Optimizing Inventory for a Multiechelon Supply Chain

EXECUTIVE SUMMARY

by

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Research Motivation

Nowadays, due to increased global economic cooperation and increasingly fierce competition, considerable special focus has been placed on supply chain management. Modern supply chain management and market competitions have compelled companies to reduce or eliminate high inventory levels and make continual improvement in the design & operations of their supply chain networks, which needs to be supported by high performance of warehouses. The inventory problem that has a significant impact on a supply chain's long term performance has become one critical decision for the whole supply chain system especially due to time-varying demand.

Historically, various echelons in supply chain have been buffered by large inventories, warehouse being one of them. Inventory usually constitutes about a large percentage of the total assests of manufacturing firms. Therefore, firms focus on multiechelon inventory management and supply chain network design to reduce their overall costs and to meet customer demand with required levels of service. The aim of this research is to analyze the multiechelon inventory system of Barry Callebaut for developing a better insight so as to serve the customer in a better manner and to accommodate the increased demand while maintaining operational efficiency. In the research, a simulation model for the design of multiechelon supply chain network is developed.

Barry Callebaut provides the entire food manufacturing industry with a wide range of cocoa and chocolate products, ready-to-use fillings and decorations, coatings and cocoa powders. Without cocoa, there can be no chocolate. So for Barry Callebaut, working to ensure a sustainable cocoa supply chain is an imperative, not an option. Barry Callebaut (BC) has a warehouse inventory problem as shown in Figure 1.

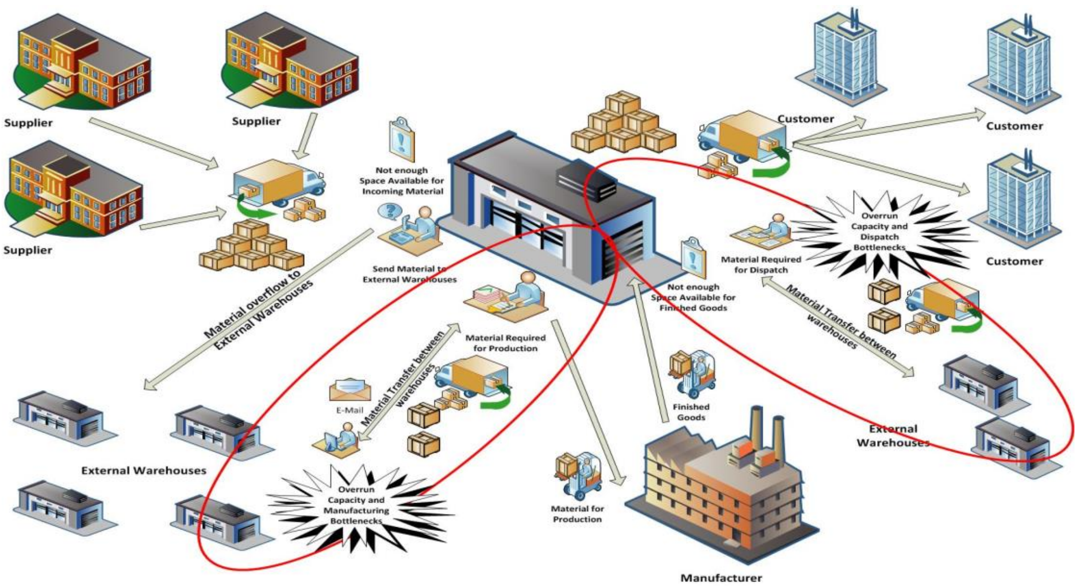

Figure 1: Barry Callebaut Warehouse Material Flow

The multiechelon system and high demand volatility combined together make inventory management for Barry Callebaut extremely difficult. Inventory is often managed on supply chain managers experience and intuition, which is by nature subject to human error. The warehouse receives and stores Raw Materials (RM), Packaging Materials (PM) and Finished Goods (FG). E.g. Cocoa, Sugar, CFC, Cocoa Mass, Cocoa Butter. Barry Callebaut rents other warehouses (3-5) to manage its supply chain. The manufacturing plant requires cocoa to come from the Barry Callebaut owned warehouse. This requires movement of materials between the warehouses, which are met by over run capacity, bottlenecks and a sub optimal inventory policy.

<u>Multiechelon System</u>

Most of the manufacturing firms comprises of networks of manufacturing and distribution facilities that procure raw material, converts them into finished goods and distribute the finished goods to customers. The term 'multiechelon' manufacturing and distribution networks are synonymous with such networks. The places where inventory is kept in the supply chain are called "echelons". Usually the complexity of a supply chain is related to the number of echelons inside it. Supply chain networks having multiple layers of inventory locations are referred to as multiechelon supply chains.

The most important factor in supply chain design is how to efficiently deal with uncertainty. The various sources of uncertainty in supply chains are suppliers (e.g., delayed delivery), manufacturing (e.g., machine breakdown), and customers (e.g., uncertain demand). Supply chain uncertainty refers to decision making situations in the supply chain in which the decision maker does not know definitely what to decide as he is indistinct about the objectives; lacks information about (or understanding of) the supply chain or its environment; lacks information processing capacities; is unable to accurately predict the impact of possible control actions on supply chain behavior; or, lacks effective control actions (non-controllability)". Addressing variability within supply chains is important because of its negative impact on firm performance (due to direct costs and opportunity costs) and its potential amplification within the firm and across firms.

The most common and important source of variability is the demand variability since the order pattern followed by the customer is very difficult to predict and is mostly very uncertain. Therefore, most of the manufacturing firms try to maintain different level of safety stocks to satisfy different types of demand. While the demand orders received by the manufacturer are usually the result of a replenishment policy, the supplier orders placed by manufacturer are also done using some replenishment policy.

Multiechelon inventory systems are important to large corporations to support their operation and the optimal deployment of inventory is a vital business function for a firm. The common phenomenon observed in the multiechelon inventory domain is the "bullwhip effect". According to Forrester , the "bullwhip effect" is the amplification of the demand variability moving towards upstream stages. Since the demand is always uncertain and the demand at an upstream stage mainly relies on the order from downstream stage, businesses must forecast demand in order to properly position inventory. Variability coupled with time delays in the transmission of information up the supply chain and time delays in manufacturing and shipping goods down the supply chain create the bullwhip effect and large amount of inventory in the system

The multiechelon inventory model is a discrete-event model; when an arrival event occurs i.e the customer demand arrives, it causes a change in the state variable that represents the inventory available at finished good storage location. This state variable and any other change its value when an event occurs, i.e., at discrete instants. The discrete event system simulation method has long been a useful tool for evaluating the performance of such a discrete system.

Research indicates that doing this by directly applying single-level approaches to multilevel problems can work poorly (Hauman,1994 and Muckstadt,1980). In order to make the mathematical model easy enough to obtain the solution, the analytical modeling of multiechelon inventory systems is limited to underlying mathematical assumptions. This provides motivation for special treatment of multiechelon supply chain. Fortunately, simulation turns out to be an ideal method for the evaluation of most of the systems with complex relationships among their members.

Inventory Replenishment Model

Figure 2 illustrates the inventory replenishment model for Barry Callebaut and the multiechelon supply chain of Barry Callebaut consisting of supplier & manufacturing plant which receives demand from customer. The manufacturing plant interacts with two buffer systems: an input buffer which stores incoming raw material and an output buffer which stores outgoing finished product.

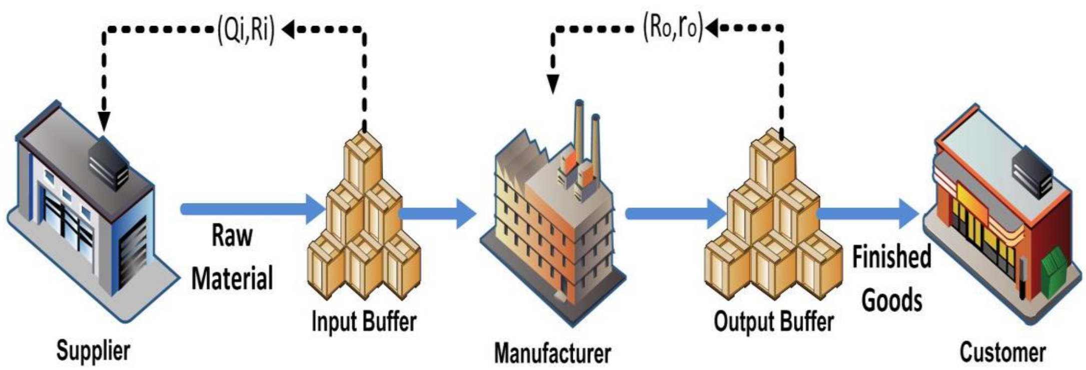

Figure 2: Multiechelon Supply Chain System Inventory Replenishment Model

The output buffer faces a customer demand stream, and to manage inventory, it uses a continuous-review (R, Q) control policy, based on demand received from the customer. As discussed earlier in section 2.2. under this policy, a replenishment of quantity R is ordered whenever the *Inventory* position (inventory on-hand plus outstanding orders minus backorders) down-crosses level Q. The unsatisfied portions of orders placed with the plant are backordered.

The plant manufacturing policy is a continuous-review (R_O, r_O) policy. The plant manufactures one product unit at a time, having consumed one unit of raw material from the input buffer. Note that shortages of raw material in the input buffer (starvation) will cause production stoppages. The input buffer, in turn, orders from an external supplier assumed to have unlimited inventories at all times, so the raw-material, lead time is limited to transportation delay, and the plant orders are always fully satisfied. The corresponding *Inventory* control policy is a continuous-review (Q_i, R_i) policy.

Analysis & Results

The various SKUs of different product families have different characteristics and contribution towards the profit of business. In order to take this into consideration, the SKU segmentation of the various SKUs of Barry Callebaut was carried out. The SKUs were segmented using ABC classification based on their values of the demand. Figure 3 illustrates the ABC segmentation of the SKUs.

Figure 3: ABC Segmentation of the SKUs.

Based on the segmentation we considered only the customer demand of A class products for simulation runs as they represented 80% of the customer sales by value.

The results of the simulation runs show that the outputs of the simulation of multiechelon inventory management model show the interdependency between various echelons of the supply chain. As demand increases, the average inventory levels deteriorate at the output buffer which is expected as the more amount of inventory is removed from output buffer to meet the demand while the manufacturing rate is constant. However, the inventory level of the input buffer does not show much variation because of the demand variability as shown in figure below.

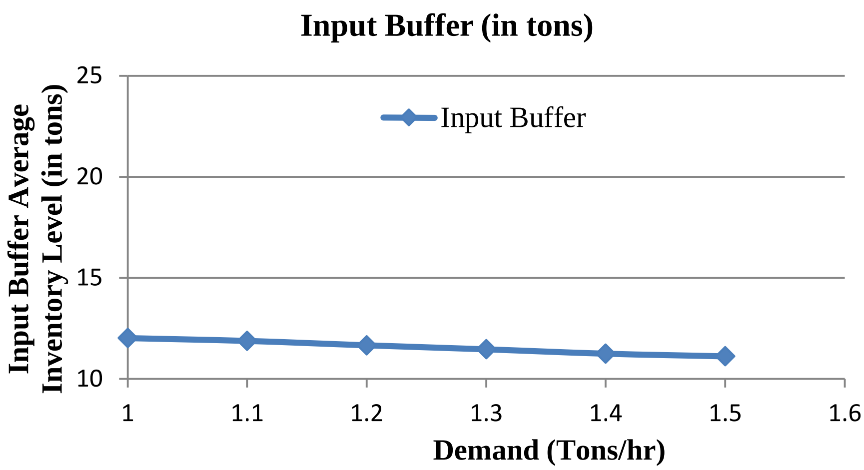

Figure 3: Input Buffer Avg. Inv. Level vs Demand

The results show that as the input buffer transportation lead time increases , it deteriorates the IFR and average inventory levels of both input buffer and output buffer considerably which results in an increase in backorders at the output buffer . Although the transportation lead time of four days keeps the input buffer at IFR above 90% but for four days input buffer transportation lead time the output IFR falls below the 90% service level.

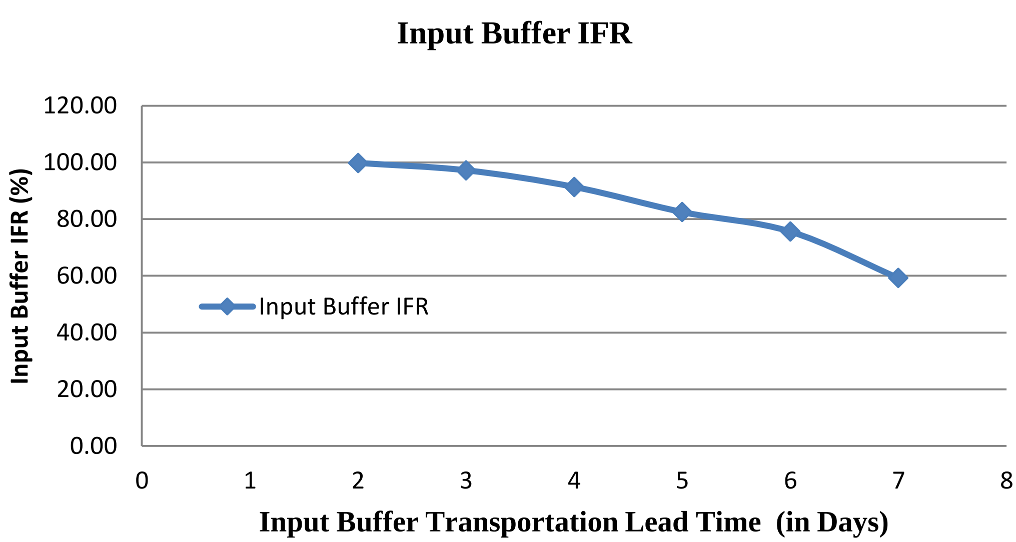

Figure 4: Input Buffer vs Input Buffer Transportation Lead Time

Hence, it is recommended that Barry Callebaut should try to keep the input buffer transportation lead time within the three day limit to keep IFR levels above 90% for both input and output buffer.

Summary

In this research , a simulation model is used to provide an insight into the necessity of inventory optimization in the multiechelon supply chain of Barry Callebaut. The research consists of multiechelon supply chain facing stochastic demand. In the first step , the SKUs based on the revenue by sales have been considered to carry out the SKU segmentation so as to focus on the customer demand of SKUs which are important for Barry Callebaut. In the second step, a simulation model was developed to analyze the multiechelon supply chain. In the third step, the results of the simulation model were analyzed to develop an insight to the multiechelon supply chain of Barry Callebaut.

Key Insights

The simulation model helped to develop the following insights from the multiechelon supply chain of Barry Callebaut facing stochastic customer demand:

- At the output buffer inventory, a slight increase in the demand deteriorates the customer service level at the output buffer considerably. This results in an increase in backorders. However, the demand variability does not cause any significant impact on the input buffer. This may be due to high input buffer level inventory. Therefore, further research needs to be carried out to investigate the reasons for same.

- At the input buffer inventory, an increase in transportation lead time impacts the input buffer inventory levels which results in deterioration of customer service level at output buffer and an increase in backorders at the output buffer . Hence the customer service level is sensitive to an increase in the transportation lead time. Hence, Barry Callebaut should work towards decreasing the transportation lead time as much as possible. The results show that for maintaining an approximate IFR of 90%, the transportation lead time should not be greater than three days.