A Decomposition Approach to Last-Mile Delivery Using Public Transportation Systems

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1 Introduction

The last-mile delivery is the most expensive part of the whole freight delivery system, in addition to being the most unsustainable one. Academia and research have been focusing on finding alternative and innovative solutions to combat the adverse effects of the last-mile delivery system. In this paper, we propose to use public transportation systems for last-mile deliveries in urban areas. One of the greatest advantages of using public transit vehicles is that it does not add any new vehicles on the road solely for the purpose of package delivery, which means no extra congestion and no extra emissions caused by traditional delivery trucks. While it would lead to lower costs for the freight delivery companies, the transit companies can be compensated accordingly, and thus it could be a win-win solution for all parties involved. This has already been demonstrated on several occassions. In the Japanese city of Sapporo, packages were transported using subway systems between suburbs and the city center [1]. Amazon is also looking towards using public buses for its deliveries, and has received a patent that would transform buses into parcel carriers [2]. These examples demonstrate the viability of such a shared transportation system.

2 Problem Statement

We study a problem which we call as the Three-Tier Delivery Problem on Public Transportation (3T-DPPT hereafter). In the first tier (T1), the packages are delivered from the Consolidation and Distribution Center (CDC), typically located on the outskirts of a city, to nearby public vehicle stops called *drop-in* stops. The second tier (T2) of the delivery is the one that occurs on-board public vehicles, which have pre-determined stops and schedules. They pick the packages from the drop-in stops and transport them to some other stops, called *drop-out* stops, which are also close to customer locations. Finally, in tier 3 (T3) the freighters pick the packages from the drop-out stops and deliver them to their respective customers, using sustainable and green modes of transport, like bikes, or even walking to make the delivery. The objective is to minimize the transportation costs in T1 and T3. We do not seek to minimize costs pertaining to T2, because here the transport occurs on public vehicles, which would be making the trips anyway. We study an operational version of the problem, so we assume that when the delivery is taking place the entire delivery system has already been set up with equipment and personnel, and the public transit companies have been compensated for the service. Hence we do not consider any additional delivery costs in T2.

3 Decomposition Methodology

Since the full problem is quite large, and challenging to solve even for small instances, we decompose the problem into T1, T2, and T3 and solve them individually. Depending on which tier we start solving the problem from we have three decomposition approaches- *D1* solves T1 first, followed by T2 and T3. *D2* solves T2 first and then T1 and T3 simultaneously. Finally, *D3* first solves T3, followed by T2 and T1. For T2, we also propose three objective functions that capture the original objective of the problem of minimizing routing costs of T1 and T3– minimizing the no. of drop-in and/or drop-out stops used (*Obj1*), minimizing the approximate routing costs of T1 and/or T3 (*Obj2*), and minimizing the approximate cost of the freighters used in T3 (*Obj3*).

4 Results and Conclusion

We created 24 instances to mimic small real-life cities, with the number of customers ranging from 10 to 80. Figure 1 shows the total routing cost for each of the instances for all the different solution methods. Each line refers to a solution approach. Table 1 shows the average percentage gap of each solution approach, the average taken over the instances it could solve, wrt the best solution found for that instance. The *FULL* problem could only solve the instances containing upto 30 customers. The overall best performing decomposition approach was found to be D2, while *D1* performed the worst. Among the objective functions *Obj2* performs the best, since it was directly related to minimizing approximated routing costs, and *Obj3* generally performs the worst. The 3T-DPPT provides promising results for the last-mile delivery problem. We compare it with a standard Vehicle Routing Problem with Time Windows (VRPTW), and find that it has the potential to reduce costs of using delivery trucks by 25-80 percent on our small-sized instances. For larger cities, the cost reductions would be even higher.

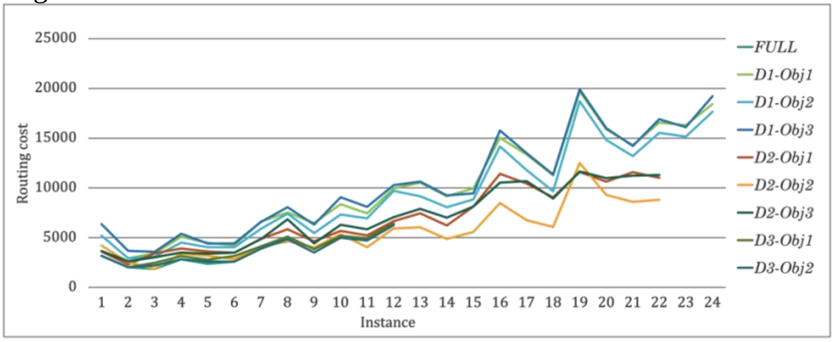

FIG. 1 – Comparison of routing costs by different solution approaches

	Routing cost T1			Routing cost T3			Total routing cost		
Decomposition technique with Objective function	Obj1	Obj2	Obj3	Obj1	Obj2	Obj3	Obj1	Obj2	Obj3
FULL	8.37%			3.06%			0.72%		
D1	8.49%			106.81%	86.08%	117.29%	69.58%	55.73%	75.99%
D2	66.94%	6.40%	53.55%	23.55%	12.60%	31.64%	31.17%	7.12%	32.96%
D3	49.98%	25.18%	--	1.02%		--	12.12%	4.73%	--

TAB. 1 – Average % deviation of the solution wrt the best solution found for the instance

References

[1] J. Kikuta, T. Ito, I. Tomiyama, S. Yamamoto and T. Yamada. New subway-integrated city logistics szystem, *Procedia-Social and Behavioral Sciences*, 39, 476-489, 2012.

[2] E. Baron. Amazon looks to turn public buses into mobile delivery stations. *StarTribune*, 2019.