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Does Parking Matter in Routing for Last-Mile Deliveries?

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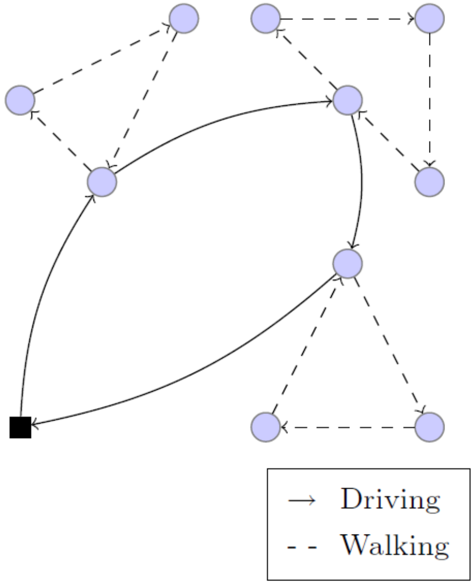
Work co-authored with Sara Reed and Barry Thomas

Parking in last-mile delivery

- Much of the existing academic work **ignores** parking
  - Think **TSP, VRP**
- But parking is a **time-consuming** part of the driver's day
- In urban environments in the United States, the average time to find parking is **9 minutes**.
- **Parking** decisions related to decision of where to **walk vs. drive**

In literature



- Optimization Decisions:
  - Partition customers into service sets for **walking**
  - Choose **parking** location in **each** customer service set
  - Determine driving and walking routes
- Objective value:

  For $0 \leq \alpha \leq 1$:

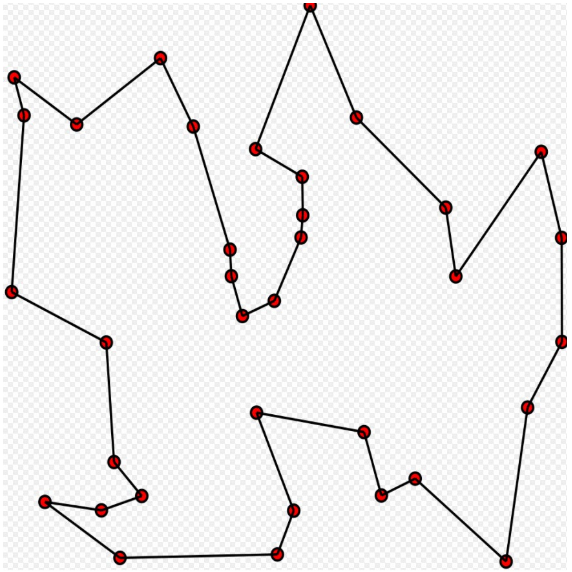
  $$\alpha \cdot \text{Driving Time} + (1-\alpha) \cdot \text{Walking Time}$$

Martinez-Sykora, Antonio, et al. "Optimised solutions to the last-mile delivery problem in London using a combination of walking and driving." Annals of Operations Research 295.2 (2020): 645-693.

In practice

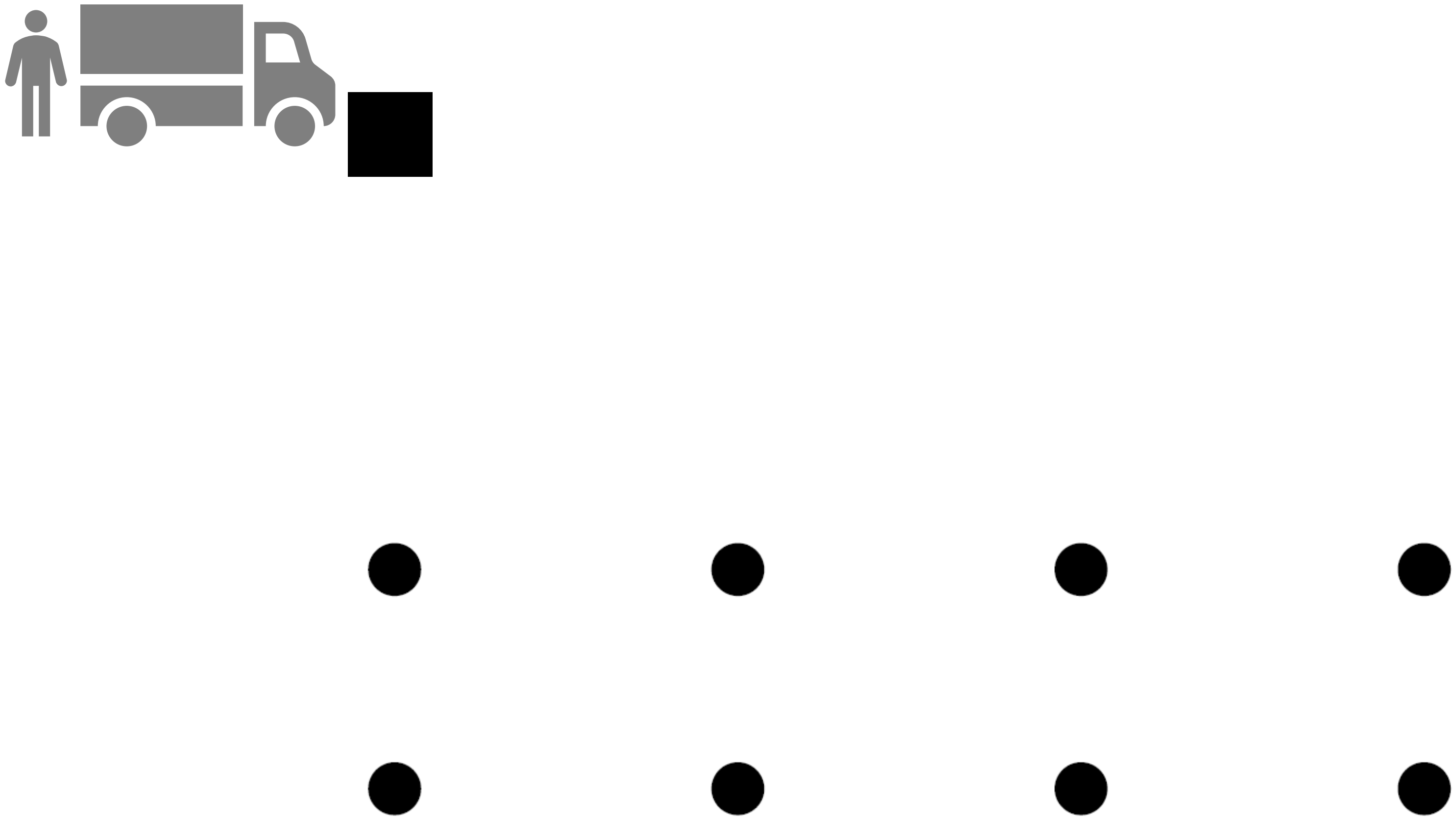
At UPS, the Algorithm Is the Driver

https://www.wsj.com/articles/at-ups-the-algorithm-is-the-driver-1424136536

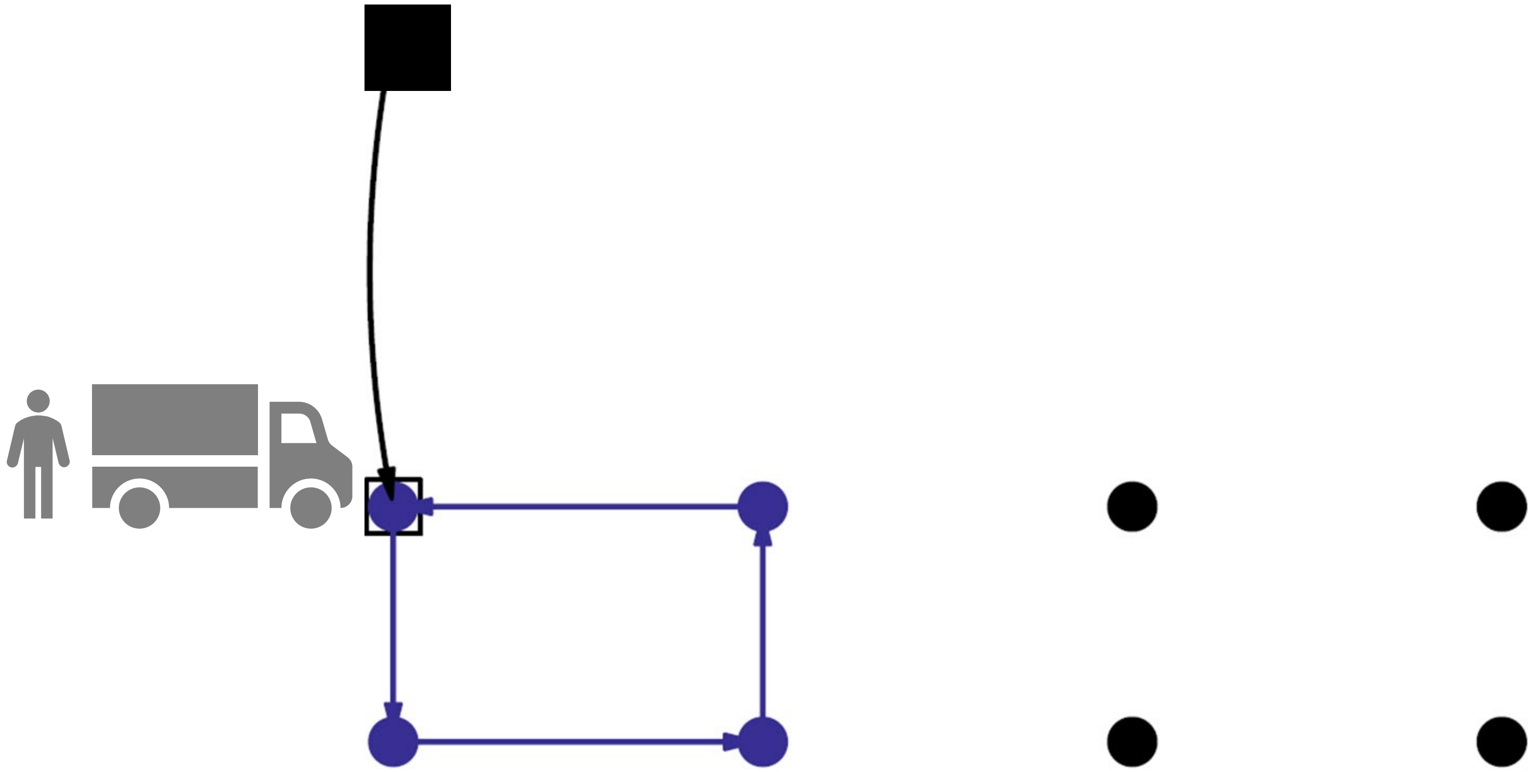


- Decision support is often in the form of a **TSP** solution
- Decision of where to **park** and **walk** made by the **driver**

Delivery with parking



Delivery with parking: Option 1



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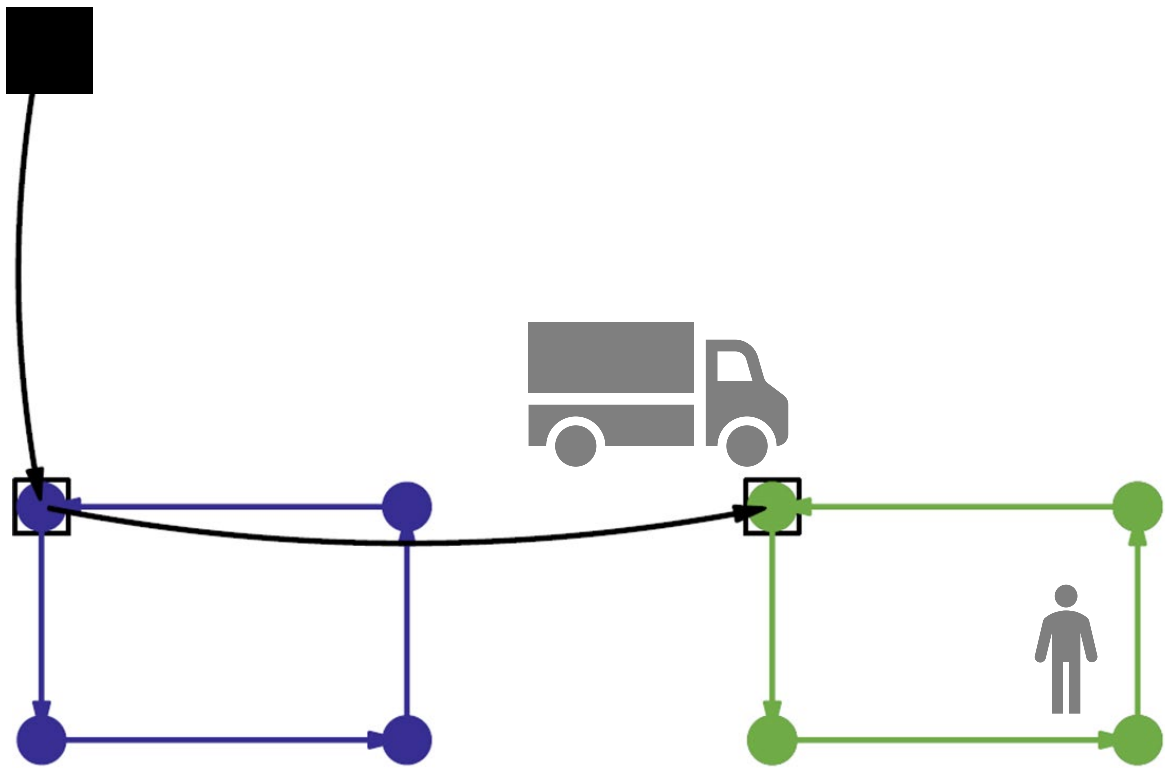

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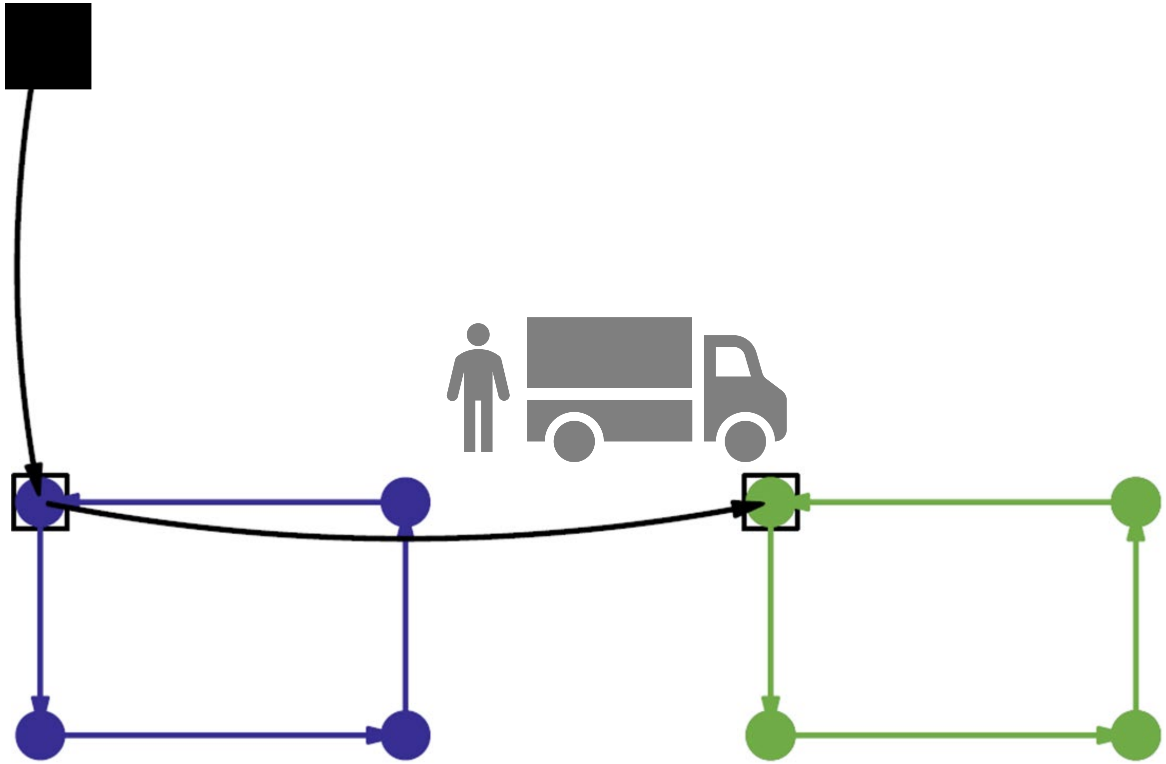

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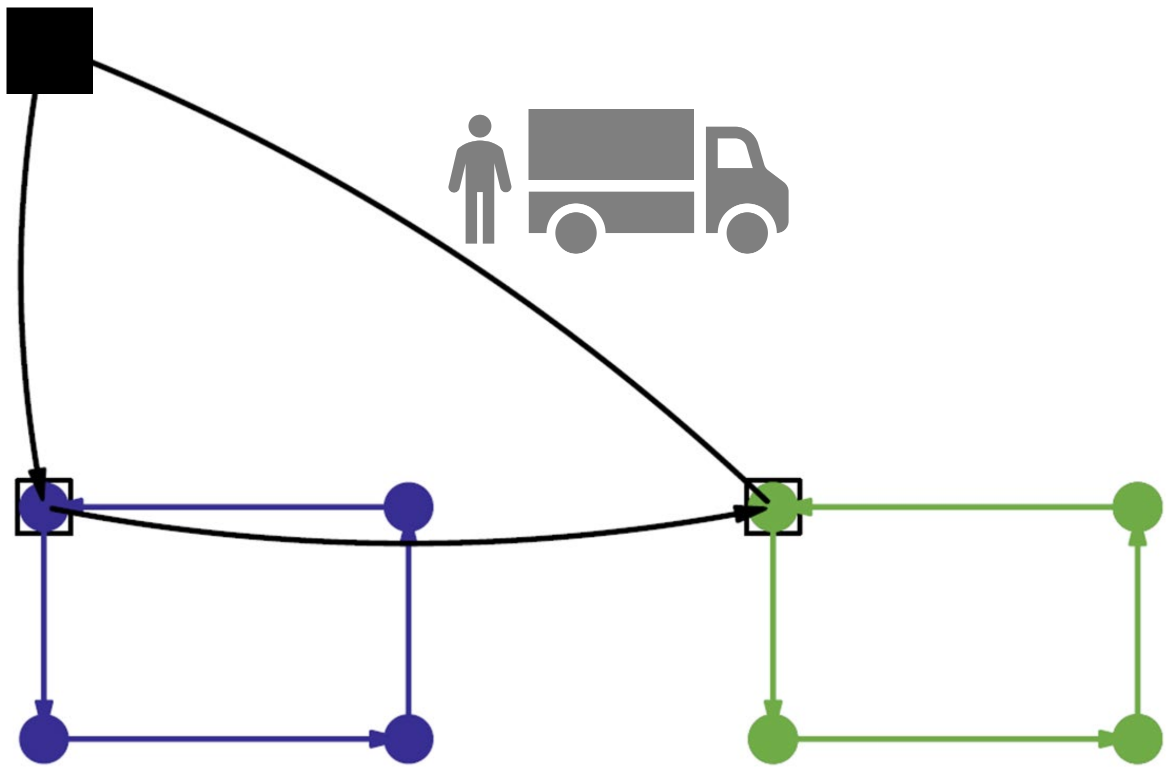
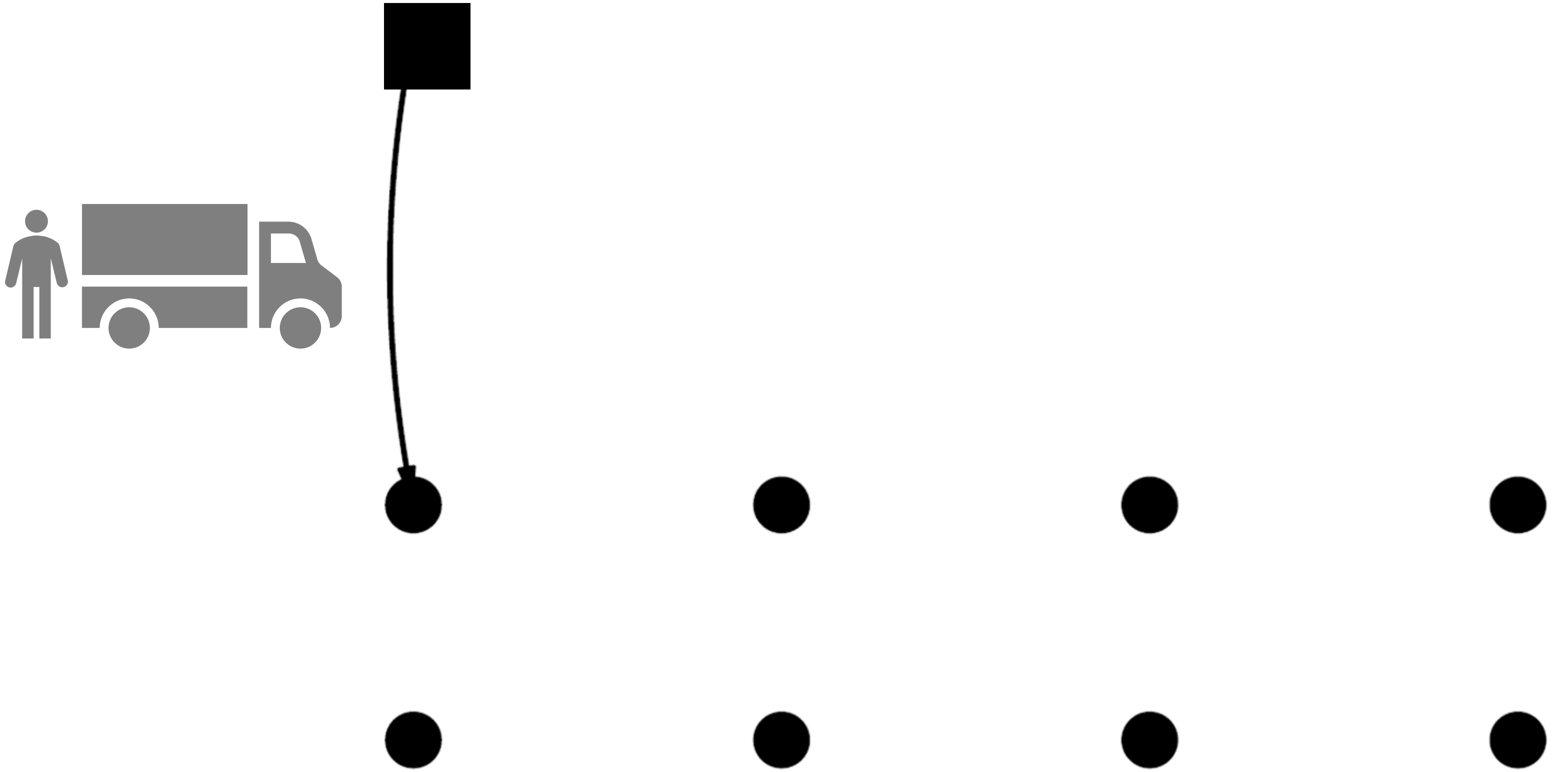


Delivery with parking: Option 2



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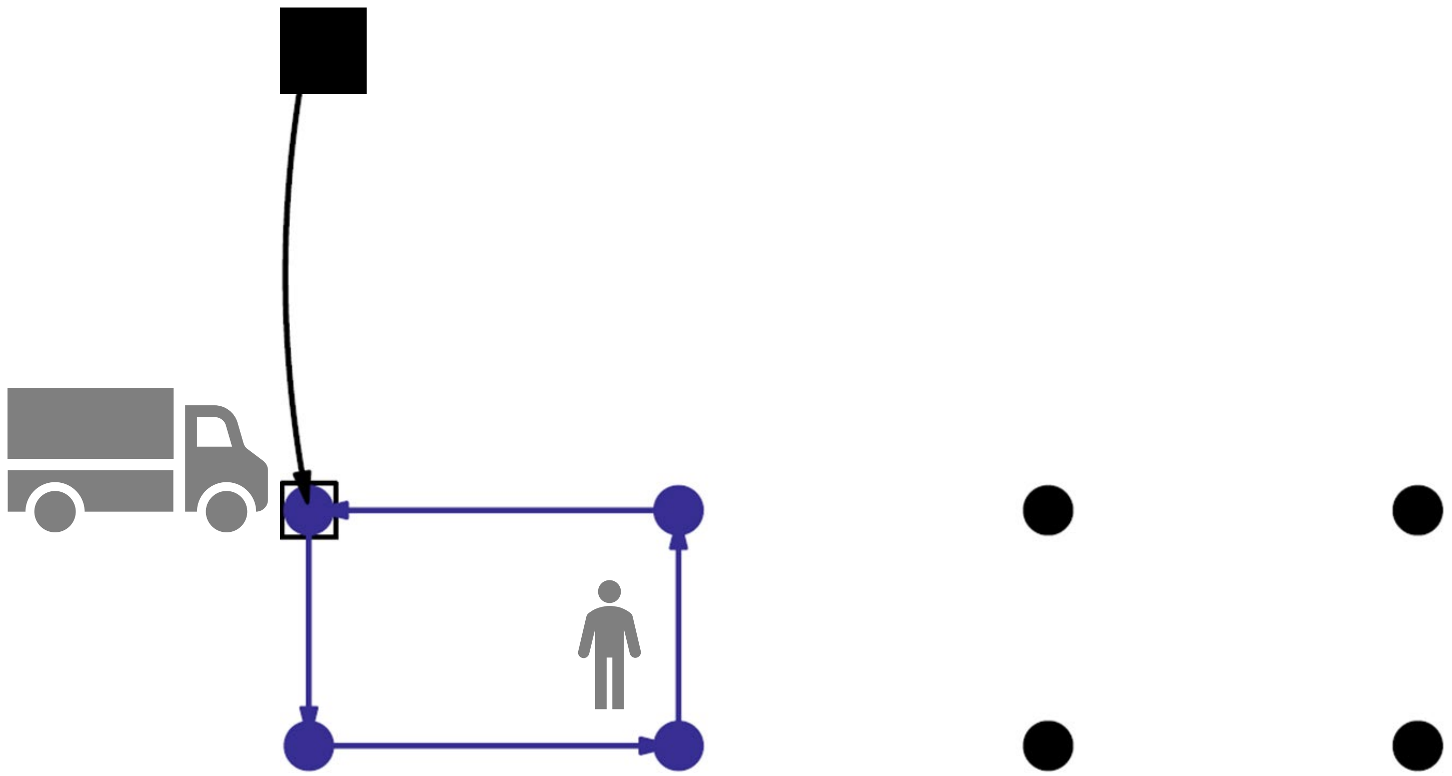

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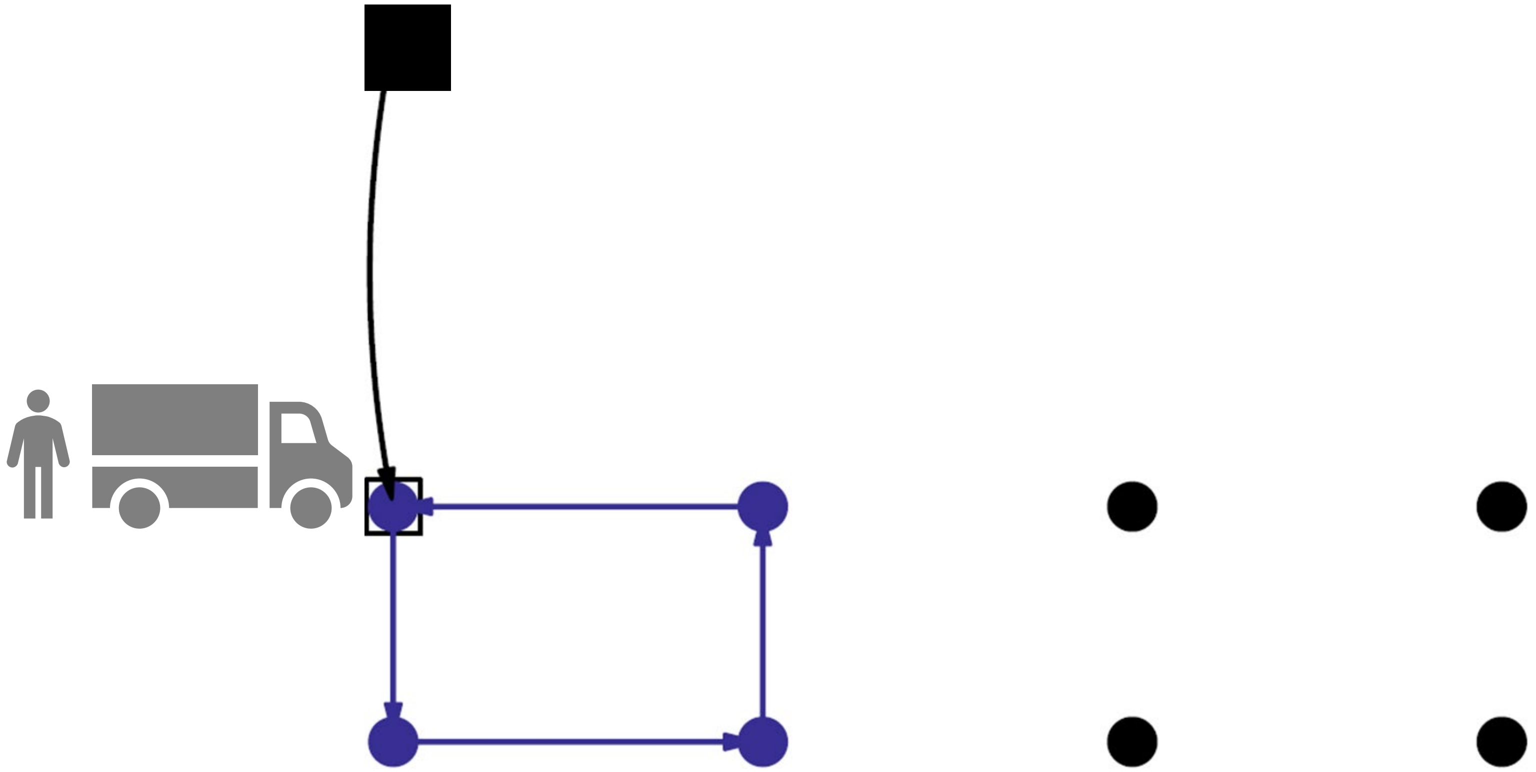

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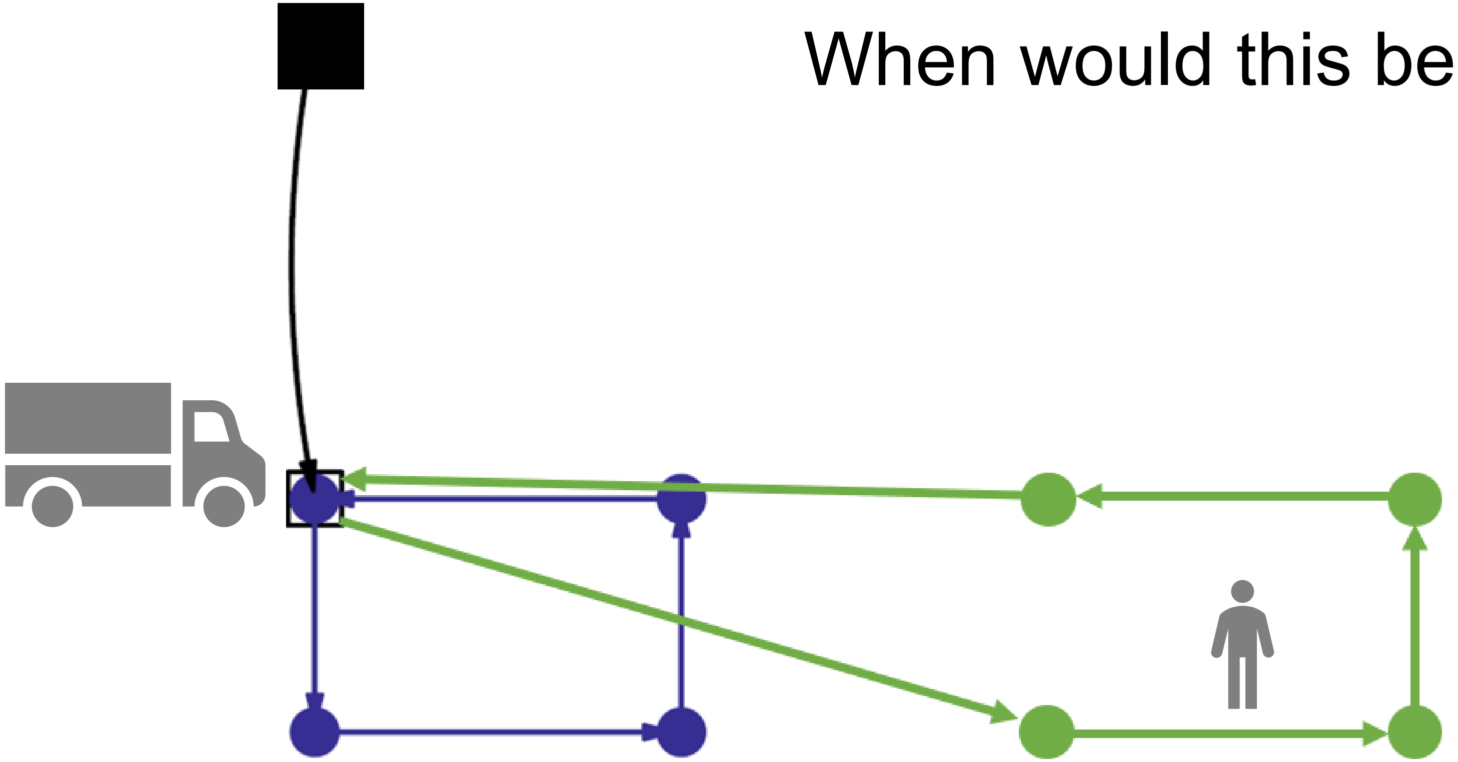

When would this be better?

Capacitated Delivery Problem with Parking (CDPP)

- **Single vehicle** with a delivery **person**
- Delivery person can return to vehicle and **reload or drive**
- **Loading time** per package f
- Delivery person has **capacity** q
- Decisions
  - Where to **drive**, **park, and walk**
- Goal: Minimize the completion time of the tour

Capacitated Delivery Problem with Parking (CDPP)

$x_{ik} = 1$ if the delivery person drives from i to k and parks at k
$y_{ij} = 1$ if the delivery person serves customer set σ_j while parked at i

$$\min \sum_{i \in \bar{C}} \sum_{k \in \bar{C} \setminus \{i\}} x_{ik} d_{ik} + \sum_{i \in C} \sum_{\sigma_j \in S} y_{ij} \left(w_{ij} + f_j \right)$$

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Time spent driving and parking (parking only at customers)

$$d_{ik} = \begin{cases} D(i,k) + p & \text{if } k \neq 0 \\ D(i,k) & \text{if } k = 0 \end{cases}$$

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Time spent serving sets of customers: walking + loading packages

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Variable Reduction

→ We can reduce y variables by decomposing sets
  - **Singleton** sets for customers where **parking** occurs (Corollary 1)
  - Sets with only **walking** customers (Corollary 2)

- Our set of improvements allow us to solve instances with 50 customers within a few hours

Benchmarks

- **Ignore parking time:** Solve the CDPP with $p = 0$.
  - Let z be the optimal value.
  - Let n be the number of parking spots in the optimal solution.
  - "Realized" completion time of the delivery tour $= z + n \cdot p$

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Benchmarks

- **Ignore parking time:** Solve the CDPP with $p = 0$.
  - Let z be the optimal value.
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  - "Realized" completion time of the delivery tour $= z + v \cdot p$
- **Transformed TSP:** Fix the order of customer service using TSP solution. Optimally solve for where to park (practice).

Benchmarks

- **Ignore parking time:** Solve the CDPP with $p = 0$.
  - Let z be the optimal value.
  - Let v be the number of parking spots in the optimal solution.
  - "Realized" completion time of the delivery tour $= z + v \cdot p$
  - Captures walking vs. driving
- **Transformed TSP:** Fix the order of customer service using TSP solution. Optimally solve for where to park (practice).
- **Relaxed Martinez-Sykora et al. (2020):** Uses M-S objective with α (literature).

Experimental Design

→ **Parameters:**

- **Counties** from **Illinois** (USDA)
  - Urban: Cook
  - Suburban: Adams
  - Rural: Cumberland
- **Location-dependent parking times:**
  - Urban: $p = 9$ minutes
  - Suburban: $p = 5$ minutes
  - Rural: $p = 1$ minute
- **Capacity of the delivery person:** $q = 3$ packages*
- **Loading time per package:** $f = 2.1$ minutes*

* ="Understanding the impact of e-commerce on last-mile light goods vehicle activity in urban areas: The case of London", Transportation Research Part D

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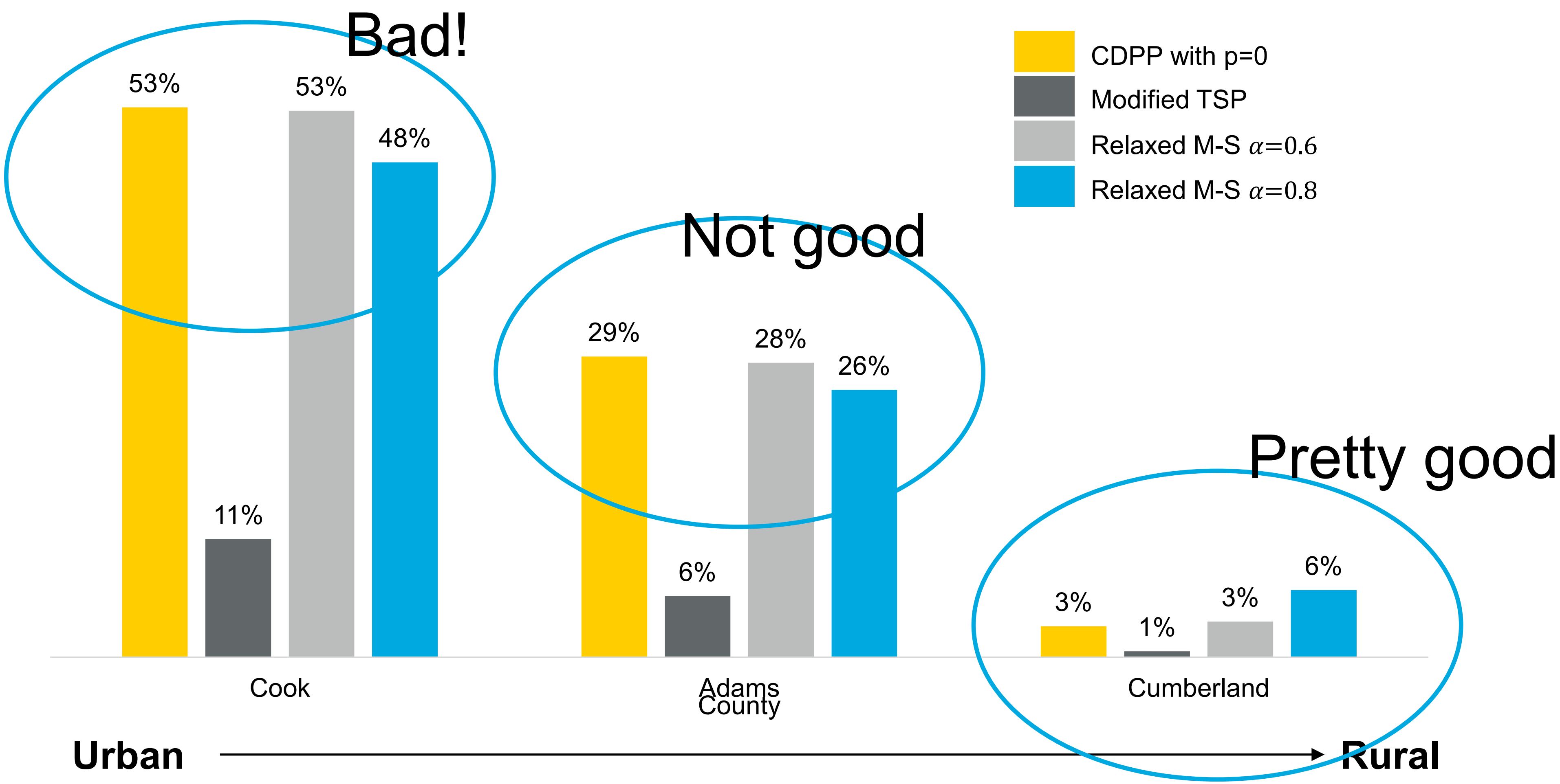
Percent increase in service time above CDPP



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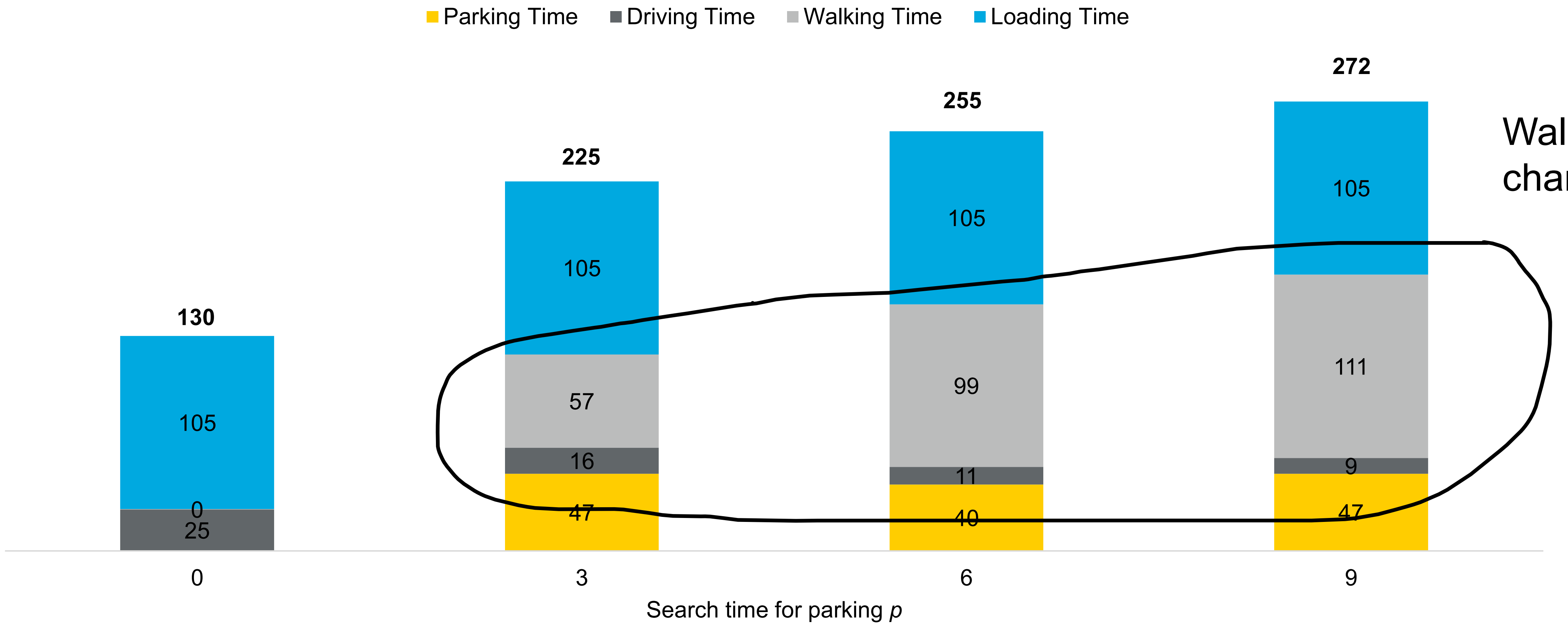
Impact of varying parking times - urban



Walking changes!

Does parking matter?

- → **Yes, parking matters**. Particularly outside of **rural** environments.
- → Outside of rural environments, longer search times for parking changes the **structure** of the solutions.
- → We also propose a two-echelon locating-routing **heuristic** finds high **quality** solutions **quickly** for **larger n** or **q**

What’s next?

- **Stochastic** “cruising” for parking spots
- **Policies** for loading zones, parking strategy questions
- Considering **parking** is a **rich** research area for last-mile

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Parking matters!

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Does Parking Matter? The Impact of Search Time for Parking on Last-Mile Delivery Optimization
Sara Reed, Ann Melissa Campbell, and Barrett W. Thomas

Preprint available on arXiv: https://arxiv.org/abs/2107.06788