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Distribution of non-alcoholic beverages in the city of Lima
AGENDA

- Introduction
- Methodology
- Results
- Conclusions
- References
Introduction
The purpose of this paper is to analyze the transportation configuration characteristics of non-alcoholic beverages in a Latin-American city.
Which are the more congested cities in the world?
Ranking of the most congested cities **Globally** (Overall daily congestion level – extra travel time – population over 800,000):

<table>
<thead>
<tr>
<th>Rank</th>
<th>City</th>
<th>Congestion Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mumbai, India</td>
<td>65%</td>
</tr>
<tr>
<td>2</td>
<td>Bogota, Colombia</td>
<td>63%</td>
</tr>
<tr>
<td>3</td>
<td>Lima, Peru</td>
<td>58%</td>
</tr>
<tr>
<td>4</td>
<td>New Delhi, India</td>
<td>58%</td>
</tr>
<tr>
<td>5</td>
<td>Moscow, Russia</td>
<td>56%</td>
</tr>
<tr>
<td>6</td>
<td>Istanbul, Turkey</td>
<td>53%</td>
</tr>
<tr>
<td>7</td>
<td>Jakarta, Indonesia</td>
<td>53%</td>
</tr>
<tr>
<td>8</td>
<td>Bangkok, Thailand</td>
<td>53%</td>
</tr>
<tr>
<td>9</td>
<td>Mexico City, Mexico</td>
<td>52%</td>
</tr>
<tr>
<td>10</td>
<td>Recife, Brazil</td>
<td>49%</td>
</tr>
</tbody>
</table>

The city
The model proposes routes that improve customer satisfaction due to on-time deliveries through the administration of inventories and the paths of the trucks filling pending orders.
The constraints

- Limited number of trucks that also have a limited capacity
- Loading requirements that are established in the contracts
- Inventory limitations
- Product stacking limitations
Methodology
A goal programming model is proposed to schedule the transportation of non-alcoholic beverages from the distribution centers to the points of sale through fleets of trucks with different characteristics.
The goals include the fulfillment of the number of pending orders, the number of available trucks, the contractually bound capacity and the distance that trucks will travel to fill the orders.
Primary sets

Customer orders \((j), (k)\)

Warehouse \((w)\)

Primary sets

SKU \((s)\)

Truck \((i)\)
Secondary sets

- $Y(i)$
- Trucks ($i$)
- Customer orders ($j$)
- $X(i,j,k)$
- $W(k)$
- $V(i,j)$
- $U(i,j)$
- $mtx_{dtc} (j,k)$
- $V(i,j)$
- $ps$
- $U(i,j)$
- $pp$
- $X(i,j,k)$
- $ttt$
- Customer orders ($k$)
Secondary sets

- Warehouse
- Sku (s)
- Customer orders (j)
- St(s)
- ps
- q(j,s)
The objective

Goals

\[
\begin{align*}
Min \ z &= \text{not\_attended} + \frac{etrucks}{MinTrucks} + \sum_{i=1}^{m} e2cap_i + \frac{edst}{Max\_Dst} \\
\sum_{j=1}^{n} \frac{W_j}{n} + \text{not\_attended} &= 1 \\
\sum_{i=1}^{m} Y_i + dtrucks - etrucks &= \text{MinTrucks}
\end{align*}
\]

Fullfilment

Number of trucks
The objective

Goals

\[
\sum_{i=1}^{m} weight_i \cdot V_{ij} + d1cap_i - e1cap_i = capacity_i \cdot Y_i \ \forall \ i \in \text{trucks}
\]

\[
\sum_{i=1}^{m} \frac{d1cap_i}{LIM\_CAP \cdot capacity_i} + d2cap_i - e2cap_i = Y_i \ \forall \ i \in \text{trucks}
\]

\[
\sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{n} mtxdst_{k} \cdot X_{ijk} + ddst - edst = Max\_Dst
\]
The constraints

\[ \sum_{k=1}^{n} X_{i0k} = Y_i \quad \forall \ i \in \text{trucks} \]

\[ \sum_{k=1}^{n} X_{ik(n+1)} = Y_i \quad \forall \ i \in \text{trucks} \]

\[ \sum_{k=1}^{n} X_{i(n+1)k} = 0 \quad \forall \ i \in \text{trucks} \]

\[ X_{i0(n+1)} = 0 \quad \forall \ i \in \text{trucks} \]

Trucks constraints: start point, routes, points
The constraints

\[
\sum_{k=1}^{n} \sum_{i=1}^{m} X_{ijk} \leq 1 \quad \forall \ j \in \text{point\_of\_distribution} \setminus \{0, n + 1\}
\]

\[
\sum_{j=1}^{n} \sum_{i=1}^{m} X_{ijk} \leq 1 \quad \forall \ k \in \text{point\_of\_distribution} \setminus \{0, n + 1\}
\]

\[
\sum_{j=1/j\neq k}^{n} X_{ijk} = \sum_{j=1/j\neq k}^{n} X_{ikj} \quad \forall \ i \in \text{trucks}, k \in \text{point\_of\_distribution} \setminus \{0, n + 1\}
\]
\[ U_{ik} \leq U_{ij} + 1 - (n + 2)(X_{ijk} - 1) \forall i \in \text{trucks}, (j,k) \in \text{point\_of\_distribution} \times \text{point\_of\_distribution} / j \neq k \]

\[ U_{ik} \geq U_{ij} + 1 + (n + 2)(X_{ijk} - 1) \forall i \in \text{trucks}, (j,k) \in \text{point\_of\_distribution} \times \text{point\_of\_distribution} / j \neq k \]

\[ \sum_{j=1}^{n} \text{weight}_j V_{ij} \leq \text{capacity}_i Y_i \forall i \in \text{trucks} \]

**Balance constraints**
The constraints

\[
\sum_{j=1}^{n} q_{js} W_j \leq st_s \forall s \in sku
\]

\[
W_k = \sum_{i=1}^{m} \sum_{j=1}^{n} X_{ijk} \forall k \in \text{point_of_distribution} \setminus \{0, n + 1\}
\]
Process
The input was the structure of the trucks, orders, products and coordinates of the point of sales in a Latin American city.
Table 1
Types of container used in the SKU of the simulated orders

<table>
<thead>
<tr>
<th>Container</th>
<th>Quantity SKU</th>
<th>Percentage SKU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packaging board</td>
<td>7</td>
<td>15.9%</td>
</tr>
<tr>
<td>Glass</td>
<td>10</td>
<td>22.7%</td>
</tr>
<tr>
<td>PET</td>
<td>23</td>
<td>52.3%</td>
</tr>
<tr>
<td>Metal</td>
<td>4</td>
<td>9.1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>44</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

*Source: author’s own elaboration.*
NOATENDIDOS = m.addVar(obj=1000, name='NOATENDIDOS')
ECAMIONES = m.addVar(obj=1, name='ECAMIONES')
EDST = m.addVar(obj=1, name='EDST')

m.update()

m.setObjective(ECAMIONES + NOATENDIDOS * 1000 + EDST + quicksum(D2CAP[i] for i in CAMION));

m.modelSense = GRB.MINIMIZE

# familia 1
for i in CAMION:
    m.addConstr(quicksum(X[i, DESTINO[0], k] for k in DESTINO if DESTINO.index(k) != 0 and DESTINO.index(k) != len(DESTINO) - 1) == Y[i]);

for i in CAMION:
    m.addConstr(quicksum(X[i, k, DESTINO[len(DESTINO) - 1]] for k in DESTINO if 0 != DESTINO.index(k) and len(DESTINO) - 1 != DESTINO.index(k)) == Y[i]);
Results
Faculty of Engineering

Results – Order point of sales

Source: author’s own elaboration.
Faculty of Engineering

Results
Table 2
*The meeting of goals with sufficient inventory*

<table>
<thead>
<tr>
<th>Points of delivery</th>
<th>Vehicles assigned</th>
<th>% of orders filled</th>
<th>% of capacity used</th>
<th>Route Distance (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1</td>
<td>100</td>
<td>23</td>
<td>15.9</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>100</td>
<td>56</td>
<td>23.6</td>
</tr>
<tr>
<td>30</td>
<td>1</td>
<td>100</td>
<td>50</td>
<td>24.6</td>
</tr>
<tr>
<td>40</td>
<td>1</td>
<td>100</td>
<td>66</td>
<td>26.6</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
<td>100</td>
<td>88</td>
<td>29.4</td>
</tr>
<tr>
<td>60</td>
<td>2</td>
<td>100</td>
<td>78</td>
<td>33.2</td>
</tr>
<tr>
<td>70</td>
<td>2</td>
<td>100</td>
<td>79</td>
<td>36.6</td>
</tr>
</tbody>
</table>

*Source: author’s own elaboration.*
The solutions allowed the scheduling of orders that had specific transportation units assigned with a graphical route.
The percentage of filled order will improve the decision making process when the time for a route design is limited.
Conclusions
We propose a model to design the shortest routes that can be used in an heterogeneous fleet with known capacities.

The results show that it is possible to find a solution when the process time depends on the number of delivery points.
One of the main contributions of the goal programming model proposal is that allows to manage the priorities in a distribution planning.

As future research, we propose other constraints such as route options, time windows, among others.
### Conclusions

**Managerial implications**

| The points of distribution can be supplied by located warehouses | The results facilitate coordination within the stakeholders |

**Research implications**

| The model combines multiple operational goals | We can optimize considering the preventive and response stage |
References


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FORMAMOS LÍDERES RESPONSABLES PARA EL MUNDO