A Decision Support System for On-Demand Goods Delivery Using Shared Autonomous Electric Vehicles

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ABSTRACT

This article presents a strategic decision support system (DSS) for on-demand delivery companies in urban areas. This DSS is designed and developed for the promising new concept of goods delivery based on a fleet of Shared Autonomous Electric Vehicles (SAEVs). A simulation-based optimization model is proposed to solve the fleet sizing and composition problems. The efficiency of the developed strategic DSS in determining best fleet size and composition under different scenarios is demonstrated. This article provides managerial insights to help goods delivery companies, who intend to use SAEVs, in determining the type and number of vehicles to acquire.

KEYWORDS

Fleet Sizing and Composition, On-Demand Goods Delivery, Shared Autonomous Electric Vehicles, Simulation-Based Optimization

INTRODUCTION

Goods movement within urban environments plays a major role in transportation. Vehicle fleets performing goods delivery operations are the main factor contributing to urban congestion and atmospheric pollution. In fact, urban freight transport amounts to around one third of vehicle kilometers that implies high greenhouse gas emissions in cities (Molfino et al., 2015). The ecological issue associated with urban goods distribution can only increase in the future as the ongoing urbanization trends and the boom of e-commerce activities are bringing more freight in urban areas.

Many new solutions are proposed to reduce the number of vehicles in downtown areas while providing acceptable levels of service and complying with sustainable development goals. Among these new solutions, Shared Autonomous Electric Vehicles (SAEVs) are highly promising (Awasthi et al., 2011). Even though the investigation of their use on public roads in city logistics is in its infancy, the idea of using self-driving electric vehicles for goods transportation has widely been used in internal transport systems such as mines, airports and shipping ports (Jaoua et al., 2012).

This paper proposes and analyses a new concept of an on-demand goods delivery system. It builds upon the previous work by (Awasthi et al., 2011). The delivery system is based on a fleet of SAEVs inspired by the Autonomous Delivery Platform recently patented by Google (Myllymaki, 2016). This fleet will be part of a goods delivery company providing logistics services for multiple retailers using a shared transport capacity business model. To the best of our knowledge, no previous published work has considered a similar goods delivery system. The aim of this study is to design...
and develop a Decision Support System (DSS) to assist goods delivery companies that intend to use SAEVs. This DSS addresses the fleet sizing and composition problems. Since uncertain features affect the design of such system, multiple scenarios with different demand levels as well as different vehicle design and charging infrastructure, are tested to evaluate the system performance.

The proposed DSS is embedded with a simulation-based optimization modelling approach. This choice is motivated by the reported success of this approach in decision-making. According to (Strand et al., 2017), its efficiency is mainly due to the capability of Simulation models to consider a large number of realistic parameters. Furthermore, in order to ensure re-usability of the DSS, we conduct a conceptual model specification phase based on the Unified Modelling Language (UML) methodology. Using such a formal methodology is highly recommended when discrete event simulation is chosen rather than analytical modelling. As stated by (Furian et al., 2015), for more efficient use of simulation, a conceptual model must be formally specified and should be software independent. After this phase, implementation of the proposed conceptual model is carried out with the popular Arena Simulation Software.

This paper is organized as follows. Section 2 reviews relevant previous studies and projects associated with city logistics using shared autonomous electric vehicles. Section 3 is dedicated to the structure of the proposed DSS. In Section 4, the implementation of the conceptual model and the coupling of simulation with the optimization module is depicted. Computational experiments and results are discussed in Section 5.

LITERATURE REVIEW

Numerous experiments are currently underway, in different parts of the world, to design innovative transport systems aiming to improve the quality of urban life. Three words are common between most of these innovative systems: autonomous, electric, shared vehicles. This concept is presented as the future of our transportation systems since it will considerably change the way people and goods are moved in urban environments.

There is a wealth of literature investigating the potential outcomes of car sharing, electric vehicles and autonomous vehicles in city logistics as separate topics. However, studies inspecting the combination of these concepts together are more limited. Table 1 summarizes the reviewed studies that examined the operations of shared autonomous vehicle fleets for both people and freight transport. Some of these studies used a fleet of shared autonomous petroleum-fueled vehicles (SAVPs) while others have considered the use of Electric Vehicles in Shared Autonomous fleets (SAEVs).

As shown in Table 1, about two thirds of the reviewed works have investigated city logistics applications that deploy only two elements of the “mobility’s trifecta” which are car sharing and autonomous vehicles. They considered conventional petroleum-fueled vehicles instead of electric ones. Only one third of these works have considered fleets of SAEVs. We also notice that, except the works of (Cepolina and Farina, 2015; Wang et al., 2006) which acknowledged the potentiality of using fleets of SAEVs for freight transport, the reviewed studies have examined the use of shared autonomous vehicles, whether petroleum-fueled or electric, in Uber-like transport systems for people movements. It is also interesting to note that since most of the reviewed works are of a conceptual nature, simulation was the most used modelling method.

(Cepolina and Farina, 2015) examined the use of fleets of SAEVs for freight transport in urban areas. They introduced an innovative concept for urban freight distribution using a small vehicle called FURBOT which can carry two boxes of consolidated packages from an urban distribution center to customers. They considered the routing problem of these vehicles and used optimizations tools to solve it.

There is a growing interest in finding new ways to implement SAEVs in urban freight transport. Amazon and Google have been specifically exploring the use of autonomous, self-driving vehicles
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