Finding Optimal Sharing Point in Shared Delivery Services Using Google OR-Tools

TRBAM-24-04470

Peyman Hashemi Baragoori[1], Bekir Bartin[2]

Motivation

- The rise of q-commerce, also known as quick commerce or on-demand delivery, has revolutionized the online shopping landscape, emphasizing rapid deliveries within a short time period.
- The COVID-19 pandemic and the subsequent restrictions played a significant role in boosting q-commerce as it allowed retailers to continue operating through quick home deliveries
- When there is an imbalance in orders, in terms of time or destination, it is often necessary to seek assistance from other drivers.
- The motivation for this current study stems from need to finding the optimal sharing point (OSP) between the two drivers to minimize the delivery completion time (DCT).

Objectives

- Developing an exact model and employing Google OR-Tools as a metaheuristic optimization method to determine the OSP within a VRP scenario by incorporating the concept of transfer nodes in the pick-up and delivery problems with transshipment (PDPT).
- Considering customer nodes as potential additional sharing points to enhance the delivery system's efficiency.
- Incorporating real-world scenarios by utilizing actual network topology and traffic information.

Methodology

- The methodology used to fulfill the objective of this study is twofold:
- First, a mixed-integer linear programming (MILP) formulation is designed and implemented to find OSP in a hypothetical scenario on a small scale and solved using the Pyomo package and CPLEX solver.
- Second, Google OR-Tools routing solver was employed to solve the problem on a larger scale.

MILP Model

$$\text{minimize } DCT$$

s.t

$$\sum_j z_j = 1 \quad \forall j \in (CU \cup SH)$$

$$\sum_i \sum_k y_{ijk} = 1 + z_j \quad \forall j \in CU$$

$$\sum_j \sum_k y_{ijk} = 1 + z_i \quad \forall i \in CU$$

$$\sum_i \sum_k y_{ijk} = 2 \times z_j \quad \forall j \in SH$$

$$\sum_j \sum_k y_{ijk} = 2 \times z_i \quad \forall i \in SH$$

$$\sum_i y_{iO_k k} = 0 \quad \forall i \in (CU \cup SH)$$

$$\sum_i y_{idk} = 1 \quad \forall i \in V$$

$$\sum_j y_{djk} = 0 \quad \forall j \in V$$

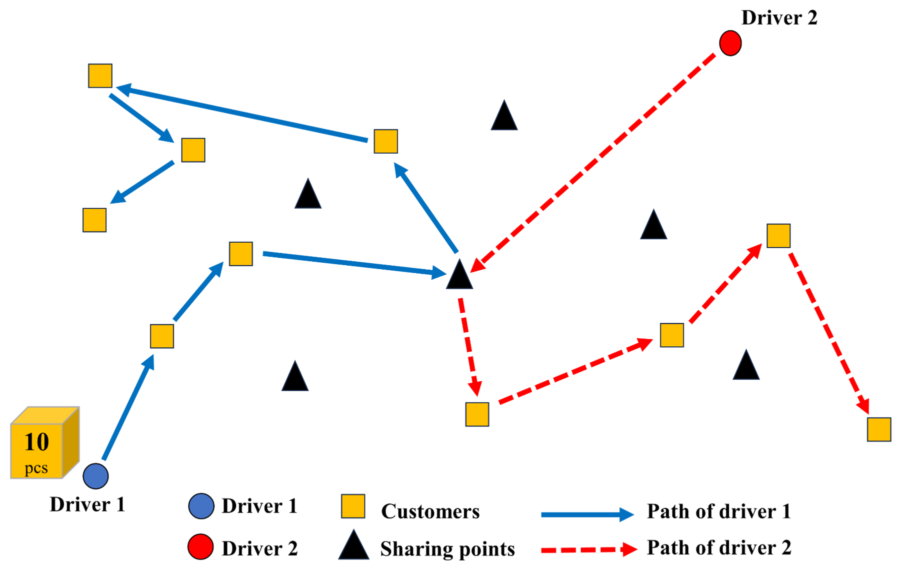
$$y_{O_2 j 2} = z_j \quad \forall j \in (CU \cup SH)$$

$$u_i - u_j + 1 \le (|V| - 1) \times (1 - y_{ijk}) \quad \forall i, j, k$$

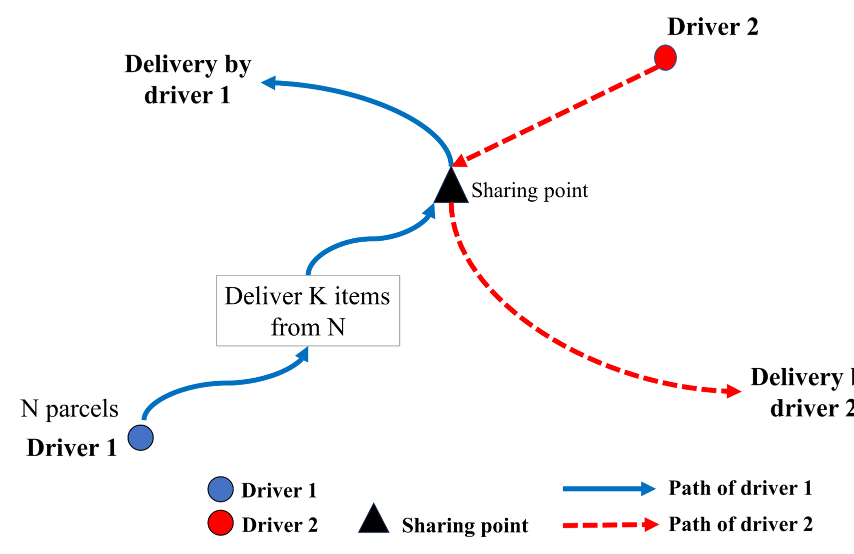
$$C_j \ge C_i + c_{ij} - M(1 - y_{ijk}) \quad \forall i, j, k$$

$$DCT \ge C_j \quad \forall j \in V$$

Notation	Description
V	The set of all nodes
CU	The set of customers' nodes (i.e., delivery points)
SH	The set of sharing nodes
O_k	The set of origin of two drivers
i, j	The indices of all nodes
k	The indices of drivers
d	The index of the virtual depot
y_{ijk}	Binary variable if driver k goes from point i to j
EN_j	Number of entering edges to node j
EX_j	Number of leaving edges from node j
u_j	Number of nodes visited at node j
z_j	Binary variable if node j selected as a sharing point
c_j	Considered traveling cost from node i to j
C_j	Considered cumulative cost for node j
M	A big integer number
DT_k	Driving Time of driver k
WT_k	Waiting Time of driver k at OSP
DCT	Delivery Completion Time



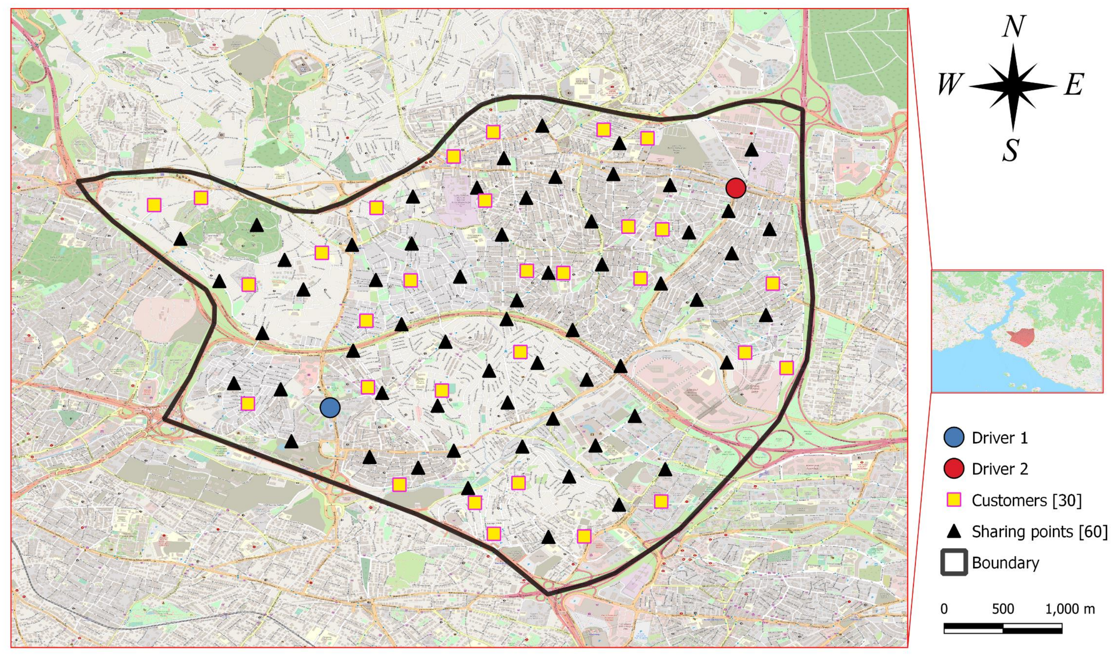
Transshipment at sharing point



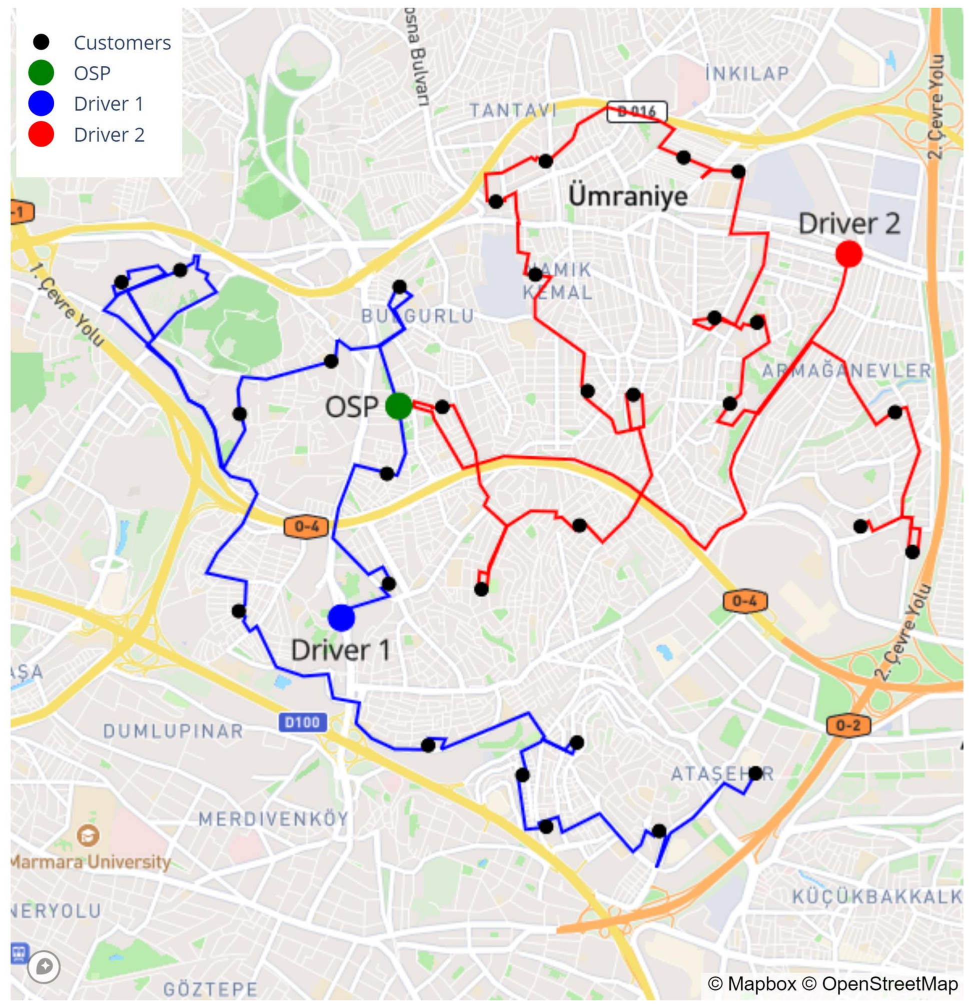
Stages of a hypothetical shared delivery process

Results

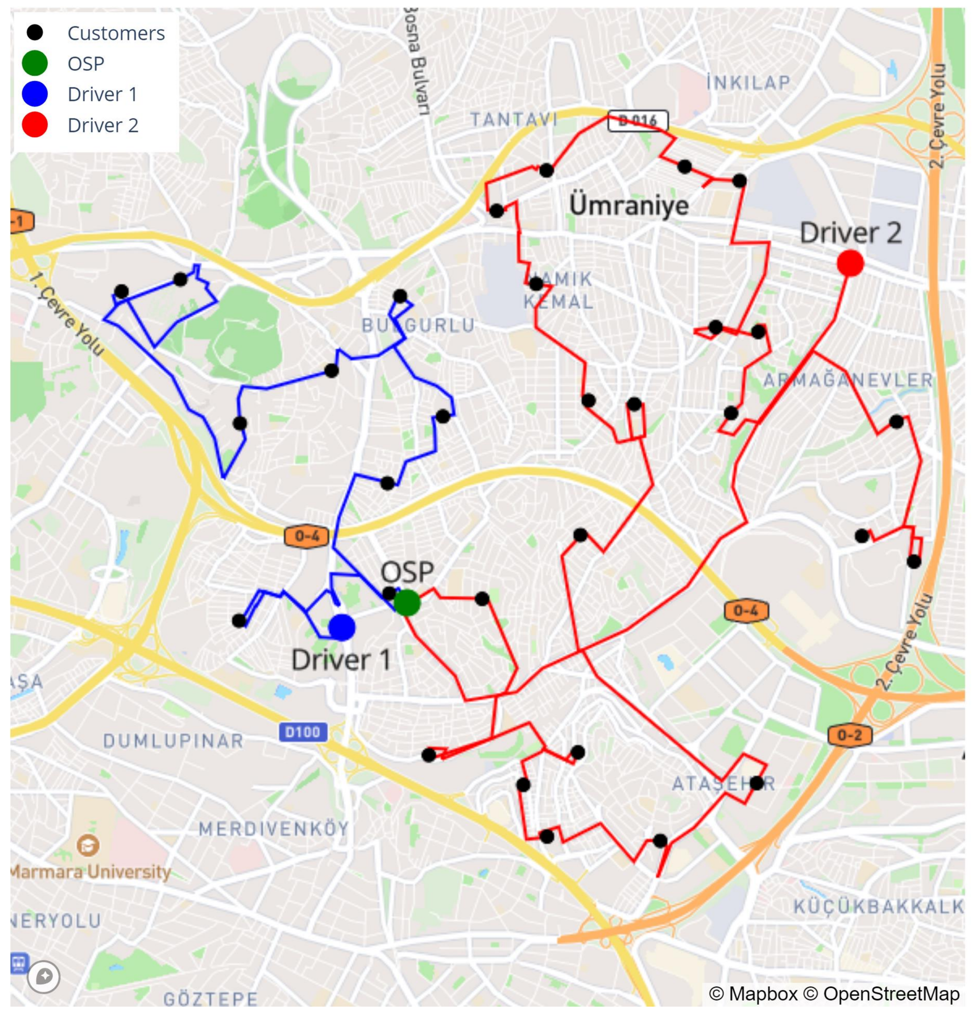
- The case study area, covers two neighborhoods, namely Umraniye and Atasehir, located in the Asian side of Istanbul, Turkey, spanning approximately 21.8 square kilometers.
- A total of 30 customers were selected for the analysis.
- In order to encompass the area, 60 points for sharing have been chosen strategically based on isochrone maps, ensuring coverage within a two-minute travel time threshold.



- Two scenarios were examined to analyze the model's outcomes. Scenario I focused on prioritizing the model's emphasis on optimizing the minimization of the duration of the longest route, while in Scenario II, the goal was to minimize the total time of two drivers' paths.



Optimal sharing plan, considering fairness between the two drivers



Sharing plan focusing on minimizing the summation of delivery times

- In Scenario I, the total delivery time for all parcels, amounted to 6,704 seconds, with 3,368 seconds for driver 1 and 3,336 seconds for driver 2, respectively. The delivery time difference of 32 seconds between the two drivers is negligible in practice, and the delivery task was completed at DCT=3,368.

Details of costs for each considered plan (all units are in seconds)

Optimization Scenario	Driver 1			Driver 2			Total			
	DT_1	WT_1	Total	DT_2	WT_2	Total	DT	WT	$DT + WT$	DCT
Scenario I	3,270	98	3,368	3,336	0	3,336	6,606	98	6,704	3,368
Scenario II	2,051	116	2,167	4,527	0	4,527	6,578	116	6,694	4,527

- In Scenario II, the total delivery time for all parcels amounted to 6,694 seconds, with 2,167 seconds for driver 1 and 4,527 seconds for driver 2. Comparatively, the summation of DT and WT decreased by 10 seconds compared to Scenario I.
- However, the delivery time difference between the two drivers is 2,360 seconds, and clearly, a balance in driving time was not achieved, as was the case in Scenario I.

Conclusions

- This paper addressed the finding of OSP for two delivery drivers, modeling it as a multi-depot open-VRP and solving it with the Google OR-Tools routing solver. Our approach addressed these key objectives:
  - I. Minimizing DCT to prioritize timely services.
  - II. Implementing a seamless sharing process without the need for physical transfer nodes.
  - III. Incorporating actual network topology and traffic considerations.
  - IV. Adding flexibility to the sharing process by considering customer nodes as additional potential sharing points.
- The model's flexibility enables users to customize parameters and coefficients for diverse objectives, whether prioritizing total delivery time or minimizing driving time for drivers in different scenarios.

[1] MSc student, Ozyegin University, Istanbul TURKEY [2] Associate Professor, Ozyegin University, Istanbul TURKEY

This study was funded by Ozyegin University and NYU C2SMARTER Center (A Tier 1 USDOT UTC)