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A Case Study on Lean Implementation in Northwestern Pennsylvania Manufacturing Companies

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ABSTRACT

With the manufacturing industry being an integral part of Northwestern Pennsylvania's economy, it is vital for manufacturers in this region to be efficient and remain competitive in the global marketplace. The use of lean manufacturing plays a key role in companies being able to do this. As technology and tools continue to evolve, it makes it difficult for companies that have existed for decades to keep up and remain competitive. This paper aims to quantify the leanness of manufacturing companies in the Northwestern Pennsylvania region and surrounding areas while helping to identify areas where the companies are lacking. Specifically, the areas of value stream mapping, pull systems, waste elimination, continuous improvement, and employee involvement are analyzed to identify leanness level and weaknesses. After collecting data from 10 small/medium sized Northwestern Pennsylvania manufacturing companies, it was found these companies are in fact struggling with the implementation of lean. The results show an average overall lean score of only 5.33/10 with a standard deviation of 1.72 for companies in this region. Additionally, the main weaknesses identified are within employee involvement, as this category has a mean score of 4.53/10 with a standard deviation of 2.54. With the culmination of results from the study, Northwestern Pennsylvanian companies can focus their process improvement efforts on these areas of lean manufacturing and increase efficiency to stay competitive with the ever-evolving global economy.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Lean manufacturing has been a key aspect of industrial engineering since 1988 when the practice was officially coined “lean”, and the concepts have been utilized in the manufacturing industry since as early as the 1850’s with the introduction of “interchangeable parts” [1], [2]. The main principles of lean are to create value added processes which eliminate waste and respect the customers’ values [1].

With continuous improvement being at the forefront of the lean movement, there are seven forms of waste that lean manufacturing focuses on eliminating [1], as seen in Figure 1.

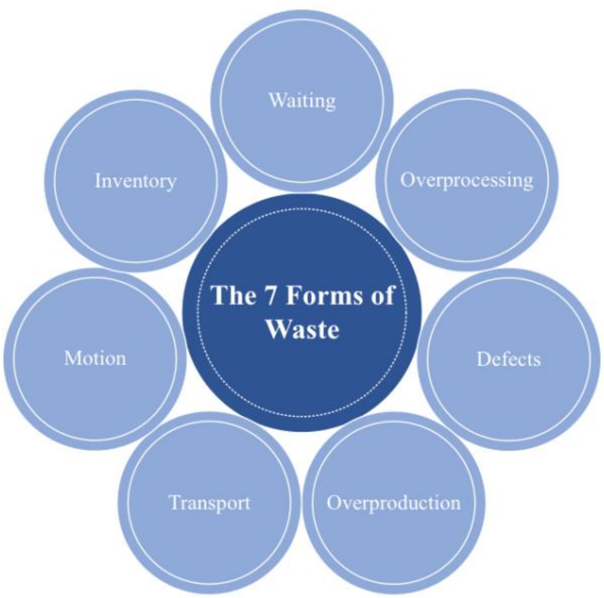

Figure 1: The 7 Wastes

These seven wastes—waiting, overprocessing, defects, overproduction, transport, motion, and inventory—are all wastes that occur in a production environment and do not add any value for the manufacturer or customer [1]. By eliminating these forms of waste, efficiency is often achieved. Furthermore, the company's processes are streamlined and accelerated by focusing on removing the unnecessary steps that were being completed. Along with the 7 wastes, many companies focus on "5S" to implement lean in their facilities. The 5S methodology focuses on the steps found in Figure 2.

Figure 2: 5S Methodology

In using these five S's, a company can achieve the following: only keep essential tools/equipment, arrange tools in an efficient manner for easy access, ensure cleanliness of the work area, maintain this level of order in every area of the facility, and continue to utilize these methods continuously into the future [3]. By implementing this process, usage becomes more efficient, energy consumption/pollution is lowered, and overall safety of the employees is increased [3]. With a combination of lean tools such as eliminating the 7 wastes and using the 5S methodology, lean can easily be implemented and potentially lead to significant impacts on a company. These are just two of the seemingly limitless lean resources that are utilized globally.

1.2 RESEARCH OBJECTIVES

The main objective of this thesis is to explore the level of lean implementation and identify areas of weakness in Northwestern Pennsylvania (NWPA) manufacturing companies. It is hypothesized that the level of lean implementation will be consistently low for NWPA small/medium sized manufacturing companies. This could potentially have an impact on the success of these small/medium sized manufacturing companies and be a contributing factor to the decline of the industry in this area. By bringing awareness to these areas of weakness, manufacturing assistance groups in the area such as Pennsylvania Technical Assistance Program (PennTAP) and the Northwest Industrial Resource Center (NWIRC) can ensure their programs are meeting the needs of companies.

Through survey collection and analysis of recent historical data on these medium-sized companies, a more extensive understanding will be obtained regarding the areas of lean implementation that are lacking in the area. Furthermore, through data collection and interviews with these NWPA companies, the study will be able to identify a broad understanding of the level of lean implementation with companies of this size. By comparing facility size and number of employees, one can see trends and draw conclusions regarding barriers to lean adoption in the manufacturing setting.

CHAPTER 2

LITERATURE REVIEW

This literature review focuses on two main concepts. The first being how to measure leanness and the use of the fuzzy logic approach. The second being the current status of the manufacturing industry in NWPA. With thorough research of past studies, the review provides a deep understanding of the key concepts needed to create a survey regarding lean manufacturing. Additionally, the literature review provides a background for the concepts that will be studied from the historical data being collected.

2.1 UNDERSTANDING LEANNESS MEASUREMENTS

Due to the vast number of techniques available for lean implementation, there is little to no ability for one to measure a company's level of lean use to an absolute value that is agreed upon universally. Each company utilizes different metrics, and one cannot be compared to another easily. With this being known, many have attempted to create assessments to compare "leanness" between companies. Specifically, leanness can be defined as the measurement of one's ability to improve their outputs while decreasing the inputs needed [4].

While numerous different spreadsheets [5], assessments [6], and models [4] have been created to measure leanness in different scenarios, it is evident the same concepts are the focal point of each one. The main lean catalysts seen in companies have been found to be value stream mapping (VSM), pull systems, just-in-time (JIT), waste elimination, and employee involvement [7]. VSM is a technique used to create a flow of the materials and information needed for each step of the process from beginning to the final customer delivery. A pull system focuses on each operation being pulled to the next rather than pushing it to the next station. JIT is a concept that focuses on meeting customers' needs immediately while simultaneously having high quality and low waste levels, similar to a pull system [7]. Additionally, an important part of lean is understanding the amount of waste being created and working to minimize the amount of waste produced. Lastly, employee involvement in lean focuses on ensuring that all employees from top management to hourly floor workers are educated and committed to the implementation of lean. Without employee involvement, lean implementation cannot become standardized and sustained in a company. These criteria can be utilized to estimate the leanness of a company.

Additionally, while waste elimination is the most common principle associated with lean, continuous improvement is also a main pillar of lean production systems [8]. One word often associated with continuous improvement is kaizen – the constant strive for perfection [8]. This Japanese word has become a way of life for many manufacturing companies around the world. While perfection cannot be reached, it does provide motivation for companies to be in constant improvement mode. Furthermore, while waste elimination can sometimes be seen as small, impactful projects, continuous improvement is a long-term commitment which can show a company's commitment to adopting lean manufacturing [6].

The main tools used by companies for continuous improvement all come back to the use of employee suggestion schemes (ESS) [9]. From prior research, it has been found that companies are most successful with the integration of new ideas when it is originated and developed by their employees [9]. Thus, the use of ESS is integral in the continuance of any continuous improvement initiatives [9]. These schemes have led to successful improvements being used in both formal and informal settings [8].

In formal settings, a “quality circle” is often used [8]. This refers to having a structured meeting time to identify areas for improvement and need in the manufacturing facility [8]. This idea of a quality circle could be seen through arranged group meetings or a reporting system where employees submit their ideas to management [8]. However, companies may begin their continuous improvement journey with a more informal approach. This is often seen when a facility has multifunctional teams, as employees have an increased attachment to the product and the company’s success from seeing the bigger picture [8]. When this cross-trained environment is used, employees tend to suggest and implement continuous improvement programs in an informal manner with their managers [8].

From this extensive research on leanness, it is evident there are a few main criteria that should be considered when identifying a company’s level of lean implementation. These criteria include: VSM, pull systems, JIT, waste elimination, employee involvement, and continuous improvement. These tools and concepts will all be considered when surveying and interviewing companies for this study.

2.2 FUZZY LOGIC APPROACH

To successfully quantify these lean concepts and tools in the survey, a combination of the leanness assessments previously completed will be utilized in a fuzzy logic approach. A fuzzy logic approach is utilized to gain an understanding, in this case from 1 to 10, where 1 is extremely not lean and 10 is extremely lean [10]. To properly utilize this approach, weights are assigned to different characteristics of the proposition and logic is used to find the degrees of truth for the proposition [10].

This approach is often used for leanness assessments, as lean is dependent on human understanding and cannot be solely measured by numbers [4]. In calculation, the leanness value (L) will be equivalent to the assigned weight (W) times the assessment rating (R) [4]. Since there are numerous factors used in the fuzzy approach, a matrix of all factors is created, and cross multiplication can be utilized to find the final leanness value (L) [4].

This approach will allow for a more reliable, quantitative result to be used for the study when looking at the leanness of manufacturers in the Northwestern Pennsylvania region. Furthermore, it will provide a reliable metric to be able to compare the results between companies.

2.3 NWPA MANUFACTURING INDUSTRY BACKGROUND

Manufacturing has been the backbone of Pennsylvania's economy for generations. Since the industrial revolution in the 1800s, the state has been a key manufacturing provider for the country, especially for iron and steel in the northwestern region [12]. By 1850, Pennsylvania transitioned from a colonial economy to an industrial economy and stayed a vital part of the economy for many years to come [12]. Moving forward to the 1900s, Pennsylvania stayed involved in manufacturing and was found to hold the largest number of big business combinations [12]. With these strongholds to so many heavy manufacturing industry companies, the state had no concern for a decrease in manufacturing jobs and was content with the work they were doing in steel, iron, transportation, plumbing, and other equipment industries [12]. Northwestern Pennsylvania had minimal competition from the other areas in the steel and iron industry, so they had little reason to change the way that they carried out their operations during this time [13].

However, as the economy evolved with an acceleration of technological changes to present time, Pennsylvania is struggling to maximize its growth in the manufacturing industry. While the remainder of the United States is growing in this industry, Pennsylvania is taking a downturn, especially in the northwestern region of the state [14]. From a study in 2022, the state had lost 10,000 manufacturing jobs since COVID-19 and the Pittsburgh/NWPA region was down approximately 1,600 [14]. On the contrary, states around the rest of the country, specifically in the south, were seeing a large increase in manufacturing jobs since the end of the pandemic [14]. If Pennsylvania were following the average trend of the nation, it would have gained 12,900 more manufacturing jobs than it had at that time [14].

Looking at more recent U.S. Bureau of Labor Statistics (BLS) data spanning from 2013-2023, this trend is still being seen even three years post-pandemic. As seen below in Figure 3, Pennsylvania saw its peak of manufacturing employees in 2019 with an average of 575,358 employees [15]. After a large drop in 2020 due to COVID-19, the market began to increase again but never came back to what it was before COVID-19. In 2023, the number of employees came up to 566,375, but was still 1.6% lower than the average in 2019 [15].

Figure 3. Pennsylvania Manufacturing Employees from BLS Data [15]

The data for the United States as a whole follows a much different trend. As seen below in Figure 4, the United States saw a similar peak to Pennsylvania in 2019 with an average of 12,817,000 manufacturing employees [16]. After a large drop in 2020 due to COVID-19, the market began to increase again and continued to become better than it was before. In 2023, the number of employees came up to 12,941,000, which was approximately 1% higher than the average number in 2019 [16].

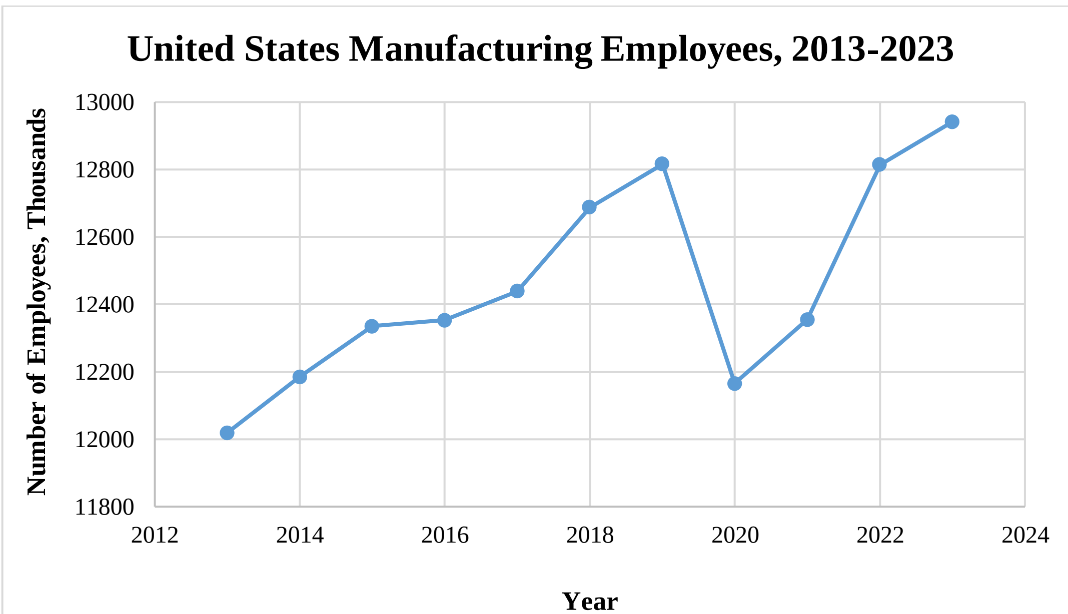

Figure 4: United States Manufacturing Employees from BLS Data [16]

Looking even deeper and focusing in on Erie, PA, the largest city in the NWPA region, the declining trend is even more significant. As seen below in Figure 5, the trendline shows the number of manufacturing employees have been steadily decreasing from 2013 to now [17]. Even without COVID-19, the city of Erie would still be struggling to keep the industrial economy alive. To compare to the United States and Pennsylvania, Erie saw a 5% decrease in employees from 2019-

2023, whereas PA saw only a 1.6% decrease and the United States saw a 1% increase [15], [16], [17].

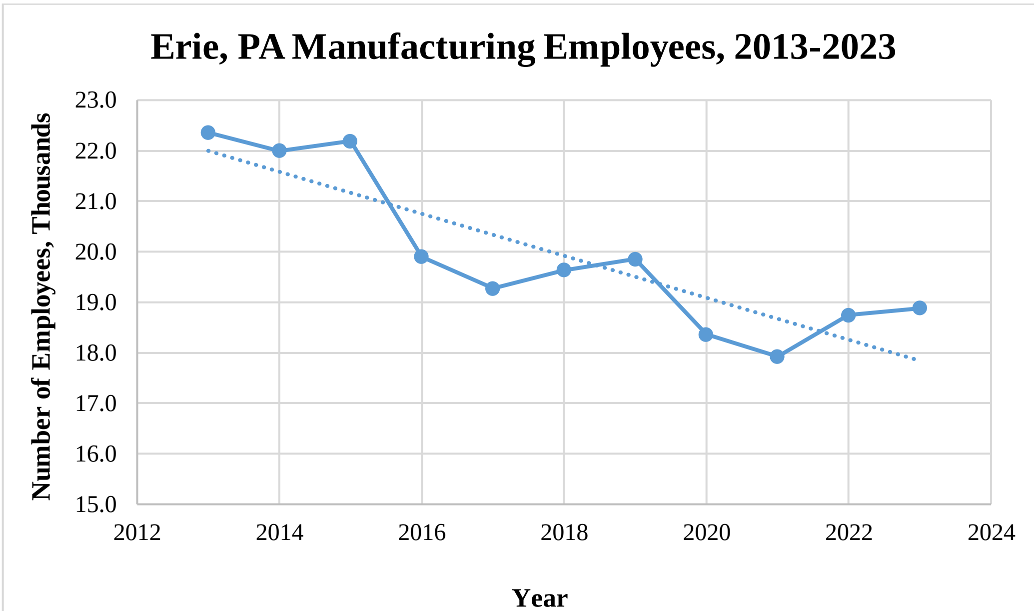

Figure 5: Erie, PA Manufacturing Employees from BLS Data [17]

From these comparisons, it is evident other states are outperforming in the manufacturing sector compared to Pennsylvania. While the rest of the country is thriving, Pennsylvania is struggling just to hold onto what they currently have, especially in Erie. Thus, it is important for the NWPA companies to look internally at their own processes and identify areas for improvement. If they can identify their weaknesses and improve upon them, there could be opportunities for the region to get their competitive advantage back in the manufacturing industry and thrive like the state once did in the past.

CHAPTER 3

METHODOLOGY

From the information obtained in the literature review, two surveys were created for this case study. The first being a preliminary survey to gain the interest of a company in the survey itself. The second being a main survey to collect the quantitative data needed to designate leanness scores. These survey results will allow for an extensive analysis of the trends and areas of need among NWPA manufacturers.

3.1 PRELIMINARY SURVEY

In designing the preliminary survey found in Appendix A, the goal was to create a relationship with the manufacturing companies being contacted. Through discussion with PennTAP employees and other professionals, it was determined companies would provide a higher response rate if they were first approached with a short number of questions to familiarize themselves with the research being conducted. Utilizing this method, broad questions were asked in the survey such as “Does your company utilize lean tools?” and “Does your company track waste volumes?” to allow for quick, easy responses from participants. Additionally, this survey asked for more specific contact information to ensure the follow-up survey was sent to someone who would have data and information regarding the topics covered in this case study.

Furthermore, the preliminary survey was tested by three professionals prior to sending it out to the manufacturing companies. In conducting this pilot test of the survey with PennTAP employees and industrial engineering professors, the survey questions were validated and determined as reliable for use in the study by the professors and technical advisors.

After testing and editing was complete, the preliminary survey was finalized as a 9 question Google Form. These 9 questions were all short answers, only requiring 4 typed responses, 5 multiple choice questions, and a small time and thought commitment.

3.2 MAIN SURVEY

Once a relationship was established with the manufacturing company through the preliminary survey, a new list of willing participants was created for the main survey to be conducted. With willing participants, this survey aimed to be more in-depth, seeking to obtain historical data to analyze for the case study.

As seen in Appendix B, there were originally two portions of the main survey: a lean assessment and energy consumption related questions. For the lean assessment, a fuzzy logic approach was utilized due to the objectiveness in this area of the industry. To start, five areas of lean were identified to be assessed. These lean manufacturing tools are VSM, pull system, waste elimination, continuous improvement, and employee involvement as determined in Chapter 2 Section 1. Furthermore, five statements related to each of these concepts (25 total statements) are listed for the manufacturing companies to consider. These statements and categories were all assigned specific weights associated with their importance level. With each statement, the company representative will provide a rating from 0-10. A response of "0" implies the statement does not apply to the company at all. A response of "10" implies the statement applies to the company 100% of the time. Responses between 0-10 imply they utilize the mentioned tools some of the time (i.e., a response of "5" equates to being true half of the time).

The remaining questions were regarding facility energy consumption of petroleum, natural gas, electricity, and water. Unfortunately, these questions received no responses in the initial stages of data collection and were ultimately removed from the study. The updated form used included solely the lean implementation questions and company information (number of employees and square footage of manufacturing facility).

3.3 SURVEY PARTICIPATION AND DISTRIBUTION

The data collection process began with identifying target companies and acquiring contacts to take part in the study. Company contacts were researched on company websites, provided from Penn State Behrend professors, messaged on LinkedIn, and approached in person at NWPA American Foundry Society meetings. The preliminary survey was given to 40 local companies. Out of these 40 companies, responses were received from 10. With this, the study had a 25% response rate for the preliminary survey.

The next step was to send the main survey. The main survey was initially distributed to the 10 contacts that responded to the preliminary survey. Out of these 10, 4 companies completed the main survey, resulting in a 40% response rate. To gain additional data for the study, the main survey was also distributed to 21 new companies. Responses were received from 6 of these companies, giving a 29% response rate. In total, 10 out of 31 companies provided responses to the main survey, giving an overall response rate of 32% for the main survey.

The preliminary and main surveys were distributed via Google Forms and paper copies. Additionally, phone calls and in-person conversations occurred to gain additional information.

CHAPTER 4

SURVEY RESULTS

4.1 PRELIMINARY SURVEY RESULTS

While the main goal of the preliminary survey was to create a relationship with manufacturing companies, broad results were also collected. The results were collected from 10 different sources in Erie, PA county and the surrounding areas, and they are summarized below in Table 1.

Table 1: Preliminary Survey Results

Question No	Question	Percent of "Yes" Responses	Percent of "No" Responses
1	Does your company utilize any lean tools (Value Stream Mapping, Kanban, Takt Time, etc.)?	70	30
2	Does your company track waste volumes?	70	30
3	Does your company track energy consumption?	50	50

4.2 MAIN SURVEY RESULTS

In addition to the preliminary survey, results were collected from these 10 sources for the main survey. These results provide an in-depth summary of the industries that were reached, sizes of the companies, and overall lean score. The results also show the overall scores for the five main categories that were studied: value stream mapping, pull system, waste elimination, continuous improvement, and employee involvement. The results for companies 1 through 5 can be seen below in Table 2.

Table 2: Main Survey Results (Part 1)

Company ID	1	2	3	4	5
Industry	Metal	Metal	Chemical	Metal	Metal
Number of Employees	18	30	33	45	50
Square Footage of Facility	16,000	50,000	N/A	30,000	27,000
Overall Lean Score	5.575	4.2025	4.22125	2.855	5.97125
Value Stream Mapping	4.5	2.95	1.75	3.5	3.25
Pull System	8	4.55	5.95	5	7.7
Waste Elimination	2.5	2.25	6.625	2	5.625
Continuous Improvement	7	6.2	3	2.2	7.2
Employee Involvement	7	5.9	2.75	1.05	5.75

Note: All scores are on a scale from 0-10.

The results in Table 2 focus on companies with less than or equal to 50 employees. The results for companies with more than 50 employees (companies 6 through 10) are seen below in Table 3.

Table 3: Main Survey Results (Part 2)

Company ID	6	7	8	9	10
Industry	Metal	Other	Metal	Metal	Metal
Number of Employees	55	85	140	150	440
Square Footage of Facility	300,000	130,000	182,000	160,000	274,000
Overall Lean Score	6.6475	5.3425	6.6425	8.49625	3.2975
Value Stream Mapping	8.6	6.9	8.05	8.8	4.1
Pull System	8.45	7	4.4	8	3
Waste Elimination	7.25	4.25	9.25	9.625	3.75
Continuous Improvement	4.1	5.3	4.8	7.5	2.9
Employee Involvement	4	1.75	6.4	8.55	2.15

Note: All scores are on a scale from 0-10.

Similar to the preliminary survey results, the companies studied in this survey are all small to medium sized businesses in Erie, PA county and surrounding areas. The number of employees ranges from 18 to 440, and the facility sizes are anywhere from 16,000 square feet to 300,000 square feet. This gave the results of the survey some diversity while staying within the scope of NWPA small/medium sized businesses. The next chapter, chapter 5, will analyze this raw data collected throughout the study.

CHAPTER 5

HISTORICAL DATA ANALYSIS

5.1 QUANTITATIVE ANALYSIS

In analyzing the data, the summary provided below in Table 4 shows the aggregate values for the collection of study participants.

Table 4: Aggregated Summary of Results

Variables	Average	Standard Deviation
Number of Employees	105	126
Square Footage of Facility	129,889	107,961
Overall Lean Score	5.33	1.72
Value Stream Mapping	5.24	2.60
Pull System	6.21	1.89
Waste Elimination	5.31	2.82
Continuous Improvement	5.02	1.94
Employee Involvement	4.53	2.54

As seen in the table, the study shows NWPA companies have an average lean score of 5.33 with a standard deviation of 1.72. This shows there is much room for improvement in applying these lean principles.

More specifically, employee involvement has the lowest categorical score from the study with a mean of 4.53 and a standard deviation of 2.54. Additionally, none of the 10 participants had this category as their strongest area from the study. With this information, NWPA companies clearly struggle with keeping their employees involved with lean implementation. This should be a focus area for companies who are actively trying to improve their effectiveness in utilizing lean principles. Furthermore, putting efforts into employee involvement is vital to the success of these manufacturing companies, as an increase of involvement would also be able to help kickstart an increase of efforts in other areas, such as continuous improvement and waste elimination. Further analyzing the results from the waste elimination portion of the survey, it was found that only 4 out of the 10 companies have employees who have completed official lean training. With only 40% of companies having leaders with lean training, it is nearly impossible for other employees to become involved in lean initiatives. Professional development sessions for lean green/black belt training could have a significant impact on the ability of these companies to improve employee involvement. Furthermore, the training would provide resources to improve the other areas of VSM, pull, continuous improvement, and waste elimination.

On the other hand, the aggregated data shows that implementation of pull systems is the process that companies have the most success with. This category has a mean value of 6.21 out of 10 with a standard deviation of 1.89, which is 27% better than employee involvement. While this still has room for improvement, it will not be a main focus for many companies in this region. The data shows that companies are strong in this area, as 5 of the 10 companies had a score of 7-8.

In addition to this summarized data, regression analysis and beta hypothesis testing was completed on the variables of number of employees, square footage of facility, VSM, pull system, waste elimination, continuous improvement, and employee involvement. It is assumed the population is normally distributed, and the samples are random and independent for the sake of the analyses. The regression analyses looked at each of these variables individually vs overall lean score to identify the key predictors of leanness. The null and alternative hypotheses were H_0: $\beta = 0$ and H_1: $\beta \neq 0$, respectively for all tests. The results from the analyses can be found below in Table 5.

Table 5: Testing Results on Predictors of Overall Lean Score

Predictor Variable	Constant	Variable Coefficient	P-Value
Number of Employees	5.546	-0.002110	0.670
Square Footage of Facility	4.980	0.000004	0.569
Value Stream Mapping	2.654	0.510000	0.009
Pull System	1.590	0.601000	0.038
Waste Elimination	2.781	0.047900	0.007
Continuous Improvement	2.280	0.606000	0.030
Employee Involvement	3.007	0.512000	0.012

*Note: Overall Lean Score = Constant + (Variable Coefficient*Predictor Variable Value).*

Since the p-value for the number of employees was 0.670, this is greater than the significance level of $\alpha = 0.05$ and one must fail to reject H_0. From this conclusion, β may equal zero, so number of employees is not a statistically significant predictor of overall lean score. This can be verified by the graph below in Figure 6, since there are many outliers in the data and no true trend on the graph.

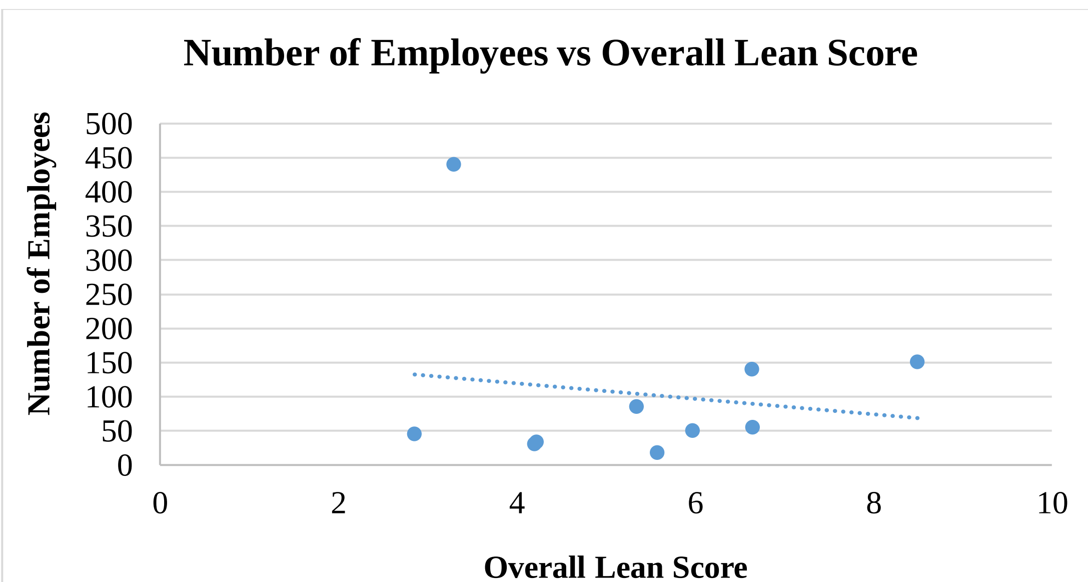

Figure 6: Scatterplot of Number of Employees vs Overall Lean Score

Similarly, the p-value for square footage of facility was 0.569, which is greater than the significance level of $\alpha = 0.05$, so one must fail to reject H_0. From this conclusion, β may equal zero, so the square footage of a facility is not a statistically significant predictor of overall lean score. This can be verified by the graph below in Figure 7, since there is no true trend on the graph.

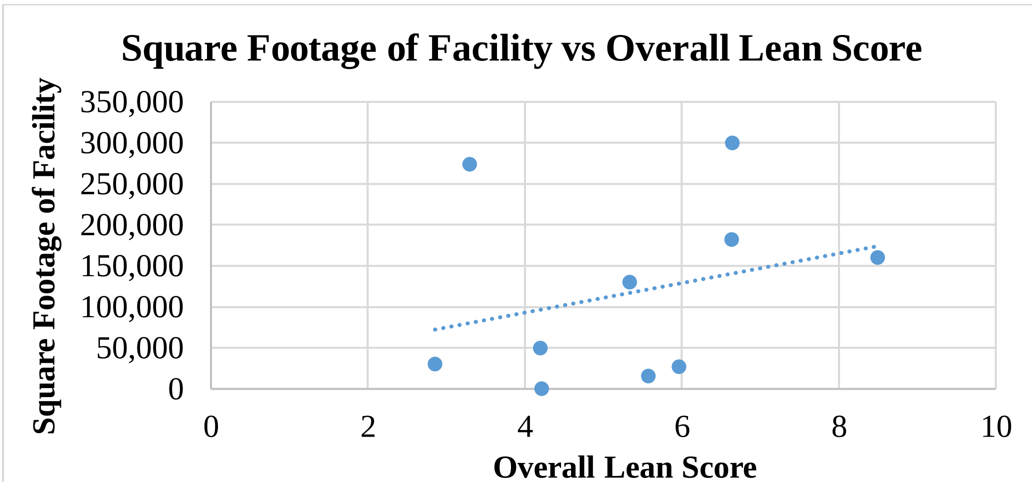

Figure 7: Scatterplot of Square Footage of Facility vs Overall Lean Score

These results make sense, as it validates that all small/medium sized NWPA manufacturing companies from the study are struggling with lean implementation, regardless of their size. This shows the main issue is truly the NWPA area and does not significantly change with the number of employees or resources available.

On the contrary, the p-values for VSM, pull system, waste elimination, continuous improvement, and employee involvement are 0.009, 0.038, 0.007, 0.030, and 0.012, respectively. These values are all less than the significance level of $\alpha = 0.05$, so one must reject H_0. From this conclusion, β does not equal zero, so the variables are all statistically significant predictors of overall lean score. This can be verified by the graphs below in Figure 8, Figure 9, Figure 10, Figure 11, and Figure 12 since there are positive correlations in all the graphs.

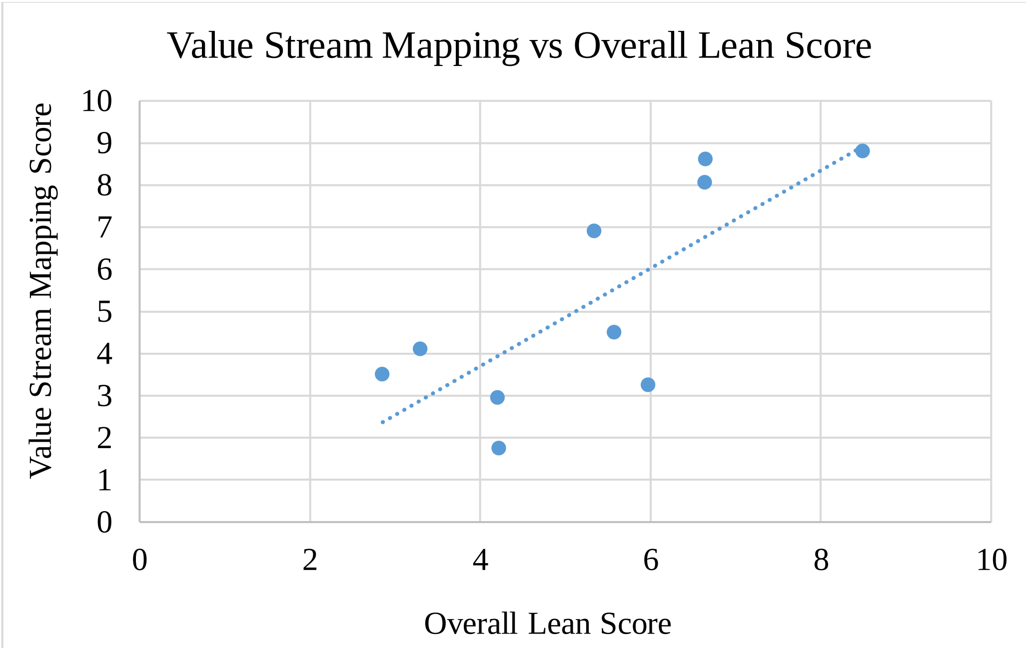

Figure 8: Scatterplot for VSM vs Overall Lean Score

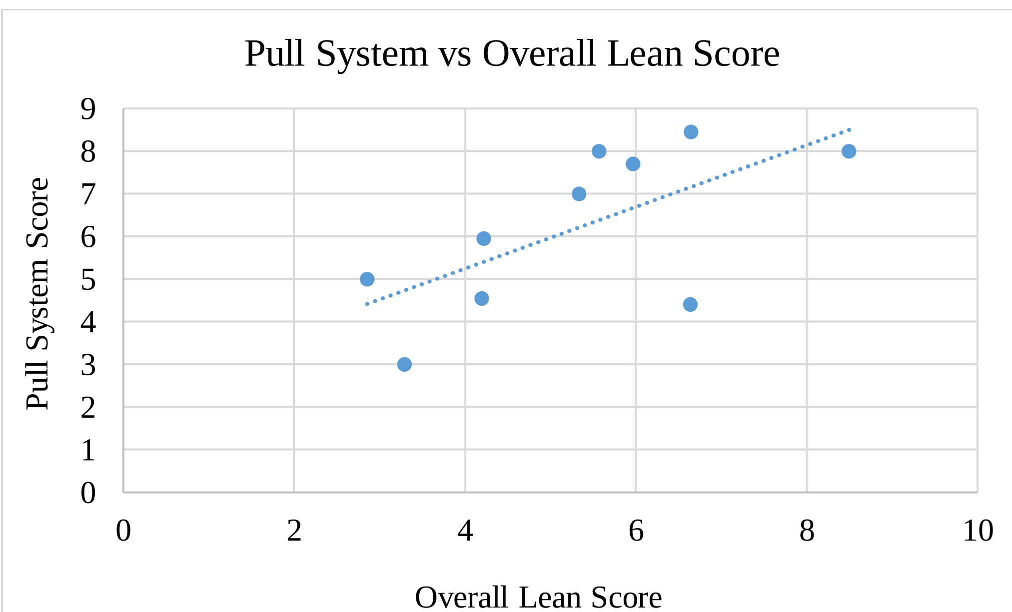

Figure 9: Scatterplot for Pull System vs Overall Lean Score

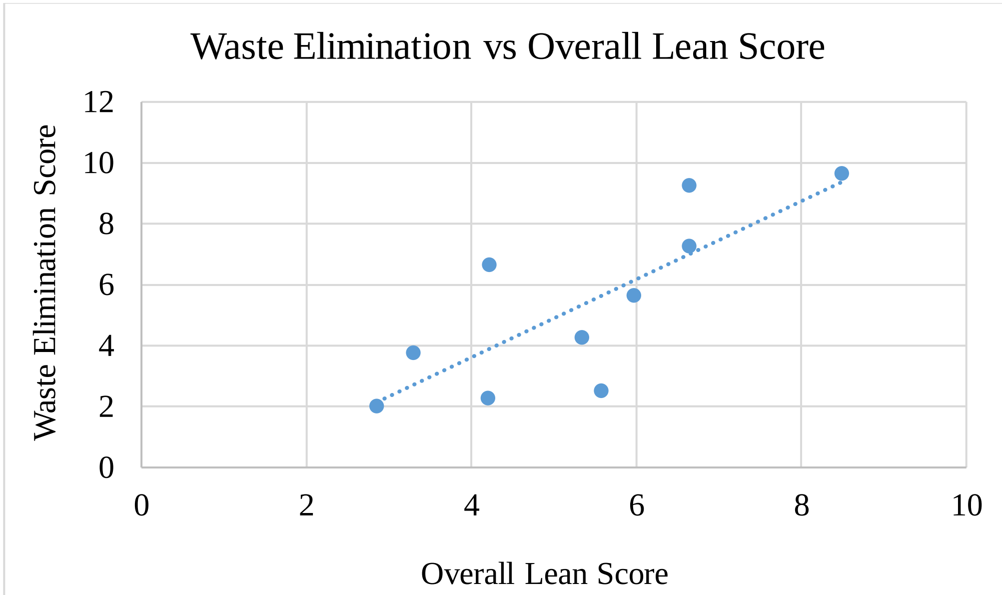

Figure 10: Scatterplot for Waste Elimination vs Overall Lean Score

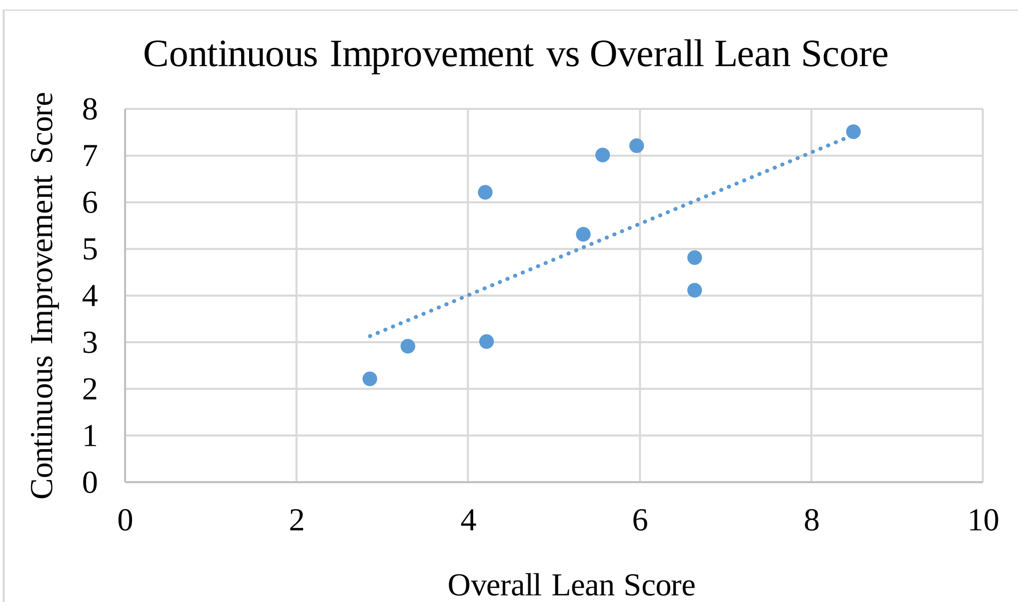

Figure 11: Scatterplot for Continuous Improvement vs Overall Lean Score

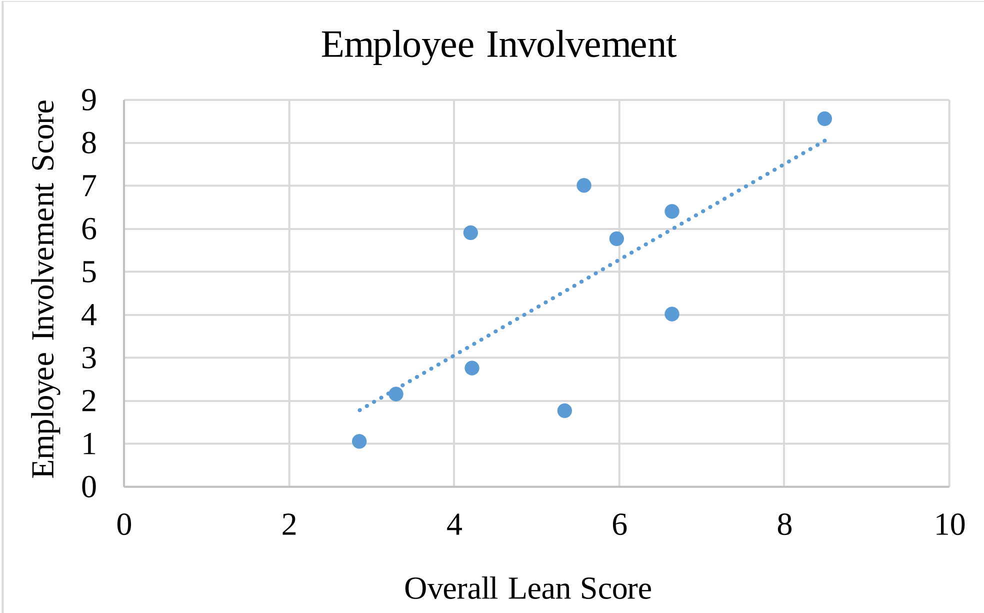

Figure 12: Scatterplot for Employee Involvement vs Overall Lean Score

5.2 QUALITATIVE ANALYSIS

In addition to the quantitative analysis, some qualitative results were found through conversations with these industry professionals from the NWPA area. As the preliminary survey results show, 30% less of companies track their energy consumption compared to their waste volumes (Table 1). This shows companies do not care as much about energy consumption, although it is a vital part of improving the efficiencies of manufacturing operations. This was validated when no companies had energy consumption values on hand to discuss and report on the main survey questionnaire. The EPA found approximately 30% of consumed energy is wasted in commercial buildings [19]. This is a significant value and should encourage companies to change their ways and begin to explore options for energy consumption tracking. The first step to becoming more efficient is identifying where the company is currently at by knowing their costs and areas for improvement.

Another area for companies to progress in is acceptance of change. With an average overall lean score of 5.33 from the study, this shows NWPA companies are missing out on almost 50% of lean resources available. Although the study does not provide a reference level for comparison to other areas of the country, this is low and not ideal. From conversations with the area's industry professionals, it was clear most companies are afraid of change and implementing modern technologies that are available. With the NWPA region being rooted in the steel and iron industries, many companies have been in operation for decades. This can inherently lead to processes staying stagnant over time. While some of these processes may still work, it does not mean they are the best methods for the operations. While it can take considerable time and effort to implement new methods, change is still vital to keeping a company competitive in today's global manufacturing economy. It is essential for companies to become aware of their stagnancy, look to their competitors for innovative ideas, and continue to change their methods to improve efficiency.

CHAPTER 6

CONCLUSION

6.1 SUMMARY OF RESULTS

Upon studying the state of the NWPA manufacturing industry, it is clear companies are stagnant, and the industry is consistently losing jobs in this region. To gain a better understanding of why this is occurring, surveys were created to analyze the ability of small/medium sized NWPA manufacturing companies to implement lean tools.

From the results of these surveys, it is apparent the majority of small/medium sized NWPA manufacturing companies are struggling with lean implementation. In studying the areas of value stream mapping, pull systems, waste elimination, continuous improvement, and employee involvement, all these categories have room for improvement. With efficiency and technological advancement at the forefront of the industry, it is essential for NWPA companies to improve their level of lean implementation. With higher lean levels, manufacturing companies in this area could increase their competitive advantage and expand the number of manufacturing jobs available in NWPA.

Specifically, the study found these companies have an average overall lean score of only 5.33 out of 10, leaving almost 50% of lean resources that are available unused. Furthermore, the category of employee involvement has the most room for improvement with an average score of 4.53 out of 10 from the study. If companies focus on employee involvement, this could also positively impact other areas such as waste elimination and continuous improvement.

The study also found number of employees and square footage of the facility are not statistically significant predictors of overall lean score, due to their p-values of 0.670 and 0.569, respectively (using $\alpha = 0.05$). This reveals that intentionality and level of training/expertise will have a much larger impact on level of lean competency than the company size or resources available at the facility. Thus, if companies can embrace change and innovation, they will have a higher chance of success with lean implementation at their company.

6.2 LIMITATIONS AND FUTURE WORK

While the study was successful, it did have a few restrictions due to the amount of time that was available for research. With only 10 study participants, the results may not be a completely accurate portrayal of all small/medium NWPA manufacturing companies. With a larger sample size, the results would have smaller standard deviations and include a larger array of manufacturing operations. Lastly, the study attempted to collect energy consumption numbers and was not able to receive these values from companies. This restricted the study from analyzing the impact of lean on energy consumption/waste and adjusted the scope of the analysis.

In understanding these restrictions, they give way for future work to be completed on this subject matter. Specifically, by collecting data from additional survey participants in the NWPA region and other areas around the country, a more comprehensive analysis could be carried out. With results from other cities, comparisons could be done to understand where the NWPA region falls with regard to the USA as a whole. Moreover, if energy consumption data could be collected, additional analysis could be done to identify if lean implementation impacts the ability to reduce the amount of energy used.

The research could also be continued with another focus. If the lean assessment could be validated as accurate over a larger sample size, the companies completing the survey could continue to use the lean assessment as they progress to measure their improvements. With lean being a fuzzy subject matter with no real metrics, this could be a beneficial tool for companies to improve their adoption of lean principles while making their operations increasingly more efficient leading to increased competitiveness in the marketplace.

APPENDIX A

PRELIMINARY SURVEY QUESTIONS

Preliminary Survey Questions

1. Company Name

2. What is the size of your facility (square feet)?

3. How many employees does your facility house?

4. Does your company utilize any lean tools (Value Stream Mapping, Kanban, Takt Time, etc.)?

5. Does your company track waste volumes?

6. Does your company track energy consumption?

7. Would you be interested in completing a further survey(s) for this study?

8. Would you prefer an additional google form survey or phone/in-person interview?

9. Who is the best contact for answering these questions regarding lean implementation and energy consumption (if not you)? (Please provide name and contact info)

APPENDIX B

MAIN SURVEY QUESTIONS

Lean Assessment				
These questions will utilize a 0-10 scale for responses. A response of "0" implies that the statement does not apply to your company at all. A response of "10" implies that the statement applies to your company 100% of the time. Responses between 0-10 imply that you utilize the mentioned tools some of the time (i.e., a response of "5" equates to the statement being true half of the time).				
Category	**Overall Weight**	**Criteria**	**Individual Weight**	**Answer (Likert's 0-10)**
1 – Value Stream Mapping (VSM) [5], [6], [12]	**0.20**	A current value stream map has been created for all processes occurring in the facility.	0.3	
		Refinements are constantly being made to the VSMs to minimize non-value add and create improved methods to produce value for the customers.	0.3	
		The company is ISO 9001 certified and has a structured quality process.	0.1	
		Scrap material is identified in mapping and reduced to below 10%.	0.15	
		Physical structure layout is considered in VSM and adjusted to optimize the efficiency of production (utilization of U shape lines, etc.).	0.15	
2 – Pull System [18]	**0.20**	Inventory is only filled when customer orders are placed (not including safety stocks).	0.15	
		Items are only produced at a station in the quantity and at the time that the next process needs it (just-in-time).	0.25	
		Assembly-line balancing of tasks and time is utilized to improve efficiency and decrease idle time at workstations.	0.25	
		Takt time and optimal number of operators/stations are utilized for all assembly areas.	0.25	
		Work-in-process costs are tracked and minimized.	0.15	
3 – Waste Elimination [5]	**0.25**	100% of the company has implemented the 5S concept: sort, set in order, shine, standardize, and sustain.	0.25	
		The 7 wastes– waiting, overprocessing, defects, overproduction, transport, motion, and inventory–are formally tracked and minimized.	0.25	
		Root cause analysis (5 why's) is taught and utilized to fix issues.	0.125	
		Standard work procedures are posted at all workstations.	0.25	
		Performance is measured to ensure that employees are meeting set standards and to identify/remove bottlenecks.	0.125	

4 – Continuous Improvement [6], [8]	**0.25**	More than 75% of employees' suggestions are implemented on the shop floor.	0.2	
		Employees are cross trained in 3+ areas so that teams can be multifunctional if needed.	0.3	
		Poka yoke technologies are implemented to eliminate operator defects in production.	0.2	
		DMAIC and FMEA analyses are used to identify areas of need for improvement.	0.1	
		Outcomes of projects are fully assessed to ensure the intended goal was met.	0.2	
5 – Employee Involvement	**0.10**	Teams collaborate to have initiatives that lead to an improved work environment.	0.15	
		There are rewards for hourly employees who contribute to 5S and continuous improvement initiatives.	0.15	
		Managers hold their employees accountable to keep the shop floor clean and contribute to 5S projects.	0.25	
		Employee productivity rates are tracked and 75% of employees spend 90% of their time available doing billable tasks.	0.15	
		Lean Green/Black Belt Training has been completed and "Lean Masters" exist throughout the company.	0.3	

Company Information/Energy Consumption
How much natural gas did your manufacturing facility utilize in 2022 (include units)?
How much petroleum did your manufacturing facility use for production in 2022 (include units)?
How many kWh of electricity did your manufacturing facility use in 2022?
How much water did your manufacturing facility consume in 2022 (include units)?
What is the square footage of your facility utilizing these energy sources?
How many employees does your facility have?
How many safety incidences did your facility have in 2022?
Do you have any data regarding waste volumes you would be willing to share? (Attach document)

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ACADEMIC VITA

GRACIE B. CHWATEK

EDUCATION

Penn State Erie, The Behrend College

- Schreyer Honors College Graduate
- Behrend Honors Program Member
- Bachelor of Science in Industrial Engineering with Honors
- Minor in Mathematics
- Graduation: May 2024

MANUFACTURING EXPERIENCE

GE Transportation, A Wabtec Company

- LEAD Operations Rotational Program (Expected: June 2024 – June 2026)
    - Leadership, Excellence, and Accelerated Development Program focused on creating senior frontline management for Wabtec Corporation
    - 6-month rotations taking place over 2 years in roles focused on Materials/Sourcing, Quality, Production Supervision, and Lean Manufacturing
    - Lean/Six Sigma Greenbelt Project/Certification and Capstone Project
- Locomotive Production Quality Intern | Erie, PA (May 2023 – July 2023)
    - Standardized the locomotive decal application process by creating a manual that decreased work time by 75%
    - Designed a wiring knowledge test to ensure new hires are properly trained prior to starting work in the Final Assembly building to reduce electrical quality defects
    - Supervised and performed inspections, fixed defects found, and prepared locomotives for shipment in the testing area
- Materials Planning and Execution Intern | Erie, PA (August 2022 – January 2023)
    - Constructed mapping of the warehouse in preparation for physical inventory, resulting in 99.9%-dollar accuracy
    - Acted as an auditor, data entry specialist, and counter for four separate physical inventories with the finance department
    - Co-owned the Kazakhstan kits being packed by analyzing and updating the shipment dates of parts for 40 locomotives
- Lean Manufacturing Intern | Grove City, PA (May 2022 – August 2022)
    - Designed 11 shadow board kit carts for the high-speed diesel engine build area that reduced unnecessary motion of operators by 11-13.75 hours per engine build
    - Completed 7 other 5S and standardization projects throughout the plant focused on removing unnecessary motion, inventory, and waiting
    - Provided one-on-one coaching to 3 interns and 1 team leader on lean resources available to employees in Grove City, PA

ENGINEERING PROJECTS & PUBLICATIONS

- Berry Global | Material Closed Loop Process on Production Line Project
    - Designed an optimal layout of equipment and processes for the plastic manufacturing process at Berry Global to utilize 99.3% of material consumed
    - Collaborators: Dr. Julia Zhao, Zachary Koch, Devin Muscarella, Michael Ulizzi
- "A Research and Industry Roadmap: Barriers and Opportunities for Increased, Lower Cost Additive Manufacturing Integration for Investment Casting Foundries" by Chris Annear, Ben Fahrney, Gracie Chwatek, Andrew Bomberger, and Paul C. Lynch
    - Published at the 2023 Investment Casting Institute Technical Conference & Expo in Pittsburgh, PA
- "A Benefit-Cost Study of Implementing Particulate Matter Filters onto Motorbikes in Kenya" by Gracie Chwatek and Omar Ashour, PhD
    - Published and Presented at the 2023 Institute of Industrial and System Engineers Annual Conference in New Orleans, LA
- Dust to Diamonds Venture (Humanitarian and Social Entrepreneurship Program)
    - Collaborated with a team of diverse majors to create a sustainable business model for a venture that would help low-income taxi drivers in Kenya
    - Partnered with stakeholders in Kenya and the Laboratory for Isotopes and Metals to conduct testing on a particulate filter

LEADERSHIP AND CAMPUS INVOLVEMENT

- Tau Beta Pi, PA Mu Chapter President (May 2022 – May 2024)
    - Arranged events for engineering students such as a question-and-answer panel of Wabtec engineers, plant tours, and member initiation ceremonies
    - Attended the National 2023 Tau Beta Pi Convention in Atlanta, GA as a voting delegate and the 2024 District 3 Conference in Newark, DE
- Pi Mu Epsilon, Chapter President/Vice President (May 2022 – May 2024)
    - Acted as the Vice President for the 2022-23 School Year
    - Acted as the President for the 2023-24 School Year
    - Ensured proper training, club registration, and initiation ceremonies took place
- STEM Leaders Peer Mentor (February 2022 – May 2024)
    - Provided personal and social mentoring to younger students in the STEM Leaders Program on a weekly basis by coordinating group meetings and discussions
    - Participated in leadership training with the Center for Community Outreach at Penn State Behrend and a leadership course taught by the directors of the School of Science and School of Engineering
- Science Olympiad Supervisor
    - Acted as an event supervisor for the 2022 and 2023 NWPA Science Olympiad Competition for middle school and high school students
    - Co-led a Wabtec sponsored anatomy table for 4^{th} and 5^{th} graders in 2022