

# Innovative strategies for sustainable urban freight distribution: application of agile algorithms to optimize micro-hubs' location in Barcelona

Eduard J. Alvarez Palau

(w. Cristian Castillo, Javier Panadero & Angel A. Juan)

27th October 2023



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101069782.

## 0. Index

---

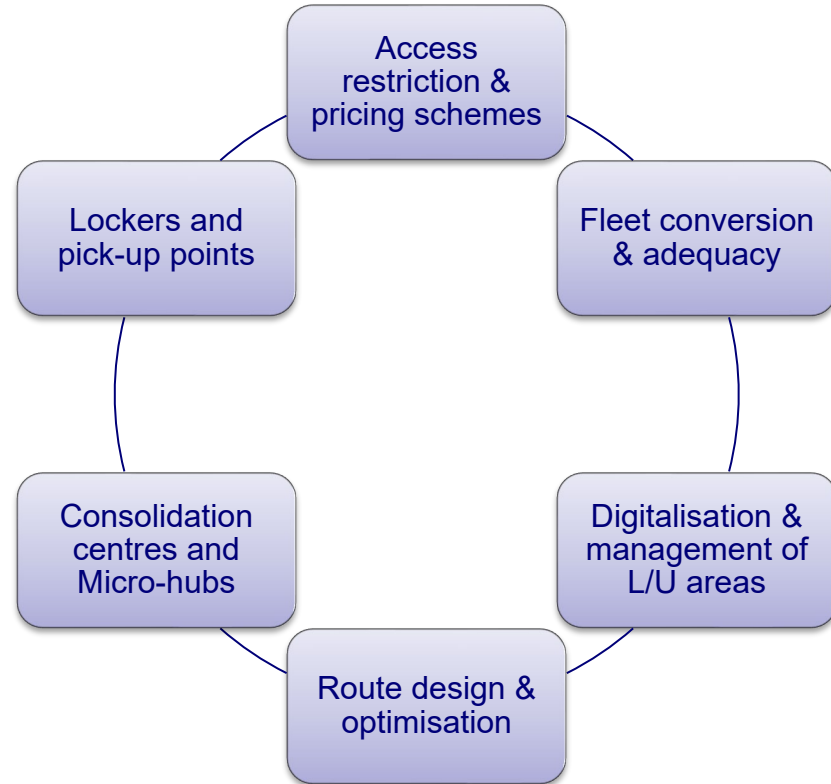
1. Introduction
  2. Strategies
  3. Problem definition
  4. Objectives
  5. Data
  6. Methods
  7. Results
  8. Conclusions
  9. Learnings
-

## Introduction

- **Urban freight distribution** (like passenger-related mobility), is cause of **many externalities**, from air pollution to CO2 emissions, noise, accidents, traffic jams, lack of parking, irregular parking, public space occupancy, or low-skills labour insecurity.
- The gradual **growth of eCommerce** is boosting the numbers of B2C parcel deliveries. And most delivery companies still rely on **vans** to perform deliveries, reinforcing unsustainable patterns.
- Public authorities just realised **urban mobility policies are not enough** to revert current trends of the transport sector, and started to dig in freight distribution.

## Strategies

- The adequacy of strategies & measures depends on the intrinsic characteristics of each city.
- However, most of the strategies can be grouped in the following categories:



# Strategies

## Consolidation centres and Micro-hubs

- Consolidator centres are located in the urban fringe. They require: 1) extensive surfaces to classify tens of thousands of parcels (20,000 to 70,000), 2) abundant parking and circulation areas for vans to pick up parcel bags. The level of automatization can vary.
- Micro-hubs are of smaller size ( $\approx$  1,500 parcels) and tend to be located in the neighbourhoods. They receive pallets, deconsolidate the cargo and classify it by routes of emission-free vehicles. The level of automatization is low.

## Route design & optimisation

- The use of GPS and fleet management software in smartphones allow for route optimisation.
- However, experienced drivers tend to alter the suggested routes. Local knowledge is crucial to find free/adequate parking and shortcuts not-considered by the navigation software.

## Problem definition

- The cheapest (and fastest) option for B2C home deliveries is to distribute parcels with vans from the consolidation centres. This is the preferred option of logistics operators.



- However, this option magnifies the externalities suffered by the citizens...



- And public administration of large cities have started tackling the matter. The implementation of restricted areas (historical areas, LEZ, etc.); the regulation of vehicles, time windows, lanes and L/U areas; the digitisation of L/U; the definition of charging schemes; or the provision of areas to set up lockers and micro-hubs are just a few examples of related policies.

## Problem definition

But...

- ... how many micro-hubs are needed?
- ... which are their desired characteristics?
- ... where should they be located?



## Objectives

- (i) to identify a **potential network of micro-hubs** that enables efficient parcel supply throughout the city of Barcelona while promoting **intermodality** in urban goods distribution;
- (ii) to develop an **agile routing algorithm** capable of generating adaptive distribution plans for dynamic environments. These plans take into account **multiple optimization** objectives, such as **operational and routing costs**.

## Data

- We select a set of premisses that could be used as a **potential micro-hub**. We include **public** (railway stations, markets, district buildings and parking lots) and **private** (shopping centres, gas stations, tobacco shops, pick up points, lockers and parking lots) facilities.
- We generate a set of **1,000 random nodes** across the city, using real postal codes to simulate **supply points** for e-commerce parcels' delivery from micro-hubs.
- Several **scenarios** are defined varying the number of total customers and their potential demand for parcel deliveries
  - a. low demand (1-5 parcels);
  - b. moderate demand (5-25 parcels);
  - c. high demand (50-100 parcels) for home delivery.

# Data

## POTENTIAL MICRO-HUBS

Category	Total [1,624]
Parking lots	620
Tobacco shop	371
Pick-up points	203
Lockers	133
Subway stations	103
Gas stations	84
Markets	39
District buildings	29
Shopping centers	18
Narrow gauge rail stations	14
Railway stations	10



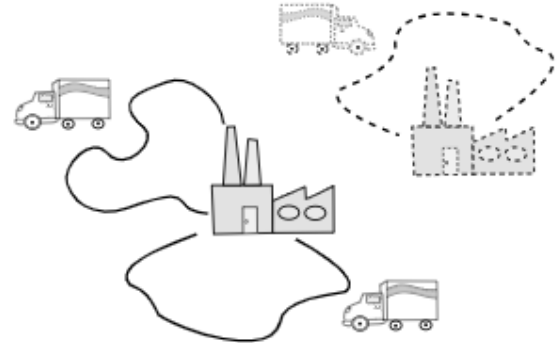
- District buildings
- Railway stations
- Parquing lots
- Tobacco shops
- Markets
- Pick Up points
- Subway stations
- Narrow gauge rail stations
- Shopping centres
- Gas stations
- Lockers



## Methods: first stage

### 1. Location Routing Problem (LRP)

- The objectives are to **determine which depots to open and routes to take while minimizing the total cost**, such that **all customers are served**, and the **total demand served by each depot and truck does not exceed its capacity**.
- A fleet of delivery vehicles with uniform capacity must service customers with known demand for a single commodity.
- Different depot locations are available.
- The vehicles end their routes at their starting depot.
- Each customer can only be served by one vehicle.



## Methods: second stage

### 2. Iterated Local Search (ILS)

- It operates by **perturbing the current solution** to generate a **new starting point** and **subsequently exploring the neighbourhood of this new solution** using a **local search**.
- We randomly select a group of customers and attempt to reassign them in a random manner to a different facility, ensuring that the facility's capacity is not exceeded.
- As for the local search phase, we utilize a two-opt inter-route operator. This operator exchanges two chains of customers, chosen randomly, between different micro-hubs. This operation continues until no further improvement can be achieved.
- The algorithm might occasionally accept non improved solutions following an acceptance criterion to update the base solution and, therefore, to escape from local optima.
- The process is repeated until the stopping criterion of this stage is met, returning the most promising solution.

## Results

- Low demand  
(1-5 parcels)

Initial conditions of the simulations					
<b>Veh. capacity</b>	300 parcels	<b>Cap. Micro-hub</b>		1,500 parcels/day	
Simulation results for three possible scenarios					
Total customers	Operating cost (€/day)	Routing cost (€/day)	Total cost (€/day)	Total micro-hubs opened	Category of micro-hubs proposed to be opened by the algorithm
100	311	111.69	422.69	1	Parking lot (1)
200	311	155.36	466.36	2	Pick-up (1) Tobacco shop (1)
400	311	214.77	525.77	5	Pick-up (2) District buildings (1) Parking lot (1) Tobacco shop (1)
600	622	259.07	881.07	7	Tobacco shop (3) District buildings (1) Gas stations (1) Parking lot (1) Subway stations (1)
800	622	301.10	923.10	9	Pick-up (5) Subway stations (2) Tobacco shop (2)
1000	933	578.07	1,511.07	12	Tobacco shop (4) Pick-up (3) Parking lot (2) Markets (1) Shopping centres (1) Subway stations (1)

# Results

- Medium demand  
(5-25 parcels)

Initial conditions of the simulations					
<b>Veh. capacity</b>	300 parcels	<b>Cap. Micro-hub</b>	1,500 parcels/day		
Simulation results for three possible scenarios					
Total customers	Operating cost (€/day)	Routing cost (€/day)	Total cost (€/day)	Total micro-hubs opened	Category of micro-hubs proposed to be opened by the algorithm
(...)					
600	2177	369.76	2,546.76	34	Parking lot (10) Pick-up (9) Tobacco shop (7) Subway stations (4) Gas stations (3) Markets (1)
800	2488	496.94	2,984.94	46	Tobacco shop (19) Pick-up (10) Parking lot (5) Subway stations (5) Gas stations (2) Markets (2) Railway stations (2) District buildings (1)
1000	3110	608.68	3,718.68	60	Tobacco shop (22) Pick-up (10) Parking lot (9) Markets (5) Subway stations (5) District buildings (4) Gas stations (2) Shopping centres (2) Narrow gauge rail stations (1)

# Results

- Large demand  
(50-100 parcels)

Initial conditions of the simulations					
<b>Veh. capacity</b>	300 parcels	<b>Cap. Micro-hub</b>	1,500 parcels/day		
Simulation results for three possible scenarios					
Total customers	Operating cost (€/day)	Routing cost (€/day)	Total cost (€/day)	Total micro-hubs opened	Category of micro-hubs proposed to be opened by the algorithm
(...)					
800	6220	887.37	7,107.37	120	Tobacco shop (39) Pick-up (24) Subway stations (15) Parking lot (14) Gas stations (8) Markets (7) District buildings (5) Railway stations (4) Narrow gauge rail stations (2) Shopping centers (2)
1000	7775	981.32	8,756.32	150	Tobacco shop (50) Pick-up (28) Parking lot (25) Subway stations (16) Gas stations (12) Markets (8) District buildings (6) Shopping centres (3) Narrow gauge rail stations (1) Railway stations (1)

## Conclusions

- These estimates yield the **optimal number of micro-hubs**, ranging from 1 to 150 locations.
- For instance, in a **medium-demand scenario** with a **high number of customers**:
  - The model recommends the establishment of **60 micro-hubs**
  - Consistent **preference for tobacco shops and pick-up points** in all optimal solutions, despite parking lots offering a larger number of available premises. This preference can be attributed to parking lots primarily serving urban areas with high mobility demands, while tobacco shops are uniformly distributed due to government licensing regulations that limit competition.

## Learnings

- The **number of micro-hubs** needed to sort freight distribution is **limited** and there is **plenty of potential facilities** that could be used.
- Logistics operators could use our results to **adjust their strategies**, creating **alliances with third parties** with local premisses that could be used as micro-hubs. It could alleviate the most expensive segment of their operations: last-mile delivery.
- **Public administrations must decide their implication and role.** Besides regulation, they could provide (subsidised) facilities to enhance intermodality and make freight delivery more sustainable.

Thank you!

-  UOCecoempresa
  -  @UOCecoempresa
  -  Blog d'Economia i Empresa
  -  Revista Oikonomics
- 



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101069782.