Multi-objective sustainable crowdshipping with different types of occasional drivers

Daniel Sanchez[1], Audrey Cerqueus[1], Khakim Habibi[2], and Alexandre Dolgui[1]
[1] IMT Atlantique
{daniel.sanchez-pineda,audrey.cerqueus,alexandre.dolgui}@imt-atlantique.fr
[2] Rennes School of Business
muhammad.habibi@rennes-sb.com

Mots-clés *: Sustainability, Crowdshipping, Multi-objective optimization, Transportation types*

1 Introduction

In the last years, Business-to-Consumer (B2C) E-commerce operations had an exponential increase, representing approximately one-quarter of total global retail sales in 2023. This growth involves an increasing requirement for urban delivery and last-mile delivery solutions. Last-mile delivery is represented as the most complex, expensive, and time-consuming part of delivery logistics. This implies that being competitive for last-mile delivery is one of the key factors for retailers, in terms of minimizing costs and guaranteeing faster delivery to meet customers' satisfaction [1]. Crowdshipping addresses this issue by using regular people who have the willingness to execute deliveries on the way to their normal destinations, without affecting their habitual route. This use of occasional drivers (ODs) aims to exploit underused capacity to cover a part of companies' transportation needs [2].

The first crowdshipping model is proposed in [2], referred as the Vehicle Routing Problem with Occasional Drivers (VRPOD), which is a variant of the classic capacitated VRP (CVRP), where the company considers a set of in-store customers as occasional drivers, in addition to a fleet of capacitated vehicles. The authors aim to minimize the total cost (of the regular fleet and compensation to ODs). This problem was extended in [3] with a variant of the VRPOD including time windows (VRPODTW). A variant of the Green VRP with Crowdshipping and Time Windows is introduced in [4]. The authors considered a mixed fleet composed of conventional capacitated combustion engine and electric vehicles, and the possibility to use ODs. This green initiative was extended in [5] where was studied the impact of using ODs on polluting emissions and the benefits in costs. The results show that the use of ODs becomes competitive in terms of CO_2 emissions and total cost, due to the reduction of conventional vehicles used.

Crowdshipping has been presented as a sustainable option, focused on reducing vehicle use and emissions generation. However, the crowdshipping initiatives have shown that the compensation schemes defined for the ODs have attracted more drivers affecting their normal routes and increasing vehicle use and generated emissions. It is frequently mentioned that a way to secure the sustainable value in crowdshipping is to consider the use of sustainable transportation modes that could replace the regular transportation modes based on fossil fuels [6].

2 Problem description

In this work sustainable crowdshipping is presented as a VRPODTW variant that considers "out-store" people that can participate as ODs, to complement a regular vehicle delivery fleet. Specifically, the problem considers generalizing the participation of different numbers of ODs that belong to different types of transportation (fueled and non-fueled vehicles) and have the willingness to execute deliveries, revealing their main origin and final destination positions. Under this model, compensation policy for ODs according to the type of transportation will be different, assigning the higher compensation to the non-fueled type, to verify benefits in ODs use under a motivation scheme for sustainable vehicles utilization. Also, for each type, the speed, capacity, emissions factors will be different. The time windows are considered for each client and for each OD final destination.

Two sustainability dimensions (economic-transportation cost/environmental emissions) in a deterministic multi-objective optimization scheme are considered. The total transportation cost includes the variables cost associated with regular vehicles, the total fuel cost associated with regular vehicles, and the cost of compensation of the ODs according to each transportation mode, assuming that the compensation will only cover the deviation required from their original trip. The environmental emissions are calculated as a relational function to the total load for each vehicle that is updated during the route, the fuel consumption, and the distance traveled.

3 Approach developed

The methodology implies the problem formulation in a bi-objective mixed integer programming perspective. For the solution, two approaches have been developed. An optimal solution approach using an epsilon constraint approach in Gurobi, and a Column Generation epsilon approach method to find feasible good solutions, to validate the problem conditions and results. Under the experimental process, a comparison between the two approaches is executed, considering short instances of clustered and random clients. The first experiments exhibit a competitive computational time with the column generation approach in comparison to the epsilon constraint approach with Gurobi. Also, the column generation approach solves small and medium instances with a gap to optimality smaller than 5%. Managerial insights will be given during the presentation regarding the impact of the use of ODs on both the cost and the CO2 emissions.

Références

[1] N. Elsokkary, H. Otrok, S. Singh, R. Mizouni, H. Barada, and M. Omar, “Crowdsourced last mile delivery: Collaborative workforce assignment,” Internet of Things (Netherlands), vol. 22, Jul. 2023, doi: 10.1016/j.iot.2023.100692.

[2] C. Archetti, M. Savelsbergh, and M. G. Speranza, “The Vehicle Routing Problem with Occasional Drivers,” Eur J Oper Res, vol. 254, no. 2, pp. 472–480, Oct. 2016, doi: 10.1016/j.ejor.2016.03.049.

[3] G. Macrina, L. Di Puglia Pugliese, F. Guerriero, and D. Laganà, “The Vehicle Routing Problem with Occasional Drivers and Time Windows,” in Springer Proceedings in Mathematics and Statistics, Springer New York LLC, 2017, pp. 577–587. doi: 10.1007/978-3-319-67308-0_58.

[4] G. Macrina and F. Guerriero, “The Green Vehicle Routing Problem with Occasional Drivers,” in AIRO Springer Series, vol. 1, Springer Nature, 2018, pp. 357–366. doi: 10.1007/978-3-030-00473-6_38.

[5] G. Macrina, L. Di Puglia Pugliese, and F. Guerriero, “Crowd-shipping: A new efficient and eco-friendly delivery strategy,” in Procedia Manufacturing, Elsevier B.V., 2020, pp. 483–487. doi: 10.1016/j.promfg.2020.02.048.

[6] E. Pourrahmani and M. Jaller, “Crowdshipping in last mile deliveries: Operational challenges and research opportunities,” Socio-Economic Planning Sciences, vol. 78. Elsevier Ltd, Dec. 01, 2021. doi: 10.1016/j.seps.2021.101063.