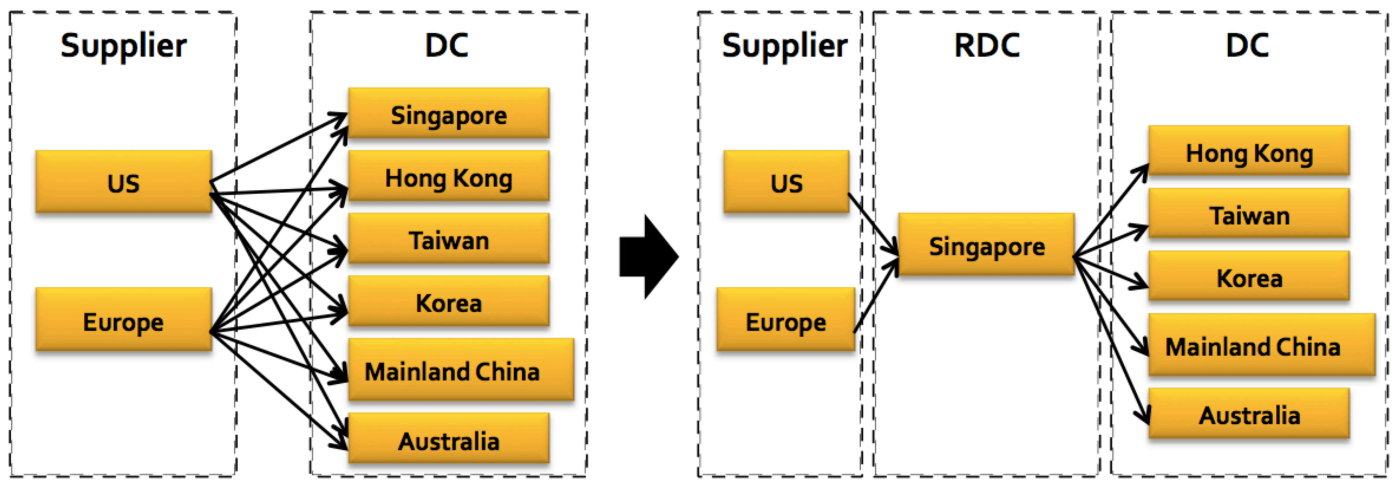
IE3100R System Design Project, Department of Industrial & System Engineering

Improving the Safety Stock Planning Strategy for a Multi-Echelon Distributive System

1. Problem Definition

BD has restructured its supply chain from a single-echelon serial system to a multi-echelon distributive system with Singapore functioning as a Regional Distribution Center (RDC) as shown:



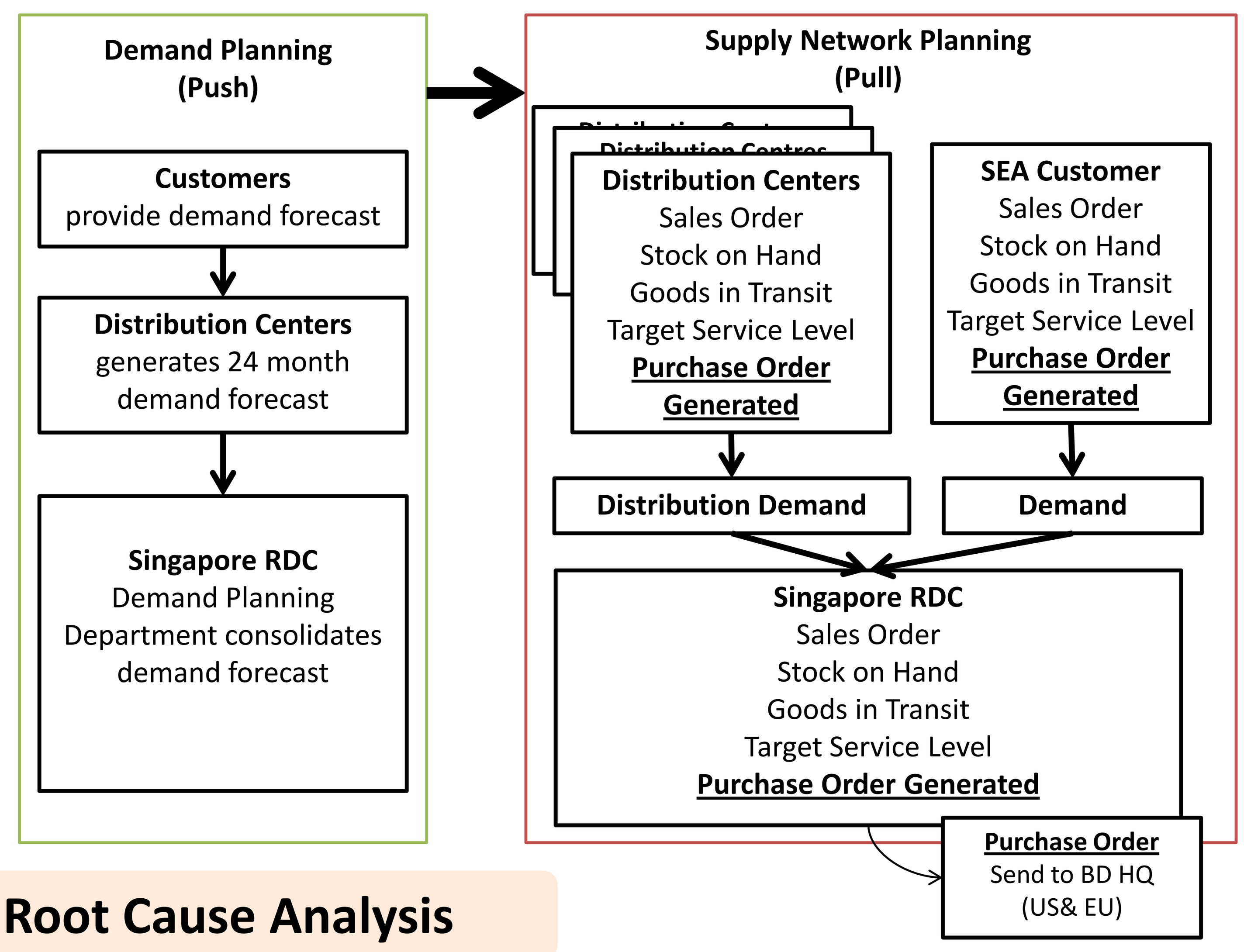
Despite the decrease of supply lead time, BD has not seen a decrease in the safety stock levels at the downstream Distribution Centers (DC) after one year implementation of the Singapore RDC.

2. Project Objectives

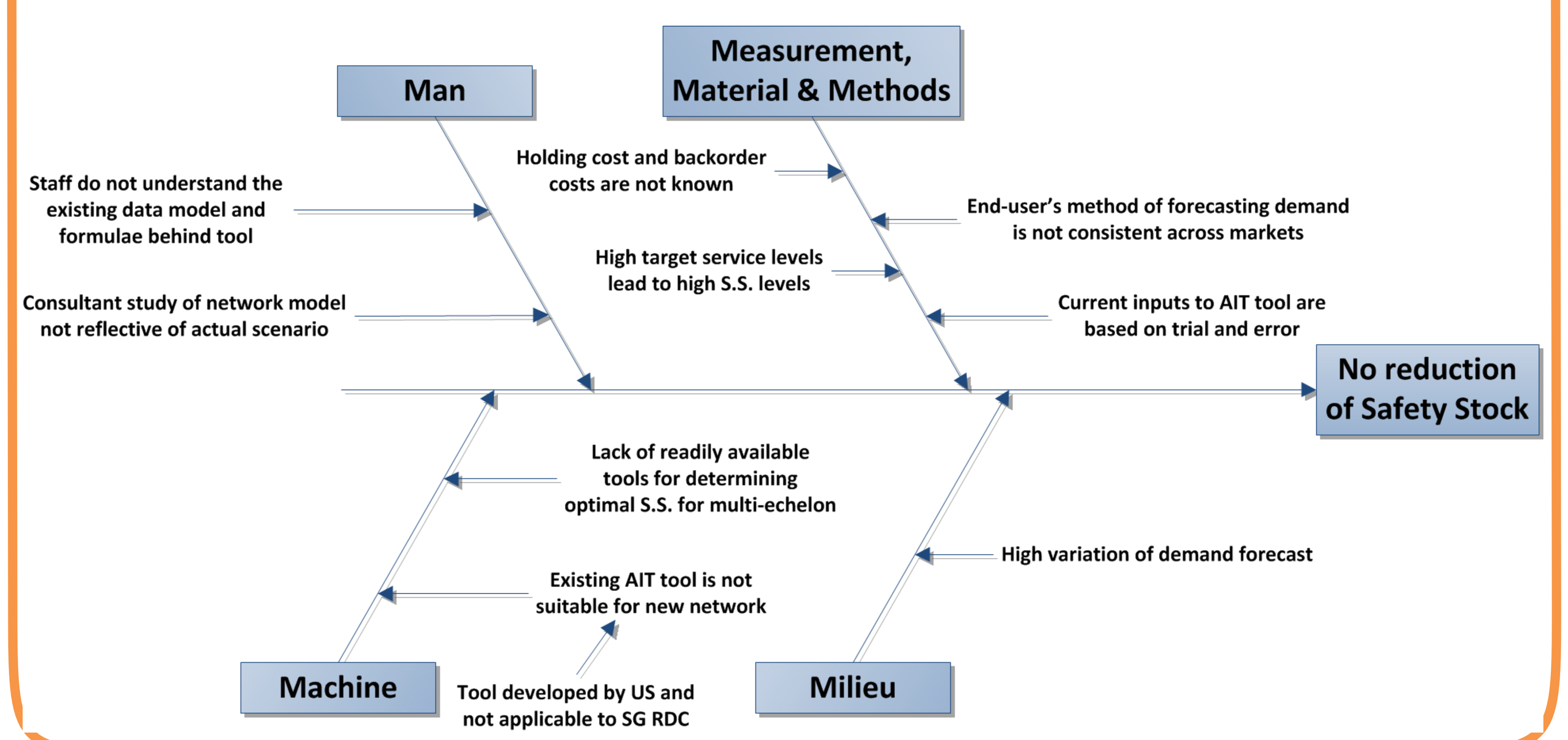
- Systems study of BD Supply Chain for Asia Pacific Region
- Identify obstacles that prevent BD from achieving full benefits of Multi-Echelon Distributive System
- Propose solution to lower safety stocks across all DCs

3. Methodology

Understand BD's Business Process



Root Cause Analysis



4. Recommendations

- Develop a supply planning tool cater to the new multi-echelon system ★
- Help BD supply planning staff to have a better understanding of multi-echelon system ★
- Develop inventory dashboard to monitor and track inventory levels

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5. Supply Planning Tool Development

Old Supply Planning Tool

Reorder Point Model w/ Safety Stock(example)

Element Type	Element	Value
Planner Input	Rolling 12 months Demand	16,800,000
Planner Input	Case Fill Target(in %)	70%
Planner Input	Demand Variability (i.e Forecast Error in %)	20%
Planner Input	Transit Lead Time	49
Planner Input	Supply Reliability Factor (% of shipments where supplier misses the delivery schedule)	80%
Calculations	Monthly Std. Dev (Phy Cs)	280000
Calculations	G(k)	2.57196
Calculations	k Factor	(2.57)
Results/Output	Reorder point (/Target Stock)	1,366,935
Results/Output	DSI Target (Days)	29

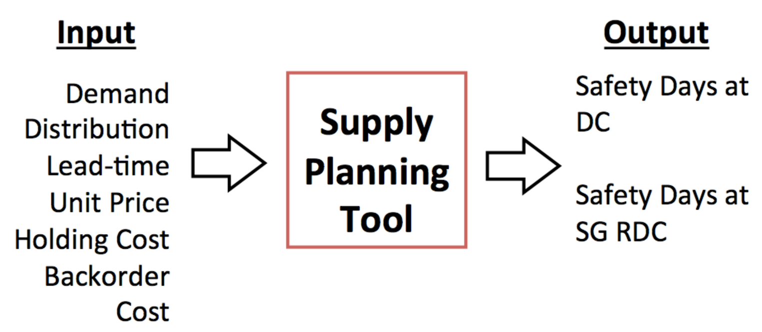
Problems with the old tool

- Only cater to single echelon serial system
- Assumption of lead time is shorter than the replenishment cycle time,which is not true in reality

New Supply Planning Tool

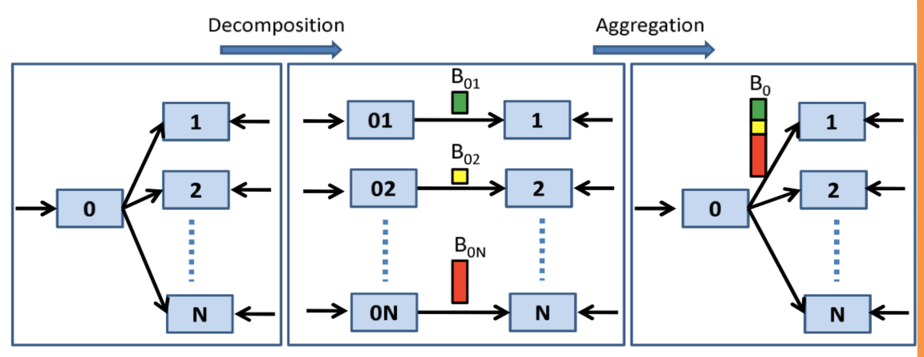
A pilot tool was developed in MS Excel using the Decomposition-Aggregation (DA) heuristics to calculate the safety stock levels required at each DC. DA heuristics is used as it takes advantage of the risk pooling effect.

Tool Functionality:

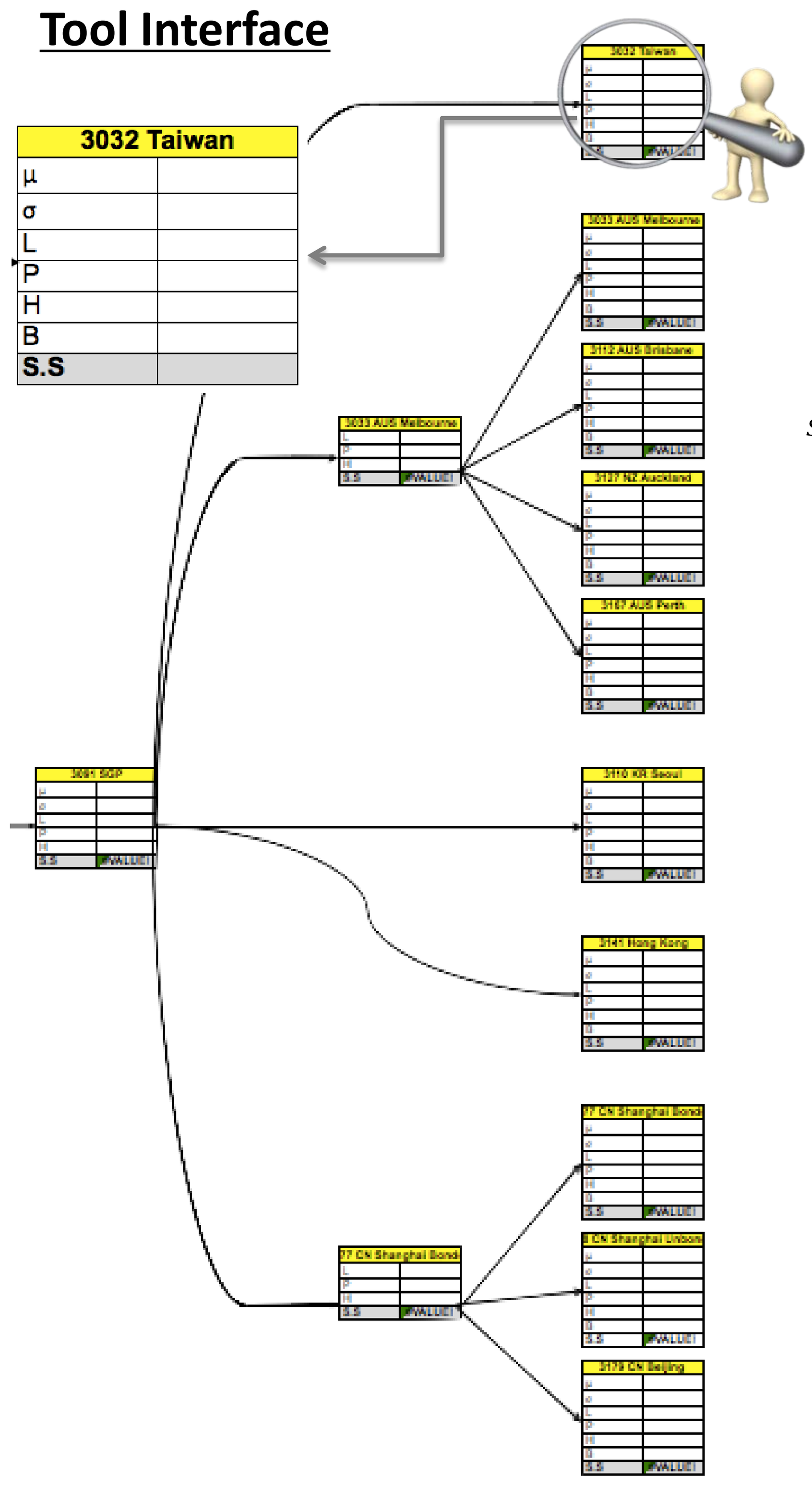


Mathematical Methodology

Decomposition-Aggregation (DA) Heuristic



Tool Interface



Step 1: Decompose distribution system into multiple serial systems

Step 2: Find optimal safety-stock levels of each serial system using newsvendor approximation

$$S_{i_w}^{SS} = \begin{cases} F_{\breve{D}_{i_w}}^{-1}\left(\dfrac{b_i + \sum_{j\epsilon\mathcal{A}(0,\mathcal{P}(i))} H_j}{b_i + \sum_{j\epsilon\mathcal{A}(0,i)} H_j}\right), i\epsilon\mathcal{L} \\ \dfrac{1}{2}\left[F_{\breve{D}_{i_w}}^{-1}\left(\dfrac{b_{\ell_w} + \sum_{j\epsilon\mathcal{A}(0,\mathcal{P}(i))} H_j}{b_{\ell_w} + \sum_{j\epsilon w} H_j}\right) + G_{\breve{D}_{i_w}}^{-1}\left(\dfrac{b_{\ell_w} + \sum_{j\epsilon\mathcal{A}(0,\mathcal{P}(i))} H_j}{b_{\ell_w} + \sum_{j\epsilon\mathcal{A}(0,i)} H_j}\right)\right] \end{cases}$$

Step 3: Aggregate non-leaf locations using 'backorder matching' to obtain optimal safety stock:

(b) Calculate expected backorder of each non-leaf location from the serial systems

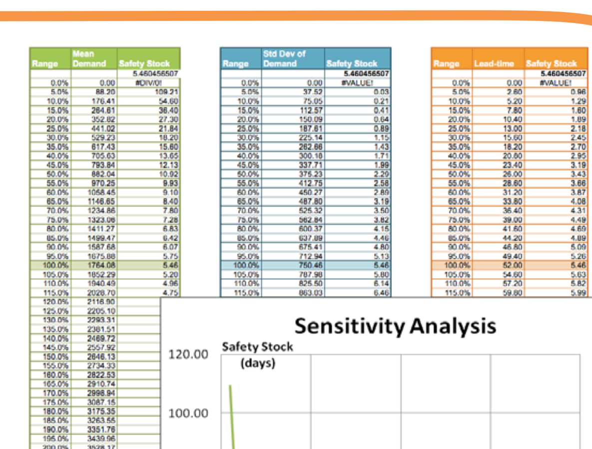
$$\mathbb{E}[B_{i_w}] = \mathbb{E}\left[\left(D_{i_w} - s_{i_w}^d\right)^+\right] = Q_{D_{i_w}}\left(s_{i_w}^d\right)$$

(b) For each non-lead location, sum the expected backorder from the serial systems. Using the total expected backorder, find the safety stock necessary to prevent the backorder from occurring

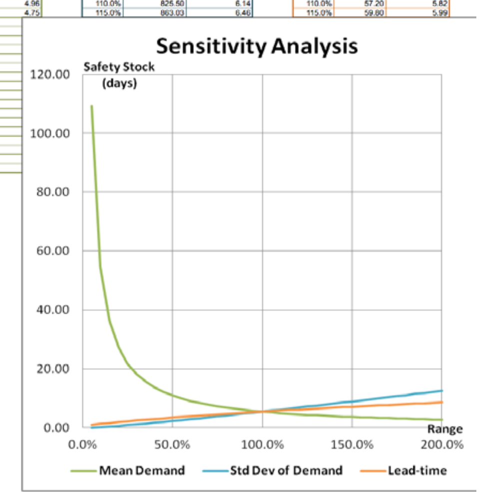
$$s_i^d = Q_{D_i}^{-1}\left(\sum_{w\epsilon p:i\epsilon w} Q_{D_{i_w}}\left(s_{i_w}^d\right)\right)$$

6. Sensitivity Analysis

Sensitivity analysis of safety stock* with input variables varying from 0% to 200% of the base value:

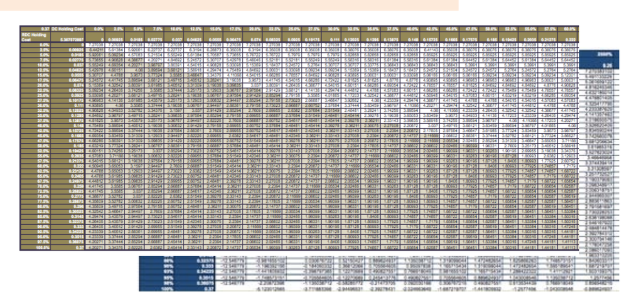


Sensitivity Analysis of Demand, Standard Deviation and Lead Time



- Safety stock is more sensitive to mean daily demand especially when demand is low: mean demand changes from 0% to 50%, safety stock reduce 90%; Larger demand can smoothen the fluctuation and reduce safety stock
- Larger standard deviation of demand, higher safety stock
- Longer lead time, higher safety stock

Sensitivity Analysis of Holding Cost and Backorder Cost



- When RDC experiences more holding cost than downstream DCs, more inventory would be held at DCs to reduce overall cost, and vise versa
- Safety stock is insensitive to backorder cost

* *Safety stock is measured in days, referring to the units of safety stock divided by daily average demand.*