Paper Review and Brief Research Proposal

Submitted to Prof. Joseph Chow as an assignment for graduate admissions at New York University

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1 Introduction

This write-up majorly focuses on the recent work of Le et al. (2021) in the development of matching-routing models for crowd-shipping systems that take into account various factors pertaining to service providers, senders, and couriers. The organization of this write-up is as follows: Section 2 presents a short overview and critique of the paper Le et al. (2021). Section 3 presents the notion of horizontal collaboration in the crowd-shipping context and the necessity for it. Finally, section 4 provides a brief research proposal for incorporating horizontal collaboration by using ideas from ().

2 Overview of Le et al. (2021)

The paper deals with developing a pricing strategy for the routing matching framework in crowd-shipping systems. In this context, the authors provide a mixed integer non-linear program formulation to maximize the platform provider's profit. The major contribution of the paper is that it integrates four components in its model: matching, routing, pricing, and compensation. The routing model uses the sender's package characteristics and the courier's location and other characteristics to output a distance matrix which is used by the matching model to match a sender to its courier. The matching procedure is done in such a way that it maximizes the profit of the provider, satisfying several demand-supply and pricing-compensation constraints. The pricing constraints ensure that the price that is posed to a sender should be less than what he is willing to pay (willingness to pay, or WTP), while the compensation constraints make sure that the price shown to a courier is more than compensation per kilometer and expected payment of the courier (expectation to be paid, or ETP). In this regard, the authors propose several strategies where either the price and compensation are fixed ("flat") or origin-destination dependent ("individual"), providing four pricing-compensation scheme combinations.

To solve the model, the authors used a linearization technique to convert the problem into a mixed integer linear program. The objective of the paper remains to maximize the revenue of the provider, which is the difference between what the sender pays (P) and what the courier receives (C), but the authors also quantify the surplus for each of the stakeholders in the crowd-shipping system. To do this, the authors define two types of surplus – sender's surplus, which is the difference between the sender's willingness to pay and the actual price they pay ($WTP - P$), and the courier's surplus, which is the extra compensation a courier gets due to the price over his expectation to be paid ($C - ETP$). (The notations have been simplified to a great extent in this write-up for better understanding.). Although the paper tests all four pricing-compensation strategies across several scenarios, it does not provide a mechanism to select the best compensation strategy beforehand. This feature could have been incorporated into the model by adding a penalty to the objective function for each of the pricing-compensation strategies. By doing so, the model would select the best pricing-compensation strategy for each scenario-supply-demand condition.

Further, the paper analyses the "value" that each stakeholder – sender, courier, and the provider gets from the model in different supply-demand scenarios. Here, the provider's profit, senders surplus, and courier surplus in computed while setting different objectives, such as maximizing profit for the platform or increasing surplus for senders and couriers. As expected, all three values of the provider's profit, sender's surplus, and courier's surplus compete with each other; for example, to maximize the provider's profit, the courier's surplus and the sender's surplus get reduced. The author compares these values across various demand-supply scenarios over all the pricing compensation schemes. The results indicate supply to demand ratio of 1.2, and an individual pricing scheme is better to maximize the provider's profit. An interesting observation is that setting a higher price to senders close to their WTP (thereby reducing the sender's surplus) gives higher compensation to couriers (which increases the courier's surplus), bringing a much higher total profit and surplus to all stakeholders. This is interesting as the senders end up paying more, still the overall the sum of profit and surplus is maximized! These results indicate the importance of a multiobjective formulation that maximizes the profit and surplus of each stakeholder. Although the paper doesn't focus on a multiobjective variant, this could be an interesting research direction.

Finally, the authors use an exact solver to solve the linearized model. The nature of the problem on the other hand, indicates a need for a real-time solver that could solve the problem in a much shorter time. For example, the running time with 50 couriers and 25 senders under fixed price/individual compensation took 10 hours to solve. Clearly, the need for a heuristic solver for the model becomes imminent, thereby providing another research direction.

3 Motivation towards horizontal collaboration

The findings reported in Le et al. (2021), discussed in Section 2, present an intriguing insight indicating that when the price is elevated and approaches the sender's willingness to pay, it results in the optimal scenario for the entire system. But, this scenario increases the price at to the sender. This would cause the sender to shop around to multiple players in the crowd-shipping business. Since the model does not include multiple crowd-shipping providers, this would pose a major drawback to the model's pricing strategies and potentially cause lesser profits to providers.

One way to deal with such a situation is to cause collaboration between multiple crowd-shipping providers. Such a collaboration is popularly known as horizontal collaborative logistics. Horizontal logistics collaboration can be defined as the cooperative effort between two or more entities that operate within the same tier of the supply chain and execute equivalent logistics processes (Cruijssen et al., 2007). Horizontal collaborations have huge potential to increase profits and reduce costs to logistic companies, yet they have received limited attention in the context of routing and matching problems (Verdonck et al., 2013). According to the existing literature, there is a shortage of understanding regarding the impact of horizontal cooperation in the context of demand-responsive passenger transportation. In horizontal collaboration, the collaborating parties may employ various tactics to fulfill their goals for this cooperation, frequently aimed at enhancing efficiency in their core operations (Cruijssen et al., 2007). Within the realm of problems closely related to crowd-shipping, horizontal collaborations have recently been explored in the context of dial-a-ride problems. One widely studied horizontal collaboration that can be adapted for use in crowd-shipping systems is the order-sharing model where various methods are employed for the redistribution of requests from one provider to another. In an order-sharing model, plausible order requests from all senders are combined for all the providers, and an overall matching is done (Cruijssen and Salomon, 2004). This process is observed to increase the overall profitability and efficiency of providers (Verdonck et al., 2013). Another variant of order sharing is done through auction-based sharing (Song and Regan, 2003). In an auction-based order-sharing system, the provider who receives a request initially assesses the profitability of fulfilling the request. If it is deemed profitable, the order is fulfilled. However, if it is not, the provider establishes a reservation price and disseminates the order to partner providers for a price auction.

The following table taken from Molenbruch et al. (2017) illustrates the impact of co-operation in cost-saving between four dial-a-ride providers.

Provider	Without cooperation	With cooperation	Saving
Provider 1	579.14	541.64	37.50 (6.48%)
Provider 2	553.60	521.74	31.86 (5.76%)
Provider 3	565.72	542.65	23.07 (4.08%)
Provider 4	558.50	524.21	34.29 (6.14%)
Total	2256.96	2130.24	126.72 (5.61%)

Although horizontal collaborations have been studied sparsely in literature in the context of the dial-a-ride problem, it is yet to be studied for crowd-shipping systems. The major factor where a crowd-shipping system differs from a dial-a-ride system is in that capacities cant be shared in a crowd-shipping system and has domain-specific features like several pricing–compensation strategies as discussed in Le et al. (2021) that don't make much sense for dial-a-ride problems. Hence, there is a significant research gap in implementing horizontal provider collaboration in the crowd-shipping system, and section 4 provides a brief research proposal in this direction.

4 Brief research proposal

In the context of managing multiple provider partners in a crowd-shipping system, each provider may have varying profit margins. As a result, providers can establish different pricing and compensation strategies according to their management policies. Therefore, the proposed model should be capable of accommodating these variations. However, despite the diversity among providers, the willingness to pay (WTP) and expectation to be paid (ETP) of the sender and couriers, respectively, remain constant since they are independent agents.

The problem thus can be formulated as follows:

Problem formulation 1:

Each provider has a fixed pricing compensation strategy (PCS-i) and a fixed minimum reservation (RES-i). The objective, when a sender raises a request for shipment from the origin to the destination, is to determine a price that maximizes the profit for provider i using the pricing compensation strategy PCS-i. If no profit can be generated, the order is circulated among other providers with different pricing compensation strategies, who aim to maximize their individual profits. Selection rules can be established for selecting the winning bid, such as maximizing profit or selecting the minimum price offered by the winning provider. If the winning bid price, combined with RES-i, is less than the sender's WTP, the price is selected and presented to the sender.

Problem formulation 2:

When a sender submits a request for shipment from a specific origin to a destination, the order is disseminated to all available providers. The objective is to maximize the profit of the provider that ultimately fulfills the order. Each provider has its own unique pricing compensation strategy.

Goal and solution strategies:

The purpose of the study would be to evaluate the effectiveness of Problem Formulation 1 (PF1) and Problem Formulation 2 (PF2) in enhancing the profits of individual providers, as well as the surplus of the sender and courier. To test these mathematical programming formulations can be easily adapted from Le et al. (2021) to the specific formulations.

In order to solve PF2, separate constraints related to the pricing compensation strategies of each provider must be incorporated into the model, along with constraints to ensure that the order is served by exactly one provider. Binary decision variables indicating the chosen provider will be necessary, and the objective function will be the sum of the profits of each provider multiplied by their respective decision variables.

PF1 is a more complex variation; in addition to the changes required to solve PF2, a bi-level mixed integer non-linear program is required to solve PF1. The upper level aims to maximize the profit of the provider who receives the request from the sender, which translates to the lowest price offered by the recipient provider. The second level aims to maximize the profit of the recipient provider who actually fulfills the shipment.

The research direction appears promising due to its success in the dial-a-ride problem and the similarity in structure between crowd-shipping models and the dial-a-ride problem. Implementing such a model would not only benefit the providers by maximizing their profits, but it would also result in a higher surplus for the couriers and senders.

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