NSP Quality Meats:

Computer Simulation of a Manufacturing Layout Change

Senior Design Project

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Executive Summary

NSP Quality Meats (NSP) is a meat manufacturer located in Owasso, OK. The manufacturing facility provides raw and cooked chicken and beef products to restaurant chains such as IHOP and Applebee's. Historically, NSP has not used a disciplined, engineering-based approach to plan and execute their production and manufacturing processes. In an effort to streamline operations, NSP recently hired an engineering team to implement and manage manufacturing improvement initiatives. One such initiative is the restructuring of the facility layout and production processes. NSP's engineering team has already developed a new layout for the facility transformation. Consequently, the engineering team is now seeking assistance to quantitatively analyze the impact of their proposed facility layout.

The senior design team (SDT) evaluated the production output performance of NSP's current facility and proposed facility through a Simio simulation model. The scope of the project was limited to include only the process steps beginning from the chicken processing line to the packaging area. The SDT's alternative solutions were to accept the proposed layout, accept the proposed layout with modifications, or reject the proposed layout.

A thorough comprehension of NSP's processes were recorded and modeled in a useful simulation of the actual production process using the SDT's detailed data observations. The SDT collected data with assistance from the NSP engineering team, the frontline employees, and the line managers. After collecting the available data, the next step was to analyze the information in order to construct a simulation model using Simio simulation software. To analyze the collected data, the SDT applied ExpertFit data distribution recommendations to Simio objects in the current layout model and proposed layout model. The introduction of a second chicken processing line and changes in material transportation distances were the key differences between the two models.

The current layout simulation model resulted in production of 64,430 pounds of chicken per day, which was within 3% of the actual average daily chicken production. The proposed layout model experienced an increase in output of 16.3%, or production of 74,920 pounds per day. These results were expected because of the increased system capacity added due to the second chicken processing line.

The utilization of each line for the proposed layout simulation model indicates a strong possibility of a bottleneck in the packaging area, which means there is likely a large amount of product that is waiting on the line but never being processed. This results in zero down time in the case of Packaging Line 2 and an extremely high average utilization rate for Packaging Line 3. As a result, the SDT suggests introducing a third packaging line to the proposed layout.

After adding the third packaging line to the proposed layout, the simulation model resulted in production of 90,781 pounds per day. This represents a percent increase in production of 40.9% over the production model levels for the current layout and a 21.2% increase in production over the production model levels for the proposed layout.

As a result, the SDT recommends implementing the proposed layout with modifications (additional packaging line). NSP is encouraged to perform an economic analysis to justify the potential long-term value creation relative to the initial costs. The SDT also recommends the NSP engineering team conduct a packaging line assignment analysis to determine how each chicken processing line should feed into each of the three packaging lines to optimize chicken production output.

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1.0 Introduction

NSP Quality Meats (NSP) is a meat manufacturer located in Owasso, OK. The manufacturing facility provides raw and cooked chicken and beef products to restaurant chains such as IHOP and Applebee's. While the Owasso location still operates independently, what is now known as NSP was the result of a merger between three independent meat manufacturing companies. The corporation is currently owned by a venture capital investment group.

The venture capital group provides direction and high-level strategic planning for NSP. NSP management consists of individuals responsible for carrying out initiatives that drive the company toward the pre-defined goals set forth by the venture capital group. The overarching goal of the venture capital group is to increase the value of NSP. The NSP engineering team expects the value of the company to grow by increasing the product output and decreasing the labor cost per pound of finished goods.

Historically, NSP has not used a disciplined, engineering-based approach to plan and execute their production and manufacturing processes. In an effort to streamline operations, NSP recently hired an engineering team to implement and manage manufacturing improvement initiatives. One such initiative is the restructuring of the facility layout and production processes. NSP's engineering team has already developed a new layout for the facility transformation. The purpose of the proposed layout is to improve the manufacturing system processes in such a way that the production of finished goods increases and labor cost per pound of finished goods decreases. The NSP engineering team based their proposed layout on intuition – what they logically believe will increase production output. Consequently, the engineering team is now seeking assistance to quantitatively analyze the impact of their proposed facility layout.

1.1. CURRENT VS. PROPOSED PRODUCTION STATE

To fully understand the problem at hand, it is important to recognize the key differences in the current production state and the proposed production state. In addition to changes in the facility layout, the NSP engineering team has also indicated interest in expanding manufacturing operations via processing equipment investments. Table 1.1 specifies NSP's current production state and proposed production state.

Table 1.1 - Current vs. Proposed Layout

Current Production State	Proposed Production State
3 Beef Processing Lines	4 Beef Processing Lines
5 Beef Packaging Lines	5 Beef Packaging Lines
1 Chicken Processing Line	2 Chicken Processing Lines
3 Oven Lines[1]	2 Oven Lines

[1] Oven Line 1 is no longer operational

Current Production State (cont'd)	Proposed Production State (cont'd)
3 Cooked Product Packaging Lines[2]	2 Cooked Product Packaging Lines
1 Marinade Preparation Area	1 Marinade Preparation Area

1.2. OBJECTIVE AND SCOPE

In this project, the senior design team (SDT) evaluated the production output performance of NSP's current facility through a Simio simulation model. Additionally, the SDT developed a Simio simulation model for the proposed layout to quantify the anticipated production output performance. The SDT evaluated alternative solutions as described in sections 2.6 and 6.0.

This project evaluated and analyzed the chicken processing line in its current state and proposed state in terms of production output. The scope of the project was limited to include only the process steps beginning from the chicken processing line to the packaging area.

Table 1.2 illustrates the key differences between the current and proposed states in reference to the chicken processing steps. Figures 1.1 and 1.2 provide a detailed facility layout of the current and proposed states.

Table 1.2 - Scope of Current vs. Proposed Layout

Product Family	Current Layout	Proposed Layout
Chicken	- 1 raw processing line - 3 oven lines[3] - 3 packaging lines[4]	- 2 raw processing lines - 2 oven lines - 2 packaging lines

1.3. IMPORTANT TERMS

Important terms relevant throughout this report include the following:

- ***Bottleneck:*** one process in a manufacturing system where its limited capacity reduces the capacity of the whole manufacturing system.
- ***Buggy:*** a Simio object (vehicle) that is responsible for transporting a user-defined quantity of entities
- ***Combiner:*** a Simio object that combines two or more separate entity types

[2] Packaging Line 1 is no longer operational
[3] Oven Line 1 is no longer operational
[4] Packaging Line 1 is no longer operational

- ***Connector:*** a Simio object that represents a zero time connection between two objects.
- ***Conveyor:*** a Simio object that moves entities at a user-defined constant speed
- ***Entity:*** a Simio object that represents a user-defined product that moves through the system
- ***Frontline Employee (FLE)***: a production employee that works directly with the product on the manufacturing floor
- ***Line Manager:*** a production employee that oversees the manufacturing processes
- ***Path:*** a Simio object that can move entities at varying speeds between two objects
- ***Process Step:*** a single production activity that is one of many steps in a manufacturing process used to create finished goods
- ***Production Line:*** a manufacturing line that performs a similar function and produces similar products (e.g. chicken processing line)
- ***Separator:*** a Simio object that separates two or more combined entities
- ***Server:*** a Simio object that uses a predefined processing time to process entities
- ***Simio:*** a simulation software capable of modeling large-scale systems and statistically analyzing the system outputs
- ***Simio Object:*** any individual part of the Simio simulation (i.e. entity, source)
- ***Sink:*** a Simio object that destroys entities (removes entities from the system)
- ***Source:*** a Simio object that creates entities given specific user-defined parameters

NSP requested the assistance of Oklahoma State University's Industrial Engineering SDT to help them understand the impact the proposed facility layout will have on the chicken production lines. NSP also asked the SDT to make suggestions for improvements to the proposed layout if economically justified.

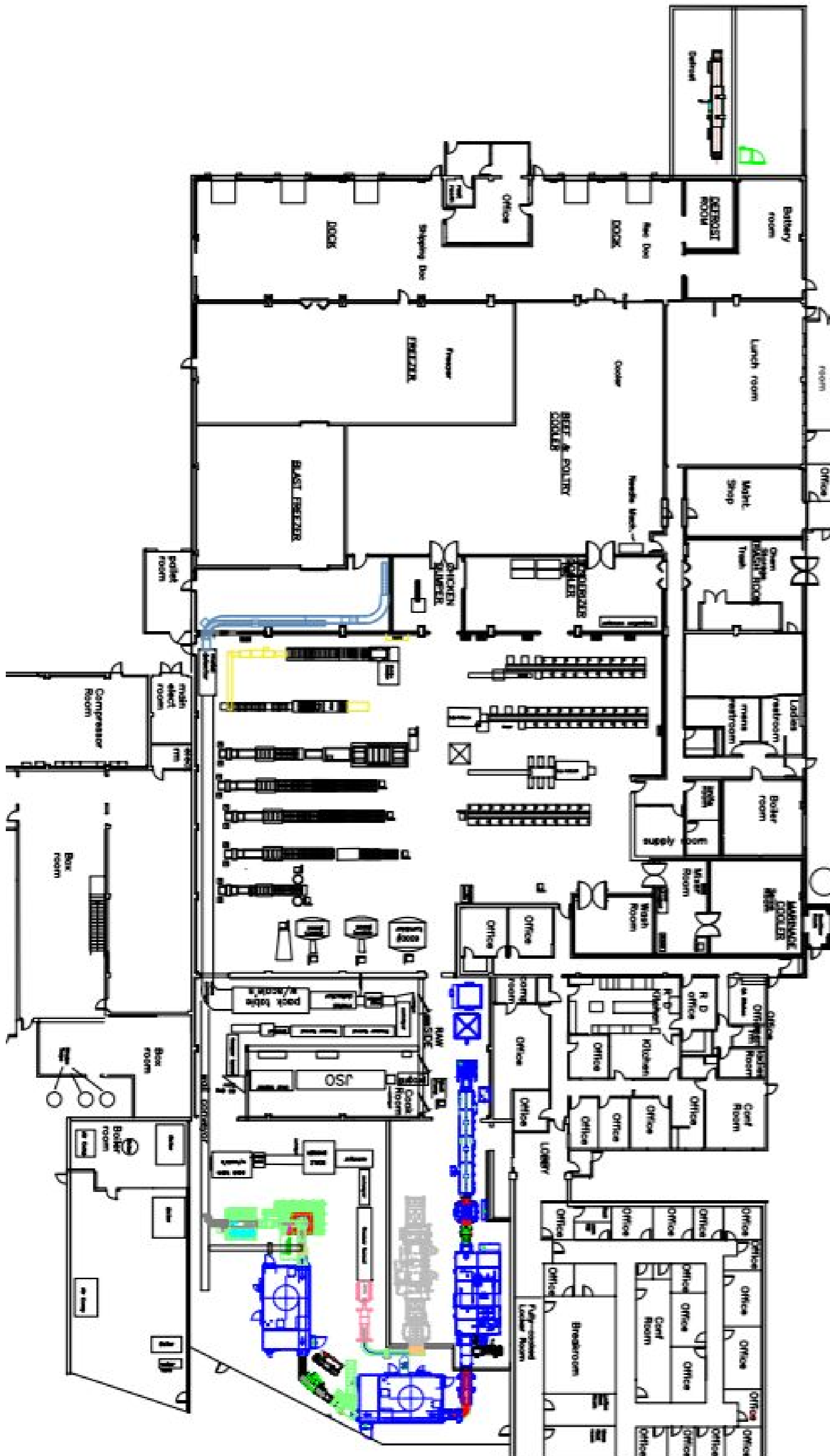

Figure 1.1 - Current Facility Layout

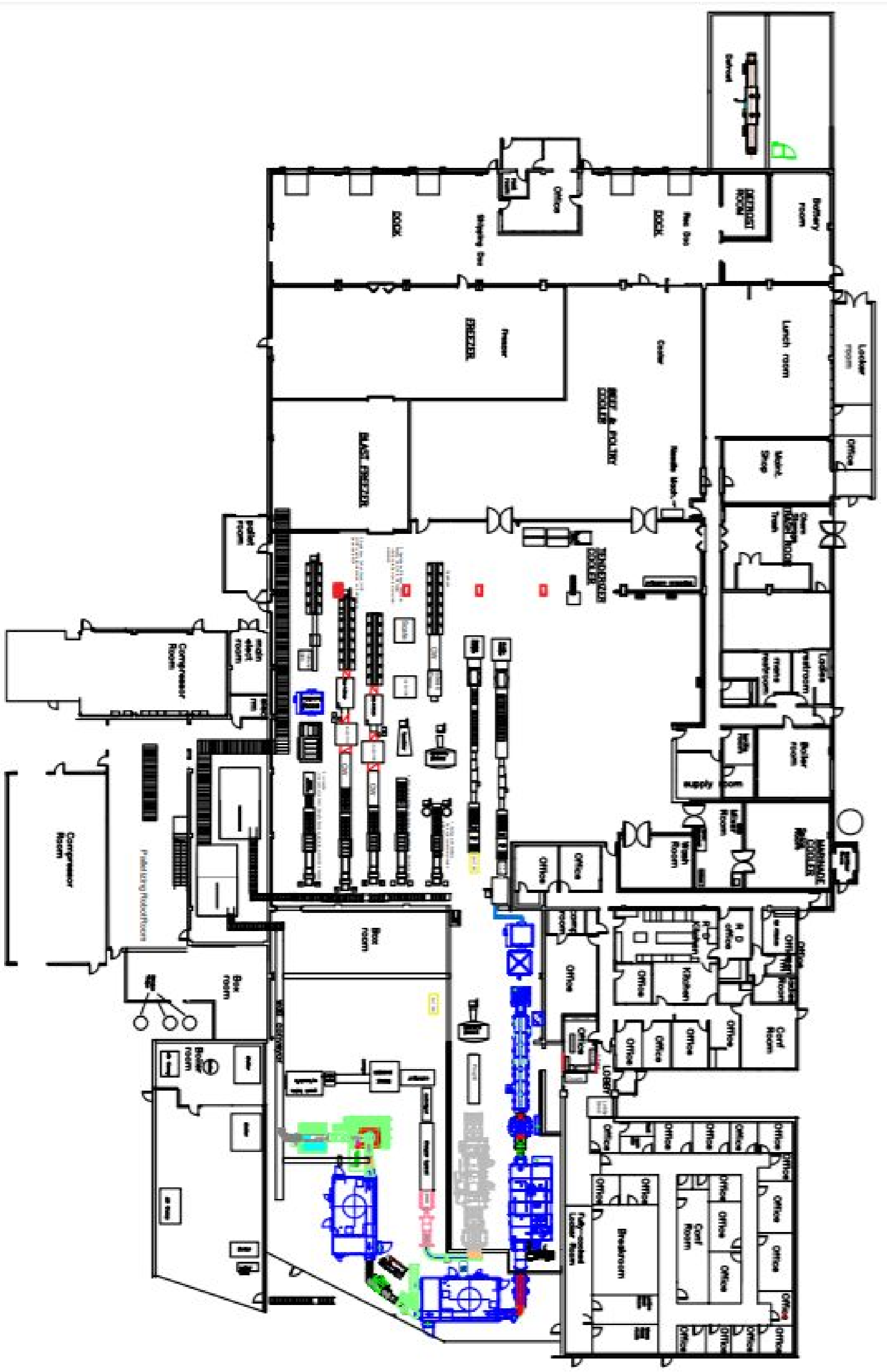

Figure 1.2 - Proposed Facility Layout

2.0 Project Methodology

This section provides a detailed framework of the problem-solving methodology used in developing solutions for NSP.

2.1 PROCESS IDENTIFICATION

2.1.1 Identified process steps for the chicken production lines in the current and proposed layouts

2.1.2 Created process charts for the chicken production lines in the current and proposed layouts

2.1.3 Created process maps for the chicken production lines in the current and proposed layouts

2.2 DATA COLLECTION

2.2.1 Established data collection timeframe with NSP engineering team

2.2.2 Created a team data collection plan to meet project requirements

2.2.3 Developed a standardized data collection sheet

2.2.4 Collected data

2.2.5 Identified the chicken products that were manufactured during the data collection timeframe

2.2.6 Obtained NSP daily production reports for specific data collection days

2.3 DATA ANALYSIS

2.3.1 Organized and compiled all data collected

2.3.2 For processes with more than 10 data points:

2.3.2.1 Utilized ExpertFit to determine the best fit distribution

2.3.2.2 Evaluated distributions using goodness of fit tests

2.3.2.3 Determined the level of significance based on goodness of fit results

2.3.3 For processes with less than 10 data points:

2.3.3.1 Analyzed available data

2.3.3.2 Determined simulation variables based on analysis results

2.4 SIMULATION MODEL

2.4.1 Applied ExpertFit distribution recommendations to Simio objects in current layout model

2.4.2 Developed a simulation model for the current layout

2.4.3 Ran the current layout simulation for 10 replications

2.4.4 Applied ExpertFit distribution recommendations to Simio objects in proposed layout model

2.4.5 Developed a simulation model for the proposed layout

2.4.6 Ran the proposed layout simulation for 10 replications

2.5 SIMULATION STATISTICAL OUTPUT ANALYSIS

2.5.1 Evaluated production output (in lbs) on the chicken production lines for current and proposed layouts

2.5.2 Evaluated utilization rates for packaging combiners for current and proposed layouts

2.5.3 Evaluated transportation times on the chicken production lines for current and proposed layouts

2.6 EVALUATING ALTERNATIVE SOLUTIONS

2.6.1 Compared production output changes between the current and proposed layouts

2.6.2 Identified areas of opportunity in the proposed layout

2.6.3 Evaluated the following alternative solutions

2.6.3.1 Accept the proposed layout

2.6.3.2 Accept the proposed layout with modifications

2.6.3.3 Reject the proposed layout

2.6.4 Formulated recommendations for alternative solution selection based on the simulation model analysis

3.0 Current State Analysis

This section provides a description of the current layout process for the chicken manufacturing line, the SDT's approach for data collection and analysis, and the statistical results from the simulation model.

3.1 PROCESS BACKGROUND

NSP currently produces products in two main product families: chicken and beef. Since the scope of this project is limited to only chicken, the current simulation model and analysis disregarded all beef processes in the facility.

Understanding NSP's current chicken production process was key in developing a simulation model that accurately depicted the various nuances in the complex set of production steps. A thorough comprehension of NSP's processes were recorded and modeled in a useful simulation of the actual production process using the SDT's detailed data observations. The SDT collected data with assistance from the NSP engineering team, the frontline employees, and the line managers. This information allowed the SDT to perform a comparative analysis of the current and proposed facility layouts.

To assist in the data analysis project phase, the SDT needed to understand how NSP creates value for their customers in the current manufacturing process. The following process steps for the chicken production line in the current layout are identified below:

Table 3.1 - Chicken Production Process Description

Operation	Description
Trim/Cut	a process that removes excess fat, foreign material, bloodied meat, etc.
X-Ray	a process that scans chicken for foreign material or leftover bone
Tenderizer	a process that breaks down collagen in the chicken to soften the cut
Marinade	a process where chicken is deposited into tumblers to marinade for flavor
Oven	a process that cooks the chicken to product specification
Chill	a process that flash freezes cooked chicken to prepare it for packaging
Packaging	a process that prepares finished product for customer delivery
Palletizing[5]	a process that prepares packaged product for shipment
Storage[6]	an area that holds finished product until it is ready for pickup

[5] Not included in project scope
[6] Not included in project scope

Figure 3.1 shows the process map of NSP's current production processes in relation to the scope of the project. The figure is separated into swimlanes to help in identifying how the specific process step is integrated into the overall system. Beef is out of the SDT's project scope, so no process steps are identified in the beef swimlane.

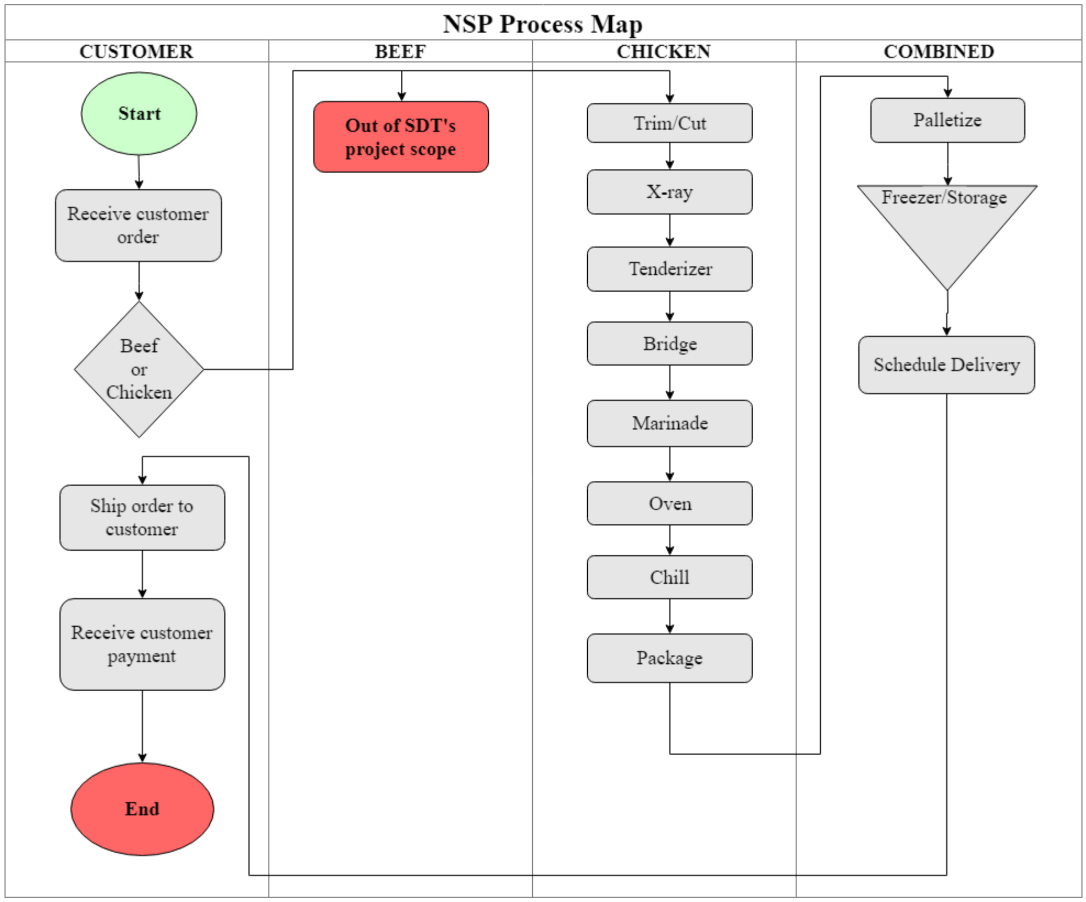

Figure 3.1 - NSP Process Map

3.2 DATA COLLECTION

An important component for creating an accurate and useful simulation was obtaining the required data to input into the model. Maintaining integrity in the data was of the highest importance in the SDT's data collection methods.

The SDT had less than a two-week time span to collect all necessary data for the project. As a result, one challenge the SDT had to overcome was how to collect a meaningful amount of data on separate days when different products were being produced. Fortunately, overlapping process steps and intrinsic similarities in NSP's manufacturing methods allowed the SDT to continue data collection mostly uninterrupted.

Data collection challenges the SDT experienced included the following:

- Day 1: Line 2 ran only beef products, so the SDT could not collect data for the respective Line 2 equipment.
- Day 3: the chicken processing line was being fed product by hand, which limited the number of recorded observations.

All data was collected by the SDT in a less than two-week span on three separate days, which allowed the team to obtain independent data. Table 3.2 identifies which chicken products data were collected for each day with respect to Lines 2 and 3.

Table 3.2 - Products for Data Collection

Oven Line	Day 1	Day 2	Day 3
2	Running Beef Only	Chicken Breast Strips	Chicken Breast Strips
3	Herb Chicken Breast	Thin Sliced Chicken Breast	Herb Chicken Breast

The following data was collected on NSP's processes:

- Chicken Interarrival Time
- Chicken Processing Line Time
- Chicken Processing Line Buggy Weight
- Tumbler Batch Size
- Tumbler Marination Time
- Oven Dwell Time
- Line 2 Conveyor Speed
- Line 3 Conveyor Speed
- Line 3 Freezer Dwell Time
- Line 3 Spiral Freezer Dwell Time
- Line 2 Packaging Rate (lbs/hr)
- Line 3 Packaging Rate (lbs/hr)

Figure 3.2 illustrates the data collection document that was used to record data for most of the above-listed items.

Data Collection MM.DD.YYYY					
Product Type					
Line 2 Processing Times					
Conveyor Speed	Oven	Slicer Rate	Freezer	Packaging	

Line 3 Processing Times				
Oven rate (lbs/hr)	Oven Dwelltime	Freezer	Spiral Freezer	Packaging (lbs/min)

Chicken Process Line		Tumbler 2 Processing Time		Tumbler 3 Processing Time	
lbs	time (min)	lbs	time	lbs	time (min)
				Chicken Interarrival Time	
				lbs	time(min)
Notes:					

Figure 3.2 - Data Collection Sheet

Data was also collected on transportation distances separating subsequent process steps. The SDT recorded these measured distances in Table 3.3 below.

Table 3.3 - Transportation Path Distances in Current Layout

Path	Current Layout Distance (ft)
Chicken Processing → Tumbler 2	80
Chicken Processing → Tumbler 1	115
Marinade Room → Tumbler 2	95
Marinade Room → Tumbler 1	120
Tumbler 2 → Oven 2	80

Data collection was an extremely important part of the project methodology. Without reliable data, the simulation model would have lacked integrity and provided inaccurate results. The SDT recognizes that given more time and data the accuracy of the simulation model could be improved.

3.3 DATA ANALYSIS

The SDT employed the ExpertFit software to analyze the collected data. ExpertFit helped the team understand the best distributions for each required processing parameter, which in turn allowed the simulation model to more closely follow NSP's processes. The accuracy of the simulation model was of paramount importance in order for the SDT to draw appropriate conclusions.

ExpertFit could only be used for the process steps where more than 10 data points were available. Due to time constraints and frequency of operations, it was infeasible to collect more than 10 data points for some of the process steps.

Table 3.4 summarizes the data availability.

Table 3.4 - Process Steps Analysis Classification

Process Steps (n > 10 data points)	Process Steps (n < 10 data points)
Chicken Processing Time	Tumbler 2 Batch Size
Tumbler 1 Batch Size	Tumbler 2 Marination Time
Tumbler 1 Marination Time	Line 2 Oven Process Time
Line 2 Packaging Process Time	Line 3 Oven Process Time
Line 3 Packaging Process Time	Line 2 Conveyor Speed
	Line 3 Conveyor Speed
	Line 3 Freezer(s) Dwell Time

The information in subsections 3.3.1 and 3.3.2 contains the results from the SDT's analysis and the corresponding Simio simulation inputs.

3.3.1 PROCESS STEPS ANALYSIS (n > 10 data points)

Chicken Processing Time Analysis Results:

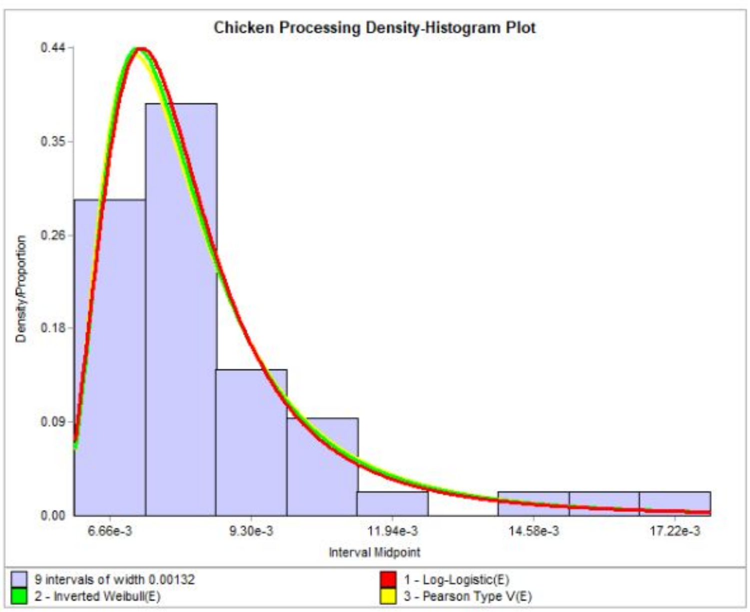

Figure 3.3 - Chicken Processing Time Histogram

Figure 3.3 illustrates a histogram of the collected data for the chicken processing time. ExpertFit fit the top three distributions for the data as indicated in the key below the figure.

Relative Evaluation of Candidate Models

Model	Relative Score	Parameters	
1 - Log-Logistic(E)	100.00	Location	0.00573
		Scale	0.00218
		Shape	2.43601
2 - Inverted Weibull(E)	96.77	Location	0.00369
		Scale	0.00378
		Shape	3.26419
3 - Pearson Type V(E)	92.74	Location	0.00506
		Scale	0.00984
		Shape	3.76739

Figure 3.4 - Chicken Processing Time Distribution Scores

Figure 3.4 indicates the relative scores for the top three best-fitting distributions for chicken processing times. Log-Logistic(E) was the top scorer and recommended distribution to model this data.

Kolmogorov-Smirnov Test with Model 1 - Log-Logistic(E)

Sample size	44
Normal test statistic	0.07417
Modified test statistic	0.49197

Note: No critical values exist for this special case. The following critical values are for the case where all parameters are known, and are conservative.

	Critical Values for Level of Significance (alpha)				
Sample Size	0.150	0.100	0.050	0.025	0.010
44	1.115	1.199	1.331	1.450	1.595
Reject?	No				

Figure 3.5 - Chicken Processing Time Goodness of Fit Test

Figure 3.5 describes the K-S test for goodness of fit for the chicken processing time data sample for the Log-Logistic(E) distribution. Based on the results seen in this figure, the SDT has decided to utilize a level of significance where $\alpha = 0.15$. It can be concluded that there is an 85% confidence level that this distribution will adequately model the true chicken processing time.

Therefore, the chicken processing time in minutes (using ExpertFit) was modeled in Simio using the following formula:

Chicken Processing Time = 0.005731 + Random.LogLogistic(2.436013, 0.002182)

Tumbler 1 Batch Size / Marination Time Analysis Results:

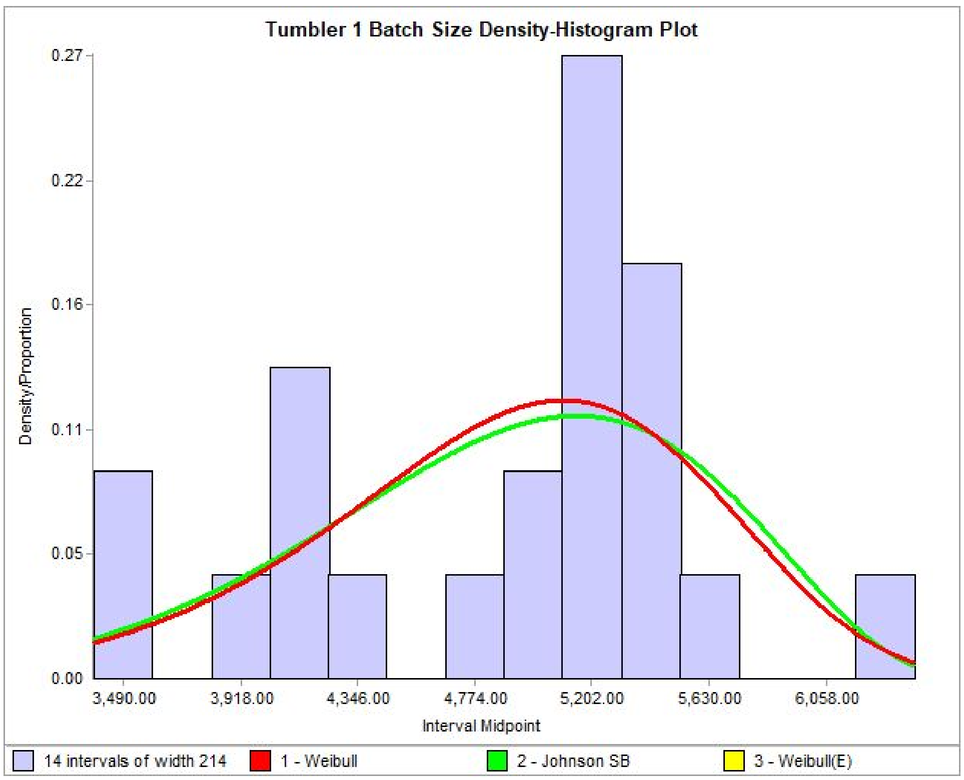

Figure 3.6 - Tumbler 1 Batch Size Histogram

Figure 3.6 illustrates a histogram of the collected data for tumbler 1 batch size. ExpertFit fit the top three distributions for the data as indicated in the key below the figure.

Relative Evaluation of Candidate Models

Model	Relative Score	Parameters	
1 - Weibull	96.67	Location	0.00000
		Scale	5,186.95668
		Shape	7.98470
2 - Johnson SB	95.83	Lower endpoint	426.97861
		Upper endpoint	6,920.95194
		Shape #1	-1.51003
		Shape #2	1.79865
3 - Weibull(E)	95.00	Location	0.94731
		Scale	5,186.00133
		Shape	7.98319

Figure 3.7 - Tumbler 1 Batch Size Distribution Scores

Figure 3.7 indicates the relative scores for the top three best-fitting distributions for tumbler 1 batch size. Weibull was the top scorer and recommended distribution to model this data.

Kolmogorov-Smirnov Test with Model 1 - Weibull

Sample size	22
Normal test statistic	0.16716
Modified test statistic	0.78407

Note: The following critical values are exact.

Sample Size	Critical Values for Level of Significance (alpha)			
	0.100	0.050	0.025	0.010
20	0.779	0.843	0.907	0.973
50	0.790	0.856	0.922	0.988
Reject?	No			

Figure 3.8 - Tumbler 1 Batch Size Goodness of Fit Test

Figure 3.8 describes the K-S test for goodness of fit for the tumbler 1 batch size data sample for the Weibull distribution. Based on the results seen in this figure, the SDT has decided to utilize a level of significance where $\alpha = 0.1$. It can be concluded that there is a 90% confidence level that this distribution will adequately model the true tumbler 1 batch size.

The recorded data also included the tumbler 1 marination processing time in minutes, which the SDT observed as a uniform distribution (modeled below). The tumbler 1 batch size in pounds (using ExpertFit) was modeled in Simio using the following:

Tumbler 1 Batch Size = Random.Weibull(7.984700, 5186.956680)

Tumbler 1 Processing Time = Random.Uniform(25, 30)

Line 2 Packaging Process Time Analysis Results:

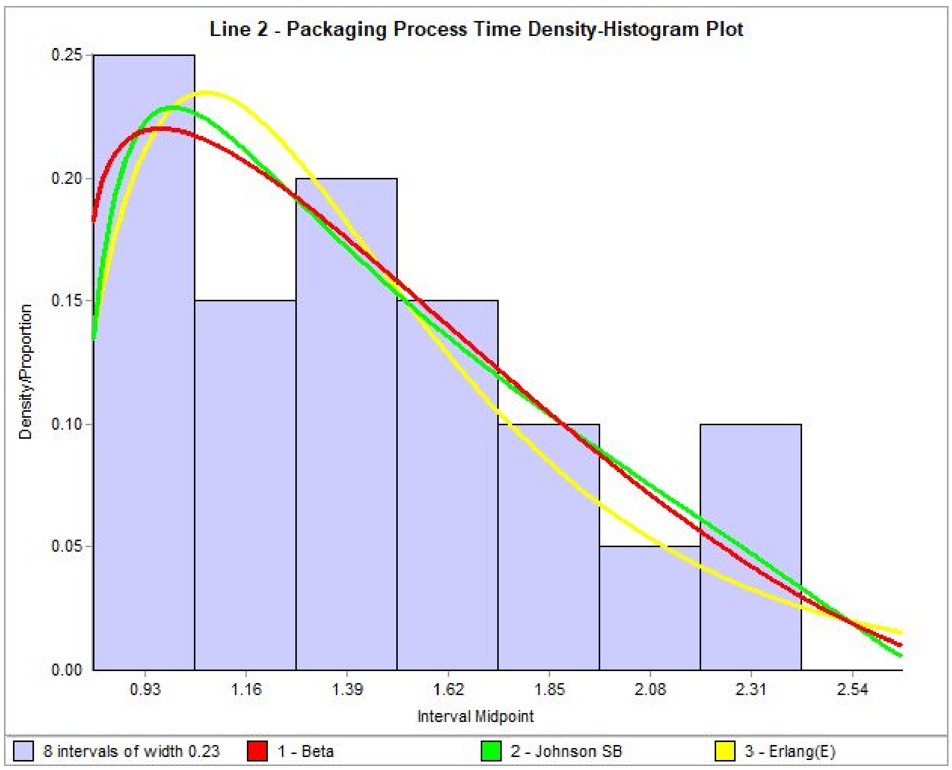

Figure 3.9 - Line 2 Packaging Process Time Histogram

Figure 3.9 illustrates a histogram of the collected data for line 2 packaging process time. ExpertFit fit the top three distributions for the data as indicated in the key below the figure.

Relative Evaluation of Candidate Models

Model	Relative Score	Parameters	
1 - Beta	98.39	Lower endpoint	0.78787
		Upper endpoint	2.89687
		Shape #1	1.15020
		Shape #2	2.64874
2 - Johnson SB	96.77	Lower endpoint	0.74259
		Upper endpoint	2.75507
		Shape #1	0.70345
		Shape #2	0.82610
3 - Erlang(E)	89.52	Location	0.70784
		Scale	0.36023
		Shape	2

Figure 3.10 - Line 2 Packaging Process Time Distribution Scores

Figure 3.10 indicates the relative scores for the top three best-fitting distributions for line 2 packaging process time. Beta was the top scorer and recommended distribution to model this data.

Kolmogorov-Smirnov Test with Model 1 - Beta

Sample size	20
Normal test statistic	0.08390
Modified test statistic	0.37520

Note: No critical values exist for this special case. The following critical values are for the case where all parameters are known, and are conservative.

Sample Size	Critical Values for Level of Significance (alpha)				
	0.150	0.100	0.050	0.025	0.010
20	1.102	1.186	1.315	1.434	1.577
Reject?	No				

Figure 3.11 - Line 2 Packaging Process Time Goodness of Fit Test

Figure 3.11 describes the K-S test for goodness of fit for the line 2 packaging process time data sample for the Beta distribution. Based on the results seen in this figure, the SDT has decided to utilize a level of significance where $\alpha = 0.15$. It can be concluded that there is an 85% confidence level that this distribution will adequately model the true line 2 packaging process time.

It is important to note that line 2 packaging process time data only includes packaging times for boxes. The Simio simulation assumes only boxes are modeled on the line 2 packaging combiner. Therefore, the line 2 packaging process time in minutes (using ExpertFit) was modeled in Simio using the following:

L2 Packaging Process Time = 0.78 + 2.108992 * Random.Beta(1.150201, 2.648744)

Line 3 Packaging Process Time Analysis Results:

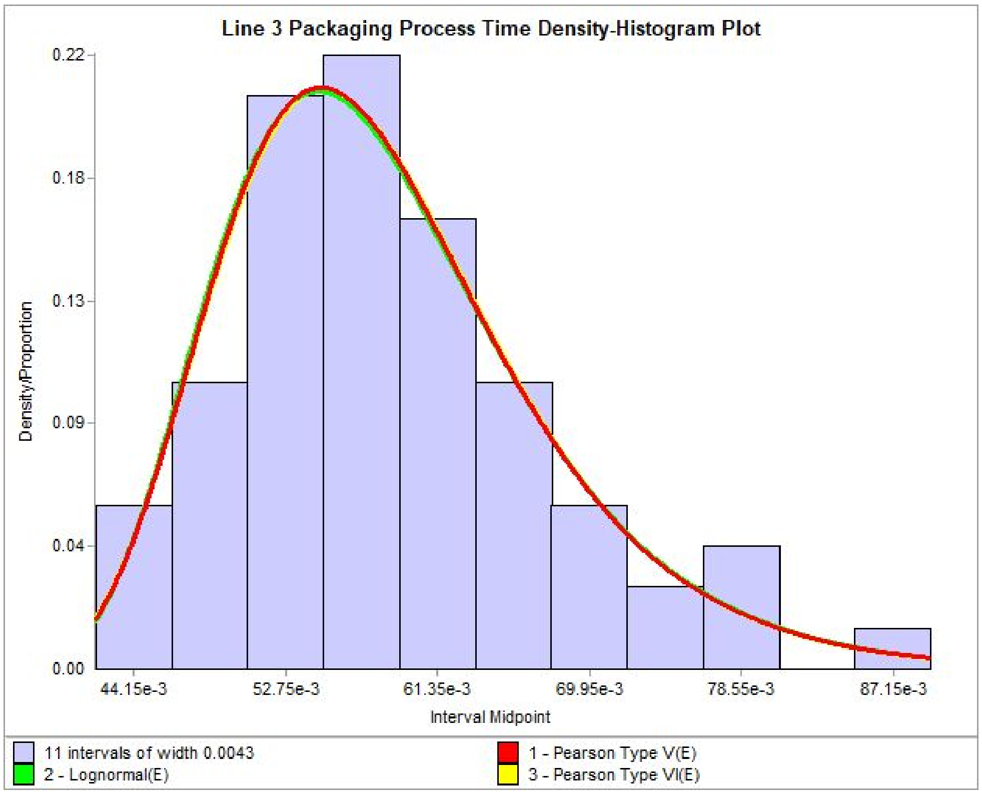

Figure 3.12 - Line 3 Packaging Process Time Histogram

Figure 3.12 illustrates a histogram of the collected data for line 3 packaging process time. ExpertFit fit the top three distributions for the data as indicated in the key below the figure.

Relative Evaluation of Candidate Models

Model	Relative Score	Parameters	
1 - Pearson Type V(E)	93.55	Location	0.01928
		Scale	0.74143
		Shape	19.86589
2 - Lognormal(E)	91.94	Location	0.02920
		Scale	0.02801
		Shape	0.30913
3 - Pearson Type VI(E)	90.32	Location	0.02215
		Scale	0.00940
		Shape #1	79.43941
		Shape #2	21.49894

Figure 3.13 - Line 3 Packaging Process Time Distribution Scores

Figure 3.13 indicates the relative scores for the top three best-fitting distributions for line 3 packaging process time. Pearson Type V(E) was the top scorer and recommended distribution to model this data.

Kolmogorov-Smirnov Test with Model 1 - Pearson Type V(E)

Sample size	68
Normal test statistic	0.04659
Modified test statistic	0.38417

Note: No critical values exist for this special case. The following critical values are for the case where all parameters are known, and are conservative.

Sample Size	Critical Values for Level of Significance (alpha)				
	0.150	0.100	0.050	0.025	0.010
68	1.120	1.205	1.336	1.456	1.602
Reject?	No				

Figure 3.14 - Line 3 Packaging Process Time Goodness of Fit Test

Figure 3.14 describes the K-S test for goodness of fit for the line 3 packaging process time data sample for the Pearson Type V(E) distribution. Based on the results seen in this figure, the SDT has decided to utilize a level of significance where $\alpha = 0.15$. It can be concluded that there is an 85% confidence level that this distribution will adequately model the true line 3 packaging process time.

It is important to note that line 3 packaging process time data only includes packaging times for bags. The Simio simulation assumes only bags are modeled on the line 3 packaging combiner. Therefore, the line 3 packaging process time in minutes (using ExpertFit) was modeled in Simio using the following:

L3 Packaging Process Time = 0.019284 + 1 / Random.Gamma(19.865894, 1.348739)

3.3.2 PROCESS STEPS ANALYSIS (n < 10 data points)

Tumbler 2 Batch Size Analysis Results:

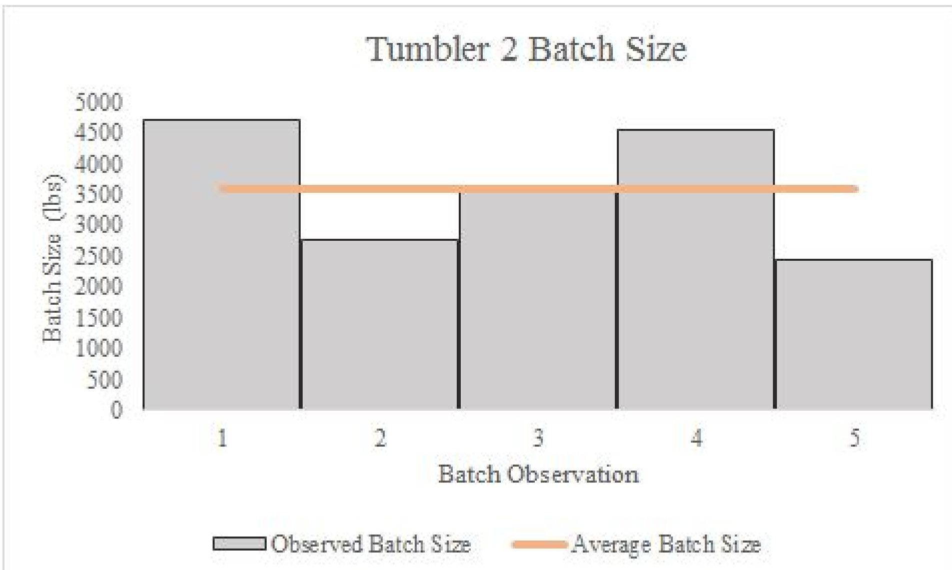

Figure 3.15 - Tumbler 2 Batch Size Histogram

Since only five batch observations could be recorded, a uniform distribution was chosen to model the batch size data. Therefore, the line 2 tumbler batch size in pounds was modeled in Simio using the following:

Tumbler 2 Batch Size = Random.Uniform(2500,5000)

Tumbler 2 Marination Time Analysis Results:

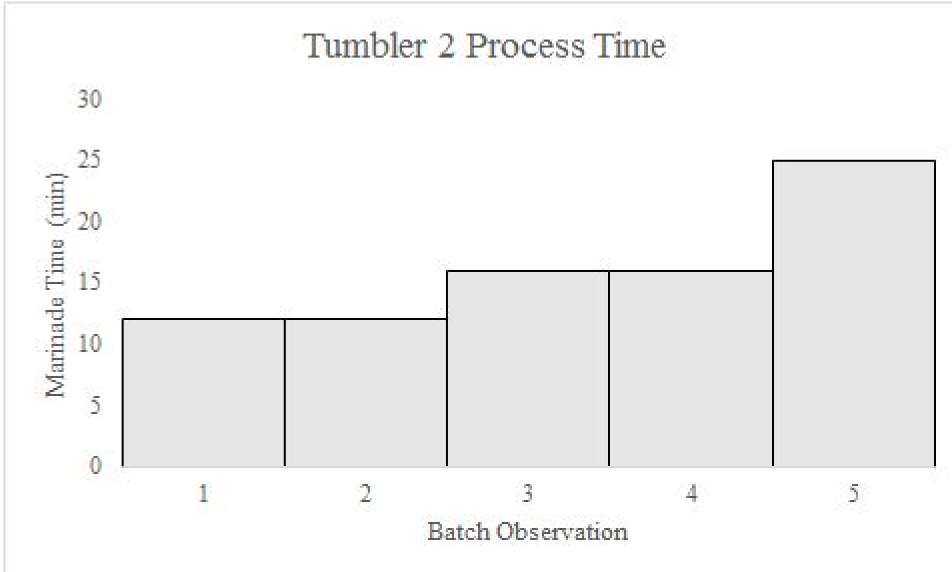

Figure 3.16 - Tumbler 2 Process Time Histogram

The marination time for chicken in tumbler 2 followed a distribution ranging from 12 minutes to 25 minutes. Therefore, the line 2 tumbler batch size and marination time was modeled in Simio using the following:

Tumbler 2 Processing Time = Random.Triangular(12,16,25)

Line 2 Oven Process Time Analysis Results:

The line 2 oven rate parameters range from being able to process 2000 lbs/hour to 3500 lbs/hour. To input this in Simio, the SDT converted 2000 lbs/hour and 3500 lbs/hour to 1/2000 hrs/lb and 1/3500 hrs/lb, respectively. Therefore, line 2 oven processing time was modeled in Simio as follows:

Oven 2 Processing Time = Random.Uniform(1/2000,1/3500)

Line 3 Oven Process Time Analysis Results:

The line 3 oven rate parameters range from being able to process 5000 lbs/hour to 7700 lbs/hour. To input this in Simio, the SDT converted 5000 lbs/hour and 7700 lbs/hour to 1/5000 hrs/lb and 1/7700 hrs/lb, respectively. Therefore, line 3 oven processing time was modeled in Simio as follows:

Oven 3 Processing Time = Random.Uniform(1/5000,1/7700)

Line 2 Conveyor Speed:

The line 2 conveyor follows a linear path without elevation change at a constant rate. To model this in Simio, the SDT recorded the conveyor speed in feet per minute (FPM).

Line 2 Conveyor Speed = 18.35 FPM

Line 3 Conveyor Speed:

The line 3 conveyor follows a linear path without elevation change at a constant rate. To model this in Simio, the SDT recorded the conveyor speed in feet per minute (FPM).

Line 3 Conveyor Speed = 44 FPM

Line 3 Freezer Dwell Times:

The line 3 freezers consist of a standard freezer and a spiral freezer. Both freezer types change product elevation and have corresponding dwell times for chicken. To model this in Simio, the SDT observed a uniform dwell time for both freezer types as seen below:

Line 3 Freezers' Dwell Time = 25 minutes

3.4 SIMULATION MODEL

After analyzing the available data, the next step was to construct a simulation model using Simio simulation software. While Simio is an effective modeling tool for many different kinds of simulations, the SDT recognizes that certain parts of the simulation may not be completely accurate or reflective of NSP's actual processes due to time constraints and data availability.

Figure 3.17 is representative of the Simio simulation model. The figure illustrates the respective distances and identifies the various process steps in manufacturing finished goods (chicken product).

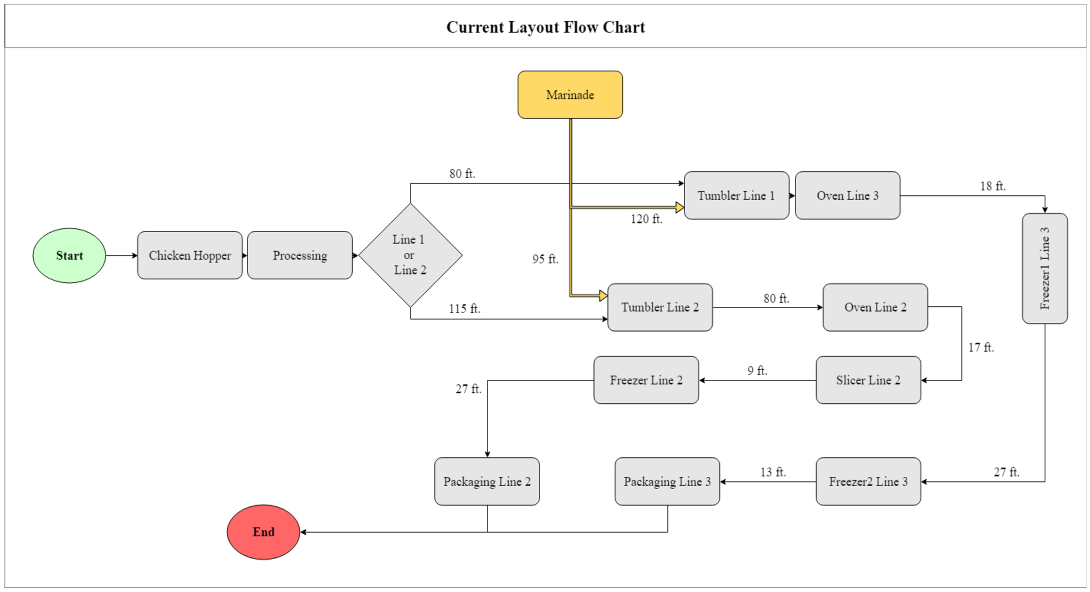

Figure 3.17 - Simulation Model Current Layout Process Flow Chart

As noted in previous sections, this simulation only considers NSP's processes from the time raw chicken enters the chicken hopper to the time it is packaged and sent to the palletizing room.

The Simio model contains four separate entity types:

- Chicken entity (Ent_ChickenBreast)
- Marinade entity (Ent_Marinade)
- Box entity (Line 2) (Pkg_Boxes)
- Bag entity (Line 3) (Pkg_Bag)

It is important to note that a single chicken entity entering the Simio model represents *one pound of raw chicken.* Therefore, each chicken entity (or pound of chicken) must be processed via a set of repeatable manufacturing steps as discussed in previous sections.

Likewise, one marinade entity represents the total volume of a batch of marinade sufficient to process a batch of chicken marinating in one of the two tumblers. In other words, one marinade entity could be assigned to a batch of 5,000 chicken entities if 5,000 pounds is the batch size for a tumbler.

The box entity is used exclusively on Packaging Line 2 and holds a batch size of 30 pounds (30 chicken entities). The bag entity is used exclusively on Packaging Line 3 and holds a batch size of 5 pounds (5 chicken entities).

The current layout Simio model was run for 10 iterations for 8 hours each with a warm-up period of 2 hours. Each object within the Simio model and the logic driving each processing and transportation step is described below.

Current Layout Simulation Model Steps:

Chicken Entity Source (Src_Chicken_Dump)

The chicken entity source releases chicken entities into the system. It is important to remember that one entity is equal to one pound of chicken. The chicken entities are released using an interarrival time equivalent to approximately 2 pounds per second.

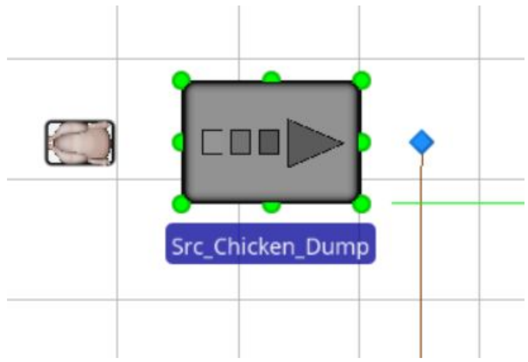

Figure 3.18 - Chicken Entity Source

Chicken Processing Server (Srv_Chicken_Processing)

The chicken processing server processes chicken entities. This server represents chicken processing steps such as trimming, cutting, X-ray, tenderizer, etc. The chicken entities are processed on the chicken processing server using the processing time described in section 3.3.1.

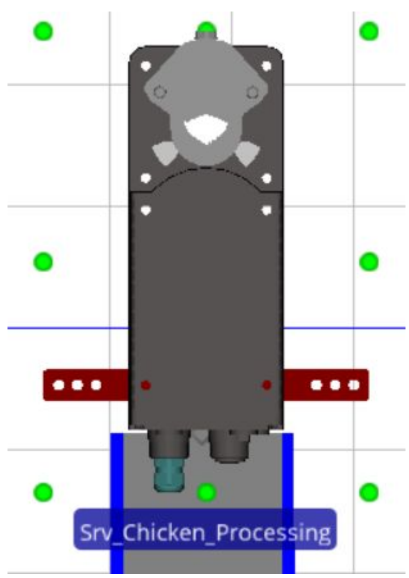

Figure 3.19 - Chicken Processing Server

Tumbler 1 / Tumbler 2 Combiners (Cmb_Tumbler_1 / Cmb_Tumbler_2)

Buggies transport the chicken entities to either Tumbler 1 or Tumbler 2. Tumbler 1 is the default option, so the buggies only transport chicken entities to Tumbler 2 if Tumbler 1 is in use. The buggies move at 2 miles per hour (assumed pace of an average worker pushing a 600 pound buggy) along the respective distances to Tumbler 1 and Tumbler 2. Both tumblers are modeled as a Combiner, which is responsible for combining a marinade entity to a batch of chicken entities. A batch of chicken entities is defined in sections 3.3.1 and 3.3.2 for Tumbler 1 and Tumbler 2, respectively.

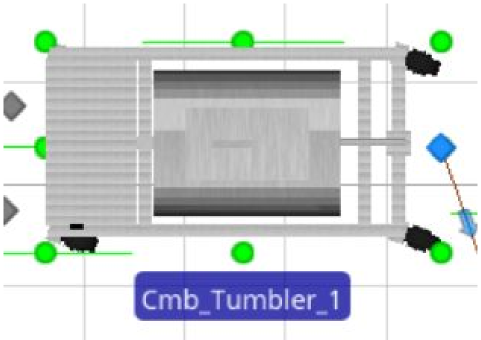

Figure 3.20 - Tumbler 1 Combiner

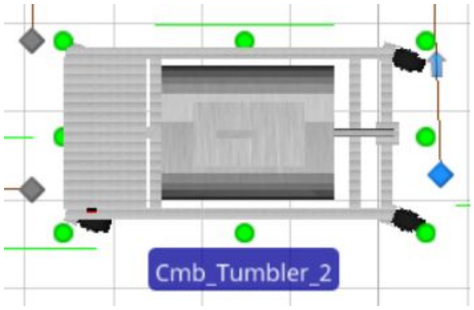

Figure 3.21 - Tumbler 2 Combiner

Marinade Entity Source (Src_Marinade_Room)

The marinade entity source releases marinade entities into the system when a batch of chicken entities arrives at either Tumbler 1 or Tumbler 2. The marinade entities travel distances to Tumbler 1 and Tumbler 2 as defined in Table 3.3.

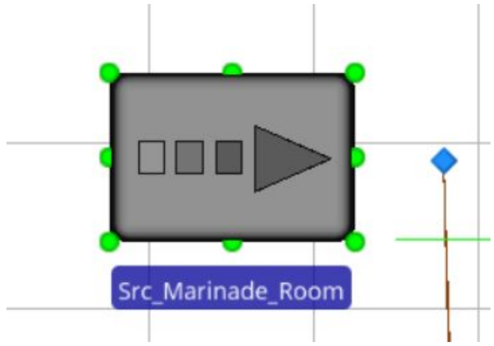

Figure 3.22 - Marinade Entity Source

Tumbler 1 / Tumbler 2 Separators (Sep_VacCat / Sep_BuggyLoad)

Tumbler 1 and Tumbler 2 Separators are located immediately after the Tumbler 1 and Tumbler 2 Combiners. Because the Combiners combine a batch of chicken entities with a marinade entity (which represents the marinating process) but are released from the tumblers as separate pieces of chicken, the separators are a zero processing time step to separate the batch of chicken entities from the marinade entity. The separators are necessary in the Simio model only. They are not an actual reflection of NSP's manufacturing processes.

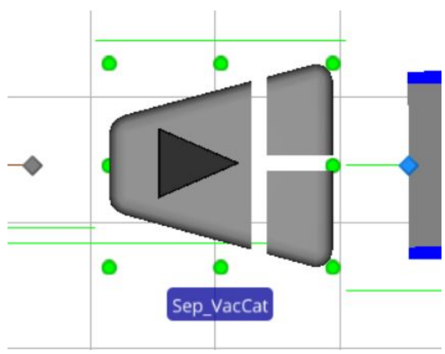

Figure 3.23 - Tumbler 1 Separator

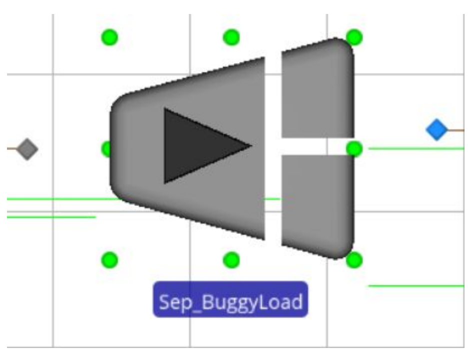

Figure 3.24 - Tumbler 2 Separator

Marinade Entity Sink (Marinade_Exit)

The marinade entity sink serves as a means to remove the marinade entities from the system once they are separated from the chicken entities. The chicken entities are considered marinated from that point forward in the model.

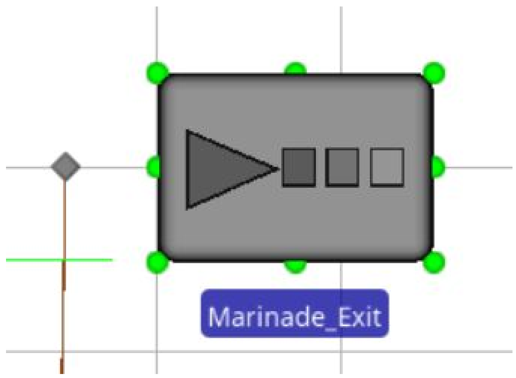

Figure 3.25 - Marinade Entity Sink

Oven Line 2 / Oven Line 3 (Srv_Oven_L2 / Srv_Oven_L3)

The marinated chicken entities proceed to either Oven Line 2 or Oven Line 3, depending on the tumbler in which they were processed. The chicken entities are processed on the oven servers for processing times defined in section 3.3.2.

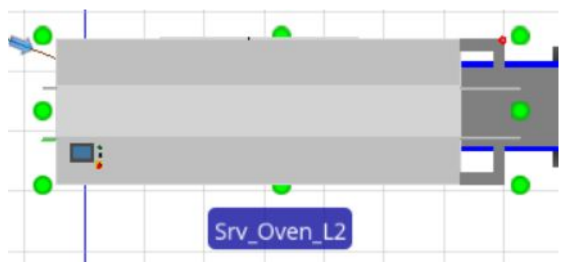

Figure 3.26 - Oven Line 2

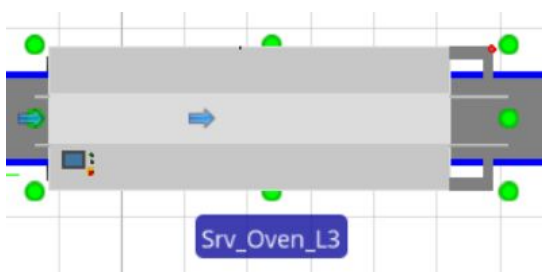

Figure 3.27 - Oven Line 3

Freezer 1 Line 3 (Srv_Freezer1_L3)

The Freezer 1 Line 3 Server cools and partially freezes the cooked and marinated chicken entities on Line 3. The server's processing time is defined in section 3.3.2.

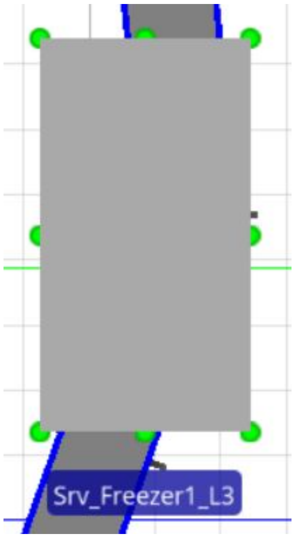

Figure 3.28 - Freezer 1 Line 3

Freezer 2 Line 3 (Srv_Freezer2_L3)

The Freezer 2 Line 3 Server finishes freezing the cooked and marinated chicken entities on Line 3. The server's processing time is defined in section 3.3.2.

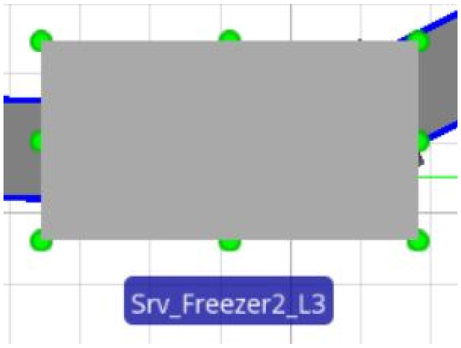

Figure 3.29 - Freezer 2 Line 3

Line 3 Conveyor

The Line 3 Conveyor represents the transportation distances between Oven Line 3 and Freezer 1 Line 3, Freezer 1 Line 3 and Freezer 2 Line 3, and Freezer 2 Line 3 and Packaging Line 3. The Line 3 Conveyor moves at a speed as defined in section 3.3.2.

Line 2 Conveyor

The Line 2 Conveyor represents the freezing and slicing processes on Line 2 for the cooked and marinated chicken entities. The Line 2 Conveyor moves at a speed as defined in section 3.3.2.

Packaging Line 2 Combiner (Cmb_Pack_L2)

Packaging Line 2 Combiner combines a box entity and a batch of 30 chicken entities to prepare the finished goods for shipment. A box entity is readily available at all times to package the chicken entities when the appropriate batch size is present. The processing time for Packaging Line 2 Combiner is defined in section 3.3.1.

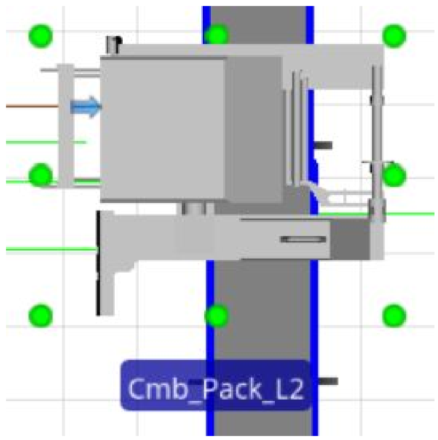

Figure 3.30 - Packaging Line 2 Combiner

Box Entity Source (Src_Pkg_Boxes)

The box entity source releases a box entity into the system when a batch of chicken entities arrives at Packaging Line 2 Combiner. A single box entity is combined with a batch of 30 chicken entities.

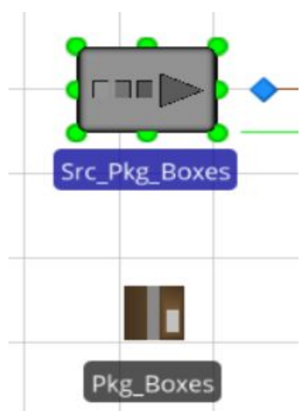

Figure 3.31 - Box Entity Source

Packaging Line 3 Combiner (Cmb_Pack_L3)

Packaging Line 3 Combiner combines a bag entity and a batch of 5 chicken entities to prepare the finished goods for shipment. A bag entity is readily available at all times to package the chicken entities when the appropriate batch size is present. The processing time for Packaging Line 3 Combiner is defined in section 3.3.1.

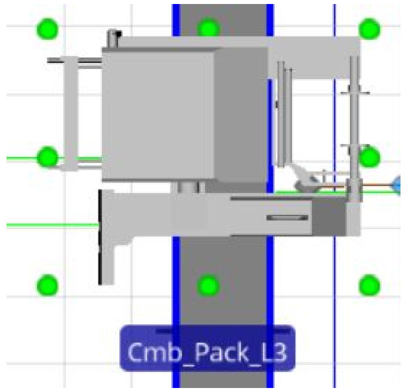

Figure 3.32 - Packaging Line 3 Combiner

Bag Entity Source (Src_Pkg_Bags)

The bag entity source releases a bag entity into the system when a batch of chicken entities arrives at Packaging Line 3 Combiner. A single bag entity is combined with a batch of 5 chicken entities.

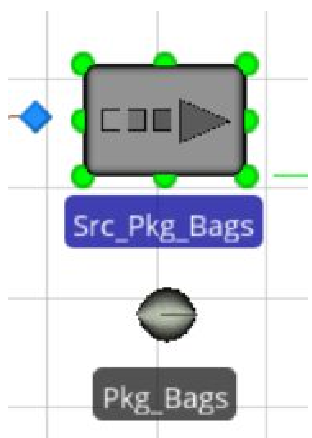

Figure 3.33 - Bag Entity Source

Line 2 Sink (Snk_L2_Exit)

The Line 2 Sink is used in the model to indicate that the manufacturing process has been completed for a box of 30 chicken entities. A connector attaches the Packaging Line 2 Combiner to the Line 2 Sink. All finished boxed products exit through the sink.

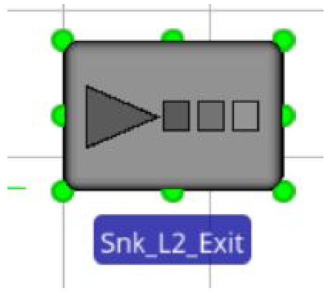

Figure 3.34 - Line 2 Sink

Line 3 Sink (Snk_L3_Exit)

The Line 3 Sink is used in the model to indicate that the manufacturing process has been completed for a bag of 5 chicken entities. A connector attaches the Packaging Line 3 Combiner to the Line 3 Sink. All finished bagged products exit through the sink.

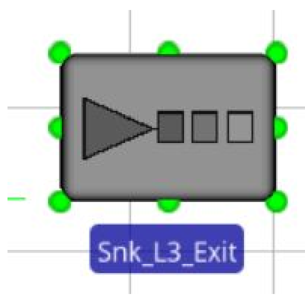

Figure 3.35 - Line 3 Sink

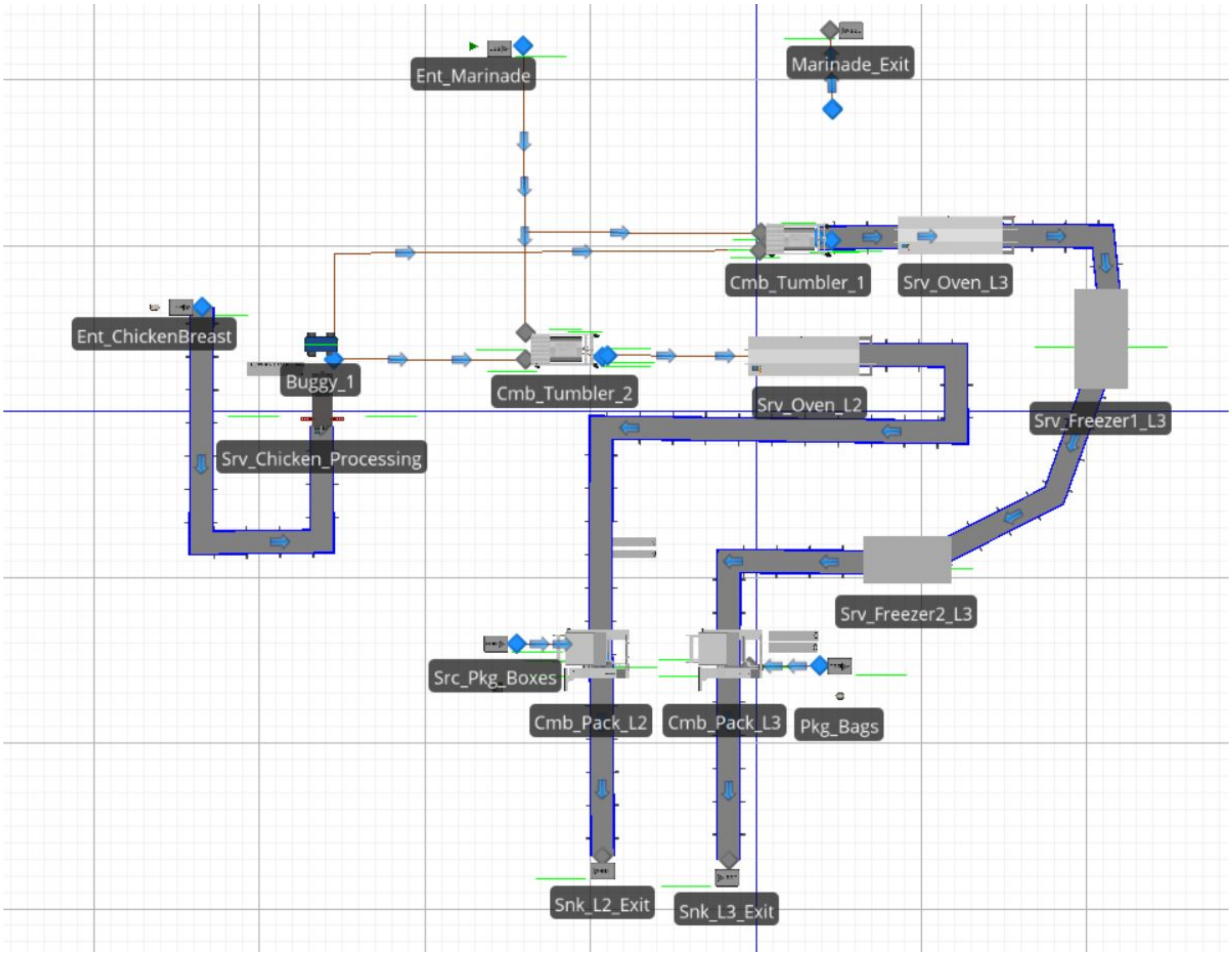

Figure 3.36 - Simio Current Layout Simulation Model

3.5 SIMULATION STATISTICAL OUTPUT ANALYSIS

After running the Simio experiment for 10 iterations with a run time of 8 hours each (warm-up period was 2 hours), the model's statistical output results were analyzed to verify the accuracy of the simulation. Table 3.5 summarizes the output results below.

Table 3.5 - Current Layout Simio Model Output Results

Object Type	Object Name	Data Source	Category	Data Item	Statistic	Average	Minimum	Maximum
Sink	Snk_L3_Exit	Input Buffer	Throughput	Number Exited	Total	5,352.20	4,420.00	5,811.00
				Number Entered	Total	5,352.20	4,420.00	5,811.00
	Snk_L2_Exit	Input Buffer	Throughput	Number Exited	Total	181.8	117	251
				Number Entered	Total	181.8	117	251

To calculate the actual finished product output in pounds on average, the SDT had to consider the number of entities (weight) of chicken in the boxes and bags. Equations 3.1 and 3.2 represent the finished goods' weight for boxes and bags, respectively.

Line 2 Sink Output = (181.8 boxes) * (2 shifts) * (30 lbs/box) **(3.1)**

Line 3 Sink Output = (5,352.2 bags) * (2 shifts) * (5 lbs/bag) **(3.2)**

Since the Simio model was ran for only one shift (8 hours) and the SDT assumed shift one runs identically to shift two, the number of entities (boxes and bags) that entered the sink was multiplied by two. This was necessary because the Simio model is a large-scale simulation of a single production day and the required computing power for an entire production day was not available to the SDT. Table 3.6 shows the summary production output for two shifts.

Table 3.6 - Current Layout Simulated Production Output

Line	Shift 1 (lbs)	Shift 2 (lbs)	Net Produced (lbs)
2	5,454	5,454	10,908
3	26,761	26,761	53,522
		Total	64,430

The Simio model output results were verified using NSP daily production reports for each of the three days of data collection as discussed in section 3.2. Table 3.7 summarizes the total chicken production output. The average of actual total pounds produced for chicken was 66,400 pounds across the three days. This represents an approximately 3% difference in actual chicken output compared to simulated chicken output. This small percent difference verifies the relative accuracy of the simulation in modeling NSP's current production processes in Simio.

Table 3.7 - NSP Daily Production Chicken Output

Oven Line	Day 1	Day 2	Day 3
2	Running Beef Only	Chicken Breast Strips	Chicken Breast Strips
3	Herb Chicken Breast	Thin Sliced Chicken Breast	Herb Chicken Breast
Total Lbs. Produced	64,000 lbs	62,190 lbs	73,000 lbs

Transportation time from the marinade room to both Tumbler 1 and Tumbler 2 was of interest to the NSP engineering team. Assuming an average pace of 2 miles per hour for a worker to push a loaded marinade vat along the respective distances, the SDT was able to calculate the transportation times. Table 3.8 summarizes these calculations.

Table 3.8 - Current Layout Transportation Times

Marinade Room → Tumbler	Current distance (ft)	Time to transport (sec)
1	120	40.9
2	95	32.4

Simio output statistics for the packaging combiners indicate the lines' utilization. These results are summarized in Table 3.9 below.

Table 3.9 - Current Layout Simio Packaging Line Utilization

Utilization	Packaging Line 2	Packaging Line 3
Maximum	99.3%	94.7%
Minimum	47.2%	71.8%
Average	72.3%	87.1%

The utilization for each line shows a high degree of variability, which is representative of NSP's chicken manufacturing processes. However, the average utilization helps verify the model's logic. Because Line 3 is the default route in the simulation, a higher utilization is expected. The average utilization rates were taken over the 10 replications in the Simio experiment model.

4.0 Proposed State Analysis

This section provides a description of the proposed layout process for the chicken manufacturing line, the SDT's approach for data collection and analysis, and the results derived from the simulation model.

4.1 PROCESS BACKGROUND

NSP's proposed production state remained the same with products from two main product families: chicken and beef. Since the scope of this project is limited to only chicken, the proposed simulation model and analysis disregarded all beef processes in the facility.

Understanding NSP's proposed chicken production process was key in developing a simulation model that accurately depicted the various nuances in the complex set of production steps. A thorough comprehension of NSP's processes were recorded and modeled in a useful simulation of the actual production process using the SDT's detailed data observations, which were used to help model the proposed facility layout. This information allowed the SDT to perform a comparative analysis of the current versus proposed facility layouts.

To assist in the data analysis project phase, the SDT needed to understand how NSP creates value for their customers in the proposed manufacturing process. The process steps for the chicken production line in the proposed layout are identical to the process steps in the current layout. Please reference Table 3.1 for more details.

Additionally, Figure 3.1 illustrates the process map for chicken products, which is exemplary of both the current and proposed facility layouts. Please reference Figure 3.1 for more details.

4.2 DATA COLLECTION

An important component for creating an accurate and useful simulation was obtaining the required data to input into the model. Maintaining integrity in the data was of the highest importance in the SDT's data collection methods.

The SDT had a less than two-week time span to collect all necessary data for the project. As a result, one challenge the SDT had to overcome was how to collect a meaningful amount of data on separate days when different products were being produce. Fortunately, overlapping process steps and intrinsic similarities in NSP's manufacturing methods allowed the SDT to continue data collection mostly uninterrupted.

All data was collected by the SDT in a less than two-week time span on three separate days, which allowed the team to obtain independent data.

The following data was collected on NSP's current processes, which helped model the proposed simulation:

- Chicken Interarrival Time
- Chicken Processing Line Time
- Chicken Processing Line Buggy Weight
- Tumbler Batch Size
- Tumbler Marination Time
- Oven Dwell Time
- Line 2 Conveyor Speed
- Line 3 Conveyor Speed
- Line 3 Freezer Dwell Time
- Line 3 Spiral Freezer Dwell Time
- Line 2 Packaging Rate (lbs/hr)
- Line 3 Packaging Rate (lbs/hr)

As stated previously, NSP's current processes are mostly reflective of the proposed processes. The major differences in the proposed layout are as follows:

- Arrangement of equipment
- Transportation distances
- One additional chicken processing line

While no additional data was collected specifically for the proposed facility layout, much of the information used in modeling the current layout was also used in modeling the proposed layout. It was assumed that transportation rates remained the same between the current and proposed facility layouts (2 miles per hour) and that the additional chicken processing line produces chicken at the same rate as the current chicken processing line.

Data was also collected on transportation distances separating subsequent process steps for the proposed facility layout. The SDT recorded these measured distances in Table 4.1 below.

Table 4.1 - Transportation Path Distances in Proposed Layout

Path	Current Layout Distance (ft)
Chicken Processing 2 → Tumbler 2	35
Chicken Processing 1 → Tumbler 1	16
Marinade Room → Tumbler 2	250
Marinade Room → Tumbler 1	236
Tumbler 2 → Oven 2	15

Data collection was an extremely important part of the project methodology. Without reliable data, the simulation model would lack integrity and provide inaccurate results. The SDT recognizes that given more time and more data the accuracy of the simulation model could be improved.

4.3 DATA ANALYSIS

Section 3.3 contains all the data analysis for the current facility layout. These analysis results were also used in constructing the Simio model for the proposed facility layout. Please reference section 3.3 for more details.

4.4 SIMULATION MODEL

After analyzing the available data, the next step was to construct a simulation model using Simio simulation software. While Simio is an effective modeling tool for many different kinds of simulations, the SDT recognizes that certain parts of the simulation may not be completely accurate or reflective of NSP's proposed processes and facility layout due to time constraints and data availability.

Figure 4.1 is representative of the Simio simulation model for the proposed facility layout. The figure illustrates the respective distances and identifies the various process steps in manufacturing finished goods (chicken product).

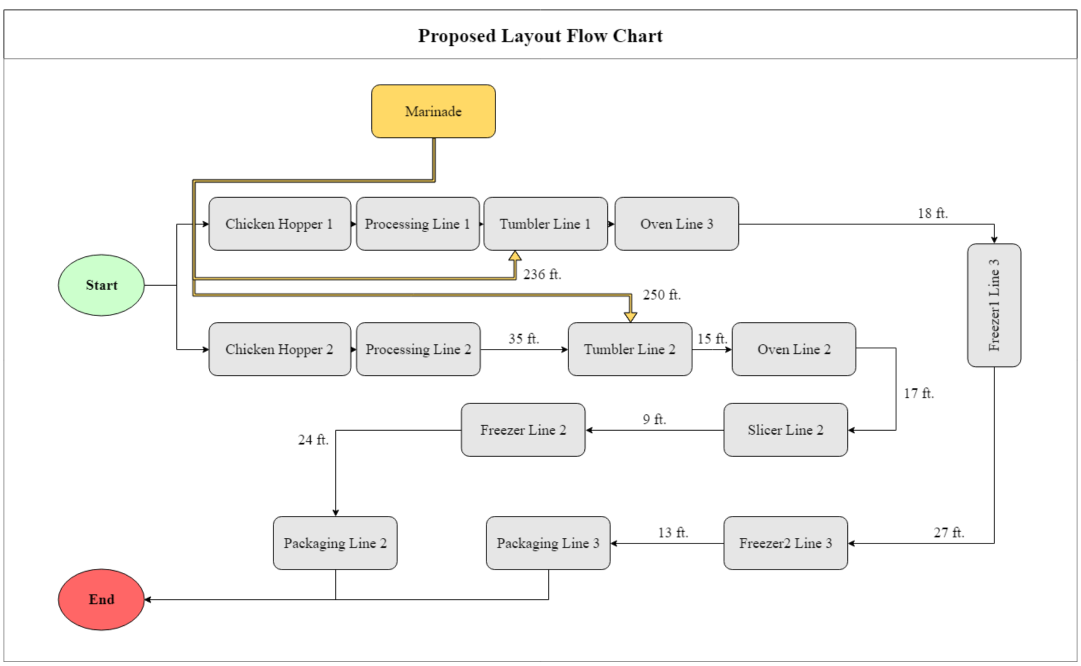

Figure 4.1 - Simulation Model Proposed Layout Process Flow Chart

As noted in previous sections, this simulation only considers NSP's processes from the time raw chicken enters the chicken hopper to the time it is packaged.

The Simio model contains four separate entity types:

- Chicken entity (Ent_ChickenBreast)
- Marinade entity (Ent_Marinade)
- Box entity (Line 2) (Pkg_Boxes)
- Bag entity (Line 3) (Pkg_Bag)

It is important to note that a single chicken entity entering the Simio model represents *one pound of raw chicken.* Therefore, each chicken entity (or a pound of chicken) must be processed via a set of repeatable manufacturing steps as discussed in previous sections.

Likewise, one marinade entity represents the total volume of a batch of marinade sufficient to process a batch of chicken marinating in one of the two tumblers. In other words, one marinade entity could be assigned to a batch of 5,000 chicken entities if 5,000 pounds is the batch size for a tumbler.

The box entity is used exclusively on Packaging Line 2 and holds a batch size of 30 pounds (30 chicken entities). The bag entity is used exclusively on Packaging Line 3 and holds a batch size of 5 pounds (5 chicken entities).

The proposed layout Simio model was run for 10 iterations for 8 hours each with a warm-up period of 2 hours. Each object within the Simio model and the logic driving each processing and transportation step is described below.

Proposed Layout Simulation Model Steps:

Chicken Entity Source (Src_Chicken_Dump)

The chicken entity source releases chicken entities into the system. It is important to remember that one entity is equal to one pound of chicken. The chicken entities are released using an interarrival time equivalent to approximately 2 pounds per second.

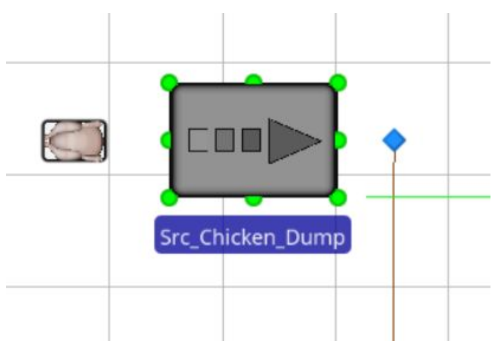

Figure 4.2 - Chicken Entity Source

Chicken Processing Server Line 2 / Chicken Processing Server Line 3
(Srv_Chicken_Processing_L2 / Srv_Chicken_Processing_L3)

The chicken processing servers process chicken entities. The servers represent chicken processing steps such as trimming, cutting, X-ray, tenderizer, etc. The chicken entities are processed on the chicken processing servers using the processing time described in section 3.3.1.

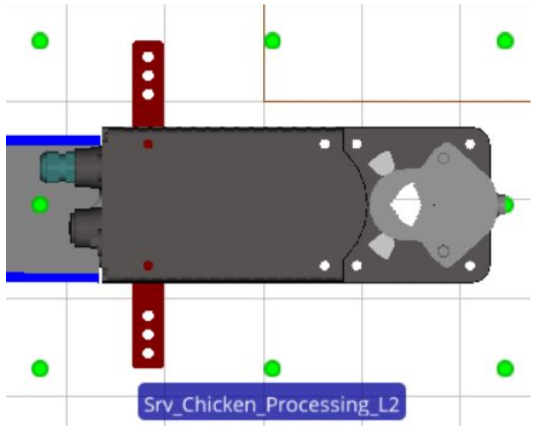

Figure 4.3 - Chicken Processing Server Line 2

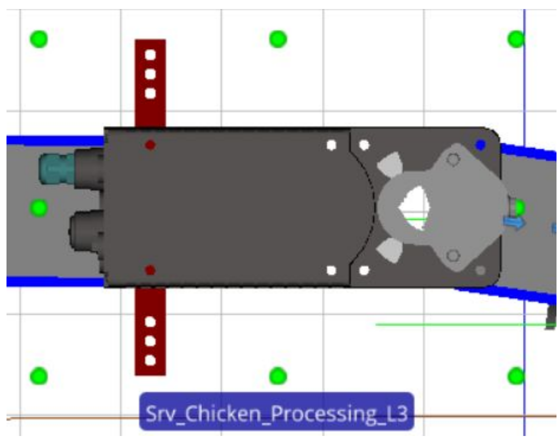

Figure 4.4 - Chicken Processing Server Line 3

Tumbler 1 / Tumbler 2 Combiners (Cmb_Tumbler_1 / Cmb_Tumbler_2)

Buggies transport the chicken entities to either Tumbler 1 or Tumbler 2. Tumbler 1 is the default option, so the buggies only transport chicken entities to Tumbler 2 if Tumbler 1 is in use. The buggies move at 2 miles per hour (assumed pace of an average worker pushing a 600 pound buggy) along the respective distances to Tumbler 1 and Tumbler 2. Both tumblers are modeled as a Combiner, which is responsible for combining a marinade entity to a batch of chicken entities. A batch of chicken entities is defined in sections 3.3.1 and 3.3.2 for Tumbler 1 and Tumbler 2, respectively.

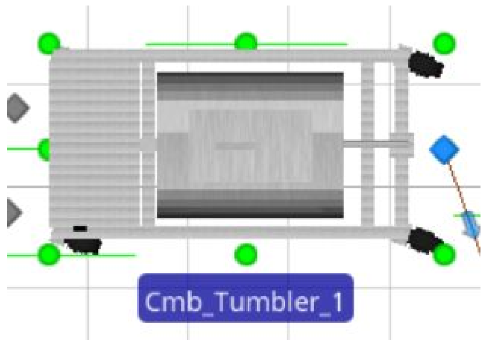

Figure 4.5 - Tumbler 1 Combiner

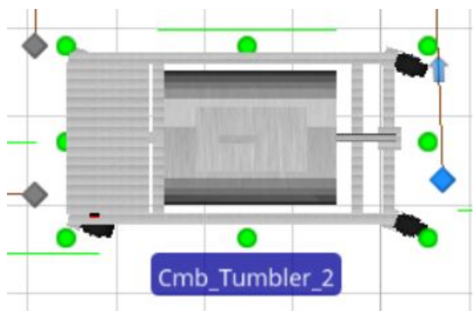

Figure 4.6 - Tumbler 2 Combiner

Marinade Entity Source (Src_Marinade_Room)

The marinade entity source releases marinade entities into the system when a batch of chicken entities arrives at either Tumbler 1 or Tumbler 2. The marinade entities travel distances to Tumbler 1 and Tumbler 2 as defined in Table 3.3.

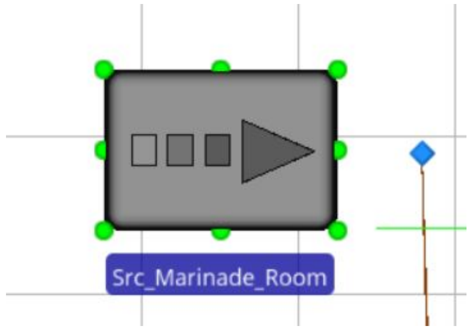

Figure 4.7 - Marinade Entity Source

Tumbler 1 / Tumbler 2 Separators (Sep_VacCat / Sep_BuggyLoad)

Tumbler 1 and Tumbler 2 Separators are located immediately after the Tumbler 1 and Tumbler 2 Combiners. Because the combiners combine a batch of chicken entities with a marinade entity (which represents the marinating process) but are released from the tumblers as separate pieces of chicken, the separators are a zero processing time step to separate the batch of chicken entities from the marinade entity. The separators are necessary in the Simio model only. They are not an actual reflection of NSP's manufacturing processes.

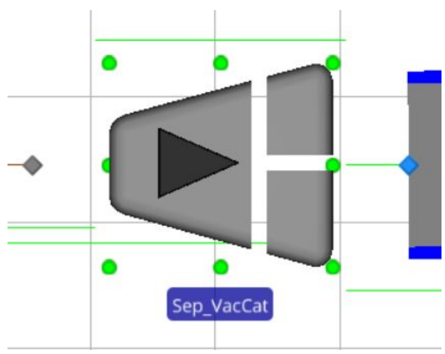

Figure 4.8 - Tumbler 1 Separator

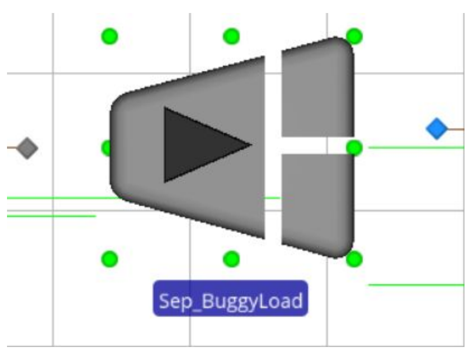

Figure 4.9 - Tumbler 2 Separator

Marinade Entity Sink (Marinade_Exit)

The marinade entity sink serves as a means to remove the marinade entities from the system once they are separated from the chicken entities. The chicken entities are considered marinated from that point forward in the model.

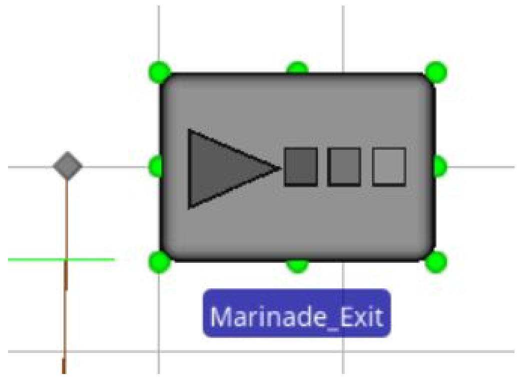

Figure 4.10 - Marinade Entity Sink

Oven Line 2 / Oven Line 3 (Srv_Oven_L2 / Srv_Oven_L3)

The marinated chicken entities proceed to either Oven Line 2 or Oven Line 3, depending on the tumbler in which they were processed. The chicken entities are processed on the oven servers for processing times defined in section 3.3.2.

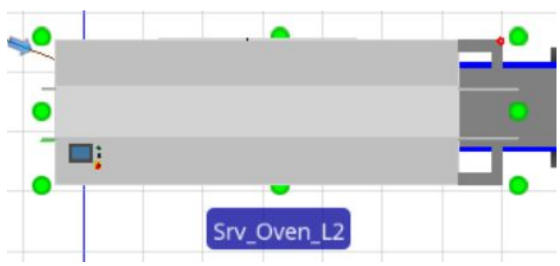

Figure 4.11 - Oven Line 2

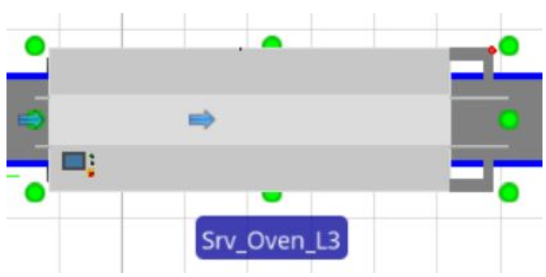

Figure 4.12 - Oven Line 3

Freezer 1 Line 3 (Srv_Freezer1_L3)

The Freezer 1 Line 3 Server cools and partially freezes the cooked and marinated chicken entities on Line 3. The server's processing time is defined in section 3.3.2.

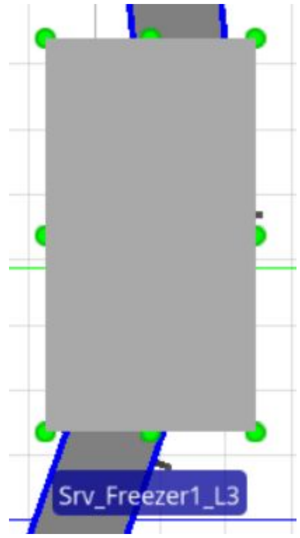

Figure 4.13 - Freezer 1 Line 3

Freezer 2 Line 3 (Srv_Freezer2_L3)

The Freezer 2 Line 3 Server finishes freezing the cooked and marinated chicken entities on Line 3. The server's processing time is defined in section 3.3.2.

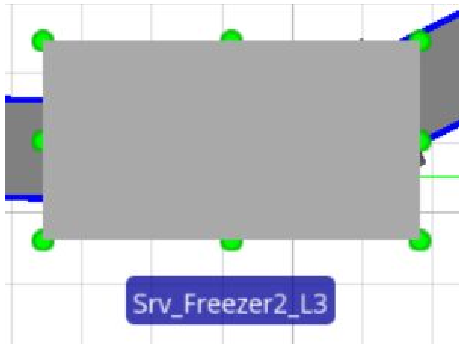

Figure 4.14 - Freezer 2 Line 3

Line 3 Conveyor

The Line 3 Conveyor represents the transportation distances between Oven Line 3 and Freezer 1 Line 3, Freezer 1 Line 3 and Freezer 2 Line 3, and Freezer 2 Line 3 and Packaging Line 3. The Line 3 Conveyor moves at a speed as defined in section 3.3.2.

Line 2 Conveyor

The Line 2 Conveyor represents the freezing and slicing processes on Line 2 for the cooked and marinated chicken entities. The Line 2 Conveyor moves at a speed as defined in section 3.3.2.

Packaging Line 2 Combiner (Cmb_Pack_L2)

Packaging Line 2 Combiner combines a box entity and a batch of 30 chicken entities to prepare the finished goods for shipment. A box entity is readily available at all times to package the chicken entities when the appropriate batch size is present. The processing time for Packaging Line 2 Combiner is defined in section 3.3.1.

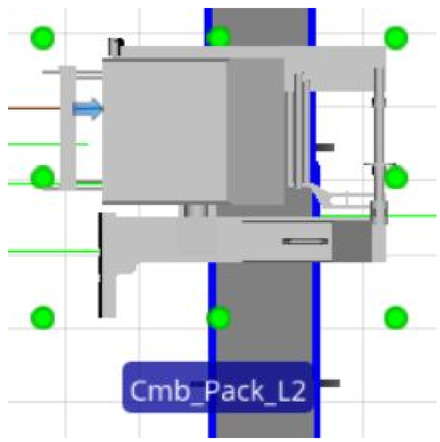

Figure 4.15 - Packaging Line 2 Combiner

Box Entity Source (Src_Pkg_Boxes)

The box entity source releases a box entity into the system when a batch of chicken entities arrives at Packaging Line 2 Combiner. A single box entity is combined with a batch of 30 chicken entities.

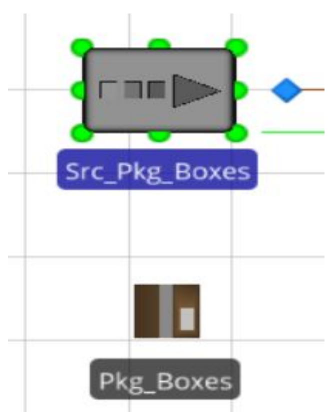

Figure 4.16 - Box Entity Source

Packaging Line 3 Combiner (Cmb_Pack_L3)

Packaging Line 3 Combiner combines a bag entity and a batch of 5 chicken entities to prepare the finished goods for shipment. A bag entity is readily available at all times to package the chicken entities when the appropriate batch size is present. The processing time for Packaging Line 3 Combiner is defined in section 3.3.1.

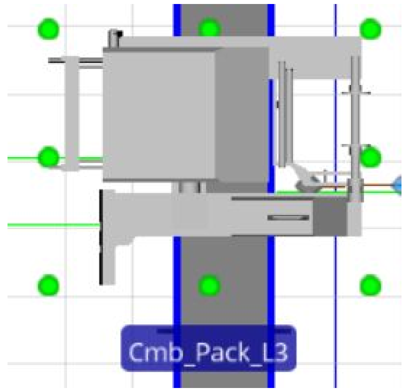

Figure 4.17 - Packaging Line 3 Combiner

Bag Entity Source (Src_Pkg_Bags)

The bag entity source releases a bag entity into the system when a batch of chicken entities arrives at Packaging Line 3 Combiner. A single bag entity is combined with a batch of 5 chicken entities.

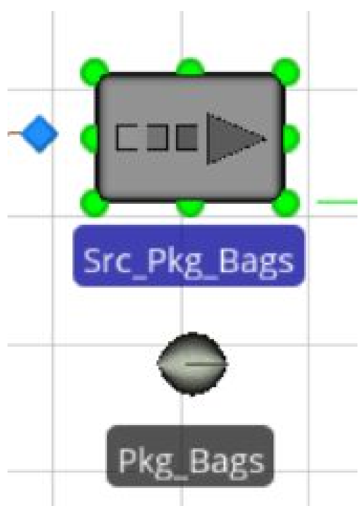

Figure 4.18 - Bag Entity Source

Line 2 Sink (Snk_L2_Exit)

The Line 2 Sink is used in the model to indicate that the manufacturing process has been completed for a box of 30 chicken entities. A connector attaches the Packaging Line 2 Combiner to the Line 2 Sink. All finished boxed products exit through the sink.

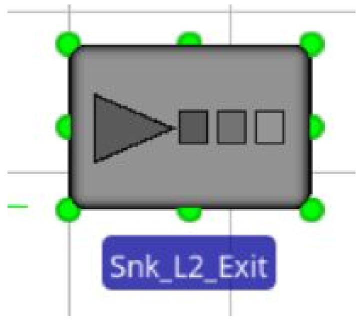

Figure 4.19 - Line 2 Sink

Line 3 Sink (Snk_L3_Exit)

The Line 3 Sink is used in the model to indicate that the manufacturing process has been completed for a bag of 5 chicken entities. A connector attaches the Packaging Line 3 Combiner to the Line 3 Sink. All finished bagged products exit through the sink.

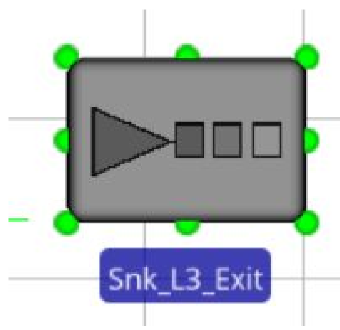

Figure 4.20 - Line 3 Sink

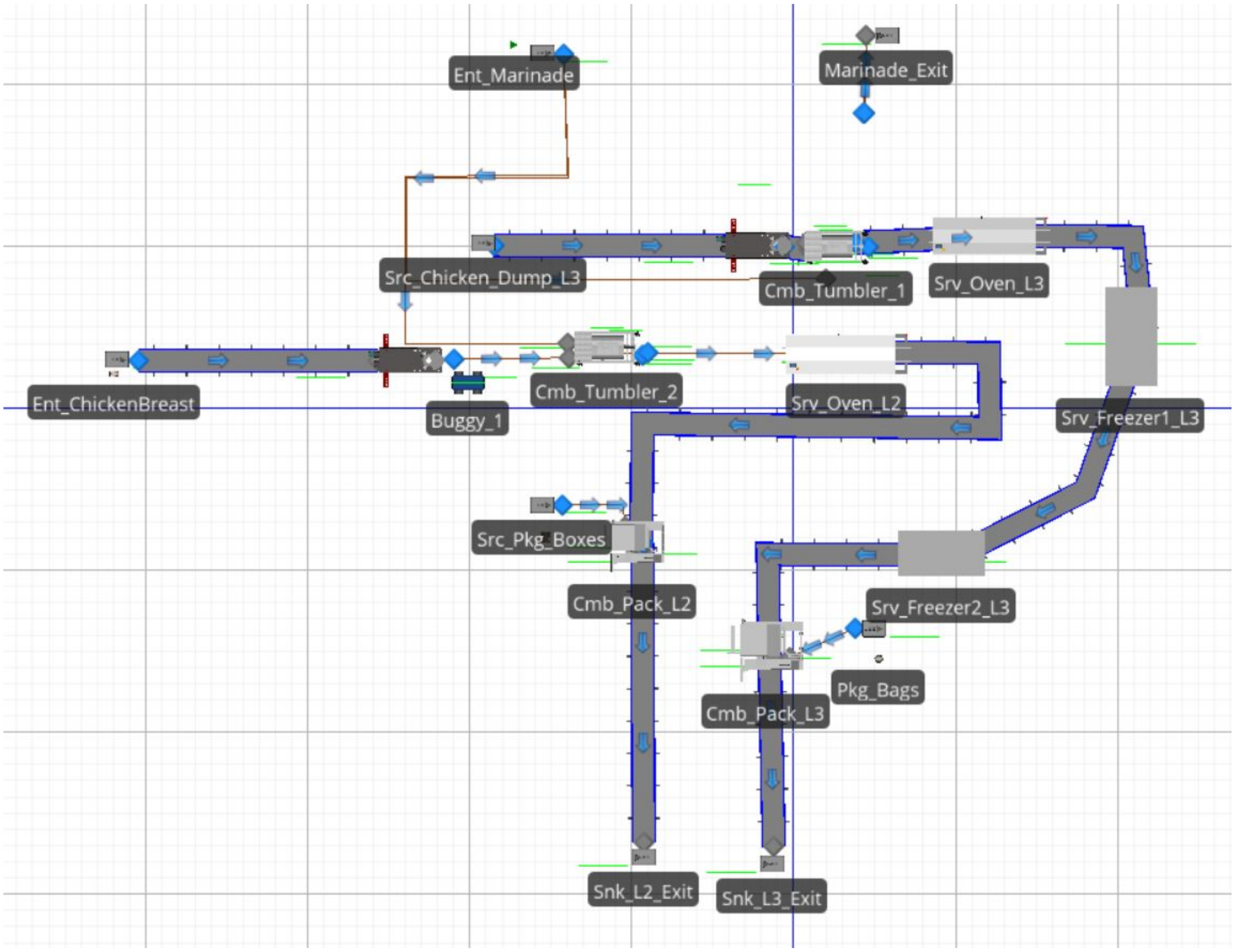

Figure 4.21 - Simio Proposed Layout Simulation Model

4.5 SIMULATION STATISTICAL OUTPUT ANALYSIS

After running the Simio experiment for 10 iterations with a run time of 8 hours each (warm-up period was 2 hours), the model's statistical output results were analyzed to verify the accuracy of the simulation. Table 4.2 summarizes the output results below.

Table 4.2 - Proposed Layout Simio Model Output Results

Object Type	Object Name	Data Source	Category	Data Item	Statistic	Average	Minimum	Maximum
Sink	Snk_L3_Exit	Input Buffer	Throughput	Number Exited	Total	5,951.80	5,268.00	6,157.00
				Number Entered	Total	5,951.80	5,268.00	6,157.00
	Snk_L2_Exit	Input Buffer	Throughput	Number Exited	Total	256.7	250	265
				Number Entered	Total	256.7	250	265

To calculate the proposed finished product output in pounds on average, the SDT had to consider the number of entities (weight) of chicken in the boxes and bags. Equations 4.1 and 4.2 represent the finished goods' weight for boxes and bags, respectively.

$$\textit{Line 2 Sink Output} = (256.7\ \textit{boxes}) * (2\ \textit{shifts}) * (30\ \textit{lbs/box}) \tag{4.1}$$

$$\textit{Line 3 Sink Output} = (5{,}951.8\ \textit{bags}) * (2\ \textit{shifts}) * (5\ \textit{lbs/bag}) \tag{4.2}$$

Since the Simio model was ran for only one shift (8 hours) and the SDT assumed shift one runs identically to shift two, the number of entities (boxes and bags) that entered the sink was multiplied by two. This was necessary because the Simio model is a large-scale simulation of a single production day and the required computing power for an entire production day was not available to the SDT. Table 4.3 shows the summary production output for two shifts.

Table 4.3 - Proposed Layout Simulated Production Output

Line	Shift 1 (lbs)	Shift 2 (lbs)	Net Produced (lbs)
2	7,701	7,701	15,402
3	29,759	29,759	59,518
		Total	**74,920**

Because the SDT was able to confidently verify the current layout model using NSP's daily production reports, it can be assumed the proposed layout model is also relatively accurate given the only changes were the addition of a second chicken processing line and some transportation distances. Furthermore, the increase in pounds produced in the proposed layout Simio output results is logical since chicken processing capacity increased. Therefore, the relative accuracy of the models is sufficient for the purposes of this project.

Transportation time from the marinade room to both Tumbler 1 and Tumbler 2 was of interest to the NSP engineering team. Assuming an average pace of 2 miles per hour for a worker to push a loaded marinade vat along the respective distances, the SDT was able to calculate the transportation times. Table 4.4 summarizes these calculations.

Table 4.4 - Proposed Layout Transportation Times

Marinade Room → Tumbler	Proposed distance (ft)	Time to transport (sec)
1	236	80.5
2	250	85.3

Simio output statistics for the packaging combiners indicate the lines' utilization. These results are summarized in Table 4.5 below.

Table 4.5 - Proposed Layout Simio Packaging Line Utilization

Utilization	Packaging Line 2	Packaging Line 3
Maximum	100.0%	100.0%
Minimum	100.0%	85.6%
Average	100.0%	96.9%

The utilization for each line indicates a strong possibility of a bottleneck at the packaging combiners, which means there are likely many entities that are waiting in the queue but never being processed. This results in zero down time in the case of Packaging Line 2 and an extremely high average utilization rate for Packaging Line 3. The average utilization rates were taken over the 10 replications in the Simio experiment model.

5.0 Simulation Results Comparison

This section summarizes the results of the current and proposed layout simulation models. Comparing the results provided the SDT insight into the relative performance of NSP's current system and the expected performance of the proposed system. The alternative solution selected by the SDT in section 6.0 used this information in part to guide the decision.

Table 5.1 summarizes the current layout and proposed layout production output.

Table 5.1 - Current vs. Proposed Production Output (lbs)

	Current Layout			**Proposed Layout**		
Line	Shift 1 (lbs)	Shift 2 (lbs)	Net Produced (lbs)	Shift 1 (lbs)	Shift 2 (lbs)	Net Produced (lbs)
2	5,454	5,454	10,908	7,701	7,701	15,402
3	26,761	26,761	53,522	29,759	29,759	59,518
		Total	**64,430**		**Total**	**74,920**

Equation 5.1 shows the percent increase calculation for production output in the current versus proposed layout model.

$$Production\ \%\ Increase = \frac{Proposed\ Layout\ Total\ Production - Current\ Layout\ Total\ Production}{Current\ Layout\ Total\ Production} * 100 \quad \textbf{(5.1)}$$

The production percent increase is equal to 16.3%. According to the SDT's simulation models, this means that if NSP were to implement the proposed layout, their chicken production would increase by 16.3% relative to current levels.

Transportation time from the marinade room to both Tumbler 1 and Tumbler 2 was of interest to the NSP engineering team. Assuming an average pace of 2 miles per hour for a worker to push a loaded marinade vat along the respective distances, the SDT was able to calculate the transportation times. Table 5.2 summarizes the transportation times from the marinade room to both Tumbler 1 and Tumbler 2 for the current and proposed layouts.

Table 5.2 - Current vs. Proposed Transportation Times

	Current Layout		Proposed Layout	
Marinade Room → Tumbler	Current distance (ft)	Time to transport (sec)	Proposed distance (ft)	Time to transport (sec)
1	120	40.9	236	80.5
2	95	32.4	250	85.3

If the proposed layout were to be implemented, the above table shows transportation time from the marinade room to Tumbler 1 would nearly double. Likewise, the transportation time from the marinade room to Tumbler 2 would be approximately 2.6 times greater in the proposed layout compared to the current layout.

While transportation time per trip significantly increases in the proposed layout compared to the current layout due to increased path distances, the frequency of trips is low. Therefore, the SDT does not expect any measurable impact to be had on the proposed layout in terms of production output.

Table 5.3 summarizes packaging line utilization in both the current and proposed layout models.

Table 5.3 - Current vs. Proposed Simio Packaging Line Utilization

	Current Layout		Proposed Layout	
Utilization	Packaging Line 2	Packaging Line 3	Packaging Line 2	Packaging Line 3
Maximum	99.3%	94.7%	100%	100%
Minimum	47.2%	71.8%	100%	85.6%
Average	72.3%	87.1%	100%	96.9%

The utilization for each line for the proposed layout indicates a strong possibility of a bottleneck at the packaging combiners, which means there are likely many entities that are waiting in the queue but never being processed. High average utilizations were expected using the model's logic since input into the system is essentially doubled with the introduction of the second chicken processing line. The packaging combiners were overloaded on line 2 due to the shorter dwell time in between the oven and the packaging line. Therefore, it can be concluded that the resulting bottleneck is limiting the output of the overall system.

6.0 Evaluating Alternative Solutions

The SDT proposed three alternative solutions to evaluate. The alternative solution selection criteria was based on increasing NSP's chicken production while maintaining reasonable functionality and manufacturing facility adaptability.

The following are the alternative solution options:

- Alternative Solution #1 - Accept the Proposed Layout
- Alternative Solution #2 - Accept the Proposed Layout with Modifications
- Alternative Solution #3 - Reject the Proposed Layout

Accepting the proposed layout would increase chicken production relative to the current layout by 16.3%, or about 10,000 pounds per day. This solution is preferred over rejecting the proposed layout as there is clearly a business case for implementing the proposed layout.

However, the Simio simulation model indicated maximum level utilization of the packaging combiners in the proposed layout, which is likely due to slow packaging rates relative to the volume of incoming finished goods.

Therefore, the SDT selected alternative solution #2. Accepting the proposed layout with modifications allowed the SDT to propose potential improvements to increase production above the proposed layout simulation production output.

Because utilization for the packaging combiners was at or near 100% in the proposed layout model, the SDT modified the proposed layout by introducing a third packaging line. Figure 6.1 illustrates the revised flow chart.

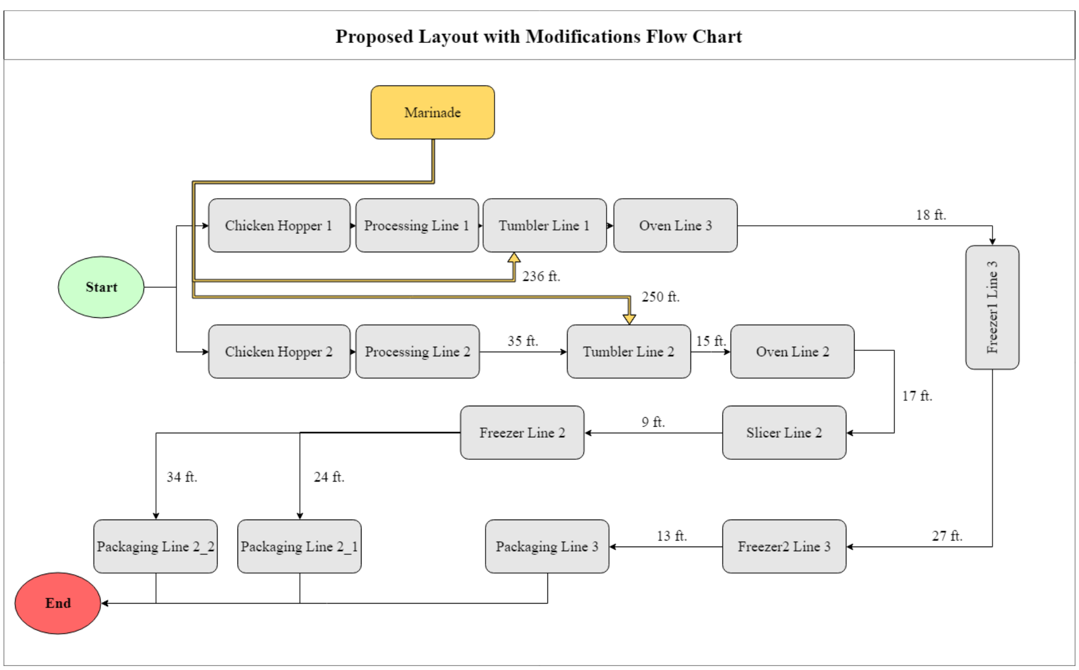

Figure 6.1 - Proposed Layouts with Modifications Flow Chart

Table 6.1 summarizes the output results below.

Table 6.1 - Proposed Layout with Modifications Simio Model Output Results

Object Type	Object Name	Data Source	Category	Data Item	Statistic	Average	Minimum	Maximum
Sink	Snk_L3_Exit	Input Buffer	Throughput	Number Exited	Total	6,032.50	5,890.00	6,163.00
				Number Entered	Total	6,032.50	5,890.00	6,163.00
	Snk_L2_Exit	Input Buffer	Throughput	Number Exited	Total	507.60	497.00	518.00
				Number Entered	Total	507.60	497.00	518.00

Table 6.2 shows the summary production output for two shifts.

Table 6.2 - Proposed Layout with Modifications Simulated Production Output

Line	Shift 1 (lbs)	Shift 2 (lbs)	Net Produced (lbs)
2	30,162	30,162	30,456
3	15,228	15,228	60,325
		Total	**90,781**

Table 6.3 summarizes the current layout, proposed layout, and proposed layout with modifications production output.

Table 6.3 - Production Output Comparison

	Current Layout			**Proposed Layout**			**Proposed Alternative Layout**		
Line	Shift 1 (lbs)	Shift 2 (lbs)	Net Produced (lbs)	Shift 1 (lbs)	Shift 2 (lbs)	Net Produced (lbs)	Shift 1 (lbs)	Shift 2 (lbs)	Net Produced (lbs)
2	5,454	5,454	10,908	7,701	7,701	15,402	30,162	30,162	30,456
3	26,761	26,761	53,522	29,759	29,759	59,518	15,228	15,228	60,325
		Total	**64,430**		**Total**	**74,920**		**Total**	**90,781**

Equation 6.1 shows the percent increase calculation for production output in the current versus proposed layout with modifications models.

$$Production\ \%\ Increase\ =\ \frac{Proposed\ Alternative\ Layout\ Total\ Production - Current\ Layout\ Total\ Production}{Current\ Layout\ Total\ Production} * 100 \quad \textbf{(6.1)}$$

The production percent increase is equal to 40.9%. According to the SDT's simulation models, this means that if NSP were to implement the proposed layout with modifications (add a packaging line), their chicken production would increase by about 40.9% relative to current levels, or 26,351 pounds per day.

Equation 6.2 shows the percent increase calculation for production output in the proposed versus proposed layout with modifications models.

$$Production\ \%\ Increase\ =\ \frac{Proposed\ Alternative\ Layout\ Total\ Production - Proposed\ Layout\ Total\ Production}{Proposed\ Layout\ Total\ Production} * 100 \quad \textbf{(6.2)}$$

The production percent increase is equal to 21.2%. According to the SDT's simulation models, this means that if NSP were to implement the proposed layout with modifications (add a packaging line), their chicken production would increase by about 21.2% relative to proposed levels, or 15,861 pounds per day.

Figure 6.2 illustrates the Simio layout of the proposed facility with the third packaging line.

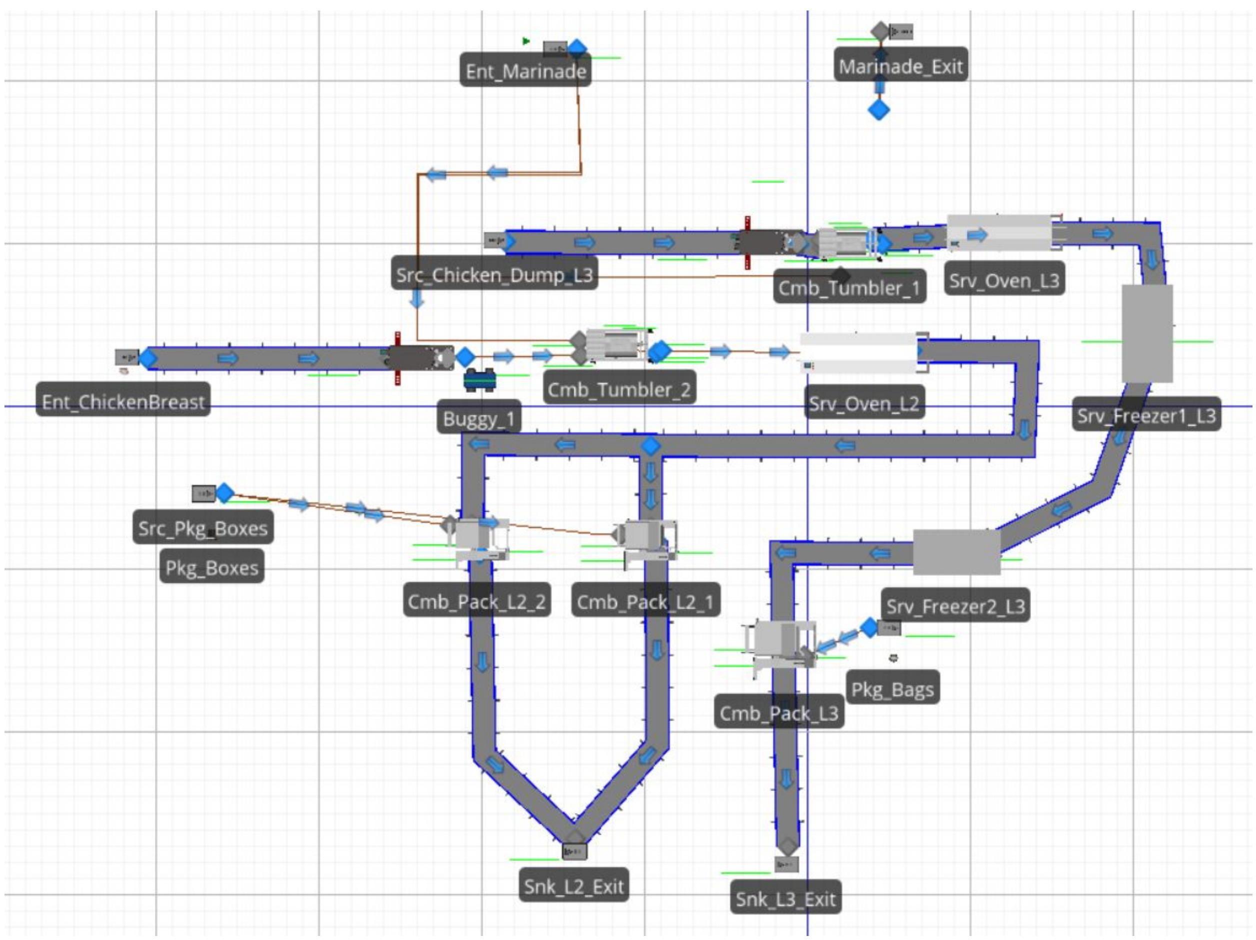

Figure 6.2 - Simio Proposed Alternative Layout Simulation Model

7.0 Conclusions and Recommendations

In conclusion, the SDT recommends implementing the proposed layout with modifications. Since extremely high packaging line utilization rates were observed, the introduction of a third packaging line was proposed. By introducing this third packaging line in the proposed layout, production output was increased significantly. The bottleneck that resulted from the proposed layout (without modifications) will also be alleviated by increasing the packaging line capacity.

While investing in an additional packaging line could be relatively costly, the SDT encourages the NSP engineering team to evaluate the long-term potential value creation that will occur by increasing chicken production. Beyond simply increasing production, the additional packaging line will help improve the functionality of the system and lessen waste by removing a substantial amount of work-in-progress.

Upon the completion of an economic justification, the SDT also recommends that the NSP engineering team investigate the optimal line assignment for the third packaging line. While the Simio simulation model places the additional packaging combiner on line 2, the system may perform better using alternative routing logic.

8.0 Appendix

Project Proposal 1/28/2019

NSP Quality Meats:
ROI Analysis of Proposed Facility Layout

An Oklahoma State University
School of Industrial Engineering and Management
Senior Design Project
Spring 2019

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NSP Quality Meats: ROI Analysis of Proposed Facility Layout

Sybille and Kris,

Oklahoma State University's IE&M senior design team is excited for the opportunity to present this proposal for NSP Quality Meats' project regarding the financial impact of alternative facility layouts. Thank you for hosting our senior design team on the afternoon of Monday, January 21 and answering questions to help us understand the project objectives. We look forward to working with NSP to develop project solutions that meet and exceed your expectations.

This proposal will outline the purpose of the project in terms of facility layout cost efficiency and potential manufacturing process improvements for NSP Quality Meats. The following pages will detail deliverables for NSP and the methodology to fulfill project goals.

The sections included in this document for your review are as follows:

1. Background
2. Objectives and Scope
3. Anticipated Methodology
4. Anticipated Schedule
5. Anticipated Deliverables
6. Anticipated Benefits
7. Risks and Mitigation Strategy

Background

NSP Quality Meats is a result of a merger between three companies backed by a venture capital investment group. The venture capital group provides direction and high-level strategic planning for NSP, but they are not involved in NSP's production operations. NSP management consists of individuals responsible for carrying out initiatives that drive the company toward the pre-defined goals set forth by the venture capital group. The overarching goal of the venture capital group is to increase the value of NSP. The NSP engineering team expects the value of the company to grow by increasing the product output and decreasing the labor cost per pound of finished goods for their manufacturing operations.

Historically, NSP has not used a disciplined, engineering-based approach to planning and executing their production and manufacturing processes. In an effort to streamline operations, NSP recently hired an engineering team to implement and manage manufacturing improvement initiatives. One such initiative is the restructuring of the facility layout and production processes. NSP's engineering team has already developed a new layout for the facility transformation. The purpose of the proposed layout is to improve the manufacturing system processes in such a way

NSP Quality Meats: ROI Analysis of Proposed Facility Layout

that the production of finished goods increases and labor costs per pound of finished goods decreases. The NSP engineering team based their proposed layout on intuition – what they logically believe will increase product output. Consequently, the engineering team is now seeking assistance to quantitatively analyze their proposed facility layout relative to the existing facility layout.

To fully understand the problem at hand, it is important to recognize the key differences in the current production state and the proposed production state. In addition to changes in the facility layout, the NSP engineering team has also indicated interest in expanding manufacturing operations via processing equipment investments. The below information specifies NSP's current production state and proposed production state.

NSP's current production state:

- 3 Beef Processing Lines[1]
- 5 Beef Packaging Lines[2]
- 1 Chicken Processing Line
- 3 Chicken Oven Lines[3]
- 3 Cooked Chicken Packaging Lines[4]
- 1 Marinade Preparation Area
- 1 Manual Palletizing Room

NSP's proposed production state:

- 4 Beef Processing Lines
- 5 Beef Packaging Lines
- 2 Chicken Processing Lines
- 2 Chicken Oven Lines
- 2 Cooked Chicken Packaging Lines
- 1 Marinade Preparation Area
- 1 Automatic Palletizing Room

Important terms relevant in the Anticipated Methodology section include the following:

- Frontline (FL) Employee: a production employee that works directly on the manufacturing floor

[1] Only 2 Beef Cutting Lines are operational at any given time
[2] Only 3 Beef Packaging Lines are operational at any given time
[3] Only 2 Chicken Oven Lines are operational
[4] Only 2 Cooked Chicken Packaging Lines are operational

NSP Quality Meats: ROI Analysis of Proposed Facility Layout

- Function: a common set of production activities for a group of FL employees (e.g. cutting/slicing/dicing beef in the Beef Processing Line)
- Process Step: a single production activity that is one of many steps in a manufacturing process used to create finished goods
- Product Line: a manufacturing line that performs a similar function and produces similar products (e.g. Chicken Processing Line)
- Muda (waste): seven generally accepted types of Muda (waste) that seeks to identify and eliminate non-value added activities; the seven types of Muda (waste) include the following:
    - Inventory
    - Transportation
    - Motion
    - Waiting
    - Overproduction
    - Over Processing
    - Defects
- Production Capacity: the maximum amount of finished goods (in lbs) that can be produced under certain manufacturing conditions. For this project, it is assumed that each product type on each product line will be manufactured for an equal amount of time.
- Production Flow: the flow of work-in-process materials through the production process

NSP has requested the assistance of Oklahoma State University's Industrial Engineering senior design team to help them fully understand the return on investment (ROI) of the layout. NSP has also asked the senior design team to make improvements to the proposed layout if economically justified.

Objectives and Scope

The following items represent the project objectives:

- Total annual labor cost analysis of the existing layout versus the proposed layout
- Production output (in lbs/year) analysis of the existing layout versus the proposed layout
- ROI analysis report for the proposed layout
- Development of potential layout alternatives to improve ROI[5]

The senior design team will be solving for the ROI of the proposed facility layout change to inform the NSP engineering team of the value creation potential. ROI is defined as the ratio of

[5] If time allows

NSP Quality Meats: ROI Analysis of Proposed Facility Layout

the change in revenue at capacity plus the change in labor cost at capacity (from the existing layout to the proposed layout) to the total investment. This definition is reflected in the Anticipated Methodology section. The methodology will provide the NSP engineering team with a framework to solve for ROI in other alternative layouts as necessary. We will be evaluating the ROI only within the product manufacturing areas.[6] This does not include other inventory, office, and breakroom areas.

Anticipated Methodology

1. Develop labor cost analysis of existing versus proposed layout
    - 1.1. Request data on average labor wages for each FL employee function and total number of FL employees in each function
    - 1.2. Calculate labor cost for existing layout
        - 1.2.1. Request process step outline for each product type for existing layout
        - 1.2.2. Determine process steps for different product lines
        - 1.2.3. Determine the actual number of FL employees needed to complete each process step
        - 1.2.4. Calculate labor cost for existing layout
    - 1.3. Calculate labor cost for proposed layout
        - 1.3.1. Request process step outline for each product type for proposed layout
        - 1.3.2. Determine process steps for different product lines
        - 1.3.3. Determine the actual number of FL employees needed to complete each process step
        - 1.3.4. Identify process steps for new automation technology
        - 1.3.5. Calculate labor cost for proposed layout
    - 1.4. Calculate labor cost change
    - 1.5. Submit intermediary labor cost analysis report to NSP engineering team
2. Develop production output (in lbs/yr) analysis of existing versus proposed layout
    - 2.1. Request average price data for different product types
    - 2.2. Calculate revenue for existing layout
        - 2.2.1. Identify the 7 types of Muda in the current layout
        - 2.2.2. Quantify production flow waste in terms of dollars for the current layout
        - 2.2.3. Determine production capacity in current layout
        - 2.2.4. Calculate total revenue for existing layout at production capacity
    - 2.3. Calculate anticipated revenue for proposed layout
        - 2.3.1. Identify the 7 types of Muda in the proposed layout
        - 2.3.2. Quantify production flow waste in terms of dollars for the proposed layout

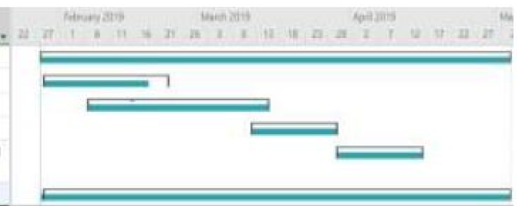
[6] Contingent on NSP's ability to provide requested data

NSP Quality Meats: ROI Analysis of Proposed Facility Layout

2.3.3. Calculate production capacity in proposed layout
2.3.4. Calculate total revenue for proposed layout at production capacity
2.4. Calculate revenue change at capacity
2.5. Submit intermediary production output analysis report to NSP engineering team
3. Determine ROI of implementing proposed layout
3.1. Collect data from NSP on total investment cost
3.2. Calculate ROI
3.3. Submit intermediary ROI analysis report to NSP engineering team
4. Develop potential layout alternatives to improve ROI[7]
4.1. Use labor cost and production output analysis to develop alternative layout(s)
4.2. Perform an economic analysis to determine the ROI of each layout alternative
4.3. Submit layout alternative(s) report to NSP engineering team

Anticipated Schedule

Task Name	Start	Finish
SENIOR DESIGN PROJECT	Mon 1/28/19 8:00 AM	Fri 5/3/19 5:00 PM
Labor Cost Analysis	Mon 1/28/19 12:00 PM	Fri 2/22/19 5:00 PM
Production Output Analysis	Wed 2/6/19 3:00 PM	Fri 3/15/19 12:00 PM
Determine ROI of implementing proposed	Mon 3/11/19 6:00 PM	Fri 3/29/19 12:00 PM
Develop potential layout alternatives to improve ROI	Fri 3/29/19 12:00 PM	Mon 4/15/19 9:00 PM
Final Report/Presentation	Mon 1/28/19 12:00 PM	Fri 5/3/19 5:00 PM



Anticipated Deliverables

Expected deliverables for the project will include periodic status reports in addition to the reports outlined below. The NSP team will receive a high-level report consistent with the scope defined regarding the following project topics:

- Labor Cost Analysis
- Production Output Analysis
- ROI Analysis Report
- Layout Alternative Solutions[8]
- Final Report/Presentation

[7] If time allows
[8] If time allows

NSP Quality Meats: ROI Analysis of Proposed Facility Layout

Anticipated Benefits

The key benefits of completing this project include the following:

- Understanding the ROI of implementing the selected facility layout
- Simplification of process flow
- Quantifying the anticipated increase in finished goods production
- Potential reduction in labor cost per pound of finished goods
- A process framework to analyze ROI for alternative/future facility changes
- Potential increase in company value

Risks and Mitigation Strategy

Successful completion of this project is highly dependent on NSP's ability to provide performance metrics and requested data in a timely manner. The senior design team has identified risks and a corresponding mitigation strategy below.

Risks	Mitigation Strategy
Lack of data to quantify labor cost/production output/economic analysis	Coordinate data studies/request data with/from POC such that data can be provided within three business days. If requested data cannot be provided, the analysis on one or more deliverables may be incomplete.
The first priority is to calculate the projected ROI of implementing the proposed layout. The short project time frame may affect our ability to complete all deliverables.	Alternative layout recommendations will be provided to NSP. Additionally, a framework for conducting ROI analysis will be provided to NSP to independently evaluate ROI for the senior design team's alternative recommendations.

NSP Quality Meats: ROI Analysis of Proposed Facility Layout

Endorsements – Endorsement below acknowledges receipt and acceptance of the proposal of a Senior Design Team from Oklahoma State University's School of Industrial Engineering and Management. The project will be executed on a 'best effort' basis and no warranty is stated or implied. All modifications to this proposal shall be provided, in writing, to all signatories for approval and acceptance.

On Behalf of NSP

Sybille Gallardo

On Behalf of Senior Design Team

E. Maddie Marko

Duke Hwang

Caleb Coats

Logan Price

01/30/19

Date of Last Signature

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Figure 8.1 - Initial Project Proposal

Item Descript	LE Qty	LE Net Wght	LE Act. Wght
081035 RAW Beef NY Strip Loin Steak 10oz	187	5,843.75	5,989.61
08808 RAW Boneless Beef Strip Loin Steak 8oz	344	2,752.00	2,985.92
22550 RAW Beef For Fajitas	75	1,500.00	1,517.33
33675 NSP Beef Trimmings - Lean Trim	488	29,280.00	29,270.36
35604 Beef Steak for Fajitas 4oz	50	2,042.14	2,042.14
35607 RAW Churrasco, Beef Skirt Steak 7oz	123	5,134.82	5,134.82
47812 RAW USDA Choice Beef Cubed Steak 8oz	132	1,320.00	1,330.00
54076 RAW Boneless Chicken Breast Meat & ThighMeatStrips	342	6,840.00	6,846.77
58099 USDA Select or Higher Boneless Beef	159	9,540.62	9,540.62
581625 RAW GFGB Sel Beef Top Sirloin Steak 6oz	764	19,692.12	19,692.12
581825 RAW GFGB Sel Beef Top Sirloin Steak 8oz	1,768	59,353.15	59,353.15
601508 RAW Chicken Breast Strips	766	15,320.00	15,384.09
64008 All Natural FC Diced White and Dark Meat Chicken	705	7,050.00	7,166.54
680009 RAW Boneless Beef Sirloin Steak	24	743.16	743.16
680535 RAW USDA Select Boneless Beef Sirloin Steak 5.5oz	507	8,715.33	8,978.85
680915 RAW KRM 9oz Beef Sirloin Tri Tip Steak Savory	107	2,937.21	2,937.21
681715 RAW KRM 7oz Beef Sirloin Tri Tip Steak Savory	179	5,800.45	5,800.45
683104 RAW Fillet of Beef Steak Strips	554	16,620.00	17,138.78
70039 FC Oven Roasted Chicken Breast Strips	935	18,700.00	18,829.66
70041 FC Seasoned Ckn Breast Cubes - Yakitori	3,940	118,200.00	118,485.12
70042 FC Grilled Chicken Breast Strips With Rib Meat	3,383	33,830.00	34,308.58
70165 MCA FC Herb Seasoned Chicken Breast	1,181	35,430.00	35,517.80
70308 Alpastor Fully Cooked Chicken Breast Cubes	915	18,300.00	18,618.60
703116 CB FC Herb Seas Ckn Brst	329	9,870.00	9,903.70
704109 FC Herb Seasoned Chicken Breast	7,419	148,380.00	149,073.24
705208 FC Roasted Chicken Breast Cubes	388	11,640.00	11,699.68
705408 FC Buffalo Style Chicken Breast Strips	173	5,190.00	5,250.77
70641 FC Thinly Sliced Seasoned Chicken Breast	689	20,670.00	20,727.38
707308 All Natural - Fully Cooked Chicken Breast Fillets	1,741	17,410.00	17,625.80
707608 FC Chicken Breast Meat With Rib Meat	697	20,910.00	20,967.98
708808 FC Diced Chicken Breast With Rib Meat	444	13,320.00	13,378.84
72308 FC Carne Asada Beef Cubes	484	9,680.00	9,839.66
76508 FC Beef Prime Rib Strips	557	11,140.00	11,218.30
78176 RAW Boneless Beef Strips	228	4,560.00	4,586.21
78527 RAW MOE'S All Natural Diced Beef Steak	2,235	67,050.00	67,276.49
88208 RAW Beef Sirloin Philly Steak	68	2,296.67	2,296.67
SC68708 RAW Bnlss B Sirloin Steak-Savory, 7oz Gluten Free	225	1,575.00	1,608.84
Total	**33,305**	**768,636.42**	**773,065.24**

Item Descript	LE Qty	LE Net Wght	LE Act. Wght
64008 All Natural FC Diced White and Dark Meat Chicken	705	7,050.00	7,166.54
70039 FC Oven Roasted Chicken Breast Strips	935	18,700.00	18,829.66
70041 FC Seasoned Ckn Breast Cubes - Yakitori	3,940	118,200.00	118,485.12
70042 FC Grilled Chicken Breast Strips With Rib Meat	3,383	33,830.00	34,308.58
70165 MCA FC Herb Seasoned Chicken Breast	1,181	35,430.00	35,517.80
70308 Alpastor Fully Cooked Chicken Breast Cubes	915	18,300.00	18,618.60
703116 CB FC Herb Seas Ckn Brst	329	9,870.00	9,903.70
704109 FC Herb Seasoned Chicken Breast	7,419	148,380.00	149,073.24
705208 FC Roasted Chicken Breast Cubes	388	11,640.00	11,699.68
705408 FC Buffalo Style Chicken Breast Strips	173	5,190.00	5,250.77
70641 FC Thinly Sliced Seasoned Chicken Breast	689	20,670.00	20,727.38
707308 All Natural - Fully Cooked Chicken Breast Fillets	1,741	17,410.00	17,625.80
707608 FC Chicken Breast Meat With Rib Meat	697	20,910.00	20,967.98
708808 FC Diced Chicken Breast With Rib Meat	444	13,320.00	13,378.84
72308 FC Carne Asada Beef Cubes	484	9,680.00	9,839.66
76508 FC Beef Prime Rib Strips	557	11,140.00	11,218.30
Total	**23,980**	**499,720.00**	**502,611.65**

Item Descript	LE Qty	LE Net Wght	LE Act. Wght
081035 RAW Beef NY Strip Loin Steak 10oz	187	5,843.75	5,989.61
08808 RAW Boneless Beef Strip Loin Steak 8oz	344	2,752.00	2,985.92
22550 RAW Beef For Fajitas	75	1,500.00	1,517.33
33675 NSP Beef Trimmings - Lean Trim	488	29,280.00	29,270.36
35604 Beef Steak for Fajitas 4oz	50	2,042.14	2,042.14
35607 RAW Churrasco, Beef Skirt Steak 7oz	123	5,134.82	5,134.82
47812 RAW USDA Choice Beef Cubed Steak 8oz	132	1,320.00	1,330.00
54076 RAW Boneless Chicken Breast Meat & ThighMeatStrips	342	6,840.00	6,846.77
58099 USDA Select or Higher Boneless Beef	159	9,540.62	9,540.62
581625 RAW GFGB Sel Beef Top Sirloin Steak 6oz	764	19,692.12	19,692.12
581825 RAW GFGB Sel Beef Top Sirloin Steak 8oz	1,768	59,353.15	59,353.15
601508 RAW Chicken Breast Strips	766	15,320.00	15,384.09
680009 RAW Boneless Beef Sirloin Steak	24	743.16	743.16
680535 RAW USDA Select Boneless Beef Sirloin Steak 5.5oz	507	8,715.33	8,978.85
680915 RAW KRM 9oz Beef Sirloin Tri Tip Steak Savory	107	2,937.21	2,937.21
681715 RAW KRM 7oz Beef Sirloin Tri Tip Steak Savory	179	5,800.45	5,800.45
683104 RAW Fillet of Beef Steak Strips	554	16,620.00	17,138.78
78176 RAW Boneless Beef Strips	228	4,560.00	4,586.21
78527 RAW MOE'S All Natural Diced Beef Steak	2,235	67,050.00	67,276.49
88208 RAW Beef Sirloin Philly Steak	68	2,296.67	2,296.67
SC68708 RAW Bnlss B Sirloin Steak-Savory, 7oz Gluten Free	225	1,575.00	1,608.84
Total	**9,325**	**268,916.42**	**270,453.59**

Figure 8.2 - Daily Production Report 03.25.19

Item No_	Description	MR Pln Qty	Qty NWght	MR Rem. Qty	MR Fin. Qty	Product Group Code
33580	Boneless Beef Trimmings	1	60	1	0	RAW BEEF
33675	NSP Beef Trimmings - Lean Trim	1	60	0	58	RAW BEEF
36645	Beef Trimmings	1	60	0	44	RAW BEEF
54076	RAW Boneless Chicken Breast Meat & ThighMeatStrips	328	6,560	0	342	RAW CKN
680009	RAW Boneless Beef Sirloin Steak	20	600	0	24	RAW BEEF
680915	RAW KRM 9oz Beef Sirloin Tri Tip Steak Savory	105	2,835	0	107	RAW BEEF
68099	RAW Boneless Beef	1	60	0	13	RAW BEEF
681715	RAW KRM 7oz Beef Sirloin Tri Tip Steak Savory	150	4,725	0	179	RAW BEEF
703116	CB FC Herb Seas Ckn Brst	450	13,500	121	329	FC CKN
704109	FC Herb Seasoned Chicken Breast	3,192	63,840	0	3,200	FC CKN
72308	FC Carne Asada Beef Cubes	506	10,120	22	484	FC BEEF
76508	FC Beef Prime Rib Strips	577	11,540	20	557	FC BEEF
78527	RAW MOE'S All Natural Diced Beef Steak	370	11,100	0	501	RAW BEEF
SAMPLE 1	CHKN RD#13648 Global Foods Partners	1	0	1	0	FC CKN
SAMPLE 3	BEEF RD#13659 Pizza Joe's	1	0	1	0	FC CKN
SAMPLE 4	BEEF RD#13662 Vocelli's	1	0	1	0	FC CKN
SAMPLE 5	BEEF RD#13660 NSP	1	0	1	0	FC CKN
SC68708	RAW Bnlss B Sirloin Steak-Savory, 7oz Gluten Free	1	7	0	225	RAW BEEF
Total		**5,707**	**125,067**	**168**	**6,063**	

MR Item Ledger Entries

Item Descript	LE Qty	LE Net Wght	LE Act. Wght
33675 NSP Beef Trimmings - Lean Trim	58	3,480.00	3,480.44
54076 RAW Boneless Chicken Breast Meat & ThighMeatStrips	342	6,840.00	6,846.77
680009 RAW Boneless Beef Sirloin Steak	24	743.16	743.16
680915 RAW KRM 9oz Beef Sirloin Tri Tip Steak Savory	107	2,937.21	2,937.21
681715 RAW KRM 7oz Beef Sirloin Tri Tip Steak Savory	179	5,800.45	5,800.45
703116 CB FC Herb Seas Ckn Brst	329	9,870.00	9,903.70
704109 FC Herb Seasoned Chicken Breast	3,200	64,000.00	64,284.24
72308 FC Carne Asada Beef Cubes	484	9,680.00	9,839.66
76508 FC Beef Prime Rib Strips	557	11,140.00	11,218.30
78527 RAW MOE'S All Natural Diced Beef Steak	501	15,030.00	15,077.62
SC68708 RAW Bnlss B Sirloin Steak-Savory, 7oz Gluten Free	225	1,575.00	1,608.84
Total	**6,006**	**131,095.82**	**131,740.39**

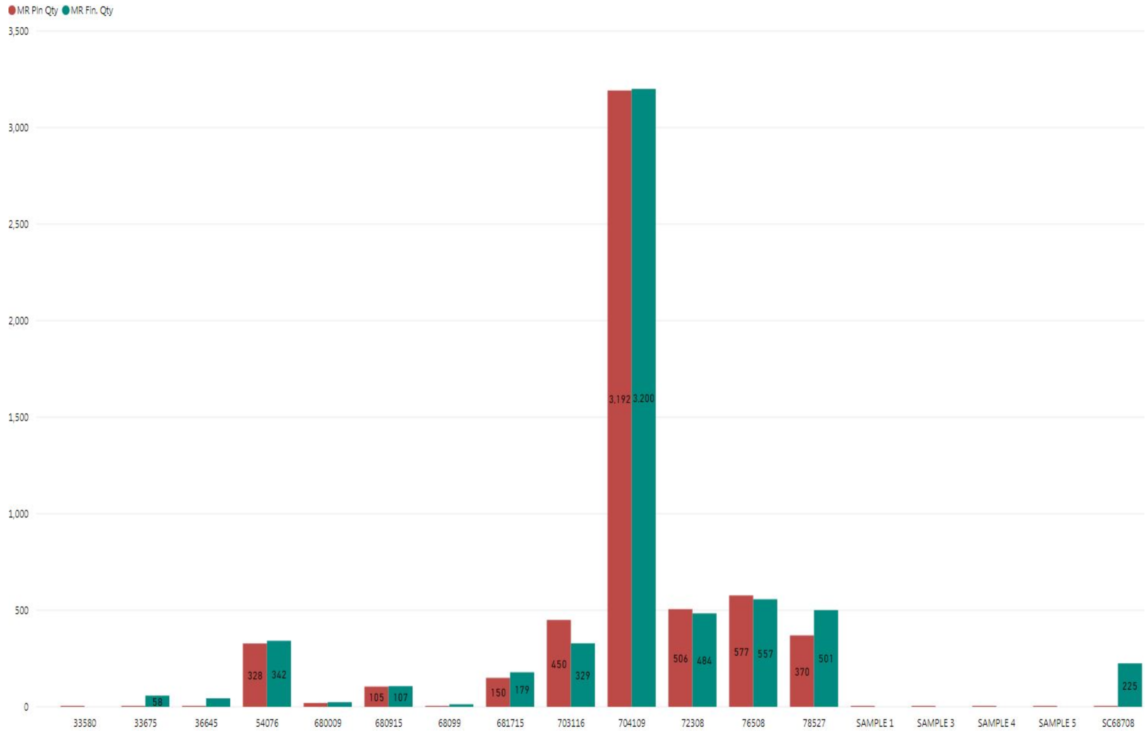


Figure 8.3 - Daily Production Report 03.29.19

Production Order Lines

Item No_	Description	MR Pln Qty	Qty NWght	MR Rem. Qty	MR Fin. Qty
33675	NSP Beef Trimmings - Lean Trim	1	60	0	75
58099	USDA Select or Higher Boneless Beef	1	60	1	0
581625	RAW GFGB Sel Beef Top Sirloin Steak 6oz	642	15,408	44	598
581825	RAW GFGB Sel Beef Top Sirloin Steak 8oz	722	23,104	0	722
70041	FC Seasoned Ckn Breast Cubes - Yakitori	2,384	71,520	3	2,381
707608	FC Chicken Breast Meat With Rib Meat	600	18,000	0	697
Total		**4,350**	**128,152**	**48**	**4,473**

MR Item Ledger Entries

Item Descript	LE Qty	LE Net Wght	LE Act. Wght
33675 NSP Beef Trimmings - Lean Trim	75	4,500.00	4,499.74
581625 RAW GFGB Sel Beef Top Sirloin Steak 6oz	598	15,374.99	15,374.99
581825 RAW GFGB Sel Beef Top Sirloin Steak 8oz	722	24,340.63	24,340.63
70041 FC Seasoned Ckn Breast Cubes - Yakitori	2,381	71,430.00	71,534.94
707608 FC Chicken Breast Meat With Rib Meat	697	20,910.00	20,967.98
Total	**4,473**	**136,555.62**	**136,718.28**

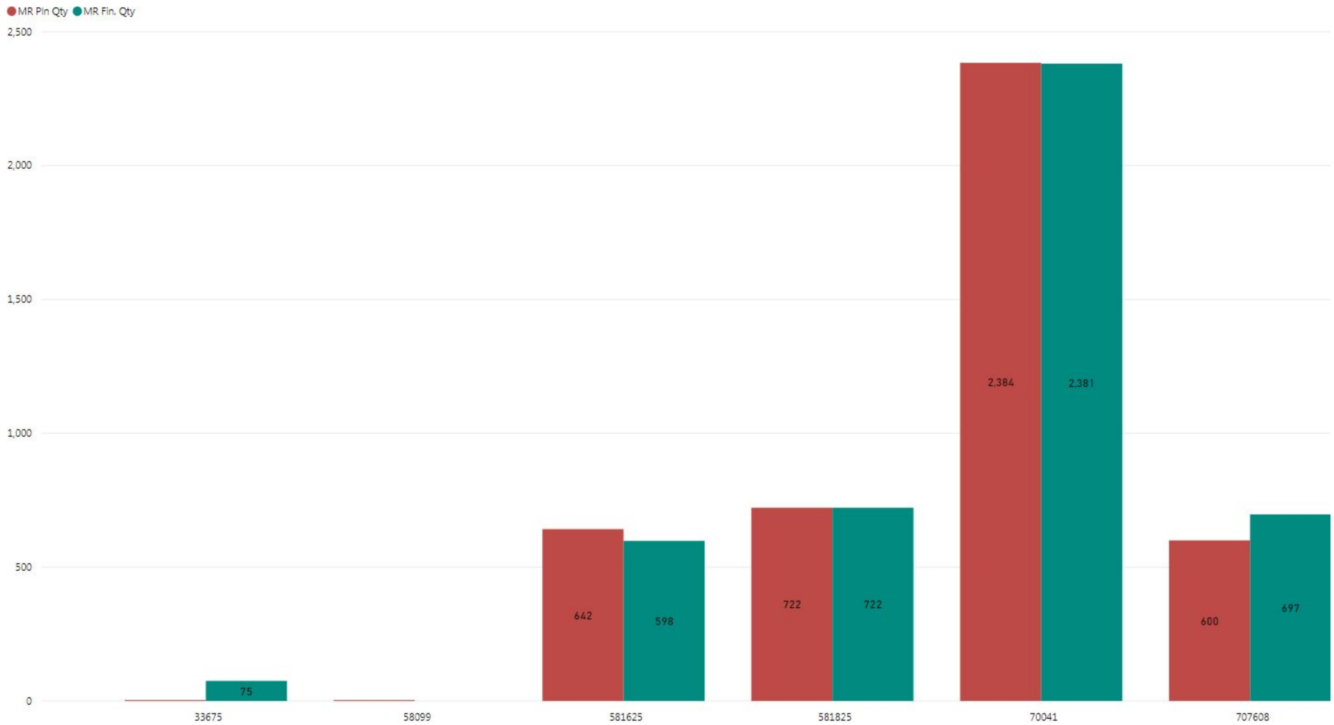


Figure 8.4 - Daily Production Report 03.30.19

Production Order Lines

Item No_	Description	MR Pln Qty	Qty NWght	MR Rem. Qty	MR Fin. Qty
13012	RAW Beef Outside Skirt Cubes	1	10	1	0
131212	RAW Churrasco Beef Outside Skirt Steak 12oz	30	270	30	0
13812	RAW Churrasco Beef Outside Skirt Steak 8oz	720	7,200	720	0
33675	NSP Beef Trimmings - Lean Trim	1	60	1	0
683104	RAW Fillet of Beef Steak Strips	300	9,000	300	0
70042	FC Grilled Chicken Breast Strips with Rib Meat	2,500	25,000	2,500	0
70165	MCA FC Herb Seasoned Chicken Breast	1,322	39,660	1,322	0
70641	FC Thinly Sliced Seasoned Chicken Breast	751	22,530	751	0
78176	RAW Boneless Beef Strips	600	12,000	600	0
Total		**6,225**	**115,730**	**6,225**	**0**

Production Order Lines

Item No_	Description	MR Pln Qty	Qty NWght	MR Rem. Qty	MR Fin. Qty
70042	FC Grilled Chicken Breast Strips with Rib Meat	2,500	25,000	2,500	0
70165	MCA FC Herb Seasoned Chicken Breast	1,322	39,660	1,322	0
70641	FC Thinly Sliced Seasoned Chicken Breast	751	22,530	751	0
Total		**4,573**	**87,190**	**4,573**	**0**

Production Order Lines

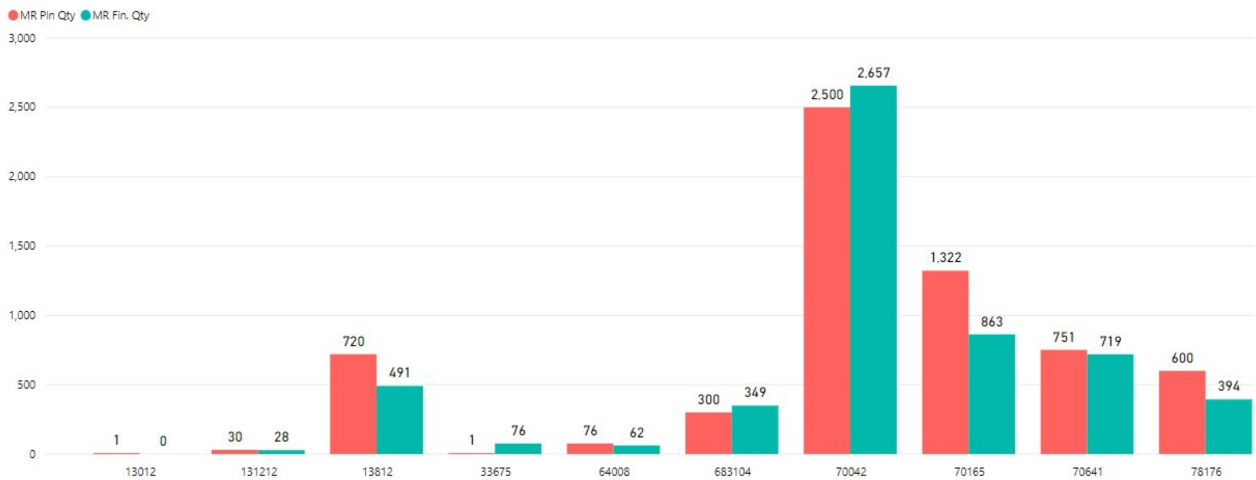
Item No_	Description	MR Pln Qty	Qty NWght	MR Rem. Qty	MR Fin. Qty
13012	RAW Beef Outside Skirt Cubes	1	10	1	0
131212	RAW Churrasco Beef Outside Skirt Steak 12oz	30	270	30	0
13812	RAW Churrasco Beef Outside Skirt Steak 8oz	720	7,200	720	0
33675	NSP Beef Trimmings - Lean Trim	1	60	1	0
683104	RAW Fillet of Beef Steak Strips	300	9,000	300	0
78176	RAW Boneless Beef Strips	600	12,000	600	0
Total		**1,652**	**28,540**	**1,652**	**0**

Production Order Lines

Item No_	Description	MR Pln Qty	Qty NWght	MR Rem. Qty	MR Fin. Qty
13012	RAW Beef Outside Skirt Cubes	1	10	1	0
131212	RAW Churrasco Beef Outside Skirt Steak 12oz	30	270	2	28
13812	RAW Churrasco Beef Outside Skirt Steak 8oz	720	7,200	229	491
33675	NSP Beef Trimmings - Lean Trim	1	60	0	76
64008	All Natural FC Diced White and Dark Meat Chicken	76	760	14	62
683104	RAW Fillet of Beef Steak Strips	300	9,000	0	349
70042	FC Grilled Chicken Breast Strips with Rib Meat	2,500	25,000	0	2,657
70165	MCA FC Herb Seasoned Chicken Breast	1,322	39,660	459	863
70641	FC Thinly Sliced Seasoned Chicken Breast	751	22,530	32	719
78176	RAW Boneless Beef Strips	600	12,000	206	394
Total		**6,301**	**116,490**	**943**	**5,639**

MR Item Ledger Entries

Item Descript	LE Qty	LE Net Wght	LE Act. Wght
131212 RAW Churrasco Beef Outside Skirt Steak 12oz	28	252.00	252.48
13812 RAW Churrasco Beef Outside Skirt Steak 8oz	491	4,910.00	5,097.47
33675 NSP Beef Trimmings - Lean Trim	76	4,560.00	4,545.92
64008 All Natural FC Diced White and Dark Meat Chicken	62	620.00	625.30
683104 RAW Fillet of Beef Steak Strips	349	10,470.00	10,805.43
70042 FC Grilled Chicken Breast Strips With Rib Meat	2,657	26,570.00	26,724.42
70165 MCA FC Herb Seasoned Chicken Breast	863	25,890.00	25,955.72
70641 FC Thinly Sliced Seasoned Chicken Breast	719	21,570.00	21,581.34
78176 RAW Boneless Beef Strips	394	7,880.00	7,899.68
Total	**5,639**	**102,722.00**	**103,487.76**



MR Item Ledger Entries

Item Descript	LE Qty	LE Net Wght	LE Act. Wght
64008 All Natural FC Diced White and Dark Meat Chicken	62	620.00	625.30
70042 FC Grilled Chicken Breast Strips With Rib Meat	2,657	26,570.00	26,724.42
70165 MCA FC Herb Seasoned Chicken Breast	863	25,890.00	25,955.72
70641 FC Thinly Sliced Seasoned Chicken Breast	719	21,570.00	21,581.34
Total	**4,301**	**74,650.00**	**74,886.78**

MR Item Ledger Entries

Item Descript	LE Qty	LE Net Wght	LE Act. Wght
131212 RAW Churrasco Beef Outside Skirt Steak 12oz	28	252.00	252.48
13812 RAW Churrasco Beef Outside Skirt Steak 8oz	491	4,910.00	5,097.47
33675 NSP Beef Trimmings - Lean Trim	76	4,560.00	4,545.92
683104 RAW Fillet of Beef Steak Strips	349	10,470.00	10,805.43
78176 RAW Boneless Beef Strips	394	7,880.00	7,899.68
Total	**1,338**	**28,072.00**	**28,600.98**

Figure 8.5 - Daily Production Report 04.01.19

Production Order Lines

Item No_	Description	MR Pln Qty	Qty NWght	MR Rem. Qty	MR Fin. Qty
13012	RAW Beef Outside Skirt Cubes	1	10	1	0
33675	NSP Beef Trimmings - Lean Trim	1	60	1	0
58099	USDA Select or Higher Boneless Beef	1	60	1	0
581625	RAW GFGB Sel Beef Top Sirloin Steak 6oz	642	15,408	642	0
581825	RAW GFGB Sel Beef Top Sirloin Steak 8oz	722	23,104	722	0
700004	FC Chicken Breast Strips - Savory	4,247	42,470	4,247	0
701708	FC Roasted Chicken Breast	400	8,000	400	0
70641	FC Thinly Sliced Seasoned Chicken Breast	751	22,530	751	0
Total		**6,765**	**111,642**	**6,765**	**0**

Production Order Lines

Item No_	Description	MR Pln Qty	Qty NWght	MR Rem. Qty	MR Fin. Qty
700004	FC Chicken Breast Strips - Savory	4,247	42,470	4,247	0
701708	FC Roasted Chicken Breast	400	8,000	400	0
70641	FC Thinly Sliced Seasoned Chicken Breast	751	22,530	751	0
Total		**5,398**	**73,000**	**5,398**	**0**

Production Order Lines

Item No_	Description	MR Pln Qty	Qty NWght	MR Rem. Qty	MR Fin. Qty
13012	RAW Beef Outside Skirt Cubes	1	10	1	0
33675	NSP Beef Trimmings - Lean Trim	1	60	1	0
58099	USDA Select or Higher Boneless Beef	1	60	1	0
581625	RAW GFGB Sel Beef Top Sirloin Steak 6oz	642	15,408	642	0
581825	RAW GFGB Sel Beef Top Sirloin Steak 8oz	722	23,104	722	0
Total		**1,367**	**38,642**	**1,367**	**0**

Figure 8.6 - Daily Production Report 04.02.19