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Assessing the impacts of deploying a shared self-driving urban mobility system: An agent-based model applied to the city of Lisbon, Portugal

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ABSTRACT

This paper examines the changes that might result from the large-scale uptake of a shared and self-driving fleet of vehicles in a mid-sized European city. The work explores two different self-driving vehicle concepts – a ridesharing system (Shared Taxi), which emulates a taxi-like system where customers accept small detours from their original direct path and share part of their ride with others and a dynamic bus-like service with minibuses (Taxi-Bus), where customers pre-book their service at least 30 min in advance (permanent bookings for regular trips should represent most requests) and walk short distances to a designated stop. Under the premise that the "upgraded" system should as much as possible deliver the same trips as today in terms of origin, destination and timing, and that it should also replace all car and bus trips, it looks at impacts on car fleet size, volume of travel and parking requirements. Mobility output and CO_2 emissions are also detailed in two different time scales (24 h. average and peak-hour only). The obtained results suggest that a full implementation scenario where the existing metro service is kept and private car, bus and taxi mobility would be replaced by shared modes would significantly reduce travelled vehicle.kilometres and CO_2 emissions.

Introduction

Mobility is an important component of all human activity, ensuring the access of citizens to exercise their social rights and the capacity to partake in productive activities. In an urban environment, with higher density of population and economic activity, mobility plays an even more relevant role, being a key component to warrant economic development and social equity.

Yet, it is also seen as one of the major problems of urban areas due to the associated externalities (congestion, greenhouse gases (GHG)), especially in highly motorised and car dependent regions (Banister, 2008). The rapid development of technology and increasing purchasing power, which in many countries has surpassed the increase of transportation costs (Glaeser and Kohlhase, 2003), promoted more disposable income to buy cars (Zegras, 2010). Even in developing countries, where the income levels are lower, cars are becoming the dominant motor vehicle, although mode shares are still favourable to collective transportation (Kutzbach, 2009).

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The supremacy of the car allied with low occupancy rates on daily trips (International Energy Agency, 1997) is producing severe impacts on the shape of societies, leading to harsh environmental and climate changes; serious loss of efficiency of the transport system caused by congestion; promotion of social asymmetry and exclusion from activities that can be only accessed by car; road accidents and the strong dependence on fossil fuels (Camagni et al., 2002; Cervero et al., 2009).

Within this context, it is fundamental to understand the underlying factors that drive modal choice and the reasons behind the dominance of the private car, creating solutions that will ally individual satisfaction with societal welfare. According to (Hiscock et al., 2002), the private car presents a clear advantage over the other transport options in three key attributes for mode choice selection: flexibility, comfort and availability. These characteristics of the private car may significantly blur the perception of other attributes of each mode, leading to a bias in favour of the private car and to lexicographical choice processes (Hess et al., 2010).

Increasing environmental concerns and the high dependence on fossil fuels are pressuring the transportation sector. In order to attain the ambitious environmental objectives in sight, Governments will have to make an extra effort, which may speed up the convergence to more efficient urban mobility solutions.

Even with the promotion of public transport (PT) networks, with the expansion of several subway systems and the introduction of new Bus Rapid Transit (BRT) and Light Rail Transit (LRT) systems, public transport continues to be losing market share to private vehicles in most developed economies (Buehler and Pucher, 2012).

Three main approaches to mitigating urban mobility problems have been proposed: influence demand to reduce travel needs (avoid), promote more sustainable transport options (shift) and deploy better technology and reorganise supply (improve).

From a technological perspective (improve), the efforts in the last decades have been concentrating on the development of cleaner energies and more efficient vehicle engines. Other significant developments were obtained through the reduction of the environmental impact of transportation infrastructure. These measures tend to be effective in the short term; however, the overall impact on the system in the long run might be negligible if transport demand continues to increase at the same pace (Banister, 2008).

From the avoid perspective, some policies have been recently designed to act on the supply side, not only promoting teleactivities but also providing more efficient infrastructure and land-use distribution. This concept emerged in the US during the last few decades under the designation of Transit Oriented Development (TOD), where the objective is to develop "Smart Growth" areas with mix land-uses and that are compact and walkable, usually around rail stations. This new urban development paradigm aims to promote accessibility to a wider variety of activities, encouraging walking and the use of more sustainable transport options against the private car (Litman, 2004).

Shifting demand towards more sustainable transport options by providing the right incentives and penalties has shown some efficacy in the last decades. Intervening on the demand side by promoting more efficient and rational use of the existent transport system has been pursued in several cities since the 90's. This concept has been denominated as Travel Demand Management (TDM) Rodriguez, 2009, gathering a set of measures that range from the introduction or promotion of more efficient transport options or the creation of financial incentives towards more efficient mobility.

There are many different measures that can be used in TDM and some of them have already been successfully implemented: moral campaigns (e.g. eco-driving); the promotion of non-motorised transport modes (Pucher and Buehler, 2008); or financial incentives as parking policies aiming at reducing cars in city centres (Higgins, 1992; Marsden, 2006; Tsamboulas, 2001; Viegas, 2005; Willson and Shoup, 1990), congestion charges (e.g. Singapore Transpor, 2011, London (Glaister and Graham, 2005) and Stockholm (Albalate and Bel, 2009); or the promotion of Intelligent Transport Systems (ITS) that may enhance the efficiency of the transport system; among other policies.

The promotion and integration of shared transport options, within a so-called shared economy paradigm has emerged. This new mobility paradigm has been found as a very interesting option to divert car users to public transport options (Köhler et al., 2009). This concept has been in discussion for several decades but only in the last decade, technology has evolved sufficiently and its key instrument – the smartphone – spread enough across the population to allow for the shared mobility market to gain some scale and become more viable.

This new approach to demand management aims at exploring mobility resources more efficiently, while preserving good levels of comfort and flexibility normally associated with the private vehicle (Enoch, 2011). The proposed shared modes tend to explore the low levels of private vehicle usage both in (internal) space and time, vehicles being active mainly during peak hours and rarely for more than 10% of the day, as well as the low level of occupancy in each trip. Despite this, they are highly valued assets – so highly valued that households put up with such levels of cost and low usage in order to derive specific benefits relating to comfortable, door-to-door and schedule-less travel. This low efficiency at the personal level is replicated at the social level with the congestion and emissions caused by the quite low occupancy levels of those private cars. Could this inefficiency be reduced while retaining these benefits?

The traditional shared mobility market tries to explore these two dimensions (sequential or parallel share of vehicles) and segmenting supply to improve demand satisfaction. Two main transport options have been widely explored: carpooling (space sharing among a group of friends) and carsharing (time sharing). Additionally, we can consider two other shared transport alternatives that further explore this spectrum of shared mobility efficiency: ridesharing or Shared Taxis, which represent an expansion to the existing taxi system where different passengers or parties share the same vehicle for parts of their rides, and on demand minibus services, that expand or replace the regular bus concept beyond fixed routes and fixed