MEASURING COST EFFECTIVENESS OF PRODUCT WHEELS IN FOOD MANUFACTURING

By

EMILIE JENSEN

B.S., University of Minnesota, 2009

A THESIS

Submitted in partial fulfillment of the requirements

for the degree

MASTER OF AGRIBUSINESS

Department of Agricultural Economics

College of Agriculture

KANSAS STATE UNIVERSITY

Manhattan, Kansas

2014

Approved by:

Major Professor

Dr. Keith Harris

ABSTRACT

The focus of this research is to create a production schedule that will increase capacity while staying within business constraints of shelf life and warehouse space in a industrial food processing environment. The results support that product wheels maximize process responsiveness by lengthening production runs, and increasing safety stock inventory. In doing so, it maintains acceptable customer service levels and minimizes overtime costs.

This study develops a model that simulates the relevant variables impacting the performance of the operation. The results show significant cost reductions are achieved by eliminating changeovers, increasing line capacity, safety stock levels protect against 99% of order variation, and warehouse space is available to house increased cycle stock and safety stock. Given the results on this line, I recommend expanding the model to other food processing locations within the business to further increase capacity and decrease overtime expenses.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

The author wishes to thank the following people for their contributions and support throughout the thesis process:

- I would like to thank my amazing husband, Michael Jensen, for all of your support on every assignment, lecture, and chat session throughout the MAB program. I couldn't have done it without your encouragement and procrastination patrol.

- On the Cargill side I would like to thank the DSO Commercial Manager, Juan Colmenares, for his guidance throughout the project. From brainstorming all the way to implementation support, and overall his deep rooted belief in my success.

- Next, I would like thank Dr. Arlo Biere and Dr. Jason Bergtold for serving on my thesis committee and providing invaluable feedback to make this paper a true academic contribution.

- Last but not least, I would like to thank Dr. Keith Harris for serving as my Major Professor. The progress from organized chaos to a fully articulate work was not an easy one, after editing countless drafts and working nights and weekends, I am proud to say that we have arrived safely at our destination.

CHAPTER I: INTRODUCTION

1.1 Company Background

Cargill, Inc. is an international producer and marketer of food, agricultural, financial, and industrial products and services. Founded in 1865, the company employs 142,000 people in 67 countries, and is the largest privately held corporation in the United States in terms of revenue. Cargill's Dressing, Sauces, and Oils (DSO) business was created in 1987. DSO refines vegetable and tropical oils into shortening, mayonnaise, dressings, and sauces for the foodservice industry. Their customers include major food manufacturers and casual dining restaurant chains (Cargill n.d.). The Sauce and Condiment Industry serves the retail and fast food markets and despite a decrease in eating out caused by the 2008 recession, the industry fared well.   Strong sales of convenience processed foods used in home cooking supported a 1.7% annual growth in the past five years (IbisWorld 2013). DSO is a relatively new entrant to the $18 billion per year revenue sauce and condiment industry, which is led by McCormick & Co, Unilever, and Kraft (IbisWorld 2013). Taking these facts into account, DSO believes there are organic growth opportunities and aims to capture gains in market share and market growth.

1.2   DSO's Objective

Each year DSO defines specific volume objectives that support the long-term goal of increasing market share and profit targets. The company's strategy to realize these targets is to create distinctive value for its customers. Over the past few years the Sales Department has been very successful in developing the relationships needed to secure

contracts/commitments to purchase DSO products; however, the commitments have outpaced DSO's production capacity. In July 2013, DSO was awarded a large contract with a fast food chain, and to meet increased sales the production personnel worked an average 20 hours per week of overtime, costing the company $50,000- $100,000 per month in wages. Due to the industry's notably low profit margin, this unbudgeted expense can reduce profitability up to 5% annually. In order to meet the FY 2013-2014 market share targets, while still meeting budget, DSO is looking for ideas on how to quickly increase production volume and decrease overtime. There are a variety of capital projects underway to help achieve these goals in the long run including building additional storage capacity and increasing operational efficiencies. However, the more pressing issue is to find a short-term solution without infringing upon current budget objectives.

1.3   Research Objective

Capital projects are out of the scope for this study given the short timeline. The focus of this study is to capture the value on the shop floor in the most efficient way possible. DSO needs to ensure it effectively uses its current assets to produce the 2000+ SKU's the business handles every year within budget. The objective of this thesis is to identify a production schedule for DSO that will increase production capacity while managing ship-shelf life, warehouse capacity, and customer service levels.

In the current organizational structure, the scheduling department is responsible for planning the production of each SKU. To ensure a practical solution, it is important to work closely with them throughout the project. The production schedulers at DSO know when

products will be made, how much is in inventory, and act as a mediator between operations and sales when customer orders are late.

1.4   Thesis Outline

Chapter 2 of this thesis will examine past studies on reducing production line overtime including changing scheduling models and effectively balancing the cost of efficiency with the cost of capital. Chapter 3 will explain the details of the theory, outline the assumptions of the model, and then collect product data. Chapter 4 will sample a production line experiencing overtime and apply a scheduling solution to create a new production schedule. Chapter 5 will analyze the resulting model, make adjustments for practical application, determine the economic implications, and outline how this process could be implemented throughout the business.

CHAPTER II: LITERATURE REVIEW

This review of literature is not intended to be exhaustive. It is intended to identify the recent research contributions related to production scheduling and it will serve as basis for the initial hypothesis development.

2.1 Capacitated Planning and Scheduling in the Food Industry

This case study reviews the informal scheduling practices of a company with large product variety and pressured profit margins. Soman et al. (2006) develop a more formal approach by first dividing products into Make-to-Order (MTO) and Make-to-Stock (MTS) categories then assigning lot sizes and safety stocks. To address inventory and customer service issues, the authors used an interesting method to determine the MTO/MTS division of products involving setup time, holding costs, and ship shelf life. This paper provided a framework to understand and recognize areas of improvement, which included the confirmation of the link between scheduling and capacity, delineation the need for improvement, explanation of the idea of feasibility checks, and demonstration of how a flowchart could be applied to this study's problem (Soman, VanDonka and Gaalman 2006).

2.2 Resource-Constrained Production Planning in Semi-Continuous Food Industries

This research was "concerned with the allocation over time of scarce resources between competing activities to meet customer orders in an efficient fashion" (Kopanos and Puigjaner 2011). The authors suggest the "topic has received new impetus as enterprises attempt to optimize their overall supply chains in response to competitive pressures" (Kopanos and Puigjaner 2011). Kopanos and Puigjaner added an additional focus of business constraints, saying, "Despite the significant literature in the broad area of

process planning and scheduling very few contributions model resource constraints in addition to the classical production constraints" (Kopanos and Puigjaner 2011). The key focus of this study was the constraint of labor resources, as absences caused huge variability in their production schedule.

2.3 Developing Product Wheels for Process Industry Operations

In a 2007 presentation by DuPont Corporation, Bennett Foster uses production scheduling examples and the application of economic lot size to demonstrate how product wheels work; it outlines that a product wheel should be used when transitions are costly and impacted by sequence, and that economic order quantity focuses on cost to determine the most economical wheel. Foster also mentions the management principles needed to make sure the plan is feasible, and an important discussion with operations and the scheduling department is needed when considering this solution.

2.4 Revisiting the shelf life constrained multi-product problem

Sanjay Sharma reviewed three methods to manage production with a shelf life constraint, which includes a reduction in the production rate, a reduction in the cycle time, or a simultaneous reduction in production rate and cycle time. Sharma, stated, "Enormous improvements are possible by synchronizing production activities sequentially in a cycle time" (Sharma 2009).   Similarly, the shelf life constrained products in this research would be on separate cycles according to product line. These findings provided insight into the manner in which DSO adopted the current MTO scheduling model.

2. 5 Multi-Product Lot Scheduling with Backordering and Shelf-Life Constraints

Yan and Banerjee managed shelf life by deriving the appropriate number of setups for each item in a cycle instead of creating multiple cycles. There were two key assumptions in their research that the demand rate for each item is known and that the setup time for each item is known. Although this research included a methods section, the process was admittedly unscientific. The research used "a greedy heuristic of successively choosing the activities, one at a time until a feasible schedule is obtained" (Yan and Banerjee 2013). Yan and Banerjee's research focused on running a product multiple times per cycle as opposed to the typical operations literature suggesting multiple cycles.

2.6 Interview with DSO Scheduling Manager

In a November 2013 interview with Dan Polak, the DSO scheduling manager regarding current scheduling practices revealed that due to the high cost of working capital, Cargill had worked with a consulting firm in 2007 to develop an action plan to reduce inventory in the plants and warehouses. He stated, "The directive to eliminate all necessary inventories was supported by popular lean manufacturing theories, and the impact on our ability to react to customer demands took the backseat. Over the years as customer service became top priority we maintained the MTO model despite increasing costs" (Polak 2013). These factors make long term planning very challenging and created a day-to-day flux reacting to order changes. Later in the interview he mentioned, "As our facilities began reaching capacity, the cost of overtime has increased, and it has become apparent that our practices must be reviewed" (Polak 2013). Six years ago "the current cost of working

capital puts a premium on holding inventory", but times have changed and the cost of capital is down while the cost of customer responsiveness has increased.

2.7 Summary of Literature Review

Research shows that reviewing production planning is a common optimization tool for businesses (Kopanos and Puigjaner 2011), and that facilities experiencing inventory and customer service issues often find a solution moving from a MTO to MTS production schedule (Soman, VanDonka and Gaalman 2006). The food industry has additional constraints such as procurement limitations and shelf life. A proven way to address these concerns include synchronizing production to cycles (Sharma 2009), creating feasible product wheels (Foster 2007), and backing into product wheels based on product shelf-life (Yan and Banerjee 2013). It seems straightforward to analyze inventories, shipment histories and produce an accurate production schedule, and many researchers have taken on the challenge, but constraints make this especially challenging and a one size fits all solution has yet to modernize the food processing industry.

CHAPTER III: THEORY

3.1 Hypothesis

The literature indicated a variety of opportunities to increase efficiencies within scheduling, and verified that a scheduling solution could reduce changeovers, minimize schedule variability, reducing overtime. I hypothesize that running an exercise with product wheels, a tool commonly used in the literature, can help in determining the appropriate balance of production asset utilization and warehouse utilization. Achieving this goal would allow DSO to meet its market share goals and maintain profitability. The focus of this chapter will examine how product wheels could help create additional capacity while maintaining the desired customer service levels.

3.2 Product Wheels

According to the product wheel research presented by Bennett Foster for DuPont Corporation, "A production wheel is a production sequence used by manufacturing operations when multiple products are made on a single line/piece of equipment using a consistent sequence and repetitive time cycle" (Foster 2007). In other words, product wheels help allocate products to its best manufacturing option and schedule the assigned products on the right resource in an optimal sequence (Snapp 2009). See Figure 3.1 for a visual representation of a product wheel, showing the interaction of make-to-stock products, make-to-order products, and the relevant changeover times.

Figure 3.1: Product Wheel Including Both Make-to-Stock and Make-to-Order Items
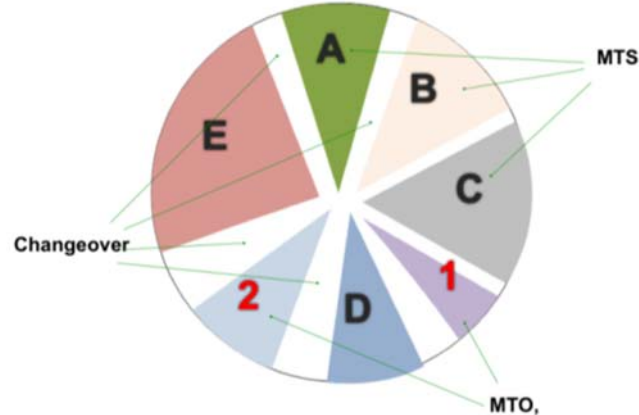
The theory stands that product wheels provide effective discipline for meeting customer demand and service levels, while maximizing process responsiveness and minimizing required inventory. Product wheels are designed to decrease cash flow cycle time, decrease controllable fixed costs, increase variable margin, and provide understanding of the relationship between transition cost and inventory cost. However, the practical solutions from product wheels need additional insight, because of the existence of minimum run lengths due to economic or technical constraints and maximum run lengths due to shelf life limits, freshness requirements, or expiration dates (Gabriela 2011).

3.3 Safety stock

In addition to the product created every run, called cycle stock, there is a level of inventory called safety stock that exists to mitigate the risk of stock outs due to uncertainties in manufacturing supply and customer demand. A recent article in APICS summarizes the business relevance, "Determining appropriate inventory levels is one of the most important and most challenging tasks faced by operations managers. If you carry too

much inventory, you tie up money in working capital; if you don't carry enough inventories, you face stock outs" (King 2011). In addition, products which are stored too long can spoil or expire, while too little safety stock can result in lost sales.

Safety stock is a calculation based on the demand per month (D), the standard deviation of demand per month, the number of days between replenishment (R), the standard deviation of replenishment time, and the desired probability that a chosen level of safety stock will not lead to a stock out called the "service level" (Z) (Bowersox 1978).

Figure 3.2: Safety Stock Equation

$$Safety\ Stock = Z \sqrt{R_{avg}\sigma_D^2 + D^2\sigma_R^2}$$

Safety stock determinations are not intended to eliminate all stock outs- just the majority of them. As shown in Figure 3.2, when designing for a 95 percent service level, the business expects that 50 percent of the time, not all cycle stock will be depleted and safety stock will not be needed. Another 45 percent of cycles, the safety stock will suffice. But in approximately 5 percent of replenishment cycles, a stock out will be expected. While designing for a higher service level would result in fewer stock outs, this requires significantly more safety stock.

Figure 3.3: Inventory designed for a 95 percent service level
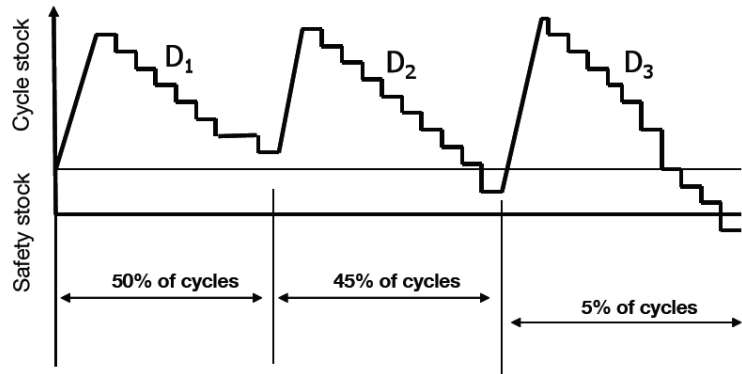
CHAPTER IV: METHODS

4.1 Developing a Trial Product Wheel

After reviewing relevant theory, it is hypothesized that creating a product wheel and optimizing production run lengths provides a viable option to reduce plant operation costs, and satisfy customer service requirements. Given the complexity of the business unit i.e. number of plant SKU's, production lines, and changing demand requirements, it is necessary to verify the optimal solution by running a trial model and analyzing the impacts on one of the highest margin at-capacity lines. The cup line packs ranch and buffalo sauces into dipping cups for large fast food chains. In the past six months, the cup line has run 1-2 days of overtime each week, eliminating the line's profitability. Although this line only runs 15 SKU's, it accounts for 5% of the business units profit and holds over 20% market share in the industry with committed volume growth in the next 2-3 years. Creating an effective sample model requires a thorough outline of business constraints. This will facilitate creating a template, using the cup line as an example, which fosters easy expansion to include the business's remaining 20+ production lines and thousands of additional SKU's.

4.2 Outlining Business Constraints

The first step in developing the model requires a deep understanding of the constraints the solution must meet in order for it to be successful. In this research there are business constraints on ship shelf life, warehousing, and customer service that have consequences regarding production scheduling.

4.2.1   Ship Shelf Life Constraint

Dressings and sauces need to be consumed within a certain amount of time or the product spoils and is not fit for human consumption. Product shelf life is different for each DSO SKU. The customer establishes how much of that time is available for DSO to hold each product before it needs to arrive at its distribution center, this is called the "ship shelf life". Total shelf life ≥ ship shelf life + time spent at distribution center + time spent before used at local store. For the cup line products, ship shelf life varies between 40 to 90 days.

A draft model presented to DSO addressed the ship shelf life constraint; however, the product wheel rotations utilized the full ship shelf life allowed for each product. The Scheduling Department is accountable for any product expirations. The departmental thinking is that an aggressive approach towards ship- shelf will lead to an increase in expirations and a negative personal performance review. This concern led to a rejection of the draft proposal. After several working sessions and analyzing the effects of various utilization levels, the schedulers agreed to review a solution that uses up to 60% of the customer mandated ship shelf life. This will be addressed by creating product wheels based on 60% of ship-shelf life instead of creating product wheels constrained by ship shelf life. As the teams get more comfortable with the idea, there is room to work with the forecasting department to optimize this figure.

4.2.2   Customer Service Level Constraint

In an effort to distinguish DSO in the industry as a supplier of choice, there was a business directive that stated DSO must have 100 percent order fill rates no matter the cost. This is especially challenging for the Scheduling Department given the high demand

13

variability in the past 6 months. The current MTO process exists because customer demand

swings have rendered forecasting unusable, and the company has negotiated 14 day lead

times that allow a reasonable schedule to be assembled to meet anticipated demand. The

Scheduling Department is hesitant to utilize a make to stock production plan that depends

on forecast because forecast errors are costly and reflect poorly on scheduler performance.

If forecast is 10% lower than expected, and the plant had produced to that forecast, some

product could expire. If orders are 10% higher than expected, the product may stock out

which could cause customer turnover. This issue will be addressed by determining safety

stock using a 99% customer service level to cover moderate demand or supply changes.

4.2.3   Warehousing Constraint

Finding the balance in safety stock is important due to the costs of holding a large

amount of inventory purely for emergency situations. The large size of the orders and

number of SKU's produced limits the responsiveness to short term changes in customer

demand. Currently, the warehouse can hold about 15,000 pallet spots, and but only 5% or

750 pallet spots are allocated for the cup line. At the moment very little safety stock is

carried as the facility operates as MTO, any changes to current operations would have to be

fully analyzed to ensure stocks are not expiring, the warehouse is not over capacity, and

that personnel are following FIFO procedures.   In September 2014, a warehouse

expansion to 25,000 pallet spots will be operational and will help alleviate the capacity

constraint.

4.3 Collecting Data

With the objective outlined and the constraints established, next comes the challenge of collecting the accurate data necessary to build a functioning sample model. The first step is collecting data on each product including: historical daily demand, setup costs including labor shrink testing and opportunity costs, contribution margin, allergens, changeover parameters, and storage cost. This information is in the Advanced Scheduling module of Adage 3.0.1 and within the institutional knowledge of personnel in different departments including warehousing, quality, product development, and operations.

4.4 Creating the Model

Using Microsoft Excel 2010 to collect the data will allow for easy sensitivity analysis down the road. Table 4.1 below shows a snapshot of the model on February 17th, 2014, because the model is integrated with live order data and each refresh will show updated figures for cycle stock, safety stock and the dependent calculations.

Table 4.1: Proposed Model Using Methodology Outlined in Chapter 4

A	B	C	D	E	F	G	H	I	J	K	L	M	N
	avg daily demand	10 day order st dev	cycle	cycle stock	safety stock	sellable DOH	calendar DOH	% of ship shelf	Ship Shelf Life	lbs/case	Cases/Pallet	max pallet	run length
69607	1081	136	15	16215	9157	23	31	63%	50	15.62	221	115	3.6
69609	754	82	15	11310	4476	21	29	48%	60	15.62	72	219	2.5
69440	462	57	15	6930	1391	18	24	40%	60	12.18	108	77	1.2
61733	341	99	15	5115	1405	19	25	50%	50	18.78	81	80	1.4
36459	230	41	15	3450	617	18	24	59%	40	18.78	108	38	0.9
69438	467	75	15	7005	1483	18	24	40%	60	12.18	108	79	1.2
68797	197	37	15	2955	463	17	23	58%	40	16.68	81	42	0.7
25362	295	93	15	4425	881	18	24	60%	40	6.28	221	24	0.4
69611	185	24	15	2775	301	17	23	38%	60	12.34	108	28	0.5
62969	258	69	15	3870	656	18	24	59%	40	6.28	187	24	0.3
70105	49	47	15	735	424	24	32	53%	60	15.62	108	11	0.2
66154	48	20	30	1440	258	35	49	55%	90	16.25	81	21	0.3
62510	22	15	15	330	135	21	29	58%	50	18.78	72	6	0.1

The data is organized by the product number in column A. Calculating the average daily demand in Column B started with discussion around the use of forecast versus historical data. DSO's forecasting team primarily focuses on creating annualized budgets, but dividing annual forecast into monthly buckets does not account for seasonality or product promotions. The historical average daily demand pulls the average order size of the product for the past 90 days from a query that is setup in the Order History tab. The query pulls from the tbl_marketplace managed in Microsoft Access using Business Intelligence to pull orders from the customer management Adage system. The order history is refreshed whenever opened by automating the refresh all connections feature in Microsoft Excel. This order history is actual customer shipments by cases by day, averaged to a daily basis. A pivot table was created to show each product individually, which led to the use of a macro that entered each individual product in the search field, pulls up the average, and returns the relevant data to column B. After the order history data is refreshed, and the macro is run, the calculations tab will display the most recent order history allowing for increased accuracy through product seasonality and customer trends.

Column C uses this same query, refresh, and macro methodology to return the 10 day order standard deviation from the past 90 days for each product using the Excel function =stdev. Due to the longer cycles the safety stock does not need to protect against daily order swings but only protect against variation between product wheels.

The next column groups the products into their product cycle. Column D will basically serve as a plug to help utilize as much of ship-shelf life as possible. Due to the ship-shelf constraints no cycle can be longer than 45 days, and keeping the objective of

16

expanding run lengths should avoid cycles shorter than 10 days. The next calculation in column E takes the days in the cycle multiplied by the average daily demand to calculate the cycle stock necessary to produce each product wheel rotation.

Safety stock calculated in column F utilizes the equation outlined in the theory section applied in Microsoft Excel as the Normative inverse of customer service level * SQRT((# of day between cycles *order st dev^2)+ (cycle time st dev ^2 * avg order size ^2)) = NORM.S.INV(.99) *SQRT((D*C^2)+(N^2*B^2).

Calculating the sellable days on hand in column G takes the inventory created each cycle and the inventory maintained in safety stock divided by the number of customer pickup days =(E+F)/B . The complication came where the warehouse only fills customer orders Monday-Friday while ship-shelf life is calculated on a seven-day week. Hence, column H, which takes the days on hand in column G plus column G divided by 5 rounded down * 2, to add weekends (= G + SUM(rounddown(G/5,0) *2), this effectively turns business days into calendar days and creates a mathematical check against ship shelf life.

Column I takes the calendar days on hand and compares it to ship shelf life using =H/J to review the percentage ship shelf utilized by the product wheel. The business unit agreed to review solutions that utilized 60% of ship shelf life so the goal of the spreadsheet was to plug in different cycles for each product to get as close to 60% as possible. With this approach a conditional formatting was added to the column to flag an uncomfortable level of inventories. Column's J- ship shelf life, K- pounds per case, and L- cases per pallet are static data on the products taken from the quality departments packaging information table

within Adage. Although infrequent- the schedulers will need to be alerted of any changes within their products as this is not directly linked to a table but manually updated.

To monitor the warehousing constraint of the model requires a solid understanding of the warehousing needs to lengthen runs and utilize product cycles. Column M calculates the max pallets on hand to ensure the solution fits within the warehousing constraint by taking the cases of inventory created each cycle plus the cases of inventory kept on hand as safety stock divided by the number of cases per pallet $=(E+F)/L$.

To properly align product wheels it is necessary to estimate the length of time each product will take on the wheel. Column N captures the run length in days by using the cases in cycle stock multiplying it by the pounds per case to create a pounds equivalent, then dividing the pounds per cycle by the number of pounds per hour the filler can run to establish the number of hours in the run. This is further complicated that the filling machines currently operated at 50% operational effectiveness (OEE). Adding this variable to the model for future updates allow for easy and realistic realignment of product cycles as OEE increases. The final equation reads $=E* K/5849 *(1/OEE)/24$. After selecting a sample production line, reviewing business constraints, collecting data, and assembling a spreadsheet, the following solution developed.

CHAPTER V: ANALYSIS & RESULTS

This chapter will compare the proposed sample model to current conditions and provide an analysis to determine economic implications, make adjustments for practical application, and outline how this process could be implemented throughout the business.

5.1 Proposed Solution

The table below shows the rotating three-week cycle of products produced each week and the number of days the line would be operating. Creating the product wheels is a two part process of balancing products equally amongst the weeks and finding the optimal sequence. For the cup line sample there are no benefits to sequencing in any particular order as all products require a full changeover due to particulates. Most lines in the facility have similar products with optimal sequences that would need to be taken into account. Thus the next step of balancing the weeks was done by plug and chug to ensure that one week is not running overtime will another ends production on a Thursday. I did not include the cycle stock amount in the product wheel table, because as discussed above this amount changes every week due to customer order patterns. Reading the two tables together gives us the solution that in week 1 the cup line would produce 16,215 cases of 69607 and 6,980 cases of 61733, which would take approximately 5 days of line time. The next week's production would run 69609, then 25362, then 69611 etcetera again only needing to operate 5 days for the week. The following week the line produces week 3 items. Then the rotation starts over with week 1 product.

Table 5.1: Proposed Solution: Product Wheel Results Derived from Sample Model

Cycle Week	Product Codes (column A from table 5.1)					Run Time (Days)
Week 1	69607	61733				5
Week 2	69609	25362	69611	62969	70105	5
Week 3	69440	36459	69438	68797	62510	5

5.2 Cost Effectiveness of the Proposed Solution

In order to measure cost effectiveness it is important to accurately compare the proposed model to the current state, and this requires more data. Reviewing 20 weeks of published cup line schedules show an average of 5 changeovers and an average run time of 6 days per week. Operating 50 weeks per year annualizes this to 250 changeovers each year. The cup line is currently staffed to operate only 5 days per week, and the main goal of this research it to reduce the costs of running the line overtime. A random sampling of weekly schedules is shown in table 5.2 below. It is important to note this is not a rotation but merely showing consecutive weeks of operation.

Table 5.2: Current State: Actual Cup Line Schedule Month of November 2013

Week of	Product Codes (column A from table 5.1)						Run Time (Days)
11/4/13	62969	69611	25362	66154	69438	69607	6.5
11/11/13	69611	36459	69440	61733	69609	62969	6.5
11/18/13	68797	36459	62510	70105	69440	69609	6

Due to colors, the use of allergens and particulates in the formulas changing products multiple times per week comes at a cost. It is necessary to completely clean and sterilize the kitchen and fillers between each product. This procedure takes between 2-3 hours to complete. The cost of each changeover is estimated at $2,152 (see table 5.3). This

was calculated using the average production floor labor wage, average shrink for the line, cost of quality tests, and the opportunity cost of capital (OCC) lost by having idle machines on an at-capacity line. DSO uses the accounting figure contribution margin (CM) to calculate opportunity cost which is defined as the average profit after expenses and found in the businesses monthly profit & loss report. As of March in FY 2013-2014 the CM for DSO is averaging 13.4 cents per pound.

Table 5.3: Cup Line Changeover/Setup Cost Calculation

CUP SETUP COSTS		
Labor	$180	$20 wage * 3 hours * 3 machines
Shrink	$80.4	600 pounds* .134 CM
Quality	$150	$7 quality test * 6 tests * 3 machines + 1 hour of lab tech labor $25
OCC	$1741	.134 CM * 34 ozs/min /16*60 mins/hr *3 hours * 3 machines *50% OEE
TOTAL	$2152	

For the cup line, the labor cost used could have been overtime wages instead of average wage levels, but wanted to a conservative savings calculation that shows the changeover time saved could either increase capacity or reduce overtime without any improvements in overall equipment effectiveness (OEE).

Reviewing the proposed model in section 5.1 finds an average 2.66 changeovers and an even 5 days of running time each week of the cycle. Operating 50 weeks each year annualizes this to 133 changeovers per year. Compared to the current state this new production schedule eliminates 10 changeovers per month, effectively reducing changeovers by over 46%. At three hours a changeover this frees up 4% of line capacity thus reducing overtime by 15 days per year.

As detailed in the theory section lengthening production runs requires a right sizing of inventories and as seen in the model this solution does comes with a warehousing expense due to increased safety stock and cycle stock. According to the location warehouse manager, the cost of holding 1 pallet in storage is estimated at $637.60 per year. This includes all relevant costs for incremental storage including pallet movement, and truck transportation cost. Given the current 750 pallets positions reserved for the cup line, only, the cost of 15 incremental pallet spaces should be included in the comparison.

Table 5.4 puts the current cost of changeovers together with the proposed cost of changeovers, and the resulting costs in incremental storage, nets DSO a savings of $235,714 per year. Although not additional earnings, the savings will be realized in operation expenses.

Table 5.4: Economic Implications of the Proposed Model versus Current State

	Annual Count	Cost	Annual
Current Cost of Changeovers	250	$2152	$538,000
Proposed Cost of Changeovers	133	$2152	- $286,216
Cost of Incremental Storage	15	$637.60	- $9,564
Total Savings			= $242,220

5.3 Sensitivity Analysis on Customer Service Level

To meet 100% of customer orders requires either a MTO as done today or an appropriate level of safety stock to meet unexpected demand. The correct level of safety stock varies by business and as demonstrated in Table 5.6 safety stock is directly correlated to the level of service. DSO currently has 750 pallet spots in the warehouse reserved for the

cup line, and the proposed model uses a 99% customer service level requiring an

incremental 15 pallet spots for a total of 765 pallet spots. I was interested in the affects the

level of service variable placed on warehousing constraints, so I ran sensitivity on the

impact on the amount of safety stock recommended per product. Only incremental pallet

spots are included in the cost calculation. Given the marginal impact on total savings I

believe a 99% level of service best satisfies the DSO's requirement of 100 percent order fill

rates.

Table 5.5: Level of Service Sensitivity on Warehousing Costs

| Level of Service	Safety Stock	Cycle Stock	Total Max Stock	Incremental Cost
90%	98	587	685	$0
95%	126	587	713	$0
99%	178	587	765	$9564

5.3 Practical Application

Using descriptive methods such as calculating the historical order size and

standard deviation gives DSO an accurate practical calculation of the safety stock levels

necessary to operate the three-week cycle production runs. This is a model that can be

and should be refreshed frequently to ensure the balance between cost of changeovers

and cost of warehousing remains up-to-date.

After presenting the new proposed cycle that satisfies the main business

constraints, there is still the overall concern from the Scheduling Department of

unpredictable customer orders which directly breaks the theoretical assumption of stable

demand for a product wheel to be successful. The current process allows quick response to

changes in orders but production issues begs the matter of responsiveness. See Figure 5.1

for a visual representation of how schedulers currently respond to sales orders and

production issues.

Figure 5.1: Current Make-To-Order Sales Order & Scheduler Response Process Flow
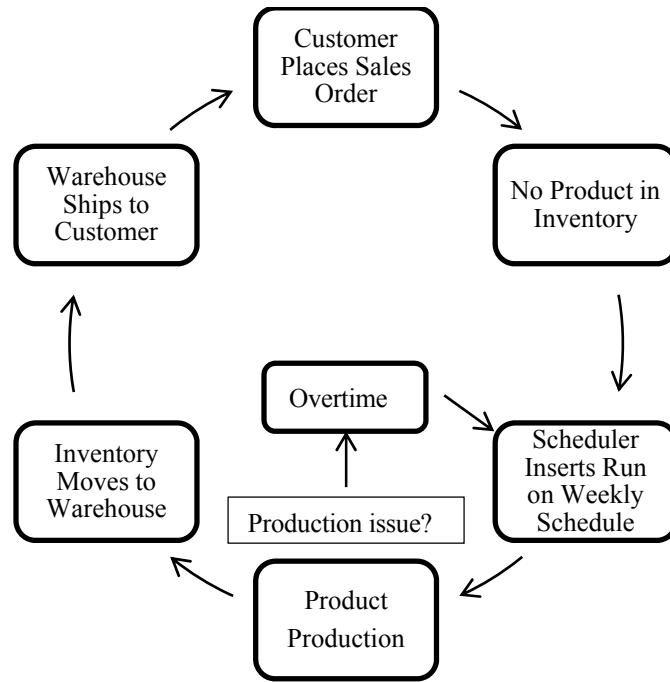
It will take time for the team to gain trust in the safety stock calculations, and as the

theory suggests a 99% customer service level still leaves room for a possible stock out or

shelf life expiration. For the majority of the time, safety stock will handle fluctuations in

customer demand without interrupting the product wheel. Figure 5.2 below demonstrates

how the proposed solution's new customer service level and safety stock will change the

scheduler's response to sales orders.

Figure 5.2: Proposed Solution: Sales Order & Scheduler Response Process
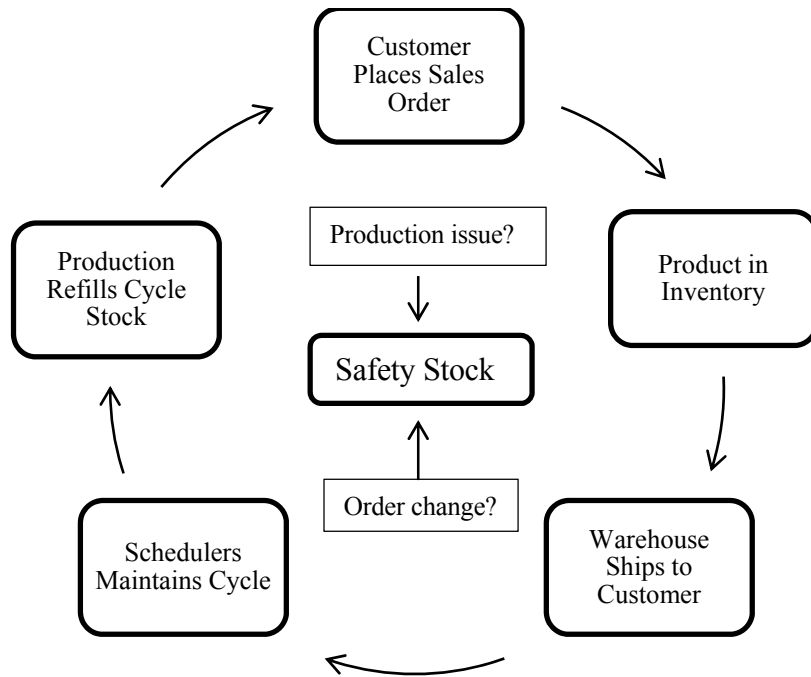
Although safety stock will help cover the business from normal swings in supply and demand, developing the right contingency plans for drastic situations is imperative for the product wheels to work and for DSO to realize the savings of reduced changeovers. Working with the Scheduling Department and commercial group we developed action plans to help address these demand swings. If customer orders are below forecast, then the schedulers have the ability to reduce the length of the next run, and work with the customer to adjust forecast and possibly extend ship shelf life. If customer orders rise unexpectedly, then the schedulers can insert an additional production run, or push back on the DC to use their safety stock to add a few days flexibility and in both cases work with the customer to get an understanding of the increase in demand. Although occasionally inserting additional

production run reduces potential savings, it is still better to implement the plan to capture the efficiencies and have a backup for worst case scenarios.

5.3 Lessons Learned from Trial Product Wheel

The business chose to move forward with a trial implementation during a slower demand season which allowed them to efficiently build up inventories to cycle stock levels. Due to the stock build up the increase in capacity was not truly felt for 8 weeks, but shortly thereafter production returned to an average 5 days per week with only marginal overtime. The good news is that the product wheels were successful in increasing capacity; the bad news is that the business has already filled this with new products and has returned to 6.5 days per week operation.

The implementation of this plan required a significant change in process and demanded extensive teamwork from individuals in each department. There was resistance from several employees, due to a non-understanding of the reasoning behind the changes. Going forward it is essential to stress the reasoning and importance of making these changes as they will reduce the extensive overtime that DSO faces allowing production employees more time to spend with their families and help DSO meet operational and financial goals.

CHAPTER VI: CONCLUSION

6.1 Final Recommendations

This paper proves that a three-week product wheel will help DSO increase capacity on the cup line while staying within customer service, shelf life and warehouse constraints. The proposed product wheel is a marked improvement over existing MTO production plans and will reduce overtime expenses associated with changeovers.

Given the cost effectiveness outlined in section 5.2, I recommend that DSO run the same model on the remaining production lines in the business. Before declaring product wheels a blanket solution to the businesses problems, DSO should review order history for products with unusual order variability and smaller volume products that may need to stay on a MTO system. Overall though, expanding the model and finding the ideal production cycle for each product line will ensure effective product wheels and accurate safety stock calculations. Warehousing constraints will become more of a factor as more production lines come on board, increasing safety and cycle stocks such that warehouse capacity is exceeded.

6.2 Further Research

It is generally understood that reducing overtime has a positive impact on safety and employee engagement, but these benefits fell outside the scope of this research. If DSO needs more evidence of the benefits of product wheels a few areas to expand upon include: employee engagement, safety metrics, line efficiencies due to longer runs, and other financial benefits regarding reduced employee turnover.

27

A second suggestion for future research include maximizing profit by optimizing the amount of shelf life are used in the product wheels incorporating the risk of stock outs versus expirations. The 60% negotiated with the business currently makes sense in the short term, but an optimal solution could be discovered as the company gets more comfortable with the idea of product wheels.

This research also serves as discussion point between the commercial team and the customers. As the business transitions to Make-to-Stock production there could be some adjustments in customer lead time policy, giving the customer a long amount of time to place orders as long as order patterns remain consistent. This give and take demonstrates the partner of choice relationship that Cargill aims to achieve.

6.3 Final Thoughts

Product wheels are an established concept in the manufacturing industry, and although the theory is widely taught in operations courses around the world, the actual implementation of the theory is much harder to realize. The additional complication of ship-shelf life might lead managers towards other capacity projects, but the exercise of balancing warehousing costs with the cost of changeovers for is good understanding for any business. Over the past 20 years there has been a focus on increasing efficiencies and designing responsive processes. The idea of lean operations with less inventory and more responsive processes revolutionized production plans across the globe, but fewer inventories isn't cost efficient when there are large swings in demand, and more recently finding the compromise between customer responsiveness and inventory time has gained focus.

WORKS CITED

Bowersox, Donald. *Logistical Management.* New York: McGraw-Hill, 1978.

Cargill. *Our Businesses: Dressing, Sauces & Oils.* n.d.
http://www.cargill.com/company/businesses/cargill-dso/index.jsp (accessed Feb 17, 2014).

Foster, Bennett. "Developing Product Wheels for Process Industry Operations." *DuPont Operations*, 2007: 1-14.

Gabriela, M. "Servicio y Tecnologia SA." *SYSTA*. April 14, 2011.
http://www.sytsa.com/ingles/PDF/Casos%20mas%20recientes/ps_p_the_product_wheel_approach.pdf (accessed 26 11, 2013).

IbisWorld. *Seasoning, Sauce and Condiment Production in the US.* Dec 2013.
http://www.ibisworld.com/industry/default.aspx?indid=276 (accessed Feb 16, 2014).

King, Peter L. "Crack the Code: Understanding safety stock and mastering its equations." *APICS Magazine*, 2011: 33-36.

Kopanos, Georgio, and Luis Puigjaner. "Resource-constrained production planning in semicontinuous food industries." *Computers and Chemical Engineering*, 2011: 2929-2944.

Polak, Dan, interview by Emilie Jensen. *Scheduling Practices* (Nov 2013).

Sharma, Sanjay. "Revisiting the shelf life constrained multi-product manufacturing problem." *European Journal of Operational Research*, 2009: 129-139.

Snapp, Shaun. *The Product Wheel and PP/DS.* Oct 12, 2009.
http://www.scmfocus.com/sapplanning/2009/10/12/the-product-wheel-and-ppds/ (accessed 11 26, 2013).

Soman, CA, DP VanDonka, and GJC Gaalman. "Capacitated planning and scheduling for combined make-to-order and make-to-stock production in the food industry." *International Journal of Production Economics*, 2006: 191-199.

Yan, Changuyan, and Avijit Banerjee. "Multi-product lot scheduling with backordering and shelf-life constraints." *Omega*, 2013: 510-516.