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# Six Sigma application in a process industry for capacity waste reduction: A case study

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A B S T R A C T

Today energy is directly related with progress or growth of any country and every event requires a huge amount of energy. In today's global competitiveness, demand for energy is very high and India is facing a problem of very poor energy supply. So, researchers and planners are worried about very poor productivity of thermal power plant and the most critical cause for this problem is high capacity waste at these plants. This paper focuses on causes of capacity waste and for this, DMAIC approach is adopted. The study also clears some myths of Six Sigma compatibility at process industries (thermal power plant) for performance improvement. After implementation of the first phase i.e. "Define", the study confirms the competence of Six Sigma in defining the issue of capacity waste.



## 1. Introduction

The utility electricity sector in India had an installed capacity of 288 GW in Jan, 2016, which is the world's third largest. In this country, renewable Power Plants constitute 28% of the installed capacity and non–renewable Power Plants constitute 72%. During the last 30 years, there has an average increase of 3.6% in energy demand per annum due to the fast growth of Indian economy. After that India has a poor supply of energy with growing demands and this supply-demand gap is increasing continuously. Installation of new thermal power plants is very difficult because it requires a big amount of money and considerable time. So, poor supply of energy has been causing serious concern and the reason of this energy deficiency is capacity waste. A case study in India estimated that the utilization of installed capacity is very poor.

This capacity can be improved by taking some of the following steps:

- Proper maintenance policy of Thermal power Plant,
- Reduce the distribution losses,

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- Improve the availability,
- Modernization and renovation of Power Plant.

These steps are very useful to increase the capacity of Thermal power Plant, to minimize the cost and to maximize the profits. Six Sigma is a systematic approach adopted by organization worldwide for process improvement. This paper focuses on Six Sigma DMAIC (Define-Measure- Analyze- Improve-Control) approach (Kaushik, 2010; Klarin et al., 2000; Mei, 2010; Sarbapriya & Mihir, 2011) for capacity management mainly in a Thermal Power Plant.

## 2. Concept of Six Sigma

Six Sigma is a well-structured program used by various industries to achieved expected performance with continuous improvement (Douglas & Erwin, 2000). Six Sigma stands for six standard deviation (Sigma is a Greek letter used to represent deviation in statistics) from mean. Six Sigma methodology provides the tool to improve the performance and to minimize the defects in any process (Vote & Huston, 2005). The higher the quality level, the better the process. The defects parts per million w.r.t. different sigma levels are shown in Table 1.

*2.1 DMAIC Methodology*

*Process Definition: The DMAIC Process*

The DMAIC (DEFINE, MEASURE, ANALYSE, IMPROVE, CONTROL) five phase methodology/process of continuous improvement is shown in Fig. 2 (Singh, 2010). It is the most popular methodology and provides the basic structure for most of the available variations today.

**Table 1**
Sigma and Corresponding PPM

| Sigma Level | Percent Yield | PPM |
|---|---|---|
| 6 | 99.9997% | 3.4 |
| 5 | 99.98% | 233 |
| 4 | 99.4% | 6,210 |
| 3 | 93.3% | 66,807 |
| 2 | 69.1% | 308,537 |
| 1 | 30.9% | 691,462 |

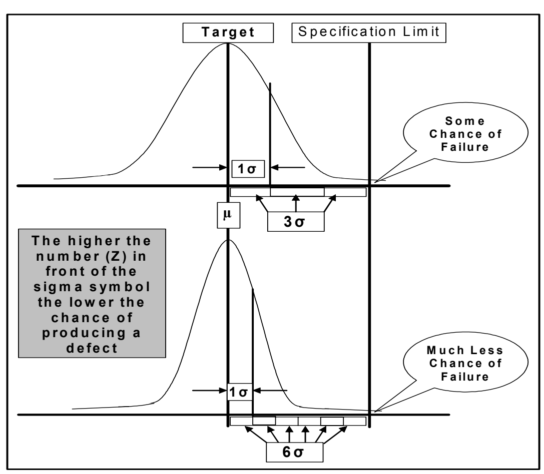


**Fig. 1.** Reducing Variation - Reducing Defects

The DMAIC steps are:

**STEP 1. DEFINE** the problem and identified the customers' requirements.

**STEP 2. MEASURE** the performance and gathers the valid all information about the process.

**STEP 3. ANALYSIS** the current performance to confine the problem. In this step new goals are set and create a route map to achieve the target.

**STEP 4. IMPROVE** the problem by selecting an optimal solution for reducing the variation.

**STEP 5. CONTROL** step ensures that the improvement in the process is not enough but achieved results are sustained and regularly monitoring the ongoing performance.

| DEFINE | MEASURE | ANALYZE | IMPROVE | CONTROL |
|---|---|---|---|---|
| What is the problem? | What data is available? | Analyze data collected. | Develop ideas to remove root causes. | What do we recommended? |
| Impact of problem. | Is the data accurate? | Determine critical inputs. | Evaluate, select & optimize best solutions. | Sustain improvement. |
| Which process to investigate? | Benchmark your current process performance. | What are the root causes of the problem? | Implement solutions. | Continuously monitor. |
| Identify team and resources. | How should we stratify the data? | Have the root causes been verified? | Hypothesis testing. | Correct problem as needed. |
| Targets. | Determine process capability. | Prioritize root causes to be worked. | Review results. | Are result sustainable? |

**Fig. 2.** The DMAIC (Define, Measure, Analyze, Improve, and Control) process

*Concept of Capacity Waste*

Capacity means a system's potential for producing goods or delivering services over a specified interval of time. There are various types of capacities including

- Design Capacity: Maximum obtainable output
- Effective Capacity (Expected Variations):- Maximum to planned and expected variations such as maintenance, coffee breaks, scheduling conflicts.
- Actual Capacity/output (Unexpected variations and demands): Rate of output actually achieved – cannot exceed effective capacity. It is subject to random disruptions; machine breakdown, absenteeism, material shortage and most importantly the demand.

These different types of capacities are very useful to find the efficiency and utilization. These are calculated as follows,

$$\text{Efficiency} = \frac{\text{Actual capacity/Output}}{\text{Effective Capacity}} \text{X}100\ \%$$

$$\text{Capacity Utilisation} = \frac{\text{Actual capacity(A.C.)/Output}}{\text{Design Capacity (D.C)}} \text{X}100\ \%$$

So, we can find the capacity waste as

$$\text{Capacity Waste(C.W.)} = 1 - \text{Capacity Utilisation (C.U.)}$$

$$= 1 - \frac{\text{Actual capacity}}{\text{Design Capacity}}$$

Hence, utilization of capacity available can reflect the effectiveness and efficiency of the production processes. Therefore, optimum utilization of capacity available is very important tool for measuring productivity.

## 3. Six Sigma and Capacity Waste

During the last 50 years, researchers have been giving the attention on the issue of capacity waste (Gajanan & Malhotra, 2007; Reid & Bulich, 1996; Shu & Ying, 2011). Kendrick and Grossman (1980) performed a survey in automobile industries and found that capacity waste in these types of industries were 40 to 48 %, on shift basis. Burange (1993) found that by fully utilizing the capacity of the manufacturing industry, the income, output and employment increase. Hendricks and kelbugh (1998) carried out a case study of a welding industry to see the impact of capacity expansion of firm. Wu (1996) found that the Chinese industries from last ten years i.e. 1985-1995 having high capacity waste (34% to 42%) and the reasons for this waste were: resources crisis, shortage of power, obsolete technology. Goldar and Renganathan (2008) analyzed the econometrically the impact of import on capacity utilization in the industrial firms of India. Bayard and Gilbert (2008) focused on capacity waste and its utilization, released to the water transport sector in China.

In India also, studies on various industries like cement industry (Lalwani, 1984), textile industry (Rao & Gipta, 1997), steel plants (Mathur, 1998) were carried out to find out the capacity utilization levels. Mahapatra and Sarkar (2008) studied the maximum capacity utilization in Tata auto industry.

Literature on Six Sigma is available in large volume but still topic is under development and there is a plenty of scope for advance research and its applications (Raju, 2000). Application of Six Sigma have been applied in many case studies and it is limited to manufacturing industry only. So, there is a great scope to get the benefits of Six Sigma for process industries. Six Sigma approach has been implemented successfully for reduction of scrap, cost reduction, improving availability and cycle time, etc., but there is a rare application of six sigma for capacity waste reduction. Researchers and Scientists have dealt with many methods and techniques like assignment modelling, line balancing, dynamic programming, queuing models, goal programming etc. to improve capacity waste but their applications have been limited. Six Sigma literature lacks in evidence for capacity waste reduction.

## 4. A Case Study

A case study has been carried out in a process industry at DEENBANDHU CHHOTU RAM THERMAL POWER PROJECT (DCRTPP) at Yamunanagar (Haryana), India. It is a unit of Haryana Power Generation Corporation Ltd. (HPGCL) which was incorporated as a Company under Companies Act, 1956 on 17th March'1997 and certificate for commencement of business was granted on 5th August'1997. The business of the generation of power of erstwhile Haryana State Electricity Board was transferred to Haryana Power Generation Corporation Limited (HPGCL) on August 14, 1998 pursuant to the implementation of power reforms in the State of Haryana. This plant is located at Ambala-Saharanpur National Highway in Yamuna Nagar near the bank of Holy River The Yamuna.

*Highlights of DCRTPP (Yamunanagar)*

- CAPACITY 600MW(2*300)
- PROJECT COST 2400CRORE
- LAND 1107(ACRE)
- DATE OF START CONS 20.08.2005
- DATE OF UNIT-1 19.11.2007
- DATE OF UNIT-2 19.02.2008
- GENERATING CAPACITY 144 LACS UNIT\DAY

For study of Six Sigma application, unit-I has been selected. For defining the problem of capacity waste, last one year data related with capacity waste has been collected. To find the capacity waste for every month, main effect analysis has been performed as shown in Fig 3. The average capacity waste was found 105.2 MW/month, which is having a substantial financial and non-financial losses.

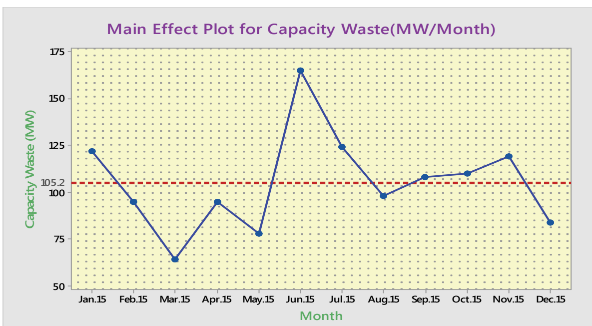


**Fig. 3.** Capacity Waste Analysis

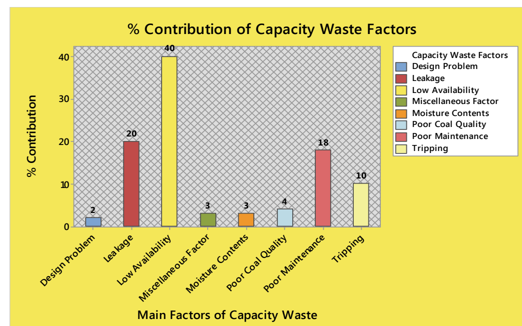


**Fig. 4.** Percentage Contribution of Capacity Waste Factors

Now the question arises that what are the main reasons of this capacity waste? To find out the answer of this question, a diagram has been drawn for capacity waste as shown in Fig 4. With the help of diagram, the main reasons are: Low Availability (40%), Leakage (20%), poor maintenance (18%), Tripping (10%), poor coal quality (4%), moisture content (3%), miscellaneous factor (3%) and design problem (2%). So, it was found that the most serious cause for capacity waste is low availability. Now, for findings the availability of a thermal power plant, it is divided into various systems like: Coal Handling and Crushing system, Steam and Power Generating system, Flue Gases and Air system, Ash handling System, Feed Water and Condensate system and D-M Make-up water system. Now availability of different sections/systems were found with the help of simulation model which is based on Markov Birth-Death Process. The different combinations of failure events and repair priorities were used to compute various availability levels. On the basis of possible combinations of failure and repair rates, the maximum value of system availability was found and it was noticed that some known and feasible values of failure and repair rates affect the availability values of different systems. So, the increase in availability for different sections were calculated as shown in Table 2. From this table, it has been observed that the percentage increase in the availability of Steam and Power Generating system is maximum i.e. there is a great scope to improve the availability or in other words, it can be said that this system had low availability as compared with other systems. Now the study on Steam and Power Generating system was carried out for capacity waste due to low availability and low availability means maximum system failure. For finding causes for this low availability or system failure, Pareto Chart was drawn as shown in Fig 5. This chart shows that 70% of the reasons are due to 20% of factors. In this case study, low availability of this system is mainly due to the failure of Economizer, Superheater and Reheater i.e. failure of Economizer, Superheater and Reheater are prime reasons of high capacity waste. By joining the mid-points of each bar, a line has drawn which demonstrated the cumulative percentage frequency of every section at each stage. This is very helpful to decide the percentage contribution of several reasons/factors for capacity waste more effectively.

**Table 2**
Percentage increase in the Availability values for different systems of a Thermal Power Plant

| Sr. No. | Different Systems of Thermal power Plant | % Increase in the Availability |
|---|---|---|
| 1 | Coal Handling and Crushing system | 2.81 |
| 2 | **Steam and Power Generating system** | **7.47** |
| 3 | Flue gases and Air system | 4.70 |
| 4 | Ash handling System | 3.86 |
| 5 | Feed Water and Condensate system | 6.82 |
| 6 | D-M Make-up water system | 5.29 |

After having been studied comprehensively, the problem is to be converted into a feasible project and it can be explained with the help of project charter as described in Fig 6. It shows the clear representation of project, project details, its aims, project team and resources available, etc. Once the problem has been converted into a project by the project charter, next aim is to point out future plans by conducting brainstorming session for the team members for systematic implementation of the project. This complete project will be a combination of implementation of Six Sigma phases i.e. Define, Measure, Analysis, Improve and Control.

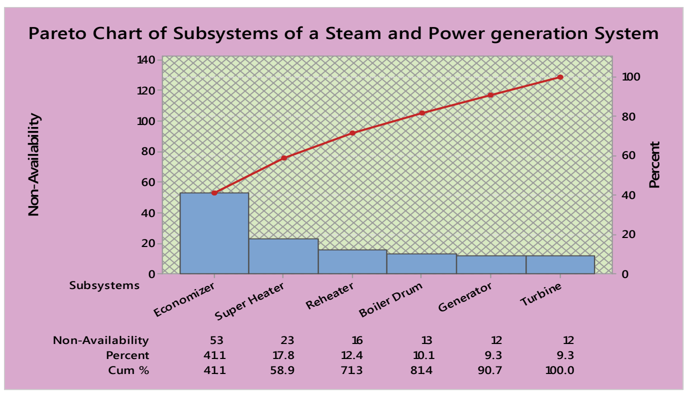


**Fig. 5.** Pareto Analysis of capacity waste factors (Non-Availability of Subsystems)

With the help of Gantt chart (Fig 7), project planning has shown which provides the time planning information of each phase while executing the overall project. After generating a satisfactory strategy and scheme for selected project, next step is to discuss the project issues in details. Project charter shows that low availability of Steam and Power Generating system is the current and the main issue under consideration. After studying the Pareto chart, it was found that 41.1% of low availability of the system due to non-availability of economizer and 17.8% and 12.4% of the low availabilities are due to non-availability of Superheater and Reheater, respectively.

## 5. Conclusion

From the findings of this case study, the following conclusions can be made:

- Failure of system or low availability has come out as the main CTQ (Critical to Quality) issue during the study of capacity waste at Thermal Power Plant.
- Economizer, Reheater and Superheater are identified as the main causes of variation for failure or low availability of the system.
- Define, Measure and Analysis phases of Six Sigma can help appreciably in exploring the application of Six Sigma for classify the various causes and its effects which are responsible for capacity waste at thermal power plant.

| SIX SIGMA PROJECT CHARTER | | | | |
|---|---|---|---|---|
| **General Information** | | | | |
| Project Name: Reduce the capacity waste through Six Sigma | | | Project No.: | 8B |
| | | | Project Location: | |
| Business Case: | | | | |
| **PROJECT DETAILS** | | | | |
| Problem Statement: | | | | |
| Goal/Objective: | | | | |
| Project KPOV(s): Numbers of Failure | | | | |
| project Scope/Constraints: | | | | |
| **RESOURCES** | | | | |
| **Sr. No.** | **Name** | **Members/Researher** | **Role** | **Initials** |
| 1 | Pardeep kumar | Researcher | Research Trainee on Six Sigma | PK |
| 2 | Omparkash | Member | Production Head | OP |
| 3 | Satnam Singh | Member | Quality Supervisor | SS |
| 4 | Viney Sharma | Member | Line Supervisor | VS |
| 5 | Tarun Gupta | Member | Maintenance Supervisor | TG |
| 6 | Shanti Prakash | Member | Technician | SP |
| **BENEFITS** | | | | |
| Expected Bottom Line Saving(Rs. Lacs) | | | | |
| National Savings(Rs. Lacs) | | | **Start** | |
| | | | Define | 1 Jan., 2015 |
| Strategic Benefits | Financial Savings & Increase in Productivity | | Measure | 25 Jan., 2015 |
| | | | Analyze | 28 Feb., 2015 |
| Other Benefits: | Energy Savings: | | Improve | 15 March, 2015 |
| | | | Control | 1 May, 2015 |
| | | | Closure & Handover | 1 Jan., 2016 |
| **AUTHORISATION** | | | | |
| Champion | | | Financial Representative | |
| | Sign | | Sign | |

**Fig. 6.** Six Sigma Project Charter

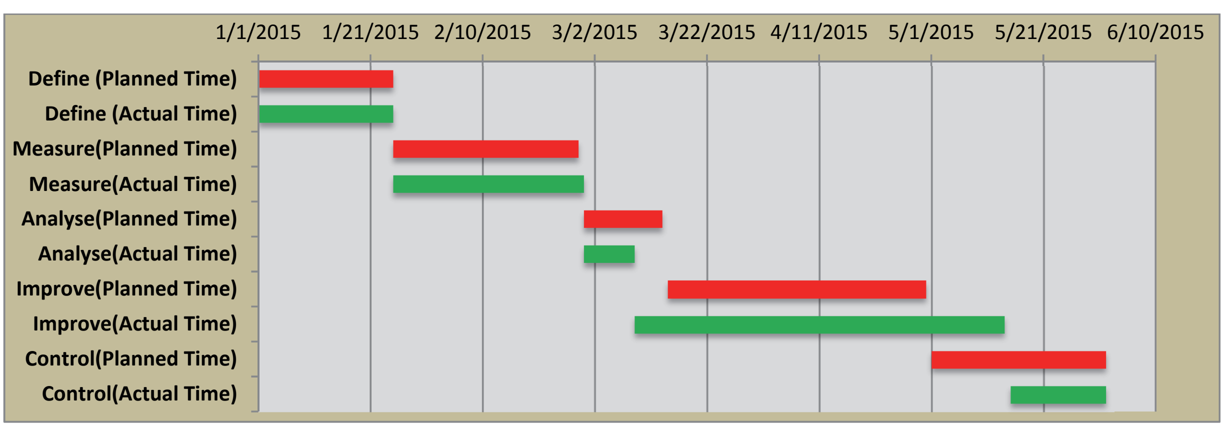


**Fig. 7.** Six Sigma Project Plan (Gantt Chart)

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