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Eliciting preferences for adoption of fully automated vehicles using best-worst analysis

Ramin Shabanpour*, Nima Golshani, Ali Shamshiripour, Abolfazl (Kouros) Mohammadian

Department of Civil and Materials Engineering, University of Illinois at Chicago, United States

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ABSTRACT

Autonomous mobility is one of the rapidly evolving aspects of smart transportation which carries the potential of reshaping both demand and supply sides of transportation systems. While understanding public opinions about autonomous vehicles (AVs) is a compelling step towards their successful implementation, still little is known about to which extent people will embrace this new technology and how the vehicle features will affect their adoption decision. This study presents a new approach for modeling the adoption behavior of fully AVs using the profile-case best-worst scaling model. In this approach, an AV profile which is characterized in terms of the main vehicle attributes and their associated levels is presented to the decision maker and he/she is asked to select the most and the least attractive attributes. Further, a binary adoption question at the end of the choice task inquires if the respondent is willing to purchase the described AV. Utilizing this method, we can recognize the difference between the intrinsic impacts of the vehicle attributes and the impact of the attribute levels on the adoption decision. Results of the analysis indicate that people are much more sensitive to the purchase price and incentive policies such as taking liability away from the "driver" in case of accidents and provision of exclusive lanes for AVs compared to other factors such as fuel efficiency, safety, or environmental friendliness. Further, it is found that millennials with higher income, those who live in the downtown area, and the majority of people who have experienced an accident in the past have greater interests in adopting this technology.

1. Introduction

Autonomous driving technology has taken huge strides forward, and is expected to be available on the market, probably not in a far future. Since 2011 that Nevada–as the first state in the U.S.–authorized the operation of autonomous vehicles (AVs), 20 other states have either allowed their testing on public roads or passed legislation related to them (NCSL, 2018). As of November 2017, Waymo's driverless cars have been driven more than 4 million miles on public roads. It becomes more interesting when we realize that while it took about 8 years to reach 3 million miles, they needed only 6 months to hit the fourth million miles (Waymo Safety Report, 2018). These trends, and many others, drive public opinion to the fact that autonomous mobility, if well implemented, would dominate the auto market in the next decades.

Not only can this modern technology have a profound impact on mobility and the way transportation systems operate, but also it

* Corresponding author at: 842 W. Taylor Street, Chicago, IL 60607, United States.
E-mail addresses: rshaba4@uic.edu (R. Shabanpour), ngolsh2@uic.edu (N. Golshani), ashams5@uic.edu (A. Shamshiripour), kouros@uic.edu (A.K. Mohammadian).

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is believed to carry the potential for revolving people's lifestyle. For instance, AVs can transform life for the elderly and people with disabilities who are not able to drive today (Fagnant and Kockelman, 2015; Harper et al., 2016). Also, if coupled with vehicle connectivity technology, AVs are expected to considerably lower traffic congestion, and consequently energy consumption and emissions (Chandra and Camal, 2016; Greenblatt and Shaheen, 2015). However, critical concerns still remain regarding regulation, liability, privacy, and security of this technology (NHTSA, 2013).

Similar to other emerging technologies, consumers' adoption behavior of AVs is expected to be subject to a considerable degree of heterogeneity. In other words, people would have different sensitivity towards various attributes of AVs. Some customers who are more concerned about driving safety might be interested in this technology because of its highly expected safety benefits (Kockelman et al., 2016). Those who are limited by affordability considerations would be highly concerned about purchase price. Some customers might be driven by policies such as taking liability away from "driver" in case of AV accidents, while others might care for more efficient energy consumptions or provision of an exclusive lane for AVs. The investigation of consumers' sensitivity to various attributes of autonomous vehicles is a critical step towards their successful implementation.

There exist few studies focusing on the adoption behavior of AVs (a detailed review of these studies can be found in "Literature review" section). The early studies in this area have conducted simplistic descriptive analyses to investigate the associations between individuals' demographic characteristics and their opinions about AVs (Kyriakidis et al., 2015; Payre et al., 2014; Schoettle and Sivak, 2014). More recent studies, on the other hand, have attempted to specify how demographic characteristics and travel habits, social factors, and built-environment attributes affect people's adoption behavior (Bansal et al., 2016; Daziano et al., 2017; El Zarwi et al., 2017; Haboucha et al., 2017; Lavieri et al., 2017; Shabanpour et al., 2017). Apparently, the literature on people's adoption behavior toward AVs is still limited, leaving major gaps for further study. In particular, the literature lacks specific research to address the question of how sensitive customers are to AV attributes and how different levels of these attributes affect their adoption decision.

Such questions are important to answer, not only from the perspective of adoption behavior analysis (and predicting adoption rate), but also with regards to marketing applications (Lynch Jr, 1985). Automakers usually offer varied models of each vehicle to target different segments of the market. In order to determine the right service to be offered to each segment, however, it is critical to first find out the preferences of each segment. This becomes even more important in case of autonomous vehicles, since the technology would come with a wide range of benefits (costs) each of which attracting (repelling) specific groups of the society. Thus, knowing the individuals' preferences and sensitivities toward different features of AVs, would help policymakers and marketing agencies determine benefit segments more accurately.

The Current study aims to contribute to the literature on adoption behavior of AVs from two aspects: (1) exploring peoples' expectations about the most and least attractive AV attributes, and (2) analyzing how the final adoption decision is a function of those expectations in addition to other predictors. To understand respondents' attitudes towards the most and least attractive features of AVs, the best-worst modeling approach is applied. Further, a binary choice model is established to understand how these attitudes influence the decision of whether to purchase the vehicle or not. The two models are jointly estimated to account for the shared unobserved factors that might affect their outcomes. In addition, the models account for both observed and unobserved heterogeneities to provide more accurate sensitivity analyses.

Stated preference (SP) choice experiments are used in this study since the vehicle automation technology is not yet available on the real market. There are two general types of SP choice experiments: single-alternative selection and rating/ranking of alternatives. The most prevalent type is single-alternative selection when the respondent is asked to choose the most preferred alternative among a choice set (Flynn et al., 2007). Such an experiment, however, fails to elicit the respondent's preferences towards other alternatives. Rating and ranking tasks are proposed to bridge this gap (Hausman and Ruud, 1987). However, these experiments may complicate the choice experiment and/or induce behaviour in respondents which may bias the model outcomes (Ben-Akiva et al., 1992).

As a variant of single-alternative selection and rating/ranking tasks, best–worst (B-W) choice experiments provide a middle ground. That is, instead of selecting the best option or ranking all the options in a choice set, respondents are asked to indicate which alternative they consider to be the best (most attractive) and which to be the worst (least attractive) within the choice task. In other words, respondents opt for the pair that "they feel exhibit the largest perceptual difference on an underlying continuum of interest" (Finn and Louviere, 1992). Three types of B-W choice experiments are proposed in the literature, named as object case, profile case, and multi-profile case (see Section 3.4 for a more detailed discussion).

With a focus on evaluating the impact of AV attributes on peoples' adoption decision, the current study adopts the profile case best-worst method in which the survey participant is presented with a single AV profile and is asked to select the most and the least attractive attributes. We chose this method as it particularly allows the impact of attributes to be measured meaningfully on a common scale. We find this property desirable given the need to directly focus on the influence of attributes, which requires further sensitivity analysis in other methods.

In order to collect information on consumers' preferences toward autonomous vehicles, we designed and launched a stated preference survey using an online platform in December 2016 in Chicago, US. One main section of the survey is dedicated to the best-worst choice experiment. In this experiment, we identified seven key attributes of AVs which can have a significant impact on people's adoption behavior. The attributes are: purchase price, fuel cost, driving range, safety, emission rate, driver liability, and exclusive lane provision. Various combinations of attribute levels were designed, and respondents were asked to indicate their most and least preferred attributes in each choice card. In addition to the B-W choice task, a binary question was added at the end of the experiment to indicate whether the respondent is willing to buy the described vehicle or not. To account for the shared unobserved factors that might affect the two decisions (B-W and adoption), we set out to model them in a joint structure. To the best of our knowledge, this study is the first to apply B-W modeling approach to investigate consumers' preferences towards autonomous vehicles.