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I. Introduction

The Inventory Management System is a system that buys ingredients, stores excess ingredients, and creates cattle and chicken feed. The three ingredients that create cattle and chicken feed are corn, lime, and fish meal. There are subtle differences in the makeup of cattle and chicken feed, however all three products are used in both feeds. The system is an s-S inventory management model. This means that when a specific product is below a threshold, an order for that product will be processed. The suppliers have an order sheet detailing the cost of different size ingredient purchasing options and if the option has the ability to be shipped overnight or must be shipped in the standard 3-5 days time. The raw material costs are copied in the planning section, see Table 2. If the Inventory Management System has left over ingredients then they must be stored. Raw ingredients are stored in a manner that allows for one thousand pounds of ingredients to be stored in a twelve square foot block. The payments for storage space are one dollar and eight cents per square foot with an additional cost of fourteen to twenty cents per square foot in utility/overhead cost.

The system does not have defined inventory evaluation conditions or feed prices and is, firstly, in need of assessment. After assessment, the company must improve the system to maximize profits. This is where the team can provide incredible insight via simulation. In order to assess performance, the easiest process is to experiment with the actual system - however this Inventory Management system current has no success settings. This would mean that all experiments would be blind and could only be evaluated after enough data is accrued. This would be very detrimental to the business. If an experiment were to go awry, customers would no longer buy from the company and the business would take a very large financial hit. Since experimenting with the actual system is not an option, the next step would be to experiment with a mathematical model. Since there are multiple undefined variables, the process of analytically defining a solution would be very tedious. Finding an analytical model might prove successful with one set of variables and price points, but would not lend itself to the ability to pivot on variable values without having to recalculate final solutions.

The best route to finding optimal settings for the Inventory Management System is simulation. Simulation has the ability to pivot on variable values and quickly recalculate immediate impact and impact on future orders. In addition, the ability to simulate a "regular" week based on historic distributions as well as the ability to simulate light or heavy order weeks would provide immense value to the company.

In order to provide a concrete solution, the team will be designing an inventory system to maximize profit for the system. The goal is to set two prices, P_1 and P_2, for the price of cattle and chicken feed, respectively, that would routinely net the company profit. The price cannot exceed a markup of 45% from the breakeven price for a pound of feed (calculated from the per pound cost from Table 2). This will eliminate the ability to charge an unrealistic amount for the product to offset a poorly planned business model. The solution will be achieved by defining when the company checks inventory, conditions for purchasing more inventory, price to charge per pound of feed, process of handling backorders, and the monthly square feet of storage.

II. Planning

The agricultural mill produces both cattle feed and chicken feed. The main ingredients are corn, lime, and fish meal. For the cattle feed the mixture ratio is 46.5% corn, 40% lime, and 12.5% fish meal, and chicken feed is 52% corn, 43% lime, and 5% fish meal. In order to develop a complete model of an proposed inventory management system to be used at the agricultural mill to manage operations and minimize costs, it must capture a reasonable operational flow of inventory; hence Figure 1 through Figure 3 conveys a conceptual model of the inventory management system with customer demand of cattle feed and chicken feed, ordering, and receiving stock.

Figure 1: Customer Operations

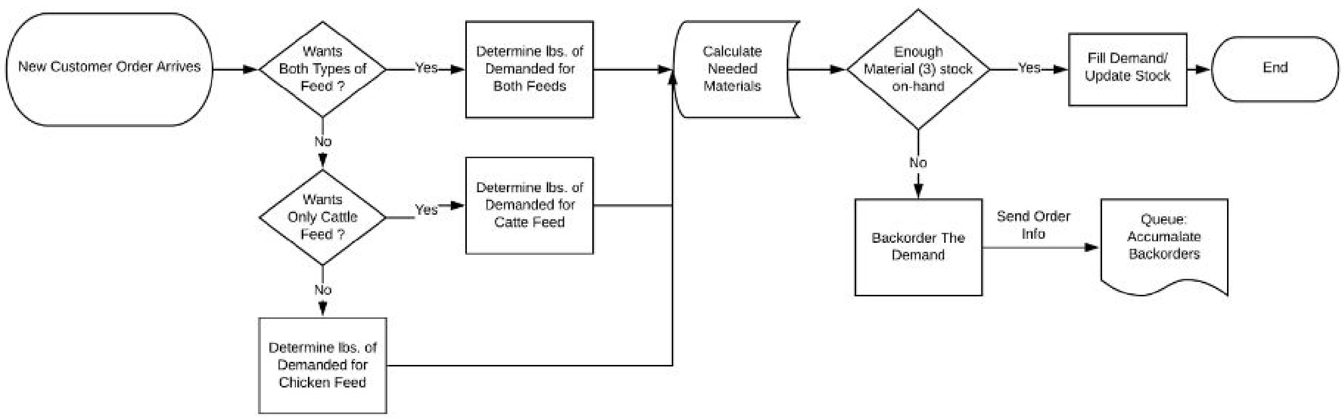


Figure 2: Inventory Ordering Operations

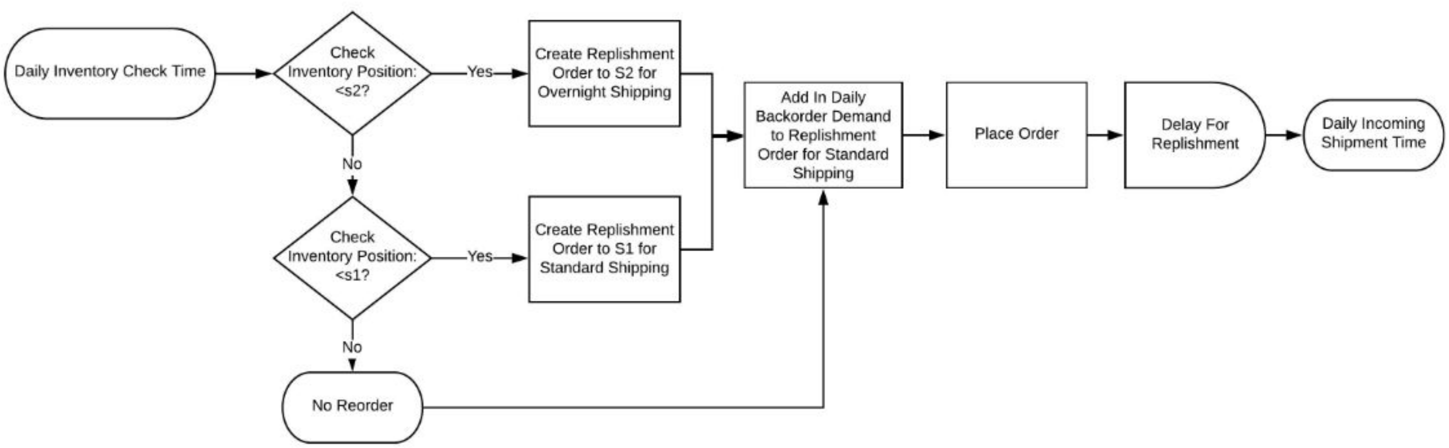
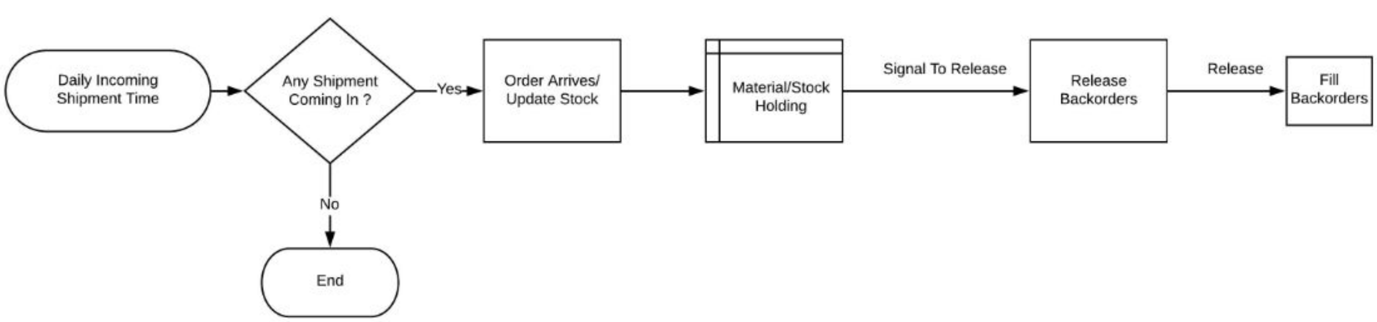


Figure 3: Incoming Shipment Operations



The conceptual model displayed in Figure 1 overall represents the agricultural mill with an inventory policy of double s-S or defined as (s2, s1, S2, S1) inventory policy with inventory evaluation after daily. This will be considered the baseline inventory policy to design an inventory policy that minimizes the costs. Initially, customers arrive to request orders with a given interarrival time as conveyed in Figure 1. Each customer order corresponds to the customer wishing to buy a random amount of chicken feed, cattle feed, or both in lbs. Thereafter, a calculation is done and stored for raw materials amount in lbs. needed to fulfill order. Then, a material inventory check is needed to determine if order can be fulfilled for all three mixture ingredients. If there is an adequate amount of raw material for the three mixture ingredients, the order is filled, and the inventory stock of raw materials drops. If a customer order cannot be fulfilled immediately due to inadequate resources of material, the order is sent to a queue of backorders with the replenishment determined and ordered when inventory is checked. Additionally, the customer is sold feed at a price of $\$P_1$ per cattle feed pound and of $\$P_2$ per chicken feed pound.

Thereafter the inventory positions are checked for each material daily as indicated in Figure 2, with accordance to the proposed (s2, s1, S2, S1) inventory policy. If the inventory or supply level is below s2 for each raw material or the lower threshold value for inventory, then an order is placed to resupply that raw material overnight to S2. Furthermore, if the inventory or supply level is below s1 but not below s2 for each raw material or the lower threshold value for inventory, then an order is placed to resupply that raw material with standard shipping to S1. Lastly the needed replacement of the inventory levels in order to fulfill the backorder queue is determined and ordered, otherwise no order is placed. All orders are created and fulfilled with pre-established raw ingredient suppliers. The order of raw ingredients contains a shipping delay and shipping order weight threshold as represented by Table 1. Furthermore, Table 2 contains the costs associated with shipping the raw ingredients to the agricultural mill.

Table 1: Shipping Details

Shipping Flat Rate	$50	Arrives in 3-5 days
	$80	Arrives next day
Max Shipping Weight	5 tons	

Table 2: Raw Material Costs

Item	Size (lbs)	Cost	Overnight shipping?
Corn	500	$100	-
Corn	100	$25	Y
Lime	500	$75	-
Lime	100	$17	Y
Fish Meal	100	$25	Y

In Figure 3 it indicates that daily, it should be checked if orders of any raw ingredient are arriving. Once the order arrives it is stored in holding after the inventory levels are updated. This stock is stored in blocks of 1000 lbs. of raw materials, occupying 12 square feet. In holding stock of the three materials, costs include a monthly rent of $1.08/sqft, while monthly utilities and other overhead costs range from $0.14 / sqft to $0.20 / sqft. Initially at the beginning proposed date to implement the new inventory policy and system, there is expected to be 3000, 2500, and 1000 pounds (lbs.) of corn, lime, and fish meal, respectively, in storage.

In the inventory system, once stock of raw material is obtained, the backorders can be released for fulfillment as indicated in the inventory control process shown in Figure 3. This entire inventory control process will be modeled in Excel, aggregated by order while breaking down associated costs and inventory levels by raw material type.

Initially, to develop a concise model of the proposed inventory system in order to conduct a discrete-event simulation, distributions concerned about the demand of cattle and chicken feed are needed to address uncertainty about the demand for agricultural mill's products. Specifically, this includes knowledge about the distribution of the inter-arrival times of the customers. Additionally, input parameters concerning the percentage of customers who order cattle feed only, who order chicken feed only, and who order both cattle and chicken feed are needed to determine customer demand allocation in the model. Thereafter, distribution declarations concerning the demand in pounds (lbs.) of cattle feed and chicken feed are needed to stochastically input uncertainty around customer order amounts. Furthermore, input parameters such as feed selling prices offered at per pound of feed and backorder discount rate needs to be addressed to obtain an inventory policy to minimize cost and maximize profit.

While the model is concerning a proposed inventory management system that will overhaul or reconfigure the current system, validation needs to be done to ensure acceptable results to the agricultural mill's stakeholders. Mainly output metrics such as average monthly profit, average monthly revenue, and average monthly cost, inventory levels need to be addressed through conducting multiple trials or replications through simulation of the model to obtain relevant statistics concerning those metrics. To ensure the validation of the model, historical demand data and interarrival time will be used to ensure the assumptions concerning input parameters and distribution are valid.

III. Input Analysis

The data used in this project was collected by Cathy Xia and Priya Natarajan due to the SARS-CoV-2 pandemic limiting our ability to collect our own data in the real world. The three input random variables in the given data are the interarrival time of orders, the amounts of demand for cattle feed, and the amounts of demand for chicken feed. Initial input analysis of this provided data was conducted using Arena's Input Analyzer.

Figure 4: Demand of Cattle Feed Histogram Chart

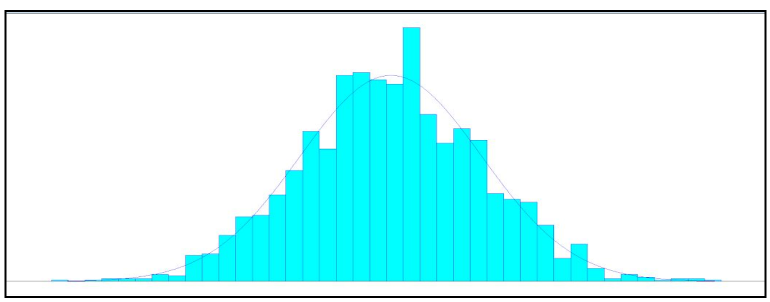


Figure 5: Distribution Summary for Cattle Feed

```
Distribution Summary

Distribution:   Normal
Expression:     NORM(0, 0)
Square Error:   0.000996

Chi Square Test
  Number of intervals    = 27
  Degrees of freedom     = 24
  Test Statistic         = 43.2
  Corresponding p-value = 0.00966

Kolmogorov-Smirnov Test
  Test Statistic         = 0.016
  Corresponding p-value > 0.15
```

```
Data Summary

Number of Data Points   = 1946
Min Data Value          = 325
Max Data Value          = 473
Sample Mean             = 400
Sample Std Dev          = 20.1

Histogram Summary

Histogram Range         = 325 to 473
Number of Intervals     = 40
```

Figure 6: Demand of Chicken Feed Histogram Chart

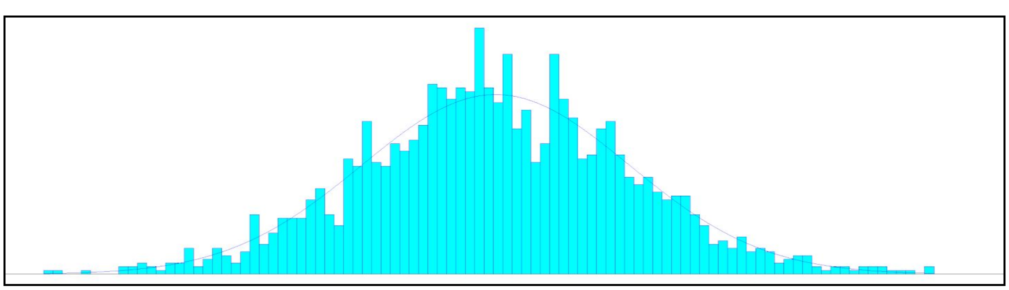


Figure 7: Distribution Summary for Chicken Feed

```
        Distribution Summary

Distribution:   Normal
Expression:     NORM(0, 0)
Square Error:   0.000684

Chi Square Test
  Number of intervals   = 60
  Degrees of freedom    = 57
  Test Statistic        = 58.8
  Corresponding p-value = 0.419
```

```
          Data Summary

Number of Data Points   = 1726
Min Data Value          = 152
Max Data Value          = 246
Sample Mean             = 200
Sample Std Dev          = 14.3

          Histogram Summary

Histogram Range         = 152 to 247
Number of Intervals     = 95
```

In both the case of cattle feed and chicken feed, the distribution of demand is either zero or approximately normal. The distribution for the demand of cattle feed has a mean of 400, a standard deviation of 20.1, and a Chi-Square test p-value of 0.00966. The distribution for the demand of chicken feed has a mean of 200, a standard deviation of 14.3, and a Chi-Square test p-value of 0.419.

Analysis for the interarrival times of orders:

Figure 8: Interarrival Time Histogram Chart

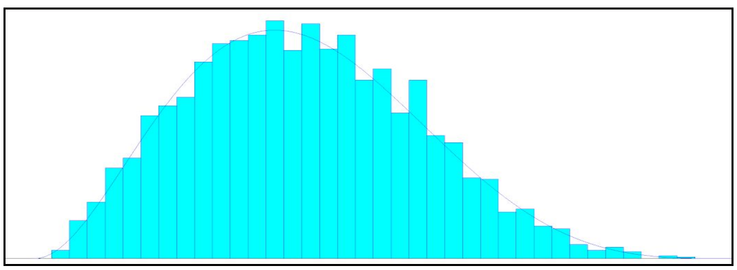


Figure 9: Distribution Summary for Interarrival Time

```
        Distribution Summary

Distribution:   Beta
Expression:     25 + 9.93 * BETA(3.06, 5.06)
Square Error:   0.000276

Chi Square Test
  Number of intervals   = 30
  Degrees of freedom    = 27
  Test Statistic        = 23.2
  Corresponding p-value = 0.67

Kolmogorov-Smirnov Test
  Test Statistic        = 0.0216
  Corresponding p-value = 0.142
```

```
          Data Summary

Number of Data Points   = 2536
Min Data Value          = 25.3
Max Data Value          = 34
Sample Mean             = 28.7
Sample Std Dev          = 1.59

          Histogram Summary

Histogram Range         = 25 to 34.9
Number of Intervals     = 40
```

The distribution of interarrival times is best represented by a Beta distribution. The distribution has a mean of 28.7 minutes, a standard deviation of 1.59 minutes, and a Chi-Square test p-value of 0.67.

Table 3: Percentage of Order Type

	Percentage
Cattle Feed	41.05%
Chicken Feed	33.54%
Both Feeds	25.41%
Total	100.00%

In addition to distributions of variables, there are constant values for the percentage of specific types of orders. These percentages will be used in decision modules as constant dividers for the incoming order types.

IV. Assumptions and Additional Data

Based on the conceptual model and given data, assumptions had to be made. The first assumption was that there is no loss product when making chicken feed & cattle feed. This means that the exact percentage to make a feed will be allocated to making the feed. There is never dropped or lost product in the process of creating the feed. In addition, the weights of each product are perfect when creating the feed. The exact percentage make-up of the feed will be allocated to the feed. Also, the team decided that the simulation would run for 90 days. This time period was chosen to best replicate the current data-set. To get accurate confidence intervals the team would run the 90 day simulation 20 times.

Other assumptions that were decided upon were to make the model as realistic as possible. Realistically 100% guaranteed is nearly impossible. We cannot guarantee supply will always be there for demand, and if we do we will just be making empty promises. Assumptions state that we will do our best to meet demand, but 100% will not be it. Likewise, realistically the feed may go bad after days/weeks, however we assume the product turnover will be quick enough that we will never have to worry about food spoiling. Furthermore, initially, the team assumed checking inventory after every customer would be the ideal policy, however after realistic consideration, this process would be very tedious and improbable for a real world system. Instead of multiple checks a day, it would be more realistic if the checking process was once a day. The team decided on a 3pm inventory check time because that time would ensure that overnight orders have a realistic probability to be shipped overnight if needed. If orders were placed at the end of the workday no overnight shipping could, realistically, be processed.

The distributions for the model will be the following: First, the monthly utilities & overhead costs will have a uniform distribution. Every square foot for each month is the same cost on the uniform distribution. A uniform distribution means that all outcomes are equally likely; each variable has the same probability that it will be the outcome. Second, all chicken and cow feed purchases are all in the same distribution. A single distribution will be used to determine how much of each feed is ordered regardless of if the customer buys both feeds or only one feed. Initially, customers were expected to have patterns of different sized orders if they were buying both feeds, in contrast to orders that were just buying one feed. After analysis on the minimum and maximum values for single feed orders and multi-feed orders, the team realized that a single distribution would appropriately represent single chicken or cattle feed orders and multi-feed orders.

There were also concerns of how exactly historical data will be used. It was known that historical data could repeat itself. Therefore, the business will use historical data to forecast future performance of the company. The historical data will help map out the trajectory of sales over time. Data points from various points in the past will be taken to approximate the rate of change in sales over time, that rate will then be applied to the most recent sales data to forecast future change in sales volume. Furthermore, the store will open at 6am and no orders will be received after 9pm. This is the case since historical data shows that orders have been placed no earlier than 6am nor any later than 9pm.

Last but not least, there were assumptions made to determine costs. Storage cost should be the maximum storage level for that month. The storage space will be calculated from 9pm inventory level. It is safe to assume that the shipped products come into the company's possession before the first order is placed for that day. The company does not have to pay for storage costs during the day, therefore when a new order comes in the storage space needed for the order will be assessed at the end of the day. Likewise, cost will remain constant. The feeds are composed of three main ingredients. Each feed has their own specific amount of ingredients in percentages. Cattle feed consists of 46.5% corn, 40% lime, and 12.5% fish meal. Chicken feed consists of 52% corn, 43% lime, and 5% fish meal. Since the prices are known, the price for feeds will remain constant throughout. Furthermore, Using the values from the problem description, the breakdown of the per pound cost to create the feeds are seen in tables 4 and 5. The mark-up is assessed and the maximum price to charge the customer is also featured on the table.

Table 4: Cattle Feed Price Breakdown

Cattle Feed					
Product	Cost of product	Lbs of product	Cost/lbs of Product	Makeup of Feed	Cost/lbs of Feed
Corn	$25	100	$0.25	46.5%	$0.11625
Lime	$17	100	$0.17	40.0%	$0.068
Fish Meal	$25	100	$0.25	12.5%	$0.03125
			Total Cost for 1 lbs of Cattle Feed		$0.2155
			Mark-Up		45%
			Price to Charge with Mark-Up		$0.312475

Table 5: Chicken Feed Price Breakdown

Chicken Feed			
Product	Cost/lbs of Product	Makeup of Feed	Cost/lbs of Feed
Corn	$0.25	52%	$0.13
Lime	$0.17	43%	$0.0731
Fish Meal	$0.25	5%	$0.0125
Total Cost for 1lbs of Chicken Feed			$0.2156
Mark-Up			45%
Price to Charge with Mark-up			$0.31262

There was certainly some additional information needed. First and foremost, the cattle feed makeup only sums to 99%. The team is not sure which product makes the last percent of the cattle feed. If the team was to have updated numbers, then the price and feed would be updated. However, for the current project we will assume that the final 1% is water which does not need to be checked during inventory checks or accounted for with payment history. Likewise, a question that came up was if we have already paid for storage for the first month. At the start of the month there is 6,500 lbs of product in storage. This storage was already paid for last month therefore the team will not need to account for any payments due to this value. The current monthly payment for storage will be paid before that night in order to not use unpaid storage. This assumption allows the team to start the simulation out of debt, but the company will need to pay for that month's storage before the end of the first day. Furthermore, do we have additional labor costs? How many people work for us and how much do they make an hour/per salary? With this additional information, the true cost of running this inventory management system would be much more accurate.

With the current information, the team will be assuming that there are no additional workers outside of the four team members. If feasible the team will add a "labor cost" function that accounted for X1 workers being paid $X2 per hour.

V. Modeling

The developed model in Excel, (see MODEL.xlsm) simulates our proposed inventory management system that customers buys cattle and chicken feeds, while the store obtains ingredients and stores them to sell cattle and chicken feed. All input parameters are available in a specified sheet for clarification.

The final model randomly generates customer arrivals i.i.d for ninety days, with customers arriving between the store operating hours (6 AM - 9 PM). For each generated customer for the ninety days, the decision to buy both feed or just one type is randomly i.i.d decided, along with the customer's demand in pounds. of each type of feed with the given distributions. The model then breaks down the customer order to the raw ingredient supply needed in pounds in terms of corn, lime, or fish meal. A primary feature of the model is a measure of the material stock for each ingredient, updating after each transaction is made for fulfilled orders. To clarify, as described earlier, the material inventory check is done to determine if order can be fulfilled for all three mixture ingredients. If there is an adequate amount of raw material for the three mixture ingredients, the order is filled, otherwise it is under "backorder" status. Lastly, the payment is received from each customer after each order transaction.

To resupply inventory as demand utilizes the raw ingredients, the model is designed to make ordering decisions based on a double s-S or defined as (s2, s1, S2, S1) inventory policy. Ordering decisions in terms of amount in pounds or shipping method for each ingredient are made at 3 PM daily for all ninety days. In the order after 3 PM, the model evaluates if the inventory or supply level is below s2 for each raw material or the lower threshold value for inventory, then an order is placed to resupply that raw material overnight to S2 if needed. Furthermore, if the inventory or supply level is below s1 but not below s2 for each raw material or the lower threshold value for inventory, then an order is placed to resupply that raw material with standard shipping to S1. The model determines that all standard shipping orders placed on the same day by ingredient type arrive discrete uniformly random between 3 to 5 days. All shipments arrive in the morning at 6 AM and material stock is updated. Furthermore, multiple trucks are ordered if the max shipping weight is exceeding for an overnight or standard order type. The cost is incurred when the order is placed for the model's purpose to manage cash flow.

Orders with a "backorder" status are recorded in another sheet, aggregated daily for the ninety days. The model effectively implements a second inventory management and control system of ordering and receiving shipments of raw ingredients, exclusively to fulfill backorders in order to satisfy customer demand in a responsible manner, other low customer stratification could change could harm customer acquisition. The "backorder" subsystem orders enough stock to fill daily backorders and it always has standard shipping. Furthermore, for those orders that were under a "backorder" status, these orders have been released to be fulfilled when the backorder shipments arrive. The backorders revenue is gained when the order is placed initially for cash flow purposes, but backorders are priced 15% less than original prices.

For determining holding costs and utilities cost, which is priced monthly per square feet, the model determines the maximum holding space used in square feet for that month with material stock being stored in blocks of 1000 lbs. of raw materials, occupying 12 square feet. This maximum holding space usage value in square feet is used to calculate the cost of monthly storage and utilities for each month. Finally, the model updates information relevant to the store's stakeholders such as monthly and quarterly expenses, revenue, profit, profit margin, and backorder percentage for each trial in a dashboard for the ninety-day single simulation trial. Another dashboard is also developed, for running up to twenty replications of the simulation to output relevant statistics regarding the inventory system.

Figure 10: Across-Replication Simulation Dashboard

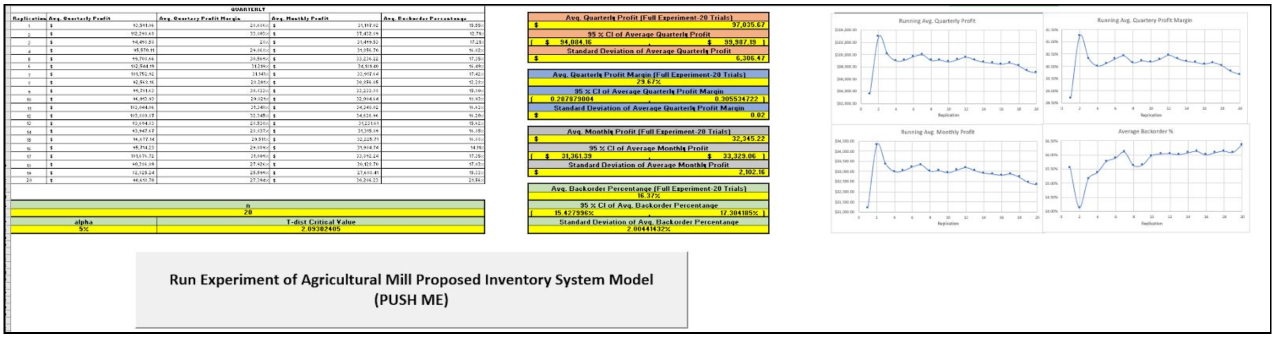
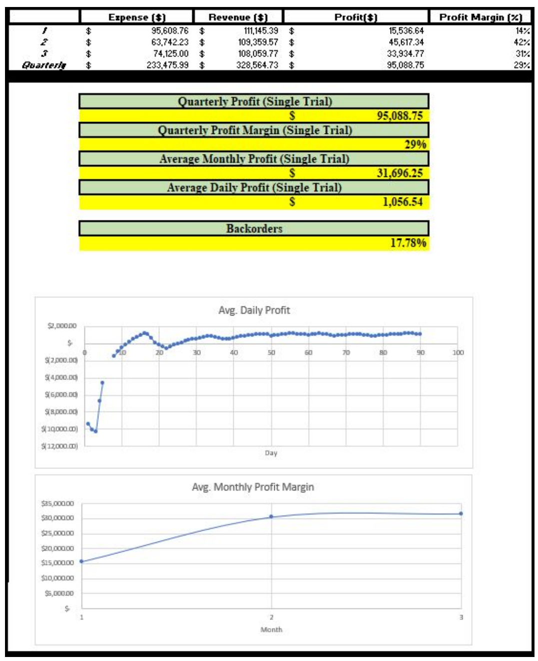


Figure 11: Within-Replication Simulation Dashboard



In developing the model, there was major difficulty in enabling the recursive properties of the model in terms of creating an updated count in lbs. of the current inventory levels for each raw material type. The current inventory levels for each raw material type depends on previously updated inventory level or difference between inventory level and customer demand, alongside incoming shipment amounts in lbs. Additionally, to create a stochastic system of the model in terms of the demand, the customer arrivals and demand were a dynamic array or changing array size when regenerated, which meant the model needed to dynamically model the stochastic demand actively. Furthermore, another challenge was to incorporate processing backorders, which increased the model's complexity of allocating orders and inventory level on another layer; thus, the processing backorder transformed into a sub-system which would incorporate the main model system for cash flow purposes. Another challenge was allocating cost associated with holding as holding costs realistically are aggregated on a monthly basis rather than daily. So, assumptions regarding how monthly rent for holding stock was determined as inventory levels changed at a customer and shipping intake level.

The major way in which the model was validated was stress testing the model to look at convergence of the across-replication sample statistics and their confidence intervals for relevant measures mentioned above. This is conveyed in the Figure 7, which contains running averages of relevant measures with accordance to the number of replications completed thus far. As indicated by model outputs by inspection, the sample statistics for the mean of all measures seem to converge or lose variability. Furthermore, when inspecting the across replication values, they are deemed to have low variability in terms of their sample standard deviation or half-width; indicating the model does not dramatically vary in output such that model verification can not be guaranteed. In Figure 11, the same convergence can be applied to other relevant measures within replication. There is a convergence of the average of the daily profit, while the monthly profit, monthly profit margin, monthly expenses & revenues show little relative variability through inspection. Lastly, as this model is a request for proposal for the agricultural mill's inventory control and management system, there is no historical data to validate and verify the output statistics. Hence, the model is verified by smooth transition and lack of high variance as in the output statistics displayed in the next section.

VI. Output Validation and Verification

The output of the simulation has been summarized in the following tables. The gathered output data from all trials and compared their mean quarterly output, relative variance, and 95% confidence interval. This comparison is done via tables and charts in excel. In addition, the team focused on the percent of backorders. The goal was to have backorders below 5% to maintain positive customer relations. Box and whisker plots were created to visualize the range and mean values of average quarterly profit. The 95% confidence interval comparison graph objectively defines if the team can claim, with 95% confidence, that one scenario's average quarterly mean is higher than another.

Table 6: Comparison of Quarterly Profit Metrics and Percent Backorders with Double S System

MEAN QUARTERLY PROFIT		LITTLE S1 and Big S2			
		25%	35%	45%	55%
Days Supply	10 Day	$90,899.90	$81,700.49	$77,480.96	$80,297.15
of Inventory	5 Day	$102,384.60	$102,774.00	$100,364.50	$98,412.40
(Big S1)	3 Day	$98,709.43	$104,033.20	$104,792.80	$103,319.80
VARIANCE QUARTERLY PROFIT		LITTLE S1 and Big S2			
		25%	35%	45%	55%
Days Supply	10 Day	$130,434,444.22	$202,957,633.54	$289,496,272.87	$317,332,182.99
of Inventory	5 Day	$32,667,168.87	$53,961,512.22	$26,824,837.73	$21,888,362.25
(Big S1)	3 Day	$9,767,125.06	$10,326,646.52	$17,140,676.42	$17,140,676.42
95% CONFIDENCE INTERVAL QUARTERLY PROFIT		LITTLE S1 and Big S2			
		25%	35%	45%	55%
Days Supply	10 Day	($85,554.80 , $96,244.99)	($75,033.01 , $88,367.97)	($69,517.88 , $85,444.03)	($71,960.02 , $88,634.27)
of Inventory	5 Day	($99,709.63 , $105,059.52)	($99,336.01 , $106,211.94)	($97,940.51 , $102,788.46)	($96,222.79 , $100,602.01)
(Big S1)	3 Day	($97,246.77 , $100,172.09)	($102,529.23 , $105,537.17)	($102,855.11 , $106,730.40)	($101,912.82 , $104,726.80)
PERCENT BACKORDERS		LITTLE S1 and Big S2			
		25%	35%	45%	55%
Days Supply	10 Day	1.40%	1.07%	0.74%	0.55%
of Inventory	5 Day	12.53%	7.85%	7.15%	5.66%
(Big S1)	3 Day	31.13%	21.73%	17.96%	15.86%

Table 7: Comparison of Quarterly Profit Metrics and Percent Backorders with Single S System

SINGLE s MEAN QUARTERLY PROFIT		LITTLE S1 and Big S2		
		25%	35%	45%
Days Supply	10 Day	$68,281.77	-	-
of Inventory	5 Day	-	$97,035.67	-
(Big S1)	3 Day	-	-	$104,689.08
SINGLE s VARIANCE QUARTERLY PROFIT		LITTLE S1 and Big S2		
		25%	35%	45%
Days Supply	10 Day	$643,264,522.28	-	-
of Inventory	5 Day	-	$39,771,563.86	-
(Big S1)	3 Day	-	-	$27,216,149.95
SINGLE s 95% CONF. INT. QUARTERLY PROFIT		LITTLE S1 and Big S2		
		25%	35%	45%
Days Supply	10 Day	($56,411.68 , $80,151.86)	-	-
of Inventory	5 Day	-	($94,084.16 , $99,987.19)	-
(Big S1)	3 Day	-	-	($102,247.49 , $107,130.66)
SINGLE s PERCENT BACKORDERS		LITTLE S1 and Big S2		
		25%	35%	45%
Days Supply	10 Day	7.01%	-	-
of Inventory	5 Day	-	16.37%	-
(Big S1)	3 Day	-	-	26.82%

Table 8: Comparison of Excel Solver Output and 5 Day, 55% for Quarterly Profit Metrics and Percent Backorders

Excel Solver vs. 5 Day 55%	MEAN QUARTERLY PROFIT	VARIANCE QUARTERLY PROFIT	95% CONFIDENCE INT. QUARTERLY PROFIT	PERCENT BACKORDERS
Excel Solver Output Analysis	$102,611.78	$30,533,581.52	($100,025.66 , $105,197.90)	3.99%
5 Day 55%	$98,412.40	$21,888,362.25	($96,222.79 , $100,602.01)	5.66%

Figure 12: Box and Whisker Plots for Quarterly Profit with Double S System

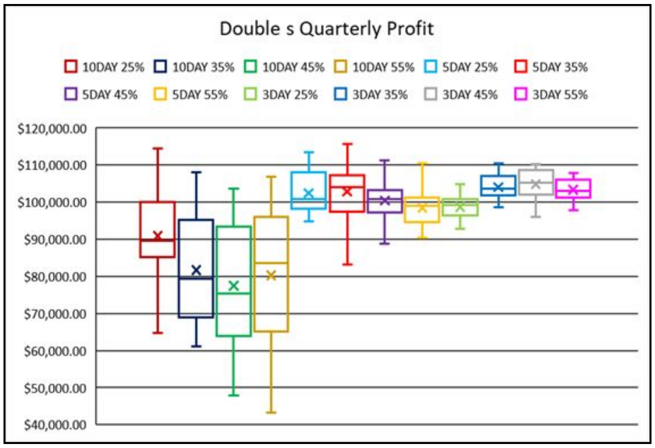


Figure 13: Box and Whisker Plots for Quarterly Profit with Single S System

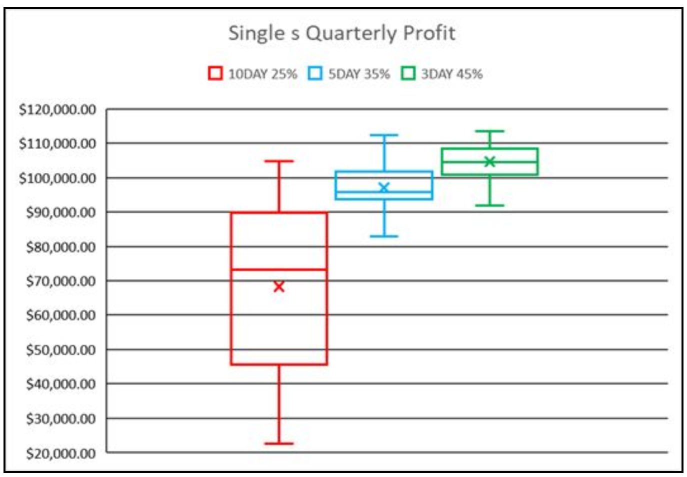


Figure 14: Comparison of 95% Confidence Intervals for Each Inventory Method

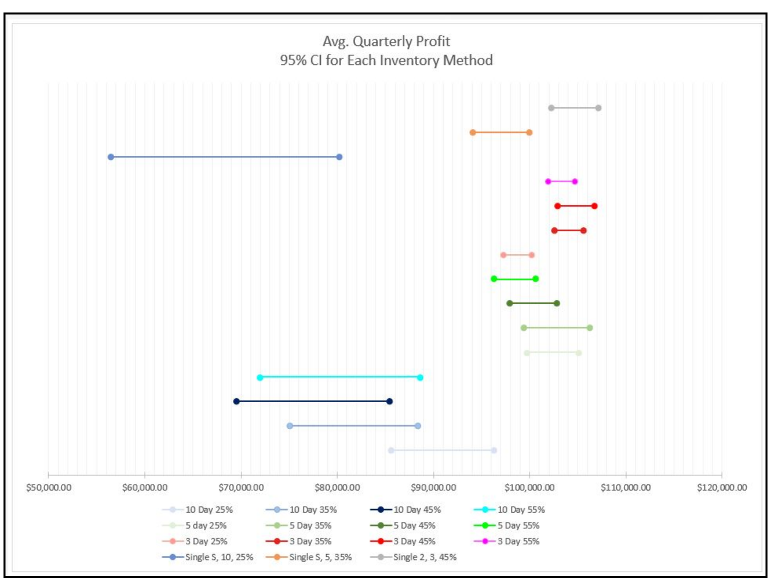


Figure 15: Comparison of 95% Confidence Intervals for Excel Solver and 5-Day 55%

VII. Recommendations and Decision Support

Based on the current settings the team recognized that there would be a very large purchase on the first night if a standard S/s inventory system was to be put in place. With the beginning monthly inventory values at , respectively, a large overnight purchase would be needed to hold the company afloat for the next couple of days until a larger, standard 3-5 day shipment could arrive. The goal was to minimize the cost of the overnight shipping order by making it large enough to last more than one day, so that a similar order would not need to be placed on the second day of operation, but small enough to only provide inventory until the bulk standard shipping order could arrive. The team settled on creating a new inventory system called the Double S inventory management system. The Double S system has components Big S_1, small s_1, Big S_2, and small s_2. Big S_1 would be the maximum values of inventory that the company will aim to have in storage after an order. The company would create a standard 3-5 day shipping bulk order setting inventory to Big S_1 if the current inventory was below small s_1, but it was above small s_2. If the inventory was below small s_2 then the company would create an overnight shipping order setting inventory to equal the values in Big S_2.

This system would place a standard shipping order when inventory diminished to a specific percentage of the full inventory and an overnight shipping order when the inventory was a very, very low percentage of the full inventory. The Double S system achieves lower back-order percentage and generates more profit by creating a weighted standard v.s. overnight shipping order system that enforces overnight orders to decrease immediate backorder and enforces standard shipping orders when current inventory is at a higher level which affords the company the 3-5 day shipping time.

Now that the inventory management system was created, the next step was to create a 1maximum inventory level. The team compared a 3-day, 5-day, 6-day, and 10-day maximum inventory policy. A "day's worth" of corn, lime, and fish meal were respectively calculated by analyzing the historical day for average cattle and chicken orders (lbs) and summing the product of the weights and their respective ingredient percentages. A "day's worth" of corn, lime, and fish meal can be seen in Figure 15. The average days worth was then multiplied by 3, 5, or 10, depending on the trial, and rounded to the nearest 500 lbs.

Table 9: A "days worth" of Each Ingredient (lbs)

	Average Corn/Day	Average Lime/Day	Average Fish Meal/Day
From Cattle	3,933.85	3,383.96	1,057.49
From Chicken	1,948.31	1,611.10	187.34
Total	5,882.16	4,995.06	1,244.82

Next the team needed to define signals for when to create standard shipping or overnight shipping orders. After theorizing that the standard shipping signal needed to be with a significant portion of the stock left, the team decided to define sets of scenarios for Big S_2 and little s_1. The first set of scenarios would have Big S_2 and little s_1 be equal. This would mean that the overnight orders would purchase up to the inventory that would signal a standard order. For this scenario, the team identified 25%, 35%, 45%, and 55% to be the signal point for Big S_2 and little s_1. The final signal, little s_2, would be when inventory was at 10% of its maximum value; at maximum it would be a day's worth of product and at minimum it would be one third of a day's worth of inventory. The second set of scenarios would be to prove that the Double S system was better than a Standard S/s system.

The team conducted 20 simulations, each with 90 days worth of customer orders, for each scenario and created tables to compare the different outputs. These tables can be seen in the Output Validation and Verification section. The team concluded that the ideal system would be the Double S system with a maximum capacity for 5 day's worth of inventory and signal points at 55% (this management system will be referred to as 5-day 55%). The Big S_1 values were 30,000 lbs of corn, 25,000 lbs of lime, and 6,500 lbs of fish meal.

Although the 5-day 55% system did not produce the most revenue for the company, the decision to reduce revenue led to the benefit of less backorders. Double S setups like the 5-day 35% system generated more revenue, on average four thousand dollars more per quarter, however the increase in backorders did not justify the increase in revenue. The company would make more money over time from the increase in brand loyalty and positive relations with more of their customers from the decreased backorder percentage.

The next step was to compare the team's theorized solution with excel solver's solution. Excel solver generated a solution that required 30,000 lbs of corn, 25,000 lbs of lime, and 6,500 lbs of Fish Meal. The signal points were as follows: Big S_1 - 100%, Big S_2 - 51.04%, little s_1 - 35.66%, and little s_2 - 17.27%. The comparison between the excel solver and the 5-day 55% outputs are seen in Table 14 in the Output Validation and Verification section. The team decided to pivot to the excel solver solution since we could be 90% confident that the mean quarterly profit would be larger than the 5-day 55% mean quarterly profit and because of the average decrease in the percent of backorders.

The best system for the Inventory management system is a Double S System with the following values and signals: Big S_1 - Corn: 30,000 lbs. Lime: 25,000 lbs. Fish Meal: 6,500 lbs ; Big S_2 - 51.04%; Little s_1 - 35.66%; Little s_2 - 17.27%.

VIII. Conclusions

Thanks to this project, the lessons we learned were the ability to choose the right simulation methodology and use it effectively. We would apply these lessons in the future by knowing how to design and implement a simulation model of systems with constraints that minimizes costs. These constraints could be customers arriving according to some distribution, varying percentage of customers ordering different products, and demand of products following unknown distributions. Furthermore, we learned how to effectively make decisions using simulation tools to create structures and policies for systems such as the s-S model.

This project highlighted important concepts learned in the ISE4100: Stochastic Modeling and Simulation class. Namely, simulation has an important place in real-world application, simulations can sometimes be very time consuming, and choosing the right method of simulation is important. This project helped gain insight into how simulation can be used outside the classroom to help people make decisions everyday that can have major impacts on their project/business. We learned how time consuming simulation can become, with team members spending many hours attempting to build the Excel simulation. In hindsight, this project demonstrated how a change in software used for the simulation could have saved us time and effort, while still getting good results.