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A preliminary analysis over the factors related with the possession of an electric bike

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Abstract

In recent decades different studies focused on how to incentivize a shift from car to bicycle. In this context the electric bike is gaining more and more popularity. Because of its higher speed and longer reach, the e-bike could be an attractive alternative to the car. Through an online survey (together with a GPS tracking campaign and a weekly travel diary) conducted in the city of Ghent (Belgium) we define the profile of the e-bike users (age, income, ownership, etc…) and analyze their mobility habits (distance travelled, purpose of the trip, etc…). The initial results obtained from a travel diary survey show how the e-bike is highly used for commuting trips while for more occasional trips (at most once per week) the car is the preferred alternative. Moreover, the analysis of the changes in the mobility habits after the acquisition of the e-bike shows how the e-bike has mainly incorporated the trips performed by bike while also causing an increase of the frequency for some trips. Summarizing, in this paper we propose a preliminary analysis over the factors correlated with the ownership of an e-bike and an overview about how people changed their mobility habits after the acquisition of the e-bike.

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Keywords: E-bike; Survey; GPS tracking; Mobility habits

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1. Introduction and literature review

In recent decades, the promotion of non-motorized modes of transport is increasing as part of more sustainable eco-mobility vision. In particular, the mode that was most influenced is cycling, due to the fact that it is low-cost, low-polluting and produces great health benefits. Therefore, a broad literature has been recently focusing on better understanding the determinants of bicycle ownership and the way to further promote bicycling (Handy et al., 2010) .

Considering this, different research directions were taken among the experts in this sector.

Groundbreaking studies (Stinson and Bhat, 2004) aimed at evaluating the factors that impact bicycle frequency use for an individual's commute to and from work as well as the integration of cycling with public transportation (Pucher and Buehler, 2008). More recently, Heinen (Heinen et al., 2010), (Heinen et al., 2011) showed the influence of bicycle commuters' attitudes on mode choice decisions, under the assumption that when the commuting journey intensifies, either in terms of distance or frequency, the general attitude towards cycling becomes more positive.

In the same historical period, numerous were also the studies that collected cycling trends and policies over different countries (Pucher John and Ralph Buehler, 2012),(Vandenbulcke et al., 2011) making a comparison among them, while also aiming to offer information about cycling safety and infrastructure facilities (bikeways, bike parking, etc…). In The Netherlands, Denmark and Germany for example, policy increases driving costs, as well as render it inconvenient in city centres through taxes and restrictions on car ownership, use and parking. Different from UK (where only about 1% of trips are by bike) these countries encourage the coordination of different sets of cycling policies. Knowledge about infrastructure preferences for cyclists led to determine how a correlation between the level of cycling confidence and preferred types of infrastructure exists (Caulfield et al., 2012),(Broach et al., 2012).

Unlike the aforementioned studies, our research focuses on the e-bike, which is nowadays gaining more and more popularity. Because of its higher speeds (compared to the ordinary bike) and longer reach, it extends the capabilities of normal cycling and could be an attractive alternative to the car. In the near future, it could become the best way to incentivize a shift from car to bicycle in order to reduce road congestion, traffic-related air pollution, road accidents and infrastructure costs.

Currently, the world's leader e-bike market is China but, in the last few years, a positive trend of the e-bike market share is also observed in north Europe (e.g the Netherlands and Germany have respectively a share of 20% and 10% in sales numbers) and in the U.S.

In (Weinert et al., 2007) and (Cherry and Cervero, 2007) the first investigation on how and why e-bikes developed so quickly in eastern countries has been performed, providing important insights to policy makers in China and abroad. They showed how timely regulatory policy can influence the purchase choices of millions, incentivizing the use of a new mode of transport introduced in the market. An additional way to increase electric bike use would also be considering control strategies that limit the number of stops for this mode, through signal coordination or grade separated intersection, thus increasing the travel time advantage of electric bikes. In (Cherry, 2007) the environmental and safety impacts of alternative modes, such as public transport or personal cars that are the usual competitor of the e-bike are analyzed. He suggested that electric bikes are a clean mode of transport with low noise levels and zero tailpipe emissions. In terms of safety, he also showed how the fatality rates are nearly as low as bicycle fatality rates and much lower than cars.

Another important role is played by the U.S. and North America. Their markets are still behind China and Europe, but a strong group of researchers (MacArthur et al., 2014), (Dill and Rose, 2012), (Popovich et al., 2014) is investigating which factors influence purchase decisions in these countries and, with a comparison between ordinary bikes and e-bikes, trying to understand whether e-bikes can effectively address barriers to bicycling and therefore encourage more sustainable mobility. Their results suggested that e-bike users cycle more often and to more distant locations. Moreover, e-bikes allow people with physical limitations to cycle thanks to electric assist.

In this big context it is important to connect past and present research efforts (regarding ordinary bikes as well as e-bikes) to current policy questions and guide research priorities for the future (Handy et al., 2014).

This paper, through an online survey together with a GPS tracking conducted in the city of Ghent, aims to contribute in defining the profile of e-bike users (age, income, residential location, ownership) and in analyzing their mobility habits. GPS data, validated with a weekly travel diary, allows us to discover for which activity the e-bike is

mainly used and how frequently it is used. To the authors' knowledge, once completed, ours will be the only study providing GPS data from one year tracking for 100 users. While reaching statistical significance with such a limited number of users is quite challenging, the main aim of this paper is still to provide policymakers with a quick glance at the current status of the e-bike market share and valuable intuitions on how this mode shift trend could be influenced.

The data used for this study comes from the SPRINT project. It was launched at the beginning of 2014 with the aim of helping the Flemish Government in better understanding how to improve the use of the electric bikes in Belgium. The goals of this project are both (i) the creation of a bicycle layer for the Flanders multimodal traffic model in order to ensure that (e-)bike remains a fundamental strategic mobility policy in Flanders and (ii) getting an answer for questions like: "Does promoting the e-bikes require a different approach compared to the ordinary bikes?", "Who are current e-bike owners?", "Which kind of infrastructure do they prefer?" . In order to support the shift from car to more sustainable modes of transport it becomes indispensable to understand whether, for example, new cycle paths that are currently being built everywhere in Flanders would also be suitable for e-bikes.
We are also aware that our sample has a specific bias: we only track e-bike owners and therefore we don't have any information about the behavior of non- electric bike owners. We'll be able (in the near future) to do a more general comparison with previous studies (e.g. SHAPES program (Int Panis,L. et al., 2011)) on ordinary bike but accepting bias due to the different structures of the two projects. We leave to future research the topic of understanding how to support the transition towards e-bike based upon the behavior of people who don't own one yet.

The city of Ghent is located in the Flemish Region of Belgium and it is the largest city of East Flanders province. The cycling infrastructure has been developed extensively over the past decade and many cycle lanes are built alongside the city's canal network. Current programs are focusing on taking more cycle lanes off-street in order to segregate them from the traffic. This is being achieved by reallocating on-street car parking so that it forms a barrier between cyclists and traffic. Recently, Ghent has also introduced a "Cycle Street" on a key cycling artery: a new concept that regards motor vehicles as "guests on the street", which means they are not allowed to overtake bikes.

The remainder of the paper is organized as follows: we first illustrate the general methodology; we then show an analysis of the preliminary results; afterwards we summarize our work in the section results and conclusion; finally we conclude proposing future research directions.

2. Methodology

The main concept is that of tracking with GPS devices 100 e-bikers and asking participants to fill in additional surveys in order to have a complete overview of their mobility habits, as well as their personal characteristics. Each user has his/her own web-page (accessible from the website http://www.mech.kuleuven.be/sprint/) in which he/she can visualize his/her daily routes and also fill in the different surveys and accessing other interesting tools (recharge point map, newsletter, etc.).

The data collection is divided in different steps and each of them is linked with a different kind of information in which we are interested:

- Pre-survey: necessary to investigate the e-biker's profile and his mobility habits, also inquiring habits before purchase of the e-bike;
- The travel diary: it is active on the member area only for one/two weeks during the year and it is necessary in order to validate our gps data;
- Accident report: it is a survey (always active on the member area) in which our users can report any kind of dangerous situation that they incurred.

In the next subsections we will describe in details these three steps.

2.1. Pre-Survey

With the pre-survey we aimed to investigate the e-biker's profile as well as his/her mobility habits before and after

the acquisition of his e-bike. Thanks to the pre-survey, we have a complete overview of the socio-demographic information of our sample while also collecting information about which mode of transport they use for a particular trip and with which frequency. We are therefore able to understand how they changed this frequency and the mode used for their daily activities after the acquisition of the electric bike.
We first analyze the socio-demographic characteristics of our sample and we later show an overview of their mobility habits. The users are homogenously distributed between the city center and the suburbs as well as regarding their gender (half of them are female and the other half male). Focusing instead on other parameters that can help us in better defining the e-bike user's profile, we should point out that most of our tracked individuals are aged between 41 and 60 and have an income proper to the middle-class (net income ranging between 2000 and 2500 euro per month).
Going instead in details over the ownership characteristics of each user (not household) and remembering that our sample has the mandatory feature of owning an e-bike,in addition to their e-bike 40% of them owns only ordinary bikes (at least one), 27% at least an ordinary bike and a car, 13% just a car and, finally, 13% an ordinary bike and a public transport subscription (pt). The following plot provides insight which mode of transport is used per activity.

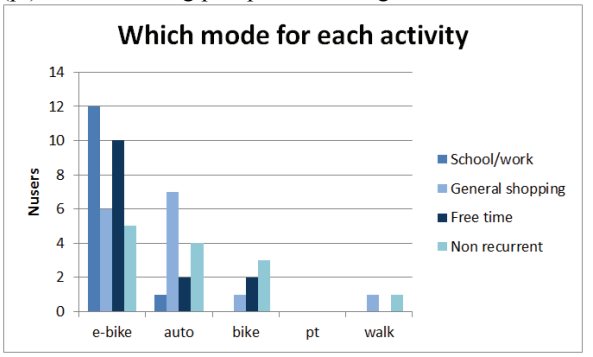

Fig. 1: Which mode of transport is used for each activity

The electric bike is the preferred mode for all purposes except general shopping. Given this insight, we decided deeply investigate the "general shopping" activity, trying to understand how people that own together at least a car and an e-bike behave. We are considering only this sub-sample because the e-bike resulted always as the favourite mode of transport except for the "general shopping", for which the user showed a preference for car.

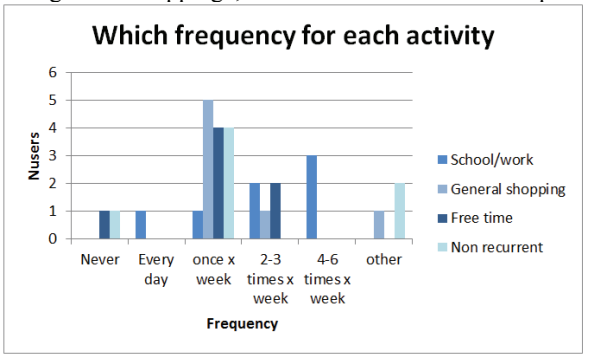

Fig. 2: Frequency of each activity

Figure 2 shows that the activity "general shopping" is performed at most once per week. It confirms how for commuting trips the e-bike is preferred over the other modes of transport (Fig.1). The same holds for non-recurrent activities, as expected.
Still considering this sub-group (e-bike and car joint ownership) we can provide more details with the graph below; this figure shows how those who simultaneously own a car and an e-bike behave after the acquisition of an electric

bike.

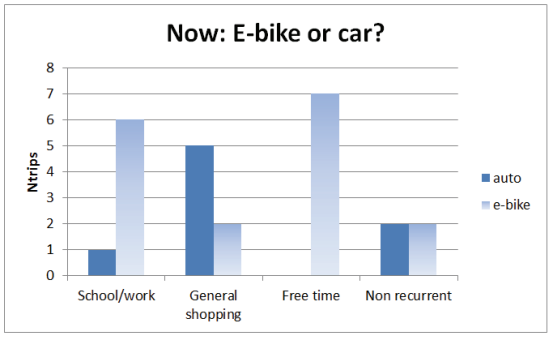

Fig. 3: Use of auto and e-bike for each activity

This plot shows how the only trips for which the auto is still preferred are for "general shopping" and this is independent from the presence of the e-bike among their mobility resources. This result is confirmed also when looking at our full sample:

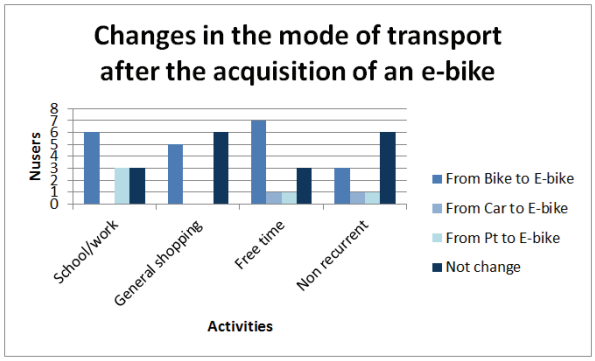

Fig. 4: Changes in the mode of transport after acquisition of an e-bike

It appears clear that the e-bike has incorporated mostly the demand that before its acquisition was utilizing public transport and ordinary bike. We have no information whether any changes in the ownership or in the relocation of their house/workplace happened after the acquisition of the e-bike. Both these factors could be relevant in understanding the behavior of some users, especially those who currently use an e-bike for very long distance trips and yet declare having used an ordinary bike for the same activity before its acquisition (this could be indeed explained by a change in the residential/workplace location).

These data also confirm some changes in the frequency of activities. Indeed, the activities now reachable by e-bike have increased in number of trips compared to the same activities previously done, for example, by ordinary bike. We leave further analysis of this aspect to future studies when the sample will be more consistent.

In the pre-survey, together with the information about user's profile and mobility habits, also questions about the presence of some facilities were included. In particular, we asked our users whether they have access to car parking, e-bike storage and e-bike re-charge spots in their neighborhoods as well as around their workplaces. We completed this analysis by asking them to rate these facilities in order to understand which are the weaknesses of current e-bike's facilities, an information that can be useful from a policy perspective. Regarding the presence of parking spots, around 90% of our users have a private spot at home and a free public car parking at the workplace. Only few exceptions have a paying parking at work.

In the following figures an overview about the presence of some facilities is presented:

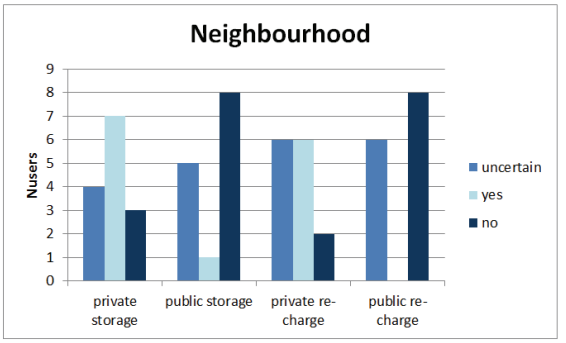

Fig. 5: Presence of facilities in the neighbourhood

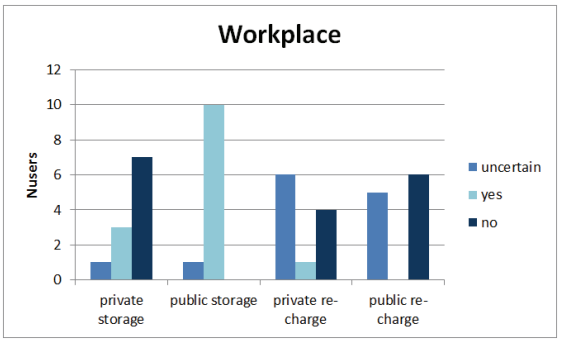

Fig. 6: Presence of facilities at the workplace

Focusing on the public facilities, what is immediately recognizable is the complete absence of public recharge spots. If the main concern is that of promoting this mode of transport, it appears clear that the first improvement should be done in this direction. Very high is also the percentage of people that are not aware of the presence of public storage/recharge spots between the locations they usually commute from/to. This mismatch could be due to, for example, little to no signposting.
Highly correlated with the figures above are the following, showing how people rate these facilities:

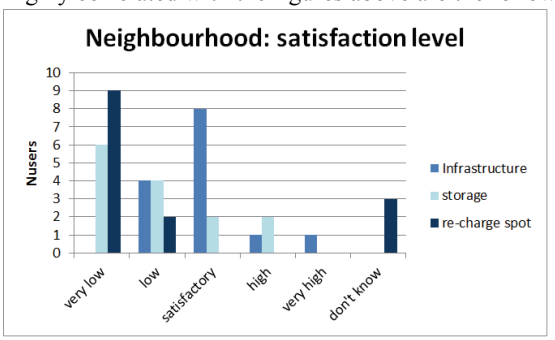

Fig. 7: Rating of the neighbourhood's facilities

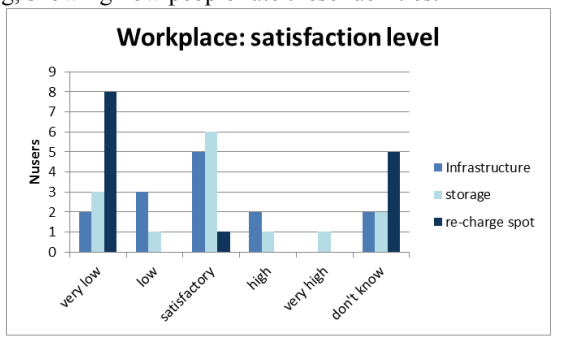

Fig. 8: Rating of the workplace's facilities

Figure 7 and 8 confirm how people are totally unsatisfied over the recharge spot facilities available. The opinion over the infrastructure is instead borderline satisfactory. From these surveys it is possible to conclude that there is a general need to improve the bicycle network as well as to incentivize general cycling. In order to increase the attractiveness of electric bikes (pricing being a main concern), investments in the connected facilities should be clearly prioritized.

2.2. Travel Diary and GPS tracking

In addition to the surveys, this study is mainly based on the use of GPS devices for tracking our participants. The limitation of this approach is that the device is installed directly on the bike, thus we are only aware of all e-bikes movements but not of the trips done with other modes of transport. Consequently, a travel diary for a period of one or two weeks (two different seasons) is indeed necessary to complement and validate this GPS data with all the information regarding the modes of transport used to perform the other activities that we can't capture with our tracking. One objective of our research is to empirically verify the relationship between attractiveness of different modes for daily activities and the modes of transport that each person decides to own. For that, data about their

mobility habits, their activity pattern and their ownership is required.
All of the tracked users own at least one e-bike. As a consequence, the travel diary confirmed how 90% of their trips are performed with this mode of transport. Moreover, it is very difficult to capture with one (or two) week(s) travel diary the non-recurrent activities that, as showed from our pre-survey, are indeed (together with general shopping) the only ones performed by car. From the travel diary surveys it also appeared that "general shopping" was always reached by e-bike. This is not consistent with the results obtained from the pre-survey, but this discrepancy might be due to the different perception that users might have when defining one activity as "general shopping". It might indeed be possible that once a week the users perform a longer, heavier shopping trip for which using a car would be a better alternative, but that this activity was not captured exactly during the week of travel diary surveying.
Another interesting investigation we made is related with the back-up mode the users would employ if their main mode (e-bike in our case) were not available. The results are shown in the figure below:

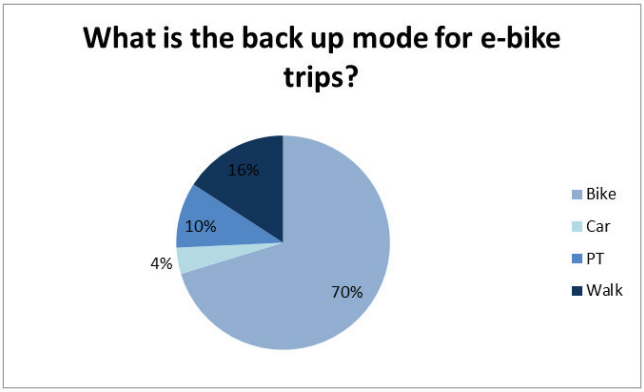

Fig. 9: What they use if the e-bike is not available

At first sight it appears evident that the bike is considered as the most relevant back-up mode. Considering the length of their usual trips that is quite long for regular cycling, we decided to go further in details. We asked them the main reason why a mode of transport would not be perceived as a valid substitute:

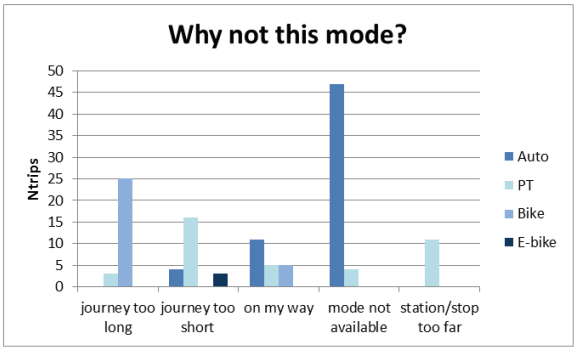

Fig. 10: Reason for which a mode is not used

According to figure 10, the majority of our users declare not to have any car available for that particular trip (they don't own it or they can't use it, possibly because another household member occupies it), or that they were already on their way (e.g. they went by e-bike to work and on the way back they stopped to do shopping). The reasons

behind the few trips not performed by e-bike are correlated with short trips or with a journey not performed alone (not represented in Figure 10).
The results shown in Figure 9 also led us to better investigate the duration of the trips. In particular we analyzed the time spent in reaching each activity by e-bike. We first show the travel time for all trips and then only for the trips started at home:

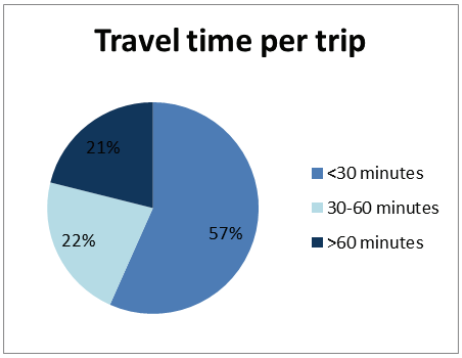

Fig. 11: E-bike's travel time

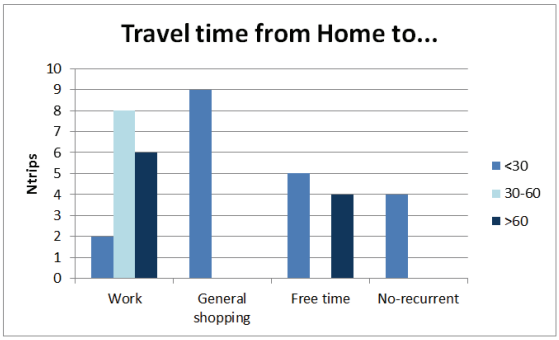

Fig. 12: E-bike's travel time for trips with home as origin

Figure 11 shows how a relevant portion of the trips lasts more than 30 minutes (43%) with 22% more than 60 minutes. This confirms our initial intuition: e-bike is a highly competitive mode of transport for long distance travel. Going into details so to determine which activities warrant the longest trips, is immediately recognizable (Figure 12) that the commuting trips (to work) are the longest. Figure 12 also shows that the "general shopping" causes the majority of the short trips. This helps to confirm the idea that recurrent general shopping is performed by e-bike but lower frequency shopping, difficult to capture with one week travel diary, is instead mainly done by car. For future surveys, we have revised the travel diary splitting the "general shopping" in "high frequency general shopping" and "low-frequency general shopping" in order to avoid the bias previously cited.

2.3. Report Accidents/Potential Accidents

With these reports we try to get a preliminary look into the safety aspects related with riding an e-bike. We decided to achieve this by creating two different surveys: a report of the accidents in which our participants were involved and a report of the potential accidents, where our e-bikers can report situations they perceived as dangerous. In both cases we asked to describe the reason that has caused (or potentially caused) the accident as well as which kind of bicycle path was present (shared/separate/no path) together with its pavement characteristics and if the accident was

due to a collision with another vehicle. The users have also the chance to upload a sketch or a picture to better describe the situation.
The investigation of these aspects is on behalf of policy makers who are interested in improving the bicycle infrastructure (if necessary) so to better suit the requirements of the e-bikers.
While no accidents were reported by the users over the few months of tracking, the survey about the potential accidents was filled it eight times.
In many cases, the perceived dangerous situations are related with darkness, raining and the poor quality of road markings. All these aspects are very common when cycling is concerned, consequently it is not possible to specifically correlate them with the use of the e-bike. What instead could have resonance or at least would warrant further investigation is the fact that a lot of situations happened during the junction crossing. What we are trying to understand is if it could be correlated with the higher speed of the e-bikes. Indeed, being it a relatively new mode of transport and not easy to recognize (compared to an ordinary bike) it could be plausible that other vehicles fail to estimate the e-bikers speed. Practically speaking, if a vehicle in proximity of a junction sees an e-bike far enough from the conflict area (in his opinion), it could decide to approach the road and only later realize that the time necessary for the e-bike to cover that distance was lower than expected.

2.4. Modeling Framework

In the field of behavioural research, a variety of techniques are employed so to model user behavior, among which discrete choice analysis. In particular, it is common practice to model the choice of a mode of transport highlighting the dependency of this choice from the vehicle ownership attribute. In our opinion, it would be worth also investigating the inverse direction: how the correlation among the travel mode choices across multiple trips for any individual can explain vehicle ownership decisions. In (Astegiano and Tampère, 2015) we investigated the relationship between the choice of a transport mode and the activity-travel chain, in order to confirm the existence of a relationship between the different activities that people perform daily and the modes of transport that each person decides to own. In (Le Vine et al., 2013) the authors developed the concept of "perceived activity set" (PAS) as the subset of one's activities that a person views as encompassing his potential travel needs, when making decisions that structurally affect his accessibility. Moreover, each person can opt for a certain personally "Restricted Choice Set" (RCS) among a given general choice set of mobility resources. The individual choice is based upon the cost of acquiring each resource and the added value that the newly available mode(s) of transport enabled by these resources would provide in accessing the activities in the person's PAS.
As soon as our sample will be completed, we'll apply this kind of model. We are strongly convinced that such a model can help us in understanding the conditions under which people would fundamentally reconsider their modal choices, in order to investigate the potential of stimulating traditional sustainable transport modes.

3. Conclusions and Future Research

This paper presented the first result from a survey and gps-tracking project in the region of Ghent, Belgium. The preliminary analyses cover only the first 16 subjects that were tracked, illustrating how later, when the 100-participant sample will be completed, we will generalize our findings. In this section we summarize all the results we showed in the previous section.
The e-bike is a mode of transport appreciated by both women and men. It is very popular among middle age users and for the Belgian standard its pricing is accessible for the middle-class. Among people who own an e-bike the rate of those which, together with it, decide to own just a car is very low (13%). Bigger is the portion of people who decide to own together an e-bike, a regular bike and a car (27%). From the pre-survey it is possible to notice how the e-bike is highly used for commuting trips while for occasional trips (at most once per week) the car is the preferred alternative. The travel diary survey data confirmed the high e-bike usage for commuting trips, while no conclusions can yet be found regarding the occasional trips. Indeed, it is very difficult to capture this kind of trips with only one week travel diary survey.
The analysis over the changes in the mobility habits after the acquisition of the e-bike show how the e-bike has mainly substituted trips previously performed by bike. This result reinforces our assumption about the non-recurrent trips (done by car). Changes of other factors (e.g. residential location) that could have a big influence on their

mobility habits were not registered in this study.
From a policy perspective studying aspects related with e-bike facilities are needed in order to improve the bicycle infrastructures and consequently to better suit the requirements of the e-bikers. The results show complete dissatisfaction with the presence of the recharge spots in the neighborhood as well as at the workplace, both considered absolutely poor. The problems related with the bicycle infrastructure are commonly shared with the ordinary bikes and mainly related with pavement conditions and road markings.
Further exploration of the safety aspects is indeed of future interest, where a deep analysis about the influence of the e-bike speed in the misperception of the other vehicles is certainly required. As already mentioned in section 3, this factor could be strongly correlated with the accidents that happen in proximity of junctions.
This study will provide more consistent results as soon as it will be complemented with a modeling framework with particular focus on (i) the mode choice level (with an expectable bias due to the fact that everybody owns an e-bike) in order to understand if their activity patterns have an influence on their ownership decisions (Astegiano and Tampère, 2015); (ii) on the route choice model which will help us in the creation of a bicycle layer for the Flanders multimodal model.

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