Critical factors for successful six-sigma implementation: an analytical hierarchy process (AHP) based

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Keywords
Critical, factors, for, successful, six, sigma, implementation, analytical, hierarchy, process, AHP, based

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CRITICAL FACTORS FOR SUCCESSFUL SIX-SIGMA IMPLEMENTATION: AN ANALYTICAL HIERARCHY PROCESS (AHP) BASED STUDY

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ABSTRACT
The purpose of this study is to identify critical factors for successful Six-Sigma implementation by using the Analytical Hierarchy Process (AHP) approach. Twenty-one experts, consisting of three-project champions and eighteen-black belts from five multinational companies (Singapore, Japan, and USA) locating in Thailand, were interviewed. The study has gone through four phases, including: (1) determining critical factors and performance measures in Six-Sigma implementation; (2) structuring the problem and building the AHP model; (3) collecting data from expert interviews; and (4) determining the normalized priority weights of individual factors and sub-factors. Expert Choice software was used to compute the normalized and unique priority weights. The result of data analysis determined the relative importance of individual factors and sub-factors, and in turn identified the critical factors on which organizations should put their efforts throughout the process of 6-Sigma implementation.

Keywords: Critical factors, Six-Sigma, Implementation, Analytical Hierarchy Process (AHP)

1. Introduction
Six-Sigma is a strategy that is gaining wide acceptance in industry. For example, in 1999 General Electric Company spent about half a billion in six-sigma initiatives and received over two billion in benefits for the fiscal year [Pande et al., 2000]. Six-sigma takes a holistic approach towards understanding and solution of problems, thus develops close links between organizational competitiveness, customer satisfactions, and continual improvement. By implementing this strategy, the organization could achieve breakthrough improvement with dramatically impact not only on financial benefits but also customer satisfaction and manufacturing capability. While the six-sigma strategy has made a substantial impact on industry, academic research in this area is lacking and lagging behind, particularly research regarding what makes a successful six-sigma implementation. Therefore, the purpose of this study is to identify critical factors for successful Six-Sigma implementation by using the Analytical Hierarchy Process (AHP) approach. This paper consists of five sections. Section 2 summarizes the relevant literature, which leads to the identification of critical factors for successful Six-
Sigma implementation. Research methodology and findings are described in section 3 and 4 respectively. Section 5 suggests some managerial implications relevant for the implementation of Six Sigma.

2. Literature Review

2.1 Brief history of Six-Sigma strategy
Six-Sigma is a concept that was originated by Motorola Inc. in the USA in 1980s [Antony, 2002]. It was a way for Motorola to express its quality goal where a defect opportunity is a process failure that is critical to the customer. This provided an important focus on the improvement rate and, in particular, that simply “better” may not be sufficient, but that the critical consideration is that of becoming sufficiently better expeditiously. Six-Sigma clearly focused resources at Motorola, including human effort, on reducing variation in all processes including manufacturing and administrative processes. To establish a clear measure on the improvement activities, this program was launched in 1987. The reason for the name was that “sigma” is a statistical measure related to the capability of the process or its ability to produce non-defective products/units/parts. In statistical word, sigma is a measure of process variability referred to as the standard deviation and “six sigma” generally implies occurrence of defects at a rate of 3.4 defects per million opportunities (DPMO) for defects to arise [Antony and Fergusson, 2004]. Note that this almost certainly implies more than 3.4 defective units per one million units, since typically any given unit is sufficiently complex so as to allow multiple opportunities for defects to occur.

Generally it is possible to calibrate the “cost of quality” or the “cost of poor quality” with the sigma level at which processes perform. Six-Sigma performance levels are generally considered to be world class with the cost of poor quality being less than 1 per cent of sales. By contrast sigma levels of three, four, and five produce DPMO rates of 66,807, 6,210, and 233, and corresponding cost of poor quality ranges of 25-40 percent, 15-25 per cent, and 5-15 percent respectively [Antony and Banuelas, 2002; Banuelas and Antony, 2002]. These numbers substantiate the importance of reducing process variation across all key primary and support processes in an organization as well as variation of that obtained from suppliers.

2.2 Factors for successful Six-Sigma implementation
Management leadership, involvement, and commitment: As reported by many previous researches, management leadership, involvement, and commitment is an important factor in Six-Sigma implementation because it improves performance by influencing other factors including total quality management (TQM) practices [Banuelas and Antony, 2002; Banuelas and Antony, 2003]. Successful implementation of Six-Sigma requires effective change in an organization’s culture, and it is almost impossible to change an organization without a concentrated effort by management aimed at continuous improvement, get involvement among people within the organization, and cooperation throughout the value chain [Breyfogle et al, 2001; Pande and Holpp, 2002].

Training and understanding the six sigma methodology, tools and techniques: Employee training is clearly identified as a critical component of workforce management when implementing significant changes in an organization [Dale, 2000; Choo et al, 2003]. If it is to be effective, (i.e. transform employees into creative problem solvers) training in quality-related issues should emphasize both tools and techniques in problem solving, effective communication, and statistical process control [Choo et al, 2003]. Workforce training in tools and techniques must be continuously carried out if the improvement effort is to be sustained, for an ongoing training program will help employees discover innovative ways to improve the organization and shoulder more of the responsibility for effecting improvements [Eckes, 2000; Halliday, 2001; Ingle and Roe, 2001].
Linking Six Sigma to business strategy: Six Sigma could not be treated as another stand-alone activity. It requires adherence to whole philosophy rather than just the usage of a few tools and techniques of quality improvement [Dale, 2000]. Organization by top management needs to be clear how Six-Sigma strategy and other business/manufacturing strategy are linked to each other and enhance the over competitiveness of the organization [Pande et al., 2000]. Since the competitiveness of most organization is to maximize profits, Six-Sigma strategy could be considered in order to make business process profitable while attacking variability which leads to high scrap rate, high rework rate, low productivity [Sanders and Hild, 2000; Banuelas and Antony, 2002].

Linking Six-Sigma to customers: One of the most important factor for successful Six-Sigma implementation if the ability to link this strategy to customers [Harry and Schroeder, 2000]. Six-Sigma should be started and ended with the customer. Projects should begin with the determination of customer needs, requirements, and expectations [Pande et al., 2000]. Therefore, the process of linking this strategy to the customer could be divided into two steps: (a) identifying the core process, defining the key outputs of these processes, and defining how much cost or profits could be reduced or increased; (b) identifying and defining the customer needs, requirements, and expectation [Banuelas and Antony, 2002].

Project selection, prioritization and project management: The prioritization and selection of projects to be selected, evaluated, and improved is needed to the successful for Six-Sigma implementation [Sandholm and Sorqvist, 2002]. Ineffective selected and defined projects lead to delayed in results and also a great deal of frustration [Pande et al., 2000]. Another important factor in implementing this strategy is that project leaders should demonstrate basic project management skills. Some previous literature indicated that in the back belt training program, project team leader and members should learn tools and techniques in effective project management [Eckes, 2000]. It is important to note that because Six-Sigma strategy is a project driven-basis, it requires for the team members to have project management skills to meet the various deadlines or milestones during the course of the project [Antony and Banuelas, 2001].

Linking Six Sigma to suppliers: Linking the continual improvement process to suppliers is important for adopting this strategy. It could be facilitated by long-term, cooperative relationships with as few suppliers as possible to ensure that the quality materials and/or services would be provided. Maintaining a small number of suppliers improves product quality and productivity of buyers by encouraging enhanced supplier commitment to both the customer responsiveness and quality improvement [Harry, 1998; Harry and Schroeder, 2000]. Additionally, Henderson and Evans [2000] suggested that linking Six-Sigma strategy to a small number of suppliers facilitates the solution of quality and delivery problems. Successful linkage encourages suppliers to become involved in the buying firm's design of products/services, and give them a chance to offer suggestions regarding product and/or component simplification. They can also help purchasers procure the materials and parts that can be used most efficiently [Hendricks and Kelbaugh, 1998; Sandholm and Sorqvist, 2002].

3. Research methodology

In order to determine the managers understanding on the critical factors that affect the successful implementation of Six-Sigma at firm level, this study have conducted an in-depth research in the Thai electronics components manufacturing industry using the Analytical Hierarchy Process (AHP) approach [Satty, 1980]. Twenty-one experts, consisting of three-project champions and eighteen-black belts from five multinational companies (Singapore, Japan, and USA) located in Thailand, were interviewed. The study involved four phases, which includes:

(a) Assessment of success factors in six-sigma implementation (See Table 1);
(b) Problem structure development and building the AHP model (See Figure 1);
(c) Collecting data and information from expert interviews (See Table 2, 3); and
Critical factor determination through the analysis of the normalized priority weights of individual factors (See Table 4).

Table 1 description of factors for successful implementation of Six-Sigma

<table>
<thead>
<tr>
<th>Factors</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor 1: Management leadership, involvement and commitment</td>
<td>Providing adequate financial support; Involving in project progress review meeting; Communicating what customer needs, requirements, and expectation throughout the organization</td>
</tr>
<tr>
<td>Factor 2: Training and understanding the Six-Sigma methodology, tools and techniques</td>
<td>Providing training budgets; Establishing the formal training programs; Evaluating the understanding of all training courses</td>
</tr>
<tr>
<td>Factor 3: Linking Six-Sigma to business strategy</td>
<td>Establishing clearly business/functional strategies; Determining the linkage among business/functional strategies; Communicating business/functional strategies to all level of the organization</td>
</tr>
<tr>
<td>Factor 4: Linking Six-Sigma to customers</td>
<td>Clear determining what customer needs, requirements, and expectations are; Communicating the common goal/objective to all level in the organization and customer</td>
</tr>
<tr>
<td>Factor 5: Project Selection, prioritization and project management</td>
<td>Determining project timeframe; Determining of authority and responsibility for each stage of project management; Follow-up the progress in periodically</td>
</tr>
<tr>
<td>Factor 6: Linking Six Sigma to suppliers</td>
<td>Determining all capable suppliers who involve in continuous improvement activities; Communicating business and functional strategy to suppliers;</td>
</tr>
</tbody>
</table>

In order to determine the relative importance of factors, judgment matrices were translated into the largest Eigenvalue problems, and then computed the normalized and unique priority vectors of weights by using the Expert Choice software [DSS, 1995]. The overall inconsistency index of judgments was calculated as 0.034 for success factors that are acceptable with level of 0.10 as recommended by Saaty [1980].

![Successful Six-Sigma Implementations](image)

**Figure 1**: AHP model for successful Six-Sigma implementation
### Table 2: Scale of Preferences between Two Factors

<table>
<thead>
<tr>
<th>Intensity of Importance</th>
<th>Definition</th>
<th>Explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two activities contribute equally to the objective</td>
</tr>
<tr>
<td>3</td>
<td>Weak importance of one over other</td>
<td>Experience and judgment slightly favors one activity over another</td>
</tr>
<tr>
<td>5</td>
<td>Essential or strong importance</td>
<td>Experience and judgment favors one activity over another</td>
</tr>
<tr>
<td>7</td>
<td>Very strong or demonstrated</td>
<td>An activity is strongly favored and its dominance is demonstrated in practice</td>
</tr>
<tr>
<td>9</td>
<td>Absolute importance</td>
<td>The evidence favoring one activity over another is of the highest possible order of affirmation</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>Intermediate values between the two adjacent judgments</td>
<td>When compromise needed</td>
</tr>
</tbody>
</table>

### Table 3: Excerpted Sample Questionnaire of AHP

**Question on what is the relative importance of benefits of Six Sigma Implementation?** Please compare the benefits of Six Sigma implementation and circle your answer using the scale below (1 = Equal; 3 = Moderate; 5 = Strong; 7 = Very strong; 9 = Extreme)

<table>
<thead>
<tr>
<th>Increasing Importance</th>
<th>Increasing Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial benefits</td>
<td>Customer satisfaction</td>
</tr>
<tr>
<td>9 8 7 6 5 4 3 2 1</td>
<td>1 2 3 4 5 6 7 8 9</td>
</tr>
<tr>
<td>Financial benefits</td>
<td>Process Capabilities</td>
</tr>
<tr>
<td>9 8 7 6 5 4 3 2 1</td>
<td>1 2 3 4 5 6 7 8 9</td>
</tr>
<tr>
<td>Customer Satisfaction</td>
<td>Process Capabilities</td>
</tr>
<tr>
<td>9 8 7 6 5 4 3 2 1</td>
<td>1 2 3 4 5 6 7 8 9</td>
</tr>
</tbody>
</table>

### 4. Findings

The results of the study are shown in Table 4. The findings show that the most critical factors for Six-Sigma implementation are: (1) Management leadership, involvement and commitment; (2) Training and understanding the six-sigma methodology, tools and techniques; and (3) Project selection, prioritization and project management respectively. The consistency ratio is 3.4% which is well below the upper limit of 10%.

### Table 4: The Analysis of the Normalized Priority Weights of Individual Factors

<table>
<thead>
<tr>
<th>Success factors</th>
<th>Priority weight</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management leadership, involvement and commitment</td>
<td>0.239</td>
<td>1</td>
</tr>
<tr>
<td>Training and understanding the six sigma methodology, tools and techniques</td>
<td>0.226</td>
<td>2</td>
</tr>
<tr>
<td>Linking Six Sigma to business strategy</td>
<td>0.137</td>
<td>5</td>
</tr>
<tr>
<td>Linking Six Sigma to customers</td>
<td>0.143</td>
<td>4</td>
</tr>
<tr>
<td>Project selection, prioritization and project management</td>
<td>0.156</td>
<td>3</td>
</tr>
<tr>
<td>Linking Six Sigma to suppliers</td>
<td>0.096</td>
<td>6</td>
</tr>
</tbody>
</table>

Note: IR=0.034
5. Managerial Implications

There are many examples of failed Six-Sigma projects. Six-Sigma can be a big success story for companies if implemented appropriately through the corporate infrastructure. It is important to note that two vital aspects for the implementation of Six-Sigma process are the commitment and involvement of the top management and development of human resources specific to Six-Sigma. Implementation requires to originate at the top echelons of a company. Key stakeholders have to be identified and committed up front. The technical know-how regarding the process management is in the heart of the Six-Sigma methodology. Appropriate training in tools and techniques of Six-Sigma is critical for the successful implementation of Six-Sigma.

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