Intelligent Supply Chain Management Toolkit

Fenglin Fan
Chengcheng Liu
Eduardo Ruffo
Xuejiao Wang
Zhifan Xu

Outline

- Problem Introduction
- How to use the toolbox
- Database Development
- Demand Forecasting
- Optimization Model
- User Interface
- Scenario Analysis

Problem Introduction

- A big clothing company is facing **increasing operating cost** with its rapid business expansion in the past few years.
  - Manufacturing Cost
  - Inventory Cost
  - Logistic Cost
- An intelligent solution is needed to **reduce supply chain management cost**

Current Supply Chain Structure

Production Plants × 71 → Distribution Centers × 17 → Retailers × 433

Production Plants

Activities:
1. Regular time production
2. Overtime production

Distribution Centers

Activities:
1. Inventory Management
2. In-coming and out-going merchandise management

Retailers

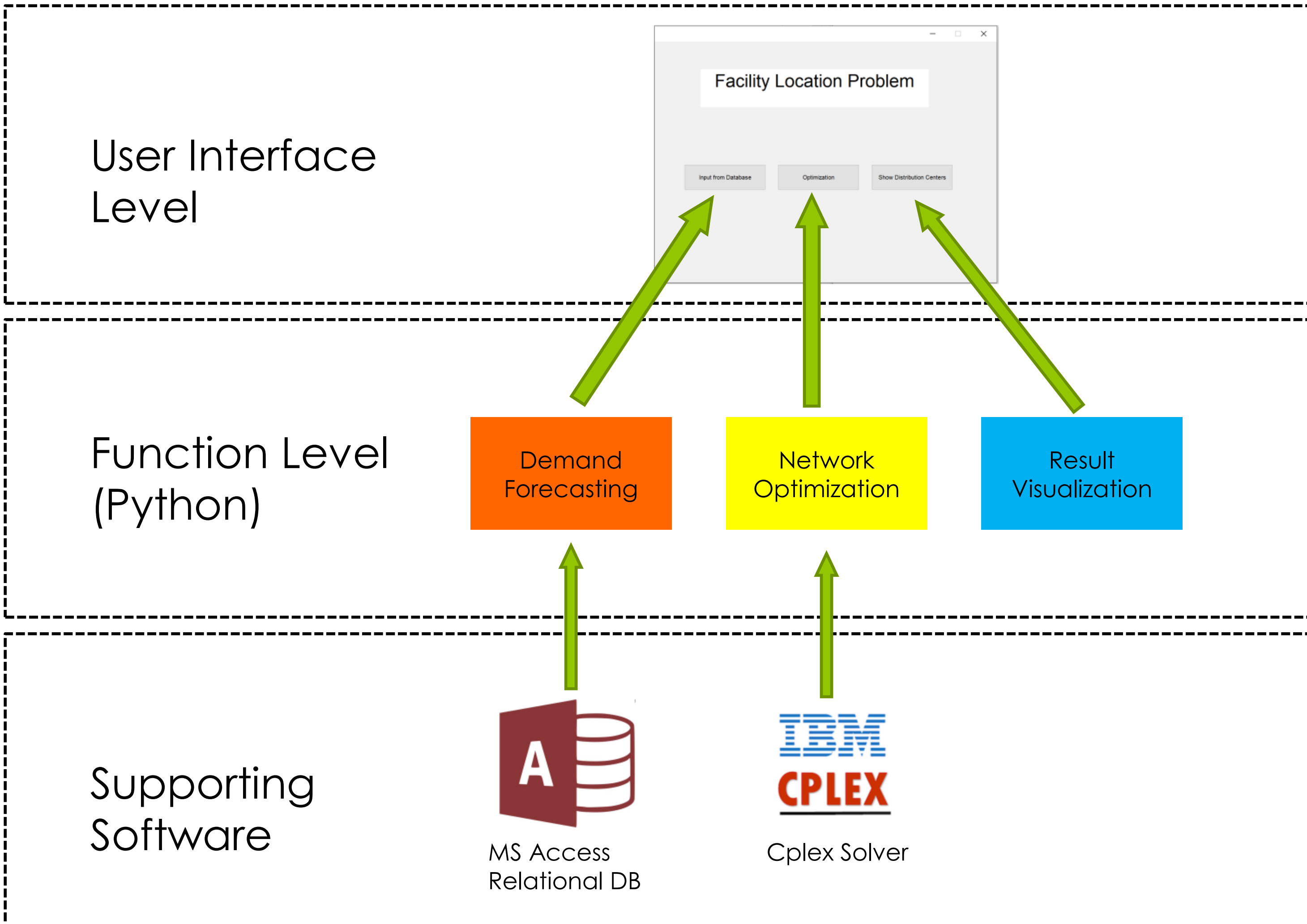
Activities:
1. Sell clothes to the customers, demand need to be satisfied

Logistics Distribution Network - China Area

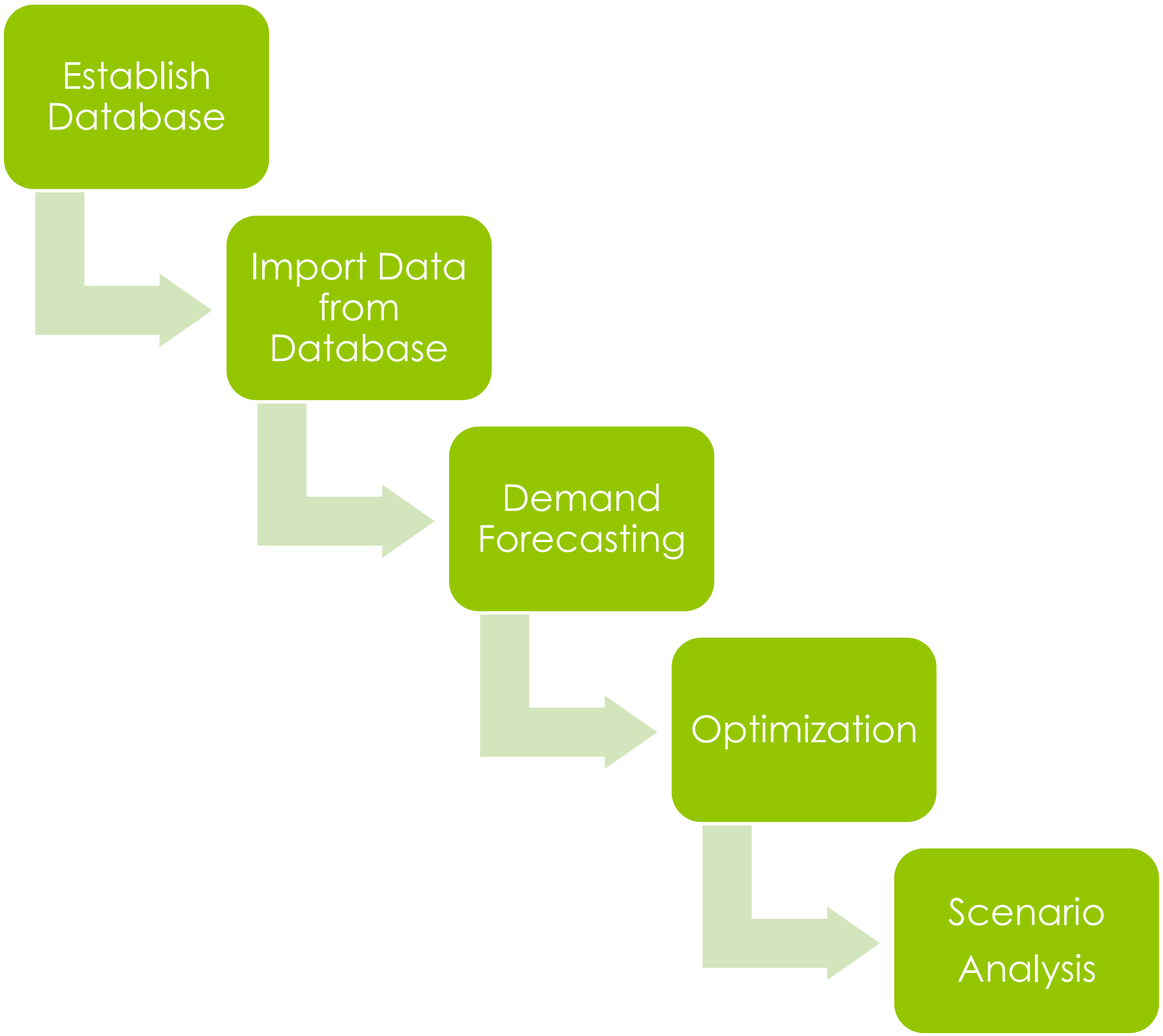
Our Goal

- Develop a toolbox with GUI, which is capable of:
  1. Forecast the monthly demand of each retailer in the next year based on the past data.
  2. Provide the monthly production plan for each plant.
  3. Provide the monthly inventory plan for each distribution center.
  4. Provide the monthly logistic network arrangement
     - Which DCs should be used
     - Shipment quantity between plants-DCs-retailers

Structure of the Toolkit

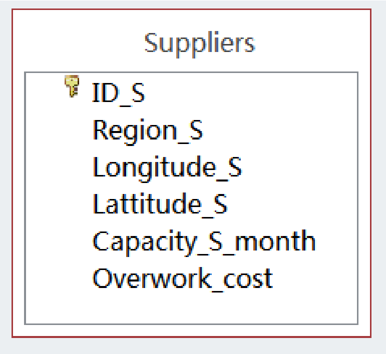


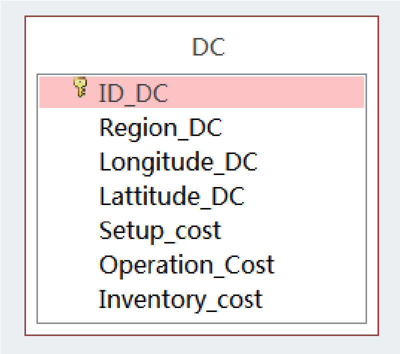
How to use the toolbox

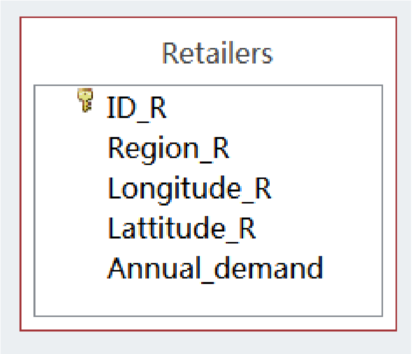


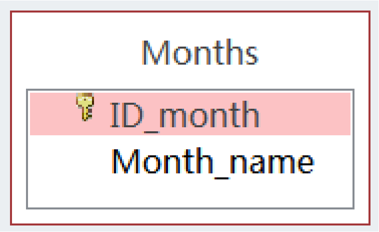
Database Development

- Entities



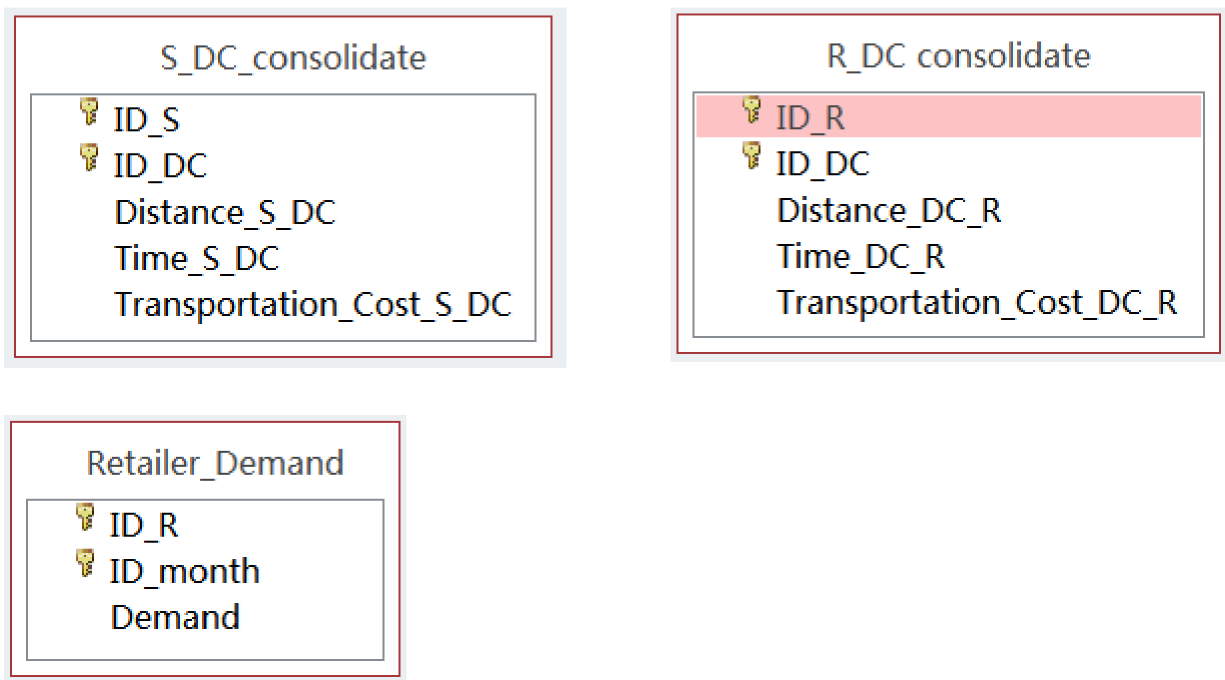






Database Development

- Relations



Database Development

- Tables for output

R_DC_Shipment
- ID_R
- ID_DC
- ID_month
- quantity

S_DC_Shipment
- ID_S
- ID_DC
- ID_month
- quantity

Production_Schedule
- ID_S
- ID_month
- overtime workforce

DC_Inventory
- ID_DC
- ID_month
- Inventory

Demand Forecasting

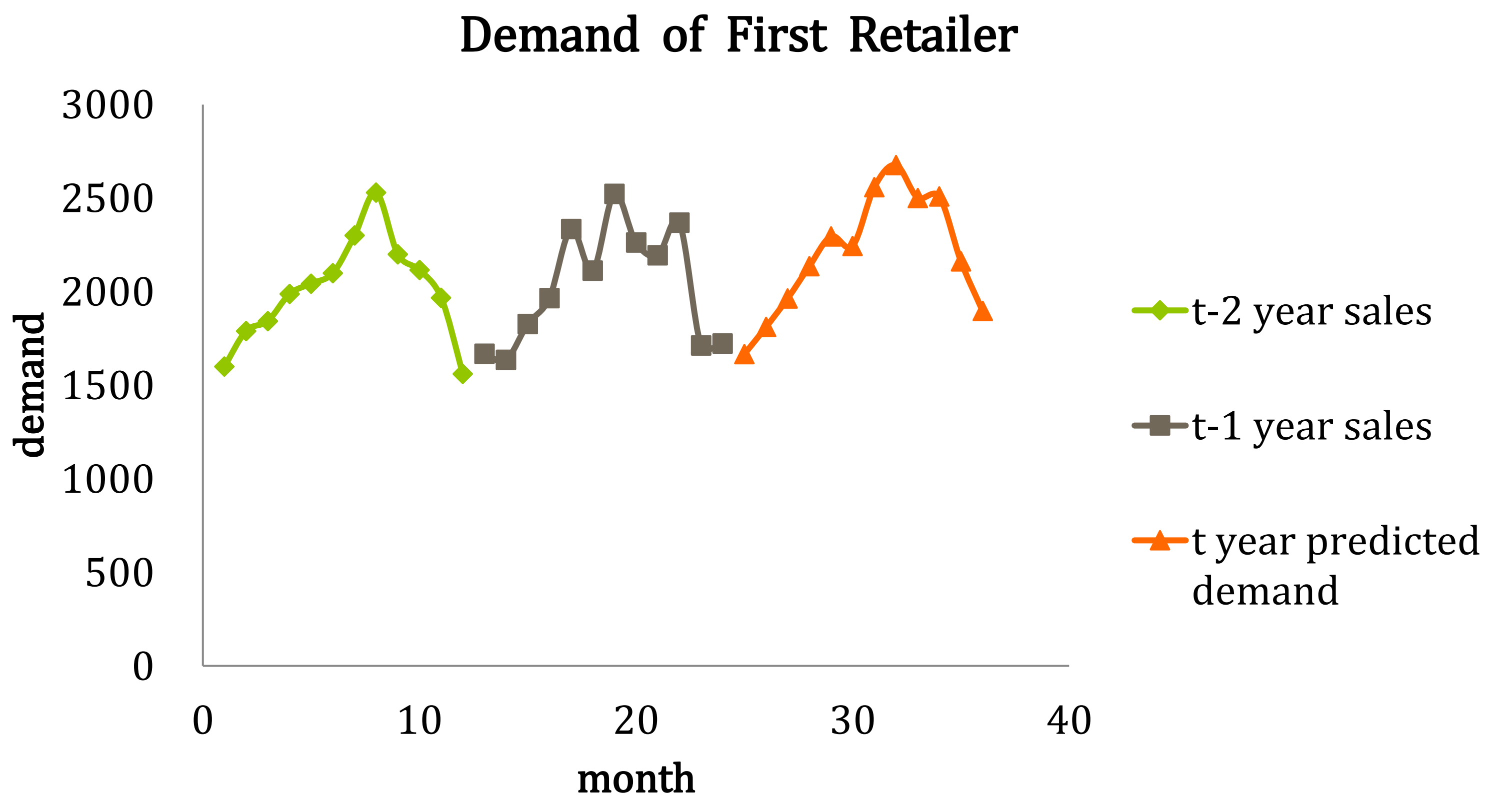
Winter's Method

1. Input last 2 years sales data
2. Use sales of (t-2) year to predict demand of (t-1) year
3. Get new seasonality factor for (t-1) year
4. Predict t year demand

Monthly Data

Demand Forecasting

Example



Optimization Model

- Objection
  1. Minimize the total cost
  2. Minimize the total weighted time
- Basic assumption
  1. The company will gain profit as long as the retailers' demand must be satisfied
  2. The basic workforce cost is fixed no matter how much merchandise was produced.
  3. There is no limitation on the transportation capacity.
  4. No initial inventory.

Optimization Model

- Sets

S	set of suppliers
R	set of retailers
D	set of DC candidates
T	set of time periods

- Variables

$shipSD_{s,d}^{t}$	shipments between supplier s and DC d at time period t, $\forall s \in S, \forall d \in D, \forall t \in T$
$shipRD_{r,d}^{t}$	shipments between retailer r and DC d at time period t, $,\forall r \in R, \forall d \in D, \forall t \in T$
$extraCap_{s}^{t}$	products produced in overwork time at supplier s during time period t, $\forall s \in S, \forall t \in T$
$invtD_{d}^{t}$	products inventory at DC d at the end of time period t, $\forall d \in D, \forall t \in T$
$selectD_{d}$	binary. Equals to 1 if DC d is selected, $\forall d \in D$

Optimization Model

- Parameters

$tpSCost_{s,d}$	transportation cost per unit freight per distance from supplier s to DC d, $\forall s \in S, \forall d \in D$
$tpRCost_{r,d}$	transportation cost per unit freight per distance from retailer r to DC d, $\forall s \in S, \forall d \in D$
$exCost_s$	extra production cost per unit freight when produced during overtime at supplier s, $\forall s \in S$
$stCost_d$	setup cost of DC $d, \forall d \in D$
$opCost_d$	operational cost of DC $d, \forall d \in D$
$invtCost_d$	inventory cost per unit freight per month at DC d, $\forall d \in D$
Cap_s	capacity of supplier s monthly, $\forall s \in S$
Dmd_r^t	demand of retailed r at time period t, $\forall r \in R, t \in T$
$distSD_{s,d}$	distance between supplier s and DC $d, \forall s \in S, \forall d \in D$
$distRD_{r,d}$	distance between retailer s and DC $d, \forall r \in R, \forall d \in D$
$timeSD_{s,d}$	Traffic time needed between supplier s and DC $d, \forall s \in S, \forall d \in D$
$timeRD_{r,d}$	Traffic time needed between retailer r and DC $d, \forall r \in R, \forall d \in D$

Optimization Model

- Constraints

Supplier Capacity

$$\sum_{d \in D} shipSD_{s,d}^{t} \leq Cap_s + extraCap_s^t \quad \forall s \in S, t \in T$$

Overtime limitation

$$extraCap_s^t \leq \frac{1}{2} \cdot Cap_s \quad \forall s \in S, t \in T$$

$$\sum_{t} extraCap_s^t \leq 2 \cdot Cap_s \quad \forall s \in S$$

Demand Requirement

$$\sum_{d \in D} shipRD_{s,d}^{t} \geq Dmd_r^t \quad \forall r \in R, t \in T$$

DC Balance

$$\sum_{s \in S} shipSD_{s,d}^{t} + invt_d^{t-1} = \sum_{r \in R} shipRD_{r,d}^{t} + invt_d^t \quad \forall d \in D, t \in T$$

DC select

$$\sum_{t \in T} \sum_{s \in S} shipSD_{s,d}^{t} \leq M \cdot selectD_d$$

Optimization Model

- Objective Function

$$totalTpCost = \sum_{t \in T} \sum_{s \in S} \sum_{d \in D} tpSCost_{s,d} \cdot distSD_{s,d} \cdot shipSD_{s,d}^{t} + \sum_{t \in T} \sum_{r \in R} \sum_{d \in D} tpRCost_{r,d} \cdot distRD_{r,d} \cdot shipRD_{s,d}^{t}$$

$$totalDcCost = \sum_{t \in T} \sum_{d \in D} \sum_{r \in R} opCost_{d} \cdot shipRD_{r,d}^{t} + \sum_{t \in T} \sum_{d \in D} invtCost_{d} \cdot invtD_{d}^{t} + \sum_{d \in D} stCost_{d} \cdot selectD_{d}$$

$$extraProdCost = \sum_{t \in T} \sum_{s \in S} exCost_{s} \cdot extraCap_{s}^{t}$$

$$totalTime = \sum_{t \in T} \sum_{s \in S} \sum_{d \in D} timeSD_{s,d} \cdot shipSD_{s,d}^{t} + \sum_{t \in T} \sum_{r \in R} \sum_{d \in D} timeRD_{r,d} \cdot shipRD_{s,d}^{t}$$

$$\min \lambda \cdot (totalTpCost + totalDcCost + extraProdCost) + (1 - \lambda) \cdot totalTime$$

Optimization Model

- Implementation
  - Python + CPLEX
  - Use NetworkX package to represent the network structure
  - Use Numpy for matrix representation

Scenario Analysis

Cost Item	Original Situation	2 x Capacity	10 x stCost
Total Cost	1.6313e+08	1.2846e+08	1.6876e+08
Total Transportation Cost	0.6490e+08	0.5045e+08	0.6696e+08
Total Operational Cost	0.7577e+08	0.7577e+08	0.7577e+08
Total Fixed Cost	0.0089e+08	0.0097e+08	0.0045e+08

Distribution Center	Original Situation	2 x Capacity	10 x stCost
Shanghai	1	1	1
Guangdong	1	1	1
Shenyang	1	1	0
Tianjin	1	1	1
Henan	1	1	0
Hunan	1	1	0
Shenzhen	1	1	0
Xinjiang	0	0	0
Hubei	1	1	1
Gansu	0	0	0
Fujian	1	1	1
Jiangsu	1	1	0
Dalian	1	1	1
Sichuan	0	1	0
Yunan	1	1	0
Shandong	0	0	0
Shanxi	0	0	0

Summary

- Database leveraged for data storage
- Winter’s method used for forecasting
- Optimization model established to solve problem
- User interface built for function integration
- Flexible scenario analysis

Thank you

Group 4

Fenglin Fan
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