The Effect of Personal Cap-and-Trade Mileage Policies on Individual Activity-Travel Patterns: The Activity Locator Project

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ABSTRACT
The objective of this work is to contribute to the debate on sustainable policies aimed at reducing personal carbon emissions from the transport sector. In particular, individuals' response to strategies that rely on individual behavioral changes, instead of technological advances, need to be tested. In this regard, the proposed research describes an experiment extending the cap-and-trade system, employed in manufacturing-based emission curb programs, to Voluntary Travel Behavioural Change (*VTBC*) program.

The methodology developed in this paper includes: (1) the implementation of a new device for daily individual activity travel patterns collection called "Activity Locator" (*AL*), and (2) the design of a new behavioral strategy called "Cap and Save" (*C&S*). The two aspects are closely interrelated, since behavioral strategies are usually difficult to evaluate; indeed, data regarding individual behavior *before* and *after* policy intervention are rarely collected.

From July to October 2009, both the *AL* and the *C&S* were tested and evaluated during a two-week survey involving a group of students of the University of Cagliari (Italy). The students' activity-travel behavior changes and their feedback on both the *AL* device and *C&S* strategy were then analyzed.

1. INTRODUCTION

Based on recent statistics, worldwide CO2 emissions during 2005 amounted to 28,051 MMt CO2eq (Million Metric tonnes of CO2 equivalents), an increase of 32% over 1990. The United States and Europe are currently responsible for about 37% of the worldwide CO2 emissions, their emissions increasing by 20% and 7%, respectively, between 1990 and 2005[1]. These increases, when considered in the context of the 5% reduction target to be achieved by 2012 as set by the Kyoto Protocol, makes it self-evident that the current practices and policy interventions implemented by national governments need to be re-examined. In particular, existing regulations and anticipated post-Kyoto policy architecture (2013 - 2018) are based almost entirely on the Emission Trading Scheme (ETS), which is implemented to curb global market manufacturing-based emissions. Little or no consideration is given to the contribution of individual citizens' behavior in their daily lives. In the transportation sector, for example, which by itself contributes to 30% of global emissions, one billion private vehicles currently on the road worldwide are considered responsible for about 60% of the total CO2 emitted. If the forecast of two billion cars by 2030 is correct, then it is timely to experiment with policies aimed at promoting more "rational" use of private cars.

It is widely recognized that GHG emissions from the transportation sector are the result of *what* individuals drive (*i.e.* vehicle efficiency and fuel type) and *how much* they drive. The majority of current programs for carbon emissions reduction focus on the first issue, almost entirely ignoring the so called "externalities" (*i.e.* congestion, urban sprawl, safety of drivers and non drivers *etc.*) related to private vehicle mileage (Litman, 2009). For example, the Italian Government, in its recently released plan to curb emissions by 2018, states that 30% of emissions cut needs to be achieved in the transport sector. However, the planned practices rely exclusively on increasing vehicle efficiency, improving fuel type and new infrastructures[2]. On the other hand, a recent study conducted by the European Commission reveals that technological advances can only contribute by 50% to emissions reduction objectives[3]. Further, the widespread adoption of scrappage schemes for replacing old vehicles with more efficient ones (*i.e.* low CO2 emissions) is likely to increase both the number of vehicles on the roads and the number of miles traveled per capita, as a result of the greater comfort and safety perceived by drivers of new vehicles (Litman, 2009). Generally speaking, private vehicle usage has become increasingly linked to individual daily activities and today represents the core of daily activity travel patterns. Individuals, in fact, schedule their activities and travel and hence life style around car use (Steg and Tertoolen, 1997).

All these things considered, implementing behavioral strategies aimed at reducing the need for individuals to drive (or reducing the mileage driven) represents one of the most topical challenges of current transportation research[4]. Unfortunately, as psychological and sociological studies have shown, behavioral strategies are difficult to realize (RAC, 1995; Steg, 1996); they require greater effort and involve some degree of discomfort, as opposed to technology strategies that require an initial investment but are definitely less restrictive of personal freedom. Further, an

[1] Transportation Energy Data Book (2009): Edition 28, Center for Transportation Analysis: Energy and Transportation Science Division http://cta.ornl.gov/data/index.shtml

[2] Direttiva 2003/87/CE – Schema di Piano Nazionale di Assegnazione, Ministero dell'Ambiente - Italian Governement.

[3] EU TRKC (2009), Transport and The Environment, Policy brochures of Transportation Research Knowledge Center, Directorate-General Energy and Transport, European Commission.

[4] CCAP (2009) Cost-Effective GHG Reductions through Smart Growth & Improved Transporta-tion Choices An economic case for strategic investment of cap-and-trade revenues, Center for Clean Air Policy Washington, DC

individual usually doubts that his/her own contribution can make the difference, and is suspicious of others' willingness to change.

The objective of this work is to contribute to the sustainable debate through the design of a behavioral strategy based on appropriate changes in the motorists' decision context (*Structural strategies*) and enhancing public awareness (*Cognitive-Motivational strategies*) (see Steg and Vlek (2009) for a review of Structural and Cognitive-Motivational strategies). This combination of strategies belongs to the so called "Voluntary Travel Behavioral Changes" (*VTBC*) approaches (Ampt, 2003; Rose and Ampt 2003; Stopher, 2005). *VTBC* programs are also called "liberal paternalistic", as opposed to compulsory measures (*i.e.* taxes, restrictions *etc.*) that are poorly accepted and unable to produce lasting effects. Each individual should be free to choose what he/she likes, even if ultimately this means choosing something not desirable (*liberal*). The *paternalistic* adjective refers to an individual's ability to choose while being guided in a particular direction. Basically, through these approaches, the policy maker attempts to influence people and their behavior to encourage them to live and travel in a more efficient and environmentally friendly way without limiting individual freedom (Thaler and Sunstein, 2008).

In particular, the proposed work involves (1) the implementation of a new device for daily individual activity travel patterns collection called "Activity Locator" (*AL*), and (2) the design of a new behavioral strategy called "Cap and Save" (*C&S*). The two aspects are closely interrelated. The *AL* is an efficient and economical system for daily individual routes and time use data collection, using a single device. The *C&S* strategy is based on the belief that individual behavior change programs are more effective if based on personal remuneration, instead of mandatory rules or external obligations.

The rest of the paper is organized as follows. The next section describes the existing voluntary travel behavior change approaches and the contribution of the current study. Section 3 describes the methodology employed. Section 4 analyses the data collected using the Activity Locator. Section 5 analyzes the results of the Cap and Save pilot survey. Finally, Section 6 contains the conclusions and further research opportunities.

2 EARLIER APPROACHES AND THE CURRENT STUDY

A voluntary travel behavior change (*VTBC*) is defined as the change that occurs when an individual makes decisions based on personal remuneration, without mandatory rules or external obligations (Ampt, 2003). Although part of TDM policies, *VTBC* programs rely on available resources and social-urban changes, more than directly on travel demand interventions. In a general sense, the ultimate intent of these interventions is to increase sustainable mode shares, endorse car use reduction, car pooling, and trip chaining, and finally encourage the use of public and non-motorized transport (*i.e.* walking and biking). There are several underlying reasons for these changes in travel behavior: dissatisfaction with current lifestyle, the desire to change behavior, someone well known and respected who has already changed, an important change in life (*e.g.* new job, new house, new partner *etc.*), or ultimately just because it is the "in-thing and "the cool thing" to do. It is important however that additional benefits ensue from improved behavior (*e.g.* incentives, tax reductions, infrastructure improvements *etc.*), which motivate individuals (Ampt, 2003).

Currently, two main *VTBC* programs are identified in the literature. The first, labeled as "Tradable Emission Permits" (*TEP*), which is under debate mainly in the United Kingdom, extends the concept of EU ETS to curb personal emissions. The key concept is that the cost of emission is borne by emitters. Thus, those who (voluntarily) decide to rationalize car use pay less (Raux, 2008; Raux and Marlot, 2005; Vlek, 2007). The second approach, called "Personal Journey Planning"

(*PJP*), originated primarily in Australia. It relies on the idea that improving the level of information helps people to decide to change their travel behavior. Based on a *TEP* system, each country would be required to establish a maximum amount of personal or household carbon emissions (cap) and the price of each additional permit used. In this type of system, governments play a crucial role by ensuring supervision and sanctioning where needed (Bruneau, 2005). On the other hand, *PJP* strategies are based on (1) social marketing to guide individuals towards environmentally friendly modes, without necessarily altering the number of out of home activities or the time spent traveling (*i.e. IndiMark*), and (2) approaches seeking to offer households with personalized alternatives to reduce travel overall, without necessarily changing the travel mode at all (*i.e. Living Change/Living Neighborhoods*) (Stopher, 2005).

In this work, the *TEP* and *PJP* techniques are weaved together, since such a combination offers three main advantages: (1) the intervention is personalized, (2) the behavioral changes are based on personal remuneration (3) the citizen is informed about the effects of private car usage on climate change. Clearly, in both the *TEP* and *PJP* approaches, data collection constitutes a critical aspect. A deep understanding of individual activity-travel behavior is in fact essential to adjust CO2 permits to individuals' freedom and comfort, and to identify the relationships between car use and the rest of daily individual decisions. In particular, GPS tracking in conjunction with time use data seems more appropriate for analyzing daily routes, mileage traveled, activity scheduling, and lifestyles in general. Recently, activity-travel surveys have seen many changes, mainly because of the advent of new technologies (GPS, Internet etc.) that permit new types of data to be collected, while also reducing costs and improving quality. Application with GPS systems has shown that travel diaries miss about 20% of daily trip making; generally short trips that are potentially more amenable to change under *VTBC* programs. Similar problems arise with time use diaries, filled in at home at the end of the day, since they rely to some degree on memory recall, and require the individual to concentrate his/her efforts on a single episode (Stopher, 2005).

The present work proposes a *VTBC* program called "Cap and Save" (*C&S*) that relies on a new data collection system called "Activity Locator". The *C&S* involves: (1) determination of weekly/annual emissions (cap), and the corresponding remuneration (save), (2) a cognitive-motivational process, (3) the analysis of activity-travel behavior *before* and *after* policy intervention, and (4) the creation of personalized alternatives. Note also that the *AL* is particularly suitable for supporting a *C&S* program since it: (1) identifies habits and requirements related to the entire range of activity-travel decisions, including the exact number of kilometres traveled and related costs, (2) is a user-friendly, low cost, portable device installed in ordinary smart phones with built-in GPS, (3) collects both position information and time use data in real time, and (4) is able to interact with the user.

To test both the *C&S* strategy and the *AL* system, a two-week survey was conducted from July to October 2009 among a group of students from the University of Cagliari (Italy). In the first week, the students were invited to carry the *AL* and report their actual daily activity-travel patterns. In the second week, the students were asked to carry the device for another week, trying to maintain a weekly *cap* of CO2 and *saving* the corresponding resources (*i.e.* carbon emissions and money). In particular, each student was provided with a set of personalized alternatives, and was asked to reduce the kilometres traveled by 20%.

3. METHODOLOGY

This section describes the methodology employed in terms of the Activity Locator system implementation, Cap and Save program design, and Cap and Save pilot survey.

3.1 Activity Locator System Implementation

The “Activity Locator” system comprises (1) a *client* software installed in a portable GPS-integrated device, (2) a *server* software that transmits and receives information to/from each *client*, and (3) an internet connection.

The client software is a Java application that can be installed in any smart phone (*Symbian* or *Android* platform) with built-in GPS currently available in the market. The application enables the tracking of individual daily routes and the collection of all activity-travel related information through a sequence of pull-down menus that reproduces the classical activity diaries. The main difference from traditional activity diaries is that activities are recorded in real time, instead of at the end of the day after returning home.

The application is accessible from the cell phone “home” screen, pressing a dedicated key on the bottom right. After a couple of authorization questions regarding personal data use and privacy issues, which the user necessarily needs to respond to, the *AL* connects to the server that then transmits a list of possible activities (Figure 1). The box on the left side of Figure 1 contains the first possible entry, which can either be a “new activity” (*i.e.* activity about to be performed) or a “forgotten” one (*i.e.* previous activity/trip, whose entry was forgotten). Further, the user ID can be changed (user), or the application updated (update). Once the user decides whether to enter a new activity or a forgotten one, the subsequent boxes elicit information on the “activity type” (*i.e.* in-home, out-of-home, trips) and further attributes of the activity. The application is also designed to send automatic pings every 5 seconds containing only positioning data (latitude, longitude). Lastly, to save battery life, the application includes another key that enables the user to turn on/off the GPS (basically the pings) when outdoors/indoors.

The server software collects the information sent by each client. After decoding and decrypting, each user can visualize the information online, after account authentication (login and password) to the web version of the server[5]. Each user can be identified in real time on a map (powered by Google Maps) by a symbol containing all the user information (*i.e.* spatial, temporal, and activity information). The data are immediately available in database formats (*i.e.* xls, csv, xml) and downloadable onto any desktop or laptop computer. The data are transferred by each client to the server and vice versa via an internet connection. In addition, the server software is designed to send a variety of information to the clients such as traffic information and survey requirements.

In this project, the activity locator was installed on 35 Nokia N95 smart phones, and on 1 HTC Magic (Android), property of the University of Cagliari (Italy). Both Nokia and HTC have built-in GPS, long battery life (up to 7 hours), and wide screens for client software requirements. The cell phones were equipped with prepaid USIM cards for sending/receiving data, calls, and text messages.

3.2 The *Cap* and *Save* pattern (guidelines)

The *C&S* program proposed in this work comprises four basic parts: (1) definition of a set of parameters (*i.e. cap*, *save*, participants in the program *etc.*), (2) a cognitive-motivational action, (3)

[5] http://whereis.softfobia.com/login.jsp (in Italian)

analysis of activity-travel behavior *before* and *after* policy intervention, and (4) creation of personalized alternatives.

The parameters of the *C&S* program are as follows:

1. The environmental *cap* measure, which translates CO2 permits into a quantity that participants can easily understand (*e.g.* vehicle kilometers to be traveled).
2. The corresponding *save* measure, which is the monetary value of the weekly *cap* in terms of personal costs (*i.e.* proportional and non-proportional costs of car use) and externalities (*i.e.* societal and environmental costs). Both costs can be calculated for each kilometer traveled[6].
3. The recipient of the *cap* - Should all car users receive a *cap*? Or should the *cap* be restricted to only car users or only car owners, or to only car drivers or only passengers? Frequently, car drivers use their cars for serving passenger that benefit passengers. In our scheme, both car drivers and passengers are provided with a personal *cap*.
4. The amount of permits (*cap)*, which is determined based on a rate of vehicle kilometers traveled in regular conditions. Previous works on voluntary travel behavior changes report a reduction rate of 10-15% off as an accepted (and acceptable) rate.
5. The permits trade scheme, or the trade scheme that participants are supposed to be part of, which may correspond to a tax reduction (*e.g.* on annual car tax) or incentives if the cap is maintained. On the other hand, an additional charge is applied for extra kilometers traveled.

A cognitive-motivational action plays a crucial role in persuading individuals to change their travel behaviour. A number of principles of persuasion can been adopted[7]: (1) *Reciprocation:* an incentive, given unconditionally, leaves the participants with the perception of having been asked genuine favour (in this research, an all-inclusive weekly phone plan and a final dinner out were offered to participants), (2) *Commitment and consistency*: if the participants take on an initial commitment, it will guide their subsequent actions (participants were first involved in testing a new device), (3) *Social proof*: choosing peer groups for the program increases the willingness to participate (a social network of students was selected in the current research), (4) *Liking*: people are increasingly inclined to follow a request brought forward by someone they like and materials should be designed and presented in an attractive fashion (the students were provided with a personalized book), (5) *Authority*: when making a decision, it is common to seek expert advice from an acknowledged source (the Department Director during a formal seminar explained climate change-related issues), and (6) *Scarcity*: the principle of scarcity reflects the fact that as opportunities become more scarce, they are perceived as more valuable (the "costs" aspect was emphasized).

The analysis of activity-travel behaviors *before* and *after* policy intervention involves the collection of accurate activity-travel patterns for two weeks plus a number of questionnaires regarding: (1) personal, household, and vehicle data, (2) climate change attitudes, and (3) feedback and suggestions. Both the activity-travel pattern collection efforts and the questionnaires rely on the support of a team of operators who (1) check for data consistency (mistakes and forgotten activities)

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[6] To give an example, the personal cost per kilometer traveled can be obtained as the sum of proportional and non-proportional costs. 0.38€/km is the average value for small petrol and diesel saloon cars (15.000 – 20.000 km traveled annually) as calculated in http://servizi.aci.it/ServizioCK/SelezioneModello. Regarding the societal costs, following Lombard *et al.* 2005, for the situation in Italy, a value of 0.37€/km (private urban trips) is calculated. In particular, the contribution to climate change is taken as 1% (0.006 €/km).

[7] See Seethaler and Rose (2005) for a general review of the six principles and for an application to VTBC programs.

during real time data collection, (2) re-call participants in order to correct the databases, and (3) create the final databases.

The creation of personalized alternatives follows the analysis of weekly activity-travel patterns from the first survey week and is based on the objective of finding sustainable alternatives for each regular trip reported. The alternatives are created for any trip mode that is considered part of an unsustainable trip (*i.e.* trips that can be comfortably substituted by bus trips or walking trips, short distance trips traveled by motorized trips, multiple vehicles driven by household members at the same time and towards the same destinations *etc.*) and for any trip purpose as well (*i.e.* discretionary trips, work/study trips *etc.*). The number of alternatives created for each participant depends on the personal cap, which is a certain rate of his or her kilometres traveled during the first week.

3.3 The Cap and Save Pilot Survey

In July 2009, a group of 18–25 year old students from the University of Cagliari, part of a common social network, were invited to an informal meeting to describe a study being carried out by CIREM (University of Cagliari). At the end of the meeting, 26 students agreed to participate in a survey to collect individual activity-travel patterns using an innovative device that needed to be tested. Each of the students received an activity locator along with a personal data questionnaire (*i.e.* address, household and personal information *etc.*) and instructions on using the device. The participants were then asked to use the *AL* to collect in-home, out-of-home and travel during the whole incoming week. Each smart phone was equipped with a 3€/week unlimited daily data plan and 3€/week for 60 min/day voice calls and 100 texts/day, which the students were invited to use.

During the survey week, a team of operators assisted the participants by (1) checking data consistency, (2) reminding the participants to turn on the device and (3) testing system performance (GPS data collection accuracy and server load/response time). To ensure that the data were as accurate as possible, the users were contacted both in real time and at the end of the day to fill in missing locations and activity attributes, usually after a text message asking for their availability. At the end of the week, the devices were retrieved and each user's activity-travel pattern was analyzed in detail. First of all, the personal weekly "cap" was computed for each participant as 20% off the actual kilometers traveled by car. Further, for each trip reported during the week, a sustainable alternative (if one exists) was created, including options for car pooling with family members or friends, public transit, parking further away than the destination, walking and even deleting unnecessary trips.

During October 2009, the same students were recalled and invited to participate in a formal seminar called "Cap and Save project". During the seminar the issues related to carbon emissions from the transportation sector were explained to the students by the Department Director. Specifically, personal and societal costs per kilometer traveled by private car were presented together with the savings corresponding to a reduction of 20% in annual average kilometers traveled. Finally, the students were clearly informed that the objective of the second survey week was to try and reduce private car usage. In order to do so, each participant received a personal book containing (1) a brief welcome message from the project coordinator, (2) a questionnaire to test their knowledge and obtain their attitudes about climate change issues (3) a reminder of personal and societal costs due to car usage, (4) general suggestions for reducing the kilometers traveled together with the personal weekly "cap" of kilometers to be traveled by car and the corresponding monetary and carbon "save" estimates, (5) a table summarizing the personalized set of sustainable alternatives, (6) information on bus services (schedules and map) for each bus trip suggested (7) a table containing the summary of all participants' (identified by anonymous ID) targets and potential savings.

At the end of the meeting, 14 students agreed to participate in the Cap and Save pilot survey (86% car drivers and 14% car passengers). They were equipped with the activity locators and asked to start recollecting their activity-travel patterns starting from the next morning. The team of operators assisted them for the whole week, though less support was needed this second time around mainly due to system familiarity and the user's increased confidence with the device. At the end of the survey, the users were asked to return the cell phones and to complete a questionnaire with their feedback regarding (1) the cognitive-motivational approach followed to present the Cap and Save project (book and seminar), (2) the Cap and Save pilot survey, and (3) the activity locator device.

Finally, the users and operators were invited out for dinner by the Department Director to express appreciation for their contribution.

4. DATA DESCRIPTION

The first and second week databases are merged and a brief description of this merged data is provided in this section. The analysis includes only the 14 students who participated and completed both survey weeks. Note that the analysis in this part is intended primarily to explore the potential of the activity locator in terms of quality and quantity of collected data. However, notwithstanding the small sample size, the data do provide some limited insights into activity-travel behavior.

Six different databases were created for each survey week: (1) Individual file (2) Positioning file, (3) Segment file, (4) Episode file, (5) Tour file and (6) Time use file. The individual file contains all the individual, household and vehicle information associated with each participant. The positioning file includes all the automatic pings (latitude, longitude) and the manually inserted activity information. The segment file aggregates the positioning cases in trip segments (trip legs due to transfers, pick up/drop off *etc.*). The episode file is created by the further aggregation of segments to obtain the final origin-destination trip (primary mode and purpose have been derived[8]). The tour file contains the different types of tours and related characteristics. Finally, the time use file contains the weekly individual time allocated to each activity type. In the remaining part of this section, a brief description of each database is provided.

Individual file. The sample comprises students from the University of Cagliari, with 57% males and 43% females; half of the students are aged 20 – 22 years, and the remaining half of the students are between 24 – 28 years of age. All the students live with their families, 79% in the capital Cagliari, and 21% in the hinterland and metropolitan area. Regarding vehicle usage, 93% possess a driving license (50% owns a car and 43% has access to the household vehicle). All the students drive small saloon cars (70% 3 doors, 1200 cc and less). 54% of the vehicles have petrol engines, Euro 4/Euro 5, and were registered after 2006. About 77% of the vehicles were brand new when purchased, with an average purchase price of 13,000€. The average annual kilometers traveled is between 12,000 and 15,000. None of the students in the sample own or use a bike, but 7% own a motorcycle. Only 14% of the sample has a monthly bus pass.

Positioning/Segment/Episode files. During the two survey weeks, a total of 61,287 positioning points (*pp*) were recoded, corresponding to 1229 activities in-home, 999 out-of-home,

[8] In this work the travel mode used in the last trip leg has been associated with the tour mode in non work, before work, home work and after work tours and the mode used in the first trip leg for work to home. In both cases, when 2 or more legs were traveled by different modes, the motorized mode received priority. In case of simultaneous presence of two and more motorized modes the order of priority is bus, car as a passenger, car as driver, and motorcycle. Walking tours are supposedly traveled entirely on foot.

and 1515 trip segments (legs). Almost 78.5% of the positioning points were collected during weekdays and the remainder on weekends. Each user, on average, recorded 3404 *pp* (265 *pp*/day) corresponding to about 28 tours (2 person tours/day), 30 activity stops (2.15 person activity stops/day), 73 trip episodes (5.65 person trips/day), and 391 km (28 person km/day). In particular, 96.3% of the total distance was traveled by car (56% as a driver and 40.3% as a passenger), while the remaining distance was split between the non-car modes as follows: walking (0.7%), bus (1%) and motorcycle (2%). Further, 47% of the total distance was attributable to urban and metro-area trips, and 53% to interurban and inter-province trips.

Tour file. The tour behavior has been analyzed separately for six different tour types: (1) Non Work/Study tours (NNW), (2) Before Work/Study (BW), (3) Home to Work/study commute (HW), (4) Work/study-Based (WB), (5) Work/Study to Home commute (WH), and (6) After Work/study (AW). The average time spent in daily tours is about 4 hours; 68% of this time was spent in stops and the remaining 32% on travel. NNW tours, which identify mainly tours during non-study days or student's tours with no work/study activity on the survey day, are more frequent during weekends (1.2 NNW person tours/day on Saturday and 0.89 NNW person tours/day on Sunday). On average, students participated in almost two commute trips on weekdays (one HW and one WH). AW tours are more frequent than BW tours, with the highest percentage of AW tours being reported on Thursdays and Fridays (50% of the students participate in after school activities). By contrast, BW participation is higher on Mondays and Tuesdays (8%).

Time use file. The time use behavior is characterized by in-home (IH) and out-of-home (OH) activity time allocation to (1) maintenance activities (*i.e.* personal care, household care, meals), (2) mandatory activities (*i.e.* work/study), (3) discretionary activities (*i.e.* recreational, social, sport, leisure (TV, books, internet), voluntary service, religion, coffee break), (4) shopping, (5) errands (car, house, etc.), (7) waiting for a ride (bus, car), and (8) sleep and relax. The results indicate a general tendency to spend more time at home in maintenance and pure leisure activities (about 36 hours a week) compared to the time spent out of home for the same activities (12 hours/week). In terms of sleeping and relaxing time, students, as expected, spend more time in-home rather than out-of-home: 58 hours/week IH (slightly more than 8h/day) vs. 5 hours/week OH. On the other hand, the time spent at home working or studying is 40% less than the time spent out of home (11 hours/week IH vs. 17hours/week OH); the time for discretionary activities is mostly spent out of home (1h/week IH vs. 14h/week OH). Shopping and errands take up about one hour a week each.

5. RESULTS

In this part, the results of the Cap and save pilot survey are described, classified into three parts: (1) attitude revealed by students toward climate change, (2) feedback on the Cap and Save project and the activity locator device, and (3) finally comparison of students' activity-travel behavior before and after the Cap and Save presentation.

5.1 Attitudes toward climate change

The students' attitudes toward climate change were investigated before the beginning of the second survey week. Based on the responses, all the students believe human behavior is responsible for climate change. 86% of the sample believes that changing individual behavior could help reduce emissions, but the majority usually does *nothing* (31.6%) *or little* (24.7%) to reduce own emissions. Among those who do something to reduce emissions, the main ways included (1) diminishing regular car usage (64%), (2) using non-motorized transport (bus, walking, bike etc) (71%), (3) buying local products (57%), (4) buying green items (86%), and (5) using eco-technologies (71%). However, the majority of the students (93%) recycles and consciously tries to make efficient use of heating/air conditioning and domestic appliances (64%).

In general, the students consider cutting personal emissions too difficult due to the following reasons: too much time and effort is required (71%), sustainable alternatives are little known (71%), and advanced planning is usually required (57%). Further, the main reason why they would reduce their carbon emissions is because the environment is a common property (86%). The desire to save money and the possibility of increasing physical activity levels each account for about 79% of the student responses. General concerns about climate change are important for 64% of the students; however, the fact that other people try to cut carbon emissions only affects 7% of the participants, indicating low levels of peer influence.

5.2 Feedback on the Cap and Save project

The students were first asked during the survey whether they were aware of the objective of the project: all of them indicated that the objective of the survey was to "reduce carbon emissions due to kilometers traveled by car". Further, they were invited to list two sustainable options which they were already aware of before the beginning of the survey. Most respondents indicated one of taking the bus, walking, or using a motorcycle as sustainable options to using the car. The responses relating to the personal book provided at the beginning of the second survey indicated that the book was in general well explained (93%) and useful and interesting (86%), but respondents did not find any original information about the alternatives provided (57%).

Regarding how many kilometers they traveled during the second survey week, about 46% could not respond and none could indicate the carbon emitted during that week. The only costs easily remembered, and only by those who indicated the weekly kilometers, were related to the proportional costs of personal car usage. Finally, responses to the questions regarding whether and how individuals had changed their behavior indicated that 28.6% did not change behavior, 57.1% changed behavior by using a non-car alternative for one or more trips originally pursued by car, and 14.3% changed behavior by reducing the distance traveled by car, either through suppressing trips or chaining trips or going to closer activity locations. Note that these behavioral change estimates are based on overall self-reported respondent perceptions of their own behaviors. Among the students who indicated a change in behavior by using a non-car alternative, 77% indicated that they used some of the modal alternatives found in the book and 90% said that the change had not been stressful at all. Among those who reported no travel behavioral change of any kind, 40% reported that they did not have the time to try the proposed alternatives, 20% indicated that they stayed at home all the time, another 20% reported that they tried but it was too hard, and the final 20% of respondents indicated that the given target was not appropriate to the second survey week.

5.3 Feedback about Activity Locator device

The questionnaire concerning the AL proved helpful for identifying gaps in the device and problems with usage. The results suggested that 35% of respondents forgot to enter pick up/drop off stops as soon as such stops were completed, 21% missed some in-home activities immediately after completion, 14% forgot one or more walking trips just after completion, 14% missed impulse (or instantaneous trips that were unplanned), and 6% each missed one or more meal activity episodes and very short/not regular activity episodes immediately after pursuing such episodes. However, the respondents also indicated that these missed activities were easy to enter as "forgotten" entries and no particular difficulties were indicated with using the device.

More than 64% of respondents remembered to turn off the GPS during indoor activities in order to save cell phone battery life, and all respondents appeared to be careful to check the GPS signal. 42% of the students sometimes experienced connection problems sending their information and 64% complained about battery life. About 50% of the students would have preferred the activity locator installed in their cell phones and about 80% were sure they would not have participated in the survey had they had to fill/correct the activity diary manually at the end of the day. Furthermore none of them were bothered by the operators' phone calls to check data inconsistencies or missing data. All of them described the activity locator as an easy and friendly device requiring really little effort and time. Interestingly, only 21% felt someone was spying on them.

5.4 VTBC analysis

In this section, the activity-travel patterns collected during the first and second weeks are compared to test whether or not some travel behavior changes had occurred and how these had affected the number of kilometers traveled and the general activity-travel participation patterns. However, because the first survey week was in the summer, while the second was in autumn, we focused our attention only on the relatively stable (across seasons) urban, metropolitan and interurban trips. Long distance trips, which are associated with inter-province trips, were not considered because they are more likely to be undertaken in summer than in autumn.

Table 2 shows the average distances traveled during each survey week and the percentage variation by car as a driver, car as a passenger and by walking for different trip purposes, separately for individuals who share a vehicle with other family members (car users) and individuals who have their own cars (car owners)[9]. The table shows that the distance traveled by car users when driving a vehicle decreased for all activity purposes during the second week, except for sports. The distance traveled by car owners when driving a vehicle increased for meal-related activities. Both classes of drivers significantly reduced the kilometers traveled for leisure reasons (see the last row of the first panel of Table 2). The second panel of Table 2 indicates that the distance traveled by car users and car owners as passengers in the vehicle increased for the work/study and sports purposes, and decreased for the social/recreational purpose. Interestingly, the results also suggest that the distance traveled by car users as passengers increased for errands and shopping activity purposes, while the distance traveled by car owners as passengers decreased for errands and shopping activity purposes.

Finally, in general, walking distances increased for car users (except for meals and sport) and decreased for car owners. These results are not immediately intuitive, and suggest the need for a larger sample collection during the same season of the year.

Table 3 presents the average weekly duration in minutes (for the first and second survey weeks) and the percentage variation for in-home and out-of-home activities. In home activities appear in general to decrease both for car users and car owners, except for the recreational and social purposes (for car users) and household care (for car owners). The decrease in in-home activity duration between the summer season and the autumn season can probably be explained by the fact that there are no classes in July and students spend most of their time at home studying for exams. On the other hand, October coincides with the beginning of the semester for Italian students and the daily schedules are mainly arranged around classes. With regard to out-of-home activities, the most

[9]Note that the only student without a driving license was excluded from the analysis reported in this table and from the following one.

significant variations are an increase in shopping and a decrease in leisure time for car users, and a strong increase in the time spent in sports for both car users and car owners.

Finally, Table 4 shows a summary of individual Cap and Save results in terms of (1) total kilometers traveled during the first week, (2) the proposed target, (3) kilometers traveled during the second week, (4) difference between kilometers traveled during first and second week, (5) percentage variation (6) annual projection of personal costs saved and (7) annual projection of CO2 saved. The table shows that 50% of the survey participants reduced the kilometers traveled, but only 30% achieved the proposed target. The average participant (last row of the table) traveled 138 km the first week, but instead of traveling 27 km less by car to cut emissions by 20%, he/she only reduced the distance traveled by 8 km corresponding to about 6% less. Maintaining this behavior, in one year, the student would save about 244€, reducing CO2 emissions by 0.06 tons.

6. CONCLUSIONS

It is widely recognized that GHG emissions from the transportation sector are the result of *what* individuals drive (*i.e.* vehicle efficiency and fuel type) and *how much* they drive. The majority of current programs for carbon emissions reduction are aimed at influencing *what* individuals drive (mainly through technological advances), with little to no emphasis on *how much* individuals drive and the related "externalities" (*i.e.* congestion, urban sprawl, safety of drivers and non drivers *etc.*) related to private vehicle mileage. But the continuous increase of carbon emissions as a direct result of human activities in the residential and transportation sectors needs to be addressed by relying on both technological advances (the *what* dimension) and individual behavioral changes (the *how much* dimension).

Currently, the implementation of behavioral strategies aimed at reducing *how much* individuals drive represents one of the most topical challenges in transportation research. The objective of this work is to test a rational combination of behavioral strategies to promote "virtuous" alternatives through appropriate changes to the decision context (structural strategies) and raising citizen awareness (cognitive-motivational strategies). This combination of strategies can be considered as a part of so called "Voluntary Travel Behavioral Changes" (VTBC) programs, which contrast with the policies aimed at reducing individual freedom (*i.e*. taxes, restrictions etc.).

In particular, in the research undertaken in this paper, a program called "*Cap* and *Save*" has been designed and tested. The name "Cap and Save" (*C&S*) comes from the popular "Cap and Trade" system that regulates EU ETS. However, in the Cap and Save context, the global market that regulates the carbon permits in the ETS is substituted by a Governmental agency that regulates and monitors individual remuneration. The *C&S* program includes four basic components: (1) definition of weekly/annual emissions (cap), and the corresponding remuneration (save), (2) a cognitive-motivational process, (3) the analysis of activity-travel behavior *before* and *after* policy intervention, and (4) the creation of personalized alternatives.

To collect detailed activity-travel patterns, CIREM of the University of Cagliari (Italy) implemented an innovative portable system called "activity locator". The system, installed in GPS-integrated smart phones, is particularly suitable for the purpose of this research because of several reasons. First it quantifies the exact number of kilometres travelled; second it identifies habits and requirements related to the entire range of activity-travel decisions; third it is a user friendly and low-cost portable device; and fourth it is able to interact with the user. Two types of data can be collected: (1) spatial-temporal positioning data through a GPS module, and (2) in-home, out-of-home activity and travel attributes data such as activity type, activity location, company, travel mode, trip purpose, and vehicle occupancy). The positioning and activity data can then be overlaid onto the urban network using GIS software to obtain participants' daily routes in a suitable format for traffic assignment.

A two week survey was conducted from July to October 2009 among a group of students from the University of Cagliari (Italy) to experiment with both the *C&S* strategy and the *AL* system. In the first week, the students were invited to carry the *AL* and report their actual daily activity-travel patterns. In the second week, the students were asked to carry the device for an additional week, trying to maintain a weekly *cap* of CO2 and *saving* the corresponding resources (*i.e.* carbon emissions and money). In particular, each student was provided with a set of personalized alternatives, and asked to target a reduction in kilometres traveled by 20%.

The results of the study provide important insights related to the activity locator device and the Cap and Save pilot survey. The activity locator had several distinctive features: it is a small device, is a new interesting content for cell phones, and is easy to install in any smart phone and in particular in Android platforms. It is inexpensive because of the GPRS/UMTS connection and can be personalized by the user. Potential sectors of application of the device include vehicle tracking, ITS and safety, and mobility management. More specifically in the research field, it can be employed in time use analysis and route choice analysis, or can be used to provide data input to other research fields (*i.e.* exposure analysis, physical health *etc*.).

The Cap and Save pilot survey has highlighted the importance of accurate activity-travel patterns data for creating real alternatives for car users. Also, a rigorous cognitive-motivational approach is necessary to persuade individuals to change their travel behavior. The pilot results do not allow us to draw general conclusions because of the small number of participants, but the suggestion is that 10-15% of car use reduction does not require any substantial effort.

The next step planned for future research is to extend the survey to a sample of representative households, improve the accuracy of GPS, increase web server application interactivity and integration with microsimulation models.

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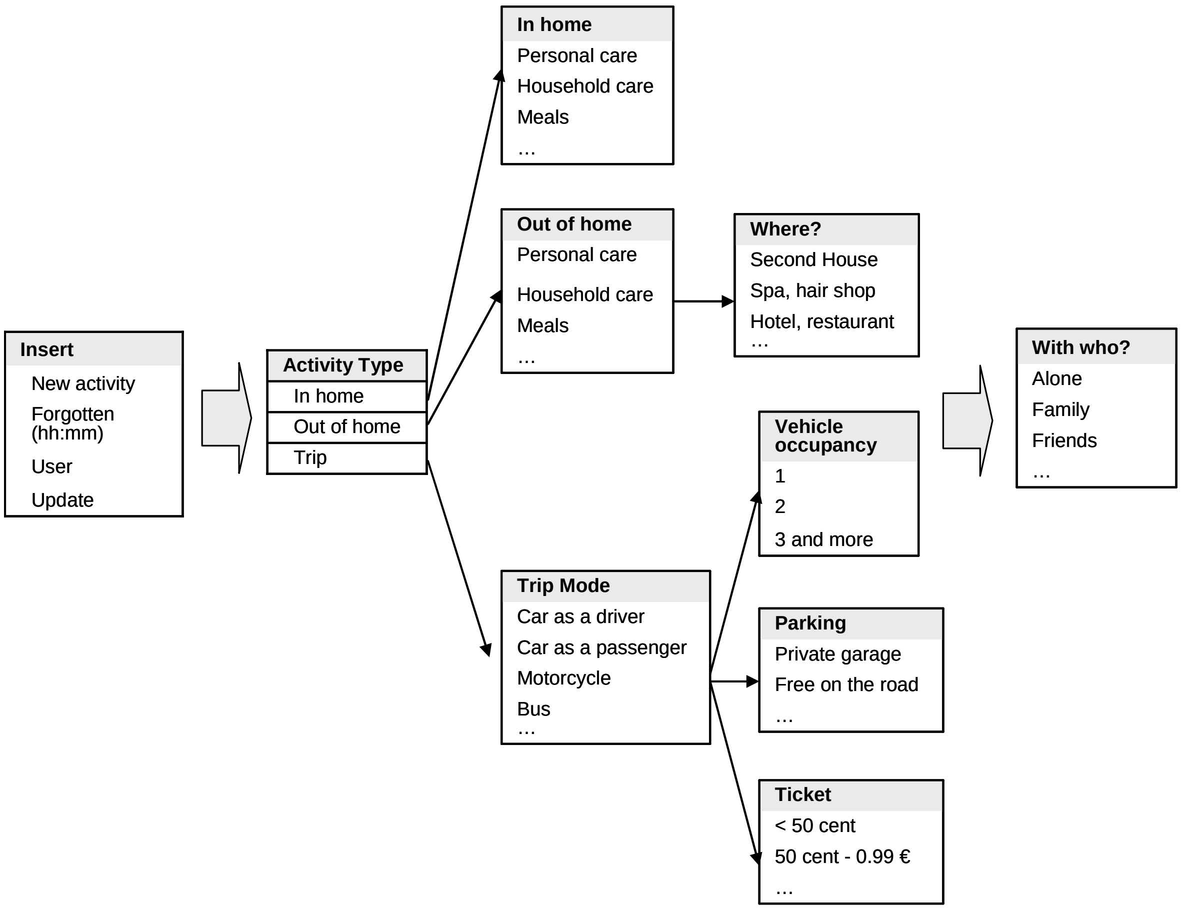

FIGURE 1 Activity Locator (Client Server structure)

TABLE 1 Distance traveled by different modes and users (km)

	Car Users			Car Owners		
	I week	**II week**	**% Variation**	**I week**	**II week**	**% Variation**
Car as a driver						
Return	61.46	60.48	-1.60%	42.64	48.30	13.26%
Meals	30.75	16.34	-46.87%	5.46	11.22	105.53%
Work/study	11.48	9.78	-14.81%	20.92	14.24	-31.92%
Shopping	10.10	8.68	-14.06%	5.46	7.35	34.65%
Errands	11.06	2.86	-74.14%	8.80	7.61	-13.56%
Recreational, Social	14.56	11.90	-18.27%	10.53	12.75	21.10%
Sport	1.17	2.26	93.16%	6.66	5.74	-13.73%
Leisure (TV, books, Internet)	4.68	1.64	-64.96%	10.29	0.96	-90.69%
Car as a passenger						
Return	28.60	21.65	-24.30%	12.82	9.69	-24.42%
Meals	8.61	7.36	-14.53%	5.52	4.98	-9.69%
Work/study	8.50	11.72	37.84%	1.19	3.80	220.48%
Shopping	1.40	3.98	184.40%	0.74	0.31	-57.53%
Errands	1.53	4.90	219.57%	2.59	1.26	-51.52%
Recreational, Social	31.10	7.45	-76.06%	12.16	9.18	-24.47%
Sport	--	3.62	+	0.13	0.97	655.56%
Leisure (TV, books, Internet)	--	--	--	1.89	1.97	4.55%
Walking						
Return	0.76	2.32	205.26%	0.35	0.08	-78.57%
Meals	0.14	0.01	-93.38%	0.30	0.18	-41.08%
Work/study	0.22	1.91	766.09%	0.30	--	-100.00%
Shopping	0.58	0.75	30.03%	--	0.10	+
Errands	--	0.47	+	--	0.08	+
Recreational, Social	--	1.72	+	--	--	--
Sport	0.48	0.24	-50.00%	--	--	--
Leisure (TV, books, Internet)	--	--	--	--	--	--

(--) Indicates a zero value
(+) Indicates a percentage variation compared to initial zero

TABLE 2 Time use (average weekly minutes)

	Car Users			Car Owners		
	I week	II week	% Variation	I week	II week	%Variation
In home activities						
Personal care	1047.23	122.88	-88.27%	1031.47	69.72	-93.24%
Household care	92.74	40.39	-56.45%	2.51	28.60	1040.84%
Meals	937.93	232.06	-75.26%	820.61	391.97	-52.23%
Work/study	1148.36	235.14	-79.52%	679.50	299.11	-55.98%
Recreational, Social	42.63	66.62	56.29%	19.57	--	-100.00%
Sport	21.50	--	-100.00%	--	--	--
Leisure (TV, books, Internet)	1027.94	474.38	-53.85%	781.10	602.15	-22.91%
Sleep/Relaxp	5325.59	931.81	-82.50%	5221.95	1209.39	-76.84%
Out of home						
Meals	566.80	483.14	-14.76%	451.02	438.29	-2.82%
Work/study	945.17	1041.33	10.17%	830.99	1030.06	23.96%
Shopping	33.34	50.46	51.32%	65.85	52.03	-21.00%
Errands	52.14	50.75	-2.67%	59.14	73.60	24.44%
Recreational, Social	386.09	453.58	17.48%	566.26	608.02	7.38%
Sport	61.98	123.59	99.39%	105.14	217.93	107.27%
Leisure (TV, books, Internet)	64.21	26.12	-59.32%	178.45	196.01	9.84%

(--) Indicates a zero value

TABLE 3 Cap and Save results

Mode	Km I Week	Target (-20%)	Km II Week	Difference in kms between I and II weeks	% Variation in kms	Money saved (€/year)	CO2 saved (tons/year)
Car as a driver	32	25	4	-28	-88%	552	0.20
Car as a driver	210	168	147	-62	-30%	1234	0.45
Car as a driver	82	66	58	-24	-30%	480	0.18
Car as a driver	242	193	176	-66	-27%	1300	0.48
Car as a driver	113	90	100	-13	-11%	250	0.09
Car as a driver	236	188	226	-10	-4%	188	0.07
Car as a passenger	211	169	203	-8	-4%	-	0.06
Car as a driver	276	221	277	1	0%	-21	-0.01
Car as a driver	73	58	75	2	3%	-44	-0.02
Car as a driver	69	58	72	3	4%	-53	-0.02
Car as a driver	64	51	70	6	9%	-120	-0.04
Car as a driver	135	108	156	21	15%	-411	-0.15
Car as a driver	130	104	151	22	17%	-430	-0.16
Car as a passenger	67	54	111	44	65%	-	-0.32
Mean	*138*	*111*	*130*	*-8.04*	*-5.69%*	*243.76*	*0.06*