



# Crowdsourcing mobility insights – Reflection of attitude based segments on high resolution mobility behaviour data <sup>☆</sup>



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## ABSTRACT

Recently, the use of market segmentation techniques to promote sustainable transport has significantly increased. Populations are segmented into meaningful groups that share similar attitudes and preferences. This segmentation provides valuable information about how policy options, such as pricing measures or advertising campaigns, should be designed and promoted in order to successfully target different user groups. In this paper, we aim to bridge between psychological, social marketing and ICT research in the field of transportation. We explore how attitude based segments are reflected in high resolution mobility behaviour data, crowdsourced via mobile phones. We use support vector machines to map eight attitudinal segments, as defined under the European project SEGMENT, to the  $n$  dimensional space defined by crowdsourced data. The success rate of the proposed approach is 98.9%. This demonstrates the applicability of the method as a way to automatically map attitudinal segments to a wider population based on observed mobility data instead of using explicit attitudinal surveys. In addition, the proposed approach can facilitate the delivery of personalised target messages to individuals (e.g. via smartphones) or at target locations where users, belonging to specific segment, are located at specific time windows since the data includes the time-space indications.

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## 1. Introduction

Based on the International energy agency findings (IEA, 2014), transportation contributes about 25% to the global CO<sub>2</sub> emission and is the only major sector where emissions continue to grow. Even though technological advances improved the energy efficiency in transport, nevertheless this has been outweighed by the increase in travel demand. In recent years, several strategies have been explored in order to lower the demand and facilitate the users' shift towards the more sustainable means of transportation. Almost all of these strategies rely on the concept of target groups, where the complexity and heterogeneity of the whole population is reduced by dividing it into relevant subgroups for which specific mobility management campaigns and policies are developed. And whether studies focus on just one target group (Bamberg et al., 2007; Delang and Cheng, 2012; Hu et al., 2013) or analyse the whole population (Diana and Pronello, 2010; Prillwitz and Barr, 2011), the impact of traditional market segmentation techniques in the field of mobility is evident. The first applications of these techniques were based on the socio-demographic segmentation and have shown that age, gender, occupation, household size, income and car ownership are highly relevant for mobility behaviour (De Jong et al., 2004). Next to the

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socio-demographic segmentation, a behavioural segmentation was also used to define segments based on the usage of different transportation modes and frequency of their use (Prillwitz and Barr, 2011). In addition, segmentation by lifestyle was adopted to better describe an individual's daily range of actions (Redmond, 2000), but none of these successfully explained the underlying individual values systems and attitudes that are most likely to have an impact on willingness to change mobility behaviour and adopt more sustainable means of transportation. Therefore, the most recent research adopts an attitude based segmentation approach in order to better understand users' motivation. The attitude based segmentation approach relies on rational choice models like the theory of planned behaviour (Ajzen, 1991). Here, next to social norm and perceived behavioural control, person's intention to perform a behavioural option is causally determined by the attitude towards the behavioural option (individual's general feeling of favourableness or unfavourableness towards this option). Attitude mirrors the beliefs that a person holds about the positive and negative consequences of mobility behaviour and the values that this person ascribes to those consequences. Therefore, attitude based segments are subgroups of population that share similar attitudes towards same behavioural options and have proven to have a high predictive power for transportation mode selection (Hunecke et al., 2010; Eriksson and Forward, 2011). The related studies, similar to the above segmentation approaches, are based on surveys over the selected sample of participants for data collection (Bamberg et al., 2007; Anable, 2005; Anable and Wright, 2013).

Nevertheless, today's advances in data collection (primary high resolution behaviour data crowdsourced from active mobile devices) (Cheng et al., 2012; Patire et al., 2015; Wu and Liu, 2014) and processing (Gong et al., 2012; Goodchild and Li, 2012; Calabrese et al., 2013) provide new insights into mobility behaviour far more detailed than the one collected via traditional travel diaries, household surveys or surveys in general. To get an impression of the difference in resolution of collected data, one can compare a typical travel survey input on how often, by which mode and what distance a person travels to work (e.g. five times a week; by public transportation; around 10 km) with crowdsourced time-space information and automatic transportation mode detection (where we have information on which public transit stops were used; how did (s) he reach the public transportation network; at what time and location did this occur; where did the trip stop; what part was done by metro, bus or tram; how long did (s)he wait for a connection; did (s)he forgot to mention that (s)he carpools, or goes to buy groceries on the way home etc.). In light of this recognised potential, a growing body of work has been done in recent years. Particularly, the potential to use Global Navigation Satellite System (GNSS) data in replacing, or improving, travel surveys with crowdsourced data has been investigated (Vij and Shankari, 2015; Calabrese et al., 2013; Hasan and Ukkusuri, 2014). Furthermore, a more detailed look in travel time estimations indicated that penetration rates for GNSS-based probe data are now suitable for travel time estimation (Patire et al., 2015). Another promising data source for mobility studies is seen in mobile network data, particularly call detail records (CDR) (Toole et al., 2015) and positioning data (Chen et al., 2015). These are most often used for deriving trip's origin and destination locations (Alexander et al., 2015; Iqbal et al., 2014) and traffic zones extraction (Dong et al., 2015). And although the applicability of big data in the field of travel behaviour analysis has gained much attention, these insights are by far unexplored in current existing segmentation theories.

Extending the current research on crowdsourced mobility data and application of market segmentation techniques in the field of mobility, and in the meantime addressing the above mentioned limitations, the fundamental research contributions of this work can be situated in the following areas (i) in this paper we aim to bridge between psychological, social marketing and ICT research in field of mobility, by exploring how attitude based segments can be deduced from high resolution mobility behaviour data crowdsourced via mobile phones. For this purpose we will rely on the results of the applied theory of planned behaviour developed under European project SEGMENT (Anable and Wright, 2013). We do this as the attitude based segmentation has proven to have the highest potential on influencing people to adopt more sustainable means of transportation. In addition, results are well documented (Anable, 2005, 2013a,b; Ladbury, 2013) and as well as examples of ongoing and completed implementations for mobility management campaigns (Machado, 2015; Lassen Bue et al., 2013). In addition, (ii) we aim at bridging between applicability of small (survey based) and big data for mobility behaviour analysis. As recent literature well identifies this gap (Chen et al., 2015; Calabrese et al., 2013; Toole et al., 2015), big data are referred only as CDR and positioning data for mobility studies and potential of mobile sensed data (data collected based on dedicated smartphone apps) is being neglected. We investigate the potential to advance mobility research and bridge between small and big data based on mobile sensed data as they allow more seamless fusion between computer science research in this field (mainly focused on data analytics, but often without adequately recognising applicability context of achieved results for mobility needs) and transportation researchers who are well familiar with existing advances in the field of transportation but still new to advanced data analytics suitable for big data. And while CDR and positioning data exhibit major benefits as standardised forms or no additional cost for their collection (telecom operators collect these data anyway for billing purposes), for mobility studies they provide no contextual information and no ground truth information that could be used for development of learning algorithms. Mobile sensed data allow more balanced approach were traditional small data can be extended in the form of on-line surveys (Ji et al., 2015) and, in this way, big data supported with matched context. (iii) We extend current level of knowledge on attitude based segments by providing crowdsourced insights into their observed high resolution mobility behaviour, whereas so far studies have mainly tried to relate self-reported mobility behaviour with persons' attitudes towards different mobility options (Molin et al., 2016; Spears et al., 2013) and examine how variance in intention to use various travel modes can be explained based on these attitudes (Eriksson and Forward, 2011; Susilo et al., 2012). In addition, (iv) we explore potential to, after collection of test and learning datasets for target area, implement less resource demanding way to assign users in one of predefined attitudinal segments based on their high resolution observed mobility behaviour.

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