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# Optimization techniques for last mile delivery in smart cities using the C – ITS

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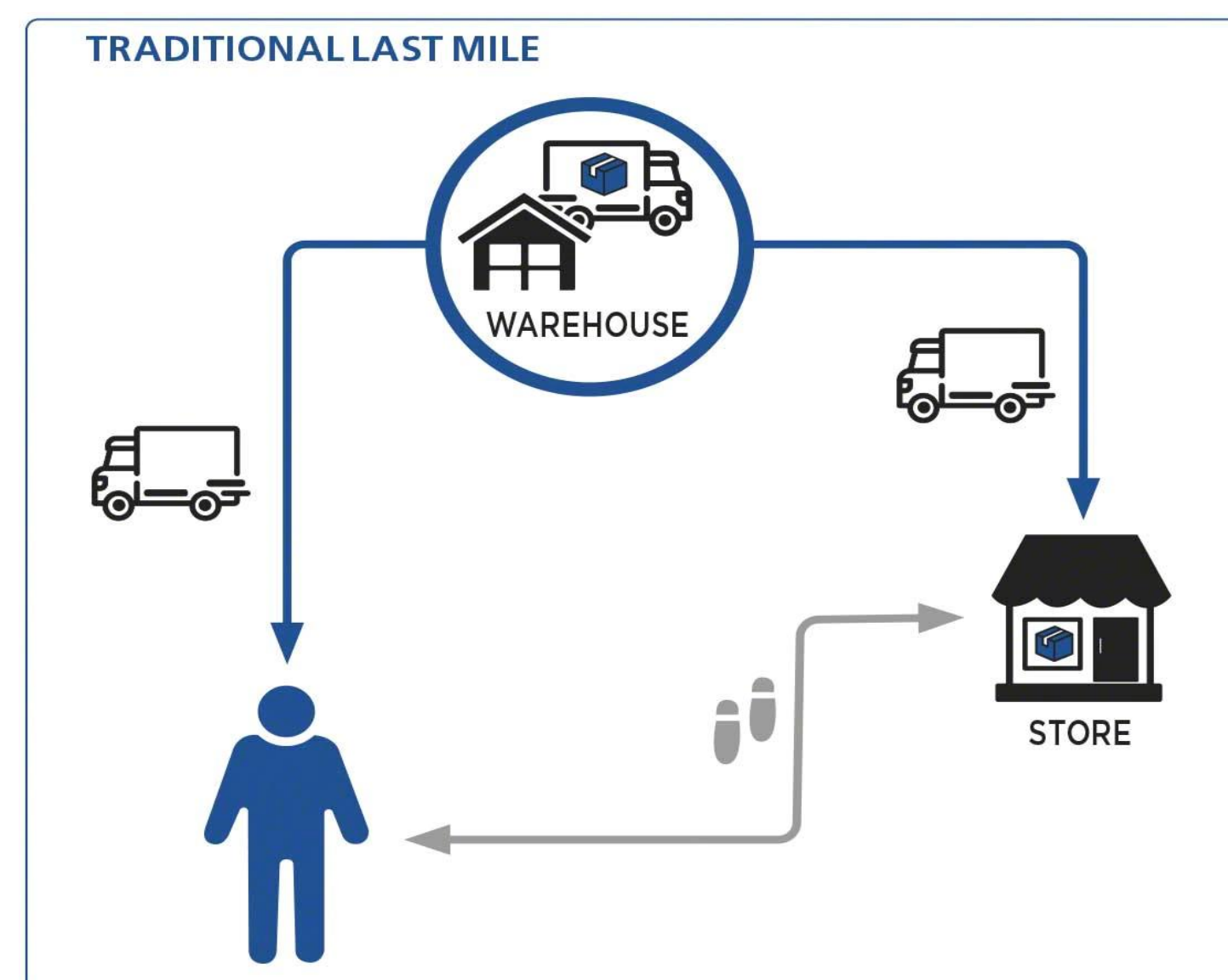
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## Introduction and problem statement

### What is the last mile delivery?

- to find transport of goods from distribution facility (depot) to customers
- most complex costly task
  - more than **53%** of total shipment cost
  - **86%** of parcels have **less than 2.3 kg** weight



### Major issues?

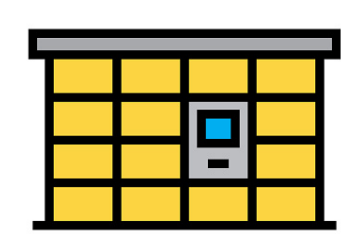
- **increased air pollution** (20% -30% CO<sub>2</sub> emission comes from the last mile delivery)
- **failed deliveries to the customers**
- **traffic congestion** (slower speed, longer trip times, increased vehicular queuing)

## Our approach



### Electric vehicle

- lower overall lifetime costs
- better, safer driving
- better efficiency
- health benefits
- reduced emissions



### Parcel lockers

- no missed delivery problem
- more efficient routing
- longer pickup window
- enabling sustainable development



### C – ITS (Cooperative - Intelligent Transport Systems)

- increasing the road safety
- incident detection
- pedestrian detection
- road weather information
- traffic signal controller
- availability of charging stations



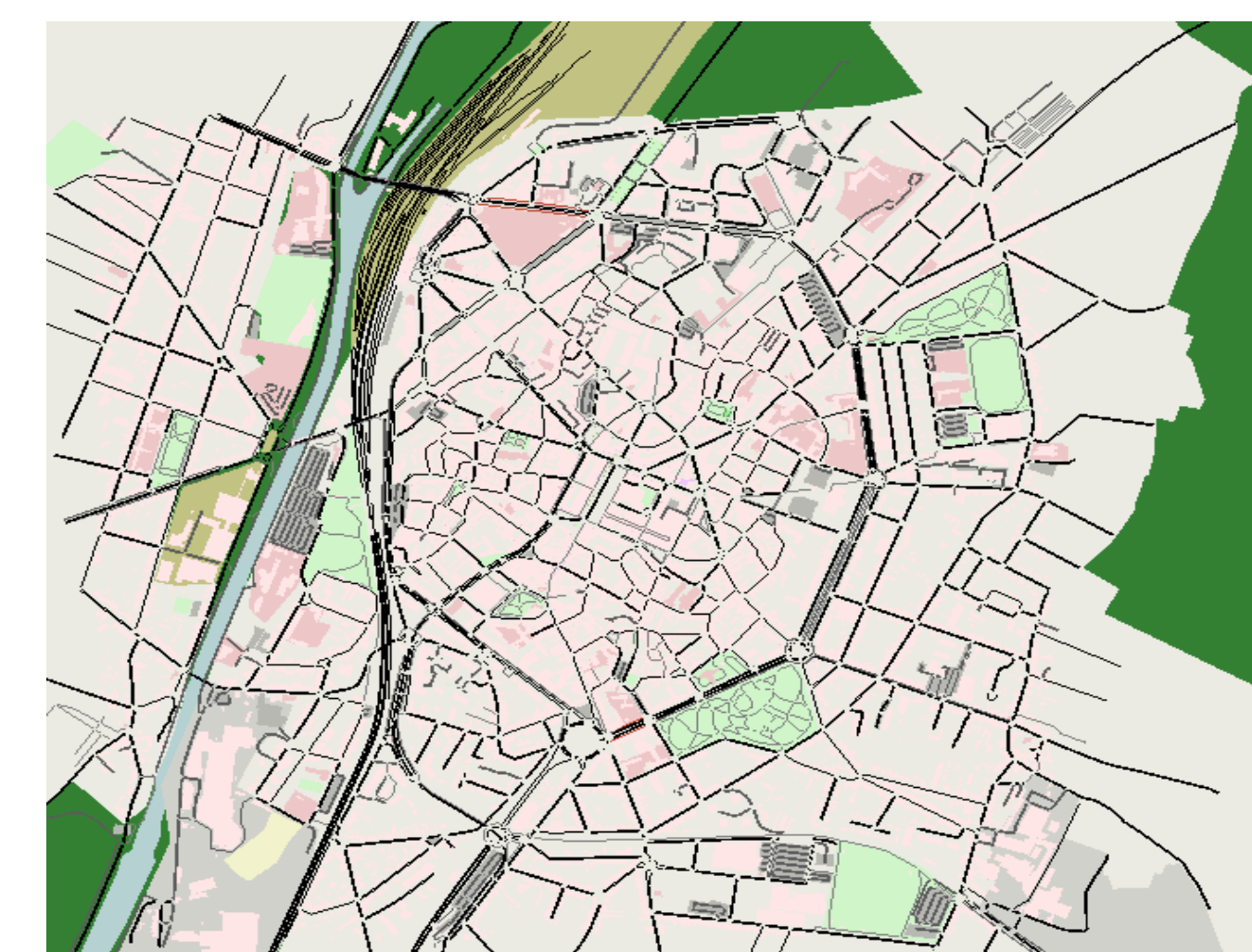
### Resulting problem

- single electric vehicle is leaving central depot (fully charged)
- delivering parcels to customers directly to their address or parcels should be leave at the parcel locker
- following the route, if it is necessary, electric vehicle can be charged at the multiple charging stations
- position of the parcel locker and charging station is on the same location

## Methods and procedures

- problem was formulated as **MILP** model
- the created model is validated using **CPLEX MILP** solver and small size instances
- for large instances, a **VNS** based heuristic is proposed
- its performance on small size instances shows that is able to reach all known optimal solutions found by **CPLEX** in very short time.

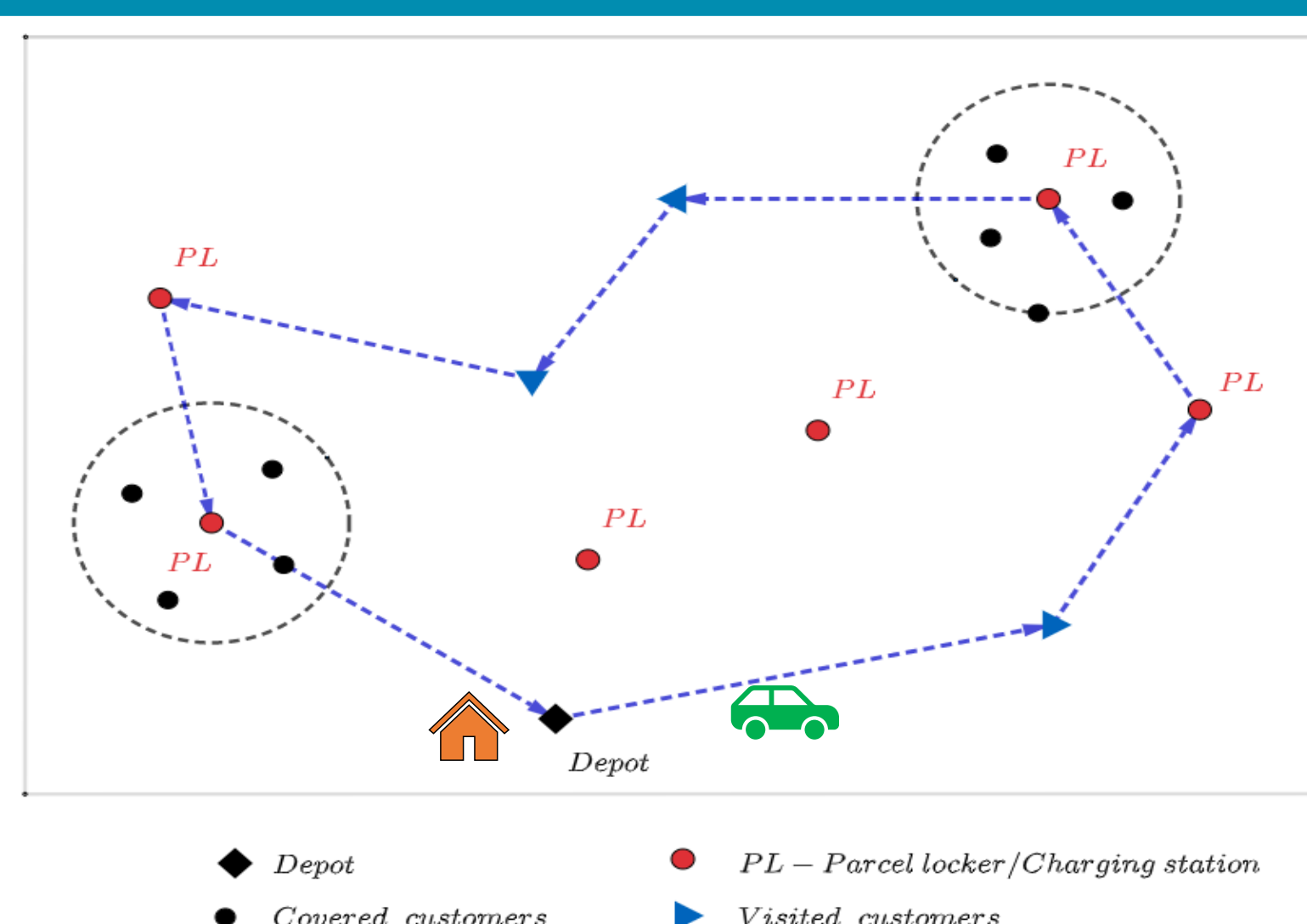
- currently, we are testing adapted instances with **SUMO** simulator for urban mobility
- **OSM** (Open Street Map) web wizard is used to collect data from the Valenciennes metropole
- different variants of traffic conditions are taken into account



## Data and results

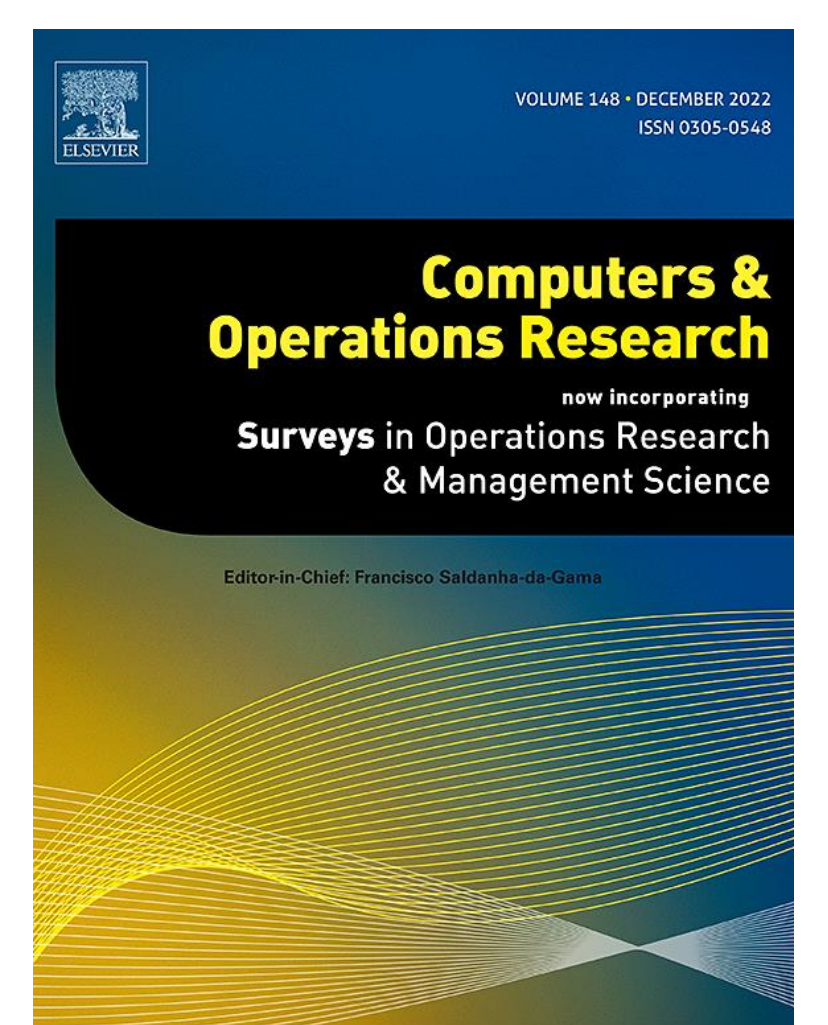
### Computational results confirm

- reduce total delivery time
  - reduce charging time at the charging stations
  - reduce air pollution
- reduce total cost of the last mile delivery



### Article

- “Covering delivery problem with electric vehicle and parcel lockers: Variable neighborhood search approach”
- **Computers and Operations Research, 2023**



## Conclusion

- covering delivery problem with electric vehicle and parcel lockers
- mixed integer programming problem which is validated by using **CPLEX MIP** solver
- general variable neighborhood search heuristic has been proposed
- investigating the introduced problem under real-time traffic data

## Future directions

- combine the model and the results with **C-ITS** (info about charging stations, charging ratios during the different hours of day)
- improve the results on larger instances with **C-ITS** using different techniques
- vehicle routing by adding another types of vehicles (e.g. hybrid or conventional ) for reducing CO<sub>2</sub> emission

## Acknowledgments

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