Group 8

PRODUCTION AND DISTRIBUTION PLANNING IN DANONE WATERS CHINA DIVISION BY ZHANG & SONG

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DANONE

ONE PLANET. ONE HEALTH

Content

1. Introduction

- Danone, which was established in 1966 and operates in 120 countries, is a global producer and distributor of foods and beverages
- Danone entered the Chinese market in 2008 to develop its water brands, including Mizone (MZ), HB, and Robust (RBW).
- Danone Waters China Division (Danone Waters) in Guangzhou is responsible for the production and distribution of these three brands.

1. Introduction

- To cope with its increased growth and maintain operational efficiency, the company develop a decision support system (DSS) to address this issue
- The objective was to find a joint cyclic production and delivery schedule so that the total cost per unit time was minimized over a planning horizon
- It was a global optimization problem because of the interdependencies between production and distribution operations and the trade-offs between the costs associated with them

1. Introduction

- simple graphical interfaces, which shielded them from unnecessary complexity
- simplified the decision-making process, developed data models, and automated the manual planning tasks using optimization algorithms

2. Problem Definition

Danone Waters faces **three major challenges** because of the company's increasing size, big data processing, and nonstandard decision making.

First problem:

- The company has experienced significant growth in recent years.
- Since the company produces and delivers hundreds of thousands of products throughout the country therefore they must plan its production and delivery processes to adapt them to market developments over time.

Danone Waters’ National Distribution Network in China

Danone Waters currently has 26 factories, 27 DCs, and more than 2,000 LWs (Figure 1).

Figure 1. (Color online) Danone Waters’ National Distribution Network in China

2. Problem Definition

Second problem:

- Optimized planning is challenging when large amounts of data are involved.
- Hundreds of thousands of products produced in Danone Waters' plants flow through its distribution network of thousands of nodes, generating millions of data points.
- This poses a significant challenge to the optimization model, which must then be able to process this large amount of data.

2. Problem Definition

Third problem:

- There is no standard decision model.
- The company's production and distribution planning was inefficient because it was based on the experience of individual planners with minimal ability for systematic thinking.

Summarized in Three Points

The company's processes could **not be adapted to changes** brought about by business growth and demand fluctuation.

Production is allocated between factories and sales areas by **experience based on proximity** without any use of scientific evidence.

There is no such a **sequential approach is suboptimal.**

3. Objectives of the Study

Three types of nodes:

- *Plants,*
- *Distribution Centers, (DC)* (in-warehouses and out-warehouses)
- *Local Warehouses (LW).*

Aim: To optimize the production and distribution from plants to DCs and from DCs to LWs.

- Made-to-order and time-sensitive products: Delivery immediately after being produced.

- **The production and outbound distribution are dependent closely and must be scheduled jointly.**

- ***System Approach :*** The whole is greater than the sum of its parts and so recognizes the importance of interaction between the constituent subsystems

- **Integrated Production- Distribution Model**

Integrated Production- Distribution Models in Literature

- ***Goal:*** to solve a production and distribution plan that minimizes the total production and distribution costs.
- IPODS problems are classified based on three dimensions:
  - the decision level
  - the integration structure
  - the problem parameters
- They are summarized in four types:
  - ***The first type -*** *single plant and a single demand,* two stages
  - ***The second type*** - *multiple production plants, multiple customers, a single product,* two stages
  - ***The third type*** - *an infinite planning horizon with a constant demand, two stages*
  - ***The fourth type*** - *multiple products, multiple periods, a finite horizon, dynamic demand over time, three or more stages*

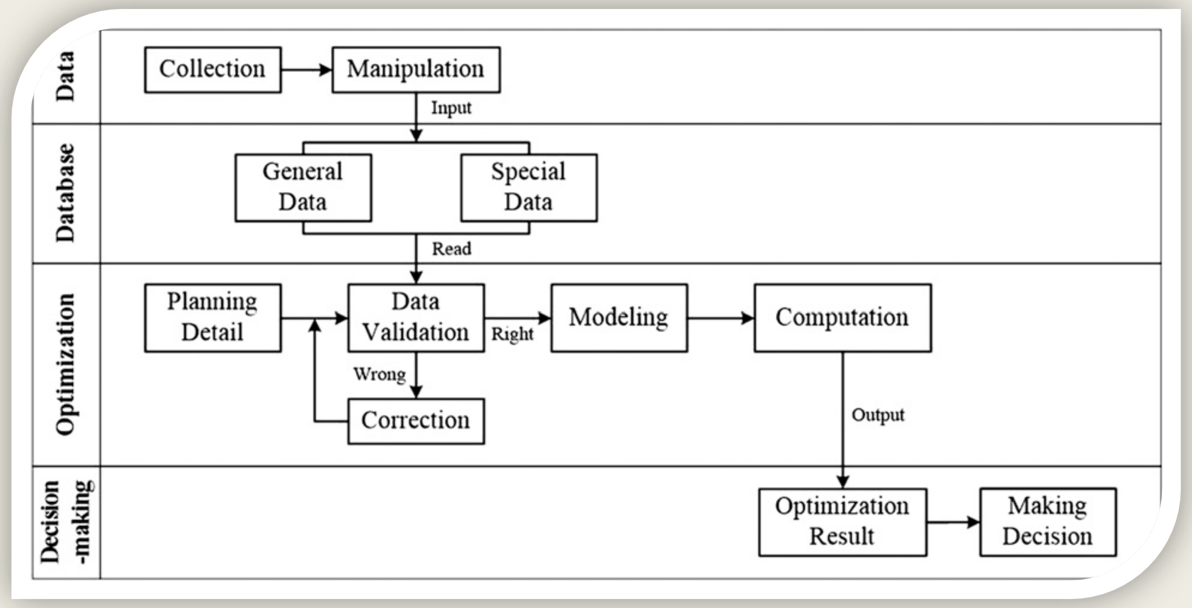
The problem Danone Waters is encountered...

- multiple plants, multiple DCs, and multiple local demands
- three-stage
- each plant has a capacity limit
- the production costs are linear for the RBW and HB brands & all-unit discount for the MZ brand
- At the DC, there is a linear inventory holding cost.
- The distribution costs are linear.
- The demand is deterministic

Objective: to find a joint cyclic production and delivery schedule such that the total cost per unit time is minimized over an infinite planning horizon.

4. Methodology

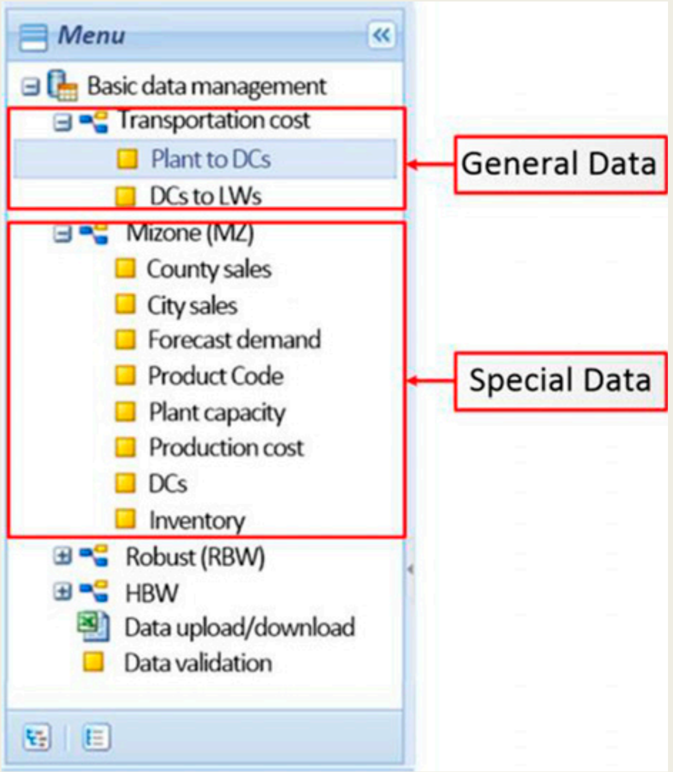
- Data Collection and Processing
  - *Data Collection*
  - *Reconciliation of Data Units*
  - *Data Processing*
- Optimization Process
  - *Planning Details*
  - *Data Validation*
  - *Modeling*
  - *Computation*



Data Collection

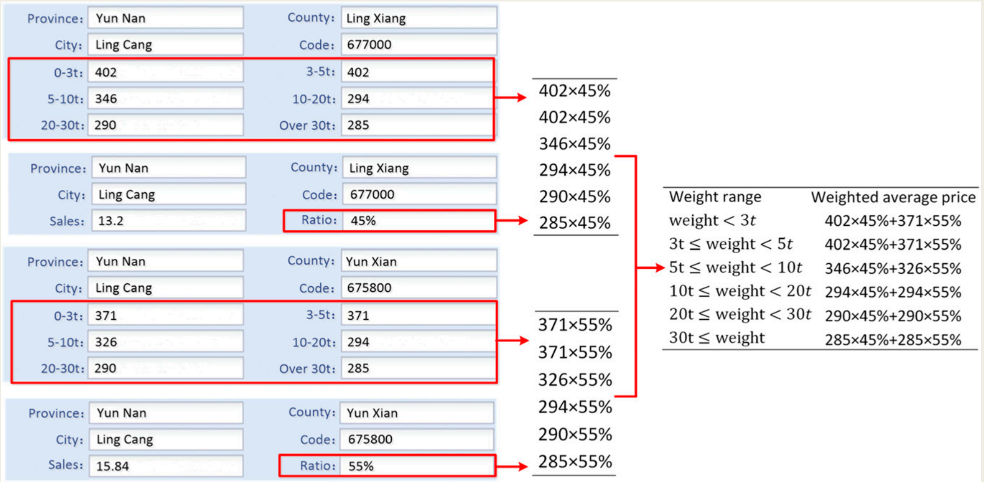
- Data that is needed for the DSS can be divided into two subgroups which are;
  - General Data: *Same for all product categories*
  - Specific Data: *Vary among product categories*

  These data is collected from various departments such as production, logistics, finance and 3P suppliers.



Reconciliation of Data Units

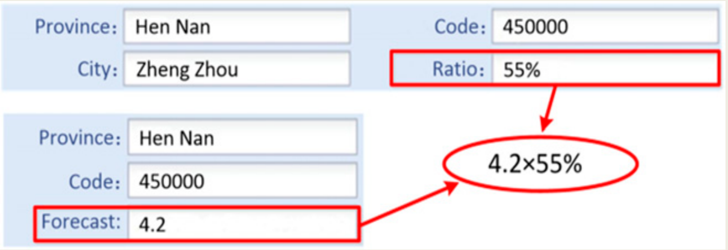
- Some of the data have to be preprocessed since they cannot be applied to the model directly. The two main reasons for this are undesirable metrics and variation through time & situation.
- Precision vs. Time
  - *Higher data precision provides higher planning precision*
  - *Less data precision means less required computing time*
- Standardized in the resolution of a city

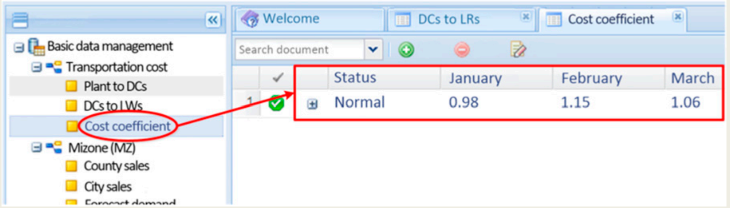


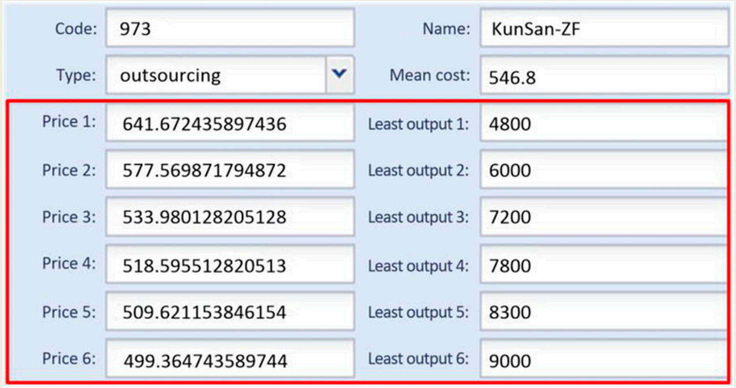
Forecast demand data- Province to City
Transportation price- County to City

Data Processing

- We have three main preprocessed data class which are transportation costs, inventory and production costs. All have preprocessed different from each other.
  - *Transportation costs*
    - Change constantly
    - Modified as a base cost (annually) multiplied by a cost coefficient (monthly)
  - *Production costs*
    - Depends on product category, corresponding plant and production output
    - Products are produced in Company owned plants which provides lower cost and outsourced plants which is used when extra demand arises and have an all-unit-discount structure
  - *Inventory*
    - Change with time because of the shelf life of the products
    - Expired products are deleted from the database

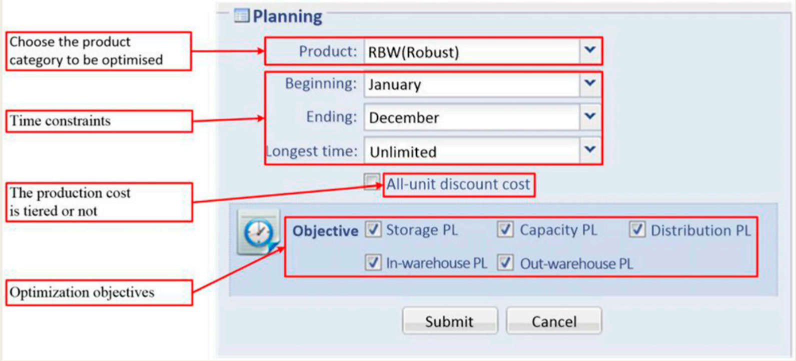


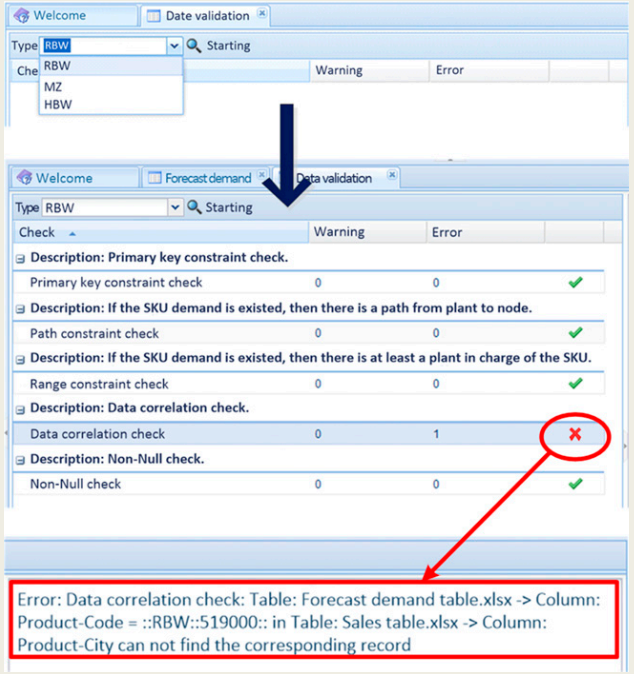




Planning Details & Data Validation

- During the planning phase, it is very crucial to determine which product category to optimize, time span, production cost type and optimization objective
- User can select several optimization objectives such as storage planning, capacity planning, distribution planning but more objectives means longer computing time
- Two types of data validation is used
  - *Completeness Check*
    - Solvable model
  - *Another Constraint Check*
    - Feasible model
- Only when all the validation steps are completed the planning can continue.





Modeling

- Our main problem is finding a joint cyclic production and delivery schedule in which the total cost per month is minimized. Total cost includes production, inventory (in and out-warehouse) and transportation costs.
- The problem contains large amount of data, thus most models cannot be solved in polynomial time. Oversimplification should be avoided.
- The RBW and HB products are suitable for LP since their production costs are linear. On the other hand, MZ’s production cost is all-unit-discount which is suitable for MIP.
- The data that is provided in previous steps are combined with two types of constraint;
  - *General Constraints: Balance and Nonnegativity*
  - *Other Constraints which ensure that solution is feasible:*
    - Ending-stock
    - Using out-warehouse
    - Production capacity of the plants

Computation

- As it is mentioned before our model has a large size. Therefore, both the LP and MIP model are solved by using large-scale LP solver (GLPK Simplex Optimizer). Most of the time is spent in the setup process and the whole model is solved in approximately in 10 minutes

5. Results

- To ensure that the model optimization was robust and to estimate the savings achieved using this approach, the performance of the optimized strategy that the approach recommended was compared with the performance of the historical strategy.
- DSS was applied to this data set to determine the production and transportation costs using the optimized strategies.

Compared with the historical values, our planning method showed a cost reduction of between 4% and 7% (Figures 10 and 11);

Figure 10. A Comparison of the Production Costs After Optimization with Costs Provided in Historical Data (i.e., Real Data)

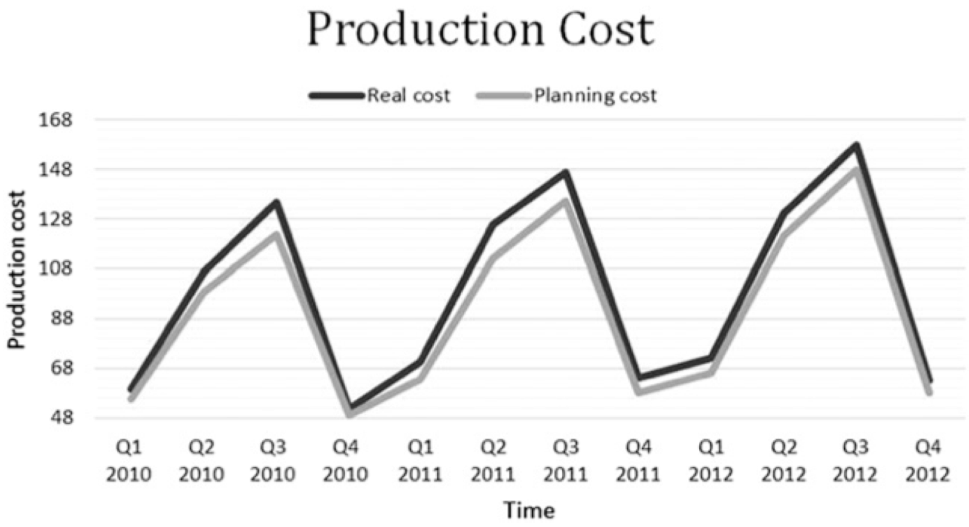
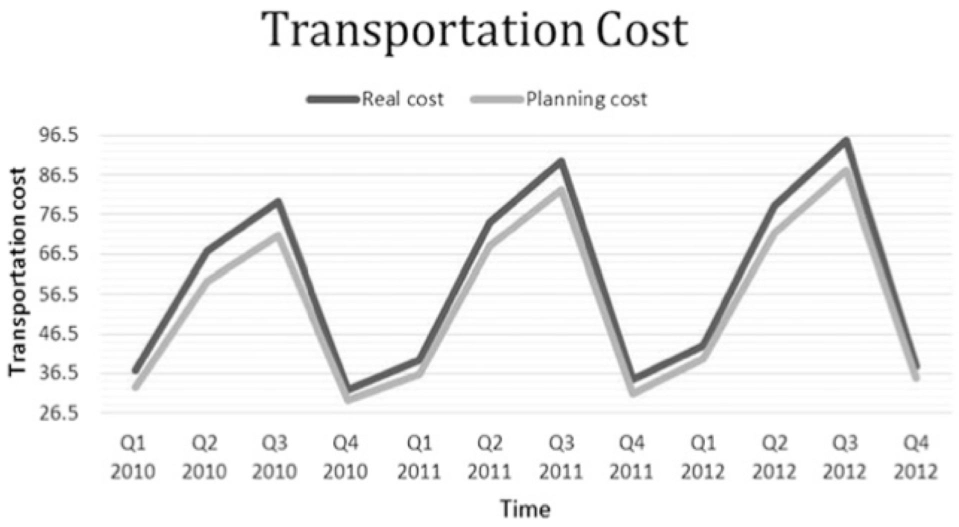


Figure 11. A Comparison of the Transportation Costs After Optimization with Costs Provided in Historical Data (i.e., Real Data)



These tests proved that the solutions were robust and that the optimization algorithm consistently converged to the true optimal solution.

5. Results

Danone Waters management began to use this model-based approach to guide its production and transportation decisions in 2013

According to the finance department's assessment,
The **total cost** incurred in 2013 : ¥698.305 million → ¥665.626 million (it is decreased by 4.6%)
Production costs : ¥431.018 million→ ¥414.878 million, (it is decreased by 3.8%)
Transportation costs : ¥267.286 million → ¥250.748 million (it is decreased by 6.2%)

An additional benefit to managers was that the DSS reduced their **decision time** and improved their **working efficiency**.

After successfully applying the DSS in South China, Danone Waters began a nationwide implementation.

The finance department’s calculations show that the cost savings rate remained above 3.5% in subsequent years.

This project has dramatically changed Danone Waters’ decision-making approach and accuracy.

- The approach achieved compelling results with the following strategies.
- Global optimization
- Data preprocessing
- Hiding complexity from the user and allowing user customization
- Field support
- Project organization and team structure

6. Linear Programming Model

Parameters

I = number of plants (including OEM)

J = total number of DCs including in-warehouses and out-warehouses (warehouses in the same city count as one)

K = number of local warehouses

S = number of SKUs of the products

$\mathbb{S}_i$ = type of SKUs that plant i can produce

T = number of planning periods (monthly)

i = subscript of plants

j = subscript of DCs

k = subscript of local warehouses (demand point)

s = subscript of SKUs

t = superscript of periods

D_{ks}^t = demand for the sth SKU in period t for k

$transC_{ij}$ = unit transportation cost from plant i to DC j

$disC_{jk}$ = weight average transportation cost from DC j to local warehouse k, including the handling cost of DC j

$inhc_j$ = unit storage cost of in-warehouse (one kind of DC)

$exhc_j$ = unit storage cost of out-warehouse (another kind of DC), including rent, drayage, handling cost

pc_{is} = unit production cost of the sth SKU of plant i

$inCa_j$ = capacity of the in-warehouse

PCa_i^t = maximum capacity of plant i in period t

SaS_{js}^t = safety factor of the sth SKU of the DC j in the period t

$Canproduct_{is}$ = whether plant i has the capacity to produce the sth SKU

$inits_{js}$ = initial inventory of the sth SKU of DC j

Decision Variables

x_{ijs}^t = freight volume from plant i to DC j

y_{jks}^t = distribution (delivery) quantity from DC j to local warehouse k

z_{is}^t = output of the sth SKU of plant i in period t

w_{js}^t = final inventory of DC j (in and out) in period t

ew_{js}^t = final stock of the out-warehouse j in period t

$$\text{Min} \ \sum_{t=1}^{T}[\sum_{i}^{I}\sum_{j=1}^{J}(transC_{ij}\cdot\sum_{s=1}^{S}x_{ijs}^{t})+\sum_{j=1}^{J}\sum_{k=1}^{K}(disC_{jk}\cdot\sum_{s=1}^{S}y_{jks}^{t})$$
$$+\sum_{i=1}^{I}\sum_{s=1}^{S}pc_i\cdot z_{is}^{t}+\sum_{i=L+1}^{I}\sum_{m=1}^{M}Opc_i^{m}\cdot oz_i^{m,t}+\sum_{j=1}^{J=1}(hc_j\cdot\sum_{s=1}^{S}w_{js}^{t}$$
$$+(ehc_j-hc_j)\cdot ew_j^{t})] \tag{A.1}$$

OBJECTIVE FUNCTION

GENERAL CONSTRAINTS

Production balance constraint:

$$z_{is}^{t} = \sum_{j=1}^{J} x_{ijs}^{t}, t = 1, \ldots T; i = 1, \ldots I; s \in \mathbb{S}_i \tag{A.2}$$

Demand balance constraint:

$$D_{ks}^{t} = \sum_{j=1}^{J} y_{jks}^{t}, t = 1, \ldots T; k = 1, \ldots K; s = 1, \ldots S \tag{A.3}$$

Warehouse stock balance constraint:

$$w_{js}^{t} = w_{js}^{t-1} + \sum_{i=1}^{I} x_{ijs}^{t} - \sum_{k=1}^{K} y_{jks}^{t}, t = 1, \ldots T; s = 1, \ldots S \tag{A.4}$$

Nonnegative constraint:

$$x_{ijs}^{t}, y_{jks}^{t}, w_{js}^{t}, ew_{j}^{t}, z_{is}^{t} \geq 0, t = 1, \ldots T; i = 1, \ldots I; j = 1, \ldots J; k = 1, \ldots K; \\ s = 1, \ldots S \tag{A.5}$$

OTHER CONSTRAINTS

SKU capacity constraint:

$$\sum_{s \in \mathbb{S}_i} z_{is}^t \leq PCa_i^t, t = 1, \dots, T; i = 1, \dots, I \qquad \text{(A.6)}$$

External warehouse constraint:

$$ew_j^t \geq \sum_{s=1}^{S} w_{js}^t - Ca_j^t, t = 1, \dots T; j = 1, \dots J \qquad \text{(A.7)}$$

Final stock constraint (except the final period):

$$w_{js}^t \geq SaS_{js}^t \cdot \sum_{k=1}^{K} y_{jks}^{t+1}, t = 1, \dots T - 1; j = 1, \dots J; s = 1, \dots S \qquad \text{(A.8)}$$

Final stock constraint of the final period:

$$w_{js}^T \geq SaS_{js}^T \cdot \sum_{k=1}^{K} y_{jks}^T, j = 1, \dots J \qquad \text{(A.9)}$$

Mixed-Integer Programming Model

Parameters

qc_{in} = unit production cost of the nth fragment of plant i
QCa_{in} = the minimum production of plant i in the nth period
PQ_i = the capacity that has been used by plant i

Decision Variables

Z_{in} = the production of plant i in the nth period
$\delta_{in} = 1$ means that the planned production of plant i falls in the nth period

Constraints

(A.2)–(A.9) and (A.10):

$$\sum_{n=1}^{N} Z_{in} - \sum_{t=1}^{T} \sum_{s \in \mathbb{S}_i} z_{is}^{t} \geq 0, i = 1, \ldots, I$$

$$QC_{i,n} \cdot \delta_{in} \leq Z_{in} \leq QC_{i,n+1} \cdot \delta_{in} \qquad \text{(A.10)}$$

$$\sum_{n=1}^{N} \delta_{in} \leq 1, i = 1, \ldots, I$$

NEW CONSTRAINTS

7. Conclusion and Recommendations

The impact of the projects can be generally categorized in three main titles

1. *Direct financial impact to the company*
   - This new DSS has a great impact on the reduction of annual production and transportation costs.
2. *Nonfinancial and indirect benefits to the company*
   - The new system make managers' job much easier than earlier. The previous complex decision making process is relieved. Also, the new system broaden managers perspective. (System thinking)
3. *Impact on other companies*
   - The inventory reduction trend in today's global market causes a stronger connection between production and distribution. A lot of firms face difficulties in doing joint scheduling which enables firms to optimize the trade-offs. This work will be reference point for them.

Recommendations

- As far as we observe that the model considers only the shelf life of the product in the inventory. However, queuing model should also be taken into consideration(e.g. FIFO)
- Authors decided to put a penalty cost for the inventory time in the future which ensures that the products will be distributed as soon as possible.

8. Contemporary Examples in Turkey

- Dairy manufacturing companies
- Bilgen B, Çelebi Y (2013) Integrated production scheduling and distribution planning in dairy supply chain by hybrid modelling
- Decision Support Systems for the Food Industry Arason S., Ásgeirsson E.I., Margeirsson B., Margeirsson S., Olsen P., Stefánsson H. (2010) Decision Support Systems for the Food Industry. In: Jain L.C., Lim C.P. (eds) Handbook on Decision Making. Intelligent Systems Reference Library, vol 4. Springer, Berlin, Heidelberg

THANK YOU FOR LISTENING
QUESTIONS?

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- Bilgen, Bilge, and Yelda Çelebi. "Integrated Production Scheduling And Distribution Planning In Dairy Supply Chain By Hybrid Modelling". *Annals Of Operations Research*, vol 211, no. 1, 2013, pp. 55-82. *Springer Science And Business Media LLC*, doi:10.1007/s10479-013-1415-3.
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