Buffering Uncertainty in Supply and Demand with JMP® Analytics and Statistical Modeling

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INTRODUCTION

Inventory plays a key role in the operations behavior of virtually all manufacturing systems. It serves as an effective way to buffer variability in a supply chain. There are many mathematical modeling approaches to inventory control in operational management. For example, from the oldest and simplest economic order quantity (EOQ) model to the more sophisticated reorder point (ROP) model. However many of the models usually assume that demand is known in advance. In this poster, we used the statistical model where demand and supply are both assumed uncertain and will be characterized statistically using JMP® Analytics (such as model fitting). The overall problem statement is to determine the optimized inventory policy that will minimize the inventory holding cost while satisfying a desired service level. The output of the model is a reasonable inventory policy expressed as a pair (Q,r) where Q is called cycle stock (how much to order) and r is called safety stock (when to order).

METHODS

Basic Assumptions

In the (Q,r) system, we monitor inventory continuously and place a replenishment order Q, every time the inventory position drops to the reorder point r. The inventory position is defined as:

Inventory position = on-hand inventory – backorders + orders (not yet arrived)

The daily demand is uncertain, but can be represented statistically by the best fit to its distribution generated using JMP® Analytics platform. The supply lead time is also uncertain, as the part suppliers may be late or early on a delivery.

Cost: The total costs correspond to a inventory policy (Q,r) which includes the holding cost, the purchase order cost (a.k.a setup cost) and the back order cost.

Procedure

1. First, we use JMP® Analytics to characterize the uncertainty in demand and supply with descriptive statistics and best fit functions (Figure 1).
2. Then we formulate the problem as:

   To Minimize: Total Inventory Holding Cost
   To Maintain: Customer Service Level
   Subject to: Average order frequency <= Freq
   & Average fill rate >= S
3. The graphical solutions of the above problem are called efficient frontiers, since they represent the lowest inventory investment for each pair of order frequency and fill rate.
4. Finally we build an interactive model in Excel to explore & visualize the dynamics interactions of the fundamental trade-offs in the Finished Good Inventory (FGI) model to gain insights to the key drivers toward operational excellence.

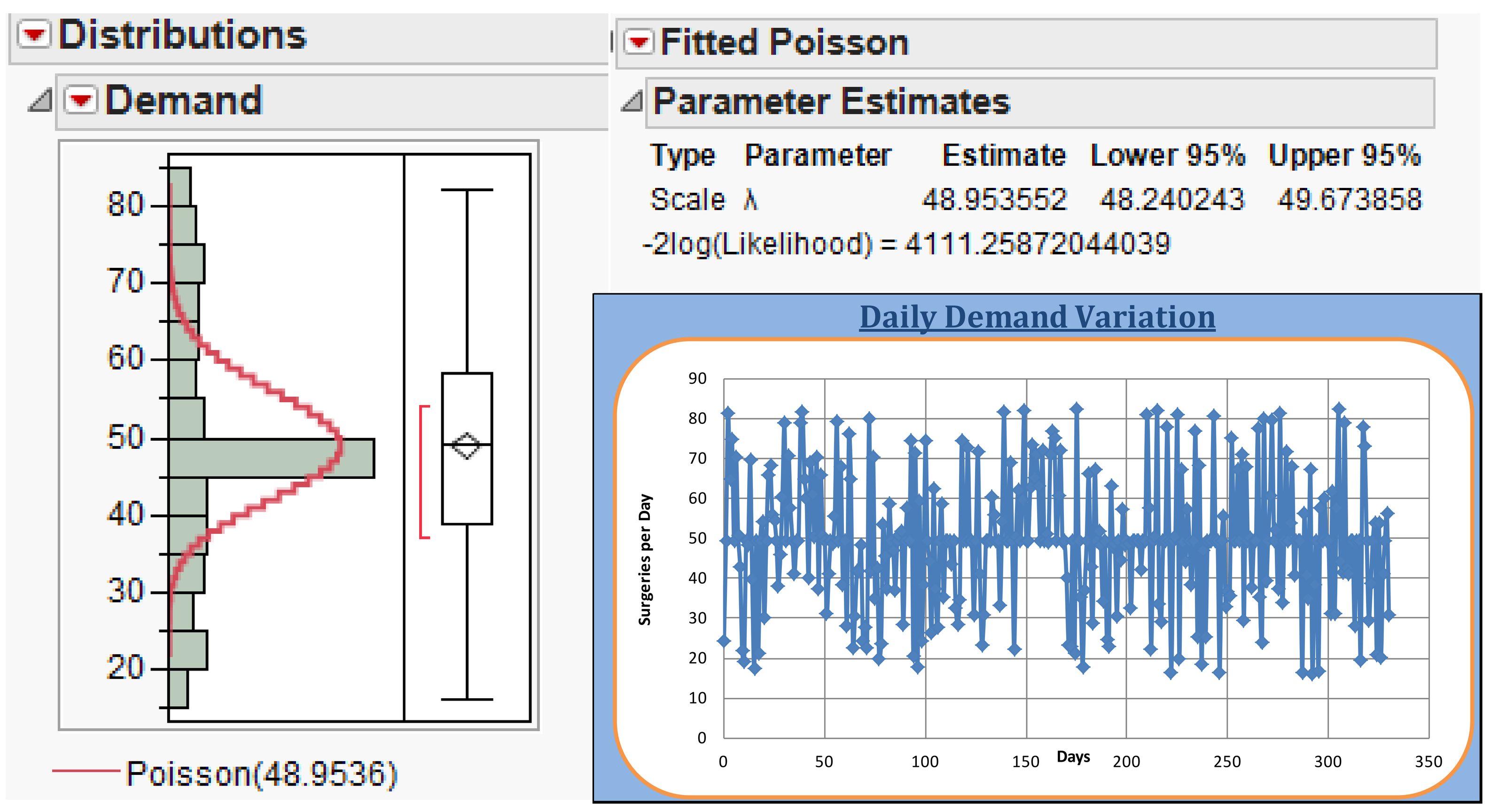

Figure 1. Simulate daily demand variation and characterize its best fit function in the Distribution Platform in JMP® (Other platforms can also be used to find best fit functions)

RESULTS

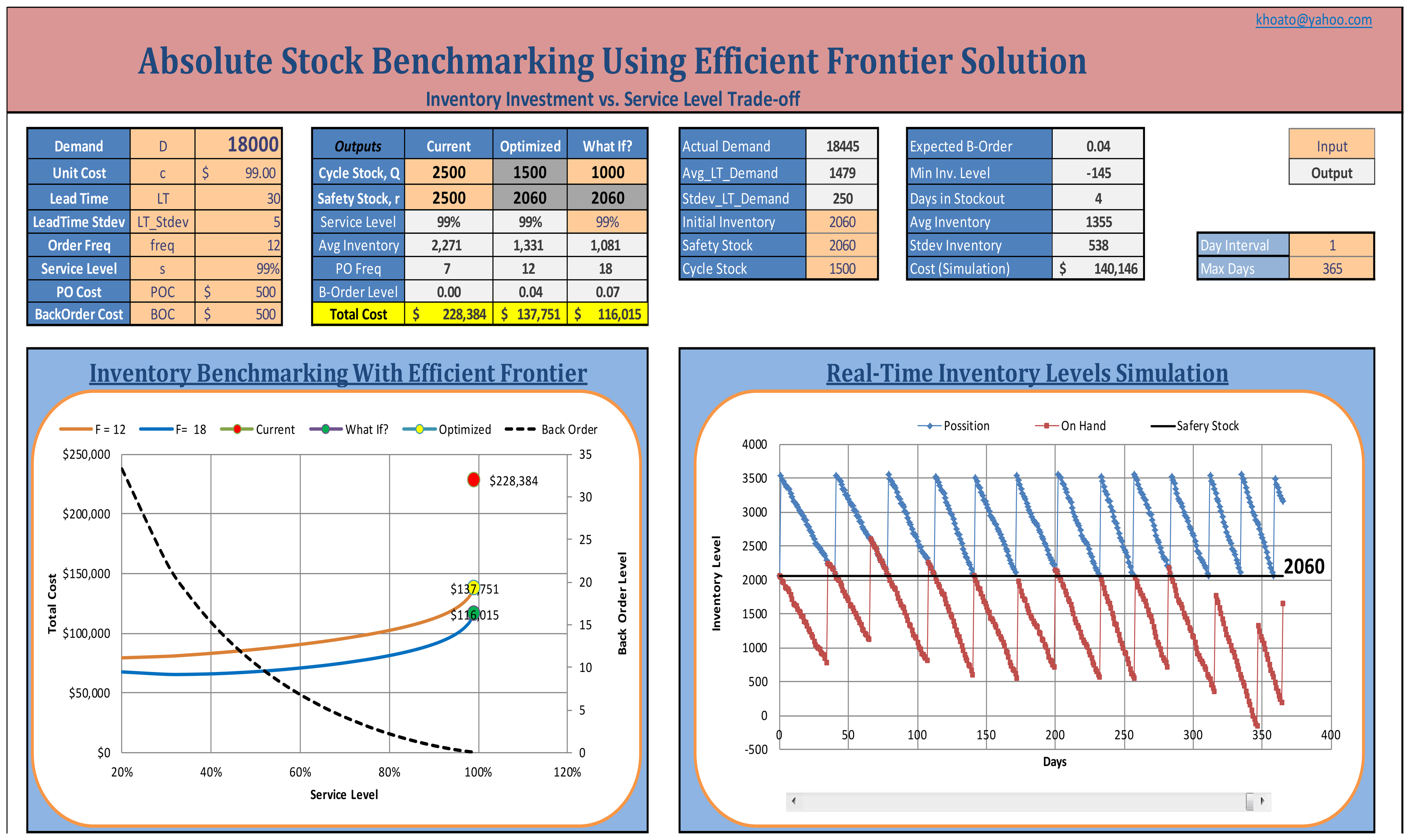

Figure 2. Example of Interactive Model used to explore trade-offs in an inventory system.

Discussion

- Finished goods inventory acts as a buffer between production and demand. FGI may be needed to: (1) insulate customers from manufacturing cycle time, aiming to provide "instant" delivery; (2) absorb variability in both production and demand processes; or (3) level out capacity loading.
- Any FGI model is based on simplified assumptions and input data that are approximated at best. Thus, what this analysis and modeling practice is doing is to help us find a reasonable policy and examine trade-offs. We should always be careful to supplement analysis with empirical observations and feedback.
- Some of the basic insights that we have gained from this statistical model:
  1. There is a trade-off between setups (replenishment frequency) and inventory. The more frequently we replenish inventory, the less cycle stock we will carry.
  2. There is a trade-off between customer service and inventory. Under the condition of random demand, higher customer service levels require higher levels of safety stock.
  3. There is a trade-off between variability and inventory. For a given replenishment frequency, if customer service remains fixed (at a sufficiently high level), then the higher the variability (i.e., standard deviation of demand or replenishment lead time), the more inventory we must carry.
- These basic insights demonstrated in this model are facts of manufacturing life. It empowers us to have a clear understanding of the dynamics of inventory, replenishment frequency and customer service which enables us to evaluate which actions are likely to have the greatest impact.
- The inventory model and the insights discussed in this poster also provide a framework for thinking about higher level actions that can change the nature of these trade-offs, such as increased system flexibility, better vendor management, and improved quality. Finding ways to alter these fundamental relationships is a key management priority for us to improve the bottom line of operational excellence.

Reference

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