THE EFFECT OF A CHANGING MARKET MIX IN SEED CORN ON INVENTORY COSTS

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Abstract

Changing product characteristics are causing U.S. seed corn companies to reevaluate their inventory strategies. A simulation model based upon the Economic Order Quantity model is built in @Risk to reflect a shortened product life cycle and product proliferation.

Inventory costs levels increase because of increased uncertainty of demand. Empirical results find that shortening the product life cycle and expanding the product line increases total inventory costs by 120.8%, increases the average inventory level (primarily due to added safety stock) by 56.2%, and increases the cost of carryover, stockout cost, and safety stock cost by 143, 165, and 119 %, respectively. To maintain higher levels of customer service with products displaying shorter life cycles, more safety stock must be held to guard against stockouts.

The Effect of a Changing Market Mix in Seed Corn on Inventory Costs

Technological innovations during the past decade have brought new challenges in dealing with supply planning and inventory management for U.S. seed companies. Over the past decade, the number of corn and soybean varieties offered by seed companies to farmers has steadily expanded. "Product cycles are becoming ever shorter, and new products are being launched at an ever faster pace"(Vasella).

Product proliferation has been caused mostly by technological innovations like genetically modified organisms (GMOs), as well as the introduction of more specialty crops. Where one variety existed before, there now possibly exists a Bt variety, a herbicide resistant variety, a specialty variety (white, waxy, high oil, etc.), or even a stacked-trait (combination) variety. Important differences also exist in product packaging, seed treatment, seed size, and maturity. For example, the variety may be a Bt (type), 80,000-kernel bag (package), with seed treatment, medium-flat (seed size), and 110-day maturity. Subtle differences in any of these characteristics likely require that the product be separated for some, if not all, stages of production, inventory control, and order processing.

Seed companies are struggling to produce, ship, store, and sell this increasing number of seed types. The specific issues caused by product proliferation reach across the company. For production plants, total throughput may be the same, but it now requires more, smaller storage tanks for bulk seed, different bags to package the seed, more switchover times to clean intake pits, bins, and bagging lines, and more items to track and keep separate in inventory.

Variations of these problems can also be observed for field production, shipping, and sales. The identity of seed varieties must be preserved throughout the supply chain. Smaller production plots, possibly smaller shipment sizes, and more information for each party in the supply chain are some of the key issues. Farmer's selection of seed may be more confused by the greater selection of hybrids, affecting sales.

The problems of product proliferation are further complicated by a shortening product life cycle for seed corn. Technology is advancing so rapidly that new product releases are cannibalizing sales and shortening the life of the other varieties in the market (Lee). Product proliferation in the case of the seed industry means that one existing variety may be replaced by several new varieties. Demand is then divided among these new varieties. Thus, more sales are coming from products that are in their earlier stages of life, as opposed to sales from products in mature stage of the product life cycle.

Demand forecasts are more accurate for products that have available past sales data rather than for new products without such data. Seed companies are finding it difficult to forecast demand for all of these new varieties and thus are in greater danger of having high inventory costs. The onslaught of new products and competition has heightened the need for knowing inventory costs. These costs can arise either from stockouts or large volumes of carryover stock or obsolete inventories.

Research Objective

The objective of this research is to determine how product proliferation and shorter product life cycles affect inventory costs and inventory requirements, and customer service levels in the U.S. seed corn industry. An Economic Order Quantity (EOQ) model is developed using Excel and @Risk to accomplish this objective. @Risk allows the model to take uncertainty into account (Winston). This is needed in this situation because many of the variables in the EOQ model are not deterministic.

The product life cycle plays a key role in the model. Therefore, the derivation of the product life cycle comes first, followed by a description of the model objective function and input variables.

Derivation of the Product Life Cycle

The Blackman-Mansfield innovation diffusion model is used to derive the product life cycle for seed corn (Lilien et al.). Variables in this model include values for the percentage of the market that adopts the innovation in year one, the total percentage of the market that will adopt the innovation in the long run, and variables that govern the growth rate between year one and total adoption. Growth rate is a function of an industry specific innovation constant, the difference in the rate of return for the innovation and the company hurdle rate, and a value defining the relative investment made to the innovation by the company.

The product life cycle curve is derived from the logistics curve. *V* represents the growth of or the increase in diffusion of the innovation into the market in year t. The value for *V* at year t, less the value for *V* in year t-1, multiplied by total capacity of the plant *O*, yields the mean demand (D_t) for year t, or:

$$(1)\ D_t = (V_t - V_{t-1}) * O$$

Results of the estimated product life cycle as determined from Equation 1 provide the values used for forecasted demand (Table 1). Forecasted demand represents the company's estimate of mean demand for each product. Forecast demand is aggregated by year in

Table 1. Demand and Price Input Values

Product Year (mid-90s Life Cycle)	Forecasted Demand (80,000 kernel units)	Standard Deviation of Demand	Price per Unit (dollars)
1	29,450	19,142	80
2	46,750	23,375	80
3	67,060	13,412	75
4	82,860	8,286	75
5	85,000	8,500	75
6	72,160	10,824	75
7	53,160	10,632	70
8	33,560	10,068	70
Product Year (year 2000 Life Cycle)	**Forecasted Demand (80,000 kernel units)**	**Standard Deviation of Demand**	**Price per Unit (dollars)**
1	74,530	48,444	100
2	123,760	61,880	100
3	134,130	33,532	100
4	92,200	23,050	95
5	45,380	15,883	95

the product life cycle. Therefore, year one demand is the total for all products in the first year of the life cycle. Estimates are generated for an 8-year product life cycle reflective of the seed industry in the mid-1990s and a shorter life cycle of 5 years depicting current industry conditions.

The standard deviation of demand begins high, decreases, and then increases again as t increases. Standard deviation or demand uncertainty is greater during the early years of the product's life and then decreases as time goes by until near product termination, where uncertainty increases somewhat (Fisher, 1997).

Expert interviews with seed corn professionals indicated that a skimming strategy is practice for introducing new products, starting at a relatively higher price. Price is gradually reduced over time, mostly on the basis of age of the product and competitive pressures.

Model Objective Function

The empirical model is adopted from the basic EOQ model (Ballou). Five general classes of costs are minimized in this EOQ model, which are given as the terms as presented in equation 2. In order, they are: 1) switchover costs, 2) carrying costs of regular stock, 3) carrying cost of safety stock, 4) stockout cost, and 5) carryover stock cost.

$$(2)\ \sum_{i=1}^{P} T_i = \{S\frac{D}{Q} + \frac{I}{2}C\frac{Q}{2} + \frac{I}{2}Czs'd + \frac{D}{Q}ks'_d\ E(z) + X * \frac{I}{2} * C\}_i$$

where:

T_i	= total relevant inventory costs for product i,
P	= the number of products represented in the product life cycle,
S	= cost to make one switchover,
D	= forecasted annual demand units,
Q	= Economic Order Quantity (EOQ),
I	= annual carrying cost of inventory, as a percent of item value,
C	= item value in dollars per unit,
z	= tabled value, as the area under the standardized normal distribution,
E(z)	= unit normal loss integral,
s'_d	= standard deviation of lead time,
k	= stockout cost per item, in dollars per unit and,
X	= quantity of carryover stock.

Description of Variables

This section presents the input variables, other than those based on the product life cycle, for this model. As mentioned, values for many of the variables are stochastic. Thus, the distributions and data sources used for each input variable, as well as a description of each input variable are presented in Table 2.

Switchover Cost (S) is incurred when a seed plant changes from producing one variety to producing the next scheduled variety. This entails changing production lines, bagging lines, and shipping functions to accommodate a different seed variety. The labor, tools, and any other

Table 2. Variable Description, Value, and Date Source

Variable Name	Symbol	Distribution & Base Value	Data Source
Switchover Cost	S	RiskNorm (3200,320)	Seed industry interviews
Price (or Item Value)	C	$80 for first 2 years, $75 for next 4, and $70 for last 2	Seed industry interviews
Carrying Cost	I	RiskTriang (.2,.25,.3)/2 (1/2 to represent ½ year)	Ballou
Stockout Cost	k	RiskNorm(60,6)	Ballou
Forecast Demand	D	8 different mean demands, one for each year / P	8-year Product Life Cycle
Actual Demand	A	RiskNorm(mean demand, s'd, RiskTrunc(0, Mean demand + (2*s'd))) / P	8-year Product Life Cycle
Number of Products	P	16 total (2 per year, 8 years)	Seed industry interviews
Lead Time of Demand	L	90 days	Average of a ½ year season
z and E(z)	z and E(z)	Tabled values – areas under normal distribution, based on customer service levels	Ballou

supplies used to switchover are broadly grouped into a single cost that is assumed to occur each time a switchover is made.

Switching cost assumes a normal distribution with a mean of $3,200 and standard deviation of $320 for the base scenario. The mean value was found by multiplying the number of hours it takes to switch by the cost per hour for switching. Eight hours per switch at a cost of $400 per hour, for a total of $3,200 per switchover for the base. Decreasing the time it takes to switchover adds flexibility to the production system and can reduce total switching costs.

Carrying cost (I) is expressed as a percent of item value per year. Carrying cost is incurred when units of product must be held in inventory either before it is shipped this selling season or because it was not sold and must be held until next season. Carrying cost in this model assumes a triangular distribution (Table 2). The value for carrying cost typically includes storage costs, damage, obsolescence, and an opportunity cost. Carrying cost is expressed as a percentage of per unit item value.

Carrying cost is part of three terms in Equation 2, regular stock, safety stock, and carryover stock. The first represents the cost associated with holding inventory that will be sold during the current selling season. The second represents the cost associated with holding inventory to protect against stockouts (safety stock). Finally, the carryover cost represents the cost incurred by carrying excess inventory to the next selling season. The first two carrying costs are incurred for the six months during production and selling, while the carryover cost is incurred for the six months after the selling season until the next year.

Stockout cost (k) comes up time after time as being critical for inventory analysis and planning.[1] This is the value placed upon a stockout and is equal to $60 dollars per unit, with a standard deviation of ten percent of the mean value.

The number of products per year (P) is a driver of total switchover costs. This input variable captures the product proliferation that has occurred in the seed industry. The total number of products for the mid-90s product life cycle equals 16, two products per year for each of 8 years in the product life cycle. The 2000 product life cycle has 30 total products and 5 years, for a total of 6 products represented each year. Seed industry expert interviews indicate an approximate doubling of the total number of products processed at each production location.

Lead-time of demand (L) is the amount of time that elapses between production of a product and when the sale of the product occurs. Demand can change between the time between

[1]Two recent articles, one by Zinn and Liu, the other by Taylor and Fawcett, reaffirmed the importance of stockout costs to inventory analysis. Additional research is underway exploring in depth the importance of stockout costs upon the seed corn industry.

of production and sale. Standard deviation of forecast demand is multiplied by the square root of lead-time to obtain the standard deviation of demand during lead-time (Equation 3), or

$$(3)\ s'_d = s_d \sqrt{L}$$

An average lead-time of 90 days is used for the base case scenario (Table 2). This value was calculated as the average lead-time for all products in the product mix for the eight-year product life cycle. The 2000 product life cycle has an average lead-time of 106 days.

For the Scenario Five, lead-time was calculated specifically for each year of demand. The level of demand uncertainty associated with each particular product determines the production order. Thus, the first product on the production schedule has a lead-time of 180 days (because seed plants typically operate approximately half of the year). Each subsequent product on the schedule will have a lead-time representative of the time remaining before the end of the year.

The products with the least uncertainty are produced first, conversely meaning that those with the most uncertainty are produced closest to the selling season. For example, the products in year three of the 2000 product life cycle have the least level of demand uncertainty (Table 1). Therefore, lead-time for year three products equals 180 days. If year three products require 20 days for production, the second product would have a lead-time of 160 days. This process continues until all products are scheduled.

Values for z are taken from the standardized normal distribution (Ballou). The desired customer service level defines the z value. For higher customer service levels the z-value also increases. The product of standard deviation of lead-time and z define the quantity of safety stock required to maintain the desired level of customer service. The values for E(z) are the unit normal loss integrals and are used to derive the likelihood of a stockout. To find the unit normal loss integral the corresponding z value must be known and located in the unit loss integral table.

The customer service level is expressed as a percentage. A service level of 90 percent implies that an order can be filled from current stocks ninety percent of the time. The service level is calculated as a weighted average for all products. The weight of each service level is the proportion of total demand product for each product. For example, assume total demand was 500,000 units and one product represented 100,000 units or 20%. If the service level was 90%, the contribution to the overall service level would be 18% (90%*20%).

In this model, outputs are calculated for nine different service levels. Inventory costs, number of switchovers, safety stock level, average inventory, and carryover stock are calculated for each service level. The optimal solution is then found by using the service level that corresponds to the least cost inventory policy.

Empirical Results

Results for five model runs are presented. Scenario One represents the baseline, which is reflective of the mid-1990s. In the next four scenarios, input values are adjusted for the number of products, product life cycle, switchover time, and lead time (Table 3). Scenario Two increases the number of products, Scenario Three shortens the product life cycle, Scenario Four decreases the switchover time, and Scenario Five uses a calculated production schedule order. Comparing the baseline to Scenarios 2 and 3 illustrates the changes inventory costs and service arising from a changing product mix. Scenarios 4 and 5 provide information on the results of potential strategies to manage a more diverse product mix.

Table 3. Scenario Input Values

Model Scenario/ Description	Product Life Cycle	Number of Products	Hours to Switchover	Lead Time Coefficient
#1 - Base	Mid-90s	16	8	90 days
#2 –More products	Mid-90s	30	8	90 days
#3 – Shorter product life cycle	2000	30	8	106 days
#4 – Decreased switchover time	2000	30	4	106 days
#5 – Calculated lead-time	2000	30	4	Varies by product

Scenario One, The Baseline

For the baseline, the mean service level was 95.2 percent and the mean minimum total cost equaled $3,224,277 (Table 4). The switchover cost and regular stock carrying cost was $331,650, while safety stock carrying cost and stockout cost was $1,145,622 and $599,877, respectively. The average inventory level was 155,236 units and the number of switches was 104 for the baseline. Carryover cost was $815,477, while carryover stock was 85,073 units.

Table 4. Comparison of Mean Results for all Scenarios

Output	Scenario #1 – Baseline	Scenario #2 – More Products	Scenario #3 – Shorter Life Cyle	Scenario #4 – Quicker Switching Time	Scenario #5 – Scheduled Production
Switchover Cost	331,650	454,131	518,192	365,786	365,786
Carry Cost, Regular	331,650	454,131	518,192	365,786	365,786
Carry Cost, Safety	1,145,622	1,033,787	2,512,264	2,808,749	2,595,581
Stockout Cost	599,877	629,538	1,587,586	1,508,984	1,385,249
Carryover Cost	815,477	581,913	1,983,411	2,445,867	2,232,699
Total Cost	3,224,277	3,153,499	7,119,646	7,495,170	6,945,100
Number of Switches	104	142	162	230	230
Average Inventory	155,236	156,521	244635.7	256,318	239,436
Service Level	95.2%	93.6%	92.5%	94.7%	94.7%
Carryover Stock	85,073	60,469	159487	196,988	180,106

The largest component of total cost for this scenario was the carrying cost of safety stock at 35.5 percent of total cost, followed by carryover cost at 25.3 percent of total cost (Table 5). In the baseline scenario, demand uncertainty has more impact on total cost than switchovers or regular stock carrying cost.

Table 5. Frequency Distribution of Costs, for all Scenarios

Output	Scenario #1 – Baseline	Scenario #2 – More Products	Scenario #3 – Shorter Life Cyle	Scenario #4 – Quicker Switching Time	Scenario #5 – Scheduled Production
Switchover Cost	10.3%	14.4%	7.3%	4.9%	5.3%
Carry Cost, Regular	10.3%	14.4%	7.3%	4.9%	5.3%
Carry Cost, Safety	35.5%	32.8%	35.3%	37.5%	37.4%
Stockout Cost	18.6%	20.0%	22.3%	20.1%	19.9%
Carryover Cost	25.3%	18.5%	27.9%	32.6%	32.1%
Total Cost	100.0%	100.0%	100.0%	100.0%	100.0%

Scenario Two, Evaluating Product Proliferation

Scenario Two considers how product proliferation affects the results, by increasing the number of products from 16 to 30. Since the mid-90s product life cycle is still being used, there are now 3.75 products represented in each of the eight years.

The mean service level for Scenario Two was 93.6 percent and the total inventory cost was $3,153,499 (Table 4). The switchover cost and regular stock carrying cost rose to $454,131 or 14.4 percent each of total cost (Table 5). Safety stock carrying cost fell by over $110,000 to $1,033,787 (38.8 percent of total cost). Stockout cost rose about $30,000 to $629,538, accounting for 20.0% of total cost. The average inventory level was about the same as in the baseline at 156,521. Carryover cost fell to $581,913 as carryover stock fell to 60,469 units.

Compared to the Baseline Scenario, the switchover costs and carrying cost of regular stock increased by 36.9 percent (Table 6). These costs make up a larger percentage of total cost due to the increased number of products being produced. The average number of switchovers increased from 104 to 142. Carrying cost of safety stock decreased by 9.8 percent and stockout cost increased by 4.9 percent, which resulted in a slightly lower total cost than in Scenario Two. The service level is also 1.7% lower.

Table 6. Percentage Change versus the Baseline Values

Output	**Scenario #2 – More Products**	**Scenario #3 – Shorter Life Cycle**	**Scenario #4 – Quicker Switching Time**	**Scenario #5 – Scheduled Production**
Switchover Cost	36.9%	56.2%	10.3%	10.3%
Carry Cost, Regular	36.9%	56.2%	10.3%	10.3%
Carry Cost, Safety	-9.8%	119.3%	145.2%	126.6%
Stockout Cost	4.9%	164.7%	151.5%	130.9%
Carryover Cost	-28.6%	143.2%	199.9%	173.8%
Total Cost	-2.2%	120.8%	132.5%	115.4%
Number of Switches	36.5%	55.8%	121.2%	121.2%
Average Inventory	0.8%	57.6%	65.1%	54.2%
Service Level	-1.7%	-2.8%	-0.5%	-0.5%
Carryover Stock	-28.9%	87.5%	131.6%	111.7%

This scenario shows that switchover costs and the carrying cost of regular stock increase with product proliferation. However, one would initially expect that the total cost would also rise due to the broadening of the product line. The results account for the added cost of switching the production plant from one variety to the next. In practice, competitive pressures may require a higher customer service level. However, total costs fall because the minimum cost is achieved at a lower service level. Results also assume that the production plant capacity and warehouse capacity are adequate to handle this type of production schedule. In addition, storage requirements or the cost of upgrading the facilities are not included in the costs.

Scenario Three, Shortened Product Life Cycle and Product Proliferation

The third scenario evaluated the effects of a shortened product life cycle in combination with an expanded product line. The only change made from the second scenario was the product life cycle (Table 3). This scenario uses the 2000 product life cycle, which is five years in length. This means that demand, product prices, average lead-time, and uncertainty levels change due to the product life cycle change.

The mean service level for Scenario Three fell an additional 1.1 percent to 92.5 percent (Table 4). The total inventory cost was $7,119,646, or 121% of the baseline cost. Compared to the baseline the combination of a shorter product life cycle and product proliferation led to sharp increases in safety stock carrying cost (119.3%), stockout cost (164.7%) and carryover cost (143.2%) (Table 6). Safety stock, stockout cost and carryover cost were $2,512,264, $1,587,856, and $1,983,411, respectively. The average inventory level was 244,635 units and the number of switches was 162 for this scenario.

The sharp increase in costs occurred because a larger percentage of demand occurs in the earlier stages of the life cycle where demand uncertainty is greater. A key point is that the added uncertainty of demand causes the need to carry large safety stocks, to avoid costly stockouts. However, results are as likely to have too much inventory as too little. The mean average inventory level increases by 57.6 percent, due mostly to the increase in safety stock.

Sensitivity analysis was conducted to determine which input variables have the greatest influence on the output variables in Scenario 3. Inventory carrying cost or C, is highly correlated with Total Cost, Number of Switchovers, and Average Inventory Level (Table 7). Switchover costs are most closely correlated with Number of Switchovers and Average Inventory Level. A wide variety of input variables are correlated between .2 and .6 with Customer Service Level and Carryover Stock.

Table 7. Correlation Coefficients Between Selected Input and Output Variables for Scenario 3

Rank Inputs	Total Cost	Number of Switchovers	Average Inventory Level	Customer Service Level	Carryover Stock
Demand Year 2	-0.190	-0.019	0.019	-0.513	-0.621
Demand Year 1	-0.147	0.037	-0.037	-0.447	-0.583
Demand Year 3	-0.087	-0.027	0.027	0.162	-0.320
Demand Year 4	-0.106	-0.035	0.035	0.206	-0.234
Demand Year 5	-0.078	0.027	-0.027	0.109	-0.226
Inventory Carrying Cost	0.840	0.612	-0.612	-0.402	0.119
Switchover Cost	-0.112	-0.739	0.739	0.485	-0.117
Stockout Cost	0.366	-0.018	0.018	-0.011	-0.046

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Scenario Four, Production Flexibility

Scenario Four evaluates the impact of greater production flexibility. For the prior scenarios, the switchover time was eight hours per switchover. For this scenario, the switchover time is decreased to four hours per switchover (Table 3). The reduction in time directly decreases the cost per switchover and thus adds more flexibility to the system by placing a smaller penalty on each product switch.

The mean service level for scenario four was 94.7 percent and the total inventory cost was $7,495,170 (Table 4). The switchover cost and regular stock carrying cost was $365,786, while safety stock carrying cost and stockout cost was $2,808,749 and $1,508,984, respectively. The average inventory level was 256,818 units and the number of switches was 230 for this scenario. Carryover cost equals $2,445,867 and carryover stock equals 196,988 units.

Adding flexibility to the production system reduces the total switching cost and the carrying cost of regular stock compared to Scenario Three. Since it is less expensive to switch, more switchovers occur in the system than compared to Scenario Three, increasing from 162 to 230.

Stockout costs decreased due to the added flexibility and the increased safety stock. The increased safety stock carrying cost and carryover cost is due to providing a higher overall level of customer service, up from 92.5 percent to 94.7 percent. This scenario shows that as higher levels of service are offered, the cost increases are not symmetric. To cut stockout costs by only $80,000, the safety stock carrying cost and carryover cost are increased by almost $800,000.

Scenario Five – Using a Calculated Lead-Time for Production Order

For this, the final scenario, a specific lead-time was calculated for each product. The products with the least amount of relative demand uncertainty were produced first. Thus, they have the longest lead-times. The products with the largest relative uncertainty were assumed to be produced last, closest to the selling season, so they had the shortest lead-time. Year three of the product life cycle had the least amount of uncertainty; it had a lead-time equal to 180 days (the entire season). Years four, five, two, and one had lead-times of 132, 99, 82, and 38 days, respectively.

The mean service level for Scenario Five was 94.7 percent and the total inventory cost was $6,945,100 (Table 4). The average inventory level was 239,436 units and the number of switches was 230 for this scenario. Carrying cost of safety stock makes up 37.4 percent of total cost and stockout cost makes up 19.9 percent, while carryover cost again makes up 32.1 percent of total cost. The results show that total costs fell by 7.3 percent compared to Scenario Four, due to decreases in stockout cost (8.2%), carrying cost of safety stock (7.6%), and carryover stock (8.7%). The only other change from Scenario Four was the reduction in the average inventory level by approximately 6.6 percent. Since the products with the highest relative demand uncertainty are produced last, the lead-time is shortened. In turn, this requires less safety stock to be carried for these items. Stockout cost reductions are derived in a similar way.

Conclusions

Changes in the product characteristics for seed corn have had major impacts on inventory costs, inventory requirements, and customer service levels. Product proliferation and shorter product life cycles have been the main causes of the changes for seed company inventory management. Seed managers are now trying to find strategies to effectively deal with these new challenges. The results of the study provide a basis for seed managers to see how costs, requirements, and service levels are impacted.

Product proliferation causes a higher number of switchovers in the production plant. Doubling the number of varieties causes the production plant to spend more time and money for clean down time. Increased clean down time causes switchover costs and carrying cost of regular stock to increase. To account for this change, managers must make sure that the production facilities are capable of making all of the additional, shorter production runs.

The results show that shortening the product life cycle and product proliferation increase total inventory costs by 120.8 percent, increases the average inventory level (primarily due to added safety stock) by 57.6 percent, and increases the cost of carryover, stockout cost, and safety stock cost by 143, 165, and 119 percent, respectively. To maintain higher levels of service with products displaying shorter life cycles, more safety stock must be held to guard against stockouts.

One possible strategy to combat product proliferation is to cut switching time by investing in time saving machines or processes at the production facility. The added capital expenditure required to implement these new processes or purchase the new equipment must be compared to the inventory cost savings. This strategy could be extended to other parts of the supply chain as well. Shortening of lead-times, implementing faster processes, or better signaling devices may have a similar affect on product proliferation.

The final conclusion regards production scheduling. Production scheduling with products with the lowest demand uncertainty produced first can reduce total costs. Demand certainty should increase as the selling season approaches. Updating demand forecasts until the closest possible time to the selling season would be advantageous. Waiting until the closest time to the selling season to process those varieties with the most variable demand reduces the chance of having such a wide margin of error.

Further use of the model may also be applicable for additional scenario evaluation. Pricing strategies, product market introduction and exit strategies, and different product mix strategies are a few of those possible scenarios. Additional work may include more aspects of the total hybrid corn planning cycle, like parent seed planning, carry-in inventory, and other stages of the two-year planning cycle.

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