AHP-QFD in assessing the outcome of gemba kaizen events

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Abstract. The study shows the application of Analytical Hierarchy Process (AHP) and Quality Function Deployment (QFD) as a tool in assessing the outcome of the Gemba Kaizen Event. AHP-QFD method is used to analyze the process of prioritizing the Lean strategy, tools and technique for a Gemba Kaizen Event performed at a manufacturing company. The data obtained from the Gemba Kaizen Event were analyzed with AHP-QFD method in which the research evaluated the best combination and prioritization of lean elements to be deployed systematically. The analysis shows the linkage between the needs and lean strategies. The study found that the main strategy to implement Lean depends on the needs of the production situation of the company. The approach is mainly about improvement in process flow, standardization of the process, creation of Kanban Pull System and process visualization for control of the production.

1. Introduction
The aim of any manufacturer today is to bring down the costs and delivery time while maintain with the highest product quality possible [1]. More than 75% of organizations presently engage in some type of process improvement strategies to meet the expectations of the customers [3], and are forced to transform their pattern of manufacturing. The industries need the advantage required to skip ahead from the competition by having the ability to respond fast to fluctuating demands and immediate deliveries of the products required [4]. Manufacturing system transformation becomes a necessity to overcome increased competition [2]. One of the most popular approach to do this is through Lean Manufacturing. Lean Manufacturing is a derivation from the production system developed by Toyota Motor Corporation (TMC) in Japan which is called the Toyota Production System (TPS) [7]. It is a philosophy of continually improving the industrial production systems through continuously structuring, operating, controlling, and managing it [5]. Correct practices should be adapted to the best practices of Lean Manufacturing and the systematic deployment method to produce the desired results. The processes are re-engineer and improve on its operational characteristics towards a lean mode of production, ridding of waste and unnecessary expenses while enforcing quality at all stages [6].

Lean strategies have been developed to reduce or eliminate waste to improve operational efficiency in manufacturing processes. However, there are problems where manufacturers encounter difficulties in selecting appropriate Lean strategies based on their needs and within their limited amount of available resources [8]. Lean is not a one-size-fits-all concept, but it is a concept which needs to be adapted according to the industry situation and environment setting [9]. Implementation strategy differs between different areas of organizations, which makes it difficult to choose a proper strategy to address a company’s problems [10]. Moreover, improper application of Lean strategies may lead to
inefficient use of the resources of the organization and reduced employee confidence [11]. The existing Lean strategy selection methodologies unable to provide a comprehensive method for selecting appropriate Lean strategies within a manufacturing company. Moreover, the present methods lack a systematic approach and analytical model for selecting appropriate Lean strategies for the identified manufacturing wastes within manufacturers’ resource constraints. This study dwells on how to select the appropriate Lean strategies and prioritize them to be applied to the manufacturing setting and scenario base on the needs. The study evaluates the Lean elements in the implementation model by analyzing the outcome from the Kaizen Events using AHP-QFD method.

2. Methodology

2.1. Gemba Kaizen Event

Gemba Kaizen Event is a structured improvement project in which Kaizen approach is used in a “short-term project focused on a specific process or set of activities, such as the work flow within a specific work center” [12]. In other definition of the term, Kaizen Event is a focused improvement event during which a cross-functional team of operators, engineers, line leaders spend several days analyzing and implementing improvements to a specific work area [13, 15]. The study adapted the TPS Standardized Work kaizen steps as the research steps to perform the Gemba Kaizen activities. The data obtained from the Kaizen Events are the primary data for the research study.

- STEP 1 Discussions & resources planning
- STEP 2 Analysis of current situation
- STEP 3 Define target
- STEP 4 Develop strategy & tactics
- STEP 5 Production & Instruction system kaizen
- STEP 6 Confirm target achievement

For this research, a case study that has the Job shop configuration were taken into the study. In order to remain anonymous and maintaining the confidentiality of the company, the company is referred to as UAF. The Kaizen Event follows the Kaizen steps as explained above to perform the improvement activities. The results from the Kaizen Events are integrated and analyzed using AHP-QFD technique. The technique is applied to prioritize the lean strategies according to the needs of each Kaizen Event. It is also used to establish the linkage between needs and problem faced with the lean strategies.

2.2. AHP-QFD technique

Firstly, in the AHP-QFD technique, the AHP analysis was applied by following the items developed by Saaty [14]. In this research, the analysis was performed to select and prioritize the Lean strategies based on the findings from Gemba Kaizen Events. The overview of the process is shown in Figure 2.1.
2.2.1 Problem definition and determination of goals
The hierarchy of the problem can be developed as shown in Figure 2.2. The goal is to prioritize the Lean strategies based on the findings from Gemba Kaizen Events.

Figure 2.2. Hierarchy of the Problem.

2.2.2 Computing the vector of Lean Strategies weights
In order to compute the weights for the Lean strategies, a set of pair-wise comparison matrices was constructed. Each Lean strategy was evaluated by using the relative scale measurement shown in Table 2.1.
Table 2.1. Pair-Wise Comparison Scale for AHP Preferences

| Definition                              | Index | Definition                              | Index |
|----------------------------------------|-------|----------------------------------------|-------|
| Equally important                      | 1     | Equally important                      | 1/1   |
| Equally or slightly more important     | 2     | Equally or slightly less important     | 1/2   |
| Slightly more important                | 3     | Slightly less important                | 1/3   |
| Slightly to much more important        | 4     | Slightly to way less important         | 1/4   |
| Much more important                    | 5     | Way important                          | 1/5   |
| Much to far more important             | 6     | Way to far more important              | 1/6   |
| Far more important                     | 7     | Far less important                     | 1/7   |
| Far more important to extremely more important | 8 | Far less important to extremely less important | 1/8 |
| Extremely more important               | 9     | Extremely less important               | 1/9   |

Next in the AHP-QFD Methodology is to perform QFD analysis. The objective of QFD analysis in this research is to analyze the linkage between company needs and Lean strategies. The flow of the QFD analysis which consists of four main steps is depicted in Figure 2.3.

![Figure 2.3. Steps in QFD method.](image)

2.2.3 Preparation of the relationship matrix

The relationship matrix was performed to establish the relationship between “WHATs” and “HOWs”. Figure 2.4 shows the relationship between Lean strategies (LS) and the company needs (N).
2.2.4 Calculation of Weights of HOWs

Weights of HOWs is denoted as Column Weights (CW). CW represents the overall relationship between the needs (N) and Lean strategies (LS). The calculation for the value of CW\(_j\) is shown as follows:

\[
CW_j = \sum [ R_{ij} \times IR_i ]
\]  

IR\(_i\) denotes the value from Importance Ratings. To further explain on this formula, a few examples depicted from Figure 2.4 are given as follows:

\[
\begin{align*}
CW_1 &= [ R_{11} \times IR_1 ] + [ R_{21} \times IR_2 ] + [ R_{31} \times IR_3 ] \\
CW_2 &= [ R_{12} \times IR_1 ] + [ R_{22} \times IR_2 ] + [ R_{32} \times IR_3 ] \\
CW_3 &= [ R_{13} \times IR_1 ] + [ R_{23} \times IR_2 ] + [ R_{33} \times IR_3 ]
\end{align*}
\]  

3. UAF case study

UAF is a wholly owned subsidiary of a Malaysian conglomerate, located in Shah Alam, Malaysia. The company consists of three plants which are the Main plant, Stamping plant and Plastic plant. The manufacturing operations are divided into 2 main categories, the Plastic operations and Metal operations. For Plastic operations, the company produces air filter products which are the air filter modules, and Non-Air filter products such as charcoal canisters, cylinder head covers, fuel filters, brake reservoirs, and plate holders to be supplied to various auto manufacturer and vehicle assembler in Malaysia. The layout of the plant generally is of Job shop configuration. This study was done at the company’s production line with a focus on air filter products ranging from Raw Material incoming until Finish Good delivery. The management wants to install the Kanban Pull System in the production area and selected the Plastic Operation value stream, which comprises of Delivery area, Warehouse, Plastic Injection lines and Plastic Assembly lines as the scope area or the targeted Value Stream to be kaizen. The major needs and goals for the Lean kaizen projects highlighted at this stage which are to improve material flow from plastic injection to warehouse, create a Pull system at air filter line, reduce the stock by 15%, increase productivity by 20% and to improve the quality at air filter line by achieving 0% customer claims.

The following are the kaizen points grasped from the MIFC before kaizen for UAF:
For the Plastic Injection lines, it is found out that production was run and scheduled according to monthly forecast and scheduled planning. The production was not tied up with sales and customer requirement thus over production of some models and parts shortage of some models frequently happen. Moreover, by planning, it leads to high raw material and finish goods, high work-in-process (WIP) stock resulting in stagnation of parts flow. The production lead time becomes long and creates a lot of non-value-added activities. The components were stored in wire mesh which leads to big production lot size of the models and creates too many WIP stocks. It also utilizes more space. The Plastic Assembly lines were arranged in 6 isolated cell layout configuration which produces a part number for each cell. The individual cell limits the sharing of workload between the operators. This is called the Fixed Manpower Configuration cell and it has no flexibility to adapt to demand changes. Hence, there was an unbalance in the workload distribution between the production cell which leads to low productivity and poor production visualization. The overall layout and material flow along the Value Stream was not smooth and the internal part supply method was not well established. The company practices Push production method which leads to long lead time and high WIP stagnation in the Value Stream.

The kaizen strategies done cover the following aspects:

Relayout for smooth flow
Smooth flow must first be established as a pre-requisite in creating the Kanban Pull System. The Production team members performed relayout of the Plastic Assembly area by grouping the cells between air filter lines and the Non-air filter lines. Rearrangement of production line according to the product group using Big Island concept was done. The machines are arranged according to process sequence. Relocation of FG storage near to plastic assembly line was done. A checking area for QC was also set up.

Standardized Work (SW)
SW for the operators was created. The Standard Work Chart (SWC) was developed for the production line and visualized at the shop floor. The quality key points are integrated into the SW. The Standard in Process Stock (SIPS) was set in the production line.

Productivity Kaizen
Improvement in productivity was done at the Plastic Assembly lines. The isolated production cells were combined thru the Big Island concept. By creating the Big Island cell, a multi model cells was created and thru Takt production, the manpower appointed to operate the cell was streamlined and given the correct workload. Waiting time and unbalance workload of the workers were eliminated thus improves productivity by improving the output per man hours.

Streamline the part supply system
The internal part supply system was improved by streamlining the part supply method between the Delivery area, Warehouse, Plastic Assembly lines and Plastic Injection lines. Flow racks and part boxes were used instead of wire mesh to store the Raw Material parts, WIP parts as well as the Finish Goods parts. The parts were stored in a fix quantity according to the determined lot size in the part boxes. Furthermore, the part supply route was streamlined by establishing Set Part Supply system and establishing the Standard Work for the material handler. Workload balancing for material handler was done. In the Set Part Supply system, the number of Transfer Person (TP), the parts that the TP need to transfer, the route the TP needs to follow in order to transfer the parts, the method and the timing of part transfer are synchronized according to the Takt production. By establishing the Set Part Supply system, material and information can be moved and transferred along the Value Stream according to JIT concept. The usage of forklift in the production area was eliminated. A Supply Part monitoring board was established to control and visualize the parts supply condition.
**Kanban Pull System**

The pulling mechanism was designed into the targeted Value Stream, starting from the Delivery area and Warehouse. The System team performed the Shipping management activities by improving the Shipping operations. The pulling effect start from the pulling from the customers, hence a clear shipping operations and control was vital in establishing the Kanban Pull System. In order to have a levelled pulling effect, *Heijunka* post was used. Line Store was designed into the system to place the FG and the Kanban chute was used to place the Kanban sequence. As for the internal Kanban, dual Kanban system was adopted, usage of PW (Parts withdrawal) and PI (Production Instruction) Kanban. The established Kanban Pull System is shown in Figure 3.1.

![Figure 3.1. MIFC for the Kanban Pull System](image)

4. **Results and Discussion**

4.1 **AHP Analysis Results**

The results for AHP analysis on Kaizen Event at UAF are divided into four sections: (i) Pair-Wise Comparison Matrix, (ii) Synthesized Matrix, (iii) Weighted Sum Matrix and (iv) Consistency Ratio as tabulated in Table 4.1, Table 4.2, Table 4.3 and Table 4.4.

4.1.1. **AHP Pair-Wise Comparison Matrix.** The results for pair-wise comparison matrix for UAF is shown in Table 4.1.

| JS-UAF   | Flow   | SW     | Part Supply | Pull | V-SFE | Productivity |
|----------|--------|--------|-------------|------|-------|--------------|
| Flow     | 1.00   | 2.00   | 5.00        | 6.00 | 4.00  | 3.00         |
| SW       | 0.50   | 1.00   | 4.00        | 5.00 | 3.00  | 2.00         |
| Part Supply | 0.20   | 0.25   | 1.00        | 2.00 | 0.50  | 0.33         |
| Pull     | 0.17   | 0.20   | 0.50        | 1.00 | 0.33  | 0.25         |
| V-SFE    | 0.25   | 0.33   | 2.00        | 3.00 | 1.00  | 0.50         |
| Productivity | 0.33   | 0.50   | 3.00        | 4.00 | 2.00  | 1.00         |
4.1.2. AHP Synthesized Matrix Results. The results for synthesized matrix for UAF are tabulated in Table 4.2. The results of priority vector show that Flow is the highest rank of Lean strategy for UAF. The lowest rank is Pull.

Table 4.2. Synthesized Matrix result for UAF

| JS-UAF       | Flow  | SW    | Part Supply | Pull  | V-SFE | Productivity | Priority Vector |
|--------------|-------|-------|-------------|-------|-------|--------------|-----------------|
| Flow         | 0.4082| 0.4669| 0.3226      | 0.2857| 0.3692| 0.4235       | 0.3794          |
| SW           | 0.2041| 0.2335| 0.2581      | 0.2381| 0.2769| 0.2824       | 0.2488          |
| Part Supply  | 0.0816| 0.0584| 0.0645      | 0.0952| 0.0462| 0.0471       | 0.0655          |
| Pull         | 0.0680| 0.0467| 0.0323      | 0.0476| 0.0308| 0.0353       | 0.0434          |
| V-SFE        | 0.1020| 0.0778| 0.1290      | 0.1429| 0.0923| 0.0706       | 0.1024          |
| Productivity | 0.1361| 0.1167| 0.1935      | 0.1905| 0.1846| 0.1412       | 0.1604          |

4.1.3. Weighted Sum Matrix Results. The result for weighted sum matrix for Kaizen Event for UAF is summarized in Table 4.3

Table 4.3. Weighted Sum Matrix results

|        | UAF     |
|--------|---------|
| Flow   | 2.3562  |
| SW     | 1.5459  |
| Part Supply | 0.3952 |
| Pull   | 0.2634  |
| V-SFE  | 0.6218  |
| Productivity | 0.9864 |

4.1.4. AHP Results on Consistency Ratio. Table 4.4 shows the results for Consistency Ratio (CR) of Kaizen Events for UAF. Based on the result, the CR for UAF is acceptable, as the ratio do not exceed 0.10. Thus, all judgments with regards to Lean strategies are consistent.

Table 4.4. Consistency Ratio

|        | Consistency Index, CI | Consistency Ratio, CR |
|--------|-----------------------|-----------------------|
| UAF    | 6.1232                | 0.0246                | 0.0199                |
4.1.5. QFD Analysis Results

**Table 4.5. QFD result for Company: UAF**

| S. No | LEAN STRATEGIES | Importance Rating | Ranking | Lead-time reduction | Stock reduction | Lot-size reduction | Productivity Improvement | Man-power reduction | Change over time reduction | Quality Improvement |
|-------|-----------------|-------------------|---------|---------------------|-----------------|--------------------|------------------------|---------------------|--------------------------|---------------------|
| 1     | Flow            | 0.3794            | 1       | 10                  | 10              | 6                  | 6                      | 6                   | 2                        | 8                   |
| 2     | SW              | 0.2488            | 2       | 6                   | 6               | 8                  | 10                     | 10                  | 8                       | 10                  |
| 3     | Part Supply     | 0.0655            | 5       | 8                   | 10              | 10                 | 8                      | 8                   | 6                       | 2                   |
| 4     | Pull            | 0.0434            | 6       | 8                   | 8               | 8                  | 8                      | 8                   | 8                       | 6                   |
| 5     | V-SFE           | 0.1024            | 4       | 2                   | 2               | 2                  | 2                      | 2                   | 6                       | 6                   |
| 6     | Productivity    | 0.1604            | 3       | 6                   | 8               | 6                  | 10                     | 10                  | 10                      | 10                  |

Table 4.5 shows the QFD result for UAF. The highest point in the column weight is Quality improvement. UAF management has set the target to achieve 0% customer claim, which is very important for the company’s credibility and image to the customers. Therefore, the main needs for UAF is on quality improvement. The second highest is on stock reduction. Productivity and manpower reduction both share the same points in the column weights. As a result, from the analysis, the linkage can be summarized and concluded as follows:

1. Reduction in production lead time - FLOW
2. Reduction in WIP stock - FLOW
3. Reduction in Lot Size – PART SUPPLY
4. Reduction in manpower usage - PRODUCTIVITY
5. Increment in productivity - PRODUCTIVITY
6. Improvement in changeover time - PRODUCTIVITY
7. Improvement in quality – STANDARDIZED WORK

SW and Productivity are strategies that have a close linkage to each other. Part Supply and Pull also links closely to each other. For strategies of Pull & V-SFE, both are ranked low in the priority vector because both strategies are usually deployed after all the other strategies are done. Pull binds all the lean elements, whereas V-SFE maintains the lean elements through abnormality control for sustain.

5. Conclusion

The AHP-QFD technique is used to analyze the data obtained from the Kaizen Event done at UAF. The technique is applied to prioritize the lean strategies according to the needs of the Kaizen Event. The result from the analysis is also used to establish the linkage between needs and problem faced with the lean strategies. UAF follows the guideline of the lean strategies prioritization in order to improve the production flow, part supply method and implementation of Kanban Pull System. The study outlines how an AHP-QFD approach, commonly used in engineering and manufacturing by virtue of selecting such as supplier selection and customer preferences prioritization, is well suited to developing a field-tested and theoretically grounded research instrument that can be useful and understandable for implementation in the industry. Other than using the AHP-QFD approach, the study can be expanded through the application of other techniques to analyze the model. Other
techniques identified as suitable to be applied are Decision Tree (DT) and Discrete Event Simulation (DES).

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