IMPROVING SUPPLY CHAIN MANAGEMENT OF A MULTI-ECHELON DISTRIBUTION SYSTEM

Department of Industrial Systems Engineering and Management
IE3100M Systems Design Project
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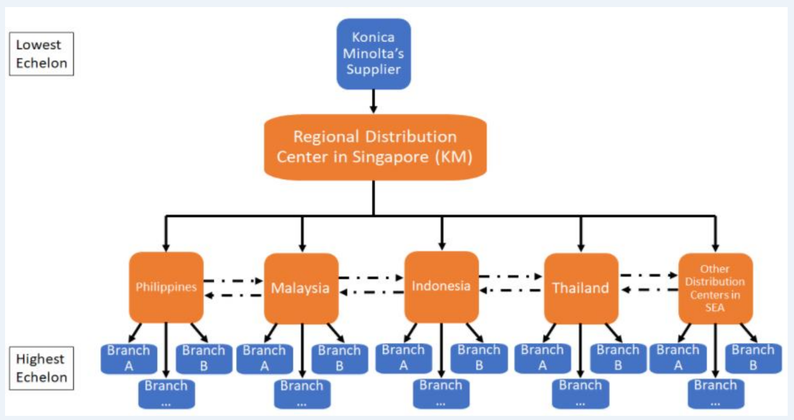
1. Project Description

Konica Minolta Business Solutions Asia Pte Ltd (KM) is part of Konica Minolta Incorporated, a Japanese technology company which specializes in advanced document management technologies and print solutions. The company adopts a multi-echelon distribution system for its supply chain management.

What is a Multi-Echelon Distribution System?

- Manages the entire supply network as a "pool," rather than as a group of independent locations.
- New inventory shipments are first stored at a central/ regional distribution center (RDC) which are the internal suppliers to the forward distribution centers (DCs) which in turn supply goods to individual branches.
- Forecasts are usually made in the lowest echelon and the echelons above benefit from that.



Core Problem

To maintain the company's vision of maintaining a high level of customer satisfaction and order fulfilment, KM has adopted an Order Up-to Level (OUTL) approach for its inventory management. However, as the company continues to expand its businesses, the OUTL approach poses great problems and burdens to its multi-echelon distribution system.

In times of declining demand in some branches for consecutive months

1. Unresponsive to changes
2. Unnecessary inventory costs
3. Inventory Obsolescence
4. New orders continuously being made from some branches due to lack of communication

→ Lower profits, Lower efficiency

Project Scope

- Focus on service parts and consumables.
- Available data from Thailand and Malaysia.

2. Project Objectives & Key Skillsets

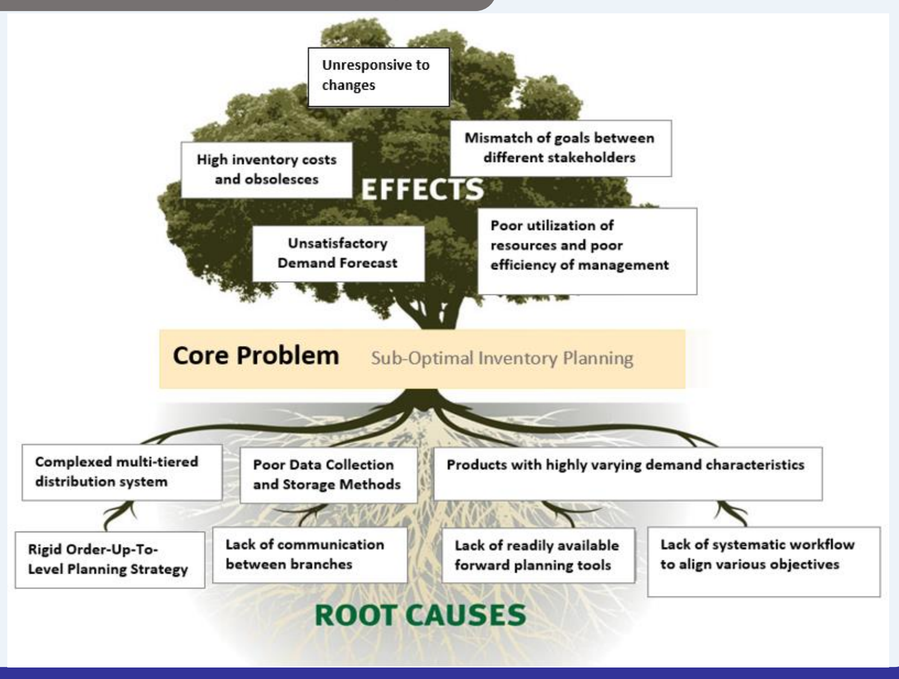
Objectives

1. Reduce inventory obsolescence while maintaining high customer satisfaction.
2. To improve inventory management at branch level.
3. Develop a tool that assists forward planning of inventory levels in a systematic way.
4. Incorporate great usability, flexibility and portability in the tool so that KM can adapt to suit future needs.

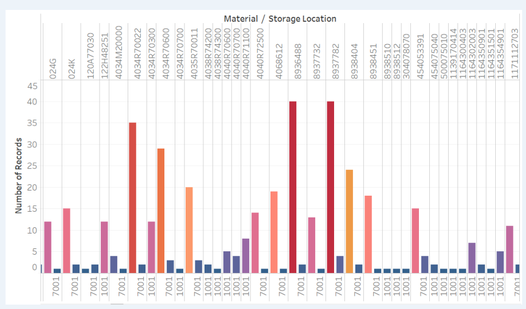
Key Skillsets

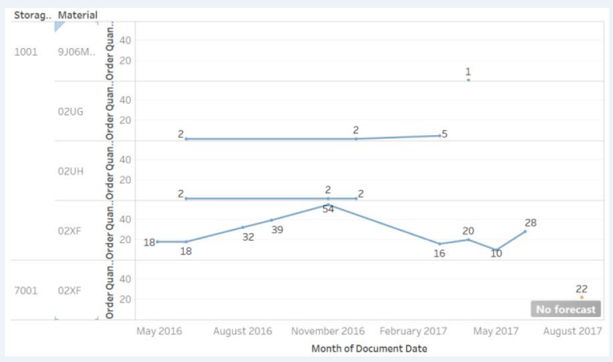
- Project Management: breakdowns the complexed problem into subproblems for ease of analysis.
- Data Visualization: Understanding of data and identification of assumptions and limitations.
- Supply Chain Management: Demand Forecasting, Cross validation and Accuracy Prediction.
- Operations Research: Linear Programming and Optimisation of distribution of SKUs.
- Software Engineering: App Development and Database Management

3. Root-Cause Analysis



4. Data Visualisation





A7Y003D	5.0		2.0
A8A6PP0000	1.0		
A8DA190	141.0	150.0	266.0
A8DA290	71.1	136.5	72.0
A8DA390	66.9	136.5	70.0
A8DA490	70.8	136.5	77.0
A8H40RD	2.0		
A8H403D	1.0		
A8H5050	7.2	8.0	12.0
A8JJWY1	2.3		4.0
A8K3190	81.6	56.0	98.0
A8K3290	45.1	42.0	68.0
A8K3390	44.6	42.0	68.0
A8K3490	44.8	42.0	68.0
A9C80ED	2.0		
A9C80KD	2.0		
A9C803D	2.0		

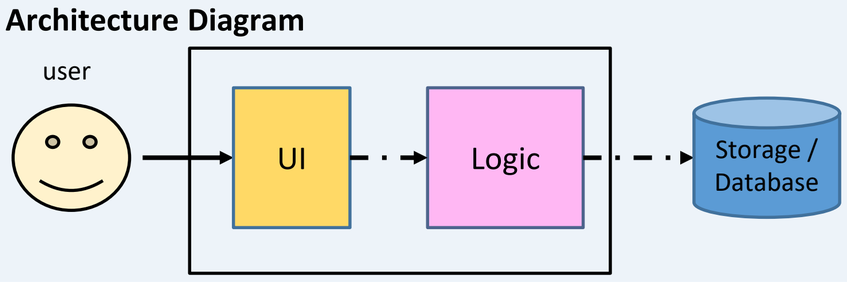
Insights:

- Demand data exhibits highly varying characteristics (stable, fluctuating, rare occurrences) for different branches over recorded time period.
- Data are highly aggregated, lack of specific characteristics (e.g. demand types –walk in, repair, regular)
- Limited data available (only around 1 year of data) → complexed algorithms may not work well

5.Methodology

Create an inventory re-planning desktop application that will forecast SKU demand at each branch and redistribute excess SKUs among branches. Data will also be stored in database server for a centralised control and management which helps to facilitate sharing of information among branches.

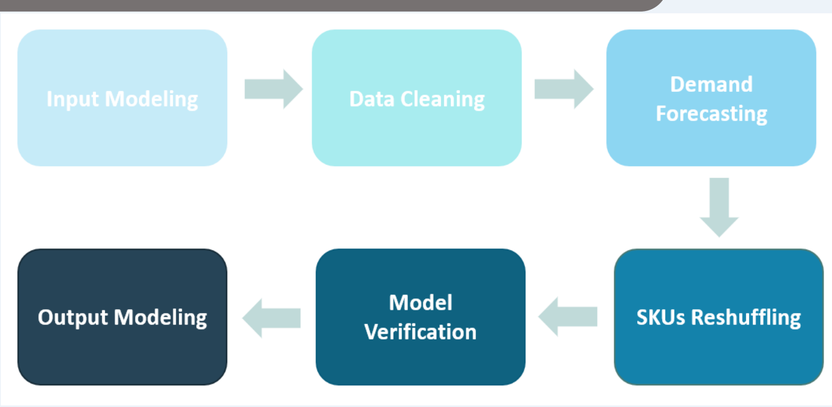
Architecture Diagram



(Software)

- Visual Studio (app development)
- R Programming (forecast)
- Visual Basic (backend processing)
- Microsoft SQL Server (database)

6.Logic Flowchart of Model



1. Input Modeling: Upload historicical demand and inventory data excel files into database and specify planning time period.
2. Data Cleaning: Extract, sort and mapped relevant data into desired formats for manipulations.
3. Demand Forecasting: Fit appropriate time series forecast model. Cross validate to obtain accuracy/error value.
4. SKUs Reshuffling: Optimise and redistribute excess SKUs among branches
5. Model Verification: Validate model with historical data.
6. Output Modeling: Display the results of the reshuffling and other relevant details in a clear and intuitive manner.

Assumptions & Limitations

- Demand for SKUs is stochastic.
- Constant lead time
- Costs of transportation between branches are negligible in comparison to the savings from reshuffling.

7. Detailed Approaches/Procedures

Demand Forecasting

- Algorithms used are auto.arima, ets and prophet.
- Ability to decompose data into trend, seasonal and residuals components.
- Do not require substantial assumption of params.
- Cross validated to obtain Mean Absolute Error (MAE).

SKUs Reshuffling

- Linear optimization model
- Redistribute excess SKUs among branches after factoring fulfilment of indiv's demand for next two months.
- Min new order → Min inventory obsol.

N_i is new orders made from branch i

A_i is available stocks at branch i

I_i is current level of inventory at branch i

D_{i1} is upcoming demand at branch i, D_{i2} is next month demand at branch i

Rij is amount of stocks shuffle from branch i to j

$$\text{Min} \quad \sum N_i$$

$$\text{s.t.} \quad A_i = I_i - D_{i1} - D_{i2} \qquad \forall i$$

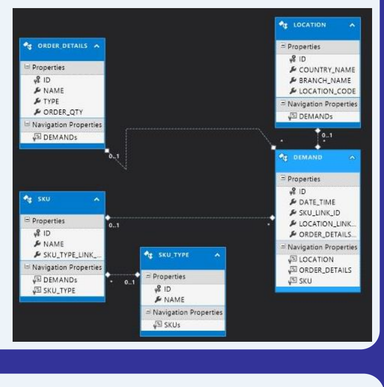
$$\text{if } A_i \le 0 \text{ then } Rij = 0 \qquad \forall i,j$$

$$\text{if } R_{ij} \ge 0 \text{ then } R_{ji} = 0 \qquad \forall i,j$$

$$N_i = \max(0, D_{i1} + \sum_j Rij - \sum_j R_{ji} - I_i) \qquad \forall i$$

Database Management

- Centralised server created on MSSQL.
- Ability to use Entity Framework
- Object Relational Mapping for structured organization of data
- Facilitates storage and transfer of data, enhance coordination between branches.



8. Result Analysis

SKU Code: 000V-19-0
Period: 12-2017

Location Code (from/to)	Error Prediction (MAE)	1001	1005	1014	7001	8001
1001	0.8	0	10	0	0	0
1005	1.2	0	0	0	0	0
1014	0.68	0	0	0	0	2
7001	1.35	0	0	0	0	5
8001	0.74	0	0	0	0	0
New Orders		0	3	0	0	0

SKU Code: 024G
Period: 12-2017

Location Code (from/to)	Error Prediction (MAE)	1001	1005	1014	7001	8001
1001	1.54	0	5	0	23	0
1005	0.79	0	0	0	0	0
1014	0.98	0	0	0	0	0
7001	1.21	0	0	0	0	0
8001	0.73	0	0	0	0	0
New Orders		0	0	0	0	0

- Details the no. of units to be taken in or shuffled out from each branch for the different SKUs.
- Anomaly data highlighted to provide greater managerial insights.
- Accuracy of model is validated using historic data from Malaysia and Indonesia, results points to at least 70% accuracy and 15% reduction in new orders to be placed.

9. Future Directions

1. Incorporate better, more robust forecasting method/algorithms when more complete data are available.
2. Scale to include to other regions such as the Philippines, Indonesia or out of Asia etc.