Product Complexity and Inventory Levels: A Case Study of Formax*

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1. Introduction

Traditionally, product proliferation is perceived as an instrument for competitive advantage since it allows companies to better match their products to customers’ requirements. However, this view is narrow because its implications on various operations have been largely ignored. In production, product proliferation will lead to a higher frequency of line setups and switching, degrading overall manufacturing efficiency. With a deluge of similar products, forecasting becomes difficult. As a result of missed forecasts which in turn call for freight expediting, transportation cost is likely to be affected as well.

While the ramifications of product proliferation are extensive, the scope of this study is limited to the impact of product complexity on inventory holding levels. Conducted in collaboration with Emanon Inc., this research examines a specific product called Formax. Due to customers’ varied requirements, Emanon produces Formax in a variety of widths, lengths, colors, to list a few. The width, in particular, goes from a narrow 4 cm to a wide 322 cm, and is in increments of 1 cm for most of the range. The total number of possible combinations of attributes is in the order of billions.

* The company name, the product name, and other details have been disguised for reasons of confidentiality
In the remainder of this section, we present a brief overview of the product’s supply chain. In Section 2, we construct a model that represents the relevant characteristics of the supply chain and state our key assumptions. Using the results obtained in Section 2 as the empirical basis, we evaluate an alternative involving width offerings reduction in Section 3. In Section 4, we optimize the model constructed in Section 2. Finally, we present our conclusions in Section 5.

**Formax’s Supply Chain Overview**

The manufacture of Formax begins with the mixing of core and additive. Subsequently, the compound is forced through a nozzle to produce a continuous, uniform sheet that is immediately slit into rolls of desired width.

In general, Emanon adopts the make-to-stock policy for Formax’s production. It holds the product in finished goods inventory at multiple warehouses and satisfies demand from that inventory as orders come in. Thus, the warehouses can be perceived as the push-pull boundary within the supply chain. Between the manufacturing and warehousing facilities, goods are normally shipped by trucks or ocean carriers. As a result of long transportation lead time, a significant amount of inventory is in transit all the time.

As a result of process limitations, a small portion of Formax is trimmed away by customers during their manufacturing stage. Currently, Emanon provides trim tubs to the customers and buys the discarded material back for re-extrusion.
2. Model Construction

To keep the scale of the model in check, we focus our analysis on a group of SKUs with all attributes being equal except for the width. Figure 1 shows the overall architecture of the model constructed using PowerChain Inventory software. Following a three-tiered structure, the supply chain begins with the procurement of raw materials, followed by the manufacturing processes, and ends with the shipping stages. By design of the software, inventory accumulates at the end of every single node.

![Figure 1: Model Architecture](image)

Most of the model inputs are extracted directly from the ERP (Enterprise Resource Planning) system. In cases where certain parameters are not available, estimates or proxies are used instead.
For instance, due to the lack of actual demand information, we treat sales as its proxy throughout this research.

We assume in this model that demands are normally, identically, and independently distributed. Owing to the lack of exact forecast data at the item level but knowing that it stays around 50%, we assume that forecast always misses by 50%. We also assume that overshooting and undershooting occur on an alternate basis such that the forecast error will not be biased in the long run.

Finally, we would like to point out the raw material inventory accumulating at the end of the procurement nodes are excluded from the cost calculations. In other words, whenever we speak of total inventory investment in the context of this research, it refers only to finished goods inventory, both in transit and in storage.

3. Master-Sizing

Master-sizing is a form of width rationalization in which rolls would only be offered in increments of a larger value. On one hand, it has the advantage of pooling risks together to reduce inventory requirements. On the other hand, it forces the company to hold wider rolls in inventory. These two counteracting effects jointly determine the net impact of this initiative on total inventory investment.
In this research, we examine four specific width interval values, namely 5 cm, 10 cm, 15 cm, and 20 cm. The model has the same structure as before except that certain manufacturing stages have to be combined together.

Results

On the premise that demand is inelastic, the blue curve in Figure 2 shows the impact of master-sizing on total inventory investment. The curve shows that total inventory investment should reduce by roughly 10% when the interval value is widened to 5 cm. By stretching the interval to 20 cm wide, we can expect total inventory investment to further reduce to around 74% of its original value.

![Figure 2: Effect of Master-Sizing on Total Inventory Investment](image)

The fact that the curve stays below the level of 100% indicates that the value of pooling more than outweighs the wider-roll effect within the range of tested interval values. However, the
relative strengths of the two counteracting effects do not stay unchanged across the range. To illustrate that, we decompose the results above and show the two effects separately. The yellow curve in the figure shows the impact of the wider-roll effect alone on total inventory investment. As depicted, the wider-roll effect causes total inventory investment to rise linearly with respect to the width interval. The purple curve, on the other hand, shows the impact of the pooling effect alone on total inventory investment. The curve slopes downwards almost linearly initially but begins to flatten as the interval value widens, indicating an eventual wane in strength of the pooling effect.

Judging from the trends of the two separate effects, the blue curve in Figure is likely to pick up when the interval value goes beyond 20 cm. In other words, the maximum achievable savings in total inventory investment by means of master-sizing is around 26%.

4. Model Optimization

The software comes with the capability of minimizing total inventory investment by treating the service time parameters between nodes as decision variables of an optimization problem. By using this feature, we see a 14.5% reduction in the total inventory investment, and the only change involved is that the service time of the manufacturing stages has to increase from 2 to 5 days.

Increasing the service time implies a shorter exposure period for the manufacturing stages but a longer exposure period for the shipping stages. Implicitly, the optimization mechanism pushes
the finished good inventory down the supply chain. In other words, it is more cost-effective for
the finished goods to be held at the external warehouses than at the manufacturing site.

The appeal of this approach is that it reduces total inventory investment without introducing the
wider-roll effect at all. However, it brings about the issue of inconsistency. Take note that the
manufacturing site does serve domestic customers directly, so a service time of 5 days basically
means a promised delivery lead time of 5 days for the domestic customers. On the other hand,
since the service time of the shipping stages stays unchanged at 2 days after optimization, the
international customers have the privilege of getting the goods sooner. This could be an issue if
some of the domestic and international customers belong to the same company.

5. Conclusions

In this research we have constructed a supply chain model for determining the effect of width
rationalization on inventory levels. We find that the value of pooling diminishes as the width
interval widens. Because the product is available in rolls and its value determined by the surface
area, there exists a wider-roll effect that offsets the pooling advantage. Although the total number
of rolls held in inventory decreases as a result of width rationalization, the total worth of the
inventory does not necessarily reduce accordingly. In other words, there is a definite range of
width interval within which the rationalization effort is favorable in terms of total inventory
investment. Beyond that range, the reverse is true.

The managerial implications of the wider-roll effect are significant. On top of causing a larger
degree of mismatch between customers’ needs and supply, master-sizing also creates more
wastage of resources because a higher percentage of the product will traverse the supply chain back and forth without getting to serve any demand. Such inefficiency comes at a price which neither the manufacturer nor its customers want to pay. Consequently, the real challenge of the rationalization program not only lies in the selection of an appropriate width interval value, but also in preventing the perception that customers are footing the cost of increased wastage. Two readily available options accomplish that: reduce the product price or increase the buy-back price. Properly wielded, master-sizing can be a winning proposition for both parties.

Through model optimization, we also find for a product chain like ours, it is more favorable to push the finished goods inventory down the chain. In other words, having the external warehouses rather than the manufacturing plant hold the inventory can effectively reduce the inventory requirements without compromising the service level.