# *Lean 6σ Green Belt Project*

## Lean 6σ Implementation at Zoni Footwear Company

**Submitted to:**

Six Sigma Global Institute (SSGI)

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## 1. Company Background:

Zoni Footwear designs and manufactures athletic shoes with two factories in Mexico. One is located in Leon (Guanajuato) and the second in Guadalajara (Jalisco). Headquarters including product design, marketing and finance are located in New York.

## 2. Shoe Manufacturing Process:

The shoe manufacturing process at both locations, follows several steps.

- Prepared rolls of synthetic material and rolls of dyed, split, and suede leather are ordered from suppliers.
- Materials are received and stored in raw materials inventory.
- Manufacturing orders for shoes are issued.
- Material is withdrawn from inventory.
- Stamping processes produce the parts for the upper part of the shoe.
- Parts are sewn and glued together. At this point, the upper looks like a round hat not a shoe.
- The uppers are fitted to a plastic mold called a last.
- The uppers are cemented to the midsole, outsole and insole.
- Shoes are inspected.
- The shoe is then sent to finished goods inventory.

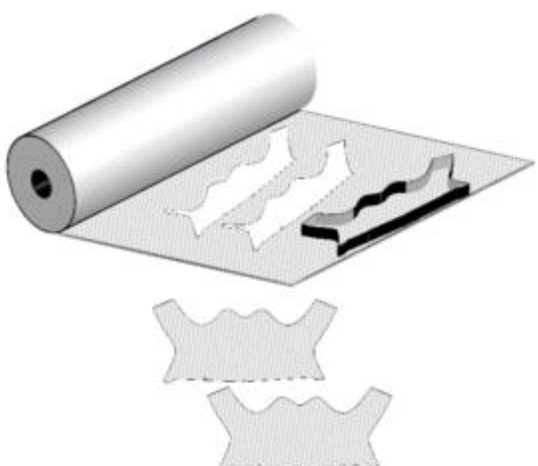

*Figure-1: Stampings are made from rolls of material*

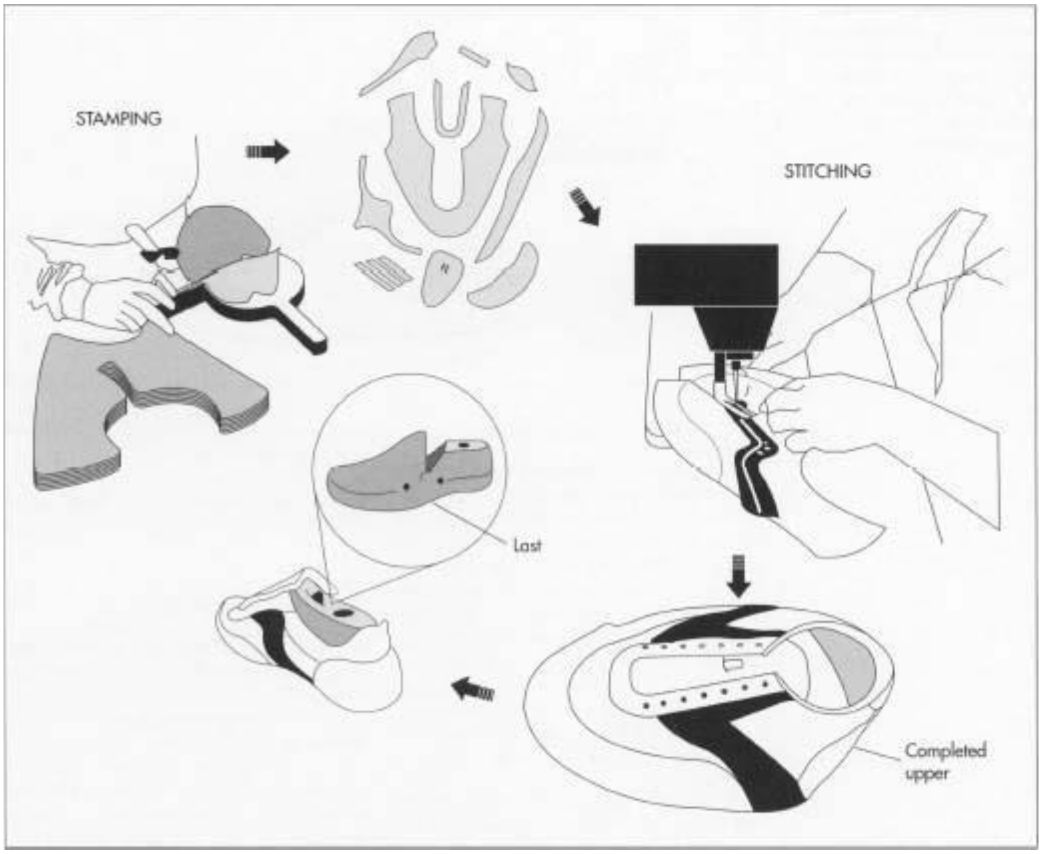


*Figure-2: A brief overview of the major steps in the manufacturing process for athletic shoes.*

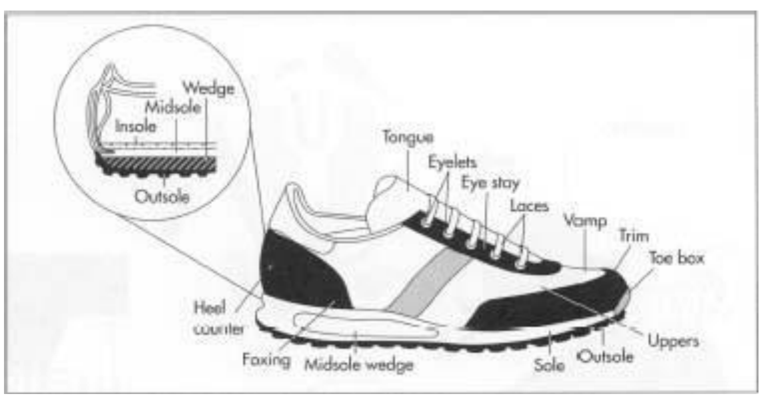


*Figure 3. Terminology of a running shoe*

## 3. Quality Control at Zoni Footwear:

Zoni's most popular shoe, the **XR-25**, is manufactured in lots of 400. Cycle time is the total time it takes to process a shoe, from raw materials to finished-goods inventory. Actual cycle time for the XR-25 is 2.3 hours. The standard time to produce a single shoe is 32 minutes.

At the end of the production cycle every shoe is subjected to a visual quality control check. Inspectors check for the following:


- Poor bonding between uppers and lowers.
- Weak, broken of damaged threads.
- Blemishes on synthetic or leather materials as shown to the right.
- Lack of flexibility and stability.
- Ability to withstand customer abuse.

When a significant number of shoes fail these tests, the process is considered to be out-of-control and a search for the root cause initiated.

***In the last year the demand for their products, especially the XR-25, has increased significantly. At the same time, however, there has been an increase in cycle time and customer complaints.***

## 4. Problem Statement: Efficiency and Quality

A Value Stream Map of the manufacturing process was drawn by a quality engineer (hypothetical) and the following problems were observed:

The map helps to understand why it takes so long to manufacture a batch of shoes.

- There is too much inventory between steps. Too much inventory between the receipt of a manufacturing order and the stamping operations, between stamping and sewing, between sewing and assembly, and between completing the shoes and quality control.

- These inventories cause delays in the manufacturing process and are wasteful. They contribute nothing to customer value, and this lack of efficiency is a symptom of even bigger problems with companies' processes.

- There are no formal guidelines to determine if a process is out-of-control and is not performing as expected. Yes, the company does visually inspect the shoes, but the tests are superficial. Only a few seconds for each shoe. Most of the shoes never get checked at all.

## 5. DMAIC approach to the problem.

DMAIC stands for Define-Measure-Analyze-Improve-Control. It is a data-driven improvement cycle used for improving, optimizing, and stabilizing business processes & designs. The DMAIC improvement cycle is the core tool used to drive Six Sigma projects. However, DMAIC is not exclusive to Six Sigma and can be used as the framework for other improvement applications.


*Figure 4. DMAIC Terminology*

### *Define*

The target process is the bonding of the uppers and lowers. In addition, efficiency of the entire manufacturing process has been identified as a problem. The primary problem is to improve the bonding, establish a new process including quality control procedures. The VOC demands shoes that will be stable, flexible, free of imperfections and where the bond between uppers and lowers is reliable over the life of the shoe. Critical to quality is the level of customer satisfaction which is largely dependent on bonding. While efficiency is a problem, the project first will focus on bonding.

### *Measure*

Inputs include fabric, adhesives, and labor. In this project the most important issue is the bond between uppers and lowers. The bonding can be measures on a scale of 1 to 10 where 1 represents unsatisfactory bond and 10 represents a satisfactory bond. Process parameters can be measured by cycle time. Productive cycle time is 32 minutes, but actual time is 2.3 hours. With a difference this large between actual and standard there is considerable room for improvement. A third metric is the size in units of the in-process inventory between specific stations in the manufacturing process.

# *Analyze*

There will be many components of the processes that must be analyzed. Several tools will be used. They include but are not limited to: Process flow using **Value Stream maps**; **X-Y analysis** to identify critical inputs; **Ordered histogram** to quantify extent of bonding problem; Testing and analysis of new adhesives; **Test of hypothesis** to determine if the new adhesive meets standards; **Re-engineering** of bonding process; **Control charts** to monitor process output; **Regression correlation analysis** to determine whether training could help further improve process output.

## 5.1. X-Y Matrix:

***# INPUTS:***

There are many inputs that affect process output, but we will focus on three. They include the **materials used, adhesives and stitching**.

The challenge is to determine which of the controllable inputs would contribute most to an improvement in output and should therefore be singled out for further analysis?

- In order to find out the Lean Six Sigma Tool X-Y matrix will be used.
- The inputs would include materials, bonding process, and stitching.

***# OUTPUTS:***

Process output would be measured in four ways: **product returns, customer satisfaction, returning customers and brand image.**

***# Importance of each output:***

Next, to estimate the importance of each output. The importance of product returns was estimated to be 5. The importance of customer satisfaction was estimated to be 9. The importance of returning customers was 9, and the importance of the brand name was 8.

***# Consequence of each input on four measures of output:***

Finally, it would be necessary to establish the consequence of each input on the four measures of output.

- The consequence of materials on product returns was 4 on a scale of 1 to 10. The consequence of bonding on product returns was 9. The consequence of stitching on product returns was 4.

- The consequence of materials on customer satisfaction was 5. The consequence of bonding on satisfaction was 8 and the consequence of stitching on satisfaction was 3.

- The consequence of materials on returning customers was 6. The consequence of bonding on returning customers was 7. The consequence of stitching on returning customers was 4.

- The consequence of materials on brand image was 8. The consequence of bonding on brand image was 6 and the consequence of stitching on brand image was 7.

Using this data, we will continue the X-Y analysis.

***The result suggested that bonding was the most import issue to address.***

| | LEVEL OF IMPORTANCE | | | | |
|---|---|---|---|---|---|
| | 5 | 9 | 9 | 8 | |
| | OUTPUTS (Y) | | | | |
| INPUTS (X) | Returns | Satisfaction | Return Cost | Image | Total |
| Materials | 4 | 5 | 6 | 8 | 183 |
| Bonding | 9 | 8 | 7 | 6 | **228** |
| Stitching | 4 | 3 | 4 | 7 | 139 |
| - | 0 | 0 | 0 | 0 | 0 |

*Figure 5. Final Output of X-Y Matrix*

X-Y Matric Excel File :

4.X-YMatrix.xlsm

## 5.2. Ordered Histogram:

While the X-Y matrix relied on intuition and experience to identify the most important issue to address, we still want concrete evidence that we are on the right track. To complete the analysis phase, we study 1000 (XR-25) shoes and then proceed to organize customer complaints by category. The table below summarizes the problems that were uncovered.

| Process Step | Customer Complaints |
|---|---|
| Poor Bonding | 70 |
| Weak Threads | 32 |
| Blemishes | 45 |
| Flexibility and Stability | 9 |
| TOTAL | 156 |

*Figure 6. Data on Customer Complaints w.r.t. Process Steps*

The results supported the claim that the most important issue was bonding.

To confirm we have prepared an ordered histogram of the data we had just collected.

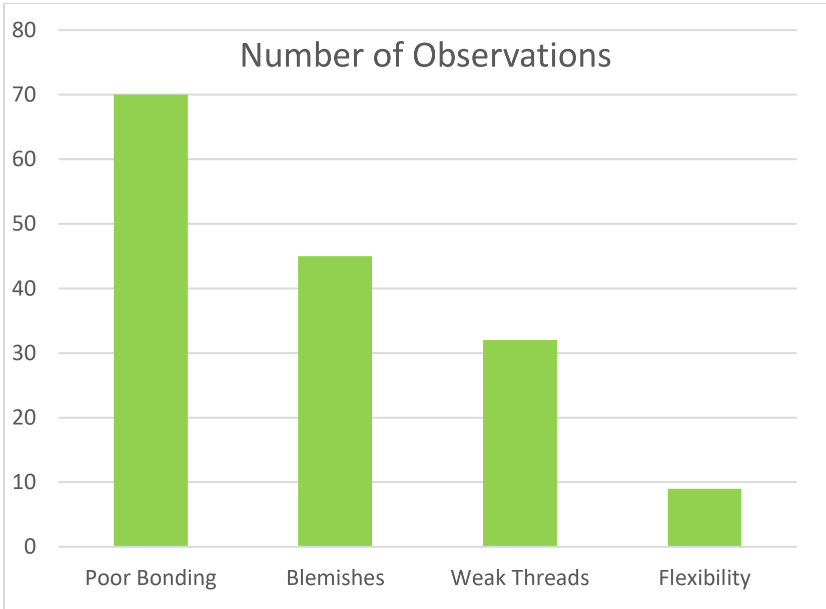


*Figure 7. Ordered Histogram for Customer Complaints*

Ordered Histogram Excel File :

5.Histogram
Ordered.xlsm

## 5.3. Defects per million opportunities (DPMO):

Based on the customer complaints in the 1000 (XR-25) shoes that we studied the DPMO comes to be 156 defects /complaints in 1000 units.

Hence we can conclude that the manufacturing process is no were near Six Sigma level which accounts to 3.4 DPMO.

## 5.4. Cost of Poor Quality (COPQ):

But what is the cost of poor quality? What costs do the company incur from a process that suffers from inefficiency and poor quality?

A high cost of poor quality would add further urgency to improving process performance.

As per the given data:-
For this calculation we decided to consider all shoes that Zoniwear manufactures. The average selling price per unit is $50. The cost to manufacture each shoe averages $15. The total number of units manufactured per year is 75,000. The percent of units found defective when subjected to the current quality control check is 5 %. The percent of units that the customer finds defective and returned for a full cash refund is 10 %. Of those units returned to the company, the percentage of customers who will take their business elsewhere and never purchase a Zoniwear product again is estimated to be 15 %. This last estimate can be used to help determine future lost sales attributed to poor quality.

**When we calculate the *Cost of Poor Quality* we compute it $1,612,500 per year.**

COPQ Estimator Excel File:

6.COPQ
Estimator.xlsm

# *Improve*

To improve the bonding process several different adhesives will be tested. Improvement will occur when a new process with a better adhesive is made operational. In addition, quality improvement will be assured with a new quality control system. While left to later, the background of this case suggests that by eliminating non-value-added steps such as unnecessary in-process inventory, process efficiency can improve. This will likely reduce cycle time. As a result, we would expect to decrease manufacturing costs while further increasing quality and improving customer value.

## 5.5. Process Re-engineering:

After collecting some information from the manufacturing department at the Leon plant.
Initially we need help in three areas.

- First, we need to find the best adhesive for the job. There are many vendors out there and we need to evaluate each one.

- Second,  need to work together and redesign the bonding process. We need to look at the steps we follow and determined if any need changing.

- Third, we need to find out how we can test the bond between the upper & lower soles.

We made several decisions after careful planning and considerations.

We can select a vendor for the adhesives using the Supplier Quality Checks. We approved several recommended changes for the bonding process as per the industry standards and  chose a machine that would work well for testing the adhesive bond to the shoes.

## 5.6. Testing the Bond:

With the preliminary work done, we decided to purchase one bonding tester. The machine would cost $55,000(given) and could test 12 shoes over a 4-hour period. The test involved bending and flexing the shoe over rapid cycles. At the end of the test, the bond would be tested and measured. The measurement scale would be from 1 to 10 where 1 represents unacceptable bonding and 10 represents excelling bonding. ***Most shoe manufacturers set 8.5 as a standard***.

## 5.7. Hypothesis Test:

Before the manufacturing process would be updated, one needs assurance that the new process would meet standards.
But how could one conclude that the new process would reach its target of 8.5?

To answer this question, a sample of 30 shoes was bonded using the new adhesive. The bonding data is shown below. While the mean was a bit off, we can consider if this was just a chance variation and that the process did actually meet the 8.5 standard. Before going any further, we also conducted a test of hypothesis, wherein our Target is 8.5.

| Sample | Result | Sample | Result |
|---|---|---|---|
| 1 | 8.8 | 16 | 8.8 |
| 2 | 9.2 | 17 | 9.2 |
| 3 | 8.4 | 18 | 8.6 |
| 4 | 9.1 | 19 | 8.7 |
| 5 | 8.3 | 20 | 8.8 |
| 6 | 8.5 | 21 | 8.2 |
| 7 | 8.6 | 22 | 8.6 |
| 8 | 8.8 | 23 | 8.5 |
| 9 | 8.5 | 24 | 8.4 |
| 10 | 8.7 | 25 | 8.6 |
| 11 | 8.8 | 26 | 8.6 |
| 12 | 8.7 | 27 | 9.1 |
| 13 | 8.5 | 28 | 8.3 |
| 14 | 8.9 | 28 | 8.8 |
| 15 | 8.5 | 30 | 8.6 |

*Figure 8. Sample data of 30 shoes bonded using new adhesive.*

**The test confirmed that the new adhesive met the target of 8.5.**

*Population mean (μ)*

8.5

Sample X

8.8
9.2
8.4
9.1
8.3
8.5
8.6
8.8
8.5
8.7
8.8
8.7
8.5
8.9
8.5
8.8
9.2
8.6
8.7
8.8
8.2

Significance Level:

- 0.01
- 0.05
- 0.10

One-tailed or two-tailed hypothesis?:

- One-tailed
- Two-tailed

*Figure 9. Hypothesis Test.*

Final Result:

The *t*-value is 3.634872. The value of *p* is .000534. The result is significant at $p < .05$.

Since p value is significant, the null hypothesis is rejected in favor of the alternative hypothesis which states that the population mean from which the sample has been taken is equal to or greater than 8.5.

<u>Consequently, the adhesive is doing its job.</u>

Hypothesis Test Excel File:

7.Hypothesis Test.xlsx

## Control

At a minimum this project requires a finished goods quality control system. It will require that samples be taken, the bond between the lowers and uppers determined, and the sample results plotted on a quality control chart. Controls must be established for process mean and variation. Finally, the quality control plan must be formalized and documented.

With confidence in the new process, the necessary changes at both plants where implemented.

After the process had successfully been in operation for a month, it was time to design the quality control system.

While the data of a previous sample of 30 shoes to test the bonding process had been taken, we would now create control charts to monitor the working process. we take 5 preliminary samples of 10 shoes each to determine the mean strength of the bond and its standard deviation.

| Observation | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1 | 8.8 | 8.0 | 8.6 | 8.9 | 8.6 |
| 2 | 8.1 | 9.3 | 8.8 | 9.1 | 8.3 |
| 3 | 9.4 | 8.8 | 8.7 | 9.1 | 9.1 |
| 4 | 7.9 | 8.5 | 9.2 | 8.1 | 8.4 |
| 5 | 8.8 | 9.2 | 9.1 | 7.9 | 8.8 |
| 6 | 8.3 | 9.1 | 8.8 | 8.5 | 9.2 |
| 7 | 9.2 | 8.7 | 8.4 | 9.1 | 9.2 |
| 8 | 8.0 | 8.5 | 8.7 | 8.2 | 8.4 |
| 9 | 8.8 | 9.3 | 8.8 | 8.4 | 8.6 |
| 10 | 9.1 | 8.8 | 7.2 | 8.7 | 8.9 |

*Figure 10. Preliminary sample data for control charts.*

The **grand mean** from these samples was **8.688** with a **standard deviation** of **0.5**.
Two control charts would be created, one for the sample mean and the second for the sample variance.

Control Chart Selection Excel File:

8.Which Control Chart.xlsm

## 5.8. Control Charts:

X̄-Chart Excel File:

9.Control Charts
X_Bar bet. 12-25.xlsn

S-Chart Excel File:

10.Control Charts
S-Chart bet. 12-25.xl

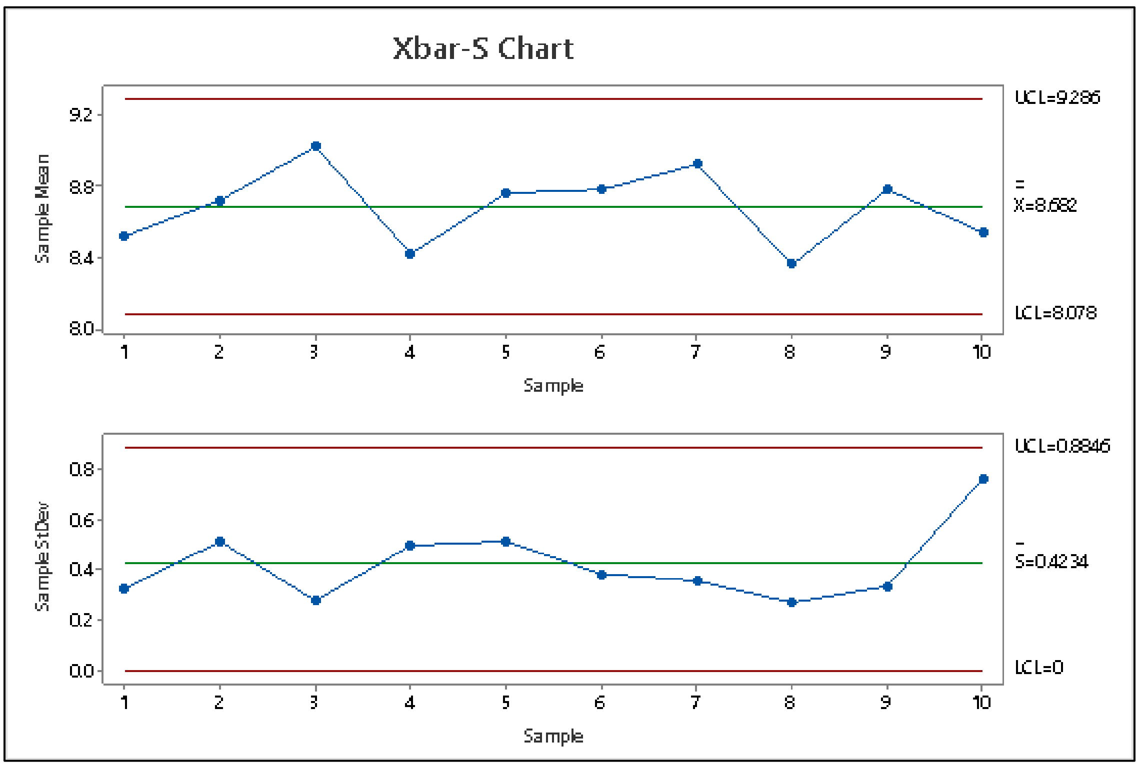


*Figure 11. X_Bar & S Chart created using Minitab.*

- Once the control charts are completed, samples of 13 shoes would be taken each day.
- **The number of shoes sampled was kept small because each shoe would be destroyed during the bonding test**.
- The mean and variability of the sample would subsequently be plotted on these two quality control charts.

## 5.9. Variation in Quality Between Leon and Guadalajara Plant:

**The new system proved successful**. Quality improved and fewer customers complained of bonding problems. But there was one issue that had yet to be resolved. We can easily suspect that if the quality of the products from the Leon plant was different from the quality produced at the Guadalajara plant. Again, data was collected. The bonding tests at the Leon plant ranged from 7.7 to 8.9 with an average of 8.5. We collected 10 bonding samples. The data are shown below.

| | Leon | Guadalajara |
|---|---|---|
| 1 | 7.3 | 9.1 |
| 2 | 8.9 | 8.8 |
| 3 | 7.4 | 7.2 |
| 4 | 7.8 | 9.4 |
| 5 | 8.1 | 8.1 |
| 6 | 7.7 | 7.5 |
| 7 | 7.2 | 8.2 |
| 8 | 8.1 | 6.9 |
| 9 | 7.9 | 7.7 |
| 10 | 8.4 | 6.8 |

*Figure 12. Sample data for bonding tests from two locations.*

We conduct a Multi-Vari analysis, and it appears that the range as well as the average for Guadalajara was greater than that for Leon. We need to make a note of this and address the problems using the same DMAIC terminology at the Guadalajara plant.

A Multi-Vari Chart compares the variation in two or more processes to determine which process or processes are contributing to variation. Since one objective of process control is to keep output variation within a specified range and thereby assure consistent output, a Multi-Vari chart is an important tool in Six Sigma analysis. First, we collect output data for each process. Once the data is collected and displayed, variation can be observed without resorting to more complex statistical methods.

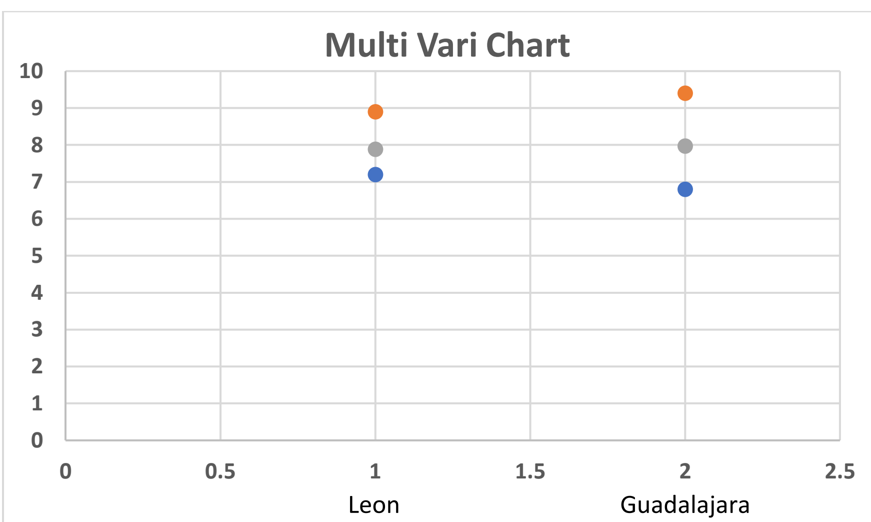


*Figure 13. Multi Vari Chart for the bonding tests data at two locations.*

## 5.10. Would Training Help?

Along with process re-engineering we can focus on one more concern which is the **human factors** in the manufacturing process. Since these process lines are depended on operator skills, the question of training the labor workforce remained. **Does training affect product quality?**

We can go back-and-forth about the value of training and collect some data to validate this claim. One can argue that there is a payoff, but how strong is that **relationship** between the training of workforce vs. the level of product quality.

The data over a period of 20 months was collected to check this relationship and is shown below. Output quality was measured on a scale of 1 to 100 where 100 represented top quality. Training was measured by the number of hours scheduled for those working on the line.

| | Quality | Training Hours |
|---|---|---|
| 1 | 72 | 4 |
| 2 | 81 | 9 |
| 3 | 82 | 10 |
| 4 | 70 | 5 |
| 5 | 78 | 8 |
| 6 | 66 | 3 |
| 7 | 81 | 7 |
| 8 | 72 | 6 |
| 9 | 63 | 2 |
| 10 | 77 | 5 |
| 11 | 68 | 1 |
| 12 | 92 | 12 |
| 13 | 70 | 4 |
| 14 | 71 | 2 |
| 15 | 88 | 11 |
| 16 | 70 | 3 |
| 17 | 77 | 7 |
| 18 | 79 | 8 |
| 19 | 73 | 6 |
| 20 | 84 | 9 |

*Figure 14. Data comparing Satisfaction with Quality.*

Two questions needed to be addressed.

- Was there a relationship between output quality and the number of hours of training, and if there was, how strong was it?

Answering these questions would help to determine how much and how often training should be scheduled.

To answer this question, we will use linear regression analysis between the two mentioned variables. After implementing a linear regression model, we get the following results:

| Regression Equation: | |
|---|---|
| **Quality = 62.18+2.21602 * (TrainHours)** | |

| | | |
|---|---|---|
| Q) | Is the regression equation significant at the 0.05 level? | **Yes** |
| | The p value is 1.93e-09. This means the decimal point should be placed 9 places to the left. So the results are certainly less than 0.5 | |
| Q) | What is the R-squared? | **0.8709** |
| Q) | Is the coefficient of the independent variable significant? | **Yes** |

*Figure 15. Results for Linear Regression Analysis.*

To Conclude:

**Training is significant with respect to quality.**
**The regression equation explains 87 percent of the variation in Quality.**
**More resources should be allocated to training.**

***Note:*** **If this analysis is conducted in Excel, the results will vary to a very small degree.**

## 6. Conclusions:

- Successfully implemented process optimization in shoe manufacturing setting using LEAN 6σ tools and techniques.
- A Value Stream Map of the manufacturing process was drawn by a quality engineer (hypothetical) and problems in the manufacturing process such as improve the bonding, establish a new process including quality control procedures were observed and addressed.
- Using X-Y Matrix we got the result that bonding was the most import issue to address in the manufacturing process.
- Using Ordered Histogram and sample collected data we proved the claim that the most important issue was bonding.

- Using DPMO, we concluded that the manufacturing process is no were near Six Sigma level which accounts to 3.4 defects per million units.

- We calculated the Cost of Poor Quality and concluded that the company incurred a loss of $1,612,500 per year from a process that suffers from inefficiency and poor quality.

- After the root cause problems were known we implemented process re-engineering to provide solutions to them and did hypothesis testing using sample data to prove the new improvements were viable and correct.

- With confidence in the new process, the necessary changes at both plants where implemented and after a month of successful operation, appropriate control charts ($\bar{X}$ & S charts) where incorporated to design the quality control system.

- A Multi Vari Analysis was carried out in the end to compare the manufacturing results of Leon and Guadalajara plant to check if the same product manufactured at two different locations had any variations.

- Lastly, since shoe manufacturing includes human workforce, we calculated the relationship between the workforce quality training and its impact on the quality of the product (shoe). The results yielded that there is a strong relationship and trained workforce results in better quality shoes being manufactured.