

Evaluating options to integrate autonomous vehicle in home grocery delivery operations

Dhanan Sarwo Utomo, Philip Greening

Centre for Sustainable Road Freight, Heriot Watt University, Edinburgh, UK

Abstract:

Introduction

Last-mile delivery is a hot topic in cities all over the world due to the following general developments and challenges (Boysen, Fedtke, & Schwerdfeger, 2021):

- Increasing demand that is driven by urbanization and e-commerce.
- The increasing demand results in more delivery vans entering city centres, which burdens the infrastructure, increases congestion, and pollution resulting in negative impacts on health and environment.
- Van delivery is costly. These costs are associated with traffic jams, missing parking spaces in congested streets as well as customers not at home to receive their parcels.
- The last-mile deliveries face tight deadlines and considerable time pressure due to the increasing parcel volumes coupled with increasing service expectations (Yaman, Karasan, & Kara, 2012).
- The aging workforce in many industrialized countries (Otto, Boysen, Scholl, & Walter, 2017), especially in a physically demanding environment such as parcel delivery has resulted in parcel delivery labour shortages (Peterson, 2018).

It can be argued that the use of autonomous vehicles (AV) is one way to overcome these challenges. AV's directly address the driver shortages and can be combined with parcel lockers to enable unattended delivery, thereby lowering overall delivery costs. AV also has the added advantage of 24-hour operations meaning that vehicles can be dispatched throughout the day, thereby reducing congestion. Finally, AVs are likely to be powered by renewable green electricity, reducing pollution and negative impacts on health and environment.

Objectives

The objectives of this study are:

- To propose an agent-based model (ABM) of home grocery delivery that incorporate AVs.
- To evaluate the benefits of using AVs for a grocery home delivery operation of a supermarket in Edinburgh.
- To propose the best possible option to integrate AVs in the supermarket's operation. This includes the operational decisions and the technological specifications.

Method

This study employs ABM approach. The model is developed based on a dataset of a real-world supermarket's operation in Edinburgh. The dataset was recorded between January and September

2020. The ABM was developed using the AnyLogic® simulation platform. There are four types of agents in our ABM: the supermarket agent, the store agents, the vehicle agents, and the customers. The agents are initiated on a GIS layer obtained from OpenStreetMap.

Each day in the simulation starts by resampling orders from the real dataset. For each order, the supermarket agent selects one of its stores to serve it. The selection process is based on the proximity between the store agent and the customer's location (Delaney-Klinger, Boyer, & Frohlich, 2003) (or delivery locker when this option is enabled). The next step is to allocate the orders to vehicles and then route the vehicles. To do this, we use a heuristic that has been developed by the Centre for Sustainable Road Freight (Utomo, Gripton, & Greening, 2019, 2021). The heuristic aims at minimising operational cost and maximising service level by selecting the closest and the most punctual vehicle. The heuristic considers constraints such as, range, capacity, time window, and driver shift.

Once we established the ABM several computer experiments are carried out. Scenarios to be explored in these experiments include:

- The supermarket operates AVs as it operates their existing diesel vehicles. In this scenario AVs deliver the groceries directly to the customer's address. Because AV does not use a driver, it is the customer who must collect the grocery from the vehicle.
- The supermarket operates delivery lockers, and AVs deliver the groceries to these lockers instead. Locker locations are determined by clustering consumer addresses. This option facilitates the possibility of unattended delivery. In addition, this option allows the supermarket to collaborate with other operators, because the delivery lockers can also be used to receive deliveries from other operators.

Criteria that will be used to select the best options are the total operational cost for the supermarket and the service level (the punctuality of the delivery).

Expected Results

Since most of the AVs to be implemented are also EVs, apart from regulatory and social acceptance challenges, AV implementation also faces similar operational challenges to EV. These challenges include substantial investment that may be required to reinforce energy infrastructures at the store and range anxiety. From this study we can propose the least cost operational strategy and technological specifications to integrate AV in the supermarket's home grocery delivery operations. The operational strategy includes whether to delivery directly to the customer's address or via delivery lockers, how the vehicles should be charged, as well as the size of AV fleet that should be operated by the supermarket. The technological specifications include the AV's capacity, battery size and the power of the charger that should be used by the supermarket.

References

- Boysen, N., Fedtke, S., & Schwerdfeger, S. (2021). Last-mile delivery concepts: a survey from an operational research perspective. *OR Spectrum*, 43(1), pp. 1-58.
doi:<http://dx.doi.org/10.1007/s00291-020-00607-8>
- Delaney-Klinger, K., Boyer, K. K., & Frohlich, M. (2003). The return of online grocery shopping: a comparative analysis of Webvan and Tesco's operational methods. *The TQM Magazine*
- Otto, A., Boysen, N., Scholl, A., & Walter, R. (2017). Ergonomic workplace design in the fast pick area. *OR Spectrum*, 39(4), pp. 945-975.

- Peterson, H. (2018). Missing wages, grueling shifts, and bottles of urine: The disturbing accounts of Amazon delivery drivers may reveal the true human cost of 'free' shipping. Retrieved Date Accessed, 11.
- Utomo, D. S., Gripton, A., & Greening, P. (2019, 8-11 Dec. 2019). *Modeling Home Grocery Delivery Using Electric Vehicles: Preliminary Results of an Agent-Based Simulation Study*. 2019 Winter Simulation Conference (WSC).
- Utomo, D. S., Gripton, A., & Greening, P. (2021). Analysing charging strategies for electric LGV in grocery delivery operation using agent-based modelling: An initial case study in the United Kingdom. *Transportation Research Part E: Logistics and Transportation Review*, 148, p 102269. doi:<https://doi.org/10.1016/j.tre.2021.102269> Retrieved from <https://www.sciencedirect.com/science/article/pii/S1366554521000454>
- Yaman, H., Karasan, O. E., & Kara, B. Y. (2012). Release time scheduling and hub location for next-day delivery. *Operations research*, 60(4), pp. 906-917.