



# WPI

## Lean Process Improvement of Roll Housing Manufacturing

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## Abstract

Siemens VAI Metal Technologies is looking to reduce costs and increase throughput of the Roll Housing manufacturing process. After analyzing the current state of the production system, our team identified two areas to help achieve this objective. Existing inventory management policies were evaluated and strategies were proposed to reduce holding costs and delivery lead times. Secondly, a value stream map was created to pinpoint further areas of improvement.

## Acknowledgements

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## Authorship

Kelsey Brofford, John DeVries, Luis Rovayo, and Sebastian Vergara all collaborated together for the writing of this report. It is important to note that, due to the nature of this project, the project group was divided into two smaller project groups; each with their own focus. Kelsey Brofford and Luis Rovayo specialized in inventory management, while John DeVries and Sebastian Vergara focused on creating a value stream map. As a result, each group member contributed to the following sections listed below. In addition to these individual contributions, Sebastian Vergara and Luis Rovayo served as the main editors of content written in the report. Kelsey Brofford standardized the formatting throughout the paper. Kelsey Brofford and John DeVries were in charge of managing appendices and figures for each of their respective projects.

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# Table of Contents

Abstract .....	ii
Acknowledgements .....	iii
Authorship .....	iv
Table of Figures .....	vii
1 Introduction .....	1
1.1 Problem Statement .....	2
1.2 Project Goals and Objectives .....	2
1.3 Project Deliverables .....	3
1.4 Project Scope .....	3
2 Background .....	4
2.1 Siemens/VAI Metal Technologies .....	4
2.2 Morgan Construction Company .....	4
2.3 Roll Housing .....	5
3 Housing .....	6
3.1 Introduction to Housing .....	6
3.2 Problem Statement .....	6
3.3 Rationale .....	7
3.4 Methodology .....	7
3.4.1 Gain In-Depth Understanding of Housing Process .....	8
3.4.2 Identify Parts in Scope by Analyzing Current Demand of the Roll Housing .....	8
3.4.3 Build a Value Stream Map of the Housing process to analyze current state .....	11
3.4.4 Analyze Results from Value Stream Map and Provide Recommendations .....	15
3.5 Results .....	16
3.6 Housing Conclusion .....	16
4 Inventory Management .....	16
4.1 Introduction to Inventory Management .....	16
4.2 Problem Statement .....	17

4.3	Rationale .....	18
4.4	Methodology.....	18
4.4.1	Excess Inventory .....	20
4.4.2	Safety Stock .....	21
4.4.3	Minimizing Inventory Redundancy.....	22
4.5	Results.....	25
4.5.1	Deliverables: Spreadsheets .....	25
4.5.2	Deliverables: Suggestions.....	27
4.6	Inventory Management Conclusion.....	27
4.6.1	Limitations.....	28
4.6.2	Recommendations.....	28
5	Project Reflection.....	30
6	References .....	31
7	Appendix.....	32
7.1	Appendix A: Pareto Chart.....	32
7.2	Appendix B: Routings .....	33
7.3	Appendix C: Process Maps .....	36
7.4	Appendix D: Value Stream Maps.....	37
7.4.1	Housing Box VSM .....	37
7.4.2	Front Plate VSM.....	38
7.4.3	Machining Assembly VSM .....	39
7.5	Appendix E: Metric Averages .....	40
7.6	Appendix F: Inventory Overlap Cost Chart.....	41
7.7	Appendix F: Safety Stock Overlap Cost .....	42

Table of Figures

Figure 1: Vee No-Twist mill ..... 1

Figure 2: Roll Housing Lead Time Diagram ..... 2

Figure 3: Roll Housing ..... 5

Figure 4: Housing ..... 6

Figure 5: Housing Methodology..... 8

Figure 6: Parts In-Scope Diagram..... 11

Figure 7: Pareto Chart by Part Description ..... 19

Figure 8: Master Excel File ..... 20

Figure 9: High Days in Bin, Zero Usage ..... 21

Figure 10: Safety Stock Overlap Excel..... 22

Figure 11: Inventory Overlap Excel ..... 22

Figure 12: Current Plant Visualization ..... 23

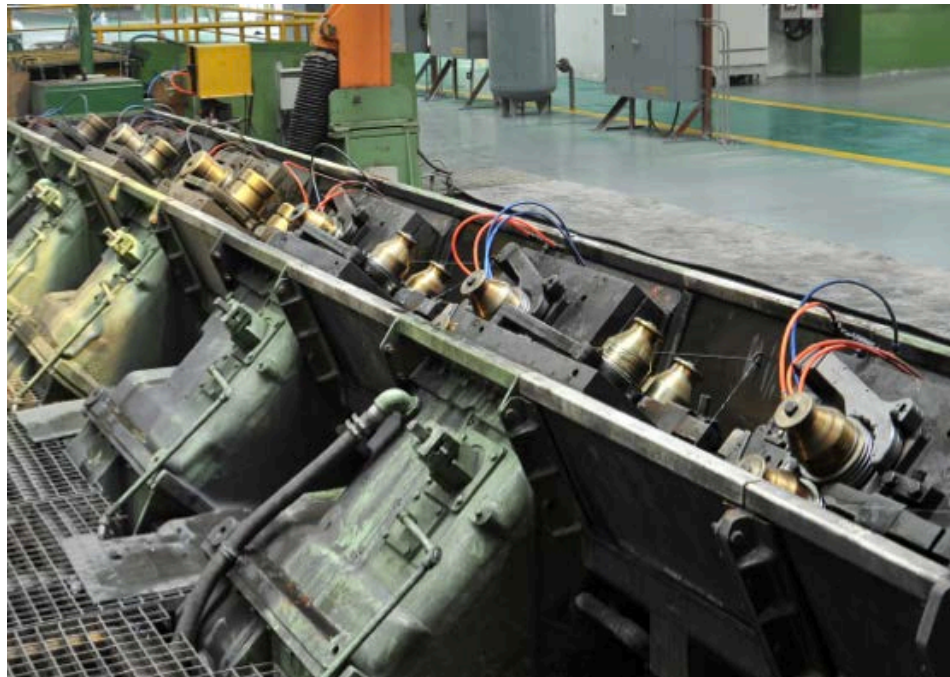
Figure 13: Proposed Master Plant Visualization ..... 23

Figure 14: Inventory Overlap ..... 26

Figure 15: Safety Stock Overlap ..... 26

# 1 Introduction

The metallurgical industry has become a very competitive marketplace over the years. Companies are constantly striving to improve the efficiency of production, increase output, and reduce scrap waste. The United States produced 13.52 million metric tons in 2014, giving it a ranking of 4<sup>th</sup> for global steel production (behind China, Japan, and India respectively) (World Steel Association, 2015). Nonetheless, this serves to show that the steel industry is a promising market to be involved in. Siemens VAI Metal Technologies (SMT), is a division of Siemens AG that focuses on iron and steel making, casting, and rolling. One of Siemens VAI's signature products in the hot rolling sector is the Morgan Vee No-Twist Mill. This mill is able to process steel at a rate of up to 120 meters per second which translates to output greater than 150 tons per hour (Siemens VAI, 2015). According to the Siemens VAI website, the advantages of the Vee No-Twist mill are its increased productivity, flexibility, quality, and versatility. A crucial component of the Vee No-Twist mill is the Roll Housing, which served as the focus of this project. A photograph of the Morgan Vee No-Twist mill followed by a Roll Housing is shown in Figure 1.



*Figure 1: Vee No-Twist mill*



## 1.1 Problem Statement

In an effort to stay competitive in the ever-expanding metals secondary processing market, Siemens VAI Metal Technologies is constantly seeking ways to improve their production strategies. In order to reduce costs and increase throughput, Siemens enlisted the help of Worcester Polytechnic Institute in the form of a Major Qualifying Project (MQP). The proposed project charter for this MQP stated a 25% reduction in the lead time for the production of the Roll Housing. Primary analysis of their existing manufacturing process indicated that a reduction of about 150 hours in lead time would meet this goal. The team explored and identified methods to improve the production of the Roll Housing and reduce the lead time. Figure 2 depicts the structure of a sample Roll Housing Assembly along with the corresponding machining and procurement lead time information for various subassemblies.

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## 1.2 Project Goals and Objectives

The original purpose of this project was to reduce the overall lead time of the Roll Housing Assembly by 25%. After researching and learning more about the Roll Housing Assembly, the scope of the project shifted. As a result, it was divided into two smaller projects, each with a specialized focus.

The first project, focused in identifying lower-level process improvement activities in order to drive out waste in the production processes. After conducting walkthroughs and studying the process, it was discovered that the Housing component of the Roll Housing Assembly did not have a value stream map of its own. The team determined that a value stream map would have to be created for the Housing component in order to identify kaizen bursts for future improvements. The second project focused on evaluating the inventory management policies for the Roll Housing and identifying ways of reducing assembly lead-time. The sponsors identified inconsistencies in their inventory management practices and, as a result, the team determined that it would be beneficial to further investigate this area.

### 1.3 Project Deliverables

After conducting a thorough analysis of the Roll Housing process it was concluded that the following items would be delivered:

1. Value Stream Map for the Housing subcomponent of the Roll Housing
2. Suggestions to improve the inventory management policies of the Roll Housing.

### 1.4 Project Scope

The scope of the project was determined through the use of various analytical tools. As a starting basis, the team analyzed a dataset of all Roll Housing orders from the years 2010 to 2014.

The team decided to create a Pareto Chart in order to pinpoint the Roll Housing types with the highest demand. This allowed the team to define the project scope. Through the application of the 80-20 Rule (also known as the Law of the Vital Few) and the assistance of the Siemens production team, 19 Roll Housing assemblies were identified for the overall project scope.

The Value Stream Map team used these 19 assemblies to determine the workstations involved in the machining of the Housing. Due to a lack of SAP data, it was not possible to calculate for Setup, Run, and Queue times. Therefore, the team modified the scope to 9 Roll Housing types that had significant SAP data.

The inventory management team utilized the results from the Pareto chart to form the initial scope. It was decided that the 19 Roll Housing assemblies with the highest demand would be appropriate set to properly represent all Roll Housing product lines. From these 19 assemblies, the team was able to formulate a list of 565 unique part numbers that were deemed critical to the majority of Roll Housing value streams. These part numbers were obtained from the bills of material provided by the Siemens

production team. Additionally, the inventory management team obtained important part attribute information from Siemens' enterprise resource planning system.

## 2 Background

The following sections provide a brief description of the project sponsor Siemens/VAI Metal Technologies, company history, industry, and major product lines. For simplicity reasons, from this point forward the sponsor will be referred to as "Siemens" and not the full company name "Siemens/VAI Metal Technologies".

### 2.1 Siemens/VAI Metal Technologies

Siemens AG is a German international conglomerate that offers a wide variety of products and services for almost every industry. Ever since its founding in Berlin in 1847 by Werner von Siemens, Siemens has grown to be a global technological powerhouse. Siemens has roughly 343,000 employees worldwide, spanning across almost every country in the world. In the fiscal year of 2014, Siemens generated £78.5 billion pounds in revenue with a net income of £5.5 billion pounds (Siemens AG, 2014). At the corporate level, Siemens is comprised of the following business units: Power and Gas, Wind Power and Renewables, Power Generation Services, Energy Management, Building Technologies, Mobility, Digital Factory, Process Industries and Drives, Healthcare, and Financial Services.

Siemens/VAI Metal Technologies (SMT) is a vertically integrated business unit that and a global leader in the metallurgical industry. Siemens Metal Technologies offers both customized and industry-standard solutions that improve the efficiency of metallurgical production facilities all around the world. Some of these services include: plant construction, modernization of existing plants, and installation of integrated state-of-the-art production systems. The Siemens/VAI partnership was started in 1995 and is currently headquartered in Linz, Austria. Siemens/VAI's customer base, roughly around 500 customers, accounts for 70 percent of global steel production (Siemens VAI, 2015).

### 2.2 Morgan Construction Company

The location for this project took place at the Siemens/VAI Metal Technologies facility located in Worcester, Massachusetts. Formerly known as Morgan Construction Company, this facility specializes in the production of high-quality rolling mills which includes rod, section, and wire rolling mills. This project focused specifically on the long rolling mills, a crucial component of the famous Morgan Vee No-Twist Mill. Morgan Construction Company was founded by Charles Hill Morgan (a WPI founder) in 1891 and

for more than a century was a worldwide leader in the production of high-quality, high-performing rolling mills. In 2008, Siemens/VAI acquired Morgan Construction Company, increasing its market share in the metal technologies industry (Siemens VAI, 2008).

### 2.3 Roll Housing

The Roll Housing, a critical element in the Vee No-Twist Mill, primarily serves the function of sizing the material (usually an alloy or steel) through the mill. Carbide rolls are mounted to the pinion shafts to roll the material to the specified size. Depending on the size and type of material the customer is producing, different size Roll Housings are available (i.e. 150mm, 230mm, 250mm, and 300mm). The purpose of using the Roll Housing is to stretch the material through tension and rolling with pressure in order to form a round (Continuous Improvement Lead, March 23, 2015).

The Roll Housing is made up of numerous subcomponents. Each of these subcomponents are individually manufactured and then put together during assembly to make the Roll Housing. The majority of subcomponents are manufactured in-house, however there are some subcomponents which are subcontracted. Additionally, because each subcomponent is utilized during assembly, they all collectively contribute to the overall lead time of the Roll Housing. A Roll Housing Assembly is shown below in Figure 3.

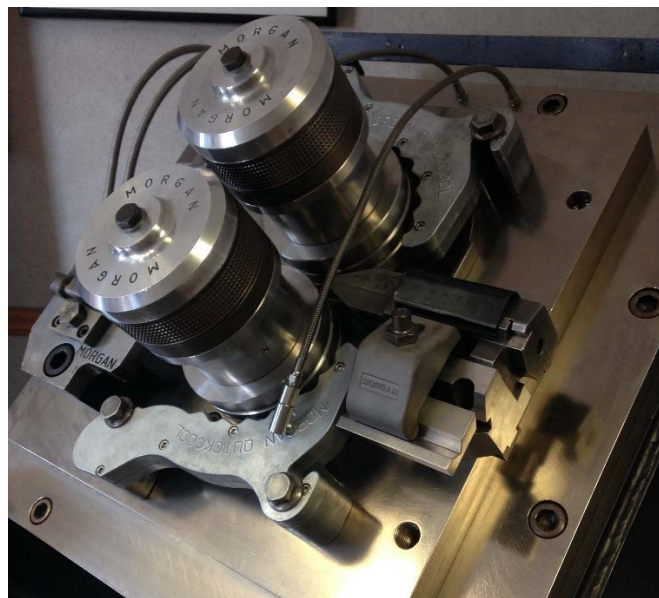


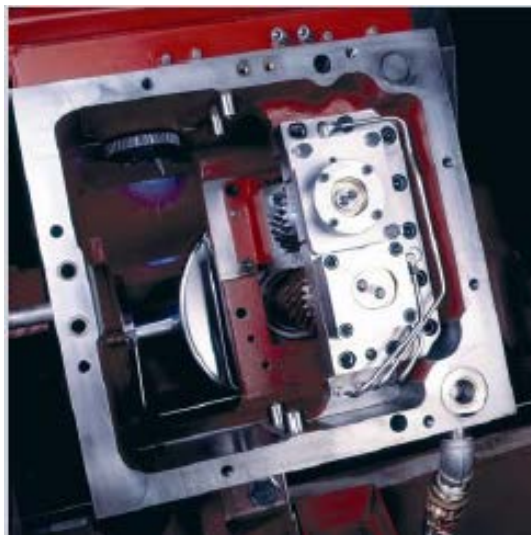
Figure 3: Roll Housing

### 3 Housing

The following sections provide information on the creation of the value stream map for the Housing subcomponent of the Roll Housing.

#### 3.1 Introduction to Housing

The Housing, one of the numerous components of the Roll Housing, refers to the shell that hosts and protects the dynamic parts of a Morgan Vee No-Twist Mill. This Housing is also referred to as an UHD (Ultra Heavy-Duty) Housing. A photo depicting the Housing subcomponent is shown below in Figure 4. Housings are essential sub-elements of the Roll Housing Assembly, which are available in various sizes (ranging from 160 mm to 250 mm) and configurations (parallel arrangements of 4, 6, 8, or 10 UHD Housings). The Roll Housing Assembly's main function is to roll the material (usually an alloy or steel material) to a pre-specified size. This function is performed by passing the material through carbide roll which are connected to pinion shafts, and all of which are physically supported by the UHD Housing. The Housing itself consists of two parts, a box and a front plate. Both the box and the face plate are machined separately and brought together in assembly to create the Housing subcomponent.



*Figure 4: Housing*

#### 3.2 Problem Statement

Siemens/VAI Metal Technologies produces the Morgan Vee No-Twist Mill, which serves the purpose of forcefully rolling steel and alloy materials into specified sizes in an automated fashion. The Roll

Housings, which are essential components of the mill, are produced in various sizes and configurations that align with the specific needs of each customer. As part of Siemens' ongoing effort to improve its manufacturing capabilities, the value stream project team was brought in to analyze the manufacturing process of the UHD (Ultra Heavy-Duty) Housing. This analysis would help reduce the overall production lead time of the Roll Housing. When conducting the primary research of the Housing production process, the team recognized a lack of formal documentation.

### 3.3 Rationale

After analyzing the overall value stream of the Roll Housing Assembly, the team and Siemens determined that there were two viable methods for achieving the 25% lead time reduction goal. The first method, explored in this section, comprised of conducting lower-level process improvement activities in order to drive out waste in production processes. By analyzing individual lead times of all major Roll Housing components, it was concluded that the Housing component played a significant role in the overall lead time of the Roll Housing. As a result, it was determined that a value stream map should be created for the Housing component of the Roll Housing. Developing a value stream map would allow the team to document and analyze the high level process of the Housing component. Furthermore, it would allow the team to identify areas of improvement and further explore lead time reduction initiatives. While time restrictions would not allow the team to implement physical changes to the process, the value stream map would serve as a useful tool in helping reduce the lead time of the manufacturing process of the UHD Housing.

### 3.4 Methodology

Figure 5 illustrates a summary of the methodology used to design the value stream map of the Housing and ultimately reduce the lead time of the Roll Housing. Each will be discussed in detail below.

Reduce Lead Time in the Housing Process of the Roll Housing	Understand the Housing Process	Walkthroughs, Machine Identification
	Identify Parts in Scope	Demand Analysis, Pareto Chart, Process Maps
	Build Value Stream Map	VSM, Metric Calculation (Run, Setup, Queue)
	Analyze VSM and Provide Recommendations	Kaizen Bursts

Figure 5: Housing Methodology

### 3.4.1 Gain In-Depth Understanding of Housing Process

Gaining an in-depth understanding of the Housing process was essential to identifying areas of improvement for the reduction of the Roll Housing lead time. To learn more about the Housing process, several "gemba walks" (walkthroughs) were conducted. These walkthroughs consisted of the following:

- Informally interviewing production supervisors, machine operators, and key stakeholders
- Identifying internal workstations and machines involved in the manufacturing of the Housing
- Using existing routings as reference to assure consistency of the process

Additionally, a process map was created to encompass the steps involved in making a Housing. This task was of significant importance as it outlined the general manufacturing process of a Housing. The Housing in highest demand, LRM: 10316653, was used to create the process.

### 3.4.2 Identify Parts in Scope by Analyzing Current Demand of the Roll Housing

To further understand the implication of demand and identify Roll Housing products of interest, a Pareto chart was created (Appendix A). The process of creating a Pareto chart was initiated by requesting the demand history for all Roll Housing assemblies over the past four years. Once the data was obtained, it was manipulated to identify the Roll Housing part numbers responsible for 20 percent of total order volume.

The first step in creating the Pareto Chart was to sort the data into subgroups by their LRM (part number) description. This was completed by utilizing a filter command. Once the data was grouped by description, a table was created with four columns titled: Description, Total Count, Cumulative Count,

and Cumulative Percent. The Description column consisted of each of the unique Roll Housing descriptions found when sorted into subgroups. It was found that there were 28 unique types of Roll Housings represented in the data. To create the Total Count column, a "SUM" function was utilized for each different description. This totaled the number of each Roll Housing type ordered in the represented time period. Having the individual demand for each unique Roll Housing, a Cumulative Count column was created. Once again, a "SUM" function was utilized to sum the demand for all descriptions up to the respective row in the table. The formula:  $\sum_{n-sub-1}^n 'Total\ Count'$  was placed in each cell to find the Cumulative Count relative to each Description in the table. Additionally, the last cell of the Cumulative Count column was compared to the calculated sum of the Total Count column in order to assure that the values were equal. Thereafter, a column was created and titled Cumulative Percent. To create the Cumulative Percent column, the formula:  $\sum_{n-sub-1}^n ((Total\ Count' - sub - n) / \sum 'Total\ Count')$  was placed in the corresponding cell of each Roll Housing Description. The final step of the data manipulation phase was to sort the Total Count column in descending order.

To further analyze the implications of this newly manipulated data, a combination bar-line graph was created. The first step in the creation of this graphic was to plot the Total Count Column data along the primary-vertical axis. The range was 0-220 orders, had intervals of twenty, and was represented by bars in the plot area. The next step was to plot the Cumulative Percent column data along the secondary-vertical axis. The range of this data was 0%-100%, had intervals of ten-percent, and was represented by a line-with-markers in the plot area. The final step in the creation of this graph was to plot the 28 Roll Housing descriptions along the horizontal axis.

After creating the graph, the next step consisted of analyzing both the table and chart in order to determine the scope for the remainder of the project. The most effective way to determine the scope was to apply the Pareto principle, also known as the "80-20 Rule". This statistical law states that about twenty-percent of the population will be responsible for roughly eighty-percent of the problem (Jacobs, Chase, 2013). When applied to the Pareto chart, the team realized that the 230 UHD Roll Housing Assembly was responsible for about eighty percent of Roll Housing demand and accounted for almost thirty-percent of the total orders. Based on this analysis, the team concluded that the 230 UHD Roll Housing Assembly should be the main area of focus.

Table 1 summarizes the list of parts that were originally identified by Siemens to be used for the value stream map based on the Pareto analysis.



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*Table 1: Original Parts*

Due to a lack of substantial data in the SAP system, the original list of parts identified by Siemens changed. The change took place as a result of not having sufficient data to calculate for queue time. Therefore, the scope of parts to be used in the value stream map was restricted to the 150 and 230 Roll Housings.

It was decided that the scope should be extended to the six Roll Housing assemblies with the highest

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Table 2, below, contains the final list of parts that were identified by Siemens to be used for the value stream map. Figure 6 showcases the final scope of parts to be used in the value stream map, by subcomponent: Housing, front plate, machining, and subcontract.

[SECTION VOIDED]

*Table 2: New Identified Parts*

[SECTION VOIDED]

*Figure 6: Parts In-Scope Diagram*

3.4.3 Build a Value Stream Map of the Housing process to analyze current state

*3.4.3.1 Process Map*

The following steps were taken to design a value stream map for the Housing process. To start out, a new process map was created to encompass all of the identified parts in scope. The process map incorporated all the possible routings into a single map that displayed physical manufacturing variations of the Roll Housing. The following process map displays the variations of the Housing along with its subcomponents (front plate, box, and assembly) for the identified parts in scope.

The process map was created by referencing the routings of all of the parts in scope. The routings were obtained from SAP and given to the team by the Siemens production team. The routings for all parts in scope can be found in Appendix B.

After examining the process map in more detail and further discussing a plan to calculate for queue, run, and setup time, the map had to be altered. As previously mentioned, the team experience a lack of substantial queue time data from SAP. As a result, a greater number of parts had to be taken into consideration. The process map had to be redesigned in order to accurately reflect how many items/orders flowed into the different workstations in scope. The team had to use a special format for the map that only depicted each work center only one time. This allowed to identify potential areas of improvement as it conceptually illustrates how busy each individual workstation is. Below are each of the respective process maps with non-repeating workstations that were used to create the value stream map.

#### *3.4.3.2 Data Analysis*

In order to calculate the metrics needed for the value stream maps, the following procedure was used. Using the identified parts, a workbook was created with the data for every order that utilized the workstations within scope. This workbook contained 21 columns of information for each order. It was determined that only 13 specific columns out of the 21 provided were necessary to perform the data manipulation. Thus, the workbook was prepped for further manipulation by first hiding all unnecessary columns. Four user-defined columns were then added to the workbook. These columns were titled: Setup, Run, Queue, and Color. The final step in the preparation of the workbook was to add filters to each column. Having completed these steps, the workbook was ready to calculate averages for Setup Time, Run Time, and Queue Time for each workstation within the project scope.

The next step in manipulating the data was to filter the columns so that they only contained relevant information that could be later selected as data points to be used for calculated averages. The Actual Start and Actual Finish columns were filtered to contain only data from the year 2013. The Yield column was filtered to exclude rows of data containing a value of "0" in that column. The Workstation column was filtered to contain only the rows of data pertaining to the workstation being analyzed at the moment. At this point, the user-defined Setup, Run, and Queue columns were calculated. The formulas in Table 3 were utilized in the calculation of these metrics for each row of data.

[SECTION VOIDED]

*Table 3: Data Analysis Formulas*

Having calculated these three metrics for every row of data, the sample population needed was determined. The statistically significant size of the sample size was calculated by utilizing the following formula:

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statistically significant. Highlighted rows were then selected to be part of the sample population if they met the following requirements: 1) calculated queue time was non-negative, 2) the data point was not the beginning process of an order, and 3) it was not a high outlier (greater than 40,000). Once determined to join the sample population, a color was assigned to the cell and highlighted.

The last step before calculating the metric averages was to execute a final filter. The Color column was filtered by the color representative of a data point that had been chosen to be in the sample population. Next, the metric averages were calculated. An average of the sample data points was calculated for each of the metrics: Setup Time, Run Time, and Queue Time. This finalized data was then placed in its own worksheet, renamed "*Workstation Name (Number of Data Points)*", and had highlights removed. These steps were repeated for each workstation under scope. A worksheet was created that contained the final metric averages for each workstation. The data in this worksheet was used to populate the final value stream map deliverables. It is important to note that the averages for workstation "Q34F" are always represented in red because there were not 101 suitable data points. This meant that those averages were not necessarily statistically significant. All other averages could be considered statistically significant, and further utilized in the analysis of the Roll Housing manufacturing processes.

### 3.4.3.3 Value Stream Map

To build the value stream map for the Housing process, the following steps were taken. Firstly, all process maps were converted to value stream notation. Subsequently, each respective workstation was labeled with its name, number of workers, setup, run, queue time, and represented by a process box. Material and information flow lines were then added to specify the flow of material in the value stream map. This was done by examining the material movement of the Housing process. After this, an information flow diagram was drawn. The information flow outlines the major communications which influence the forecasting, planning, and order fulfillment of the Housing process. More specifically, the diagram outlines the information flow from sales to production control and from store to customer. The info needed to create the information flow was obtained by the head scheduler in charge of the Housing production.

Following, the total run and queue times for each of the parts in scope were calculated. This was done with the purpose of identifying the worst case scenario and representing it in timeline of the value stream map. This procedure was needed in order to capture the LRM with the longest run and queue times and be able to differentiate it from the other parts in scope. After choosing the LRM with the highest queue time, each respective workstation was then populated with its corresponding run and queue in the timeline. If the new chosen LRM did not utilize a workstation from the value stream map, "N/A" was written to denote not-applicable under the worst case scenario. Lastly, the total run and queue times for the worst case scenario were placed into the value stream map.

A comment box was then added to the value stream map to state the Takt time associated with the making of the Housing process. Assumptions in Table 4 were taken into consideration when calculating for Takt time:

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Table 4: Takt Time Assumptions

To compute for Takt time, Equations 2 and 3 were used in sequence:

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Equation 2 calculates the total hours available by multiplying working days per year and hours per daily shift. Equation 3 calculates Takt time by dividing total hours available by the number of pieces needed to make. This procedure was used to create each respective values stream map for the box, front plate, and assembly.

#### 3.4.4 Analyze Results from Value Stream Map and Provide Recommendations

The final step in creating the value stream maps was to add kaizen bursts. Various kaizen bursts were strategically placed in the maps to highlight potential areas of improvement. These kaizen bursts ranged from simply pointing out problem areas to providing specific actions items in order to improve the process and ultimately help reduce the lead time. Some of the simple bursts included: “Long Lead Time”, “High Queue”, and a combination of “High Queue, Low Run”. The purpose of these bursts was to simply draw the attention of the viewer towards potential high-level areas of improvement. These bursts require a kaizen event in order to further analyze the source of these problems and identify prospective methods towards resolving them.

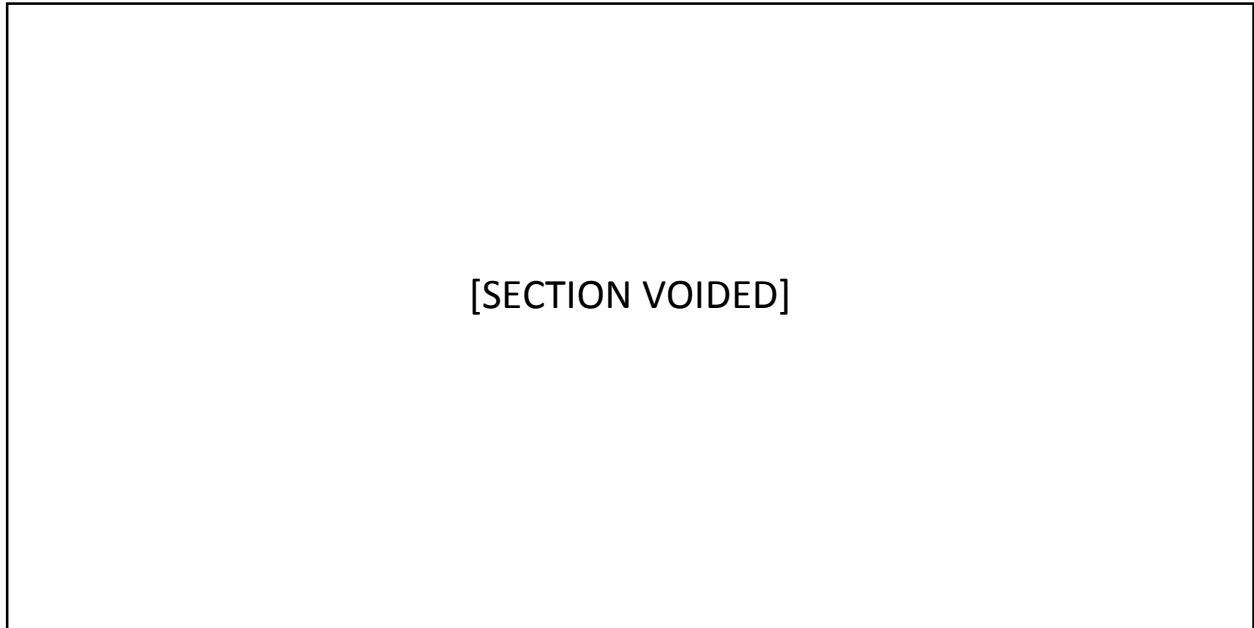
In addition to this, other kaizen bursts contained slightly more detailed explanations for potential improvement opportunities and how to address the problem. For example, one of these kaizen bursts

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### 3.5 Results

The value stream maps created for the Housing component: Front Plate, Box, and Assembly, can be found in Appendix D. Each value stream map contains an information flow diagram, material flow process, worst case scenario timeline, Takt time box, and kaizen bursts.

### 3.6 Housing Conclusion



## 4 Inventory Management

The following sections provide information on the inventory management aspect of this project. From this point onward, all the following material in this section will be in reference to the inventory management project

### 4.1 Introduction to Inventory Management

Inventory is one of the eight identified wastes in the lean philosophy (Liner, 2014). Unused or unnecessary inventory not only takes up physical space but also ties up cash flow in the supply chain. Determining how much inventory to keep, if any at all, is an ongoing activity that has been addressed by many different companies for many years. Inventory management is a crucial aspect of operations management. In order to achieve a truly lean state, there must be minimal levels of inventory. At the same time however, there must also be a balance to prevent against stock outs occurring. Predicting future demand can be difficult, and as a result, forecasts are never one-hundred percent accurate. Due

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goods) as well as the strategic planning of purchasing, production, and replenishment. The two main types of inventory management strategies are materials requirements planning (MRP) and Just-In-Time (JIT) production (Chase, 2013). JIT involves utilizing a purchasing plan that will deliver raw materials just as they are needed to begin production. Material requirements planning is driven by sales forecasts. Orders for raw materials are scheduled based upon the forecasted demand and quantities are driven through the bill of materials (BOM). Both strategies have their benefits as well as their shortcomings, which is why some companies utilize a combination of both methods. (Jacobs, Chase, 2013). The goals for this project were to reduce carrying costs and improve cash flow by helping define inventory management policies.

#### 4.2 Problem Statement

Successful inventory management requires being able to keep track of all products and materials as they are stored, retrieved, and transported. In order for this to happen, the operations of the warehouse

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#### 4.3 Rationale

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#### 4.4 Methodology

The results of the Pareto analysis conducted at the beginning of the project determined the scope of the inventory management portion of the project. The 19 assemblies for this analysis, shown in Figure 7, were chosen based on their high demand frequency and criticalness to the Roll Housing value stream.

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*Figure 7: Pareto Chart by Part Description*

In order to better understand the nature of the parts within the scope, the team decided to create an informative dataset of all the part numbers and relevant attributes. Microsoft Excel was the primary tool used to facilitate our data analysis and organization of our part dataset. The bill of materials (BOM) for the 19 assemblies were extracted from SAP and exported into multiple Excel files. All of the BOM workbooks were consolidated into one master list of parts. By removing duplicate entries, this list was further condensed into a final list of 565 unique part numbers. These 565 parts represent all the part numbers (from raw material to finished assembly) that serve as the analytical basis for the project. In addition to part numbers, the team was also able to obtain information on lead time, cost, yearly demand, and inventory data from SAP for the parts in scope. The group utilized the “VLOOKUP” function in Excel to extract attributes of the individual parts from the workbooks to put all part characteristics into one master table. A snip of this table is shown in Figure 8.

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*Figure 8: Master Excel File*

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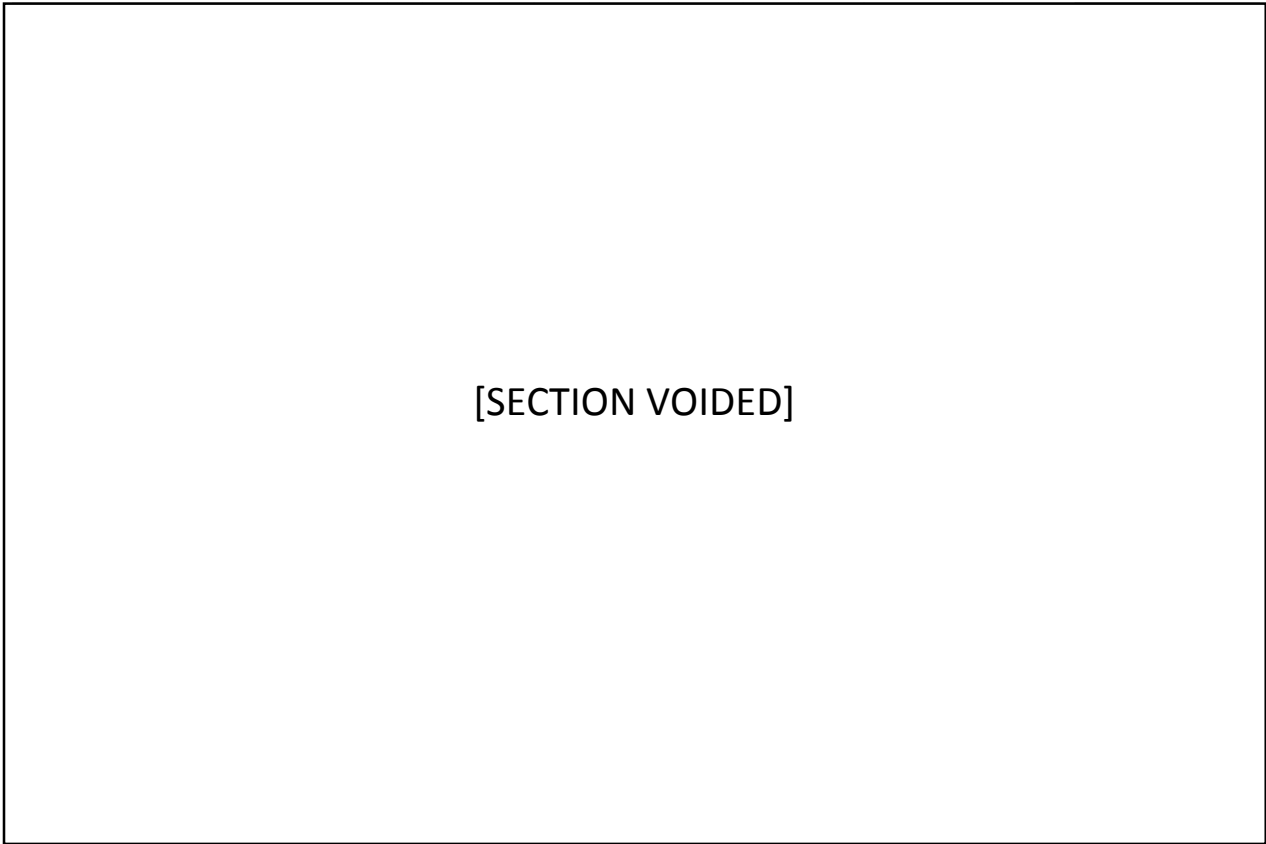
days in bin. The team decided to focus on the inventory management processes, such as safety stock. The original plan was to divide the compiled part list into “bins” based on lead time, usage, cost, criticalness. The team would then assign each bin an inventory management strategy to best fit that grouping’s characteristics.

The attempted implementation of this method led to several generalizations. There were too many characteristics not taken into account by the bins that the inventory management techniques could not be applied to all parts in that grouping. The number of simplifications being made greatly decreased the value of this deliverable and its usability. In order to produce something useable, the scope of the inventory management project needed to be narrowed. Two of the “bins” were chosen as the main focus: parts with no demand in the past year that had inventory in stock and parts with long lead times and high demand. These two part groupings represent both excess inventory to the company and parts that would most likely delay a project and would benefit the most from established safety stock levels. Additionally it was decided that further investigation into the overlap between the two plants held much potential for improvements. The inventory management portion of the project was broken into three subsections: excess, safety stock, and overlap.

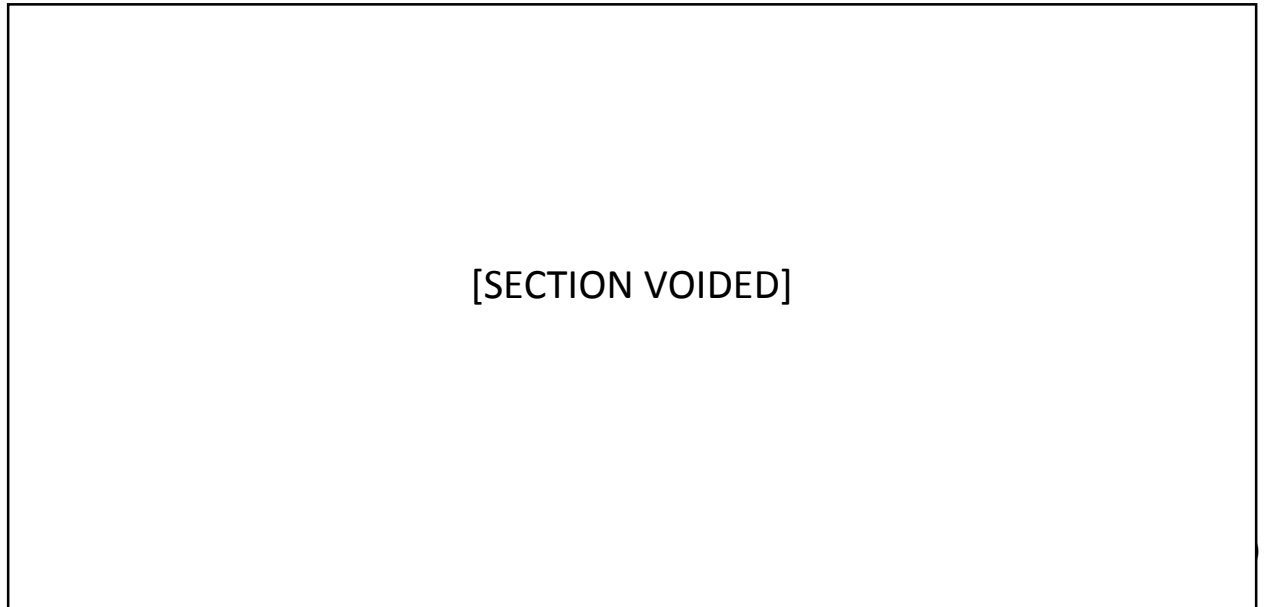
#### 4.4.1 Excess Inventory

The first issue investigated was the excess inventory. The master excel sheet was sorted to show parts with the highest days in bin. The list was cut off to contain parts with days in bin over 188 days – the original quoted lead time, with the cut off list encompassing 10% of all parts in inventory. The new list

was then filtered to show parts with zero demand in the past year. The filtered table is shown in Figure 9.



#### 4.4.2 Safety Stock

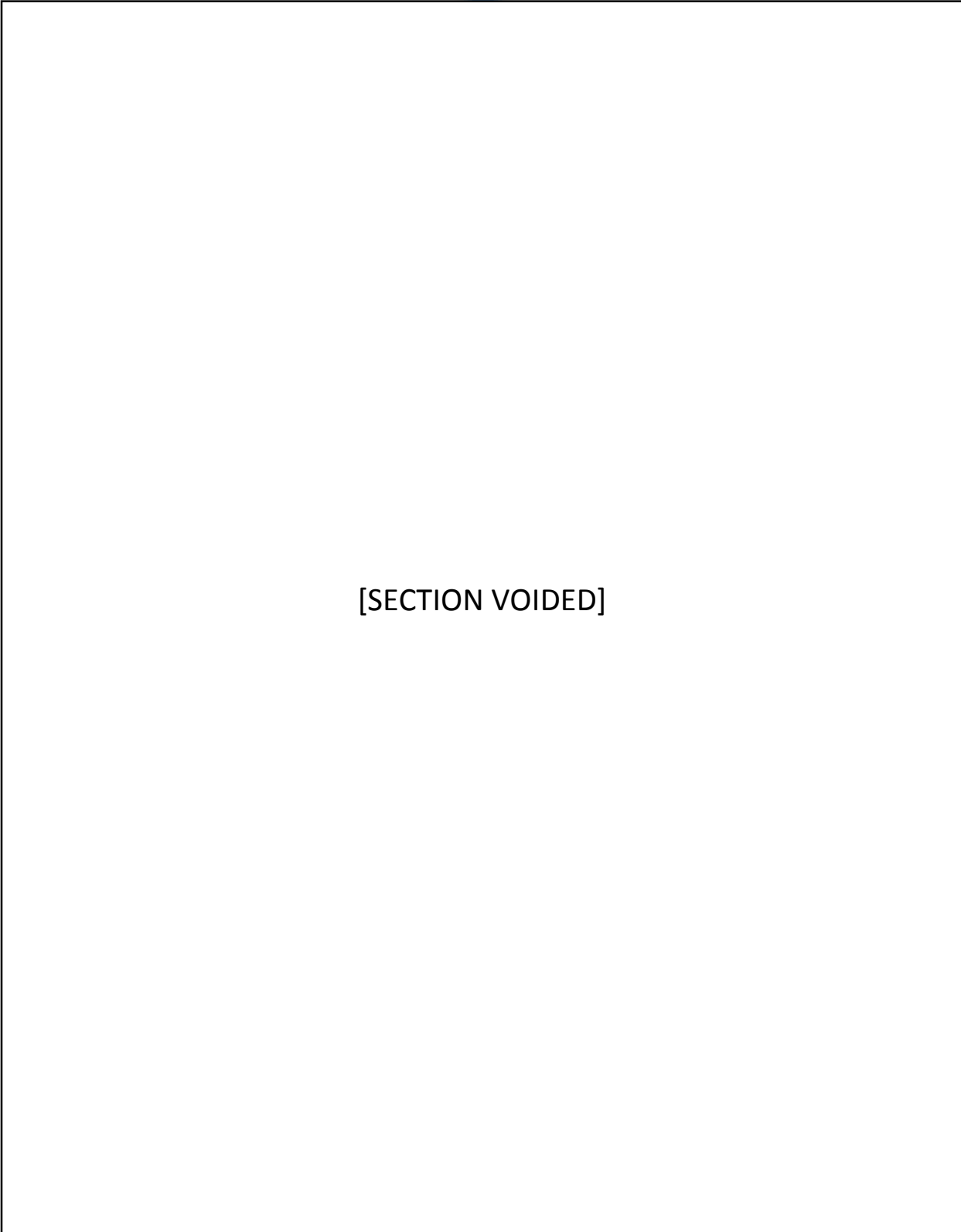


The MSS safety stock levels were carefully monitored in order to keep customers satisfied with short lead times. Despite the specific formula, MSS expressed that they were not satisfied with the current approach to safety stock.

#### 4.4.3 Minimizing Inventory Redundancy

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The biggest separating factor between the two plants was that they operated financially independent of one another. A visualization of the current plant setup is shown below in Figure 12.



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Table 5: Current Safety Stock Costs

Next the team researched safety stock formulas to try to find one that best fit Siemens' variable demand. In the end, the team decided to use the formula currently in practice by MSS to demonstrate the potential savings. By taking the previous demands and lead times for all items overlapped between the two plants new combined safety stock levels were calculated. The combined safety stock levels were calculated at four different service levels. Table 6 shows service levels and their corresponding z-scores (Chase, Jacobs, 2013).

Desired cycle service level	Z-score
84	1
85	1.04
90	1.28
95	1.65
97	1.88
98	2.05
99	2.33
99.9	3.09

Table 6: Service Level Values

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stock increases because the safety stock levels would be much higher than their current numbers. At any lower service level, the company would save money by combining safety stock levels. The team’s calculations of potential savings based on service level are shown in the Table 7.

<p>[SECTION VOIDED]</p>
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*Table 7: Proposed Safety Stock Solution*

#### 4.5 Results

The deliverables for the inventory management portion of the project were atypical project deliverables. Rather than an end objective, spreadsheets were created during our analysis and suggestions were developed throughout the course of the project. These deliverables are especially valuable because they pave the way for further improvement and building blocks for future projects.

##### 4.5.1 Deliverables: Spreadsheets

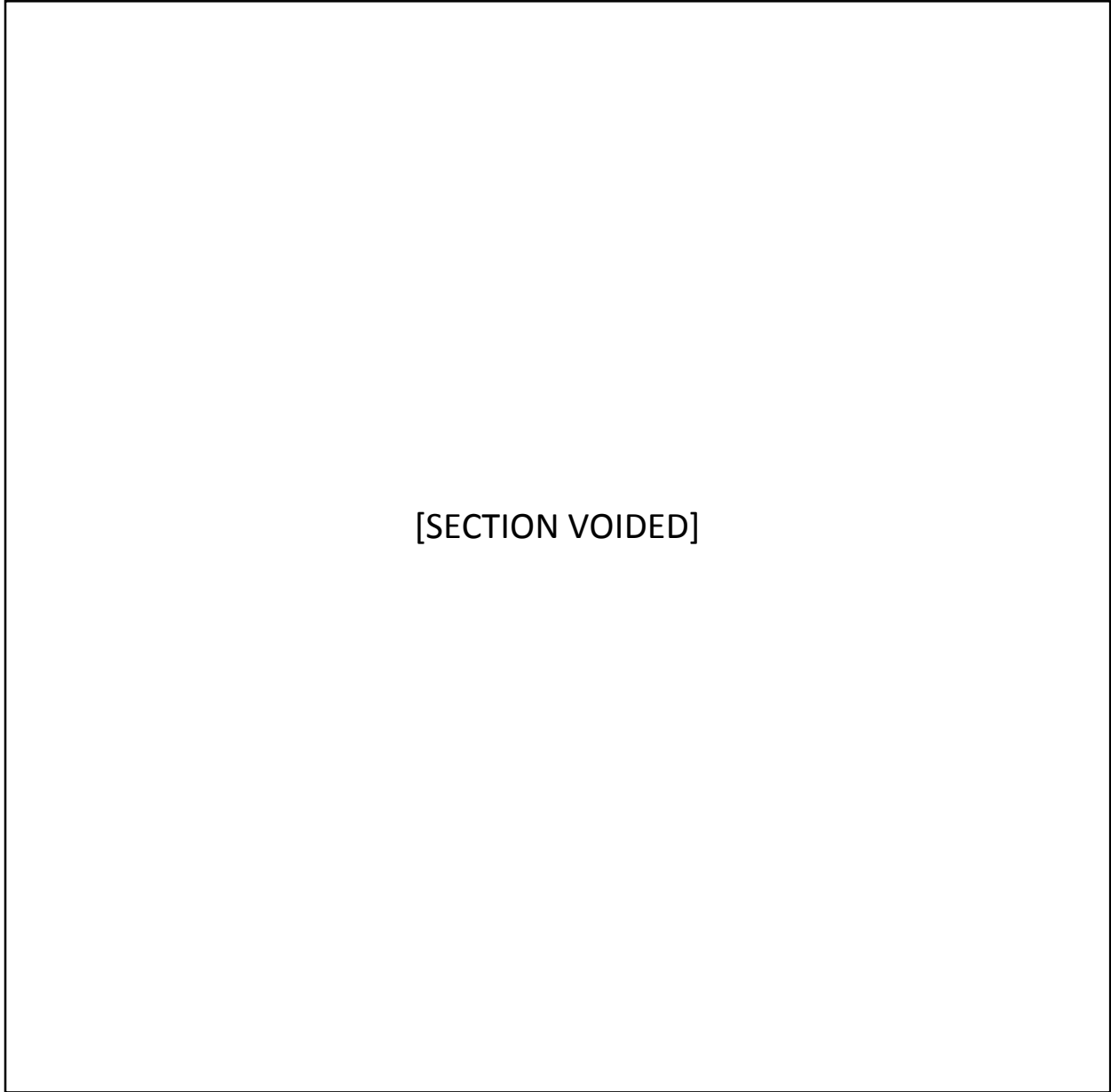
Several useful spreadsheets were created over the duration of the project. Early on after the scope was determined, a condensed spreadsheet of all parts from the most popular assemblies was created. The part’s attributes were included in this table. This table has and will prove very valuable for later analysis. From this master spreadsheet sub-tables were created for parts with specific attributes. The table was filtered to create a table for excess parts: parts with inventory on hand but no demand in the past year. This table will be helpful for Siemens’ inventory reduction efforts. The table was also filtered to create list of parts that would benefit the most from established safety stock levels. These were parts with high demand and long lead times. This new table will be useful when new safety stock levels are established.



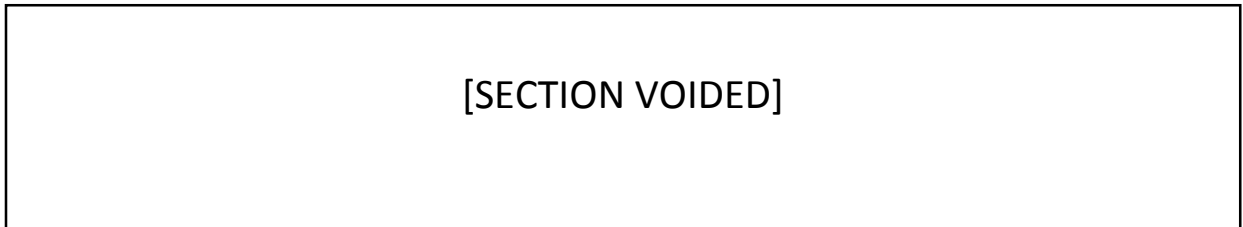
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#### 4.5.2 Deliverables: Suggestions

Over the course of the project several areas of improvement were identified. The most basic of these



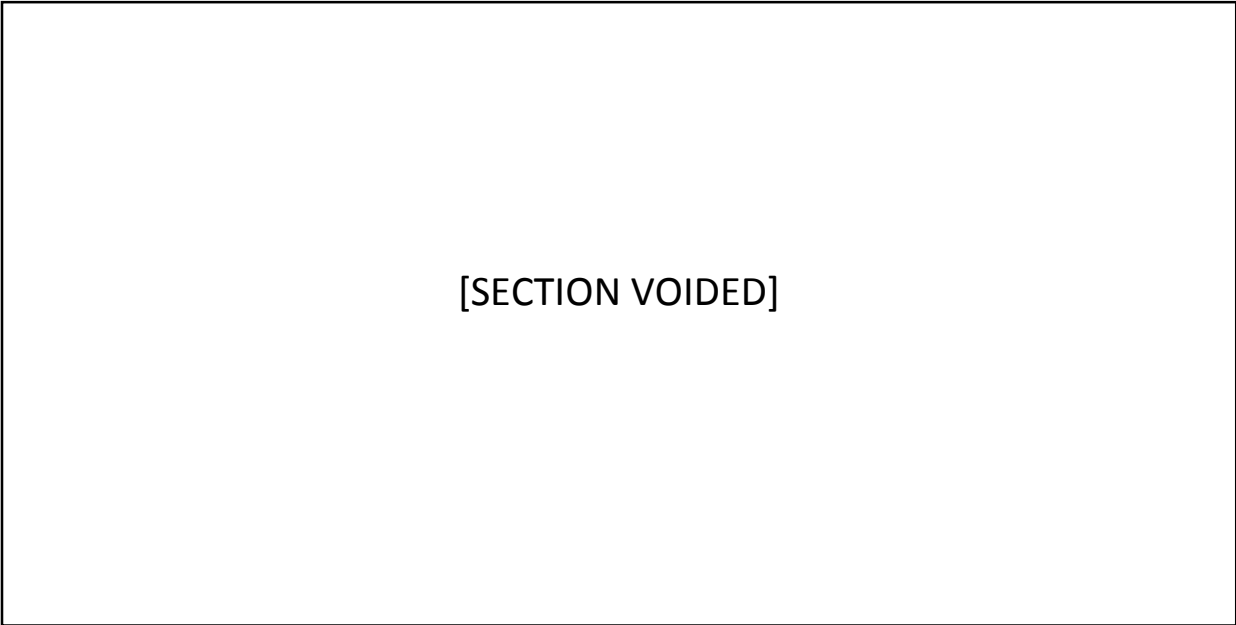
#### 4.6 Inventory Management Conclusion



enterprise resource planning software SAP and improvement of technical functionalities and communication across the entire plant.

4.6.1 Limitations

Although the proposals seemed like a great improvement opportunity, it was realized that the recommendations were subject to some limitations. One of the hardest aspects of this project dealt with figuring out how to provide Siemens with a physical implementation of the suggestions. As mentioned before, due to the team’s limited manufacturing experience, physical process change was not implemented.



4.6.2 Recommendations

The following sections explain the team's suggestions and recommendations for reducing inventory holding costs and streamlining the inventory management system currently in place.

4.6.2.1 Consolidated Virtual Plants



combined safety stock quantities would help Siemens deal with fluctuating volume of demand for all their product lines.

#### 4.6.2.2 *Inventory Optimization Software*

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#### 4.6.2.3 *Future Studies*

Throughout the course of this project, the team was able to identify various opportunities that future WPI MQP groups could focus their efforts on. As mentioned above, it might be useful for future groups

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## 5 Project Reflection

Through this project, our group learned a very valuable lesson; understanding the importance of employee culture and the impact that culture has on the implementation of a process improvement project. In order to have a successful implementation, all stakeholders involved have to be fully invested and aligned with the goals of the project. This includes manufacturing operators/associates, supervisors, leads, as well as mid and upper management. Including all parties involved will not only guarantee an effective implementation, but will also help sustain a lean operation in the long run.

During this project, our group was able to gain valuable first-hand experience that exposed us to various aspects and areas of working in a manufacturing environment. Our team took more of an outsider-consulting role with this project and contributed by identifying areas for potential cost and lead-time savings. Our group was also able to produce a value stream map and kaizen burst opportunities that could be implemented by future groups.

The secondary purpose for this project was to create the foundation for future groups to continue helping with the reduction of Roll Housing total assembly lead time. This project will be an ongoing venture between Worcester Polytechnic Institute and Siemens Metal Technologies (now officially Primetals) and it is important that the findings from each project be properly transferred from year to year. Our group performed a lot of the initial research and process background, which will save future groups time when they are conducting their projects.

While this project may represent the end of our education at Worcester Polytechnic Institute, we recognize that we will continue to expand our Industrial Engineering expertise upon entry to industry. It is essential to stay up to date with modern practices related to our field and commit to the engagement of life-long learning.

## 6 References

- Arnold, J. R. T. (1996). Introduction to materials management. Upper Saddle River, N.J: Prentice Hall.
- Liker, J. K. (2004). The Toyota way: 14 management principles from the world's greatest manufacturer. New York: McGraw-Hill.
- Richard B. Chase, and F. Robert. Jacobs. Operations and Supply Chain Management, the Core. New York: McGraw-Hill Irwin, 2013. Print.
- Rother, M., Shook, J., & Lean Enterprise Institute. (2003). Learning to see: Value stream mapping to create value and eliminate muda. Brookline, MA: Lean Enterprise Institute.
- Siemens AG Corporate Communications. (2014). Siemens Achieves Guidance for Fiscal 2014. [Press Release]. Retrieved from: <http://www.siemens.com/press/en/pressrelease/?press=/en/pressrelease/2014/corporate/2014-q4>
- Siemens AG Corporate Communications. (2008). Siemens to Acquire Morgan Construction Company [Press Release]. Retrieved from: [http://www.siemens.com/press/en/pressrelease/?press=/en/pr\\_cc/2008/01\\_jan/is11076786.htm](http://www.siemens.com/press/en/pressrelease/?press=/en/pr_cc/2008/01_jan/is11076786.htm)
- Siemens AG. About Siemens. (n.d.). Retrieved April 10, 2015. Retrieved From: <http://www.siemens.com/about/en/>
- World Steel Association. "Crude steel production 2015" (2015, March 1). Retrieved April 10, 2015, from <http://www.worldsteel.org/statistics/crude-steel-production.html>

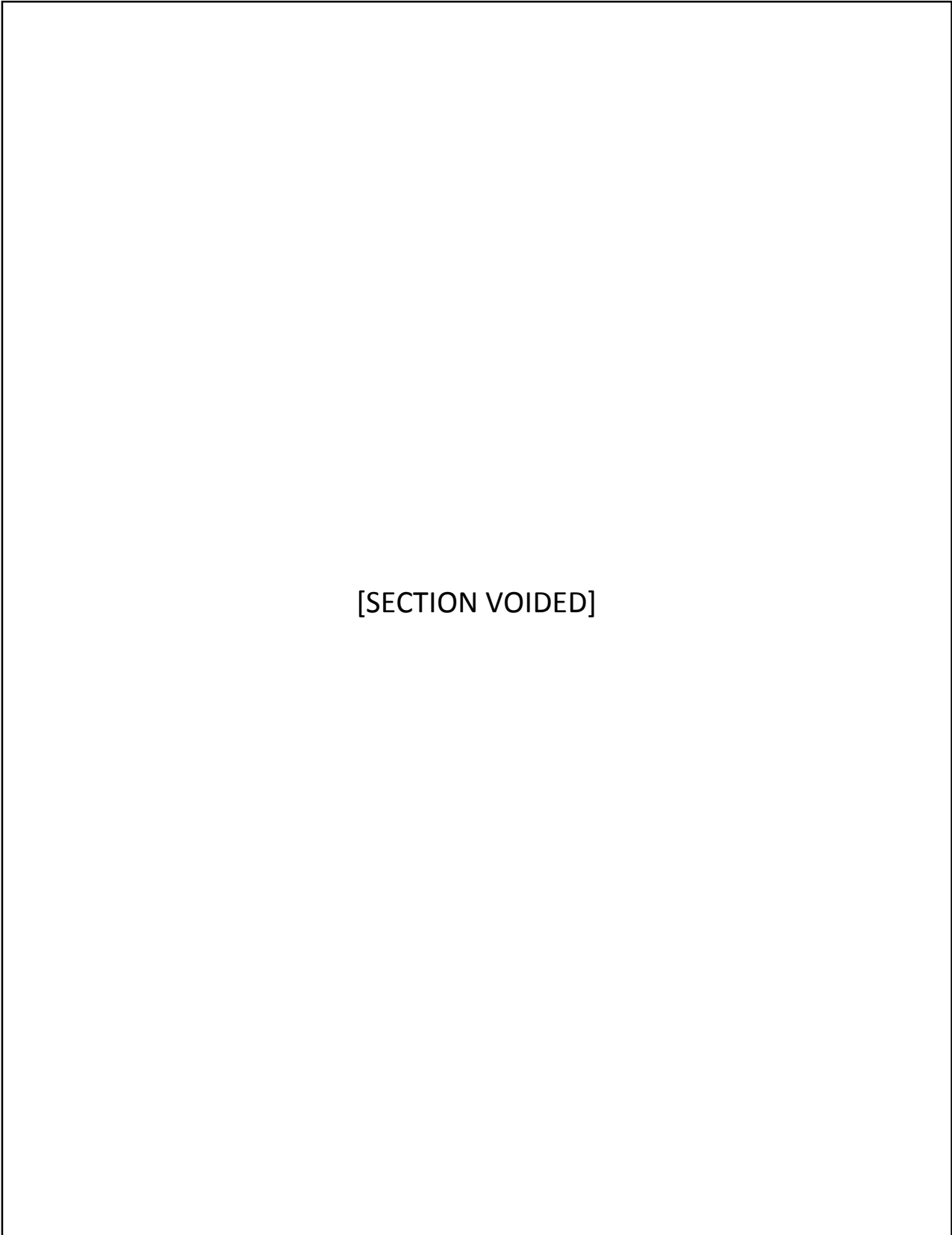
## 7 Appendix

### 7.1 Appendix A: Pareto Chart

#### Pareto Chart by Descriptions

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7.2 Appendix B: Routings



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### 7.3 Appendix C: Process Maps

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## 7.4 Appendix D: Value Stream Maps

### 7.4.1 Housing Box VSM

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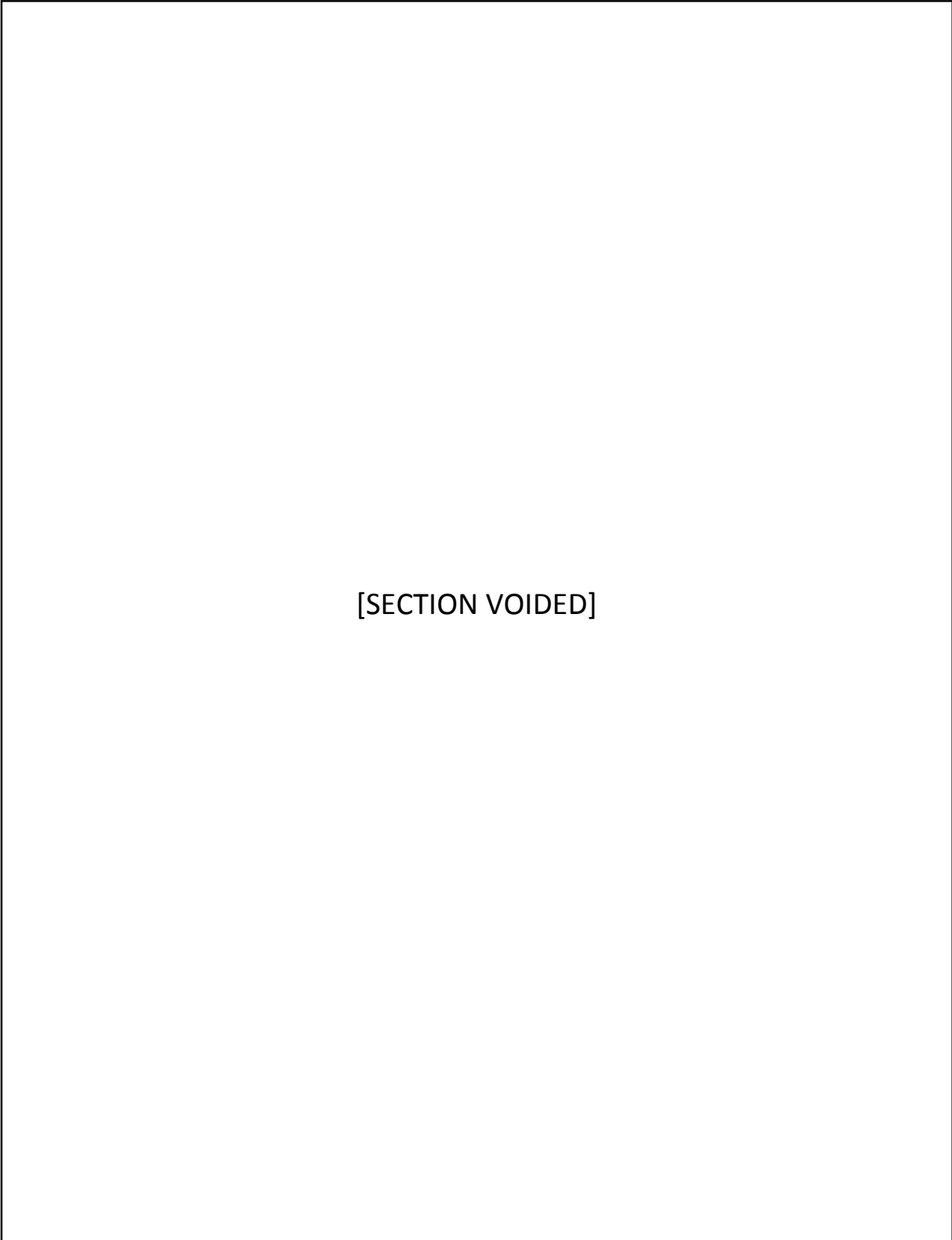
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## 7.5 Appendix E: Metric Averages

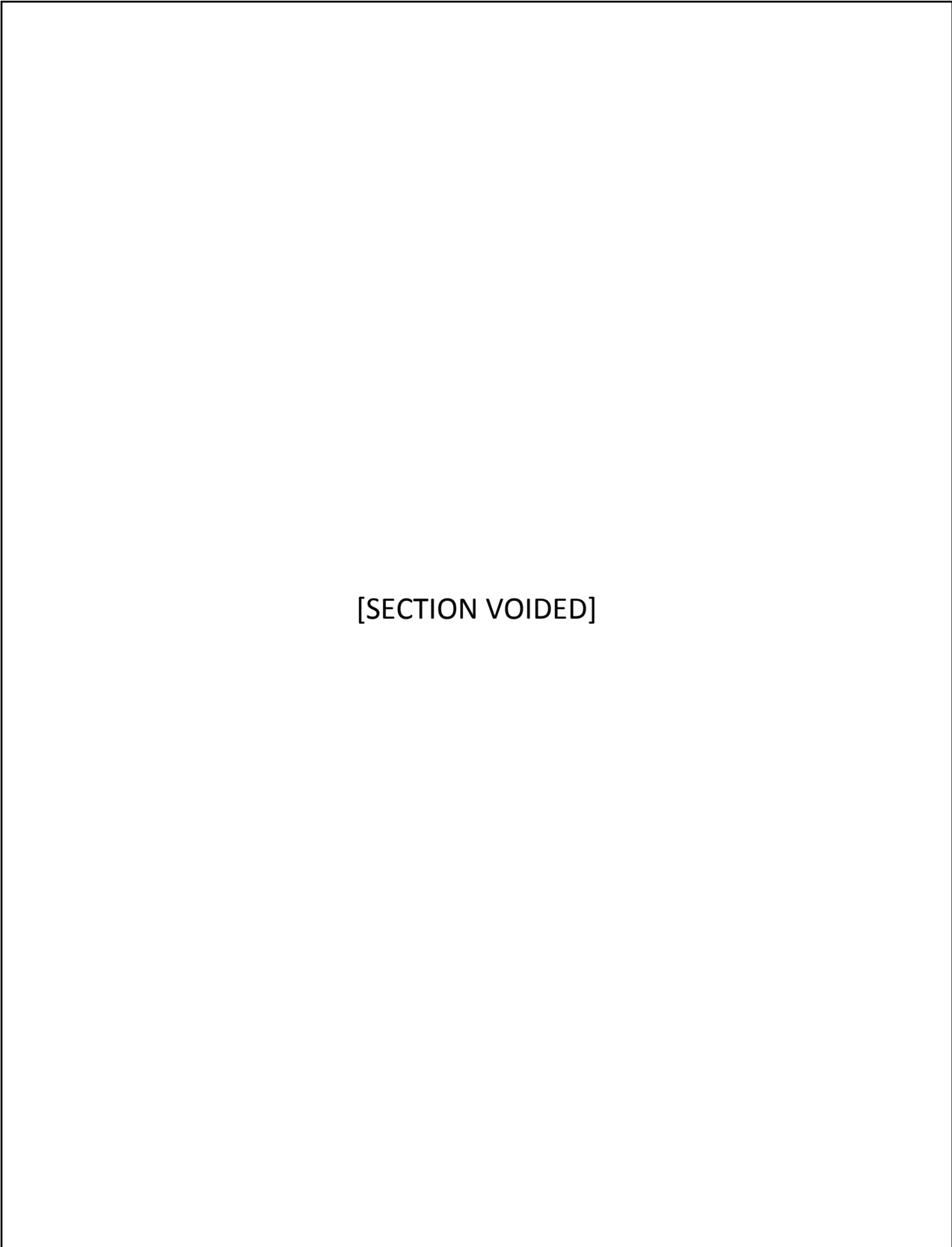
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7.6 Appendix F: Inventory Overlap Cost Chart





7.7 Appendix F: Safety Stock Overlap Cost



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