How to plan the future e-truck infrastructural network?

A numerical experiment

Yoan Charpentier

Polytech Clermont

yoan.charpentier@etu.uca.fr

September 25, 2024

Overview

The UiT

Figure: UiT The Arctic University of Norway

Figure: Narvik on a map

Internship subject

How to **plan** the future e-truck **infrastructural** **network** ?

- network : supply chain (SC)
- infrastructural : warehouses (WH), charging stations (CS)
- plan : place infrastructures to create a coherent network

Goal : plan simultaneously **warehouses** and **charging stations** in a network.

Organization

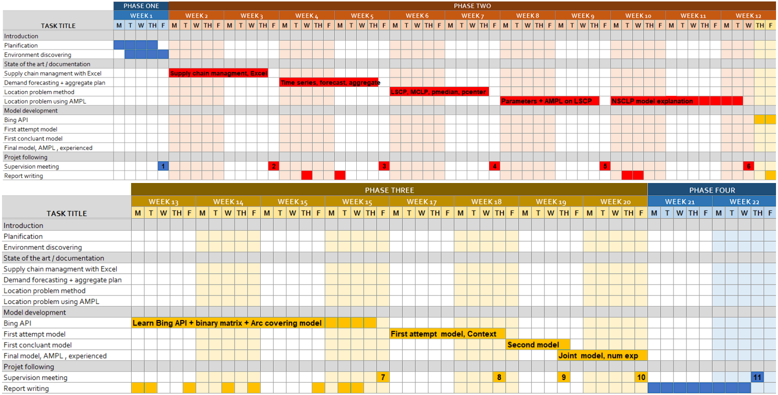


Figure: GANTT Diagram

What is a Supply Chain (SC) ?

Definition

Supply Chain [1]: All parties involved, directly or indirectly, in fulfilling a customer request. Products or supply moves from suppliers to manufacturers to distributors to retailers to customers along the chain. It is a dynamic process that involves the constant flow of information, product and funds between different stages (one player involved).

Supply network ?

Objective

Maximize the overall value generated. (often minimize costs...)

[1] Chopra, S., Meindl, P. (2013). Supply Chain Management: Strategy, Planning, and Operation. Prentice Hall.

How to build a SC ?

Key drivers

1. Facilities
2. Inventory
3. Transportation
4. Information
5. Sourcing
6. Princing

Factors influencing

1. Strategic
2. Technological
3. Macroeconomic
4. Political
5. Infrastructure
6. Competitive

Trade-off between **responsiveness** and **efficiency**.

Several models studied

- **CPLM (Capacited Plant Location Model)**
- SSCPLM (Single Source Capacitated Plant Location Problem)
- LISM (Locating Infrastructures Simultaneously Model)

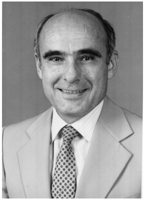
CPLM

$$
\begin{aligned}
\text{Objective function :} \quad & \min \sum_{i \in \mathcal{I}} c_i x_i + \sum_{i \in \mathcal{I}} \sum_{k \in \mathcal{K}} a_{ik} s_{ik} \\
\text{s.t.} \quad & \sum_{k \in \mathcal{K}} s_{ik} \leq K_i x_i \quad \forall i \in \mathcal{I} \\
& \sum_{i \in \mathcal{I}} s_{ik} = d_k \quad \forall k \in \mathcal{K} \\
& x_i \in \{0,1\} \quad \forall i \in \mathcal{I} \\
& s_{ik} \geq 0 \quad \forall (k,i) \in \mathcal{I} \times \mathcal{K}
\end{aligned}
$$

- K_i : capacity of warehouse i
- d_k : quantity required at demand point k

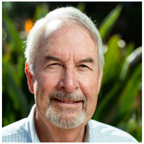
Historic review

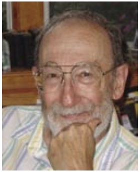
S.L. Hakimi (1964)



Police presence on highways, telecommunication

R. Church, C.S. ReVelle (1974)





MCLP

D. Schilling et. al (1993)

First review

2 3

[2] S. L. Hakimi, (1964) Optimum Locations of Switching Centers and the Absolute Centers and Medians of a Graph. Operations Research 12(3):450-459.

[3] Schilling, D.A., Jayaraman, V., Barkhi, R. (1993). A REVIEW OF COVERING PROBLEMS IN FACILITY LOCATION. Computers Operations Research.

Example

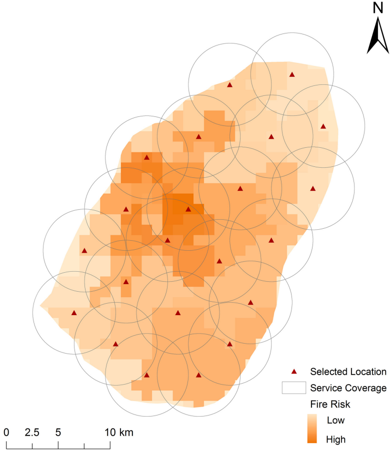


Figure: LSCP applied on fire station placement in Nanjing, China[4]

[4] Yao, J., Zhang, X., Murray, A. T. (2019). Location optimization of urban fire stations: Access and service coverage. CEUS, 73, 184–190

Set Covering models

- LSCP (Location Set Covering Problem) [5]
- MCLP (Maximal Coverage Location Problem) [6]
- **NSCLP (Network-based Set Covering Location Problem)** [7]

[5] Toregas, Constantine, Swain, Ralph, ReVelle, Charles and Bergman, Lawrence, (1971), The Location of Emergency Service Facilities, Operations Research, 19, issue 6, p. 1363-1373.

[6] Church, R., ReVelle, C. The maximal covering location problem. Papers of the Regional Science Association 32, 101–118 (1974). https://doi.org/10.1007/BF01942293

[7] Yu, H et al. (2024) A Network-Based set covering model for charging station location problem: a case study in Norway. Advanced Manufacturing and Automation XIII, 204 – 211

NSCLP

$$\text{Objective function :} \quad \min \sum_{j \in \mathcal{J}} b_j y_j$$

$$\text{s.t.} \quad \sum_{j \in \mathcal{J}} \mathbb{1}_{\{d_{jk} \leq r\}} y_j \geq 1 \quad \forall k \in \mathcal{K}$$

$$\sum_{j' \in \mathcal{J} \setminus \{j' \neq j\}} \mathbb{1}_{\{d_{jj'} \leq r\}} y_{j'} \geq y_j \quad \forall j \in \mathcal{J}$$

$$y_j \in \{0,1\} \quad \forall j \in \mathcal{J}$$

- b_j : price for setting up a charging station at j
- $d_{pp'}$: denotes the distance between two different points

Methods

Microsoft Excel

Developper solver tool

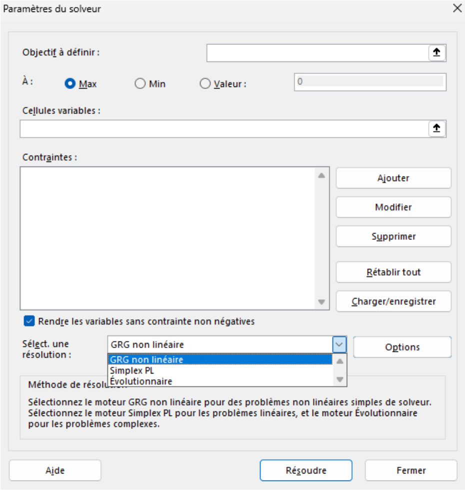


Figure: Excel solver window

AMPL

Model file (.mod), data file (.dat), runing file (.run)

.mod file structure

Define sets, parameters, (checks), decision variables, objective function, constraints

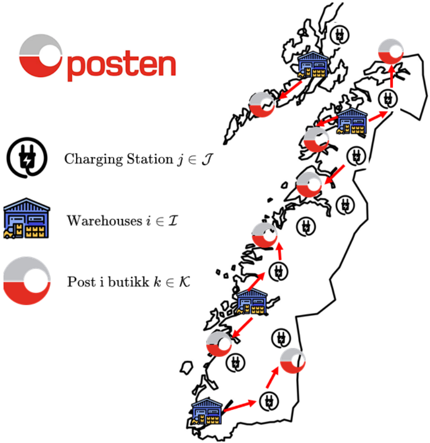
.dat file structure :

sets, parameters in a matrix form

Context

Supply chain manager for *Posten*.

Goal : plan simultaneously **warehouses** and **charging stations** a network



Details

- **Each ride** should be feasible
- Demand should be met
- Warehouses interacts with demand clusters through charging stations (or not)
- The model should be **capacitated** (*i.e warehouses have an inventory that should be tracked*)

Model Formulation

$$\text{Objective function :} \quad \min \sum_{i \in \mathscr{I}} c_i x_i + \sum_{j \in \mathscr{J}} b_j y_j + \sum_{i \in \mathscr{I}} \sum_{k \in \mathscr{K}} a_{ik} s_{ik}$$

$$\text{s.t.} \quad \sum_{k \in \mathscr{K}} s_{ik} \leq K_i x_i \quad \forall i \in \mathscr{I}$$

$$\sum_{i \in \mathscr{I}} s_{ik} = d_k \quad \forall k \in \mathscr{K}$$

$$\sum_{j \in \mathscr{J}} \mathbb{1}_{\{d_{ij} \leq r\}} y_j \geq x_i \quad \forall i \in \mathscr{I}$$

$$\sum_{j \in \mathscr{J}} \mathbb{1}_{\{d_{jk} \leq r\}} y_j \geq 1 \quad \forall k \in \mathscr{K}$$

$$\sum_{j' \in \mathscr{J} \setminus \{j' \neq j\}} \mathbb{1}_{\{d_{jj'} \leq r\}} y_{j'} \geq y_j \quad \forall j \in \mathscr{J}$$

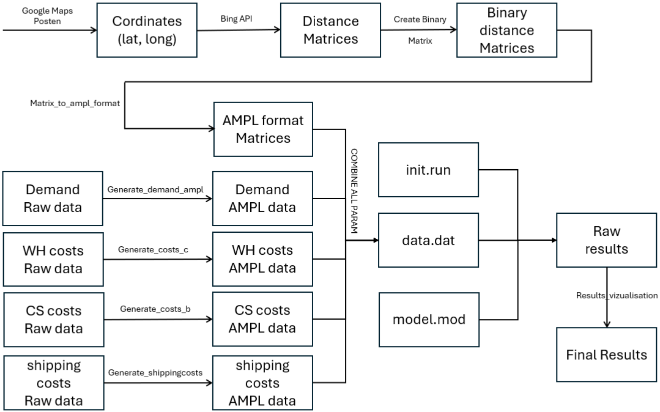
$$s_{ik} \geq 0 \quad \forall (i,k) \in \mathscr{I} \times \mathscr{K}$$

$$y_j, x_i \in \{0,1\} \quad \forall j \in \mathscr{J}, \forall i \in \mathscr{I}$$

Assumptions

- Demand clusters are reduced to *Post i Butikk* locations
- Collect between 30 and 40 CS candidate locations
- Collect 30 demand point locations
- Collect between 5 and 10 warehouses
- Prices are **all** set to 1 $\implies$ only CS radius is considered

Data Pipeline Framework



Map with all locations

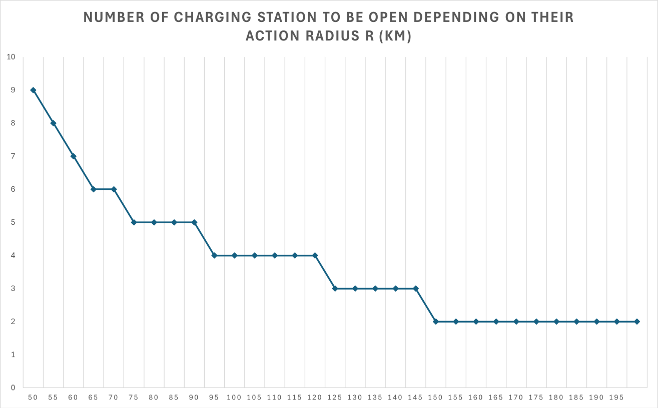
Map with results 1

$r = 90$ km : 5 CS and 4 WH

Map with results 2

$r = 130$ km : 3 CS and 4 WH

Numerical experiment



Why no analysis on warehouses placement ?

Perspective

Project perspective

- Correct NSCLP problem (Pair selection)
- Real case study (WH placement)
- Combine different covering and infrastructure models

Internship review

- Research and development
- General interset subject

Thank you