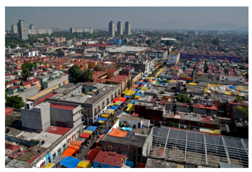
A new cost structure for the facility location problem applied in MegaCities



Josué C. Velázquez Martínez
Advisors: Dr. Edgar Blanco & Prof. Jan Fransoo

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Motivation and Description.

Emerging markets are known for having fast and large growing markets and low labor costs, which make them very attractive for international business (Meyer and Tran, 2006).

Among emerging markets, Megacities constitute important opportunities for large industries to invest in these regions, characterized for a large concentration of population.

Motivation and Description.

The10 largest cities in Latin America make a contribution similar to US and Western Europe (MGI, 2011).

However, these regions have infrastructure deficits, specifically in transportation (Bugliarello, 1999).

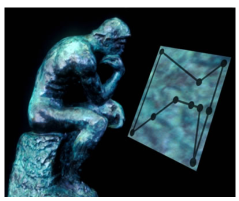
Industries are highly fragmented which cause an important competition.

Motivation and Description.

Significant concentration of large demand is located in a great number of small stores, where commonly large trucks cannot enter because the streets are too narrow.

This characteristic suggests the implementation of more robust transport cost structure for relevant supply chain problems.

We selected the p-Median Facility Location problem.



Motivation and Description.

Facility Location is critical to the efficient and effective operation of a supply chain (Daskin et al., 2005).

The problem was introduced by Weber (1909) and a large number of extensions and applications can be found in the literature. Refer to (Daskin, 2008) (Daskin et al., 2005) and for a recent review refer to (Melo et al., 2009) (ReVelle, et al., 2008).

- The fixed charge (un)-capacitated facility location problem and other applications such as multi-item and multi echelon

Motivation and Description.

The p-Median problem is formulated as follows (P1):

$$OF1: Min \rightarrow \sum_{j \in J} \sum_{i \in I} h_i d_{ij} Y_{ij}$$

Subject to

$\sum_{j \in J} Y_{ij} = 1$	$\forall i \in I$	(1)
$\sum_{j \in J} X_j = p$		(2)
$Y_{ij} - X_j \leq 0$	$\forall i \in I \; \forall j \in J$	(3)
$X_j \in \{0,1\}$	$\forall j \in J$	(4)
$Y_{ij} \in \{0,1\}$	$\forall i \in I, \forall j \in J$	(5)

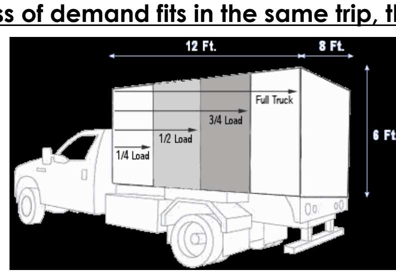
The objective function minimizes the demand-weighted total distance.

Motivation and Description.

Traditional approach does not take into account the truck capacity and it <u>assumes a constant cost per distance per unit</u> (ReVelle, et al., 2008)

However, the transport cost is mainly driven by the <u>required number of shipments</u> to deliver the demand in a specific location.

- **<u>If an excess of demand fits in the same trip, this cost remains constant</u>.**



Research questions.

Is the truck accessibility in megacities a significant characteristic that drives to a different solution for the facility location problem?

Is there any implicit assumption of the truck accessibility made by the traditional approach applied in megacities?

Proposal.
Model description.

We propose the following p-Median model:

$$Min \rightarrow OF2 = \sum_{j \in J} \sum_{i \in I} A_{ij} n_{ij} + \sum_{j \in J} \sum_{i \in I} v_{ij} d_{ij} [n_{ij} f_{ij}]$$

Subject to

$\sum_{j \in J} Y_{ij} = 1$	$\forall i \in I$	(1)
$\sum_{j \in J} X_j = p$		(2)
$Y_{ij} - X_j \leq 0$	$\forall i \in I \; \forall j \in J$	(3)
$X_j \in \{0,1\}$	$\forall j \in J$	(4)
$Y_{ij} \geq 0$	$\forall i \in I, \forall j \in J$	(5)
$n_{ij} = \frac{h_i Y_{ij}}{W_i f_{ij}}$	$\forall i \in I \; \forall j \in J$	(6)

Proposal.
Analytical properties.

We define the following properties for the proposed approach:

Property 1. *There exists at least one optimal solution for the proposed approach such that holds the single sourcing condition.*
Property 2. *let* $X^* = \{X_j \setminus j \epsilon J\}$ *and* $X'^* = \{X_j \setminus j \epsilon J\}$ *be the optimal location solutions obtained by the traditional approach and the proposed approach respectively, and let* $\frac{h_i}{W_i} = \alpha_i + \beta_i$, *such that* $\alpha_i \in \mathbb{Z}_+$ *and* $\beta_i \in (0,1)$, $\forall i \in I$, *If* $\alpha_i = a$ *such that* $a > 0 \ \forall i \in I$ *then* $X^* = X'^*$.
Corollary 2.1 *Let* $X^* = \{X_j \setminus j \epsilon J\}$ *and* $X'^* = \{X_j \setminus j \epsilon J\}$ *be the optimal location solutions obtained by the traditional approach and the proposed approach respectively. If* $W_i = \beta$ *and* $h_i = \gamma$ *such that* $\beta > 0$ *and* $\gamma > 0$ *are a fixed truck capacity and a constant demand* $\forall i \in I \ \forall j \in J$, *then* $X^* = X'^*$.
Property 3. *Let* ${X_k}^* = 1$ *and* ${X_l}^* = 1$ *be the optimal location solutions of the 1-Median facility location problem obtained by the traditional and the proposed approach respectively. Suppose that* $h_i = \gamma$, $\gamma > 0$ *is a constant demand* $\forall i \in I$. *If* $W' = W_1' = \ldots = W_{n'}'$ *and* $W'' = W_{n'+1}'' = \ldots = W_n''$ *where* $0 < n' < n$, *such that* $W' < W$, *then* $\sum_{i=1}^{n'} d_{il} \le \sum_{i=1}^{n'} d_{ik}$.

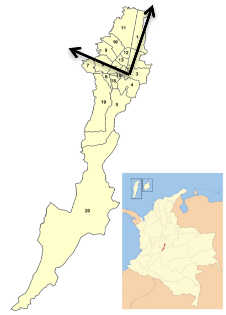
Proposal.
Analytical properties.

<u>Property 1</u> shows that the single sourcing condition is also applicable to the proposed approach.

<u>Property 2</u> The traditional approach assumes a constant number of shipments.

<u>Property 3</u> For the 1-median facility location problem with constant demand and two different truck capacities, the <u>proposed approach</u> <u>*locates the facility closer to the demand nodes with the smallest truck capacity than the traditional approach.*</u>

Proposal.
Experiment description.

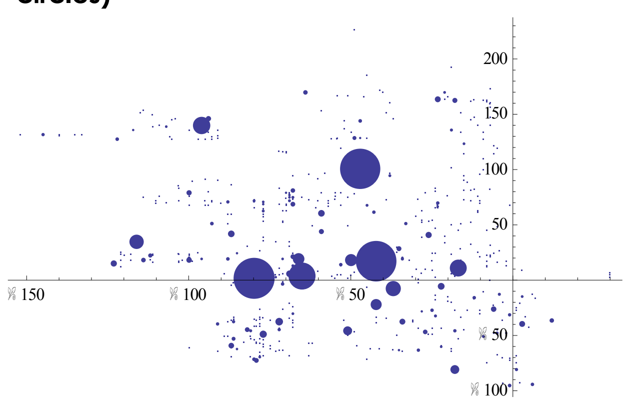


- Bogota company -> Food service industry.
- ~ 10,000 tons of demand per year just in Bogota region.
- The address in Bogota are located in coordinates of "carrera" (x-axis) and "calles" (y-axis).
  - Since Bogota has "perfect" blocks of 100 meters in "perfect" squares, we can estimate the distance by using "Manhattan" dist.
- There is not information related to the type of trucks.

Type of Truck	Capacity Tons
2 TON	2
DOBLETROQUE	33
	35
MINIMULA	40
NHR	4
NKR	7
NPR	7
	10
SENCILLO	17
TM 3 EJES	70
TM CARGA SECA	64
TM REGFRIGERADA	60

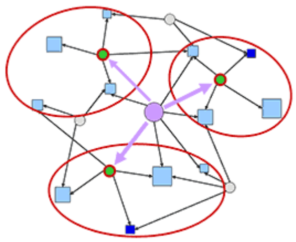
Proposal.
Experiment description.

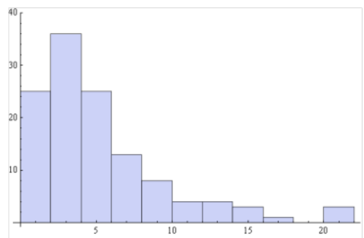
- Demand nodes (Carreras-Calles, Large demands->Large circles)



Proposal.
Experiment description.

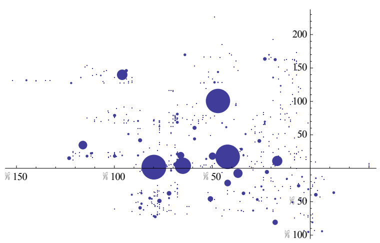
In order to reduce the negative effect of the FTL assumption, we group the clients in clusters based on proximity (15 x 15 blocks), and we define the center of each cluster based on the "median method". Here the histogram of number of customers per cluster:

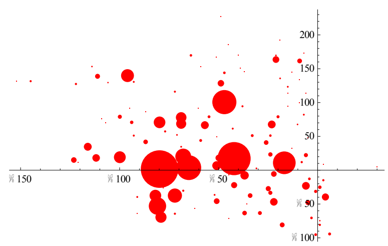




Proposal.
Experiment description.

Demand per client VS Demand per cluster:



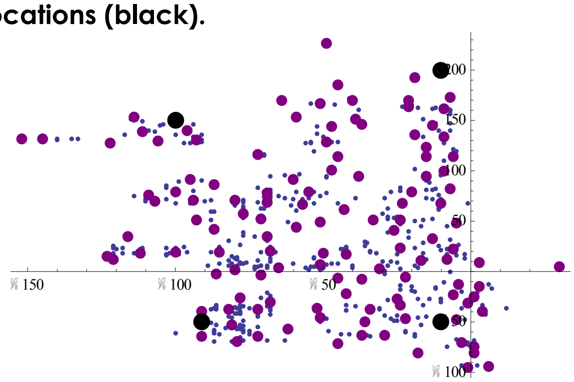


Proposal.
Experiment description.

We define the following candidate location based on feedback from experts.

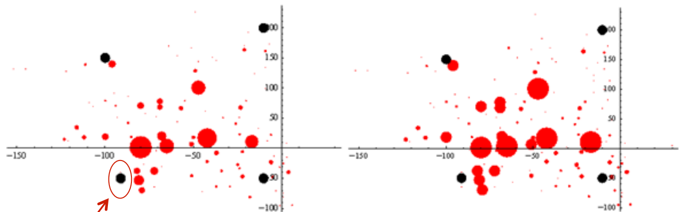
Proposal.
Experiment description.

The following chart shows demand nodes (blue), the medians of the clusters (purple) and the candidate facility locations (black).



Results.
Scenario 1) Any truck can reach any region

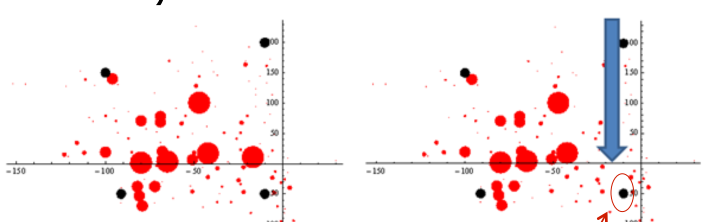
- The following chart shows the aggregate demand (left) and the truck capacity (right) per cluster.
  - We define the truck capacity by the rule of allocating a truck with a capacity greater or equal to the order size.



Solving the1-median FL problem, both the traditional and the proposed approach provide the same optimal location in {-91,-50}. *Property 2*

Results. Just 2 tons truck is accessible to "La Candelaria" region

- "La candelaria" {-17,11} is only accesible for trucks of 2 tons of capacity. (We were assigning 33 tons truck in the first scenario)



Solving the1-median FL problem with this "small" change, the proposed approach locate the facility in {-10,-50}
Property 3

Conclusions.

The analytical properties show that the effect of the truck capacity is considered implicitly in the traditional model, under the assumption of a positive correlation of demand and truck capacity-> i.e *the number of shipments remains constant*.

- This strong assumption could be valid under characteristics of *developed cities* where large trucks can reach many different locations of large demand within the region.
- However, in the case of some megacities not all the trucks can reach all destinations.

Conclusions.

The difference in cost assuming αlfa=1 (cost per kg-km) monetary unit (mu) is 5.3 millions of mu, which shows the significant impact of the traditional approach about the accessibility of the trucks in a region, by only changing the truck accessibility from large to small in one cluster.

The experiments and the theoretical analysis show that specific characteristics of retail distribution in megacities in developing countries may lead to structurally different models.

Conclusions.

These results may provide the required support for more <u>empirical work</u> in some other practical applications for similar regions.

The results may motivate future research related to the <u>extension of the model in more complex problems</u>, such as multi-item and multi-echelon.

THANK YOU!¡

<u>QUESTIONS?¿</u>