Embotelladoras ARCA Uses Operations Research to Improve Territory Design Plans

IE 479 Distribution Logistics

Article Presentation

Chosen Article

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Introduction

Embotelladoras ARCA

– The second-largest bottler of Coca-Cola products in Latin America.
– Dedicated to the production, distribution, and sales of soft drink brands owned by the Coca-Cola Company, ARCA, and third parties.
– The company has soft drink sales of more than 1.2 billion unit cases.

Problem Definition

The market's large size leads to several problems.

- Imbalanced product demand and number of customers among the territories.
- Balancing the number of customers ➡ a fair work distribution among the salespersons who handle the individual orders.
- Balancing product demand ➡ a fair distribution among the truck drivers.
- How to segment or partition customers into clusters or territories (Territory Design Problem).

➡ Problem of grouping basic units (i.e., city blocks, zip codes, or individual customers), which we call BUs, into territories according to specific planning criteria.

Assumptions

- Deterministic product demand.
- A fixed set of territory centers (focusing on the allocation phase of the process)
- 50 territories, 5000 BUs

Planning Criteria

Given a set of city blocks or BUs, it is desired to create a specific number of territories according to the planning criteria:

1. Compactness: customers are as close to each other as possible
2. Balance: with respect to number of customers and product demand
3. Territory connectivity: a truck assigned to a territory can deliver goods without leaving the territory
4. Disjoint BU assignment: avoids assigning two given BUs to the same territory
5. Similarity to an existing plan for a subset of BUs.

Method

The figure shows the steps in the pseudocode of the solution procedure. .

function method()
Input: A problem instance.
Output: A feasible solution X.
1 Solve model AMR and obtain solution X.
2 Identify a set C of violated constraints of model AM for solution X.
3 If $|C| > 0$, add these constraints to model AMR and go to Step 1.
4 Return X.
end method

- Solve the AMR (allocation model relaxation) and check if the solutions obtained satisfy the connectivity constraints.
- To determine the violated connectivity constraints, solve a relatively easy separation problem and add these cuts to the AMR.
- This procedure iterates until no additional connectivity constraints are found; therefore, an optimal solution to the AM is obtained.

Method

The figure shows the decision variables and parameters for the Allocation Model.

- V be the set of BUs, $|V| = n$;
- E be set of edges representing adjacency between BUs;

- V_c be the set of territory centers, $|V_c| = p$;
- $A = \{1, 2\}$ be the set of BU attributes corresponding to the number of customers ($a = 1$) and product demand ($a = 2$);
- $c(k)$ denote the index of the territory center k;
- d_{ij} be Euclidean distance between BUs i and j;
- w_i^a be the value of attribute $a \in A$ in BU $i \in V$;
- $w^a(V_k) = \sum_{i \in V_k} w_i^a$, the size of territory $V_k \subset V$ with respect to activity $a \in A$;
- $\mu^a = w^a(V)/p$ be the average size (and therefore target value) of activity $a \in A$;
- $N^i = \{j \in V: (i, j) \in E\}$ be the set of BUs adjacent to BU $i \in V$;
- H be the set that contains all pairs of BUs that must be assigned to different territories;
- F^i be the prespecified subset of BUs associated with center i from an existing plan;
- q_{ij} be the penalty term for not assigning BU j to center $i \in V_c$, equal to $0.5d_{ij}$ for $j \in F^i$;
- τ^a be the user-specified tolerance parameter for activity $a \in A$;
- α be the user-specified parameter for setting a minimum threshold on the number of BUs that must be assigned from the existing plan.

The decision variables are defined as $x_{ij} = 1$ if the BU j is assigned to a territory with a center in i, and 0 otherwise; $i \in V_c$, $j \in V$. Note that $x_{ii} = 1$ implies that BU i is a territory center.

Method

The figure shows the Allocation Model.

$$\min \left\{ \sum_{\substack{i \in V_c \\ j \in V}} d_{ij} x_{ij} + \sum_{\substack{i \in V_c \\ j \in F^i}} q_{ij} (1 - x_{ij}) = f(x) \right\} \tag{1}$$

$$\text{subject to} \quad \sum_{i \in V_c} x_{ij} = 1 \quad j \in V, \tag{2}$$

$$\sum_{j \in V} w_j^a x_{ij} \leq (1 + \tau^a) \mu^a \quad i \in V_c,\ a \in A, \tag{3}$$

$$\sum_{j \in V} w_j^a x_{ij} \geq (1 - \tau^a) \mu^a \quad i \in V_c,\ a \in A, \tag{4}$$

$$\sum_{j \in \cup_{v \in S} N^v \setminus S} x_{ij} - \sum_{j \in S} x_{ij} \geq 1 - |S| \quad i \in V_c, \quad S \subset V \setminus (N^i \cup \{i\}), \tag{5}$$

$$x_{ij} + x_{ih} \leq 1 \quad i \in V_c,\ (j, h) \in H, \tag{6}$$

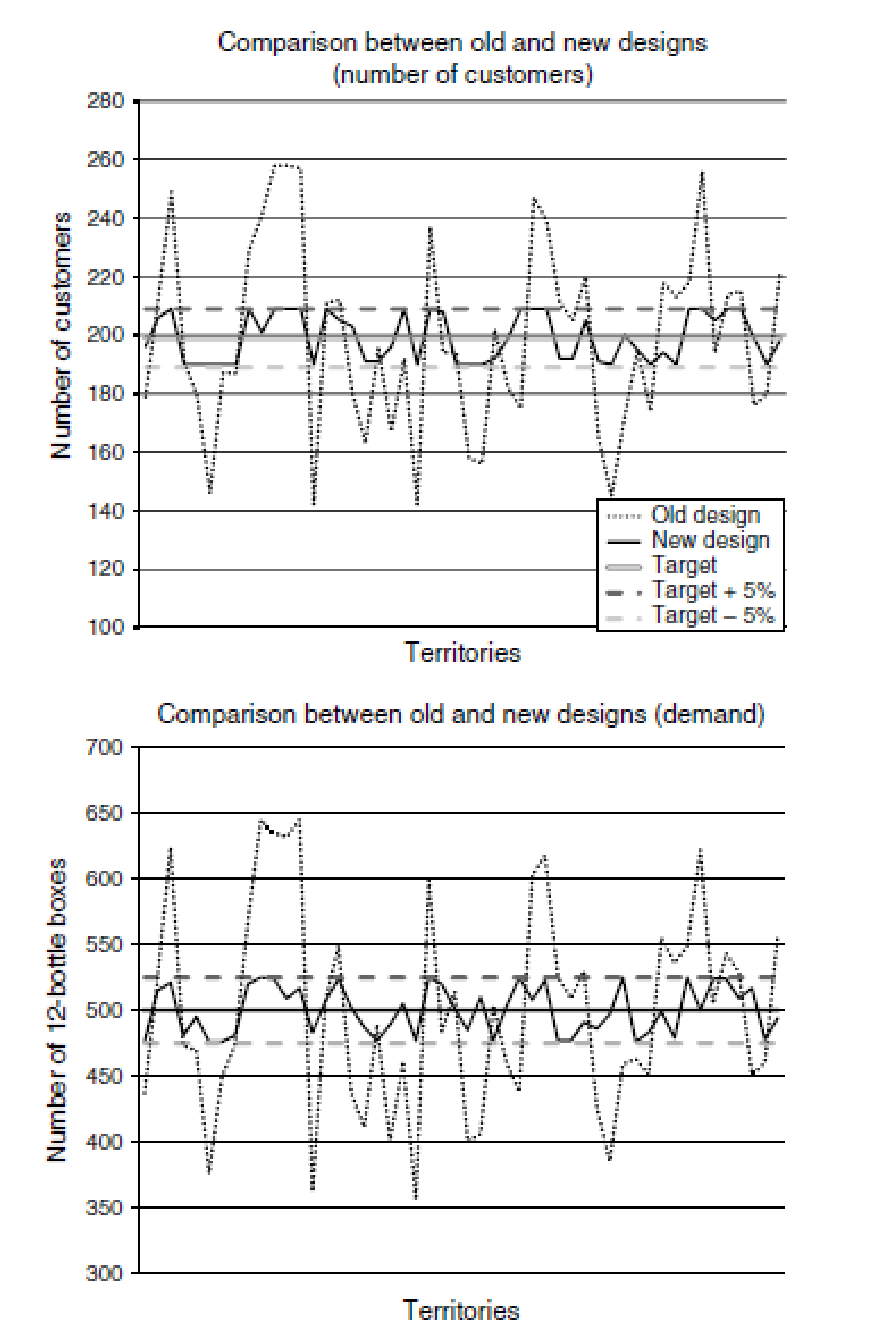
$$\sum_{i \in V_c} \sum_{j \in F^i} x_{ij} \geq \alpha |\cup_i F^i|, \tag{7}$$

$$x_{ii} = 1 \quad i \in V_c, \tag{8}$$

$$x_{ij} \in \{0, 1\} \quad i \in V_c,\ j \in V. \tag{9}$$

Results

A comparison between old and new design in terms of number of customers (top) and product demand (bottom). The charts plot the distribution of the corresponding activity measure for each of the 50 territories. The tolerance limits are depicted as dotted lines..



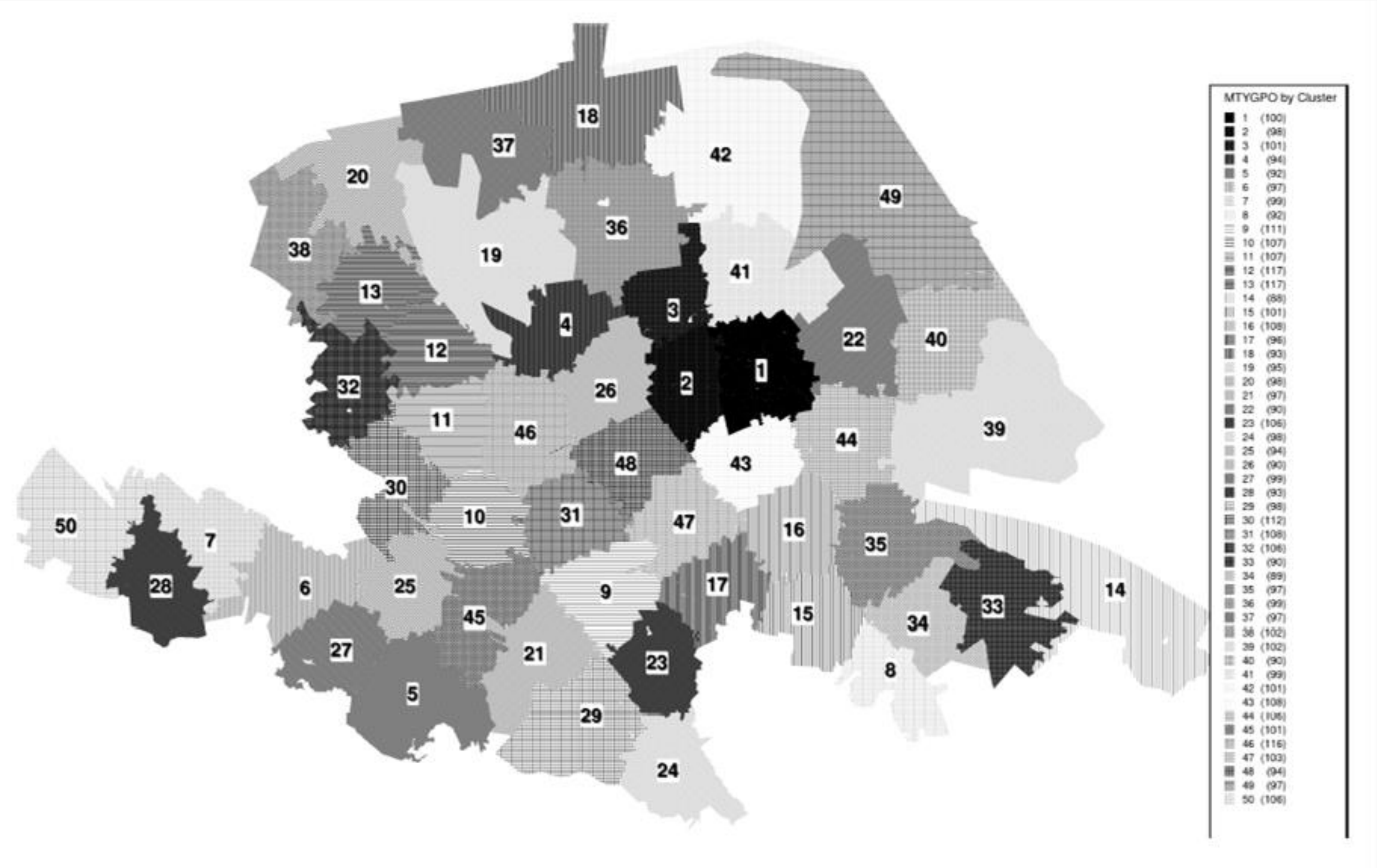
Results

This figure displays the previous territory plan used by Embotelladoras ARCA in Monterrey.

Territory 1 had 95 BUs, territory 44 had 128 BUs.
Territory 14 had 68 BUs, territory 33 had 100 BUs.

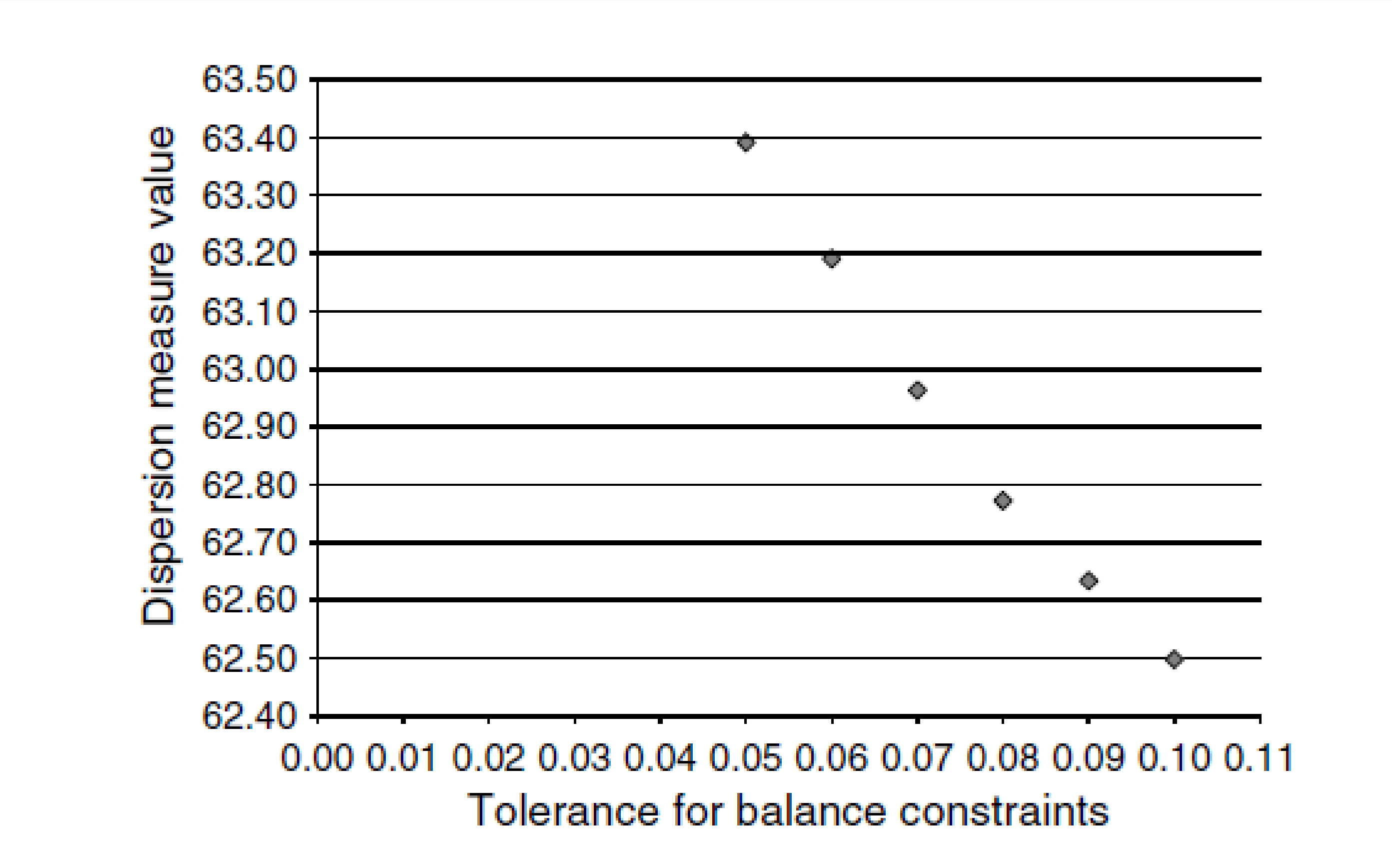
Results

This figure shows the new territory plan in Monterrey (tolerance = 5 %) after the solution of the developed model..



Territory 1 now has 100 BUs, territory 44 has 106 BUs.
Territory 14 has 88 BUs, territory 33 has 90 BUs.

Results



This figure plots the trade-off between the balance constraint tolerance parameter and the dispersion measure value

Implementation Challenges

Several technical issues arose during the implementation of the new designs:

- **Reducing the many territory imbalances**

  -Achieved by incorporating the balancing constraints into the model and defining an appropriate value for the tolerance parameter

- **Issue of realignment**

  -Many customers have established long-term relationships with the team (salespersons and truck drivers)

  -Achieved by incorporating a penalty term into the objective to penalize for differences from the existing plan

Benefits

- Identification of a rational set of activity measures to target and balance each truck resource
- Manual planning process time was reduced from 2 weeks to less than 1 hour using the new OR application
- 15 % reduction from the original number of delivery routes
- Streamlined truck capacity aligned to a new end customer distribution strategy
  ➡ (8% savings of the entire fleet)

Benefits

- Identification and implementation of an optimal cost of service, depending on each route model type

➡ optimal frequency for customer delivery operations with less travel time

- Improved territory compactness and elimination of territory overlapping

- The model will allow the company to speed up some other route-to-market initiatives of special interest among Coca-Cola bottlers worldwide

Comparison in Turkey

District Design And Route Planning For Customer-Related Field Operations Of Natural Gas Distribution Systems: A Case Study

- Implemented on a natural gas distribution company
- Main purpose: Performing field operations in time with minimum number of mobile teams
- District Design Problem

MF : Maximum workload amongst districts
MC : Maximum compactness amongst districts
Model:
$$\text{Minimize } Z_1 = MF$$
$$\text{Minimize } Z_2 = MC$$

- Mobile teams are assigned to districts to planning services using the mathematical model of Multiple Travelling Salesman Problem

Comparison in Turkey

- Territorial Design for Matching Green Energy Supply and Energy Consumption: The Case of Turkey
- Case—Assigning Regions to Sales Representatives at Pfizer Turkey

Additional References

- **GRASP with path relinking for commercial districting**
  - If the centers are "badly" located, the resulting design may cause a serious deterioration in objective function
  - Center-based dispersion functions have the disadvantage of being very costly within heuristic search
  - Non-center based dispersion function
  - Longest distance between any two basic units in a territory
  - Heuristic rather than mixed integer programming model
  - Greedy Randomized Adaptive Search Procedure (GRASP)

$$\min_{X \in \Pi} \quad f(X) = \max_{k \in K} \max_{i,j \in X_k} \{d_{ij}\}$$

Thank you for listening

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