Packaging Process Optimization Using Six Sigma

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Abstract

Continuous quality improvement is one of the keys for business success as well as business problem solving. Six Sigma is the most recognized and perceived quality change technique. Six Sigma can be defined as a statistical measure of variability which is the cause of defective and out-of-control processes. In this paper, six sigma was utilized to eliminate duplex gluing defects in cartoon production at Noor company. The number of defectives has been successfully decreased after identifying and changing the level of three factors were found to be the reason behind the increasing defective units. These factors are speed, amount of pressure applied to fix glue, and how long the pressure time.

Key words

Six Sigma, DPMO, DMAIC, Master Black Belt, Green Builts, ANOVA.

1-Introduction

Six Sigma is a term for process performance that produces only 3.4 defects for every million opportunities or 3.4 DPMO, in other words, almost defect-free performance.

Very limited number of global companies have attained Six Sigma. Most organizations, however, are working at levels of around four sigma, or approximately 6,000 defects per million (A. & Y. 2005). Also, Six Sigma is the focus of many businesses as there is a direct relationship between the number of product defects, wasted operating costs, and the level of customer satisfaction.

Six Sigma can be viewed as a strategic improvement methodology with six steps: define, measure, analyze, improve, and control (DMAIC). DMAIC is used to carry out the philosophy of Six Sigma in manufacturing, design, engineering, human resources, purchasing, customer service, and others (Huckabee, T. 2015).

Six Sigma has a clear focus on achieving measurable and quantifiable financial benefits and gives importance to strong and passionate leadership support. In fact, it solves problems through the use of both human elements like culture change, and customer focus, and process elements such as process management, statistical analysis and measurement system analysis (D. Sunil et al 2013).

Six Sigma has an organizational hierarchy structure for managers and employees depending on their expertise. The Master Black Belt is the one with the highest level of technical and organizational efficiency and plays technical leadership in the Six Sigma program. Whereas Green Belts are the employees trained in Six Sigma tools who contribute in Six Sigma projects but still have other responsibilities (Gaspersz, V. 2007).

There are two known methodologies for Six Sigma. The first one is the DMAIC which stands for Define, Measure, Analyze, Improve, and Control. Define is the first step that enable the leaders set the goals of a selected projects and develop the statement of work. Measure is the origin where the team gauge the improvement of the project. Analyze is the stem where the team identify the possible causes of defects that affects the outputs of the organization. Improve is where the team brainstorm for countermeasures for lasting improvements. And lastly, Control is the step to reduce variation by controlling the inputs and monitoring the outputs.

The other one is the DFSS (Design For Six Sigma), which has two well-known methodologies. First is the IDOV, wherein the first step is Identifying the criteria for success, second is Design wherein the parameters of design identified in the first step is translated into an effective design. Third step is Optimize wherein the further consideration of the design is ensured for effective marketability, and lastly, validate that checks if the process is complete and valid to meet all requirements needed in practice. The second DFSS methodology is the DMADV or Define, Measure, Analyze, Design, and Verify, which has almost the same characteristics as IDOV. DFSS has other methodologies such as DCCDI which stands for Define, Customer Concept, Design, and Implementation is another, and DMEDI or Define, Measure, Explore, Develop, and Implement (Al Hassan, MD 2014).

Even though DFSS and DMAIC are often noted to have similarities, they are different in purpose as DFSS is to solve issues coming from an end user, while DMAIC solves operational issues. Moreover, DMAIC is the standard methodology for all companies while DFSS has IDOV, DMADV, DCCDI, and DMEDI. DMAIC also focuses on improving the existing processes while DFSS focuses on designing and developing new products and processes through the Six Sigma.

In its broadest sense, Six Sigma is a methodology that businesses can use to improve the output quality of a process by eliminating wastes of the process. Six Sigma has its roots in the repetitive processes of manufacturing; however, the same tools can be used efficiently in any business process from hiring new people to effective product design and marketing plans (Huckabee, T. 2015).

The foundation of the Six Sigma technique is statistics; sigma stands for standard deviations from the mean of a data set, in other words a measure of variation, while Six Sigma stands for six standard deviations from the mean. When a process reaches six sigma level, that process will be running close to perfection, producing a mere 3.4 defects per million. By using statistical and analytical tools, a firm can reduce the amount of variation in a process by removing the causes of variation therefore increasing the output quality of the process (Hidayat, A. 2006).

A great example of a company that have successfully implemented six sigma is Motorola, saving $15 billion in the first 10 years of Six Sigma implementation. Moreover, GE boasts gains of $2 billion to the bottom line in 1999 and $2.4 billion in 2001 because of Six Sigma. DuPont realized more than $1.6 billion in cost savings the first four years of Six Sigma. Several other companies and even municipalities have had similar success by implementing Six Sigma (Indrawati, S., & Ridwansyah, M. 2015).

Six Sigma technique is believed to be a philosophical approach that demands the effective use of data and business analysis (iSixSigma.com 2002). The American Society for Quality website (ASQ, 2004) provides a huge amount of information about Six Sigma and its great impact on industry. The website states that 'the simplest definition for Six Sigma is to eliminate waste and to mistake proof the processes that creates value for customers." They described Six Sigma as "a business strategy that focuses on variation reduction as well as defect elimination." ASQ states that Six Sigma provides a method to learn about processes so that sources of variation can be identified and eliminated to enable the organization to ultimately exceed customer expectations (A. & Y. 2005).

The objective of six sigma technique is to improve profits through defect reduction, yield improvement, improved consumer satisfaction and best-in-class product / process performance (Yadav, A., & Sukhwani, D. V. 2018).

Six Sigma concepts have been utilized on process improvement using a measurement-based approach for variation reduction. In this research, Six Sigma methodology will be applied to optimize the process of Duplex Gluing by decreasing the number of defects.

2-LITERATURE REVIEW

The idea of Six Sigma was initially conceived by experts at Motorola during the early 1980s. Chairperson of Motorola at the time, Bob Galvin, presented an extremely demanding quality goal to his employees in 1981, which may have been the stimulus for Six Sigma (Arcidiacono, G. et al 2012). Motorola needed to improve their profitability by producing products to meet customer requirements. During the time when Six Sigma programs were first developed, there target was the high-end savings programs, predictably able to achieve cost savings of $170,000 per project (A. & Y. 2005).

Bill Smith's who was an engineer at that time, conducted a research regarding process capability and defect reduction. Around 1985, his research became the basis for Six Sigma innovation. Moreover, Mikel J. Harry, who was then part of Motorola's technical staff, and his colleagues later have refined the Six Sigma strategy by decade's end (Arcidiacono, G. et al 2012).

Because of Motorola's success, many other companies adopted Six Sigma and achieved positive results after its application (GE an, Ford, Johnson Controls, TRW, Delphi, Raytheon, Lockheed-Martin, Texas Instruments, Sony, 3M, and many others)(Zaman Mehdiuz et al 2013).

Although Six Sigma is found mainly in large manufacturing operations, they are becoming more prevalent in small businesses, transactional business processes (e.g., HR and purchasing), as well as in the service sector. Smaller companies have also had similar financial success by implementing Six Sigma compared to larger companies but on a smaller scale. From a financial perspective, it appears that Six Sigma have had a considerable impact on various businesses and organizations across a variety of industries (Arcidiacono, G. et al 2012).

However, a research study conducted in the UK noted that less than 10 percent of companies using Six Sigma are having positive results. The Research covered implementation status of Six Sigma in UK organization, problems faced in implementing the program, hard and soft success factors of its implementation, and key benefits of Six Sigma implementation (Kumar, M. 2007).

3-Case Study

"Noor Carton and Packaging Industry" is an ISO, HACCP and BRC accredited company specialized in the production of Paper and Paper Board Packaging. Products include detergent cartons, tissue boxes, dry food, packaging for greasy meat products, restaurant take-away packaging, pharmaceutical packaging, industrial packaging and many more, which makes it a one stop shop for all packaging needs.

Their duplex packaging plant is well equipped with the latest available technology that ensures products conform to customer requirements.

Today, the plant has a capacity to print over 20 thousand tons per year, backed by a network of national and international suppliers. In December 2001 the duplex plant obtained its ISO 9001-2000 accreditation.

3.1. Sigma Level Calculation

The process of printing and packing will undergo different stages of Production, Purchasing, Pressing, Cutting,Stripping, Molding, Packing, Window patching, Gluing and Shipping. In this case study, Six Sigma will be used to improve the operation of Duplex Gluing operation.

The following corresponds to one month of Data:

- The total quantity produced is 25,000 units
- The Number of Defected units is 13,025
- The defect rate was more than 50%

To determine the current Sigma Level, the following formulas were used:

$$\text{DPU (defects/unit)} = \frac{\text{Number of defects}}{\text{Number of Units}} = \frac{13025}{25000} = 0.521 \quad (1)$$

DPO (defects/opportunity) =

$$\frac{\text{Number of defects}}{\text{Number of Units} * \text{Number of Opportunities}} = \frac{13025}{25000*2} = 0.2605 \quad (2)$$

DPMO(Defects/million opportunities) =

DPO*1000000 = 0.2605*1000000= 260,500 (3)

Which reflects a sigma level equal to σ = 2.02

The current process is at Sigma level 2, which indicates that Duplex Gluing Operation has the capability of producing 260,500 defects per million opportunities. Therefore, an improvement to reduce the number of defects is required.

3.2. Implementing Six Sigma Concepts

3.2.1 Define Phase

Based on the data collected from AL-Noor Factory and the current sigma level (which is equal to 2.2), the gluing duplex process should be analyzed to decrease defects, improve quality and increase the sigma level.

3.2.2. Measure Phase

brainstorming sessions were conducted to identify the potential causes of the defects.

After investigating Machinery (conveyor, duplex Glue applicator ...etc.), Materiel (i.e. Glue), and Manpower (Operators, Training …etc.), established processes and required standards seem to be respected and no major issues were identified. That is why, the focus was directed to Methods, mainly the following gluing process factors:

1- Speed of sheets (number of sheets/hour)
2- The pressure intensity (psi)
3- The pressure time (seconds)

Speed, Pressure level and Pressure time were recorded for 14 sample and results are shown in table 1 below.

Table 1:Number of Defects per sample

Sample No	working Condition			Number of inspections	Number of defects
	Speed (sheet/ hr)	Pressure (psi)	Amount of pressure time(sec)		
1	153	3	3	70	36
2	138	2	2	65	31
3	177	4	3	65	26
4	155	2	5	80	22
5	176	5	5	60	17
6	155	2	5	55	15
7	175	5	2	40	9
8	167	5	2	45	14
9	165	3	2	35	16
10	152	5	3	50	19
11	175	3	2	40	12
12	177	4	3	45	18
13	147	4	2	60	27
14	160	5	3	55	23

Table 2: Data Descriptive

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
speed(sheet/hr)	low	26	159.9231	13.5320	2.6538	154.4574	165.3888	138.00	178.00
	high	74	171.9189	15.4217	1.7927	168.3460	175.4918	138.00	199.00
	Total	100	168.8000	15.7980	1.5798	165.6653	171.9347	138.00	199.00
pressure(psi)	low	26	3.8077	1.1668	.2288	3.3364	4.2790	2.00	6.00
	high	74	4.2027	1.6046	.1865	3.8309	4.5745	1.00	8.00
	Total	100	4.1000	1.5076	.1508	3.8009	4.3991	1.00	8.00
time of pressure(second)	low	26	3.3846	1.4987	.2939	2.7793	3.9900	2.00	7.00
	high	74	4.5676	1.6476	.1915	4.1859	4.9493	2.00	8.00
	Total	100	4.2600	1.6855	.1685	3.9256	4.5944	2.00	8.00

Table 3: Anova Table

		Sum of Squares	df	Mean Square	F	Sig.
speed(sheet/hr)	Between Groups	2768.640	1	2768.640	12.367	.001
	Within Groups	21939.360	98	223.871		
	Total	24708.000	99			
pressure(psi)	Between Groups	3.002	1	3.002	1.325	.252
	Within Groups	221.998	98	2.265		
	Total	225.000	99			
time of pressure(second)	Between Groups	26.924	1	26.924	10.375	.002
	Within Groups	254.316	98	2.595		
	Total	281.240	99			

3.2.3. Analyse Phase

Analysis of variance (ANOVA) is a statistical technique that is used to check if the means of two or more groups are significantly different from each other. ANOVA checks the impact of one or more factors by comparing the means of different samples.

Table 2 depicts the descriptive statistics of the samples when subject to low and high levels of speed, pressure and pressure time. The minimum, maximum, mean, standard deviation and standard error for each sample is calculated as shown in the table. Furthermore, lower and upper bound of mean are calculated with a confidence interval of 95%.

Moreover, the Analyse phase of the DMAIC process involved 2^3 factorial design. 2^3 factorial designs involve studying the variables. Analysis of Variance ANOVA is used to determine whether these independent variables significantly affect variation in our dependent variables.

ANOVA is a statistical technique that is used to check if the means of two or more groups are significantly different from each other. ANOVA checks the impact of one or more factors by comparing the means of different samples.

Table 3 below shows the most critical factors that have an effect on the product. Table 3 presents the values of Sum of Squares (SS), Degree of freedom (df) and Mean Square (MS) for between groups and within groups.

Based on these values, F-stat parameter was calculated

As can be seen from table 3, the F statistics for speed and pressure time (that are equal to 12.367 and 10.375 respectively) are significant. Whereas the F-stat for pressure is equal 1.325 which is not significant compared to others. Therefore, it can be concluded that for duplex gluing operation, the factors that affect the efficiency of the process are: Speed and pressure time with optimal levels being set at 175 and 2 respectively.

3.2.4. Improve and Control Phase

Table 4 presents the sample data after setting the speed around 175 (sheet/hr) and pressure time at 2 (sec).

Table 4 data is used to calculate the sigma level after improvement.

DPU (defects/unit) = $\frac{\text{Number of defects}}{\text{Number of Units}} = \frac{3900}{25000} = 0.156$ (4)

DPO (defects/opportunity) =

$$\frac{\text{Number of defects}}{\text{Number of Units} * \text{Number of Opportunities}} = \frac{3900}{25000*2} = 0.078 \quad (5)$$

DPMO(Defects/million opportunities) =

DPO*1000000 = 0.078*1000000= 7800

From the table, σ = 2.91 (6)

Thus the current process is at Sigma level 3, which means it has the capability of producing 78,000 defects per million opportunities.

Table 2:Defects after improvement

Sample NO.	Number of inspections	Number of Defects
1	70	11
2	65	9
3	65	7
4	80	7
5	60	6
6	55	5
7	40	3
8	45	4
9	35	5
10	50	6
11	40	3
12	45	5
13	60	8
14	55	7

The new sigma shows a significant improvement as compared to the previous one. Figure 1 below show the P- chart after applying the new speed and time for applying pressure.

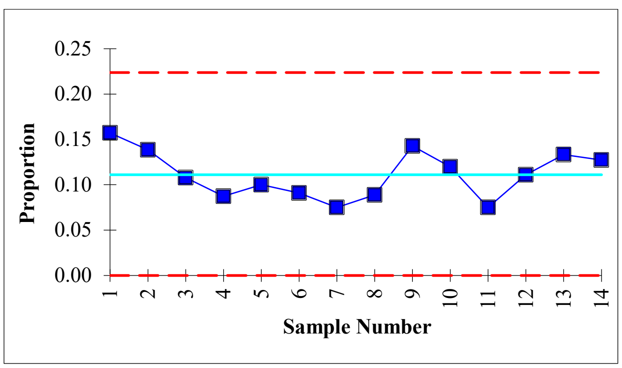

Figure 1:P-chart after improvement

4.CONCLUSION

In this study, six sigma methodology (DMAIC) has been applied on the gluing operation at Al-Noor factory.

Initially, the number of defective units at gluing section was considered as significant and needed to be improved. After Data collection and Analysis, three factors (speed, pressure level and pressure time) were considered as potential causes. The most influential causes have been identified as speed and pressure time and their optimal levels were suggested to be at 175 (sheet/hr) and for 2 (sec).

After applying the new recommended levels, the number of defective units has been significantly decreases from 297 to 101 units, which consequently increased the level of sigma from 2.2 to 2.91.

Figure 2 and Figure 3 below illustrate how the defects rate is reduced after applying the new speed and amount of pressure time factors.

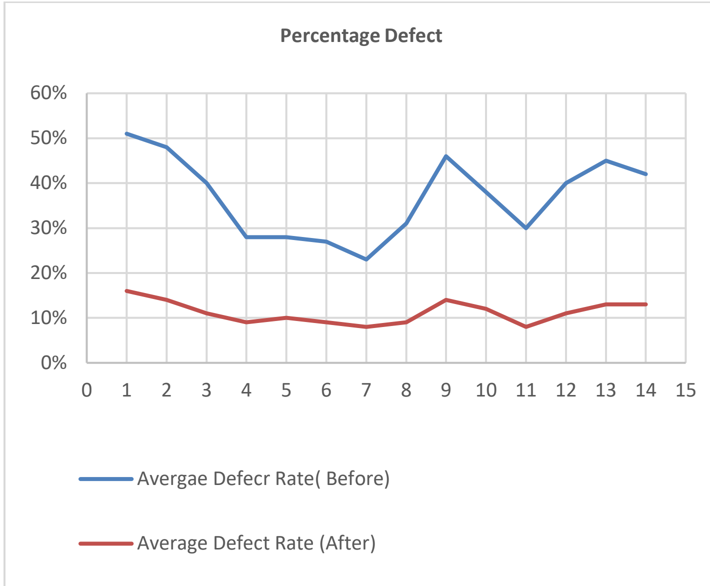

Figure 2: Number of defects (before & after)

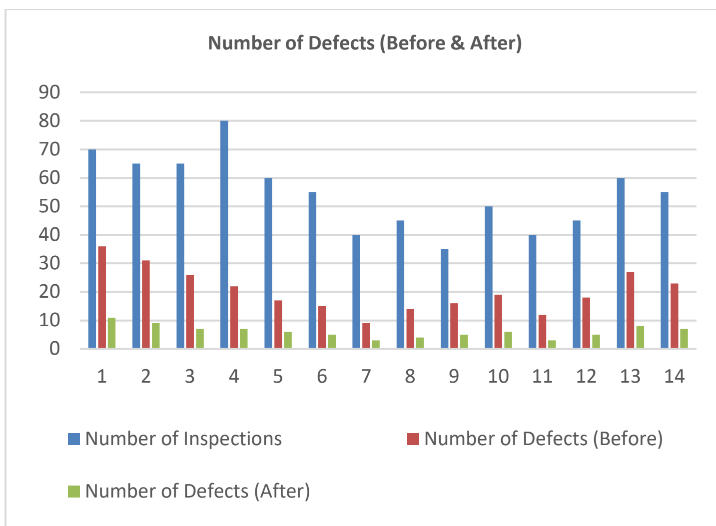

Figure 31: Defect Percentage

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