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Fully automated vehicles: A cost of ownership analysis to inform early adoption

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A R T I C L E   I N F O

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A B S T R A C T

Vehicle automation and its adoption by the vehicle purchasers is an active area of research among transportation academics. So far, most of the interest in the adoption of *fully* automated, driverless vehicles has focussed on private vehicles alone, yet full automation could be beneficial for commercial vehicles too. This paper identifies the vehicle sectors that will likely be the earliest adopters of full automation. Total cost of ownership analysis is used to compare the costs (and benefits) of vehicle automation for private vehicles among different income groups and commercial vehicles in the taxi and freight sectors in the UK. Commercial operations clearly benefit more from automation because the driver costs can be reduced substantially through automation. Among private users, households with the highest income will benefit more from automation because of their higher driving distances and higher perceived value of time, which can be used more productively through full automation.

1. Introduction

Fully automated, autonomous, driverless or self-driving cars are currently at the peak of Gartner's technology hype cycle (Gartner, 2015), indicating intense attention from the media and expectation from the members of the public. Since Google's demonstration of the much-publicised self-driving car in 2012, the question is no longer about 'if' but about 'when' they will become available in the market. All the major mainstream vehicle manufacturers are known to have an automated vehicle programme, with some claiming the availability of fully automated vehicles in showrooms by 2020. All these activities have generated acute interest among transport researchers and professionals about the potential impacts of vehicle automation on the transportation system. Most of the attention has been in the context of how full automation could substantially improve road safety (Department for Transport, 2015a), change the way we travel (Wadud et al., 2016) or change the way we own or share vehicles (Krueger et al., 2016), ultimately also affecting energy use and carbon emissions (Wadud and Anable, 2016) and resulting in other broader societal impacts (Correia et al., 2016). Nearly all the researchers focus on one specific impact of automation (e.g. Fagnant and Kockelman, 2014; Spieser et al., 2014 for shared mobility, European Transport Safety Council, 2016 assessing safety impacts, Miller, 2015 investigating impact on insurance industry, etc.), while others attempt to model the aggregate impacts on travel and energy demand (e.g. Wadud et al., 2016).

One area that is very important in understanding the potential impacts of vehicle automation is the uptake of fully automated vehicles. Studies on temporal evolution of uptake of automated vehicles generally follow Rogers' innovation diffusion curve (Rogers, 1995), which can be expressed through the well-established Bass, Generalized Bass or S-shaped growth curves

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(KPMG, 2015; Lavasani et al., 2016). On the other hand, some studies investigate the consumer's willingness to pay for various vehicle automation features, including full automation (Bansal and Kockelman, 2016). All these studies focus only on passenger travel, i.e. they study the uptake of full automation in passenger vehicles. Despite the attention on passenger car travel thus far, early adopters of full automation could well be in other areas, e.g. in freight and logistics sector, where there is already some experimentation with advanced technologies such as drone delivery by Amazon. Recent experimentation of automated platooning of vehicles on motorways also primarily includes trucks, rather than cars (e.g. SARTRE in Europe). Commercial mobility service providers such as Uber and Lyft are also very active in the vehicle automation area.

The role played by the early adopters in product satisfaction and its communication is crucial for later success in mass adoption and thus substantially affects the shape of the uptake curve of any new technology, including fully automated vehicles. It would therefore be useful to understand which sectors of the road transport system would likely adopt full automation first. However, little is known about the potential early adopters of full vehicle automation, especially in relation to personal and commercial vehicles. This research aims to fill this gap by comparing the total cost of ownership (TCO) of fully automated vehicles in different vehicle sectors in the UK. To our knowledge, this is the first study to develop such costs for different vehicle groups under a full automation scenario. We also extend the traditional TCO analysis by including the costs of time spent driving personal vehicles and incorporate the potential heterogeneity in TCOs for different income groups.

The paper is organised as follows. Section 2 draws insights from the literature on factors affecting vehicle purchase and the application of TCO analysis in this context. Section 3 describes the method and data used for the analysis, including the assumptions made. Section 4 presents the results for different scenarios and tests the sensitivity of the results with regard to some of the input parameters. Section 5 draws conclusions.

2. Insights from literature

There are a number of factors that affect vehicle purchase decisions. These factors and their relative importance substantially vary between consumer and vehicle types. Lane and Potter (2007) divided these influencing factors into two groups: situational and psychological. Situational factors include vehicle economics, regulatory environment, vehicle performance and suitability, and existing infrastructure; often these can be measured objectively. On the other hand, psychological factors are difficult to quantify and can include attitude, lifestyle, personality and self-image for private purchases. Although business purchases (fleet, freight trucks) put more emphasis on situational factors—especially vehicle and wider logistic economics—psychological factors such as risk perception, corporate culture, and company image can still have a role to play (Lane and Potter, 2007). A recent survey in the UK found that fuel economy/running costs, size/practicality and vehicle price were the three most important factors to the consumers while purchasing their most recent private car (Lane and Banks, 2010). All of these fall within the situational factors and underline the importance of vehicle economics in making a purchase. We therefore focus primarily on vehicle purchase and use economics to identify the potential adopters for whom vehicle automation can be beneficial early on.

TCO analysis is the vehicular counterpart of life cycle cost analysis, which is well known in business procurement and project appraisal. The technique is primarily used to compare the relative economic advantages of different competing vehicle technologies. TCO analysis has become especially popular in the context of alternative powertrains in vehicles, with numerous studies applying the method to compare the costs of conventional internal combustion engine vehicles with hybrid electric vehicles, battery electric vehicles, plug-in hybrid electric vehicles or fuel cell vehicles (e.g. Lipman and Delucchi, 2006; Thiel et al., 2010; Contestabile et al., 2011; Wu et al., 2015; Palmer et al., 2017). While comparative TCO is not the only factor that affects the adoption of different technologies (e.g., range anxiety is an important factor for Battery Electric Vehicles), Tran et al. (2013) showed that financial costs and benefits are still the most important factor in the UK. Therefore, we opt for TCO analysis to understand the comparative cost advantages for different vehicle user groups, with an implicit assumption that vehicle sectors with the largest cost advantages are likely to be the earliest adopters.

The technique for conducting a TCO analysis is relatively straightforward: TCO is the sum of all the costs related to a car purchase and driving it over the period that one owns it. Lipman and Delucchi (2006) include the following in their TCO analysis: vehicle purchase (as annual depreciation), fuel, insurance, maintenance and repair, engine oil, replacement tire, safety and emissions inspection fee (Ministry of Transport – MOT – test in the UK), parking, tolls, etc. Battery costs are also included when conventional vehicles are compared with electric vehicles. Social costs of emissions and noise are generally not included in TCO analysis because they are often not considered (or, at best, qualitatively considered) in individual vehicle purchase decisions. While TCO analysis may not have been very popular in the vehicle purchase literature in mainstream transport research, components of the TCO analysis are still used to characterise the vehicle attributes in vehicle choice models, which are more popular in the discipline (e.g. Hackbath and Madlener, 2013). As such, TCO analysis is useful not only in their own right (as in here) but also as an input to discrete choice-type models to predict future market share. Results of TCO analysis can also be incorporated directly in the Generalized Bass type technology diffusion models (e.g. Lavasani et al., 2016) or system dynamics models for vehicle uptake (e.g. Shepherd et al., 2012)—all of which use relative costs of competing technologies as an input. As such, it is an important parameter in understanding potential adoption of automated vehicles in the future.