SAFETY MANAGEMENT IN MANUFACTURING INDUSTRY: A LEAN SIX SIGMA APPROACH

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Abstract

The lean manufacturing company under consideration recorded the high accident rates for last few years. These accidents cause the organization the heavy man-day loss, the production loss and heavy costs of insurance. The objective of health and safety department at the manufacturing company was to set and improve accident prevention system. The paper presents how does the six-sigma technique will help to evaluate the safety and environmental hazards in performance of organizations. It is observed that the study helped the management to measure, analyze and improve overall safety plan to protect the life and health of the employees.

The paper discusses real life case where six sigma has been successfully applied at one of the Indian small scale unit to improve safety in processes. The main aim behind this project lies to overcome those problems of the industries which are causing loss due to safety. In order to build up system capabilities and graduate towards higher sigma levels of operation, the backbone exercise of six sigma management system is reached by carrying out the failure mode effect analysis.

Keywords: Six sigma, DMAIC, Safety, Lean Manufacturing, Defects, Variation, Accidents

1. Introduction:

Generally it is needed to prevent accidents before it happens to ensure safety of life. Various other safety programs are used in industries to improve safety. Six sigma is a highly disciplined process that helps us focus on developing and delivering near-perfect product and services. The word Six Sigma is a statistical term that measures how far a given process deviates from perfection. The central idea behind six sigma is that if you can measures how many “defects” you have in a process and how to eliminate them. The same methodologies are applied to prevent accident to thus, enhancing safety.

2. DMAIC PHASES OF SIX SIGMA

We have applied the six sigma process on safety in a manufacturing firm. The company is situated in the middle of Nagpur. It is the central India’s largest manufacturer of double roller machines. It is spread over an area of 5.5 acre with the built up area about 9000aq. meter their manufacturing facilities are ISO 9002 and IS 16949 certified that ensures reliability they are supplying their products throughout the country and exporting along foreign countries.

2.1 Objectives of six sigma in this Study are :

- To improve the Worker’s efficiency of working.
- To reduce the number of accidents occurring inside the Industry.
- To identify hazards and control risks while maintaining assurance that these risk controls are effective.
- To avoid the industrial production shut down.
- To avoid financial loss.
- To solve dispute like compensation, requirement by employees.

3. Application of DMAIC Process in the company

3.1 Define Phase:

PDCA

In define phase the PDCA is one of the tool to identify the problems related to safety of workers and industry. PDCA helps to make plan for detecting the total inefficiencies in any plant. On the basis of PDCA data is collected and managed.
3.1.1 SIPOC

Basically SIPOC is a define level tool helps to decide the direction of process or project flow and their benefits. SIPOC stand for Supplier Input Process Output Customer which defines the each point as below-

- **Supplier** – Start point of any project from which project handover ahead.
- **Customer** - Acceptance point of project at any level. Customer may be the supplier when he forward this project to other with some changes.

#### Table 1: SIPOC Chart

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
<th>Customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Engineer</td>
<td>Projects</td>
<td>Weekly assignment</td>
<td>Unit Behavior</td>
<td>Worker</td>
</tr>
<tr>
<td>Automotive Dept.</td>
<td>Vehicles</td>
<td>People, Vehicles, tools and facilities needed</td>
<td>Zero injuries</td>
<td>Worker</td>
</tr>
<tr>
<td>Training Centre</td>
<td>Weekly method</td>
<td>Travel to work site</td>
<td>Corrective actions</td>
<td>Worker</td>
</tr>
<tr>
<td>Safety Dept.</td>
<td>Safety rules</td>
<td>Conduct work</td>
<td>Improvement in worker’s efficiency</td>
<td>Worker</td>
</tr>
<tr>
<td>Product Engineer</td>
<td>Initiatives</td>
<td>Complete record assessment</td>
<td>Last week procedure</td>
<td>Worker</td>
</tr>
</tbody>
</table>

3.2 Measure Phase:

The measure phase generally deals with the data generation related to accidents in company. It again deals with the statistical organizing of data and calculation of sigma level of that company on the basis of that data. The following bar graph shows the distribution of accidental data in per month.

**Figure 3 No. of accidents per month**

Calculation of sigma level before improvement phase

- **Unit-Employee**
  - Defect-Employee Recordable injury
  - Given-550 employees & 112 injuries
  - Opportunity for error in unit
    
    \[=1/\text{workday (250/year)}\]
  - Defects per unit(DPU)
  - DPU=Total defects/Total units
    
    \[=112/550 = .2036/\text{year}\]
  - Defects Parts per Million (ppm)
  - Defects parts per million
(DPU/Year*1000000)/Opportunity for error in 1 unit
=((-2.036/year)*1000000)/(250/year)
=814.54 PPM/day
=0.8406 + √((29.37)-(2.22ln(ppm)))
=4.64 sigma

3.2.1 Cause and effect diagram:
The diagram shows causes of accident in industry and their effects. The diagram helps to study the industry in proper way. It again indicates the defect areas where the methodology is to be applied. Generation of proper solution is effective in causes and effects diagram. Following dig. is generated accordance to industry condition.

In this phase the data collected and statistically represented are analyzed or studied to generate the proper solution so that the Sigma Level can be improved towards the Six Sigma Level. The data carefully analyzed then presented again statistically. For analyzing data FMEA tool is used.

3.3.1 FMEA (Failure Mode Effective Analysis)

FMEA is the tool of analyze phase used for analysis of industry in a deep sense. It shows the functional process, failure types, occurrences, severity of defect and proper recommended actions to be taken. On the basis of risk priority number, we can decide the attention to be provided. Higher the RPN, lower the safety so our aim is to reduce it.

<table>
<thead>
<tr>
<th>FMEA/Process</th>
<th>Failure Type</th>
<th>Severity</th>
<th>Occurrence</th>
<th>Detection</th>
<th>Risk Priority No.(RPN)</th>
<th>Recommended Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improper storage of material</td>
<td>Corrosion</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>45</td>
<td>There should be a proper place for storage and well defined path for transport vehicles.</td>
</tr>
<tr>
<td>Environmental effect</td>
<td>Noting and smoky atmosphere causing injuries</td>
<td>3</td>
<td>10</td>
<td>4</td>
<td>200</td>
<td>Standard work and armonizing should be there.</td>
</tr>
<tr>
<td>Worker’s negligence towards safety</td>
<td>Injury, cuts, damages and hazardous problem to them</td>
<td>6</td>
<td>8</td>
<td>3</td>
<td>240</td>
<td>Awareness programs should be provided to the workers regarding safety.</td>
</tr>
<tr>
<td>Manual Handling of materials</td>
<td>Slips during work</td>
<td>4</td>
<td>8</td>
<td>7</td>
<td>224</td>
<td>These should be minimized use of machinery and its equipment like thick, belts, cautious handling</td>
</tr>
<tr>
<td>Path of travelling of material from one step to other step</td>
<td>Congestion area for working and handling, walking person in inventory</td>
<td>6</td>
<td>9</td>
<td>7</td>
<td>518</td>
<td>There should be defined path for travelling of material in shop. More safety guidelines should be provided for travelling of material.</td>
</tr>
</tbody>
</table>

Figure 5 Cause and effect diagram Chart

Figure 6 Failure Mode Effective Analysis


3.4 Improvement phase

The improvement phase is prepared by considering the various safety problems found in the FMEA in order to improve these safety problems by providing the proper solutions so as to achieve high safety standard. Following are the six safety problems with proper solution.

3.4.1 Safety problem 1. Unloading of material from trucks to storage place

**Solution**
1. Now uses small cranes for lifting materials
2. Uses hand glows during handling
3. Direct truck parking in storage place which effects in minimum manual handling of materials.

![Picture 1]

3.4.2 Safety problem 2. Grinding operation on raw material creates smoke and spark

**Solution**
1. Workers now uses smoke control mask
2. Opening of side sheet for better ventilation & smoke exhaust.
3. Workers now uses full size aprons for avoiding spark contact.

![Picture 2]

3.4.3 Safety problem 3. Manual handling of material

**Solution**
1. To lowering work effort now using Manual handling trucks having rubber tire at the place of metal wheels as shown in image.
2. Now using cranes for material loading & unloading on planer machines
3. Work traveling path is now cleaned for safe material traveling material traveling

![Picture 3]

3.4.4 Safety problem 4. Improper storage of material

**Solution**
Materials are now properly planned and kept by using appropriate space on the floor and also avoiding further congestion in the path.

![Picture 4]

![Picture 5]
Improperly placed material is cleaned now from non storage place.

Picture 6

3.4.5 Safety problem 5. Environmental effect like dust & smoke.

Solution
1. Quantity of exhaust fans are increased now
2. More openings are provided for ventilation & lightning
3. Fan for workers to provide comfort working conditions.

3.4.6 Safety problem 6. Improper location for painting the machine parts in between other shops causes breathing problem.

Solution
1. Suggesting to place the painting shop separately from the shop floor.
2. Design & friction of painting booth to be undertaken.

3.4.7 Improved sigma level calculations

- Defect-Employee Recordable injury
- Given-550 employees & 38 injuries
- Opportunity for error in unit
  \[ = 1 / \text{workday} \times (20.83/\text{month}) \]
- Defects per unit (DPU)
- DPU=Total defects/Total units
  \[ = \frac{38}{550} \]
  \[ = 0.069 \]
- Defects Parts Per Million (ppm)
- Defects parts per million
- \( (\text{DPU}/\text{Year} \times 1000000)/\text{Opportunity for error in 1 unit} \)
  \[ = (0.069 \times 1000000)/(20.83/\text{month} \times 7) \]
  \[ = 473 \text{ ppm/day} \]
  \[ = 0.8406 + \sqrt{(29.37 - (2.22 \ln(\text{ppm}))} \]
  \[ = 4.81 \text{ sigma} \]

3.4.8 Long term & short term improvement

<table>
<thead>
<tr>
<th>Short term Improvement</th>
<th>Long term Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Basic facilities to workers</td>
<td>1. Improvement in high cost safety conditions</td>
</tr>
<tr>
<td>2. Improvement in Material loading &amp; unloading techniques</td>
<td>2. Improvement in painting department</td>
</tr>
<tr>
<td>3. Improvement in Grinding department</td>
<td>3. Improvement in total manual handling</td>
</tr>
<tr>
<td>4. Improvement in storage conditions</td>
<td>4. Improvement in departmental machine setup</td>
</tr>
<tr>
<td>5. Improvement environmental conditions</td>
<td>5. Work place modification due to large capital requirement</td>
</tr>
</tbody>
</table>

Table 1

3.4.9 Improved accidental graph:

Figure 7 Number of accident per month

Figure 8 Number of accident Department Wise
3.5 Control Phase

This is last phase of DMAIC where the implemented improvement parameters are under control or not is checked. This phase is consider to maintain the achieved sigma level. Thus, in order control improvement the regular check is been made mandatory for the workers/ Supervisor in orders to avoid the mistake, which may lead to safety problems causing accidents . The following control chart is used.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Problem</th>
<th>Cause</th>
<th>Check</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Loading of material from store to loading area</td>
<td>Material change for lifting machine</td>
<td>Wrong hand during handling</td>
<td>Loading in proper handling area</td>
</tr>
<tr>
<td>2</td>
<td>Thermal expansion cracks break on tube</td>
<td>Material change</td>
<td>Wrong hand</td>
<td>Loading in proper handling area</td>
</tr>
<tr>
<td>3</td>
<td>Manual handling of material</td>
<td>Wrong hand</td>
<td>Wrong hand</td>
<td>Loading in proper handling area</td>
</tr>
<tr>
<td>4</td>
<td>Improper storage of material</td>
<td>Material is store in proper way</td>
<td>Wrong hand</td>
<td>Loading in proper handling area</td>
</tr>
<tr>
<td>5</td>
<td>Faulty control valves</td>
<td>Material is store in proper way</td>
<td>Wrong hand</td>
<td>Loading in proper handling area</td>
</tr>
</tbody>
</table>

Figure 9 Control Chart

Conclusion: After applying six sigma Methodology on safety issue in manufacturing we have achieve following sigma level.

<table>
<thead>
<tr>
<th>Before Improvement</th>
<th>After Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.64</td>
<td>4.81</td>
</tr>
</tbody>
</table>

On the basis of above result it is concluded that the sigma level can be improved till six sigma with continuous improvement in safety conditions for long period. Safety working practices are promoted in the Industries, lowering down the risk of accidents causing injuries thus enhancing productivity and cost reduction on accidents.

References:
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