Methodology to evaluate performance of urban transshipment last mile network with electric vehicles in low emission zones

- Arjun Nallapeta
- Tharsis Teoh

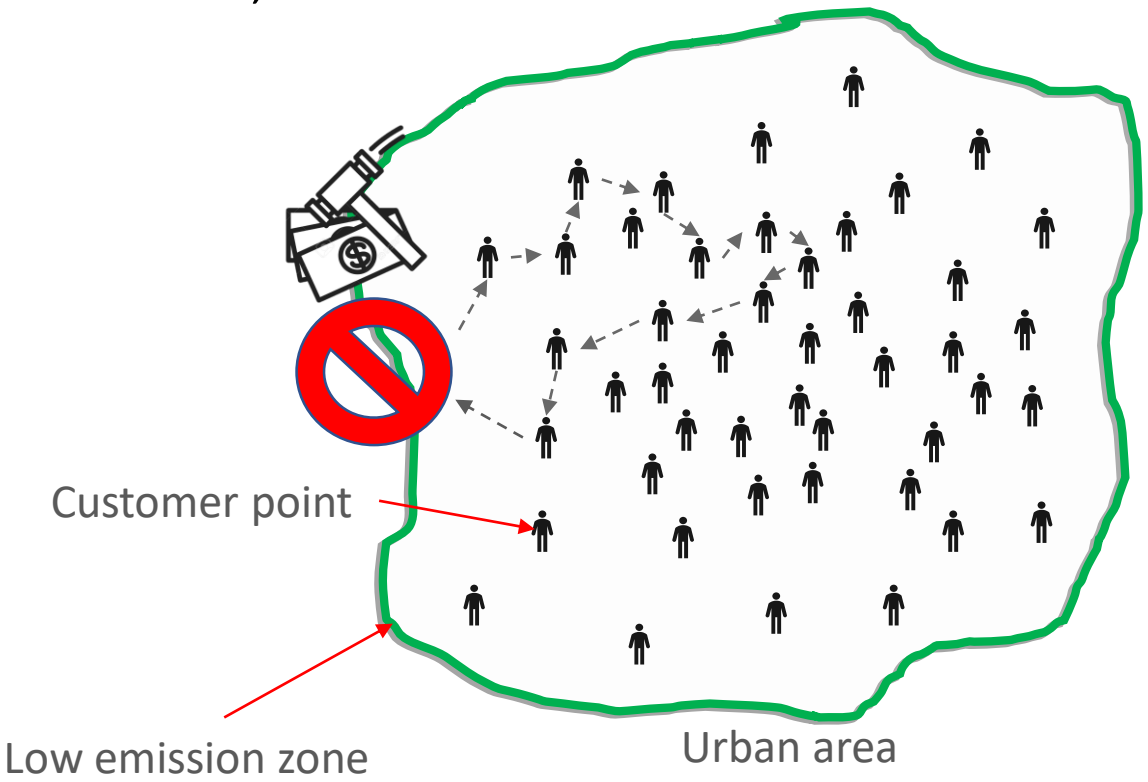
Panteia
Research to Progress

Conventional last mile package delivery network

- Delivery to customers from **sorting center located in suburbs** with **fleet of diesel vans.**
- Diesel vans cause **air pollution and traffic issue** in developing countries with high customer density in urban regions such as Brazil,India etc.
- Introduce **low emission zones** (LEZ) like in London, Amsterdam etc. ?

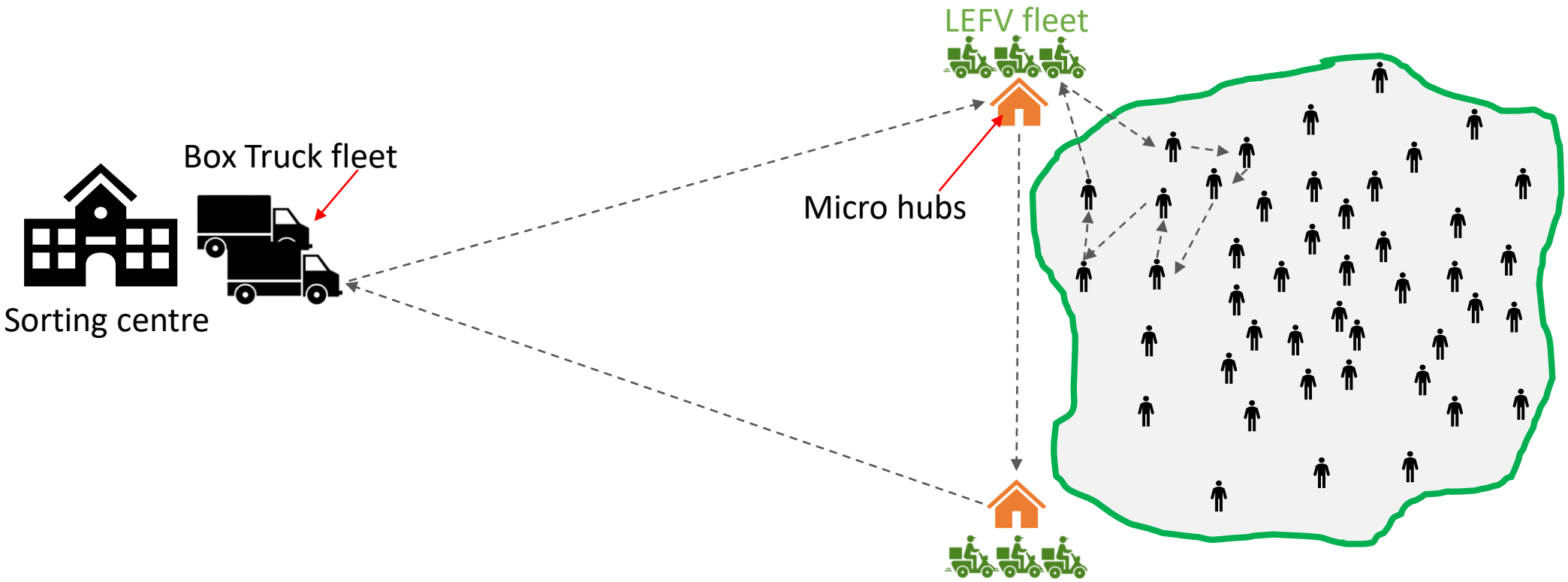
Sorting centre

Diesel van fleet



Urban transshipment delivery network

- **Micro sized hubs** for deconsolidating and cross docking packages
- Located at **proximity** to Urban areas.
- **Light electric freight vehicles** (LEFV) with limited driving range to deliver packages.
- **Potential logistics solution** for low emission zones (LEZ).



Research Rationale

What is the ideal configuration of the transhipment network?

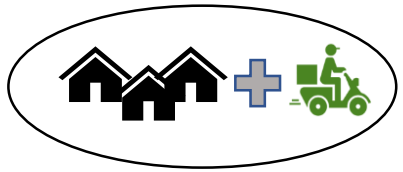
- **Fleet size of box trucks** at sorting centre

- **Ideal locations** of micro hubs and their corresponding **sizes**

- **Fleet size of LEFVs** at ideal locations of micro hubs

How to analyse costs /performance of transhipment network ?

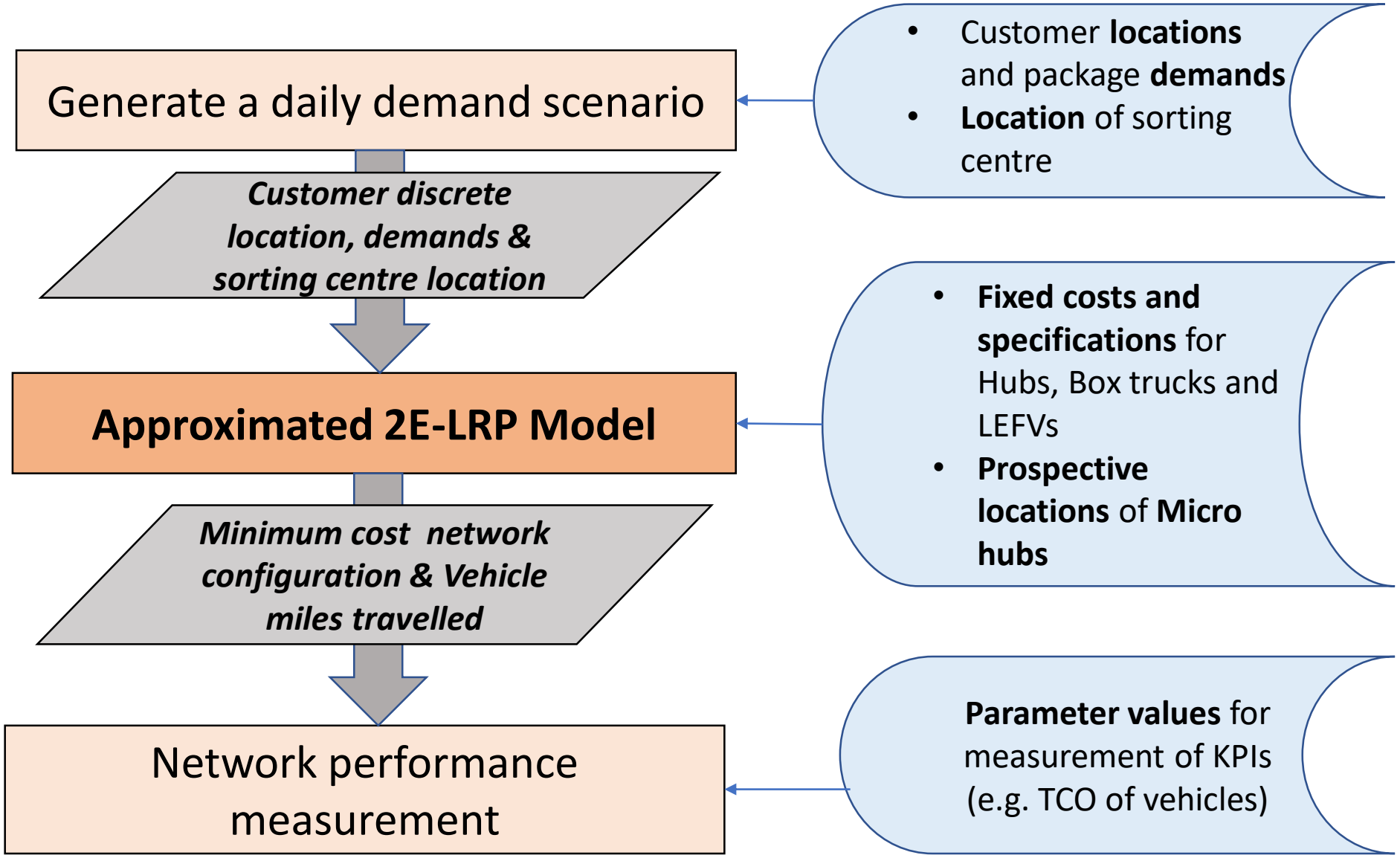
- **Traditional two echelon location routing problem (2E-LRP**) to find **ideal network configuration** and **costs** (Fixed & variable)
- LRPs are **computationally complex** requiring sophisticated heuristics for real life instances
- **No simple method** exists to evaluate and compare above network's performance



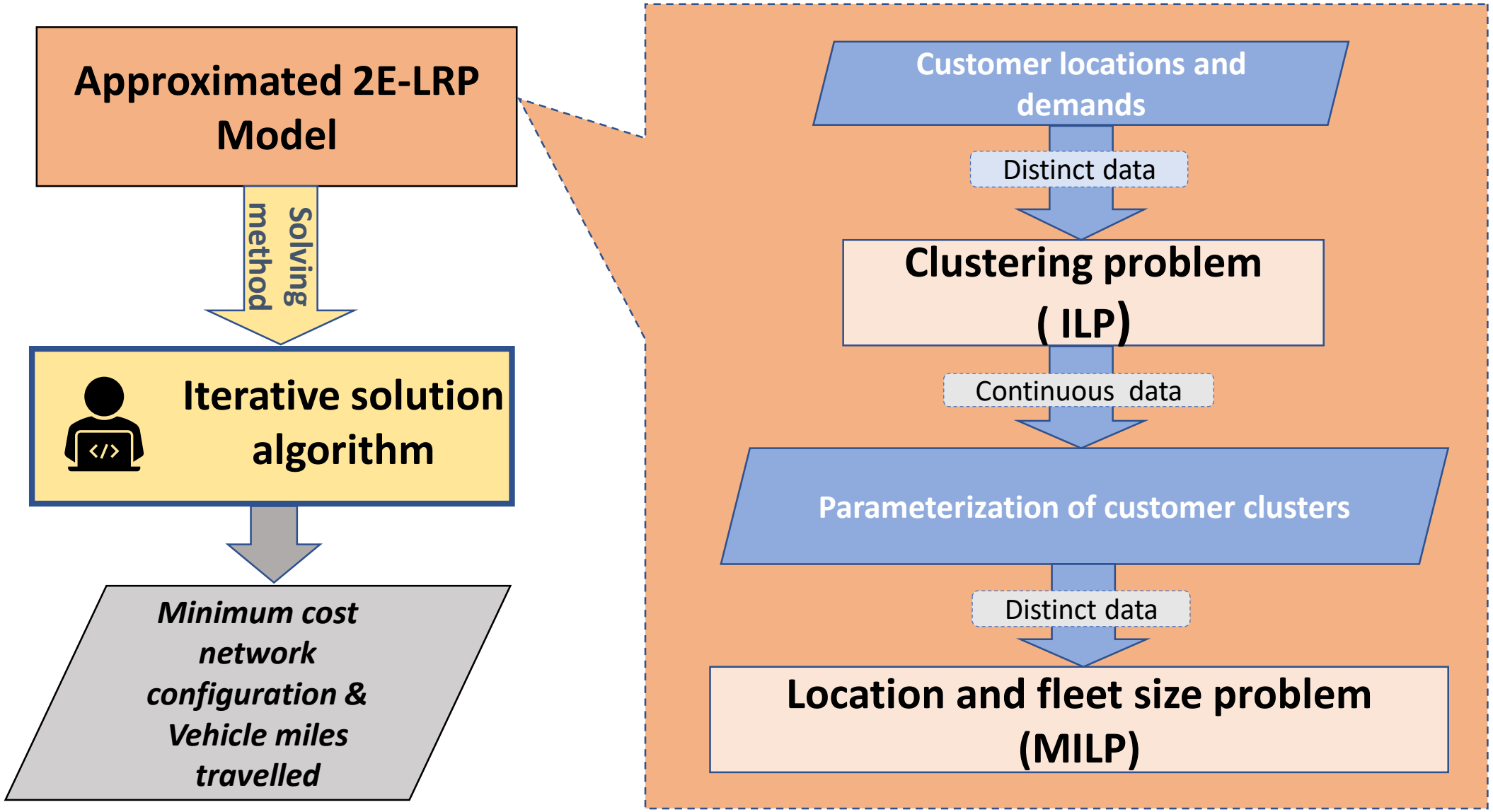
VS

Electric vans

General methodology framework

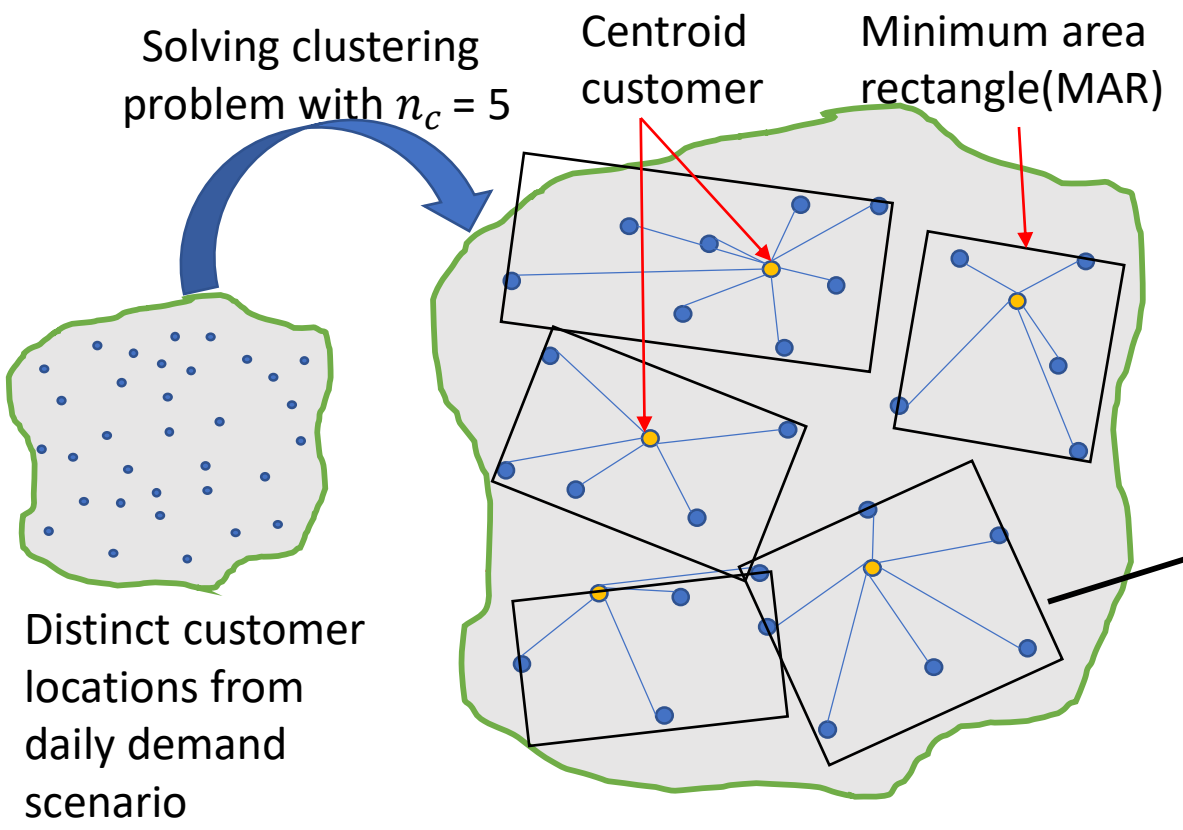


Approximated 2E-LRP Model



Clustering problem

Illustration of clustering problem



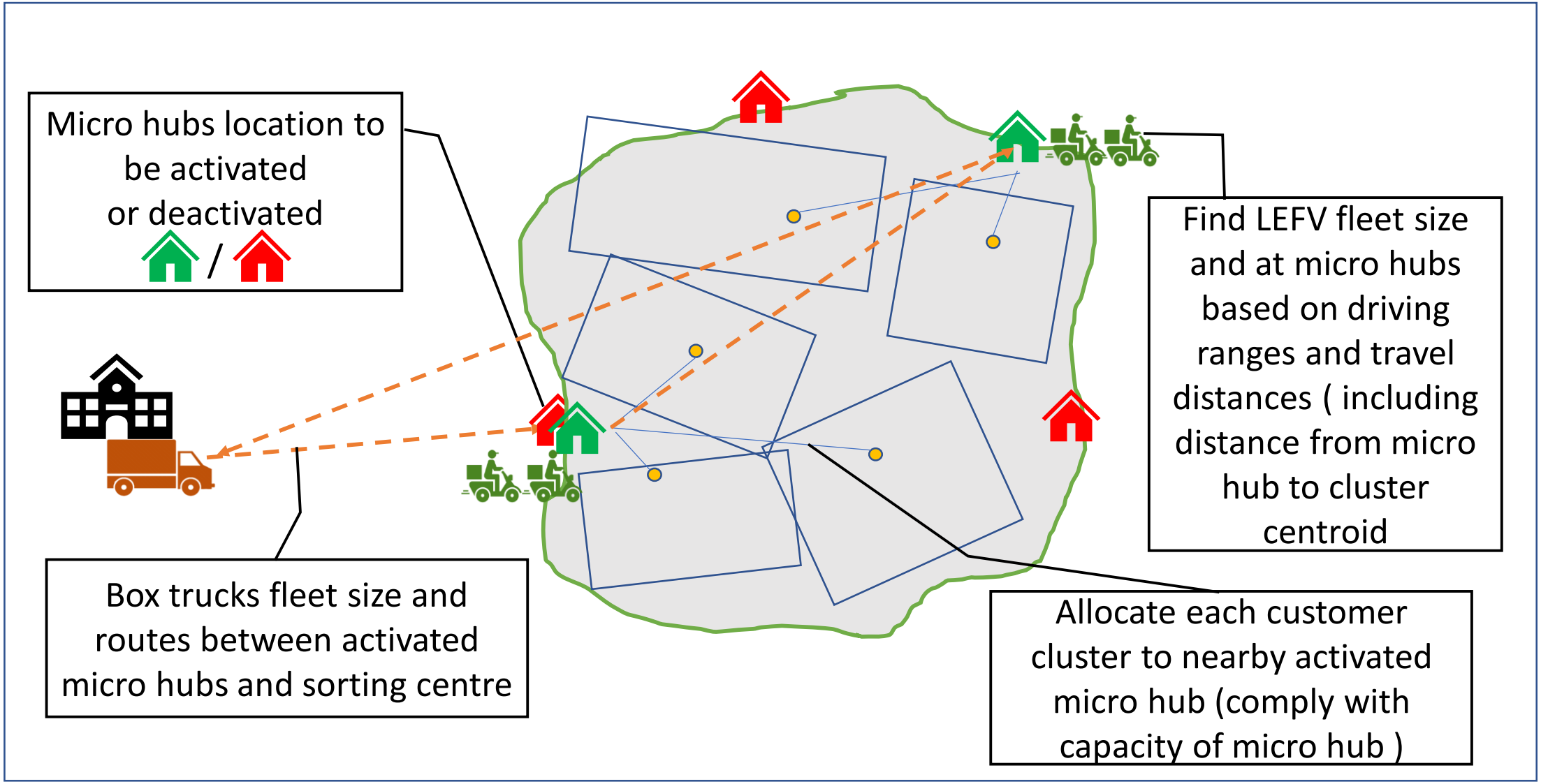
Parameters of each cluster

- Area of a MAR- $\boldsymbol{A}$
- Number of customers in cluster - $\boldsymbol{n}$
- Total customer demand of cluster - $\boldsymbol{Q}$
- LEFV travel distance - $\boldsymbol{Td}$ ($\boldsymbol{n}$, $\boldsymbol{A}$)- *Continuous approximation model based on Figliozzi(2008)**

*Figliozzi, M. (2008). Planning Approximations to the Average Length of Vehicle Routing Problems with Varying Customer Demands and Routing Constraints. *Transportation Research Record, 2089*, 1 - 8.

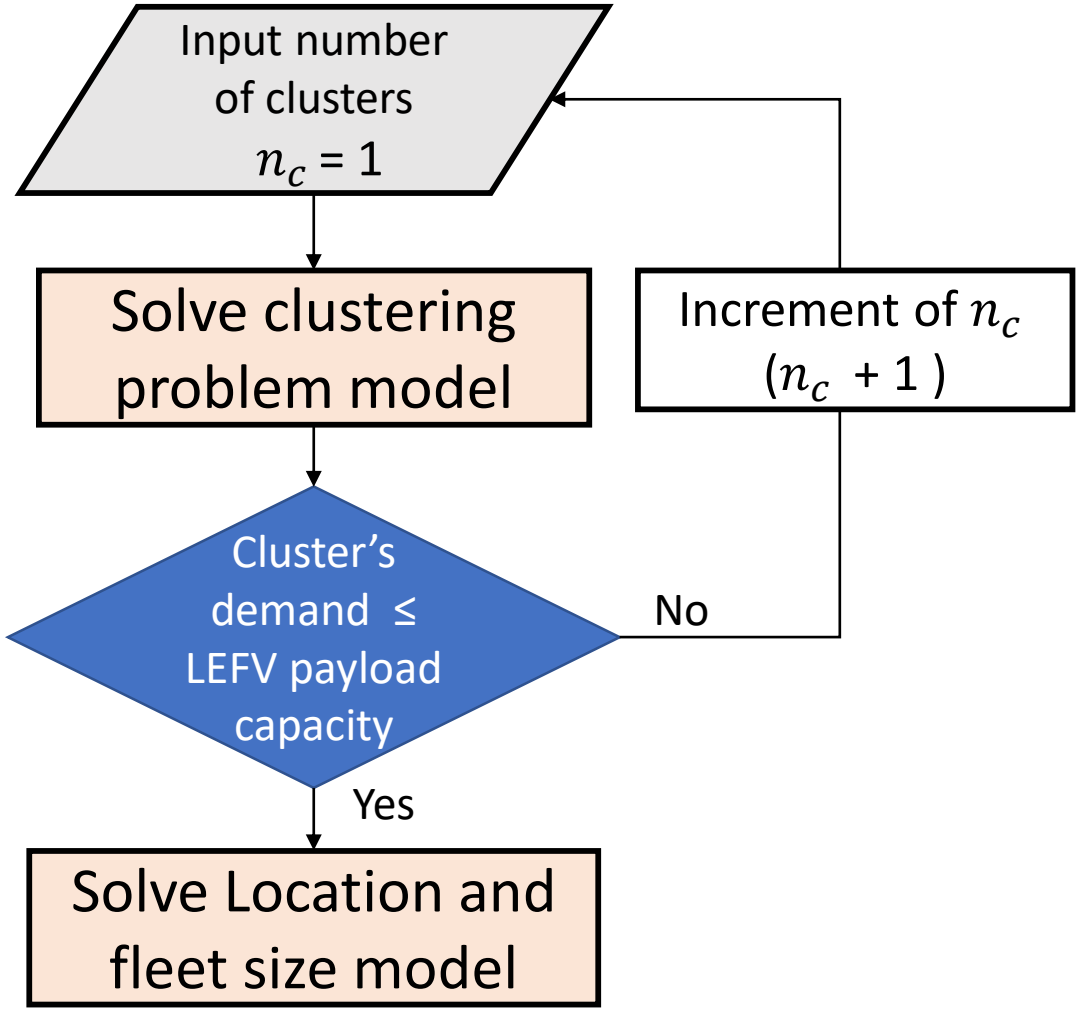
Location and fleet size problem

Illustration of location and fleet size problem



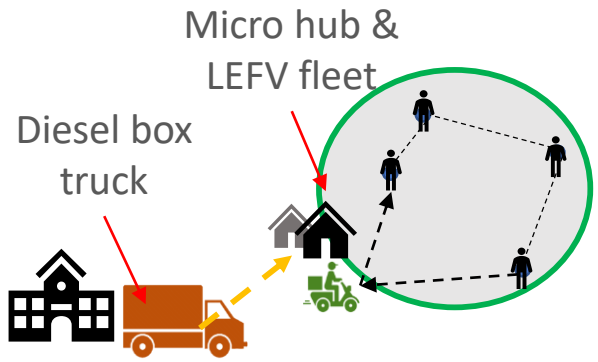
Iterative solution algorithm

- Ensure the **total demand of every cluster** is **less than the payload capacity of LEFV** (weight/ volume)
- An **hierarchical clustering** process (top to bottom)
- Every hierarchy level is reached in **every iteration**

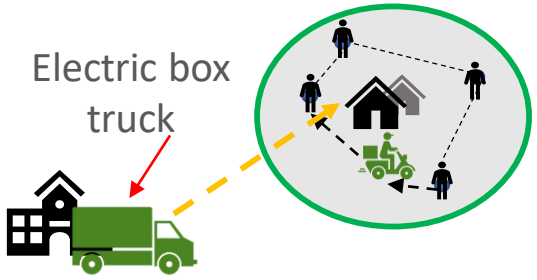


Case study description

- Customer distribution
  - **Three VRP instances** from **Uchoa et al. 2016*** with increasing customer density.
  - **Low** (2.5 /sq km); **Medium**(5/ sqkm); **High**(9.5/sq km).
- Customer demand
  - Demand of every customer is assumed to be of **one package**.
  - Size of all packages is **42L**
- Network alternatives
  - Two network alternatives (alt) considered:



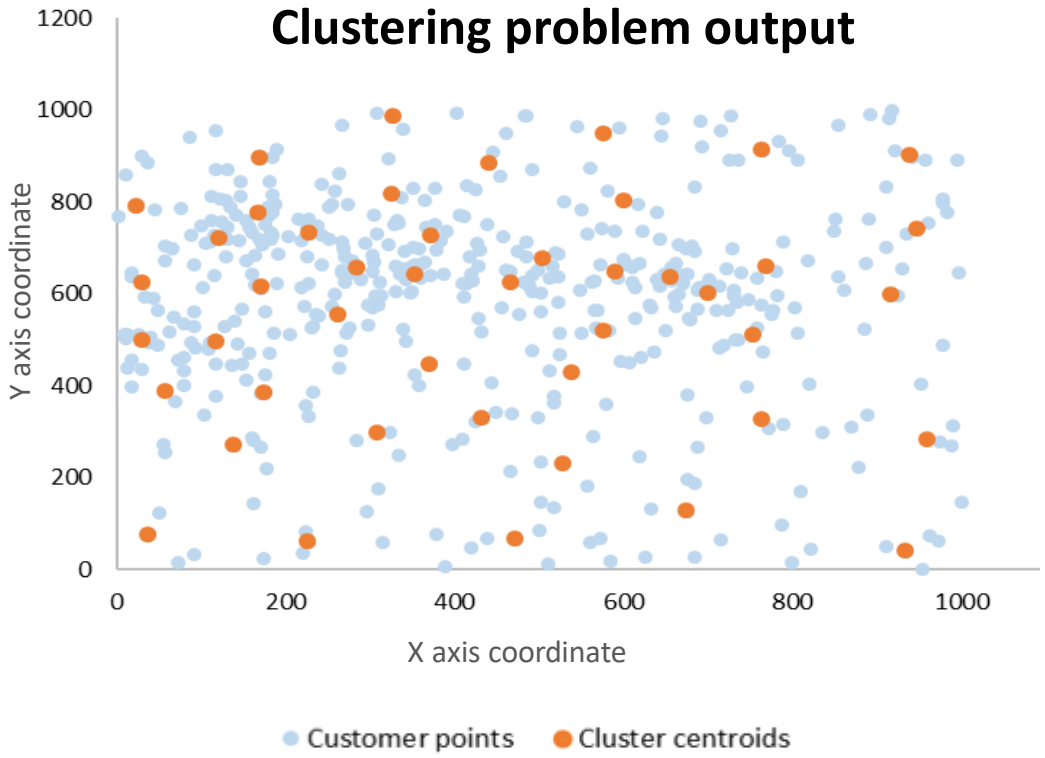
Alt 1- Micro hubs at periphery of LEZ and diesel box trucks



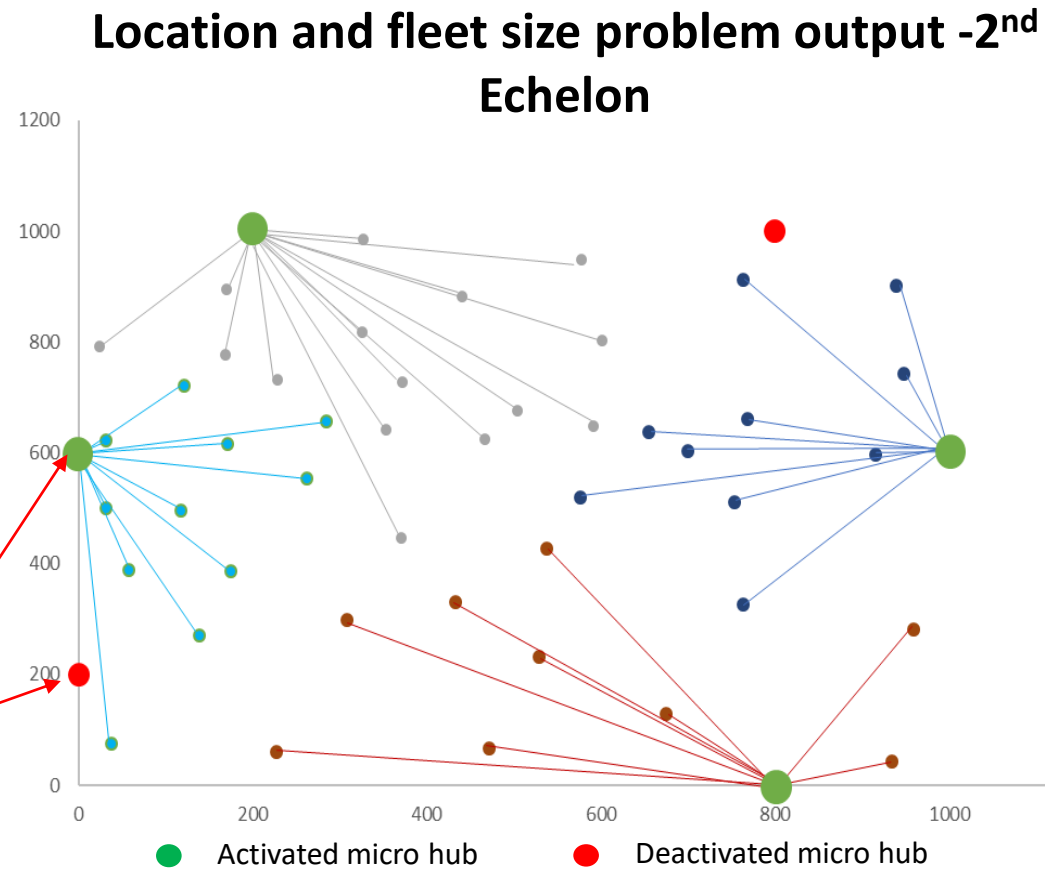
Alt 2- Micro hubs inside LEZ and electric box trucks

* Uchoa, E., Pecin, D., Pessoa, A., Poggi, M., Vidal, T. and Subramanian, A., 2017. New benchmark instances for the Capacitated Vehicle Routing Problem. *European Journal of Operational Research*, 257(3), pp.845-858.

Model outputs (for Medium instance)

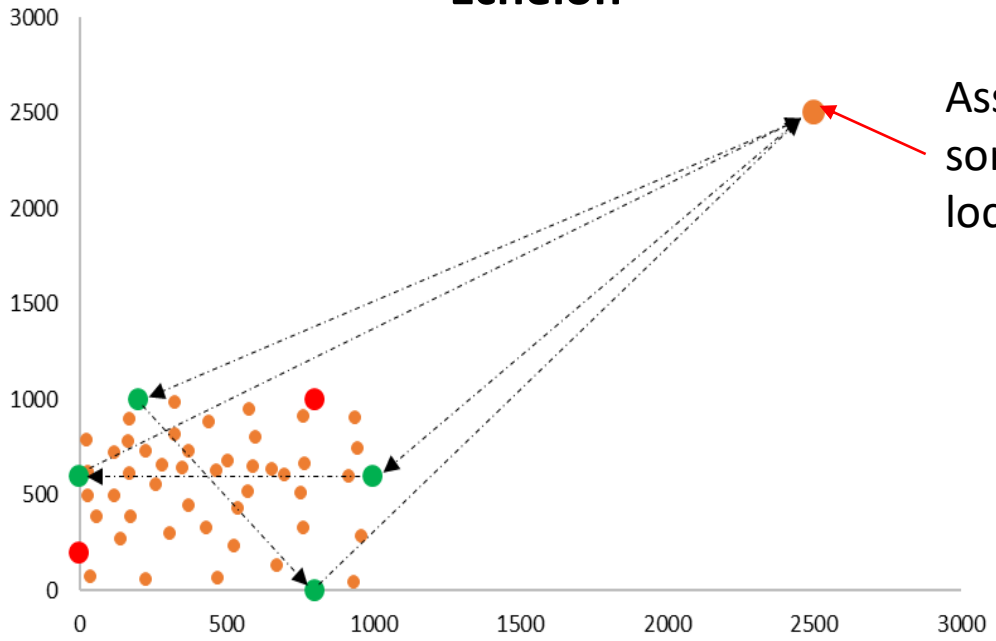


Prospective micro hub locations



Model outputs (for instance with density 5 per sq km)

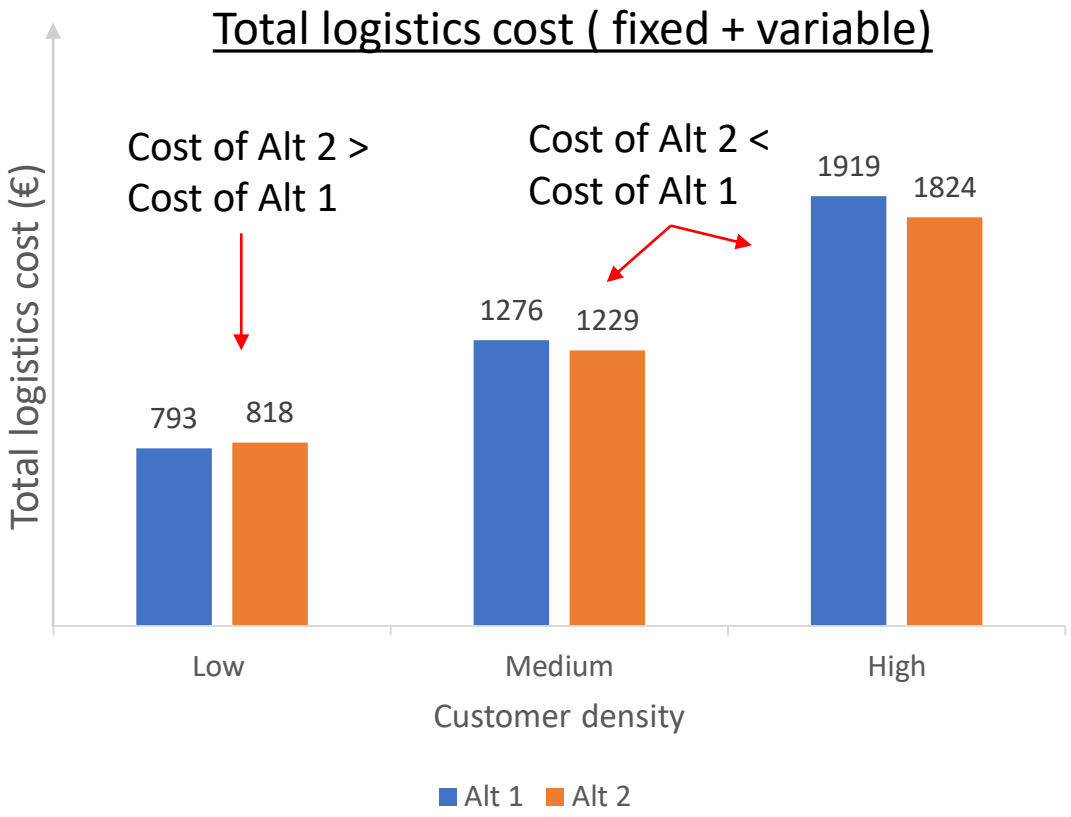
Location and fleet size model output -2nd Echelon

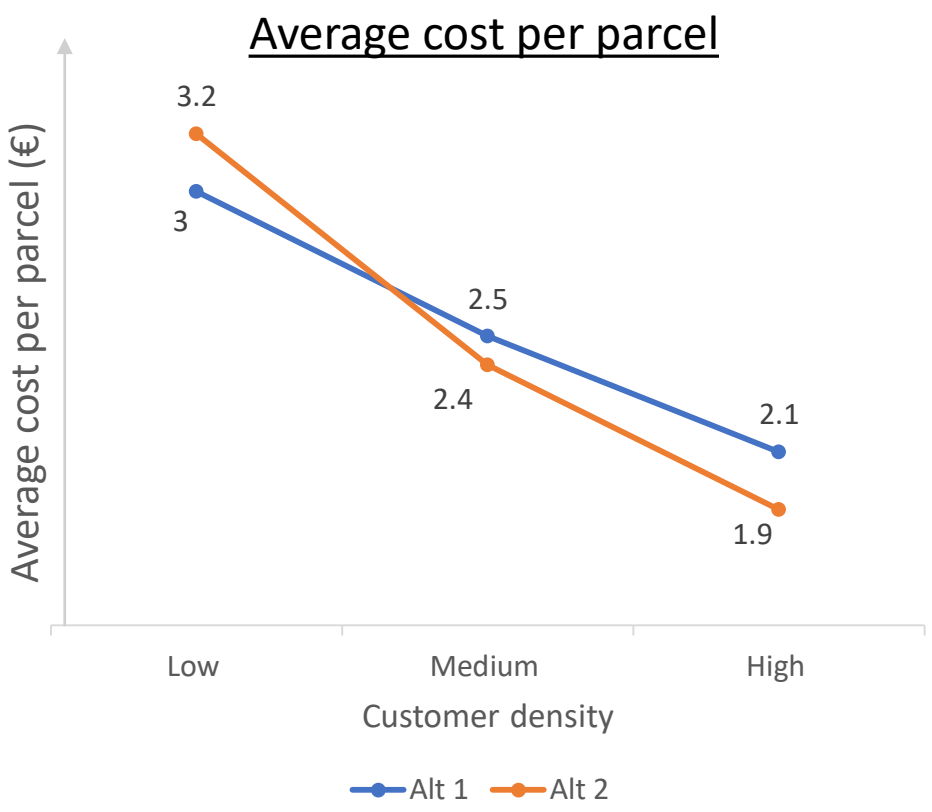


Validation of CA method

Output	**Difference in outputs between approximated 2E-LRP & exact routing method(CVRP)**
Fleet sizes at micro hubs	**Same at all micro hubs**
LEFV Miles travelled	**Slightly higher** (avg 6 %)

KPI values and comparison across instances



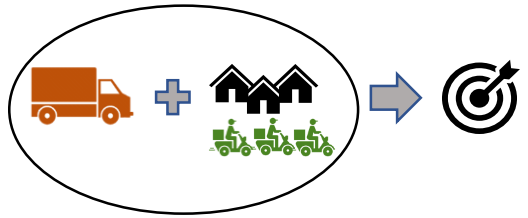


- Adopting **Alt 1 from conventional network** reduces total CO2 emissions by **40 %** (avg)
- Adopting **Alt 2 from conventional network** reduces total CO2 emissions **70 %** (avg)

Discussion of the research

- **Simple simulation** of cost optimal network configuration for two echelon urban transshipment network.

- Capable to predict a network **close to global optimum** adequate for **strategic analysis.**



- Can solve **real size problem instances** without complexity.

- **Locating micro hubs inside LEZ** and **using electric box trucks** reduces the costs when **customer density is high**.

Critique of the research

- **Solution closer to global optimum** can be achieved through **improvement heuristics.**

- **Heterogenous fleet of vehicles** are not considered**.**

- The model is **not applied** to a **real case study.**

Please feel free to reach out to us at-

- Arjun Nallapeta- a.nallapeta@panteia.nl
- Tharsis Teoh- t.teoh@panteia.nl

Questions?