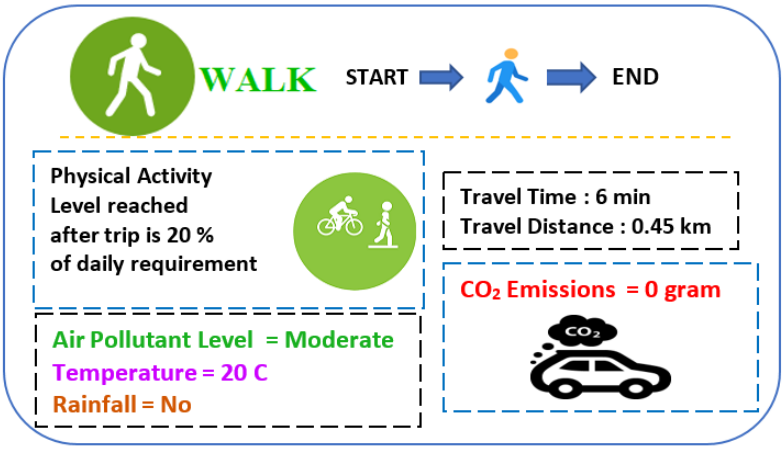


o OPTION 2 OF 2

Q18 If you have to perform similar shopping trip as shown above. Which travel model you will select. Please select one option

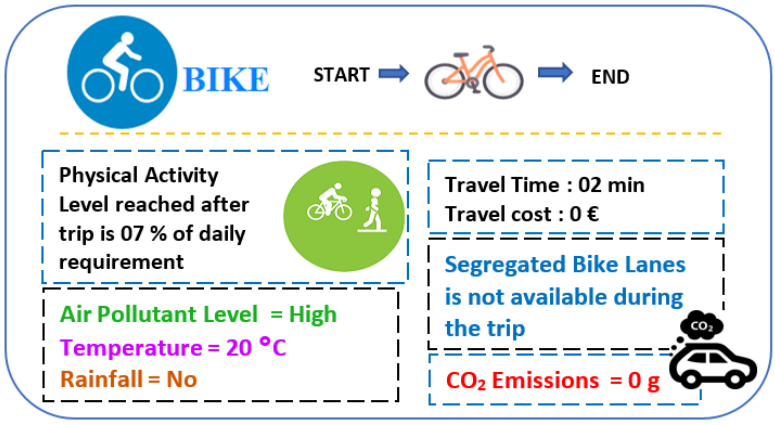
o 

OPTION 1 OF 2

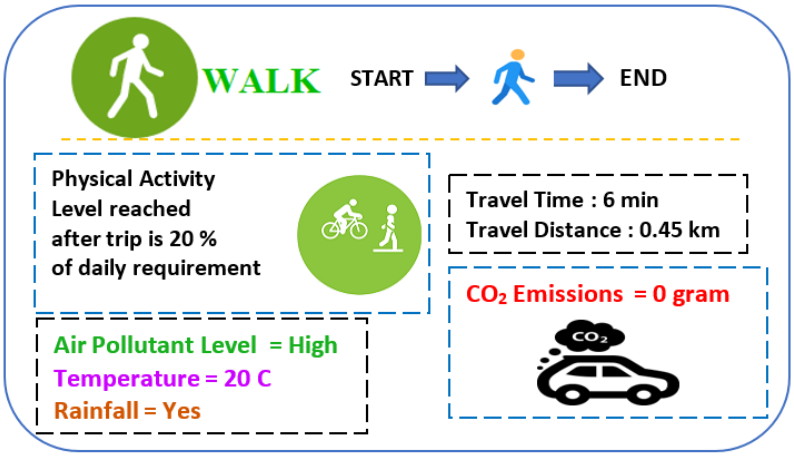
o 

OPTION 2 OF 2

Q19 If you have to perform similar shopping trip as shown above. Which travel model you will select. Please select one option

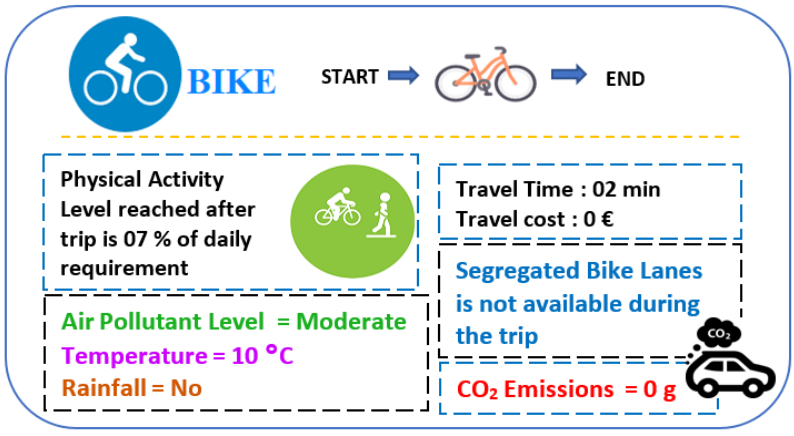


o OPTION 1 OF 2

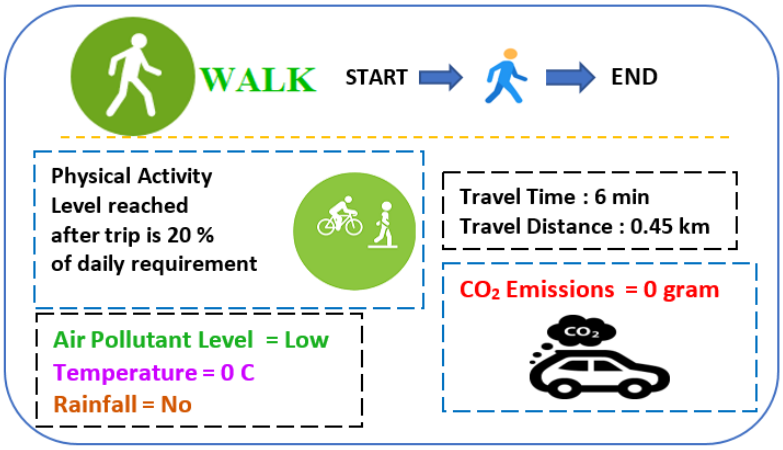


o OPTION 2 OF 2

Q20 If you have to perform similar shopping trip as shown above. Which travel model you will select. Please select one option



o OPTION 1 OF 2



o OPTION 2 OF 2

QUESTIONS ABOUT THE STUDY

Q21 Upon participating to the project pilot, did you change your transport routine?

o Yes
o No

Q22 If you select YES, then please explain why?

_____
_____
_____
_____
_____

Q23 What have you learned from your participation to the pilot?

_____
_____

Q24 Please shortly describe what you like most during the study and what you found

less interesting or difficult to understand?

10.4 Annexure-IV: Study Brochure

Did you know that …

… pollution in cities decreases the life expectancy of their citizens by two years.
… air pollutants such as ozone can damage the lungs and heart in a similar fashion as smoking does.
… your help is useful to reduce the negative effects of air pollutants.

How can you help?

Within the iSCAPE project, we implement and test smart solutions for reducing the negative effects of air pollution. These solutions aim to change the activity-pattern of the citizens by offering customized guidance, and to improve the air quality with this behavioural intervention. The study is carried out in six European cities, including Hasselt. In order to see whether these solutions are effective, **we need your help!**

You are expected to …

- use an Android smartphone.
- take the device with you to record your travel behaviour and exposure to air pollutants.
- continue doing this for at least three weeks.

Interested?
Contact us by e-mail: iscape@uhasselt.be

www.iscapeproject.eu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 689954.