Applying Six Sigma To Reduce Energy Intensity In The Tapes Industry

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1. Executive Summary

Six Sigma is a disciplined, data-driven, statistics based, problem solving, methodology and approach. The Six Sigma method can be applied in any process improvement project. This technique can be used in manufacturing, finance, R&D, sales, marketing, customer service, and any operational or transactional activity. This paper explores the Six Sigma "DMAIC" process to reduce energy intensity in tapes manufacturing.

“DMAIC” is an acronym. DMAIC projects have 5 phases: Define, Measure, Analyze, Improve, and Control. Each phase of Six Sigma DMAIC process is explored in this paper.

2. Introduction

Six Sigma is a set of tools and strategies used for process improvement. It identifies the inputs and causes of errors or defects. Six Sigma puts systems in place to control the inputs. By controlling the inputs, we reduce variation and improve performance. Six

Sigma is built around the internal and external voice of the customer. Voice of the customer is critical because it can help your company understand which programs and services to offer, critical features, and specifications. It helps identify where to focus improvement efforts. Many companies such as Motorola and General Electric are famous for using this strategy.

Six Sigma is a statistical term that describes six standard deviations between the average and the nearest specification limit. As shown in table 1, the higher the sigma value, the lower the defect per million opportunity rate (DPMO).

Table 1: DPMO and Sigma relationship.

Sigma	DPMO	% Defective	% Defect Free
2	308,538	31%	69%
3	66,800	6.7%	93.32%
4	6,210	0.62%	99.38%
5	230	0.023%	99.97%
6	3.4	0.00034%	99.9997%

3. <u>Project Selection</u>

Day to day problems represent opportunities. If you can make a business case to improve a project, you have a potential opportunity. Projects are most likely to be successful if the problem is related to a key business opportunity, if it is measureable, if it can be linked to a defined process, and if you can clearly define defects and measure them. This is true regardless if you are faced with a problem in R&D, operations, customer service, sales, or any other business entity.

4. <u>Project Charter</u>

Project Charters include the project title, project description, scope, boundaries, goals, objectives, team members, schedule, and support required. They need to be specific, measurable, agreed upon, realistic, and time based.

Charters clarify team expectations. It keeps your team focused and on time. They ensure team alignment with organizational priorities.

They need to be flexible. As we measure and learn more about the baseline performance opportunity, the solution may require us to adjust our approach. This may include resources, expertise, skill sets, baseline, and defect definitions.

5. <u>Define</u>

In Define, we identify the output characteristics, define performance standards, and describe the process. This is where we establish the opportunity, map out the process, understand customer's impact, and create the problem statement, scope, and project charter.

We start by identifying the product or service that causes problems. This is called the project Y (output characteristic). Ideally, output characteristics should be specific, measurable, describe the problem, and they should be important to the organization's performance. It is not uncommon to have to pareto the data and re-analyze as you quantify the biggest improvement needs of your organization. For example, you may begin a scrap reduction project knowing that Machine Z produces the highest scrap. With further analysis, you learn that 75% of Machine Z's scrap comes from defect Z or customer Z. Based on the re-analysis, the revised Y = Z% from the identified biggest Z.

The project Y (output characteristic) is known. However, we need to understand the desired characteristics. In many cases, the customer gives this to us in specifications, terms, and conditions. In other situations, we need to work with our internal and external customers to establish them because they are not always clearly defined.

We need to review our specifications to determine if they are appropriate. They need to be reasonable, understandable, measurable, and attainable. We have to understand if it is based on the customer's actual needs, if it directly relates to the performance of the characteristic, and if it is clearly stated and defined.

Formal projects are typically started with a Problem Statement. This defines what, when, where, how many, and "how do I know" with respect to the problem. Decisions made from problem statements need to be based on data.

The next step is to determine the project scope. To do this, we typically start the Supplier-Input-Process-Output-Customer "SIPOC" process map. This helps us define the scope, better understand the process, identify the inputs, and understand the outputs of the process. We start by constructing a basic process map. Each output from the process step is listed and is expanded to include the customer from that output step. Then, the inputs from each process step are listed. Finally, the suppliers of each input are included.

Other LEAN Manufacturing scope tools include Value Stream Mapping, spaghetti diagrams, and detailed process maps. These additional tools help identify further details of the process. It makes steps visible so they can be addressed and helps build consensus on the "as-is" process. These help define accountability, responsibility, flow, and prioritization.

The next step is to complete a project charter. This typically includes the project title, project description, scope, boundaries, goals, objectives, team members, schedule, and support required. Project charters define the goals, objectives, and expectations of everybody on the team.

It is important to remember that our charters should be flexible. As we learn more about our opportunity, the details and direction of the charter may change. We may discover that we need to adjust our focus, resources, expertise, and defect definitions as required by the data.

6. <u>Measure</u>

In Measure, we establish baseline performance of how our current state process is performing. We learn about calibration concepts and how data is measured through measurement system analysis (MSA). After our measurement system is established, we measure and collect data to determine our baseline performance.

Calibration involves comparing a measuring device against a known set of traceable standards such as NIST. It confirms that a measuring device is capable of working as designed to acceptable levels of precision. Calibration concepts include identification, test frequencies, established methods, records, and training.

Measurement System Analysis (MSA) is used to determine whether or not a measuring device is appropriate for the intended application. It is a scientific study that analyzes the validity of a measuring system. It quantifies variation including equipment, appraiser, and total system. MSA is a critical first step that should precede any data based decision making. We need to do this to understand if the measurement process is capable of detecting and satisfying the requirements both currently and over time. Measurement System Analysis validates data we collect to establish our baseline and maintain and improve our processes.

The most common technique for performing MSA is called the Gage Repeatability and Reproducibility (Gage R&R) study. Repeatability and Reproducibility quantify our measurement system precision. Repeatability means if I measure something and measure it again, I repeat the same number. Reproducibility means if I take a measurement and another person takes the same measurement, we get the same reproducible number. A Gage R&R evaluates measurement accuracy by comparing repeated measurements against known standards. It also quantifies measurement resolution which is the ability to detect differences between different samples.

There are a number of techniques and methods for performing a Gage R&R. The proper technique depends on the type of data (variable or attribute). Variable data is sometimes referred to as continuous data and can be compared to a speedometer on the car. Attribute data is discrete data and can be compared to counts or individual attributes. A Gage R&R study tells us whether or not the measuring system meets the criteria required to evaluate our Project Y.

At this point in the Measure Phase, we understand what we need to fix and how we are going to measure it. However, we do not know how big the problem is. In order to quantify the magnitude of the opportunity, we start by establishing our current baseline performance. There are many quantification tools including control charts, histograms, normality tests, and process capability. There is no single tool that makes sense for every problem. The objective is to select a tool and use data to quantify the current state of the problem.

Common ways of quantifying the problem include defects per million opportunities (DPMO), sigma score, and process capability. These techniques tell us how good or bad our baseline is. If the baseline performance is poor, a high reduction rate goal such as 80-90% may be attainable. However, if baseline is particularly good, a 50% reduction may be overly aggressive.

7. <u>Analyze</u>

In the Analyze Phase, we analyze the current process to understand problems and their causes. Up to this point, we have focused on the Project Y (output). In Analyze, we focus on the X (inputs).

Common Analyze tools include brainstorming, process maps, fishbone diagram, failure mode and effects analysis (FMEA), 5 Why, cause & effect diagram, and control & impact matrix. Some of the more math intensive techniques include hypothesis testing, and regression.

The main objective of the Analyze Phase is to answer the question: "what are the causes of the output defects?"

As we make changes in the input X, the output Y is impacted. Sometimes, the impact from one of the inputs may be significant or have a large effect. Other times, the impact from one of the inputs may be minor or the effect may be negligible. In the Analyze Phase, we use statistical tools to determine the mathematical relationships between input "x" and output "y." In this phase, we screen potential input X and identify the key process input variables (KPIV).

8. <u>Improve</u>

In the Improve Phase, we focus the function of each KPIV (x). We improve the process by identifying and implementing solutions to the problems. The main objective of the Improve Phase is: "how do we remove causes of the defects?" We identify improvement breakthroughs, high gain alternatives, select a preferred approach, perform cost / benefit analysis, and create a preliminary implementation plan.
Common Improve tools include brainstorming, affinity diagrams, impact / effort matrix, solution / prioritization matrix, experimentation, 5S, standard work, and design of experiments (DOE). Brainstorming, affinity, impact / effort, and solution / prioritization techniques focus on prioritization improvement strategies. 5S and standard work use LEAN Manufacturing strategies that identify waste and process improvement solutions.

DOE techniques are the some of the more data intensive improvement strategies. In a design of experiments, we model our process performance under different types of conditions such as low, medium, and high. It establishes a cause and effect relationship between a process Y and the possible X's. DOE helps us optimize input x values to maximize performance.

9. Control

In the Control Phase, we implement strategies to control the improved process through standardization and ongoing monitoring. The primary objective is to maintain the improvements and "sustain the gain."

Control systems vary on a scale from 0 to 3. The lowest level is 0 and the focus is basic communication. The highest level is 3 and the approach is 100% prevention.

Basic Level 0 examples can include communication postings, quality alerts, newsletters, signs, and training. Level 1 control systems focus on the Y and allow the defect to occur. These can include examples such as standardized work, color coding, statistical process control (SPC), control plans, and reaction plans. Level 2 control includes input (x) SPC control, daily process checks, regular procedure audits, and automated input tracking. Level 2 shifts our focus from the output Y to the input X and enables us to react quicker. Level 3 controls include closed loop control systems, design and machinery changes, layout changes, and mistake-proofing (Poka Yoke). The Level 3 controls prevent the defect from occurring with 100% probability. This is because it does not rely on the human factor. In the Control Phase, we ensure that the implemented improvement changes are sustained and the process cannot revert to its prior state. In addition, this allows information to be translated and shared to accelerate similar improvements in other areas.

10. DMAIC In Energy Intensity Reduction

Now that we have a basic understanding of the DMAIC Six Sigma process, let's apply it to reduce energy intensity in the tapes industry.

Define

Our project started by identifying the output categories that we wanted to control. These were electricity (KWH), gas (therms), and water (gallons). A project charter was developed and the team with a core group of divisional energy leaders was established. In addition, energy leaders were identified at each plant location. Early on, we realized that we need to adjust our focus and normalize the data in terms of production lbs to establish standardized energy intensity metrics. Our objective was to reduce energy intensity in electricity (kWh/lb), gas (therms/lb), and water (gallons/lb) by 1% year-over-year. These 3 categories of energy intensity became our 3 project outputs (Y).

Measure

Our measurement system analysis (MSA) showed that we had many inconsistencies in each plant's ability to read utility bills. We trained our employees and our skill sets improved. However, we still experienced variation from plant to plant because of staffing changes and differences in utility bill data presentation by region, state, city and municipality. Ultimately, we elected to outsource the utility bill management and data collection process. This eliminated our measurement error, greatly improved repeatability and reproducibility, and satisfied the Gage R&R requirements. Energy intensity data was collected to establish baseline performance in electricity, gas, and water. We developed this at the plant, division, and corporate levels. In addition, energy self-assessment surveys were created to determine the baseline level of energy efficiency engagement at each site.

Analyze

Plant energy intensity data was analyzed for year-over-year performance on a plant-by-plant basis, similar processes and product lines, division wide, and company-wide to determine intensity improvement opportunities. The energy surveys were analyzed to identify energy engagement, system, and infrastructure opportunities. These energy engagement activities were used to identify energy reduction inputs (X's) and their impact on energy intensity output (Y).

Improve

Energy reduction actions were identified, prioritized, and implemented at the plants. Specific energy events targeted sources of energy waste in areas of compressed air, steam, chiller systems, insulation, lighting, electric motors, and energy management systems. Additional energy reduction events included energy waste walk audits and energy audits. During the waste walk events, we took a plant-wide approach and identified any source of energy waste. This ranged from unoccupied offices with their lights on to equipment running when no product was present. During energy audits, we had external energy experts analyzing the process for wasted energy opportunities.

There were some situations where the business case for improving energy efficiency could not be made because of a long financial payback. In these situations, we implemented a strategy of replacing equipment with the most energy efficient option available at end of equipment life.

Control

A variety of control methods are used to sustain the energy intensity gain.

Level 0 control represents the most basic level of control. This was accomplished through monthly project communication, homepage energy ads, and the company's energy intranet website.

Level 1control systems standardize and normalize data measurement systems. In Level 1, we normalized energy intensity measurement and reporting. We used kWh/lb to measure electrical intensity, therms/lb to measure gas intensity, and gallons/lb to measure water intensity. Through normalization, we were able to evaluate performance on a normalized basis and eliminate the effect of increasing or decreasing volume.

In Level 2, our approach was to use our control systems to share and translate individual plant energy reduction activities across the divisions and across the company as utilities best practices. These systems include energy waste walk audits, electric motor management programs, steam management, chiller system management, insulation, and lighting. The utilities best practice translation activities occurred via mass-emails and on the company's intranet energy website. The translation process involved employees ranging from the plant janitor to the COO and implementing best practices across the company.

Level 3 control includes energy management systems such as real-time kWh metering with programmed reaction plans, start-up and shut down protocols, and utility bill management (UBM) data tracking and performance reporting.

Summary

Against the stated goal of 1% year-over-year energy intensity reduction, the tapes company achieved goal in electricity, gas, and water at the corporate level. (Table 2) The tapes company achieved the goal in reducing electrical intensity in 2 of 4 divisions. In gas and water intensity, the tapes company achieved goal in 4 of 4 divisions.

Table 2: Energy Intensity Performance

ELECTRICITY: KWH/LB TOTAL KWH/LB					GAS: THERM/LB TOTAL THERM/LB				WATER: GAL/LB TOTAL GAL/LB			
Total kwh/lb	kwh/lb 14	kwh/lb 15	YOY kwh/lb delta	YOY % kwh/lb delta	Therm/lb 14	Therm/lb 15	YOY therm/lb delta	YOY % therm/lb delta	Gal/lb 14	Gal/lb 15	YOY gal/lb delta	YOY % gal/lb delta
Division 1	1.0090	1.0058	0.0032	0.3%	0.00118	0.00105	0.00013	10.7%	0.2587	0.2296	0.0292	11.3%
Division 2	0.9908	0.9723	0.0185	1.9%	0.00080	0.00060	0.00020	24.4%	0.2980	0.2480	0.0501	16.8%
Division 3	0.3004	0.2959	0.0046	1.5%	0.00119	0.00110	0.00009	7.3%	0.0275	0.0240	0.0035	12.9%
Division 4	0.3886	0.3902	-0.0016	-0.4%	0.00374	0.00334	0.00039	10.6%	0.2086	0.1919	0.0167	8.0%
Total Corp	0.6158	0.6088	0.0070	1.1%	0.00165	0.00147	0.00018	11.2%	0.1718	0.1500	0.0217	12.7%

The Six Sigma process has driving energy intensity improvement and makes the tapes manufacturing company competitive. It is a toolset and methodology that can be applied to solve any problem anywhere.