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**Abstract** - The research has carried out to introduce Six-Sigma philosophy in Bangladesh, especially in Manufacturing Industry. To show the technical pathway of implementing this technique in our industries for improving the productivity and quality was the main concern of this paper. Present Sigma Level is calculated as a part of the framework and total factors, which are directly related with the process, are taken under calculation. At the same time all the process related to production are clearly observe. As a whole, the total improvements of production system by implementing the Six-Sigma tools were our research goal. A Fan Manufacturing Company was our research area where it has possible to analyzed and implemented. In the thorough procedure, DMAIC is used as technical tools for developing the process. Finally, by changing the traditional layout to balanced layout model as per DMAIC approach, remarkable improvements have been achieved.

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# Productivity Improvement of a Fan Manufacturing Company by using DMAIC Approach: A Six-Sigma Practice

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## I. INTRODUCTION

Six-Sigma is a statistical measurement of only 3.4 defects per million and regarded as a management philosophy focused on eliminating mistakes, waste and rework. It establishes a measurable status to achieve and embodies a strategic problem-solving method to increase customer. Satisfaction and dramatically reduce cost and increase profits. The real power of Six-Sigma is simple because it combines people power with process power. If an organization is focused on customer satisfaction, then Six-Sigma will offer a method and some tools for the identification and improvement of both internal and external process problems to better meet customer needs by identifying the variations in organization's processes that might influence the customer's point of view, negatively.

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There are countless benefits of having employees trained in the practices of Six-Sigma. Some of the benefits include the following: cost savings, increased productivity, and lower frequency of defects, shorter cycle time, and improved customer satisfaction. Below are just two success stories that had their own particular benefits after implementing Six-Sigma. Many more companies have also had positive results with Six Sigma. One of the earliest success stories begins with Motorola, the founders of Six-Sigma. At the Schaumburg, Illinois facility, ten years after implanting Six-Sigma, great successes were seen. Though Fredrick Taylor, Walter Stewart and Henry Ford played a great role in the evolution of Six-Sigma in the early twentieth century, it is Bill Smith, Vice President of Motorola Corporation, who is considered as the Father of Six-sigma.

M. Sokovič et al. undertook projects to identify areas in the process where extra expenses exist, identify the biggest impact on production expenses, introduce appropriate measurement system, improve process and reduce expenses on production times, and implement improvements [1]. Gustav Nyren represented the variables influencing the chosen characteristics variable and then optimized the process in a robust and repeatable way [2]. John Racine focuses on what six-sigma is today and what its roots are both in Japan and in the west and what Six-Sigma offers the world today [3]. Zenon Chaczko et al. introduced a process for the module level integration of computer-based systems, which is based on the Six-Sigma Process Improvement Model, where the goal of the process is to improve the overall quality of the system under development [4]. Philip Stephen highlighted a distinct methodology for integrating lean manufacturing and Six-Sigma philosophies in manufacturing facilities [5].

This work is specially carried out to identify the problems that cause defects in various steps of production and to improve each step by increasing productivity and reducing cost. DMAIC is found as the solution maker in this paper. Lean Manufacturing has added an extra dimension in the productivity improvement approach in this research.

## II. METHODOLOGY

To implement Six-Sigma it is needed to follow DMAIC approach step-by step. In the following sections, this approach is briefly described for the concerned organization. It is a very important stage to consider because lack of proper analysis may lead to the process to a wrong way, which will deviate, from the main function of improvement. In this stage, different basic tools of quality are preferably used to analyze the real condition of the processes. Every successful work goes on some specific sequence. This work also completes some specific step. After completing each successful, it is necessary to move next step. The steps that are followed for data analysis are:

Step 1- Find out the existing sigma level of the production shop.

Step 2- Analysis the existing layout of the production shop.

Step 3- Analysis the existing operation sequence by the process block diagram.

Step 4- Analysis the existing problem by cause and effect diagram.

Methodologically the total process of the work is divided into two basic stages, Measurements and Improve-ments. A systematic pathway is followed to meet up the goal. Firstly, the Sigma Level of the existing process of the Fan manufacturing company is measured and other related factors are calculated. Base on these measurements, secondly the improving tools and techniques are implemented. All the scope of implication of new philosophy and techniques are systematically identified.

The paper is discussed comparing the productivity and efficiency before and after applying the balancing technique. Considering experience, capacity, production line is selected. Two important attributes have been considered, one is possible standard method for each process and another is considerable time in between the input has been fed to actual individual capacity of each worker. The time is recorded to make each process for each worker to find out the number of operator and individual capacity. To find out the (standard allowable minute) S.A.M value, process wise capacity has been calculated, in addition to that the target, benchmark capacity, actual capacity, labor productivity and line efficiency are calculated. Line has been balanced considering the bottleneck and balancing process where the balancing process has shared the excess time after the benchmark production in the bottleneck process. After balancing, new workers have been proposed and final capacity of each worker has been reallocated. have compared the line graph after balancing the line, labor productivity, and line efficiency. Finally, a proposed production layout has been modeled with balanced capacity. Sigma value

increases the process performance in a better way. Another way of measure the process capability and performance by the statistical measurements like Cp, Cpk, Pp and Ppk. The Six-Sigma means a 3.4 % defects part per million or yield of 99.9997% (perfect parts). Following is the table of comparison of different Sigma values at different defects part per million and capability of process here.

Table 1 : Six-Sigma value chart

SIGMA	DPMO
6 sigma	3.4 (World Class)
5 sigma	230
4 sigma	6200 (Industry Average)
3 sigma	67000
2 sigma	310000 (Not Competitive)
1 sigma	>310000

DPMO- Defects per Million Opportunities

The DMAIC is a basic component of Six-Sigma methodology- a better way to improve work process by eliminating the defects rate in the final product. The DMAIC methodology has five phases Define, Measure, Analyze, Improvement, and Control.

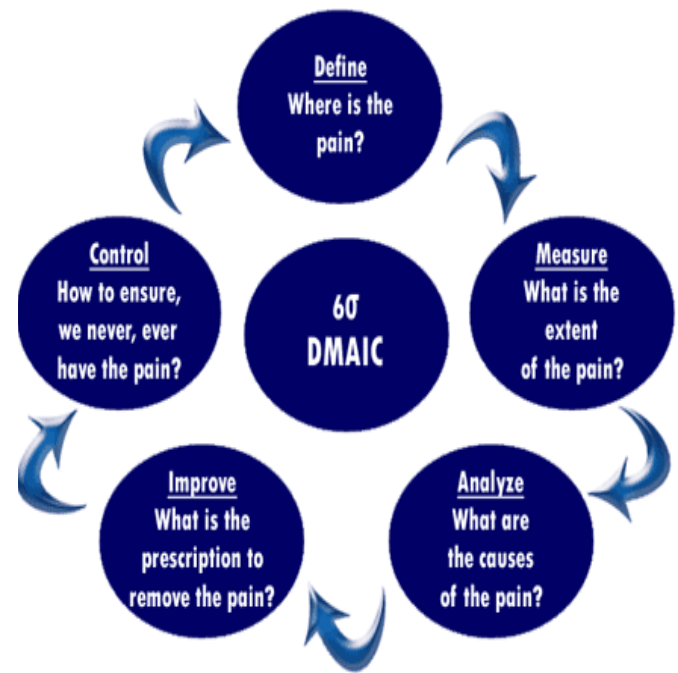


Figure 1 : DMAIC Methodology

Line balancing is the assignment of work to station in a line to achieve the desired output rate with the smallest number of workstations. Normally, one worker is assigned to a station. The line that produces at the desired pace with the fewest worker is the most efficient one. Achieving this goal is much like the theory of constraints, because both approaches are concerned about bottleneck. Line balancing differs in how it addresses bottlenecks. Rather than, (1) taking on new

customer orders to best use bottleneck capacity or (2) scheduling so that bottleneck resources are conserved, line balancing takes a third approach. It creates workstation with workloads as evenly balanced as possible. It seeks to create workstations so that the capacity utilization for the bottleneck is not for the higher than for the other workstations in the line. Another difference is that line balancing applies only to line processes that do assembly work or to work that can be bundled in many ways to create the jobs for each workstation in the line.

### III. RESEARCH OUTCOMES

Sigma level is a procedure to know the existing condition of a production shop. The calculation of sigma level is based on the number of defects per million opportunities (DPMO). In order to calculate DPMO, three distinct pieces of information are required:

- a) The number of units produced.
- b) The number of defects opportunities per unit.
- c) The number of defects.

$$DPMO = \frac{(\text{No. of Defects} * 100000)}{((\text{No. of Defects opportunities per unit}) * \text{No of units})}$$

For this purpose, the relevant data is collected. By using this data, the defect rate of each process is calculated and converted it into the total defect. From collected data, the number of units produced was 240 pieces per day, the number of defects opportunities per unit was 5 and the number of defects was average 18 pieces per day. Finally, this information is put into sigma level calculator. This automatically finds the DPMO of the production shop, which are 15000. After plotting the required information into sigma level calculator, the calculator shows that the sigma level of the production shop is 3.7, which was below average. At the Define phase of DMAIC, approach a major problem was found that was the existing layout. The layout problem was a challenge to management because of the complex interactions of several key factors and the difficulty in assessing their impact on the system performance. Maintaining best utilization of human resources by providing a comfortable and safe working environment an effective and efficient layout is mandatory.

The layout was analyzed based on:

- Placing equipment in a position resulting in its maximum utilization (adjusting machine capability and manpower utilization).
- Reducing congestion in the flow of materials or people through successive stages in the process (by applying supermarket).

- Providing easy access for equipment maintenance and repair.
- Creating efficient production lines for a smooth and rapid product flow.
- Suitable means for fast and safe materials handling.
- Maintaining best utilization of space.

Maintaining best utilization of human resources by providing a comfortable and safe working environment.

After completing the successful analysis of production layout further study was focused on process block diagram. To find out the existing problem of a complete production process, it is more preferable to represent the operation sequence by process flow diagram. For this purpose, the operation sequence is analyzed and obtained the flow chart.

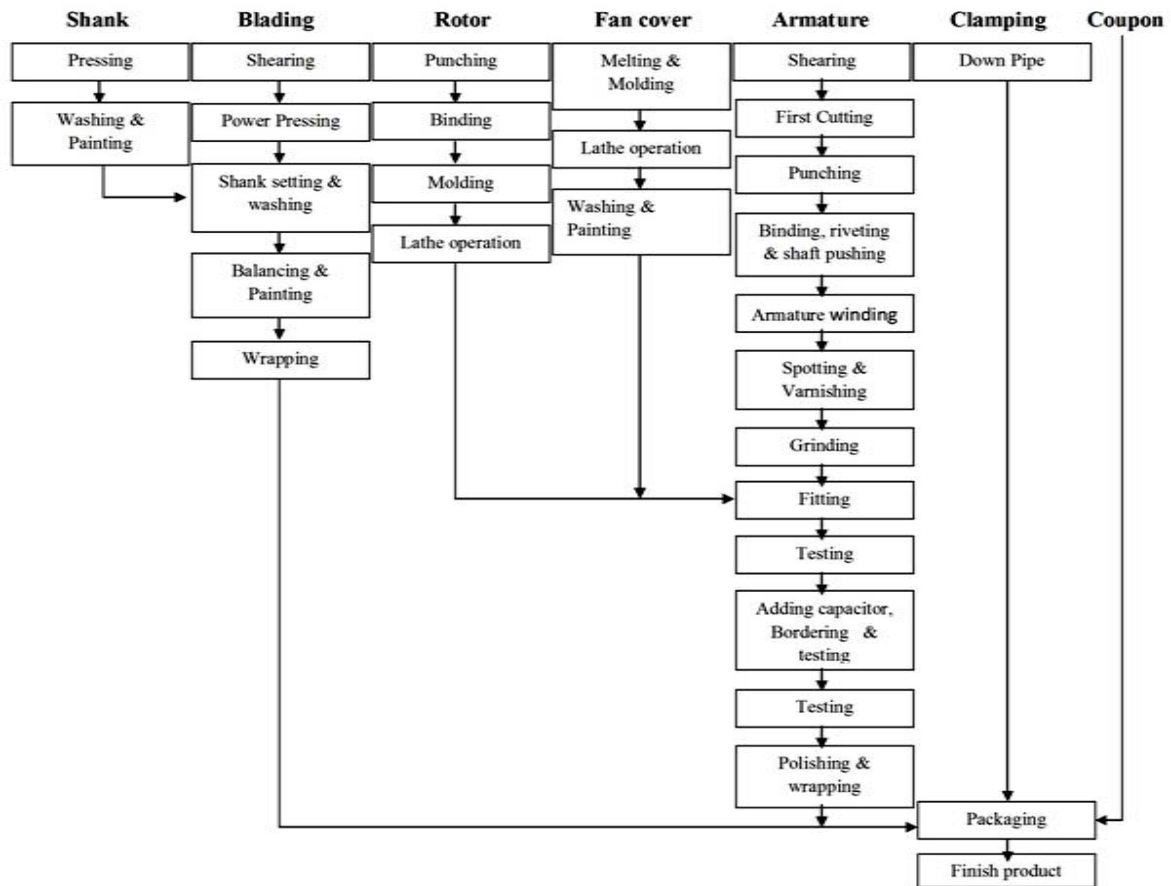


Figure 2 : Process flow chart of the production shop

The next step was to find the root cause and sub-cause of the existing process. The required cause & effect diagram is shown below:

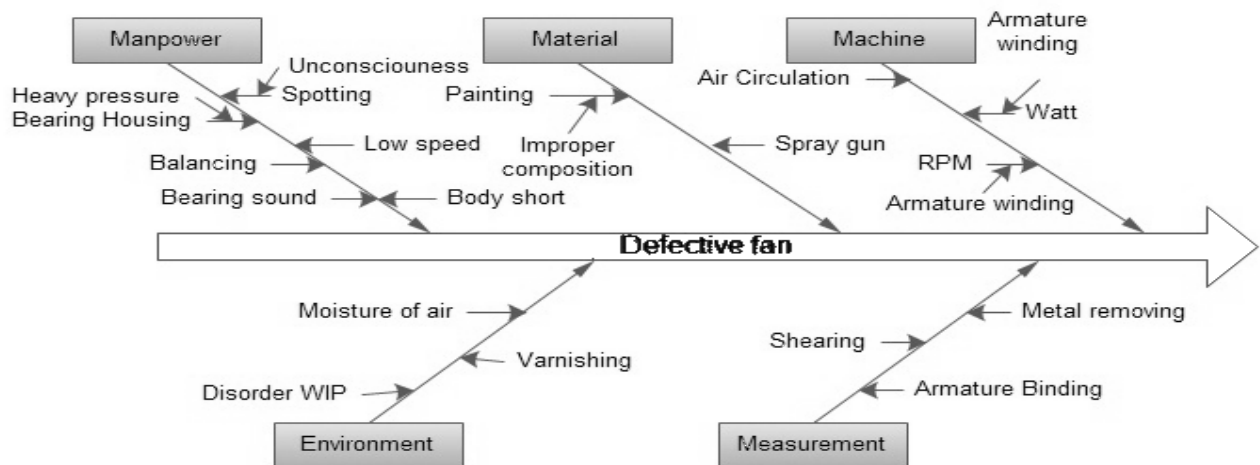


Figure 3 : Cause and Effect Diagram

Process wise capacity of each workstation has been found where Standard allowable minutes (S.A.M) has been calculated. The target per hour for the line calculating total 98 manpower worked on that line for

480 minutes with a S.A.M value of 126.05. The Benchmark target have standardized of 298 pieces of production at 80% efficiency. Observation before balancing the line has been reflected as labor and

machine productivity is 2.45 and 8.28, line efficiency is 64.31%. Some variations are identified in process capacity from the benchmark target and the lower capacity from the benchmark target is the bottleneck process, as production flow would stick on the bottleneck point. Comparing total capacity of each process to the 80% benchmark target, the bottleneck processes have identified named **Pressing 1, Pressing 2, Binding, and Grinding.**

a) *Balancing Process*

Balancing method is very essential to make the production flow. Considering working distance, type of machines and efficiency, workers who have extra time to work after completing their works, have been shared their work to complete the bottleneck processes.

Operator who work in Process no. 9 Hydraulic pressing, have been worked for 36 minutes per hour in her first process, capacity 42 pieces and then have been worked in the process no. 4 pressing 1 for last 24 minutes to make additional 12 pieces for overall capacity of 42 pieces on process no. 4. Similarly Process no. 10 shaft pushing have been worked for 42 minutes and rest 18 minutes have been worked on process no. 5 pressing 2 to make total capacity of 39 pieces which was originally 30 pieces. Process no.12 and 22 have been similarly worked on the process no.7 and 16 for the capacity of 43and 41 pieces per hour.

After considering all the factors and the balancing process, a layout was proposed.

Table 2 : Balancing Sheet

Shifted manpower	From		To	
	Process No	Time	Process No	Time
1	9	36	4	24
1	10	42	5	18
1	12	20	7	40
1	22	50	16	10

Balanced capacity	Previous capacity	Process Name	S.A.M	No. of worker	Process No	Process No	No. of worker	S.A.M	Process Name	Previous capacity	Balanced capacity
40	40	Shearing	3	2	1	2	1	1.5	Ar. Parting	40	40
40	40	Ar. Punching	1.5	1	3	4	1	2	Pressing 1	30	42
39	30	Pressing 2	2	1	5	6	0		Pressing 3	0	0
50	50	Riveting	1.2	1	8	7	3	5.14	Binding	35	43
38	55	Shaft pushing	1.1	1	10	9	1	.86	Hyd. Pressing	70	42
42	42	Balancing	1.43	1	11	12	3	3.27	Shank Joining	55	42
65	65	Coiling	23	25	14	13	5	4.6	Winding	65	65
55	55	Spotting & varnishing	6.55	6	15	16	1	1.7	Grinding	35	41
40	40	Surface finishing 1	9	6	17	18	3	4.5	Drilling	40	40
40	40	Surface finishing 2	6	4	19	20	2	3	Washing	40	40
40	40	Painting	18	12	21	22	1	1.2	Fitting I	50	42
40	40	Fitting 2	4.5	3	23	24	10	15	Quality Control	40	40
40	40	Packaging	6	4	25						

Figure 4 : Proposed Layout of the production process

After taking appropriate actions for improving the process, it has been checked again. Based on the results of this assessment, previous steps may be repeated to achieve the desired level. It is not possible always to get success at the first time, so recurring of all the steps will lead the process to be set at the preferred point.

#### IV. RESULT

Changing from traditional layout to balanced layout model, there are considerable improvements have moved. In a day we have boost up the production up to 312 and with manpower of 98, line efficiency has been improved from 64.31% to 83.60%, which is shown in above table. The Benchmark target have standardized of 298 pieces of production at 80% efficiency. There were some uncertainties in the validity and reliability of the sampled data. These were based on the assumption .As the main purpose of this research is to increase productivity, it has been tried to achieve this by improving the level of sigma. Though this case study has been conducted in a fan manufacturing organization, the procedures and the outcomes will be suitable for any manufacturing organization. During the study not all, the information was collected instantly, but some previous records have been also used for better understanding.

#### V. CONCLUSION

The six-sigma framework provides an impetus for establishing best practice with the company. It also provides the company with a performance benchmark on which it could base its future performance enhancement programs. As it has been observed that the level of its sigma is not satisfactory, there is no way to improve this by DMAIC. The implementation of six-sigma will save money, which will result higher profit of the organization. As the businesses are influenced by globalization, the competition is arising more and more and so, to sustain in the global business every organization needs to maintain appropriate quality level. This study will contribute to a new management approach on improving business process for both efficiency and consistent quality customer service. In the case organization, it is noted that the workers are very busy to produce their expected amount of fan. Almost all time they perform repetitive task, which waste time. As a result, sometimes they produce defective fan. Consequently, there is less possibility for producing defective fan, which is the main target of six-sigma by following DMAIC. On the other hand, by applying line balancing, productivity increases from 240 to 312 per day by reducing defect. Finally, it is said that, it is possible to improve productivity by using six-sigma, which is the main purpose of this research. In the future, it is likely that more changes will emerge; making Six

Sigma an even more beneficial application for organizations of all types and sizes. It is believed that other companies can learn the insights from this study to identify further research areas for efficiency and quality services. To ensure this quality and the sustainability, six-sigma will no doubt play a vital role in the long run in our country.

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