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An optimal configuration for the Micro-hubs and Cargo bikes for last mile freight delivery: Results from the comparative analysis of the developed model

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Agenda/ Outline

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- Scope in urban freight Transport
- State of Art

Motivation, Research Gap and Questions

Problem Formulation

Developed LRP Model

Results from the comparative analysis

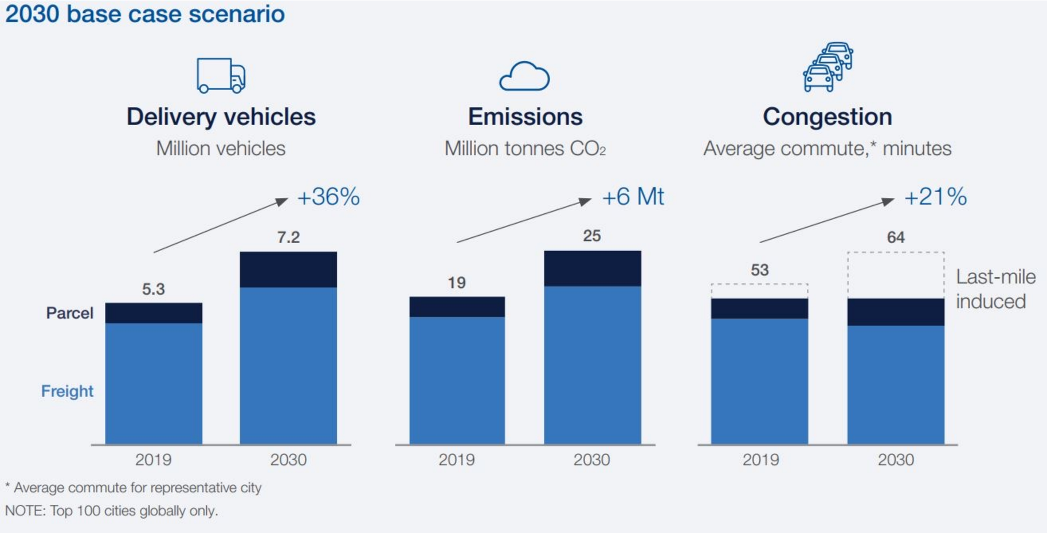
Conclusion

Introduction

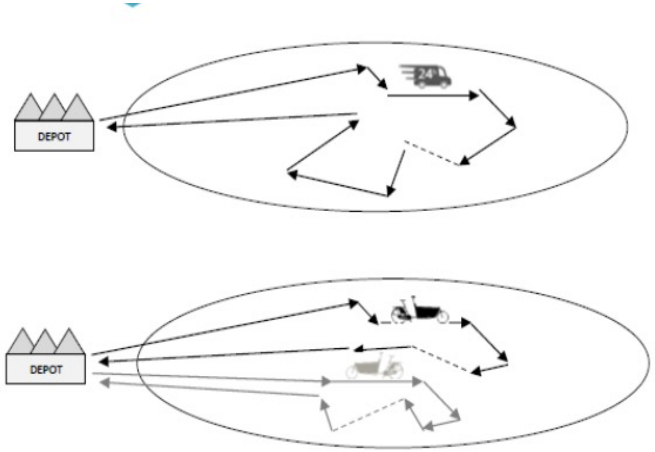
Share of urban freight transport in overall urban transport in Europe

Share of trips of urban freight transport	15% (10-20%)
Share of km of urban freight transport	20% (15-25%)
Share of fuel consumption and emissions of urban freight transport	30% (20-40%)

Source: Cycle Logistics Report (Europe), 2019



Source: World Economic forum Report, 2020

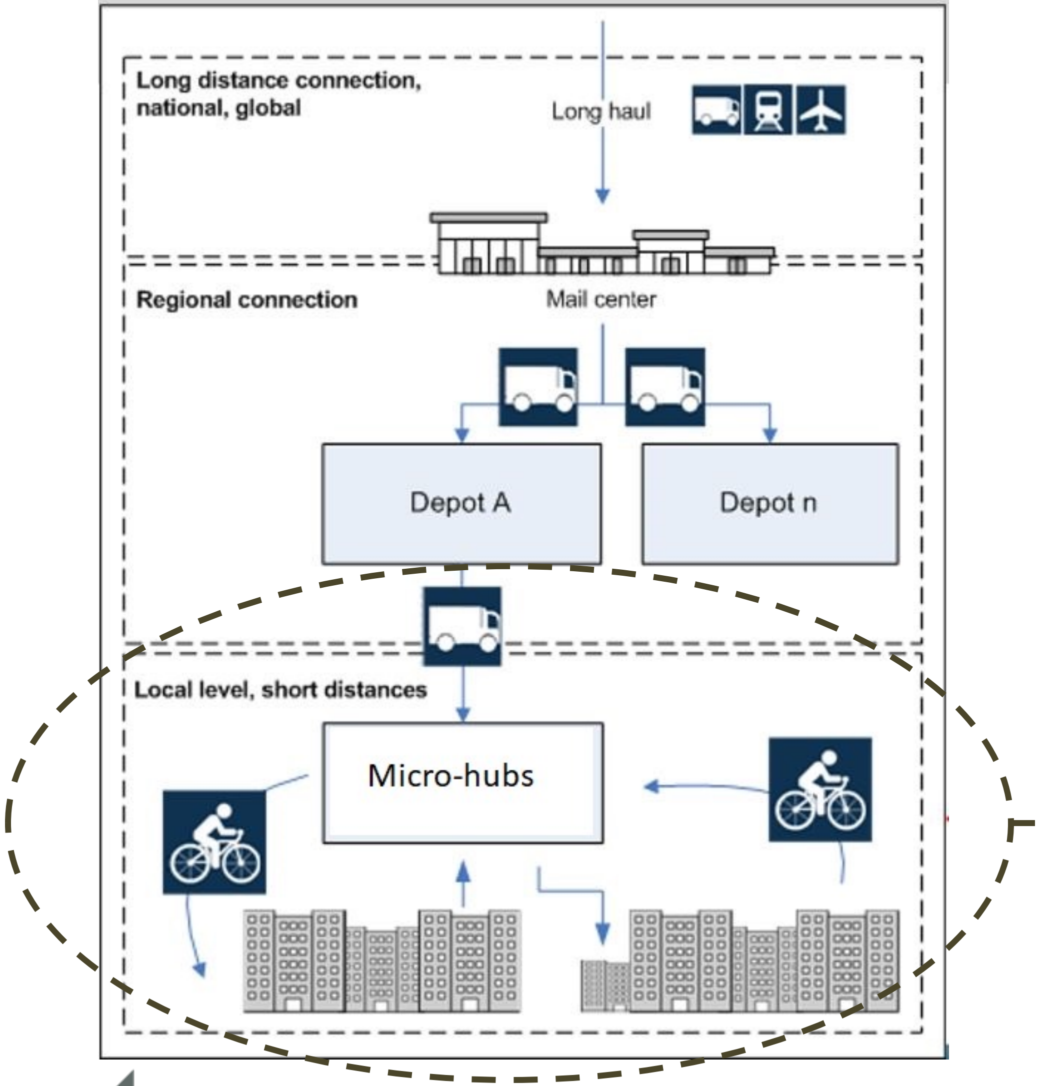


Source: Maes et al., 2017

Less traffic, noise and GHG emissions

More public space

Scope in Urban Freight Transport



Source: Maes J. (2011)

Last Mile Freight Transport

CEP (Courier, Express and Parcel) services

State of Art

Study	Scope	Results
Verlinde et al. (2014)	***Pilot Study***: 1 Mobile depot + 4 electric cargo bikes	24% reduction in CO_2 emission (kg) 59% reduction in PM2.5 emission (gm) 72% reduction in Spatial consumption on road Transport cost ***doubled***
Navarro et al. (2014)	***Pilot Study***: 1 micro-hubs+ 2 freight cycles	Saving in fuel consumption: 400 l/month Reduction in distance travelled : 64 km/month
Neils et al. (2018)	***Pilot Study:*** Truck trailer + cargo bike	Saving of CO_2 emission: 7.5 tons per year Reduction in distance travelled: 135 km/ day
Nürnberg et al. (2019)	Cargo bikes	Lack of suitable bicycle infrastructure hinders the advantage of cargo bikes
Allen et al. (2000)	Cargo bikes	87% of the total time of delivery of goods is spent in search of parking space for long distance delivery without consolidation points
Brown et al. (2011)	**Pilot Study**: Micro-hubs+ 6 e-cargo tricycle and 3 e-vans	Reduction in CO_2 emission (kg): 54% Spatial consumption on road reduced by 56%
Arvidsson et al. (2018)	**Trial Study**: Freight Bus+ electric cargo bikes	**24% increase** in transport cost
Arnold et.al (2018)	Distribution points + cargo bikes	***134% increase*** in delivery time ***9% increase*** in operational cost 40% decrease in external cost
Gruber et al. (2014)	Cargo bikes	48% of trips by motorised vans can be substituted by cargo bikes

Motivation, Research Gap and Questions

Motivation

- Potential to be an economically and environmentally feasible and viable in last mile freight delivery

Research Gap and learnings from previous studies

Research mostly focused on trials/ pilot studies

- Trials not applicable in generalized scenario
- Random selection of location for micro-hubs
- Lack of proper configurations of vehicles used
- Uncertain economic viability
- Lack of proper Implementation Framework for LSPs/ City Planners

Research Questions?

- How can the logistics setting using cargo bikes and micro-hubs be framed in a existing scenario?

Problem Formulation

Optimal Network Configuration

- *Optimal location of micro-hubs*
- *Optimal number of micro-hubs*

Location Model for micro-hubs

- *Optimal number of cargo bikes*
- *Routing configuration*

Vehicle Routing Model

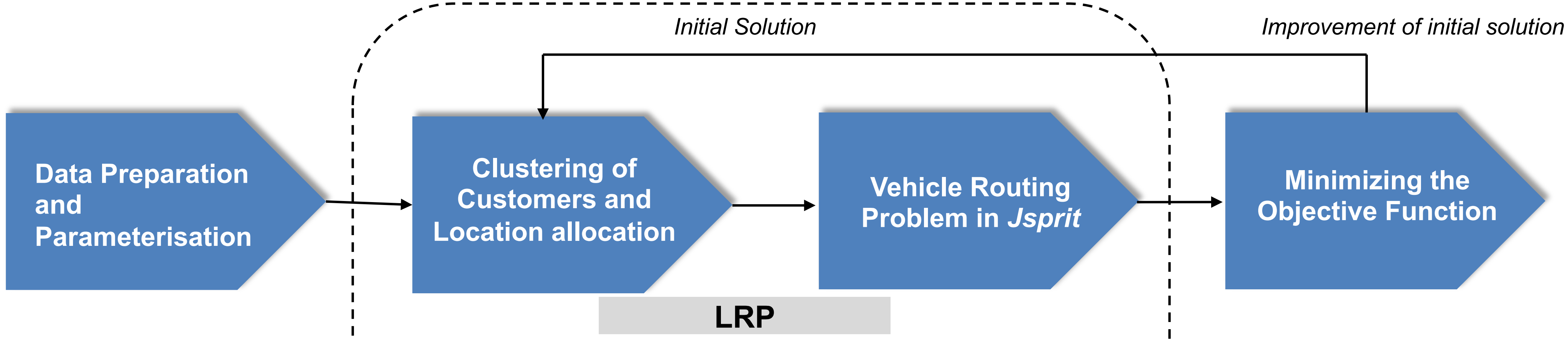
Location- Routing problem (LRP)

Objective Function:

$$\sum_{j \in J} f_j . X_j + \sum_{j \in J} \sum_{i \in I} \sum_{k \in K} c_{ij} . Y_{ijk}$$

facility cost — Transport cost

Proposed Greedy Search Heuristics Algorithm for LRP



Stage 1

Stage 2

- Clustering of customers with Greedy Search Algorithm
- Assignment of clusters to micro-hubs based on Gravitational centres
- Removal of unopened UCCs

Stage 3

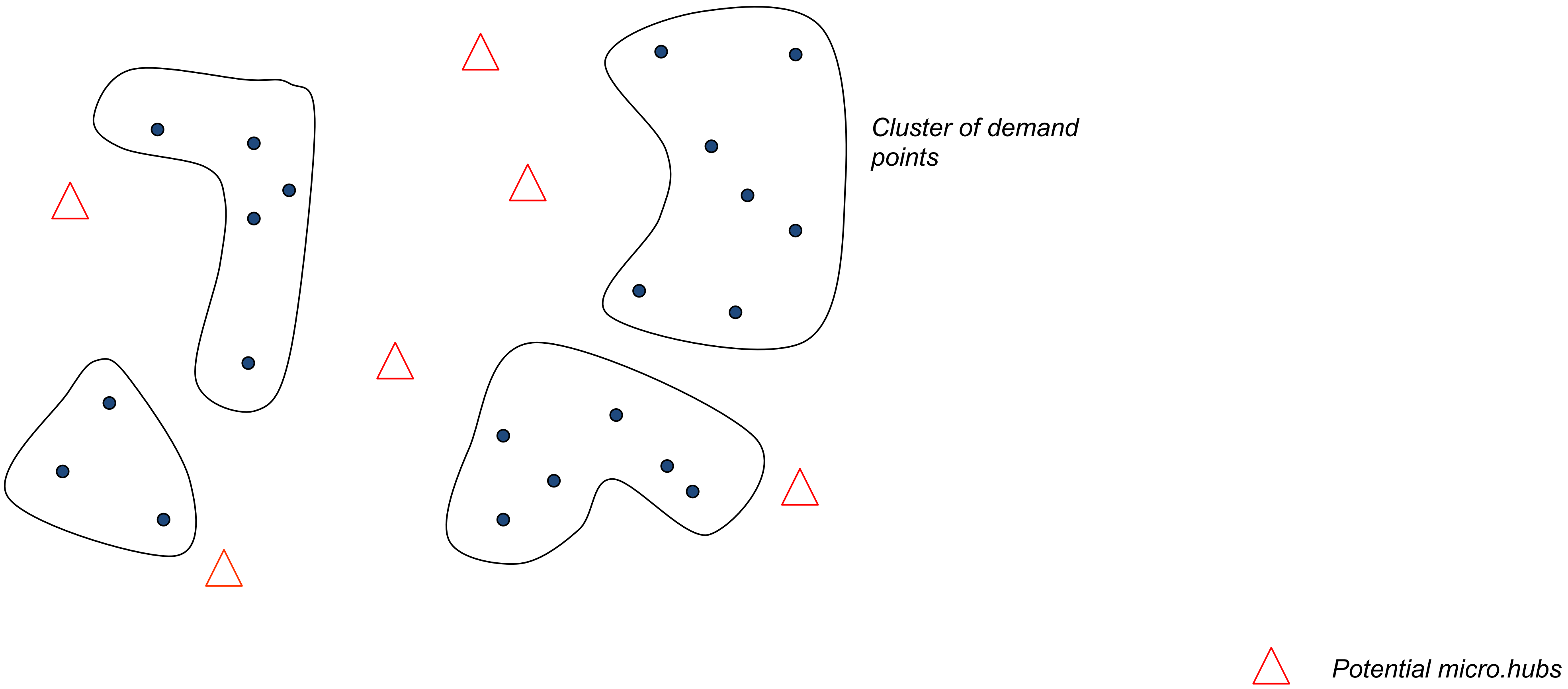
- Solving VRP in *Jsprit*

Stage 4

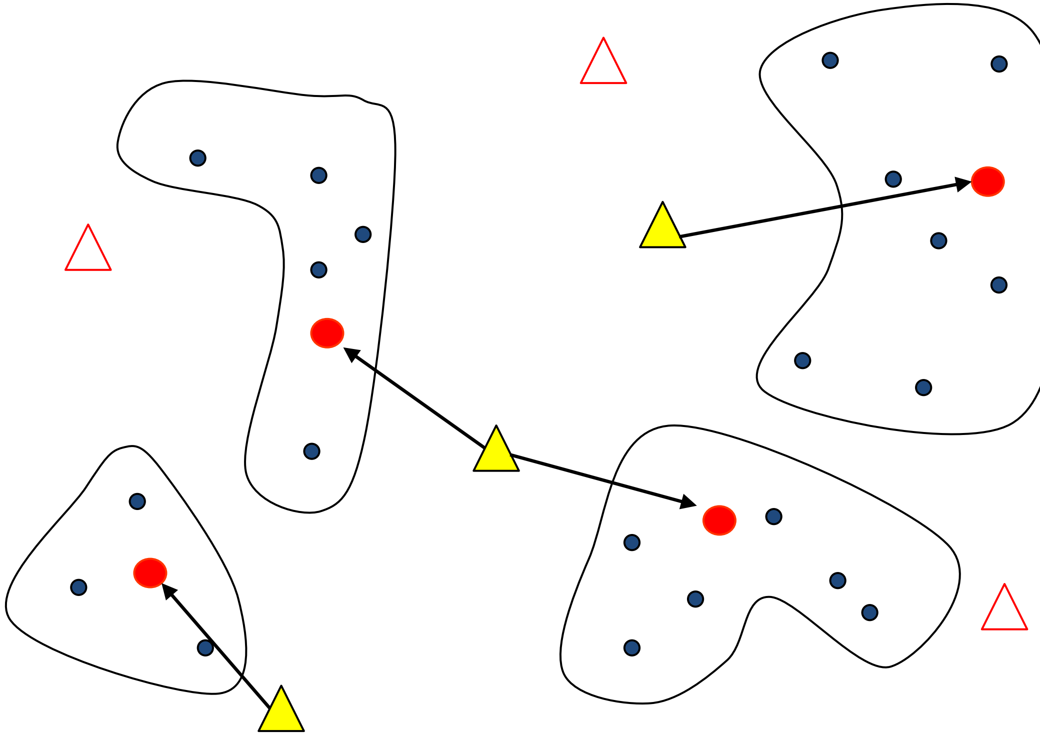
- The parameters and constraints are varied wr.t to different scenario
- Iterated until the cost functions are minimized

Objective Function: $\sum_{j\in J} f_j . X_j + \sum_{j\in J}\sum_{i\in I}\sum_{k\in K} c_{ij} . Y_{ijk}$

Proposed Greedy Search Heuristics Algorithm for LRP



Proposed Greedy Search Heuristics Algorithm for LRP

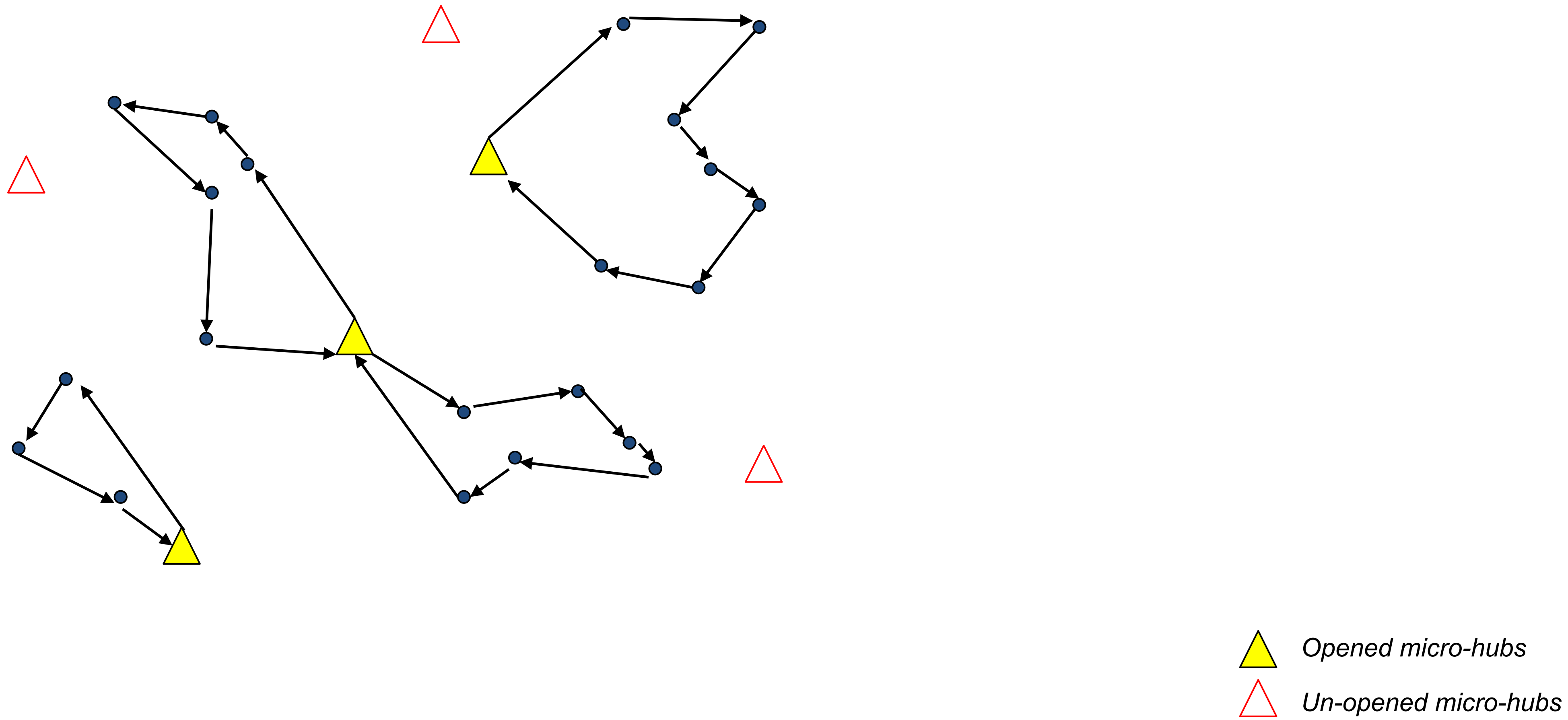


$$(X, Y) = \left(\frac{\sum_{i \in I} x_i}{n_I}, \frac{\sum_{i \in I} y_i i}{n_I} \right)$$

Assigned micro-hubs

Unassigned micro-hubs

Proposed Greedy Search Heuristics Algorithm for LRP



Comparative Results with others algorithms in Literature

Instances: no. cust X no. Dept	*GRASP (Prins et al. 2006)*	*LRGTS (Prins et al. 2007)*	*CH (Barreto et al. 2007)*	*Proposed algorithm*	*Min. no. Of vehicles*	*Min. no. of depots*
Christ69–50×5	599.1	586.4	582.7	465.768	6	5
Christ69–75×10	861.6	863.5	886.3	761.523	6	7
Christ69–100×10	861.6	842.9	889.4	842	11	7
Gaskell67–21×5	424.9	424.9	435.9	411.11	3	2
Gaskell67–22×5	585.1	587.4	591.5	589	3	2
Gaskell67–29×5	515.1	512.1	512.1	519	3	2
Gaskell67–32×5	571.9	587.4	571.7	560.11	4	3
Gaskell67–36×5	460.4	476.5	470.7	399.592	4	3
Min92–27×5	3062	3065.2	3062	3062	6	3
Min92–134×8	5965.1	–	6238	5118.219	11	8

Fig: Result of initial solution
Source: own

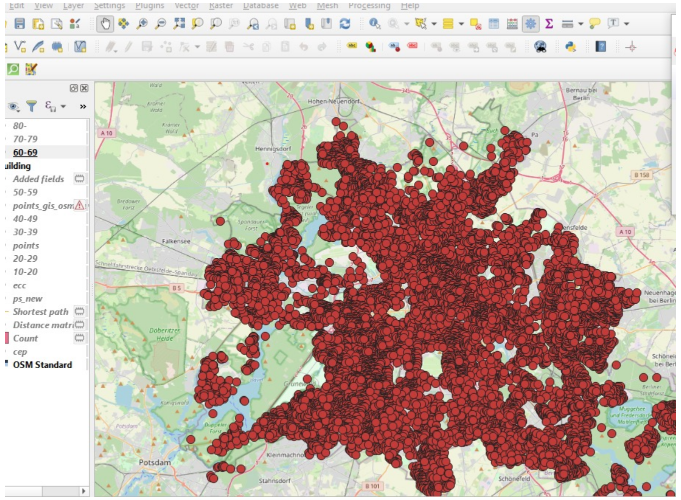
Conclusion and remarks

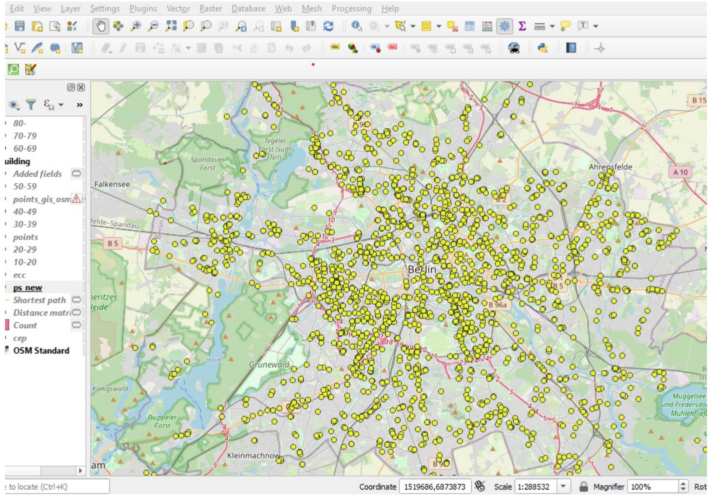
- Micro-hubs together with smaller vehicles, such as cargo-bikes could be a feasible solution to last-mile delivery, when the configuration of their network is optimal.
- The developed model results for optimal solution when compared with previous known literatures of LRP
- Initial results from the developed model shows optimal results but can be improved further
- However, the developed model needs to be assured for larger instances of data

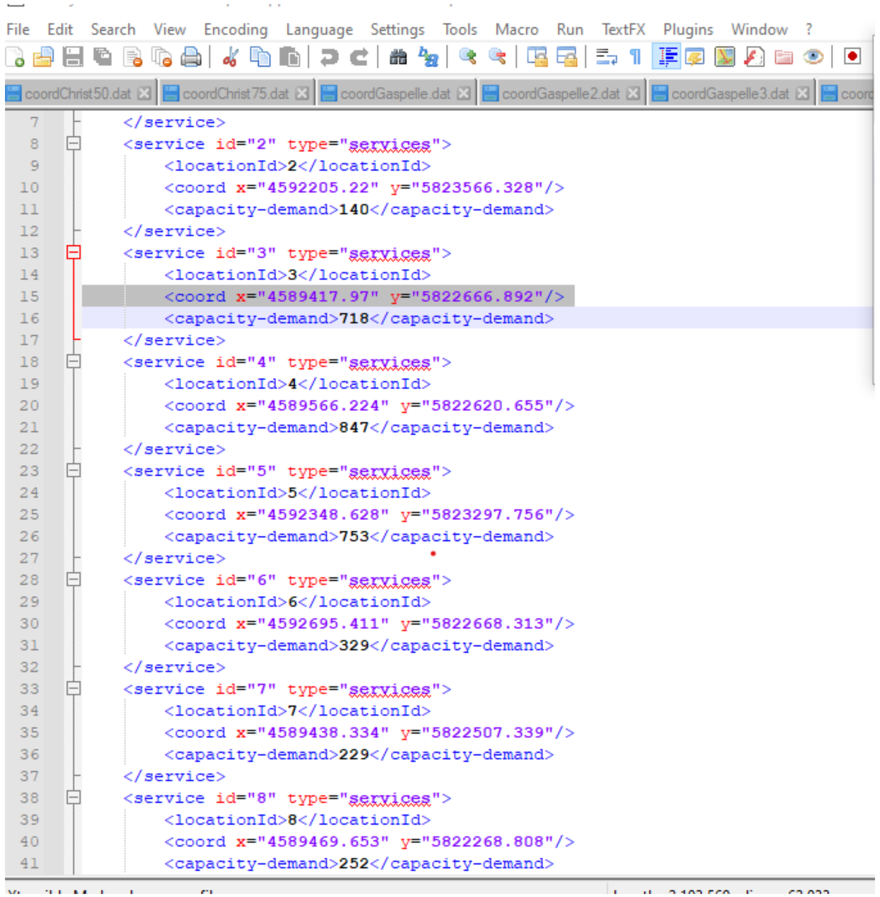
Problem Size for the study

Potential location: 2,020, capacitated, opening cost f_j
Customers: over 220,000 demand h_i
Vehicles *:* infinite fleet, capacity u, total transport cost as c_{ij} (fixed+variable)
Available data:

- Customer georeferenced points
- Potential UCC georeferenced points
- Generation of demand randomly for a given day
- Fleet characteristics in xml







Source: own

Thank you for your attention!

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