CHAPTER 6

CASE STUDY - III

The details of the case study are presented in the following subsections:

6.1 ABOUT THE COMPANY AND NEED FOR CASE STUDY

The case study has been conducted in valves manufacturing organization located in Tamil Nadu, India. The organization has implemented quality strategies and keen to implement VSM. The case study is detailed in the subsections below.

6.2 CURRENT STATE MAP

The graphical representation of the current status of the process for identifying changes required to reach a desired future state.

Production time calculation:

The production time are calculated as follows

Total available time in a shift = 8hr × 60min = 480 min
Total tea, snack and dine break = 60 min
Actual available production time/ shift = 480 – 60 = 420 min

= 420×60 = 25200 sec
The total available production time to meet customer’s demand is 25200s.

Takt time

The time at which product must be produced by the company to satisfy customer demand.

Time calculation for case study:

\[
\text{Takt time} = \frac{\text{available production time}}{\text{total daily quantity required}} = \frac{25200}{8330} = 3.02 \text{ s/product}
\]

Table 6.1. Show attribute collection checklist for case study

Before mapping the current state, the main production processes are decided for the product as follows:


Table 6.1 Attribute collection checklist for case study

<table>
<thead>
<tr>
<th>Attribution collection checklist for case study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total time per shift = 8hr = 480 min</td>
</tr>
<tr>
<td>Total tea, snack and dine break = 60 min</td>
</tr>
<tr>
<td>Total available time for production = 420 min</td>
</tr>
<tr>
<td>(subtract breaks time from the total time per shift)</td>
</tr>
<tr>
<td>Quantity of parts shipped/ month and per day = 165000 and 5500</td>
</tr>
<tr>
<td>Total cycle time = 28s</td>
</tr>
<tr>
<td>Number of operators = 7</td>
</tr>
</tbody>
</table>
Table 6.2 Data collection for case study

<table>
<thead>
<tr>
<th>Process</th>
<th>Cycle time (s)</th>
<th>Changeover (s)</th>
<th>Operators</th>
<th>Availability (s)</th>
<th>Uptime (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48.0</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>98.41</td>
</tr>
<tr>
<td>2</td>
<td>48.0</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>98.41</td>
</tr>
<tr>
<td>3</td>
<td>48.0</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>96.82</td>
</tr>
<tr>
<td>4</td>
<td>48.0</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>99.60</td>
</tr>
<tr>
<td>5</td>
<td>48.0</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>98.41</td>
</tr>
<tr>
<td>6</td>
<td>48.0</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>98.41</td>
</tr>
<tr>
<td>7</td>
<td>48.0</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>98.41</td>
</tr>
</tbody>
</table>

Table 6.3 Current State Data

Table 6.3 shows the current state data for various operations.

The organization receives a weekly shipment of 50000 units per day.
Average demand: 250000 units per month i.e., 8333 units per day.

Customer requirements:
Current state data collection sheet for case study.

Table 6.2 Data collection for case study

6. Number of operators
5. Uptime
4. Changeover time
3. Operators
2. Availability
1. Cycle time
Figure 6.1 Current State Map for the case study
6.3 FUZZY QFD

QFD is a technique for translating the customer demands into design targets and major quality assurance points to be used through the production phase. In our study QFD has been used for finding out the benefits to be achieved using the lean tools employed in the process improvement.

The major steps include the following:

1. Identification of required improvements
2. Identification of significant lean tools
3. Development of relationship matrix
4. Development of correlation matrix
5. Prioritization of Lean tools

The required improvements in our case study include work place cleanliness, reduction of WIP, reduction of changeover time, reduction of manpower, reduction of transportation.

The identified tools include 5S, QCO, Poka Yoke, Work cell, Kanban. The symbols used for depicting relationship include strong (●), medium (○) and weak (◇)

Figure 6.2 shows House of Quality diagram for fuzzy QFD.

HOQ has been constructed between required improvements and identified tools. The highly prioritized techniques include QCO and Kanban. The objective of this HOQ is to prioritize the Lean tools that provide opportunities to achieve the expected outcomes. Improvements are referred to as “Whats” and identified tools are referred to as “HOWs”.
Since the identification of appropriate lean tools for the expected outcomes is done based on the human judgment, fuzzy logic has been used as an effective method. In order to overcome the vagueness associated with linguistic judgment in building HOQ, the relative importance (RI), relationship and correlations have been expressed with triangular fuzzy numbers.

The importance weights \(w_i\) is a fuzzy vector representing the RI of expected improvements on a linguistic fuzzy scale. The importance weights and corresponding fuzzy numbers for rating expected outcomes are shown in Table 6.4.

### Table 6.4 Importance weights and corresponding fuzzy numbers for rating the expected outcomes

<table>
<thead>
<tr>
<th>Importance weight (w_i)</th>
<th>Fuzzy Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high (\text{VH})</td>
<td>(0.7;1;1)</td>
</tr>
<tr>
<td>High (\text{H})</td>
<td>(0.5;0.7;1)</td>
</tr>
<tr>
<td>Low (\text{L})</td>
<td>(0;0.3;0.5)</td>
</tr>
<tr>
<td>Very low (\text{VL})</td>
<td>(0;0;0.3)</td>
</tr>
</tbody>
</table>

The relationship matrix \((R_{ij})\) \((i=1,\ldots,n; j=1,\ldots,m)\) of HOQ is a matrix whose entry \((i,j)\) reveals how much the \(j^{th}\) lean tool is useful against \(i^{th}\) expected outcome.

The degree of relationship the graphic symbol and the corresponding fuzzy numbers are shown in Table 6.5.
Table 6.5 Degree of relationship, the graphic symbol and the corresponding fuzzy numbers

<table>
<thead>
<tr>
<th>Degree of relationship</th>
<th>Graphic Symbol</th>
<th>Fuzzy Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong</td>
<td>●</td>
<td>(0.7;1;1)</td>
</tr>
<tr>
<td>Medium</td>
<td>○</td>
<td>(0.3;0.5;0.7)</td>
</tr>
<tr>
<td>Weak</td>
<td>▽</td>
<td>(0;0;0.3)</td>
</tr>
</tbody>
</table>

After assessing the relation between expected improvements and identified lean tools, the relative importance $RI_j$ of $j^{th}$ identified tool has been computed using the formula:

$$RI_j = \sum_{i=1}^{n}(w_i \otimes RL_{ij}), \text{ where } j = 1, ..., m$$ (6.1)

This is followed by the development of correlation matrix which expresses the correlation between $j^{th}$ and $j'^{th}$ ($j', j = 1, ..., m$, $j \neq j'$) tools. The correlation entry is defined as $T_{j'j}$. The degree of correlations, the graphic numbers and the corresponding fuzzy numbers are shown in Table 6.

The final score of $j^{th}$ lean tool is computed using the following equation:

$$score_j = RI_j \oplus \sum_{j' \neq j} (T_{j'j} \otimes RL_{j}), \text{ where } j = 1, ..., m$$ (6.2)

The result of HOQ between expected outcomes and identified lean tools is the ranking of tools. The fuzziness of scores is to be removed in order to rank lean tools. The crisp value of a triangular fuzzy number is computed using the following equation:

$$crisp \ value = \frac{i+2m+u}{4}$$ (6.3)
Lean tools with the highest scores have significant impact on expected outcomes

Table 6.6 Degree of correlations, the graphic symbol and the corresponding fuzzy numbers

<table>
<thead>
<tr>
<th>Degree of Correlation</th>
<th>Graphic symbol</th>
<th>Fuzzy Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong Positive (SP)</td>
<td>●</td>
<td>(0.3;0.5;0.7)</td>
</tr>
<tr>
<td>Positive (P)</td>
<td>+</td>
<td>(0;0.3;0.5)</td>
</tr>
<tr>
<td>Negative (N)</td>
<td>□</td>
<td>(-0.5;-0.3;0)</td>
</tr>
<tr>
<td>Strong Negative (SN)</td>
<td>◊</td>
<td>(-0.7;-0.5;-0.3)</td>
</tr>
</tbody>
</table>

Figure 6.2 House of Quality diagram for fuzzy QFD
6.4 DEVELOPMENT OF FUTURE STATE MAP

The identified techniques for waste elimination will be incorporated in the future state map. The future state map enables the identification of improvement proposals for eliminating wastes, thereby streamlining the processes.

Operator balance sheet for current state:

Total cycle time = 28s, Takt time = 3.02s and 7 operators

Figure 6.3 shows cycle time for various operations

![Cycle Time Chart](chart.png)

**Figure 6.3 Cycle Time, Operator balance chart for Current State Map**

After reviewing the current state, discussion is made with the operators and production supervisor to set the total cycle time of 18s as a target for the future state which is derived from the total cycle time 28s of current state. Only 6 operators are required to achieve this cycle time.
Number of operators = \(18/3.02 \approx 6\) Operators

The new target can be achieved by making the following changes:

1. Reduction in cycle time
2. Distribute the work of 7 operations among 6 operators
3. Reducing the changeover time in operations
4. Rearrangement of processes according to operators’ allocation

It has been decided to operate the process with 6 operators with a total cycle time of 18s.

The operator balance chart for the future state is shown in Figure 6.4.

- Total cycle time = 18 s
- Takt time = 3.02 s
- Operators = 6

![Cycle Time Chart]

**Figure 6.4 Cycle time, Operator balance chart for Future State Map**
Plan for work cells

One piece flow is promoted by adapting work cells, since in work cell equipments and people are arranged in process sequence. The cell includes operations necessary to complete a product.

Achieving a balanced design depends on applying principles of cell design.

Three future state cells:

1. I Cell (Process 1 and Process 2)
2. II Cell (Process 3 and Process 4)
3. III Cell (Process 6 and Process 7)

New attributes for each cell

**I Cell**

- Cycle time: 5 s
- Changeover: 200 s
- Availability: 25200 s
- Uptime: 99.20 %
- Operators: 2

**II Cell**

- Cycle Time: 6 s
- Changeover: 300 s
- Available time: 25200 s
- Uptime: 98.80 %
- Operators: 1
III Cell

CT – 6 s
C/O – 200 s
Available time – 25200 s
Uptime - 99.20 %

Operators: 2

Figure 6.5. depicts the future state map with all improvement proposals incorporated

Figure 6.5 Future state Map