VALUE STREAM MAPPING ON FOAM INJECTION MOULDING PROCESS – THE STARTING POINT OF A SIX SIGMA PROJECT

by

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ABSTRACT

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Organizations today are utilizing a combination of Lean and Six Sigma techniques to streamline their processes. Value stream mapping captures the current state of the process in its entirety and objectively analyzes the areas where lead time improvements can be introduced. This study looked at an Injection Molding process and identifying the bottlenecks which impact the increase in the lead time of the manufacturing process, eliminating the non value added activities and developing a future state value stream for the process. The study also focuses on application of six sigma tools to analyze the probable causes of defects and recommend areas of improvement to reduce the scrap or rework.

Acknowledgments

There are two people in my life that urged me on by way of their untiring support and seemingly unlimited belief in me, to those parents, all else pales. Thank you mom and dad for being there for me from so far away. Though I would love to have you besides me when I graduate but I know that you have me in your thoughts. I would like to dedicate this project to you. There are many that from behind the scenes have encouraged and supported my work, and I thank them from the bottom of my heart.

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I would also like to thank everyone who supported me directly and indirectly in completing this research work.

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Chapter I: Introduction

With the increasing success and acceptance of Six Sigma more and more manufacturing organizations today are using a combination of Lean and Six Sigma tools to improve their processes and reduce variation. The two methodologies compliment each other in a lot of ways. Six Sigma eliminates defects but it does not address the question of how to optimize process flow; Lean principles exclude the advanced statistical tools required to achieve the process capabilities needed to be truly 'lean'. However utilizing both methods simultaneously holds the promise of being able to address all types of process problems with the most appropriate tool kit. This research work utilizes the tools of both methodologies to help a manufacturing company reduce the lead times and scrap of a foam molding process. Value stream mapping is applied to map the current and future process and help make recommendations to reduce scrap. Six Sigma methodology of problem solving is utilized to shortlist variables that can be studied further during design of experiments to further cut down the scrap and rework.

A Lean Strategy brings a set of proven tools and techniques to reduce cycle times, inventories, set up times, equipment downtime, scrap, rework and other wastes of the hidden factory. The focus is on value from customers' perspective and flowing this through the entire supply chain.

Value Stream approach to map the process was considered most appropriate for this study as the process uncovers problems that cannot be solved without reducing process variability. Process variability is the reason for many of the seven wastes; for example, it can be responsible for overproduction, excess inventory, defects, over processing, etc. In some cases, process variability cannot be reduced with a simple fix such as a go/no-go fixture; the tools of Six Sigma and the Six Sigma define, measure, analyze, improve and control (DMAIC) methodology are very effective in these cases. This is where Six Sigma fits into lean and was considered the most appropriate for the study.

Statement of the Study

This manufacturing company under study utilizes the foam injection molding process to produce seats for the automobiles it manufactures. The process is automated and runs on a line with foam injection, heating and curing of molds in a sequential process. The company has been experiencing high scrap rates to the tune of 3-5% and longer leads times due to increased rework of defects. The main objective of this study is to develop both the current and the future state value stream map for the injection molding process and make recommendations for improving the lead times. Also, utilize various six sigma tools to analyze the probable causes of defects and recommend areas of improvement to reduce the scrap or rework. The scope of the project includes define, measure, and analyze phases of six sigma DMAIC methodology and identifies critical areas of improvement by analyzing the process variables. Improve and control phases were not within the scope of the project due to time and financial limitations.

Statement of the Problem

To reduce lead times by cutting down non value added activities and identify key variables leading to bubbling.

Purpose of the Study

1. Reduced total lead time and to point towards possible causes of excess bubbling.
2. Make recommendations towards reduction of defect rate due to bubbling.

Assumptions

1. The company has basic understanding of the Lean and Six Sigma techniques.
2. The management is willing to commit to the changes in the system recommended by the study and the people are willing to accept it.
3. Budget constraints are there on the project as no money is available for buying new equipment or implementing design changes.

Research Delimitation

The scope of the project involves developing the current state and future state value stream map based on the data collected from the process over a period of week .No effort would be made to look at the lead times of the individual sub processes over an extended period of time. The study was not provided with any documented information on the lead times of individual sub processes. The other limitation of the project is that it only covers define, measure, and analyze phases of DMAIC (six sigma) methodology and identifies critical areas of improvement by analyzing the process variables. Again, Improve and control phases are not within the scope of the project due to time and financial limitations.

Definition of Terms

Lean Manufacturing: Lean manufacturing refers to manufacturing paradigm based on fundamental goal of Toyota Production System-continuously minimizing waste to maximize flow. It fundamentally seeks to remove non-value-added processes from production in order to improve efficiency. (Tapping, Luyster and Shuker, 2002)

Value Stream Mapping: The visual representation of the material and information flow of a specific process.

Total Cycle Time: The total of the cycle times for each individual operation or cell in a value stream. Total product cycle time is ideally equals total value-added time.

Takt time – Takt time is the rate at which a company must produce a product to satisfy customer demand. (Tapping, Luyster & Shuker, 2002).

Cycle time – The time that elapses from the beginning of a process or operation until its operation. (Tapping, Luyster & Shuker, 2002)

Uptime: The percentage of hours available for each manufacturing day.

Six Sigma: Six Sigma is a management philosophy attempting to improve effectiveness and efficiency. It is equivalent to no more than 3.4 bad customer experiences for a million customer opportunities. (Eckes, G., 2003)

Critical to Quality: Attributes most important to the customer.

Defect: Failing to deliver what the customer wants.

Process Capability: What a process can deliver.

Variation: What the customer sees and feels Stable.

Operations: Ensuring consistent, predictable processes to improve what the customer sees and feels.

Work In Process (WIP): Inventory that has been started in one or more operations but is not yet completed into a finished cabinet.

Kaizen: A method to continuously improve a value stream that relates to product flow through a value stream or process flow through an individual process.

Chapter II: Literature Review

Currently there are two premier approaches to improving operations. One is lean manufacturing and the other is Six Sigma. They are promoted as different approaches and different thought processes. Yet, upon close inspection, both approaches attack the same enemy and behave like two links within a chain- that is; they are dependent on each other for success. They both battle variation but from two different points of view. Lean and Six Sigma integration takes two powerful problem-solving techniques and bundles them into a powerful package. The two approaches should be viewed as complements to each other rather than as equivalents of or replacements for each other (Pzydek, 2000).

Background

Motorola is where Six Sigma began. Mikel Harry began to study the variation in various processes within Motorola. He soon began to see too much variation in any process resulted in poor customer satisfaction and ineffectiveness in meeting customer requirements (Eckes, 2003).Six Sigma helped Motorola to realize bottom line results documented more than $16 billion in savings as a result of their Six Sigma efforts (Motorola, 2004). Consequently Allied Signals and General Electrics followed suit with their success stories to increase six sigma as an established quality methodology in the industry. (Peter & Pande, 2002).

At its core, Six Sigma is a measure of process quality and a methodology for making process improvements. The essence of lean thinking is grounded in the Toyota Production System, which considers people and processes to be its two main pillars

(Tapping, Luyster and Shuker, 2002). Both approaches represent tool sets, belief systems, and ways of thinking. This is truly a case where you can take and use the best of both worlds - you can have your six sigma cake and eat your lean cake too. Once lean techniques eliminate much of the noise from a process, Six Sigma offers a sequential problem-solving procedure, the DMAIC cycle (design/measure, analyze, improve and control), and statistical tools so that potential causes are not overlooked, and viable solutions to chronic problems can be discovered.

Lean Manufacturing and Noise

Lean tackles the most common form of process noise by aligning the organization in such a way that it can begin working as a coherent whole instead of as separate units. Lean manufacturing seeks to co-locate, in sequential order, all the processes required to produce a product. Instead of focusing on the part number, lean methodology focuses on product flow and on the operator. Flow- focused cells in an organization reduce the communication barriers that exist at the numerous interfaces between operations and greatly reduce the time to achieve a completed part. (Breyfogle, Cupello & Meadows, 2003)

Denecke's view that a lean approach attacks variation differently than a Six Sigma system does (Denecke, 1998). For example, lean manufacturing focuses on variation associated with different lean practices employed to speed production and improve quality. Examples of individual practices that can contribute to noise include maintenance, cleanliness, process sequence/co-location issues, and so on. Lean drives two key components of quality: process speed and the feedback of information. If all required machinery is placed together and parts are flowed one piece at a time, any quality problem should be identified by downstream processes immediately. Further more, the location of multidisciplinary operators allows speedy communication and problem solving without outside intervention. With cross-training operators understand how upstream processes affect downstream quality.

Lean Manufacturing changes the set of problems the organization must address and increases the price of failure. The organization is forced to respond to the lean definition of waste in process-travel distance, wait time, non-value-added cycle time, setup time, inventory levels, overproduction, and so on. Setup time is an especially important measure in the lean manufacturing line. Once the first machine starts setting up for a different part configuration, the rest of the line becomes starved for parts- in other words, setup time becomes cumulative. The time involved in setting up the entire cell is the sum of all the individual setup times. A two-hour setup per machine may result in 20 hours of downtime for the entire cell. A host of problems and opportunities that the organization could afford to hide in the past now become critical owing to the cumulative effect. A Six Sigma organization needs to understand the special demands of lean manufacturing if it plans to move toward a quality system that embraces both approaches.

Six Sigma and Noise

The data driven nature of Six Sigma problem solving lends itself well to lean standardization and the physical rearrangement of the factory. Lean provides a solid foundation for the Six Sigma problem solving where the system is measured by deviation from the improvement to the standard.

One of the most difficult aspects of Six Sigma work is implementing and sustaining gains. Even experts in the applications of Six Sigma techniques struggle to effectively safeguard the production process from noise. Typically, the employee responsible for implementing Six Sigma is such a strong agent of change that when he or she leaves the area in question to work on a new problem, a vacuum of sorts is created. The process variation may build up over time and allow quality problem to resurface. The type of noise that resurface typically involve part variation and overall process variation-for example, poor yield, scrap and rework, raw material variability from multiple vendors, and so forth. Lean provides an excellent safeguard for Six Sigma practitioners against many common sources of noise. (Breyfogle, Cupello and Meadows, 2001)

Synergy

A Successful Six Sigma operation begins with a clear definition of the goals of the organization's improvement process. Without this the change will never be "owned" by the organization. It will always be an outsider's idea of what's best for the company. Similarly lean requires employee involvement to bring about substantial kaizen improvements. (Wheat, Mills & Carnell, 2003)

There are several similarities between these two tool sets. Both approaches require the use of teams, be they kaizen teams or six sigma project teams. Both approaches function best if they have managed by experienced (certified) people, such as black belts, green belts, or lean consultants. Both approaches require behavior change and systems change to occur if you want to see true improvement, and both approaches can save you significant time and money if they are effectively implemented. The first steps in tackling a Six Sigma Process are the process map, problem statement, objective, and capability study. Without these essential foundations in place, the project cannot succeed.

Lean and Six Sigma together, represent a formidable weapon in the fight against process variation. Six Sigma methodology uses problem-solving techniques to determine how systems and processes operate and how to reduce variation in process. With the lean emphasis on standardization, Six Sigma practitioners can be ten times more effective in tackling process noise.

Value Stream Management and Mapping

Value stream mapping can be a communication tool, can be a business planning tool, and a tool to manage change process. The process includes physically mapping the current state while also focusing on where we want to be. Value stream management can serve as a starting point to help management, engineers, production associates, schedulers, suppliers, customers recognize waste and identify its causes. The goal is to identify and eliminate the waste in the process. Waste being any activity that does not add any value to the final product. Value stream management is a strategic tool to figure out where to go with the flow of the entire process. This is also a tactical tool that allows management to identify the bottlenecks and identify the problems in individual value streams.

Value Stream Management process supports the transformation into a lean enterprise by providing a structure to ensure that the lean implementation team functions effectively. It provides for a clear and concise communications between management and shop floor teams about lean expectations and about the actual material and information flow. It provides a good form of visual communication and updates can be reflected as they occur.

Like most processes Value Stream Management has people playing pivotal role. Any process can fail to achieve results if the people fail to apply it properly and if they lack understanding of the nature of the process.

Continuous improvement (CI) is achieved through the value streams. Lean organizations have CI teams assigned to each value stream. These are made up of people working in the value stream but may have some outsiders also. The purpose of the CI team is to review the value stream performance measurements each week and initiate projects to make these measurements improve every week.

There is a place in lean companies for the top-down, breakthrough kaizen events, but as time goes on the emphasis of improvement moves to the continuous improvement teams within the value streams. These teams must be within the value streams because they must have view of the entire flow of the processes. This way the focus will always be on improving the flow and increasing the value to the customers; avoiding the pitfall of making local improvement that does not benefit the overall process (Gordon and Ria, 2003).

Some key points to remember about Value Stream Management.

Value Stream Management is a process that

1. Links together people, lean tools, metrics, and reporting requirements to achieve a lean enterprise.
2. Ensures that lean is sustained.
3. Allows everyone to understand and improve their understanding of lean concepts.
4. Makes possible controlled process flow on the floor.
5. Generates an actual lean design and implementation plan.
6. Requires a lean coordinator to ensure that the process goes smoothly.

Value Stream Management does not involve

1. Just forming Kaizen teams and waiting for results
2. Just mapping the value stream to show material and information flow.
3. Just forming self directed teams and waiting for results.
4. Appointing improvement coordinators or "lean coordinators" and making responsible for improvements.

Most importantly, Value Stream Mapping is not a method for telling people how to do their jobs more effectively. It is systematic approach that empowers people to plan how and when they will implement the improvements that make it easier to meet customer demand. (Tapping, Luyster and Shuker, 2002)

DMAIC Methodology (2004, GE.com)

Define the Customer, their Critical to Quality (CTQ) issues, and the Core Business Process involved.

1. Define who customers are, what their requirements are for products and services, and what their expectations are

2. Define project boundaries the stop and start of the process
3. Define the process to be improved by mapping the process flow

Measure the performance of the Core Business Process involved.

1. Develop a data collection plan for the process
2. Collect data from many sources to determine types of defects and metrics
3. Compare to customer survey results to determine shortfall

Analyze the data collected and process map to determine root causes of defects and opportunities for improvement.

1. Identify gaps between current performance and goal performance
2. Prioritize opportunities to improve
3. Identify sources of variation

Improve the target process by designing creative solutions to fix and prevent problems.

1. Create innovate solutions using technology and discipline
2. Develop and deploy implementation plan

Control the improvements to keep the process on the new course.

1. Prevent reverting back to the "old way"
2. Require the development, documentation and implementation of an ongoing monitoring plan
3. Institutionalize the improvements through the modification of systems and structures (staffing, training, incentives)

Chapter III: Methodology

The main objective of this study is to develop a current and future state value stream map for the injection molding process of the company under study and utilize various six sigma tools to analyze the probable causes of defects and recommend areas of improvement to reduce the scrap or rework. The perceived need in this area was due to growing concern among the process owner about the increasing scrap and rework rate of the process and deteriorating quality of the product. The results of this research work will have direct effect on the six sigma effort of the company in improving the quality of the product, improving the information flow and reducing the scrap and rework due to poor quality thereby considerably reducing cost of poor quality. The study would also make recommendations based on analysis of variance the variables to studied further during design of experiments (DOE).

Subject Selection and Description

The information needed to map the process was collected by thrashing out an attribute check list as depicted in Table 1, p 15. The sample of data for the Value Stream was collected by observing the process itself. The cycle times were monitored and recorded. The process was captured diagrammatically along with the number of operator and their contribution to the process at each step of the entire process.

The defect data was collected over a period of two weeks. As there are a number of variables involved in the study which could contribute to the defect as defined by the process. It was felt appropriate to apply six sigma problem solving techniques to shortlist the variable which could be studied and analyzed further.

Table 1) Attribute Collection Checklist for Value Stream

- ☐ Total Time per shift
- ☐ Regularly Planned downtime occurrences such as breaks and lunch that reduce available time
- ☐ Total available daily production time (subject regularly planned downtime occurrences from the total time per shift)
- ☐ Delivery Schedules
- ☐ Cycle Times
- ☐ Changeover times
- ☐ Work-in-process (WIP) amounts
- ☐ Number of Operators
- ☐ Shifts on which the process operates
- ☐ Exceptions that may occur due to rework.
- ☐ Disruptions in manufacturing flow
- ☐ Preventive maintenance schedules
- ☐ Line Speeds.
- ☐ Economic Lot Sizes (economic order-quantity).

Data Collection Procedures

The research started with collection of information regarding the existing process flow and detailed mapping of it. The initial data captured about the process had details such as number of operators, identifying the cycle times and waiting times in each step. This information was collected by interacting with various people involved in the process and by visual observation at the site. The information generated by continuous interaction with the process owners, end users and business analysts helped in creating the current state value stream map showing the process flow, product flow, information flow and the communication flow. Then based on the concepts of lean philosophy, the current state is expanded into the future state value stream map by eliminating the non value added activities, elimination of waste, improving the communication and information flow and implementing the pull system techniques. A detailed project charter was prepared to define the scope of the project. The process layout defining the steps was laid down diagrammatically. A detailed problem solving approach was utilized using the supplier, input, process, output and customer analysis (SIPOC) and Fish Bone analysis. SIPOC (Table 3, p. 21) was conducted to identify the input variables of the process and Fish Bone Diagram (Figure 1, p.22) was used to further narrow the list to the important variables which could be studied further in design of experiments. The Six Sigma Level of the process was analyzed by closely observing the defect data collected. Qualitative & quantitative recommendations were made on the basis of the analysis made out of these tools.

Data Analysis

Define

The project needs were evaluated by defining the factors critical to quality and clearly identifying what constituted defect. Defects were defined by the identifying the critical to quality characteristics and voice of customer who wanted a seat without air bubbles. Based on these characteristics the process owner of the next operation had defined defects as a bubble bigger than three- fourth of a centimeter.

This phase was initiated by interviewing various levels within the process and the organization. The define phase was also characterized by the definition of the scope of the project. The project charter as shown in (Table 2, p. 18) laid down the project objectives and the goals. The define phase included the following:

- Define and research the current state. The current state value stream map provides a detailed insight into the current state of the process.
- Definition of the future state. The future state map and the recommendation for continuous improvement of the future state define the future state.
- Data collection by focusing on project critical to quality (CTQ's) and the voice of customer.
- Supplier Input Process Output Customer Analysis (SIPOC)

Table 2) Project Charter

Project Charter

Resource Requirements

Project No:	
Project Name:	Foam Moulding Process
Green Belt or Black Belt	NA
Master Black Belt	NA
Finance Partner:	NA
Champion:	NA

Team Members: **Name**	**Function**	**% Time**	**Initials**
Prashant Srivastava	Project Lead	100	
Jeff Schwochert	Process Owner	100	
Mike Armbrust	Project Champion	75	

General Information

Location:	Foam Moulding Division, Polaris
Business Segment:	
Business Objective:	
Customer CTQ(s):	Minimal size of Air pockets Minimal number of Air pockets
Current Process Capability:	Sigma, C_{pk}, DPMO, Cycle-time, etc.
Date:	

Tollgate Schedule

Activity	Date
Start	
D	
M	
A	
I	
C	
Close	

Project Definition

Project Problem Statement:
To reduce lead times by cutting down non value added activities and identify key variables leading to bubbling.

Project Objective Statement:
The main objective of this study is to develop a value stream map for the injection molding process of the company under study and utilize various six sigma tools to analyze the probable causes of defects. The study would also recommend areas of improvement to reduce the scrap or rework.

Project Scope/Limitations:
The scope of the project includes define, measure, and analyze phases of DMAIC (six sigma) methodology and identifies critical areas of improvement by analyzing the process variables. Improve and control phases are not within the scope of the project due to time and financial limitations.

Project Goals and Targets:
To point toward possible causes of excess bubbling to be investigated further during design of experiments and make recommendations towards reduction of defect rate due to bubbling.

Measure

The measure phase encompassed defining the project metrics. The monetary justification was not carried out as financial information for an in-depth analysis considered primary for a six sigma project was not divulged by the company. The metrics developed focused on customer satisfaction and voice of customer as the major driving forces. A powerful approach would be to combine the two, translating customer satisfaction and other strategic metrics into monetary implications for the review of executive management. This could be considered a limitation of the project and should be taken up by the project champions during the control and improve phase of this project if they decide to take the recommendations of this project.

The type of data which was collected was based on the following questions which were short listed and were observed during the data collection on the shop floor.

1) The outline of the injection molding process.
2) What is the time taken at each step of the injection molding process?
3) The no. of resources which are used at each step of the process
4) The reject or scrap rate at each step.

Analyze

The data collected was used to calculate the takt time, total cycle time, total queue time and total lead time. The total cycle time is calculated as the sum of all individual cycle times for individual operations and total queue time is calculated as sum of all queue times for individual operations. Finally the total lead time is computed as the sum of total cycle time and total queue time. These calculations were performed for the current state value stream map. The bottlenecks are identified in the entire process, the potential areas are identified in order to reduce the total lead time, improve the product transformation flow and improve the communication flow. SIPOC (Table3, p.21) was done to list the input variables which have a direct impact on the process output. Fish Bone Diagram (Figure1, p.22) was used to further shortlist the key variables to be studied in design of experiments.

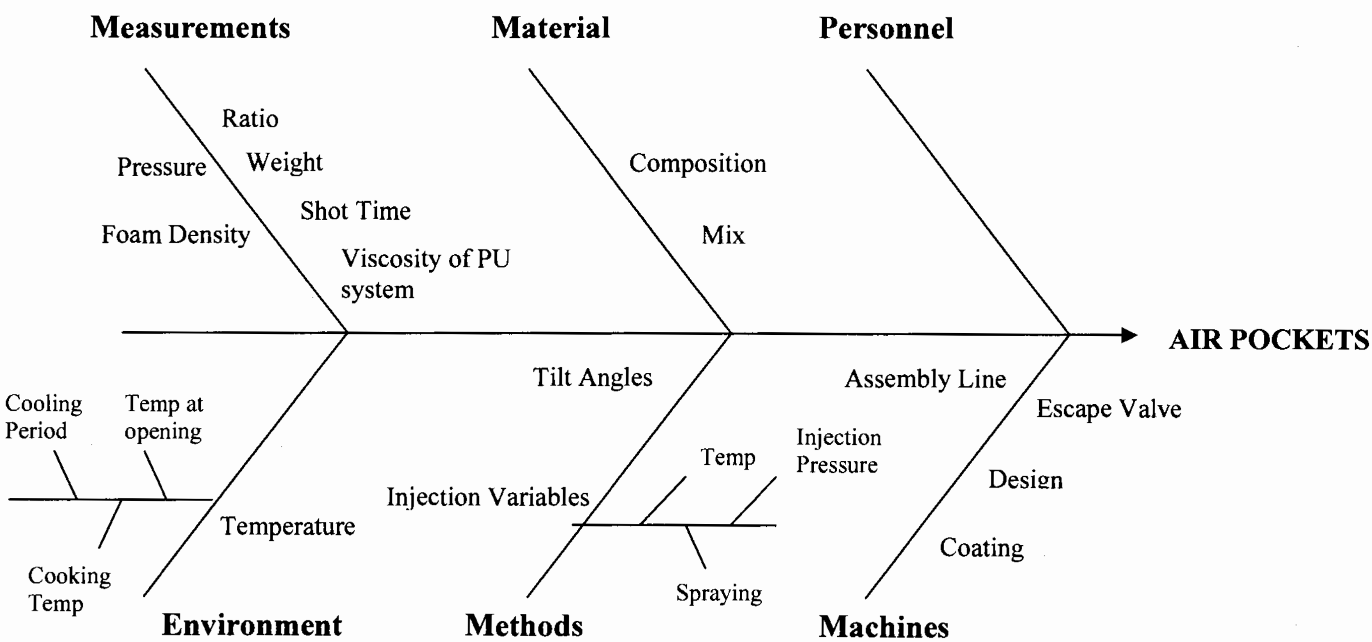
Improve

The improve phase essentially was making recommendations for improving the target process by designing creative fix and solution based on the data collected and analyzed.

Table 3) **<u>SIPOC ANALYSIS</u>**

Who are the suppliers for our product or service? How capable are they in meeting our process requirements?		What must my suppliers provide to my process to meet my needs?		Determine the start and end points of the process associated with the problem and the major steps in the process.		What is the most appropriate end point for the process? What product or service does the process deliver to the customer?		Who are the customers for our product or service? What are their requirements for performance	
Suppliers		Input		Process (High Level)		Output		Customers	
1	BASF	1	IsoCyanate		**Start Point:**	1	Foam Bun	1	Polaris Customers
		2	PU		Spraying the Tool	2	Softness		
		3	Mix Temp			3	Bubbling		
		4	Pressure						
		5	Mix Ratio		**Operation or Activity**				
		6	Injection Time	1	Closing the Tool				
		7	Humidity	2	Scanning the Tool number				
		8	Tool Temp	3	Injection of Mix				
		9	Curing time	4	Cooking				
		10	Cooking Time	5	Curing				
				6	Opening the Tool				
				7	Removing the Foam mould				
				8	Degassing				

Figure 1) Fish Bone Diagram



Control

The control phase would be a post study initiative to keep the process on the new course by preventing it to revert back to the old way. It would require the development, documentation and deployment of an ongoing monitoring plan. Also institutionalizing the improvements through the modification of systems and structures such as staffing, training and incentives.

Limitations

1. The research was limited to the injection molding process of seat manufacturing department in an XYZ manufacturing company.

2. It may be expensive to bring the new process changes.

3. If people are not ready to accept the change then the projected results are unachievable.

4. The new changes may take long time to implement and it depends on how much resources and costs are allocated.

5. The duration of the data collection process was short as the schedules were limited.

Chapter IV: Results

Item Analysis

The purpose of the study was to conduct a detailed analysis of the process by mapping it and thrashing out the non value added activities which led to increased costs and the total lead times. Value Stream maps were drawn detailing the time and resources consumed at every stage of the process. The current state value stream map provides a detailed insight into the material and information flow from the point of injection of foam into the mold to the time the foam is released to the seat shop for wrapping the covers in its current state and conclusions were drawn for the future state based on the inputs from the process owner and the people involved in the process and taking out the non value added activities. The process skeleton is as shown in Figure 2.

Process Skeleton

1. Injection of Recipe Mix
    a. Toolbox Spraying
    b. Machine prepares mix
        i. Machine reads id tag
        ii. Prepares appropriate mix
        iii. Feeds tube
    c. Operator injects Mix in tool box
        i. Operator reads Toolbox no
        ii. Selects appropriate mix and hits feed button
        iii. Fills mould through input valve

2. Cooking

   a. Tool rolls into cooking chamber

   b. Cooks for 4 min

3. Curing

   a. Cooling period (approx 1 min) before opening

   b. Operator opens toolbox for cooling

4. Degassing

   a. Removal Operator removes seat foam and places in degassing machine

   b. Degassing Operator compresses foam for degassing

5. Batch Stamping

   a. Operator stamps date batch under seat

   b. Places on moving conveyor for curing

The entire objective of using the value stream approach for this study was to thrash out the actual causes of waste/scrap in the process and provide the XYZ Company with recommendations to channelize their Six Sigma efforts. All these sub processes are broken down and measured for time and resources involved and the waste that they contribute towards. Also to point out if there were any bottlenecks in work in process.

The Current State Value Stream

An attribute check list was prepared (Table 1, p.15) after working in the conference room as a team and drawing a rough sketch of the main production operation on a white board and as represented in Figure 2. Once the check list was ready the research was primarily conducted from the shop floor starting with the down stream

operation (i.e., shipping), and later on collecting the actual process data as shown in Figure 3.

Figure 2. Process Skeleton

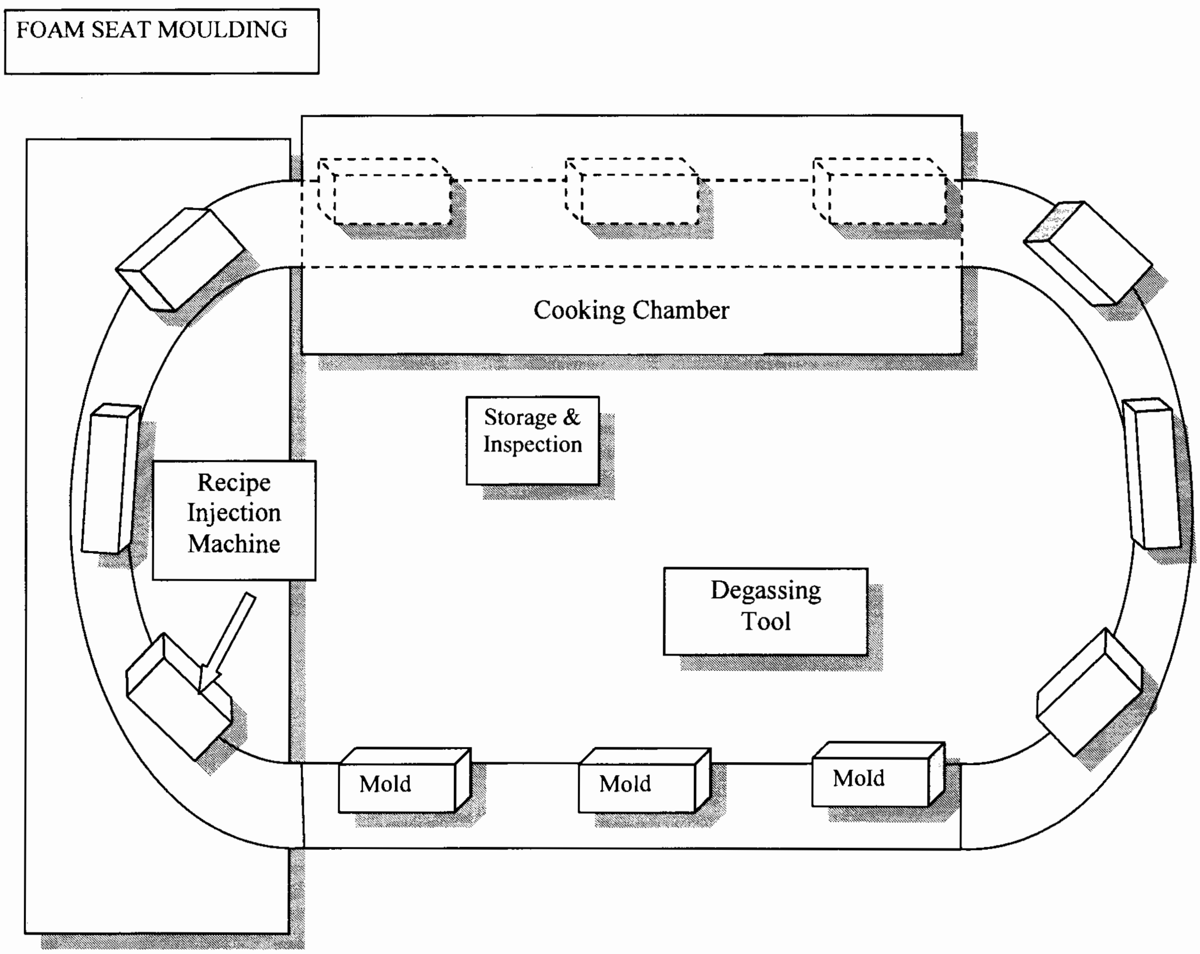
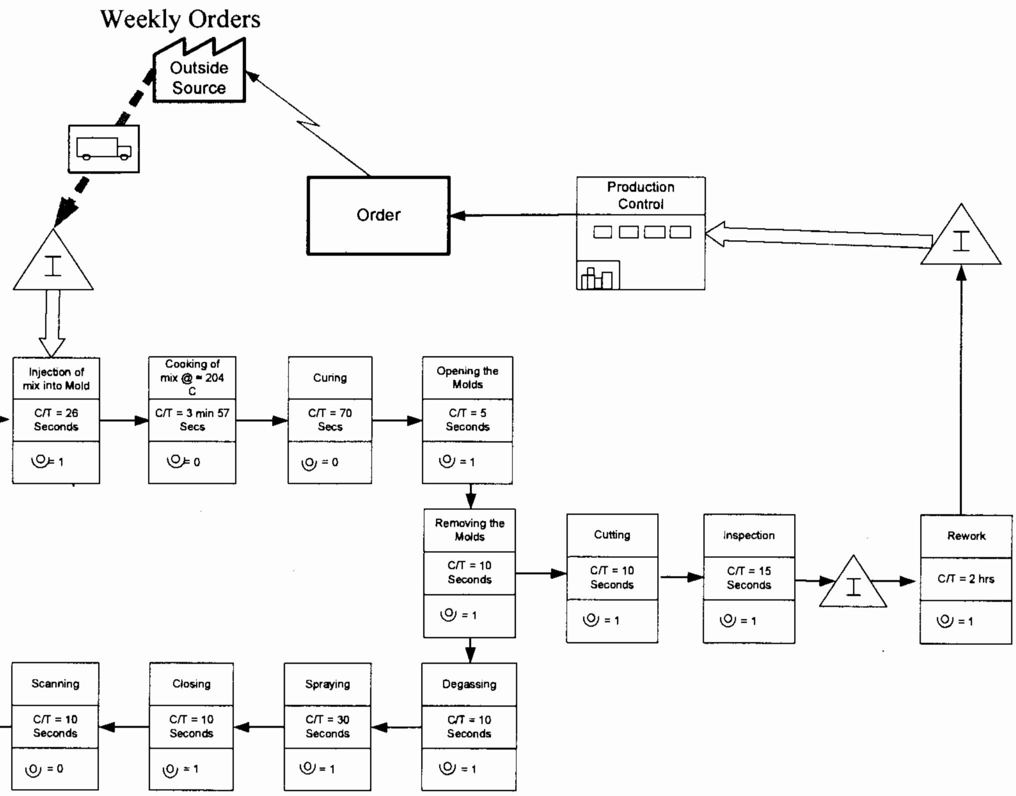


Figure 3) *Current State Value Stream of an Injection Molding Process, March 2005*



Total Available production time = 460mins = 276,00sec

Changeover time = 0

Uptime = 100 % (continuous flow)

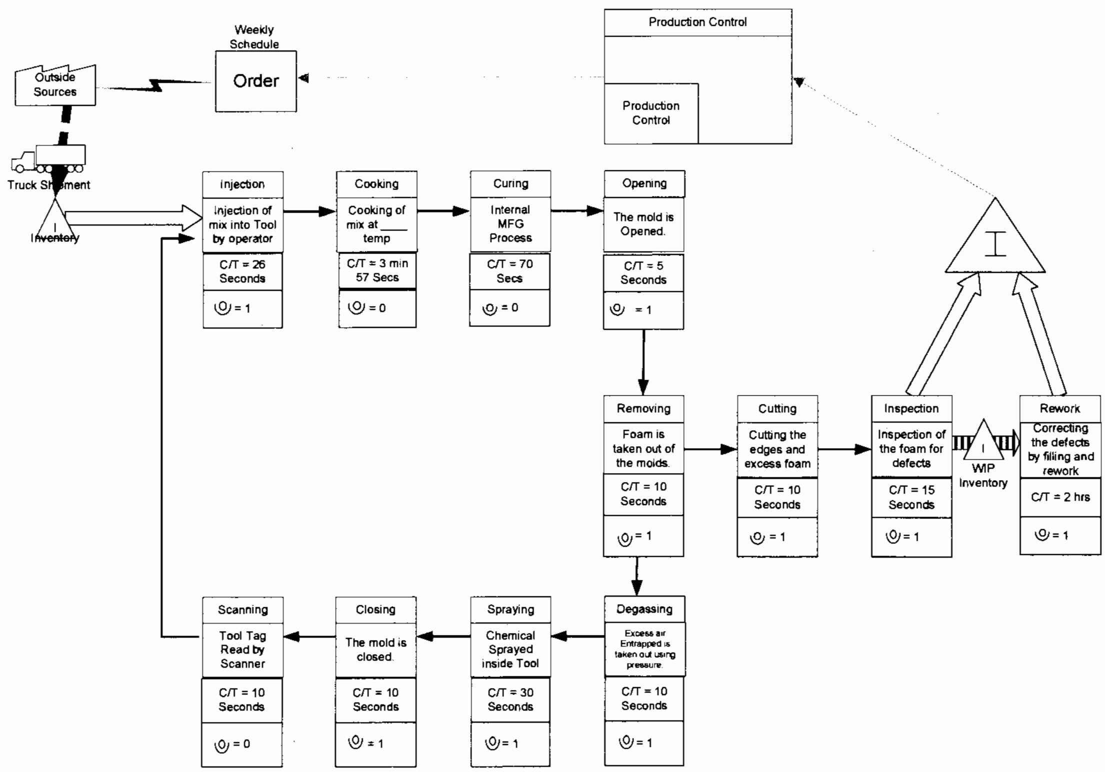
Daily quantity requirement ≈ 100

$$\text{Takt time} = \frac{\text{Total available production time}}{\text{Daily quantity requirement}}$$

$$= \frac{27600}{100} = 276 \text{ secs}$$

In the process studied the cycle times were to a very large extent independent of human interface as most of the steps were automated. The human intervention was primarily to monitor the molds and taking the necessary steps to ensure the process ran smoothly. During the entire cycle there are 6 operators who got involved in the process at different stages of it. The mold is injected with the foam at predefined pressure and temperature through an injection nozzle. Once the molds come out of the oven an operator opens the mold and takes the foam out and places them on the degassing unit. The foams are then picked up by an operator who chips the edges and stamps the batch number details on every foam. Another operator sprays a cleaning agent on the mold and cleans the foams properly. The operator doing stamping puts the foam on the moving conveyor for curing and segregates visually the foams needing rework. The moving mold on the line is then closed by an operator and the cycle repeats itself in the line. After the foam cures, it is inspected by the rework person and rework is performed to bring the foams to a satisfactory quality for performing the next step.

Figure 4) *Future State Value Stream of an Injection Molding Process, March 2005*



Future State Value Stream

The future state value stream would by enlarge be the same in terms of sequential steps of the process. The cycle times cannot be reduced drastically as all steps are automated and does not involve a lot of human intervention and is dependant on the speed of the line. However a significant area of improvement is the predicted in Work in Process (WIP) Inventory once the foams come out of the mold and are treated for rework. The current value stream indicated that the current waiting period for the foams once inspected varies from anywhere from 2 hours to 2 days before they are treated for defect depending on the requirement from the next process. This can be significantly reduced by controlling the defects from the process, better demand and shift scheduling. This would reduce the lead times significantly by reducing the WIP inventories and force the process to just-in-time production. The recommendation for further improving the future state value stream were a part of the study and are listed underneath.

Recommendations for Future State Value Stream

A lean matrix should be defined before proceeding with the mapping of the future state. The company should look at Inventory turns, days of inventory on hand; defective parts per million or sigma level, total value stream work in process, total cycle time or total value adding time, total lead time and uptime. The map development can be split into 3 stages as discussed below.

Stage 1: The future state map should begin by using the voice of the customer and how the communication is carried out between suppliers, production control and the shipping departments. The main focus at the initial stage should be demand and therefore the Takt times should be calculated. Some of the questions that need attention are whether you can meet demand using the current production methods and whether you need buffer and safety inventories.

Stage 2: In the next stage focus implementing just-in-time production techniques for ensuring continuous flow. This should be followed by the determining how to control the upstream production and removing bottlenecks to continuous flow by implementing first in first out lanes, use of kanban system and using computer assisted scheduling commonly referred to as material requirement planning.

Stage 3: Focus on leveling which helps distribute production over a shift or a day the work required to fulfill customer demand. The goal in this section is to draw the parts of the future-state that determine how kanban cards will be used and distributed and where in the process the production scheduling happens.

Chapter V: Discussion

This research work concentrates in reducing the lead times and scrap of a foam molding process for a seat manufacturing division of a company using a combination of Lean and Six Sigma methodology of problem solving. The Study will also make recommendations to reduce high scrap rate based on root cause analysis using define, measure and analyze of DMAIC methodology.

The paper looked at the current state value stream map and made recommendations for how the company can further proceed with the future state map. The entire cycle time from the time mold is injected with foam to the time it comes out of the mold is around 9 minutes. The scope of reducing time during this phase would be fruitless as it would involve varying the system variables such as temperature of the oven, the speed of the conveyor and the pressure of release of the foam into the molds. This could impact the end product and is not advisable without a conducting design of experiments. The one area where the process has a scope to reduce lead times is the scrap checks and reworks area. As most of the quality check are performed visually by human operators. It is a time consuming process and varies depending on the number of seats being produced in a production run and the scrap rate.

Normally, depending on the quality of finish the foam spends an additional 2 hours for visual scans, rework and going back on the conveyor belt to wait for it to be used by the seating division. As this is a variable the future state value stream should focus entirely on reducing the waiting lead time from the time the foam gets out of the inspection to the time it is used by the next operation. The two areas where the company could save substantial time are by reducing the rework and better capacity planning and forecasting of their consumption.

The paper would attempt in making recommendations to reduce defect on the basis of qualitative six sigma techniques used such as SIPOC and fish bone analysis to identify the root cause.

Limitations

1. The research was limited to the injection molding process of seat manufacturing department in an XYZ manufacturing company.
2. It may be expensive to bring the new process changes.
3. If people are not ready to accept the change then the projected results are unachievable.
4. The new changes may take long time to implement and it depends on how much resources and costs are allocated.
5. The duration of the data collection process was short as the schedules were limited.

Conclusions

The value stream process is an efficient way to map processes and begin the define phase of the six sigma methodology. The value stream maps are an effective tool to help focus on a six sigma project and identify the areas of the operations where you need to focus. The future state value streams help stream line the process by keeping the customer as the focal point which is the starting point of any six sigma effort. The research reiterates that both the methodologies are intermingled and draw from each other. An effective quality program should give due consideration to both the methodologies. The study recommends that the mix ratio be further studied using design of experiments to analyze the impact on bubbles as single variate ANOVA analysis reveals a high degree of correlation between defects scrapped and mix (Table 5, p.37).

Recommendations

1) The areas where the company can substantially benefit and reduce lead time are cutting the non value added work such as rework which can be curtailed by reducing defect (bubbles).

2) The lead time can be reduced further by better scheduling of jobs.

3) The readings in the measure phase show very high variation within the system (Table 4, p.37). The present process accounted for 102167 defects per million opportunities (as opposed to 3.4 defects per million opportunities associated with Six Sigma). The current sigma level of the process is 2.7. A significant cost saving can be achieved by reducing defects and improving sigma level by 1 sigma.

4) A correlation analysis of the variables (Table 5, p.37) with the defects scrapped reveals that there is high degree of correlation between the amount of isocyanate in the mix. The amount can be varied in the mix and a study can be conducted to observe the effect on bubbles while doing the design of experiments.

5) The cause and effect diagram shows the variables such as temperature, pressure and angle of tilt have an affect on the air pockets and should be an area of focus in the design of experiments.

6) The mold line is unstable and vibrates during the entire cycle. The process needs a more stable trolley system. The movement of trolley can also cause the formation of bubbles during anytime in the process due to uneven settling of foam under gravity.

7) The time that the molds are left for curing ranges from 2 hrs to 2 days depending on the demand by the next operation and scheduling of jobs. A better demand planning and scheduling would help reduce the WIP inventory and lead to substantial savings. A lean matrix formation would take care of these issues.

8) A brief visual study conducted by the company indicated that the angle of tilt, pressure and temperature changes helped in reducing the errors. A detailed six sigma analysis of variance (ANOVA) analysis is recommended to check the correlation between these variables and the bubble formation.

9) Last but not least a change in design of the seats is proposed. There could be an inherent problem with the design of the molds as the other molds did not show bubbling as that of the predator and scrambler molds did. However as a design change requires substantial financial and resource allocation. It is recommended that based on the findings of this study a DOE be carried out first. A multivariate correlation analysis with a focus on variables such a mix ratio, angel of tilt, temperature and pressure be carried out to narrow down on the cause of bubbling before changing the design.

Table 4) Six Sigma and Capability Analysis

Six Sigma/Capability Calculator				
Defects			Defective	
Number of units	323		Number of units	323
Number of opportunities per unit (Min. 1)	1		Number defective observed	33
Number of defects observed	33			
			Proportion defective	0.10
Defects per Opportunity (DPO)	0.10		% Yield	0.90
Defects per Million Opportunities (DPMO)	102167.18			
Equivalent Measures of Capability			Equivalent Measures of Capability	
DPU	0.10		DPU	0.10
DPPM	102167.18		DPPM	102167.18
Yield	0.90		Yield	0.90
Cpk Ppk	0.42		Cpk Ppk	0.42
Process Sigma Level	2.77		Process Sigma Level	2.77

Table 5) Correlation Analysis

Correlation of input factors to Defect Rate

	ISO Temp	Resin Temp	Weight	lbs ISO
Defects Scrapped	0.471	-0.208	0.390	-0.027
	0.169	0.564	0.266	0.942

	lbs Resin	Rate	OvenTemp	Mold Temp
Defects Scrapped	0.193	0.260	0.211	0.565
	0.592	0.468	0.558	0.089

Cell Contents: Pearson correlation
P-Value

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