San José State University

Warehouse Efficiency Improvement Project at BG Manufacturing –

The Six-Sigma Approach

ISE 250 – Leading Six Sigma Improvement Project

Project Team:

Samarth Bhargava (011549642)

Shyam Sundar Krishnan (011825528)

Rakesh Manjunath (011822525)

Huai-Chen Shih (011812684)

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Abstract

The main purpose of this project is to apply Six-Sigma tools in the improvement of the process at BG manufacturing company. The objective of this project is to assess and analyze the process and check for various possible solutions to improve the process and suggest recommendations to increase the customer satisfaction and to improve the quality of the process by reducing the time. The initial analysis of the process showed that the time taken to finish an order request is high compared to the other competitors which increased the budget of the company. By using the Six sigma (6σ) approach we could identify the main causes for the delay in the process. Later we decided to move forward and use the Define Measure Analyze Improve Control (DMAIC) approach which would be the best way to resolve the problems. And by using DMAIC approach we could sort out the major causes and make feasible recommendations to the company for continuous improvement.

Introduction

Six sigma is one of the special tool largely used all over the world by most of the companies where companies desires to maintain and improve the world class quality with proper execution and continuous improvement. Six Sigma (6σ) is most often used in almost all parts of the world in all manufacturing companies where the process variation is analyzed using different tools and techniques to examine the quality of the product or process and improve its quality, helps improve customer satisfaction, and reduces the cycle time. It also helps in identifying the defects and its root cause for the problem so that a possible solution can be used to overcome the issue and improve the quality, quantity, time and satisfaction.

BG Company is a leading manufacturing company producing various electronic components and different testing equipment’s. Since the company works on manufacturing various components, it's required to maintain enough supply of goods required for the manufacturing process. The company has two different warehouses located in a short distance from the company. One small warehouse located next to the company and another big / main warehouse located one mile away from the company. All employees were given with the required tools for the job. If required they can request for the tool from the smaller warehouse or from the main warehouse. But the tools collected were not returned, if tools not available in the smaller warehouse instead of checking in the main warehouse they go to a third party to purchase a new tool which is available in main warehouse. Smaller warehouse not monitoring the availability of tools, time taken to deliver the tool from main warehouse to the smaller warehouse is high, wrong tools were given to the employees and all the equipment's stored in the warehouse were not organized. We have decided to use the six sigma techniques and tools to identify the issues, find the root cause of the problem and recommend the company the feasible solution.

PROJECT CONSTRAINTS

Due to non-discretionary issues company management did not provide us the financial details to analyze their purchase information to calculate the profit/loss details. Only data's related to quantity of goods picked & packed and time taken to deliver is collected during the project. Further details about the financial status were not available before and after improvement process.

SOLUTION APPROACH

Since it is an existing process we thought using the six-sigma tool and techniques will help us improve the process by using the DMAIC (Define, Measure, Analyze, Improve and Control phases). Initially we planned to identify the various steps involved in the process by using the SIPOC (Supplier, Inputs, Process, Outputs and Customers). Later the project team collected various data's with respect to picking, packing, shipping and delivering process. After collecting all the required data's for the project the project team analyzed the process bottlenecks. Then the problems / issues were identified by using the Ishikawa diagram / Fish bone Diagram by identifying the root causes for the issues / problems. Brainstorming helped us in identifying the potential problems and feasible solutions for the problems. After collecting all the required information for the process the project team validated all the information for the possible improvement for the project and came out with the best suitable recommendations for the problems / issues. The recommendations were provided to the company for implementation and fresh data's have been collected after implementation of the recommendation. The data collected before and after recommendation has been compared, data's were compared both graphically and statistically. By using the "before" and "after" state data's we plotted different control charts for various process to compare the improvement.

DEFINE PHASE

The Define Phase help us figure out the definition of the project. We create a Charter to define the problem to solve, the purpose of the project, the scope of the project, things to deliver, the measurements, and resource we can use. We also provide a SIPOC table to help us understand the process and the scope of the problem.

PROJECT CHARTER

OVERVIEW

BG Manufacturing is a producer of electronic components and testing equipment. It has two warehouses, a main warehouse 1 mile away and a smaller one for convenience next to the central office. The smaller warehouse is used to store all the commonly and daily used materials while the bigger one stores the rest of the inventory. The company faces the problem in the inventory management that the employees are ordering the materials required to the smaller warehouse from the third party rather than getting it from the main warehouse. The inventory cost of BG Manufacturing increases because they use extra space in the large warehouse to store the materials. Also, they waste money to buy the materials they already have. Since the warehouses are poorly managed, we are committed to offer improvement solution to help the organization to manage the warehouse.

PURPOSE

Since inventory costs are wasting in BG Manufacturing, we want to find a solution to solve the problem. Our goal is to apply DMAIC tools to reduce the inventory costs and enhance the efficiency of the smaller warehouse.

SCOPE

Here are the scopes listed:

- Standards and procedures for picking, packing, and shipping
- Inventory management skills
- Data collecting
- Statistic testing

DELIVERABLES

Here are the deliverables:

- Present the report by May 16th, 2017
- Provide required training to employees to follow the standard and procedure
- Provide inventory managing skills
- Provide feasible recommendations for the improvement.

MEASURES:

Here are the measures:

- The shipping on-time process time are used as the measurements
- The picking and packing accuracy are used as the measurements.

PROJECT TEAM:

Process improvement team comprise of following and their roles

- Samarth Bhargava – SME
- Shyam Sundar Krishnan – Project manager and expert in sigma
- Rakesh Manjunath – Data analyst
- Huai-Chen Shih – SME subject matter expert

Stakeholders - BG Manufacturing manager, inventory manager

SIPOC

From the SIPOC, we can see the process of the warehouse. Internal employees first go to the small warehouse to find the materials. If there are no materials in the small warehouse, they must inform the large warehouse. If there are no materials in the large warehouse as well, they can order them from the materials suppliers. And if the large warehouse has the materials, it will take time to deliver them to the small warehouse. Therefore, some employees skip the phase of asking the large ware house, and order the new materials instead, even if there were materials they need in the large warehouse.

<table>
<tr><th>Suppliers</th><th colspan="2">Inputs</th><th>Process</th><th colspan="2">Outputs</th><th>Customers</th></tr>
<tr><td>Material suppliers</td><td colspan="2">Materials</td><td rowspan="2">Shown below</td><td colspan="2">Materials</td><td>Internal employee</td></tr>
<tr><td></td><td colspan="2">Human resource</td><td colspan="2"></td><td></td></tr>
<tr><td colspan="7">Process</td></tr>
<tr><td colspan="7">Internal employee make a requirement of materials</td></tr>
<tr><td colspan="7">Check the small warehouse</td></tr>
<tr><td colspan="2">If there are materials in the small warehouse</td><td colspan="5">If there aren’t materials in the small warehouse</td></tr>
<tr><td colspan="2">Deliver the materials to the firm</td><td colspan="5">Inform the large warehouse</td></tr>
<tr><td colspan="2" rowspan="5"></td><td colspan="5">Check the large warehouse</td></tr>
<tr><td colspan="3">If there are materials in the large warehouse</td><td colspan="2">If there aren’t materials in the large warehouse</td></tr>
<tr><td colspan="3">Deliver the materials to the small warehouse</td><td colspan="2">Order the materials from the suppliers</td></tr>
<tr><td colspan="3">Deliver the materials to the firm</td><td colspan="2">Allocate the materials</td></tr>
<tr><td colspan="3"></td><td colspan="2">Deliver the materials to the firm</td></tr>
</table>

Table 1 : SIPOC

MEASURE PHASE

Measure phase is the second phase in the DMAIC. We have coordinated with the BG company management and collected the required data’s for the project such as number of items picked, number of items packed, number of items correctly picked, number of items correctly packed, Shipping details, delivery details. By using the collected information we have identified the accuracy / efficiency of picking and packing and the time taken for shipping and delivering.

DATA COLLECTION AND MEASUREMENT

Data has been collected about defects involved in picking, packing and calculation of shipping time. The time taken for shipping of item on time is also measured. Each step in the process is identified and timed as the process continues. Pareto chart is drawn to identify the key elements of the problem-Picking, Packing, Shipping on time. Percentage/ number of defects of total items or equipment processed is calculated to validate Pareto analysis. Control charts are drawn to statistically examine the process.

The following measurement criteria was established:

Picking process –

- Picking accuracy: the % of items picked correctly per picker and overall per day.
- Average number of items picked per hour per picker and overall.
- Number of errors found at the time of picking.

Packing process –

- Packing accuracy: the % of items packed correctly per packer and overall per day.
- Average number of items packed per hour per packer and overall.
- Number of errors found at the time of packing.

On-time shipping process –

- Time when order was placed for shipping.
- Approval time.
- Time when item is ready to be shipped.
- Work completed / shipment complete time.

Data Collection for Picking process:

Date	Items Picked	Items Picked Correctly	% Picked Correctly
3/21/17	245	224	91.42857143
3/22/17	190	168	88.42105263
3/23/17	197	187	94.92385787
3/24/17	222	211	95.04504505
3/27/17	207	194	93.71980676
3/28/17	260	242	93.07692308
3/29/17	176	166	94.31818182
3/30/17	158	140	88.60759494
3/31/17	206	195	94.66019417

Table 2 : Data collected for Picking process.

Data Collection for Packing process:

Date	Items Packed	Items Packed Correctly	% Packed Correctly
3/21/17	227	216	95.15418502
3/22/17	175	165	94.28571429
3/23/17	197	174	88.3248731
3/24/17	212	201	94.81132075
3/27/17	199	187	93.96984925
3/28/17	204	194	95.09803922
3/29/17	166	154	92.77108434
3/30/17	125	119	95.2
3/31/17	219	199	90.86757991

Table 3 : Data collected for Packing process

Data Collection for On-time shipping process:

Order No	Order time	Approval time	Time when ready to be shipped	Work completed time
1	09:15	10:25	10:45	01:30
2	09:25	10:05	10:30	01:45
3	10:15	11:30	12:05	02:30
4	09:00	10:15	12:05	02:45
5	10:25	11:30	01:00	03:15
6	09:45	10:30	11:45	02:30
7	09:20	10:15	11:30	03:15
8	10:10	11:00	12:30	03:25
9	10:05	11:30	12:45	02:35
10	09:30	10:15	12:15	03:15
11	09:35	10:00	11:30	02:30
12	10:45	12:15	02:15	04:30
15	11:00	12:30	02:30	04:45

Table 4 : Data Collected for On-time Shipping process

Data was collected for few orders from the time its packed and ready to be shipped till the item has been shipped/work completed. Data was collected using stop clock.

Using the above data collected, we could develop Pareto charts for each of the process – Picking, Packing and Shipping.

PARETO CHART

The Pareto Chart helped us to visualize the errors in the process which required improvement. From the data’s collected earlier we have plotted the Pareto chart which displayed the variation in the process with respect to accuracy and time. Based on which we concentrated on the errors depending upon the percentage of errors.

Pareto chart for Picking process:

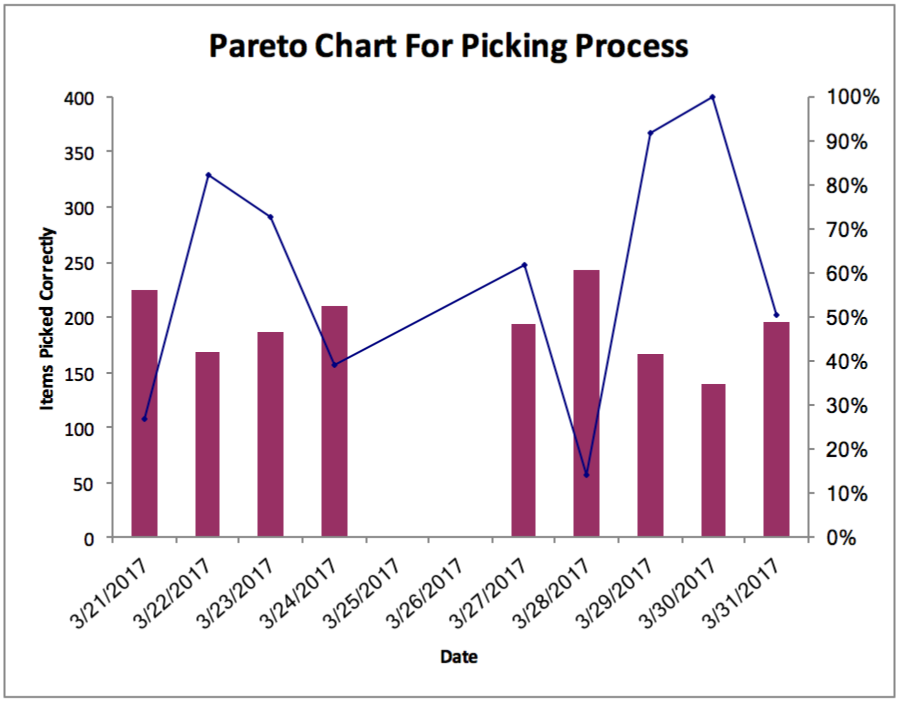

Figure 1:Pareto chart for Picking process

Pareto chart for packing process:

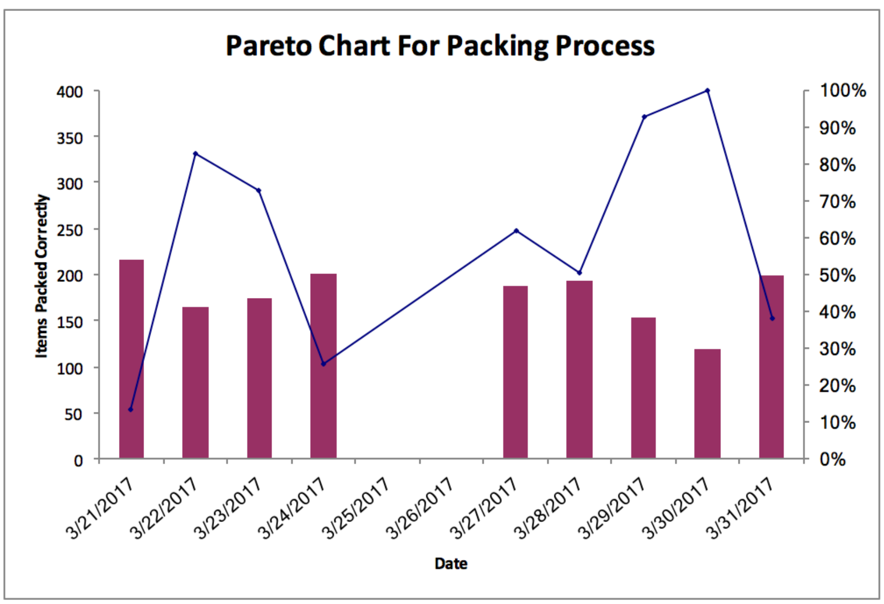

Figure 2:Pareto chart for Packing process

Pareto chart for error analysis during the process:

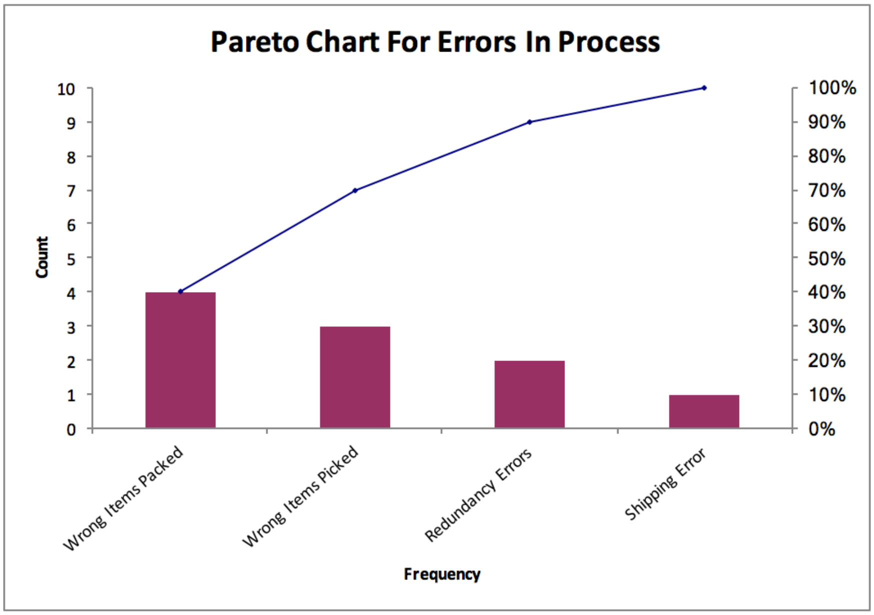

Figure 3:Pareto chart for error analysis during the process

ANALYZE PHASE

Analyze is the third step in DMAIC. In this phase, a detailed analysis is done in order to identify the root cause of the problem-service time. Ishikawa diagram is done to detail the causes for the effects identified in the Pareto analysis. Then a Root Cause Validation is done to validate the major causes for the same we propose solution for improvement.

The "as is" analyses of the Inventory for the company is done and the following observation are found.

ISHIKAWA DIAGRAM:

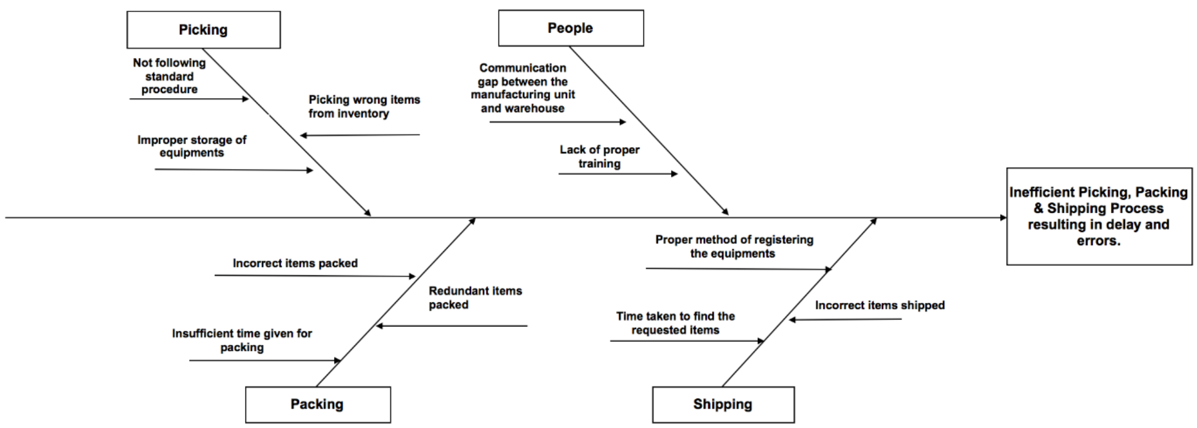

Figure 4:Ishikawa Diagram

ROOT CAUSE VALIDATION:

Cause Description	Significant	Non-Significant
People		
Lack Of communication gap between employees	v	
Lack of proper training for the employees	v	
Stressed out employees		v
Picking		
Employees not following standard procedure	v	
Picking wrong items from the inventory	v	
Loss of order receipt		v
Improper storage of equipment	v	
Packaging		
Items incorrectly packed	v	
Redundant items packed	v	
Insufficient time for packaging	v	
Packing material not available		v
Shipping		
Not using proper method for registering equipment	v	
Incorrect items shipped	v	
Unavailability of shipping trucks		v
Time taken to find the requested items	v	

Table 5:Root Cause Validation

IMPROVE PHASE

The main purpose of the DAMIC Improve phase is to identify the root cause of the problem and to categorize the solutions to overcome the problems. This phase helps the company to resolve the issues / problems identified by finding an action plan to overcome the issues. This phase helps us to choose the best suitable method to solve the problem.

The analyze phase helped in identifying the causes of the problems and its root causes. By analyzing all the possible solutions in the inventory management, the improve phase is used to address the problems.

The root causes of the problems were identified and listed in the cause and effect diagram.

FMEA (Failure Mode and Effects Analysis)

Failure Mode and Effects Analysis is a systematic approach used to identify the potential causes of the problem, then the problems were analyzed for the possible solutions and everything is documented. FMEA method is carried out throughout the process to improve the performance and to reduce the cost and time.

An RPN (Risk Priority Numbering) is calculated based on the root causes categorized between Low, High and Critical Risks.

Risk Priority Numbering = Severity * Occurrence * Detections.

The values for Severity, Occurrence and Detection are allotted between 1-10 depending on the severity of the cause.

RPN Prioritization Table:

Priority	RPN	Action Required
Critical	>350	Unacceptable risk; failure mode shall be eliminated.
High	101-350	Failure mode severity and/or probability of occurrence shall be reduced to bring down RPN to "Low".
Low	< 100	Acceptable risk; at team's discretion, investigate design modifications, alternative designs, or incorporate preventive maintenance program to reduce risk.

Table 6:RPN Prioritization Table

FMEA Tables:

ess /Input Design	Potential Failure Mode	Potential Effect(s) of Failure	SEV	Potential Cause(s)/Mechanism of Failure	OCC	Current Process Controls To Prevent Failure	DET	RPN	Recommended Actions	Person Responsible For Actions	SEV	OCC	DET	RPN
y in ing ntory	Non-availability of tools	Tools has to be bought from third party	10	Poor planning in maintaining inventory.	5	Monitor the usage of the tools frequently and place orders by forecasting the usage.	10	500	Forecast the availability and order in a weekly basis.	Inventory Manager	6	3	5	90
	Wrong picking strategy	Forces the employees to look for alternate options.	10	Not following the standard procedure.	4	Follow company's standard procedure.	7	210	Train and test the employees about company's standards and procedures.	Management.	6	4	4	96
	Improper storing of inventories.	Will increase the search time of the inventory. Which potentially increases the packing time.	10	Poor warehouse management.	5	Using bins with proper labeling system.	10	500	Using warehouse management software like SAP, Maximo, etc. to maintain a proper warehouse.	Inventory Manager.	8	3	4	96
	Staff's Inadequate knowledge about warehouse management.	Increases the delay in packing the tool.	8	Employing a person without prior knowledge or experience about warehouse management.	7	Train the employees before assigning tasks.	8	448	Management should arrange for trainings periodically.	Inventory Manager.	6	3	4	72
	Miscommunication between employee and warehouse staffs.	Delivering wrong items or increases delay in delivery.	8	Communication issues.	6	Confirm the order with the customer/employee.	7	336	Management must arrange for trainings for employees to improve their interpersonal skills.	HR department.	5	4	4	80

Table 7:FMEA Table for Delay in Packing the inventory

It is recommended to implement the 5s technique. 5stechnique involves Sort(SEIRI), Set in order (SEITON), Shine (SEISO), Standardize (SHEIKETSU) and Sustain (SHITSUKE).

Process Step/Input or Design Item	Potential Failure Mode	Potential Effect(s) of Failure	SEV	Potential Cause(s)/ Mechanism of Failure	OCC	Current Process Controls To Prevent Failure	DET	RPN	Recommended Actions	Person Responsible For Actions	SEV	OCC	DET	RPN
Delay in shipping the inventory.	Missing orders from smaller warehouse.	Increases the shipping time.	8	Staff misplaces the order receipt due to lack of attention.	4	No control measures.	4	128	Follow up with the main warehouse and check the status. Use inventory management software's to place orders.	Inventory Manager.	7	3	2	42
	Delay due to defects.	Increases shipping time.	7	Malfunction due to improper maintenance.	3	Repairing the available tool.	3	63	Periodic maintenance will reduce the defects. Implement 5s.	Maintenance Dept.	6	2	2	24
	Inaccurate data entry.	Delay the shipping.	8	Software malfunction or human errors.	4	Trouble shoot the software. Enter data's with care.	4	128	Required training must be provided for the staff's.	Staffs.	5	3	2	30
	Process inefficiency.	Increases the waiting time of the employees.	7	Too much paper works and approvals.	5	Approve / reject and clear all outstanding requests	5	175	Use the software for any request or approval.	Management.	5	2	2	20
	Lack of performance.	Delay in processing the request.	8	Staffs are not monitored properly.	4	Monitor the productivity of the employee's performance.	3	96	Set targets for each employee and monitor them to meet the targets.	Inventory Manager.	6	2	2	24

Table 8:FMEA Table for Delay in shipping the inventory

Process Step/Input or Design Item	Potential Failure Mode	Potential Effect(s) of Failure	SEV	Potential Cause(s)/ Mechanism of Failure	OCC	Current Process Controls To Prevent Failure	DET	RPN	Recommended Actions	Person Responsible For Actions	SEV	OCC	DET	RPN
Delay in delivering orders.	Delay in delivering due to transportation.	Increases delivery time.	9	Delay in delivering inventories periodically.	5	Deliver the inventories whenever required.	2	90	Arrange for the proper transportation to deliver goods whenever required.	Transportation Manager.	7	4	2	56
	Reactive delivery planning method.	Increase delivery Time.	9	Pending deliveries from the previous days order.	4	Deliver each day's package the same day to avoid accumulation of orders.	2	72	Prioritize and deliver important inventories and deliver the rest periodically.	Inventory Manager.	7	3	1	21
.	Prioritization of orders.	Increases delivery time.	9	Not prioritizing the orders based on need.	3	Check the importance of the inventory and prioritize the delivery.	3	81	Use the prioritization option in the software and arrange for quick action.	Inventory Manager.	7	2	2	28
	Delivering Wrong inventories.	Increases Deliver time.	10	Inaccurate data entry or malfunction in software.	5	Verify the order and confirm the order by checking the items.	8	300	Use the RFID and check the order, shipment details. Confirm the order prior to delivering by comparing with the order placed.	Inventory Manager.	4	4	6	96

Table 9:FMEA Table for Delay in Delivering the orders

ROOT CAUSE ANALYSIS AND FEASIBLE SOLUTIONS

Root cause	Major Sub Causes	Feasible Solutions
Delay in picking and packing inventories.	Not following standard procedure. Requesting for the inventories just before the job.	Follow the standard request procedure, plan before and request for the required inventories well before time. Employees should request for the tools by giving sufficient time for the warehouse supervisor / in charge to arrange for the tools.
	Not returning the tools taken from the Warehouse	Employees after finishing the jobs should return their collected tools to the warehouse.
	Time taken by the warehouse team to provide tools to the employees.	Warehouse staffs should maintain all the frequently used tools in the small warehouse. Sufficient quantity of the frequently used tools should always be available. If some tools are less in quantity, small warehouse staffs should coordinate with the main warehouse and arrange for the tools.
	Communication gap between small warehouse and main warehouse staffs.	Small warehouse staff should communicate with the main warehouse to maintain the availability of the frequently used tools.
	Labelling the storage locations and maintaining a proper register.	All the storage area to be labelled properly and a register to be maintained so that any warehouse employee can access the requested tool without anyone help.

Table 10:Delay in picking and packing the inventories

Root Cause	Major Sub Cause	Feasible Solutions
Delay in shipping inventories.	Lack of training for the warehouse employees.	All the warehouse employees should be given proper training with the latest technology and use the latest software to maintain inventory.
	Non-availability of the tools / inventory.	Warehouse staffs should do a regular check on the tools / inventories in the smaller warehouse and refill the tools / inventories whenever required. Warehouse staffs should maintain the inventories employee friendly by proper maintenance so that employee can work safe.
	Improper storage of the inventories.	All the inventories should be stored in a proper location in the warehouse, so that warehouse employees can find the requested tool immediately without any hassle. A well experienced staff should be appointed to maintain all the inventories in the warehouse.
	Insufficient storage space in the warehouse.	Warehouse staffs should frequently check the inventories in the warehouse and monitor the usage of the tools to find which inventory is used often, moderately and rarely. So that the smaller warehouse can move the rarely used inventories to the main warehouse.
	Finding the requested tools.	All the inventories should be properly tagged with details and the storage location to be organized in a way anyone can access any inventory anytime.
	Labelling the storage locations and maintaining a proper register.	All the storage area to be labelled properly and a register to be maintained so that any warehouse employee can access the requested tool without anyone help.

Table 11:Delay in picking and packing the inventories

Root Cause	Major Sub Cause	Feasible Solutions
Delay in delivering inventories.	Delay of delivery due to transportation.	Warehouse usually arranges transportation periodically. Warehouse should change their transportation strategy to deliver the goods depending on the urgency.
	Delay in delivering tools from main warehouse to smaller warehouse.	Employees should provide sufficient time to the warehouse staffs to arrange for the requested tools. Also, the warehouse staffs should transport / arrange for the tools in a short duration to avoid employees buying from the third party.
	Reactive delivery planning method.	Warehouse staffs must prioritize in delivering the inventories. Warehouse should deliver the orders requested for the day the same day to avoid backlogs.
	Delivering wrong inventories.	All inventories must be cross checked with the original order prior to delivering. Using RFID will reduce the verification time if all data's are entered accurately.

Table 12:Delay in delivering Inventories

By analyzing the data's before implementing the recommended solutions the root causes for the problems were identified and the feasible solutions were given to the company for implementation. After implementing the proposed solutions, we collected the data's and compared the data's with the "before" state. While comparing the results from "before" and "after" state data's we have achieved the following:

1. Reduced the time taken to deliver the inventory.
2. Increased the picking, packing and shipping efficiency.

CONTROL PHASE

CONTROL CHARTS

Based on the data collected on the picking, packing and shipping process we develop X bar charts. After continuous monitoring of these process we collect the ‘as is’ data and ‘improved process’ data.

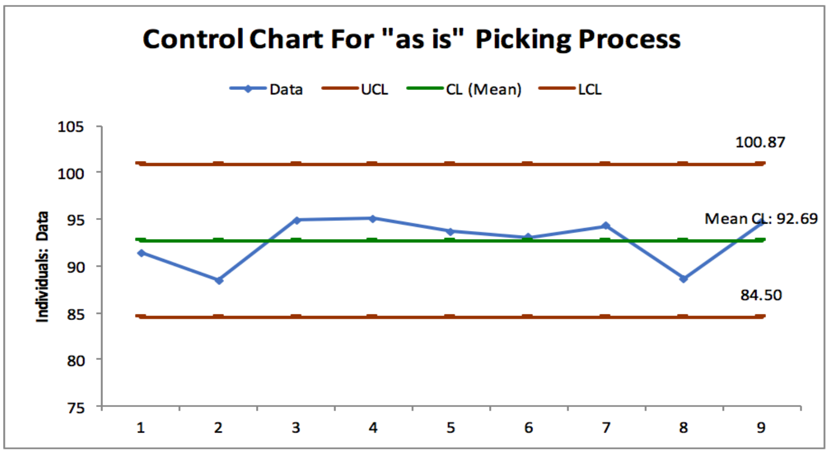

Figure 5:Control Cart "before" picking process

The above chart shows the “as is” Picking process, the percentage of correctly picked items before implementation of DMAIC method. The above was collected for a week and half (9 working days) and average of the correctly picked items was about 92.69%.

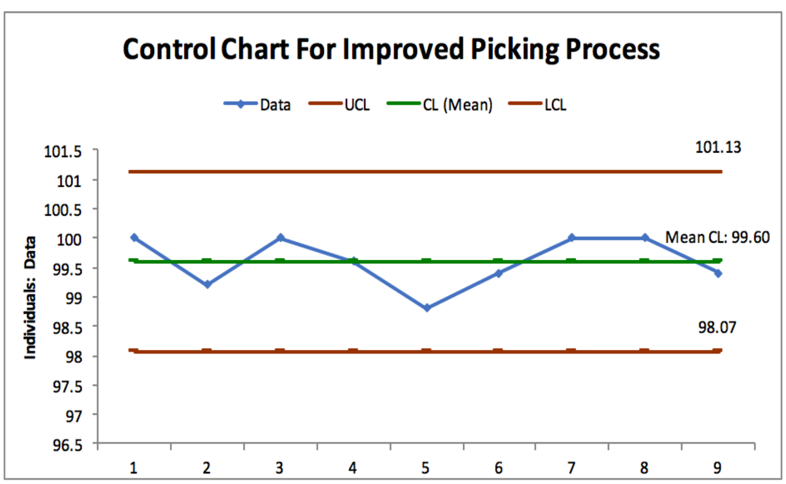

Figure 6:Control Chart "after" picking process.

In the above chart, is for the data collected for the improved process. Here the percentage of correctly picked items has improved to 99.60%. It is seen that the data falls between the control limits and exhibits less variation unlike the “as is” process.

Similarly, the data was collected for Packing and Shipping time process and X-bar charts was developed.

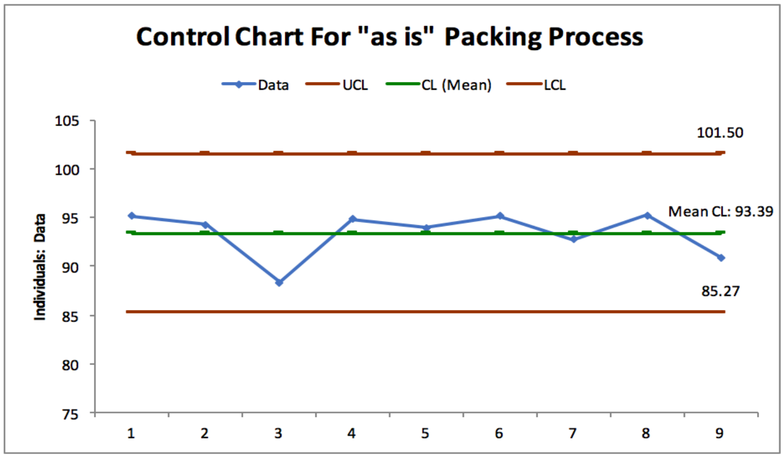

Figure 7:Control chart "before" packing process

The percentage of correctly packed items was about 93.39% and in this old process it exhibited more variation due to redundancy and improper techniques.

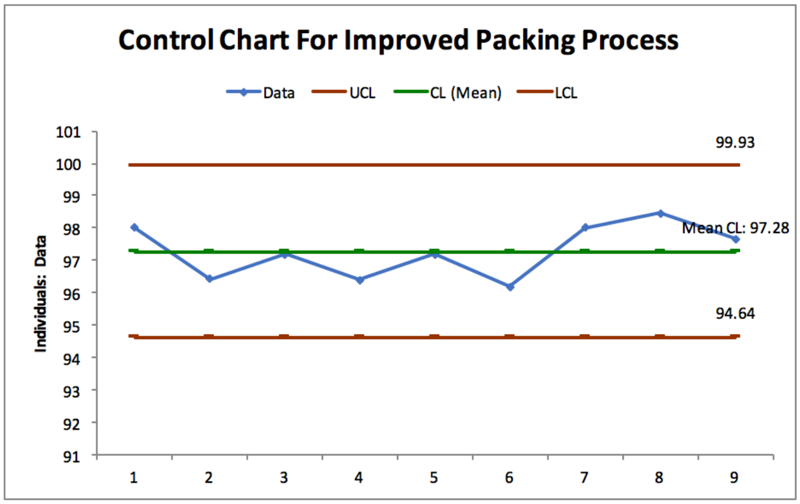

Figure 8:Control chart "after" packing process

The data was under control limits and we observed improvement in the percentage of correctly packed items up to 97.28%.

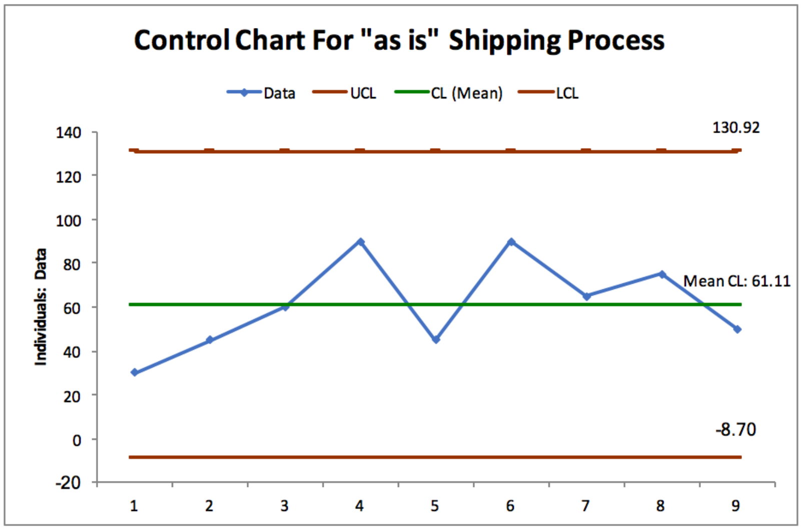

Figure 9:Control chart "before" shipping process

In above chart, the shipping time is observed to be high, due to delay in shipping time and improper techniques.

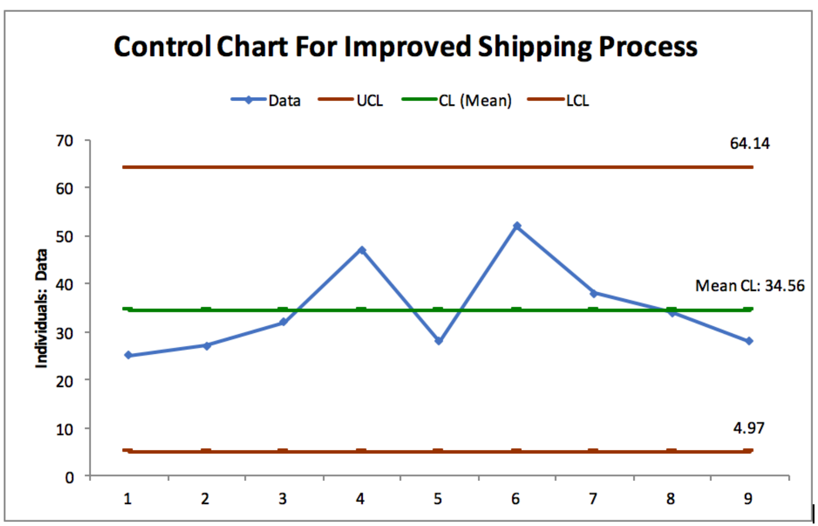

Figure 10:Control Chart "after" shipping process

Average of shipping time was reduced to 34.56 minutes, compared to 61.11. Shipping time data was under control limits and variation was relatively less compared to the older process.

HYPOTHESIS TEST

Picking accuracy:

Because the sample is small, we apply t – test hypothesis. We set the alpha value as 0.05. First, we do the F – test to see if the variances are the same. We get p – value equal to 0.000017 which is smaller than alpha. Thus, we reject the null hypothesis that the variances are the same. Then, we do the t – test hypothesis with different, unknown variances. We set the hypothesis as:

$$H_0: \mu \le \mu_0$$

$$H_a: \mu > \mu_0$$

After the test, we get p – value for one tail equal to 0.000025 which is smaller than alpha. Hence, we reject the null hypothesis and we have 95% confidence to say that the mean value of improved picking accuracy is larger than the mean value of "as is" picking accuracy.

Packing accuracy:

Because the sample is small, we apply t – test hypothesis. We set the alpha value as 0.05. First, we do the F – test to see if the variances are the same. We get p – value equal to 0.0031 which is smaller than alpha. Thus, we reject the null hypothesis that the variances are the same. Then, we do the t – test hypothesis with different, unknown variances. We set the hypothesis as:

$$H_0: \mu \le \mu_0$$

$$H_a: \mu > \mu_0$$

After the test, we get p – value for one tail equal to 0.0004 which is smaller than alpha. Hence, we reject the null hypothesis and we have 95% confidence to say that the mean value of improved picking accuracy is larger than the mean value of "as is" picking accuracy.

Shipping process:

Because the sample is small, we apply t – test hypothesis. We set the alpha value as 0.05. First, we do the F – test to see if the variances are the same. We get p – value equal to 0.0187 which is smaller than alpha. Thus, we reject the null hypothesis that the variances are the same. Then, we do the t – test hypothesis with different, unknown variances. We set the hypothesis as:

$$H_0: \mu \geq \mu_0$$

$$H_a: \mu < \mu_0$$

After the test, we get p – value for one tail equal to 0.0026 which is smaller than alpha. Hence, we reject the null hypothesis and we have 95% confidence to say that the mean value of improved shipping process time is smaller than the mean value of "as is" shipping process time.

CONCLUSION

The process improvement team was out to improve on two critical factors of improving the efficiency of the warehouse and reduce the inventory costs by implementing better picking, packing and shipping process. Picking, packing and shipping data was observed and experimental results was analyzed before and after process.

Furthermore, process improvement options were implemented to better the picking process and packing process, so that we can improve the percentage of correctly picked and packed items.

Average percentage of picking correctly is increased from 92.68% to 99.60% and for the packing correctly the percentage was improved from 93.39% to 97.28%. Time taken to complete the shipping process was improved and the time taken was reduced by 34.56 minutes.

The resulting values are the summary of the experimental results:

Parameters	Average % Percentage		% Change
	Before	After	
Correctly Picked items	92.68	99.6	7.46%
Correctly Packed items	93.39	97.28	4.16%
	Average time taken (minutes)		% Change
Shipping Time	61.11	34.56	-43.40%

Table 13:Summary Table

Stakeholders were satisfied with the implemented change. They implemented the required techniques within each team under each department. They have identified areas of improvement. Overall the influence of the improvement process was successful within each department. Now each team work together and more efficiently. Overall it contributed to reduce the inventory costs and improve the efficiency of the warehouse. The impact on us, is that we have understood the Six-sigma Methods and techniques and its effect on the project.

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Appendices

Value Stream Mapping

Before Improvement:

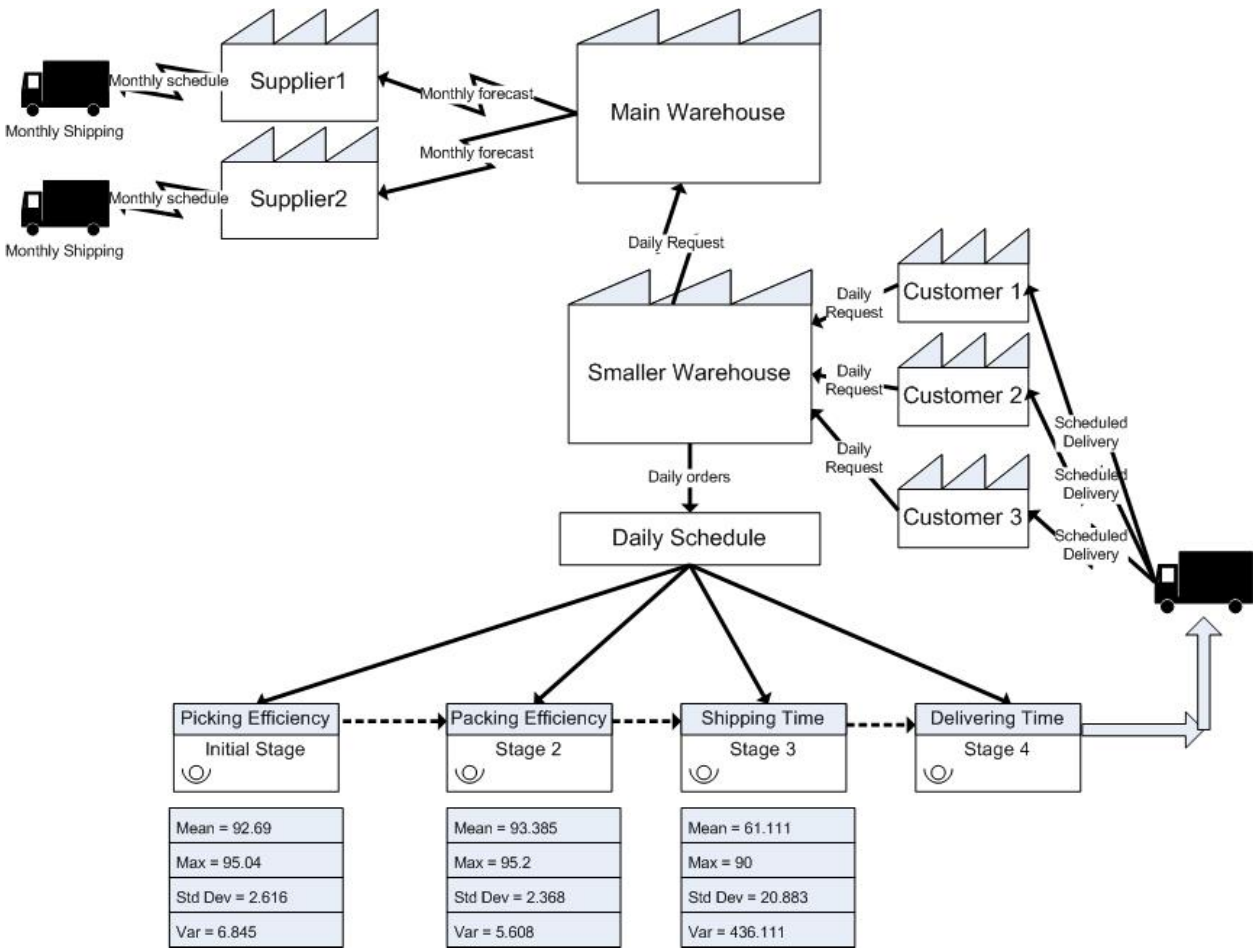

Figure 11:"before state" Value Stream Mapping

After Improvement:

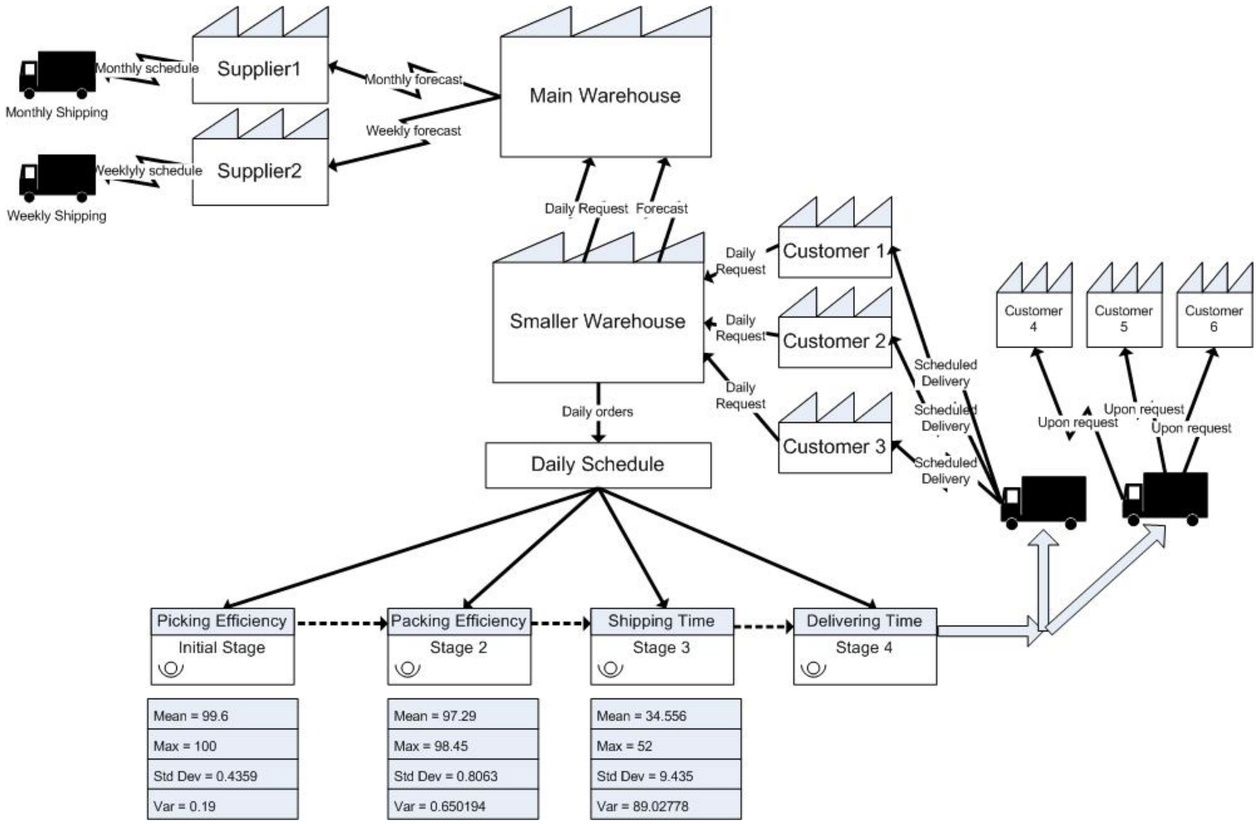

Figure 12: "After state" Value Stream Mapping

F-Test Two-Sample for Variances		
	"as is" picking	*improved picking*
Mean	92.68522222	99.6
Variance	6.844547944	0.19
Observations	9	9
df	8	8
F	36.02393655	
P(F<=f) one-tail	1.74463E-05	
F Critical one-tail	3.438101233	

Table 14:Picking Accuracy – F – test

t-Test: Two-Sample Assuming Unequal Variances		
	"as is" picking	*improved picking*
Mean	92.68522222	99.6
Variance	6.844547944	0.19
Observations	9	9
Hypothesized Mean Difference	0	
df	8	
t Stat	-7.821343961	
P(T<=t) one-tail	2.56792E-05	
t Critical one-tail	1.859548038	
P(T<=t) two-tail	5.13585E-05	
t Critical two-tail	2.306004135	

Table 15:Picking Accuracy – t – test

F-Test Two-Sample for Variances		
	"as is" packing	*improved packing*
Mean	93.38544444	97.29222222
Variance	5.608040528	0.650194444
Observations	9	9
df	8	8
F	8.625174478	
P(F<=f) one-tail	0.00314649	
F Critical one-tail	3.438101233	

Table 16:Packing Accuracy – F – test

t-Test: Two-Sample Assuming Unequal Variances		
	"as is" packing	*improved packing*
Mean	93.38544444	97.29222222
Variance	5.608040528	0.650194444
Observations	9	9
Hypothesized Mean Difference	0	
df	10	
t Stat	-4.68504785	
P(T<=t) one-tail	0.000430443	
t Critical one-tail	1.812461123	
P(T<=t) two-tail	0.000860886	
t Critical two-tail	2.228138852	

Table 17:Packing Accuracy – t – test

F-Test Two-Sample for Variances		
	"as is" shipping	*improved shipping*
Mean	61.11111111	34.55555556
Variance	436.1111111	89.02777778
Observations	9	9
df	8	8
F	4.898595944	
P(F<=f) one-tail	0.018729608	
F Critical one-tail	3.438101233	

Table 18:Shipping Process – F – test

t-Test: Two-Sample Assuming Unequal Variances		
	"as is" shipping	*improved shipping*
Mean	61.11111111	34.55555556
Variance	436.1111111	89.02777778
Observations	9	9
Hypothesized Mean Difference	0	
df	11	
t Stat	3.476478563	
P(T<=t) one-tail	0.002590244	
t Critical one-tail	1.795884819	
P(T<=t) two-tail	0.005180487	
t Critical two-tail	2.20098516	

Table 19: Shipping Process – t – test