A sugar distribution network: Designing and planning

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Tale of a battle!

Angry producers  vs  Naughty merchants
Agenda

• The problem
• Classification of provinces and customers
• Distribution channels/methods
• Refinement/Distribution/Storage planning
Demand

• 30 provinces
• 4 market segments
  – Households
    • Groceries
    • Small local super markets
  – Confectionerries/workshops
  – Small industries
  – Big industries (mostly soft drinks)
• Total demand
  – 1300000-1500000 tons/year
Supply

- Domestic production
  - Sugar cane
    - SCDS: 350000 tons/year
    - others
  - Sugar beets
- Import 🥕
Supply

- 30% SCDS
- 60% Other SC producers
- 7% Domestic sugar beet prod.
- 3% Import
Strategy

• To be independent of the merchants (partly)
• To have own distribution network
• Closer contact with final customers
Categorization of provinces

• Constructing sale regions

• Applying the same distribution method and organization for the provinces of the same region

• Utility : similar AND adjacent provinces in the same region
Steps

• Definition of indicators
• Data gathering
• Categorization algorithms
• Comparison of different categorizations
# Indicators

| Density of demand points | Distance to Khuzestan | Border points and ports | Ratio of sale plan to demand | Density of industrial demand points | Density of sale plan in the market segments | Density of demand in market segments | Consumption pattern in market segments | Density of railway network | Density of road network | Density of transportation companies | Average road transport cost | Density of sugar beet refineries | Geography/Demography | Consumption and distribution pattern | Transportation facilities, infrastructure and costs | Facilities of sugar production and refinement |}

## Neighborhood

| Surface | Demand | Sale plan | Limits |}

## Similarity
Calculation of similarities

- Values of indicators for the provinces
- Giving weights to the indicators → AHP
- Normalized similarity of the provinces \( m \) and \( n \)

\[
I_{mn} = \sum_{i} w_i \left[ 1 - \left( \frac{|a_{in} - a_{im}|}{a_i} \right) \right]
\]

- \( a_{in} \): Indicator \( i \) for the province \( n \)
- \( w_i \): Weight of the indicator \( i \)
- \( a_i \): Maximum gap between two provinces in the value of the indicator \( i \)
The first categorization algorithm

- Sort the provinces WRT demand density
  - Most important indicator
- Construct the cores of the regions
- Add neighbor similar provinces to the cores until constraints are violated
The second categorization algorithm

- Entry-to-entry multiplication of similarity and neighborhood matrices
- Diagonalization of the produced matrix
- Regions: blocks around the main diagonal
Comparison of categorizations

• Generating new categorizations by interviews and exchanging provinces between neighbor regions

• Criterion of utility: average of average similarity of the provinces of the regions

\[
\sum_{i=1}^{n} \frac{2 \sum_{j=1}^{N_i} \sum_{k=j+1}^{N_i} I_{jk}}{N_i \ast (N_i - 1)} \]

\[
\sum_{j=1}^{N_i-1} \sum_{k=j+1}^{N_i} I_{jk}
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Final regions
Choosing distribution methods

• Best distribution method for each (region, segment)
• Classification of 8 original market segments into 4
• Data gathering in 7 sample cities for the 7 regions
Possible distribution methods/channels

- Distribution company
  - Establishing a new one
  - Contract with existing companies

- Via syndicates

- Direct sale

- Via agents
  - Big
  - Small

- Via merchants
  - Keeping a part of current quota
  - Distribute the rest by new methods

Standards for distribution quota and storage capacity set according to:
- distribution power
- financial factors
- organizational needs
- reliability requirements

Min quota
Max quota
Procedure of choosing distribution methods

• Definition of comparison indicators
• Removal of infeasible methods w.r.t. limiting (constraint-like) indicators
• Making compensatable (objective-like) indicators independent: 21 initial indicators $\rightarrow$ 14 independent indicators
• Giving weight to objective-like indicators
• Evaluation of each indicator for each (region, segment)
• Normalization and summarization of indicators
• Ranking distribution methods
## Comparison indicators

<table>
<thead>
<tr>
<th>Class</th>
<th>Indicator</th>
<th>Compensatable/Limiting</th>
<th>Qualitative/Quantitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution capacity</td>
<td>Lead time</td>
<td>C</td>
<td>Quantitative</td>
</tr>
<tr>
<td></td>
<td>Flexibility of purchasing methods</td>
<td>C</td>
<td>Qualitative</td>
</tr>
<tr>
<td></td>
<td>Closeness to final customer</td>
<td>C</td>
<td>Quantitative</td>
</tr>
<tr>
<td></td>
<td>Effect on demand</td>
<td>C</td>
<td>Qualitative</td>
</tr>
<tr>
<td></td>
<td>Applicability to the market segment</td>
<td>L</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Financial</td>
<td>Investment return period</td>
<td>Both</td>
<td>Quantitative</td>
</tr>
<tr>
<td></td>
<td>NPV</td>
<td>Both</td>
<td>Quantitative</td>
</tr>
<tr>
<td></td>
<td>Initial investment needed</td>
<td>C</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Non-financial</td>
<td>Compatibility with strategies</td>
<td>L</td>
<td>Qualitative</td>
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<tr>
<td></td>
<td>Negative effects in the market</td>
<td>C</td>
<td>Qualitative</td>
</tr>
<tr>
<td></td>
<td>Durability</td>
<td>C</td>
<td>Qualitative</td>
</tr>
<tr>
<td></td>
<td>Effect on the bargaining power of the customers</td>
<td>C</td>
<td>Qualitative</td>
</tr>
<tr>
<td></td>
<td>Needed organization</td>
<td>C</td>
<td>Qualitative</td>
</tr>
</tbody>
</table>
## Results

<table>
<thead>
<tr>
<th>Market segment → Region ↓</th>
<th>Households</th>
<th>Workshops</th>
<th>Small industries</th>
<th>Big industries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) North-west</td>
<td>Small agents</td>
<td>Small agents</td>
<td>Direct sale Big agents Small agents</td>
<td>Big agents</td>
</tr>
<tr>
<td>2) North</td>
<td>Small agents</td>
<td>Small agents</td>
<td>Direct sale Big agents Small agents</td>
<td>Big agents</td>
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<tr>
<td>3) Tehran</td>
<td>Small agents</td>
<td>Small agents</td>
<td>Big agents Direct sale Small agents</td>
<td>Big agents</td>
</tr>
<tr>
<td>4) North-east</td>
<td>Small agents</td>
<td>Small agents via syndicates</td>
<td>Big agents Direct sale Small agents</td>
<td>Big agents</td>
</tr>
<tr>
<td>5) Centre</td>
<td>Small agents</td>
<td>Via syndicates Small agents</td>
<td>Big agents Direct sale Small agents</td>
<td>Big agents</td>
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<tr>
<td>6) South-west</td>
<td>Small agents</td>
<td>Small agents</td>
<td>Big agents Direct sale Small agents</td>
<td>Big agents</td>
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<tr>
<td>7) South-east</td>
<td>Small agents</td>
<td>Small agents</td>
<td>Big agents Direct sale Small agents</td>
<td>Big agents</td>
</tr>
</tbody>
</table>
Results
Planning of agents

• Decisions
  – Number of small and big agents in each province
  – Volume of sugar which agents of each province distribute
    • In the same province
    • In the other provinces of the region

• Objective: to minimize total transportation cost
  – Based on road mode (trailers)

• Constraints
  – Demand
  – Total volume of sugar which can be distributed by the agents of a province
    • Big agents: 150% of the demand
    • Small agents: 120% of the demand
    • A province may receive part of the needed sugar from other provinces
    • Agents located in each province may be more than what is needed there
Decisions

– Location and capacity of intermediate warehouses

– The amount of sugar to be refined in external and internal refineries in each month of the year

– Inventory of raw and refined sugar at the end of each month, in all of the storage points of the network:
  - [Internal] Warehouses of raw and refined sugar in Khuzestan
  - Warehouses of the external refineries
  - Intermediate warehouses of the company
  - Warehouses of the agents

– The amount of transportation of raw and refined sugar among storage points of the network and the customers
  - Customers:
    - Receiving sugar from the warehouse of the agent (Group A)
    - Receiving sugar without being stored in the agents (Group B)
Objective

• Minimize total cost:
  – Annual capital cost of the intermediate warehouses
  – Inventory holding cost at the internal (of the company in Khuzestan), external (refineries) and intermediate warehouses
  – Cost of refining in external refineries
  – Transportation cost of raw and refined sugar among storage point of the distribution network (factories in Khuzestan, external refineries, intermediate warehouses, agents and customers)
  – Loading and unloading costs of sugar through the process of transportation
Constraints

- Capacity of production and storage
- Demand satisfaction (sale plan)
- Balance relations of inventory and transportation at storage points of the network
- Initial conditions (inventory)

- Solver: LINGO 8.0
What happened at the end?

• Sad ending: the distribution sub-company failed
• The merchants dominate the market – Massive imports – Dumping prices
• Tactical/Operational planning cannot work when strategy is poor