3.1 THE SIX SIGMA QUALITY PHILOSOPHY

Six Sigma has been used by some of the world’s most successful companies leading to savings of billions of dollars, striking increases in speed and capacity in their processes and achieving new, stronger customer relationships. Six Sigma is a flexible system used to achieve, sustain and maximize business success. There is extensive published information on the growing number of Six Sigma users. An overview is shown in Fig. 3.1. Examples of companies that have implemented Six Sigma are GE, Siemens, Nokia, American Express and Volvo. Six Sigma is focused on six key principles which are summarized below. [Bicheno 2000]

**Critical to Quality:** The customer is the starting point and what is important for the customer needs to be identified.

**Defect:** Anything that does not deliver exactly what the customer needs

**Process Capability:** The processes need to be able to deliver what the customer wants

**Variation:** As it is experienced by the customer

**Stable Operations:** The goal is to secure reliable, robust processes that improve the customer’s satisfaction.
**Design for Six Sigma**: The design must meet all the customer requirements and the capability of the process.

![Graph showing the increase of companies implementing Six Sigma](image)

Fig. 3.1- Overview of the increase of companies implementing Six Sigma
[Source: Klefsjo and Bergman 2004]

Six Sigma is a process improvement methodology that uses data and statistical analysis to identify and manage process variations to reduce or eliminate “defects” in a company’s operational performance. Developed by Bill Smith at Motorola Corporation in 1986[Lo et al.2009], Six Sigma can be applied to any work or process by adapting the goals like, improve customer satisfaction, increase profitability, and increase productivity [Lo et al.2009].

Six Sigma uses data and statistical analysis to improve processes by focusing on input variables. The methodology identifies sources of variability in the work
process that result in defects. Six Sigma traditionally sets the improvement goal of 3.4 defects per million opportunities. Once these sources have been identified, they are modified to reduce the defects.

Six Sigma has two key methodologies, each consisting of five phases: DMAIC (define measure, analyze, improve, control) and DMADV (define, measure, analyze, design, verify) [De feo et al.2005]. The first methodology is used for existing processes, while the second is used to design new processes.

Six Sigma was originally used in manufacturing corporations, but has branched out in such diverse areas as the banking, health care, military, and telecommunications industries. One of the earliest corporations to use the methodology was General Electric (GE), which reported benefits of more than $300 million during its first year of application [Das and Hughes, 2004]. Other major companies that have reportedly used Six Sigma include Ford, Caterpillar, Microsoft and Siemens.

The focus on achieving Six Sigma quality is commonly referred to as design for Six Sigma (DFSS). The two goals in designing for quality are:

(1). Striving to maintain performance within acceptable limits, consistently (reliability), and (2). Striving to reduce performance variation and thus increase robustness [Koch P.N.et al.2004].

3.2 IMPLEMENTATION
Most of the literature concerning Six Sigma focuses on successfully implementing Six Sigma practices into one’s organization. Implementation comes in one of two models: tool-based and projected-based [Lo et al.2009]. Tool based implementation focuses on “the mechanics of tool execution, as opposed to when and how a tool should be implemented and integrated with other tools.” Project-based implementation involves tools being “taught and then applied to projects that are defined before [training] sessions begins”.

The Six Sigma methodology is conducted by a team of people in five roles. The team is led by the quality leader/manager, who is responsible for representing the customer’s needs. Master Black Belts are responsible for specific areas or functions of a business, such as human resources, and work closely with the process owners, who are individuals responsible for a specific process. Black Belts lead the quality projects and work full time with the company until the projects are complete. They also train the Green Belts, who are company employees trained in Six Sigma. [Das and Hughes, 2004]

3.3 DMAIC IN SIX SIGMA

DMAIC or Define-Measure-Analyze-Improve-Control, principle is used to execute six sigma projects in an organization.

3.3.1 DEFINE PHASE AND TOOL

Define (D) is the first step of the Six Sigma methodology where leaders are expected to select projects, set initial goals or targets, and develop a project
charter or statement of work (SOW). Costs of poor quality associated with the new or existing process being analyzed are estimated. Improvement targets are set often in terms of sigma and cost [Pande et al.2000]. Leadership selects the appropriate team members. The team then determines more precisely the criteria that are critical to the customer. Run charts, interviews, or surveys, for example, are utilized to obtain leads and useable figures. A high-level process map of the existing process is to be developed with start and end-points clearly illustrated. A progress report to leadership normally concludes each step [Pande et al.2000].

3.3.2 MEASURE PHASE AND TOOL

Measure is the second step of the Six Sigma methodology and is denoted by the capital letter M. The goals of Measure appear to activate only in the mode of data management, which includes both collection and organization of the data for the purpose of observation. However, the modes of identification and solution generation may be triggered on a small scale as well. FMEA and MSA are tools that serve largely in a verification capacity, which fall into the problem identification and data management stages.

3.3.3 ANALYZE PHASE AND TOOL

The third step, A, is analyze. Here teams identify several possible causes (X’s) of variation or defects that are affecting the outputs (Y’s) of the process. One of
the most frequently used tools in the analyze step is the cause and effect diagram.

A Six Sigma team explores possible causes that might originate from sources, such as people, machinery and equipment, environment, materials and methods. Another highly effective technique to expose root cause is asking “why” to a possible cause at least five times [Goeffnet, 2004]. Team member suggestions may need to be clarified before proceeding further, so each and every team member has a clear understanding of the cause being presented. The resulting list should be reduced to the most probable root causes. Causes can be validated using new or existing data and applicable statistical tools, such as scatter plots, hypothesis testing, ANOVA, regression, or design of experiments (DOE). Experts warn not to assume causation or causal relationships unless there is clear proof. Furthermore, validating root causes can help teams avoid implementing ineffective improvements and wasting valuable resources. [Pande et al. 2000]

3.3.4 IMPROVE PHASE AND TOOL

The team then enters the improve (I) step. Here a team would brainstorm to come up with counter measures and lasting process improvements that address validated root causes. The tool most preferred for this process is the affinity diagram, which is a brainstorming technique where a topic or issue is presented to a small team who then quickly list ideas or solutions [Goeffnet, 2004]. The team should narrow the list to one or two potential improvements that are step deliverables. These should be selected based on probability of success, time to execute, impact on resources, and cost. If newly gathered data indicates that the
small-scale implementation is a legitimate success, teams should proceed to full-scale implementation [Pande et al. 2000].

3.3.5 CONTROL PHASE AND TOOL

The final step for at least the black belt and many of the team members is control, which is signified by the capital letter C. At this point devices should be put in place to give early signals when a process is heading out of control. Teams may develop poka-yokes or mistake proof devices that utilize light, sound, logic programming, or no-go design to help control a process [Pande et al. 2001]. The ultimate goal for this step is to reduce variation by controlling X’s (i.e., the inputs) and monitoring the Y or Y’s (i.e., the outputs) [Goeffnet, 2004].

In brief Six Sigma improvement framework and tool kit can be shown as given below [Siviy 2008]

3.4 SUCCESSFUL APPLICATION OF SIX SIGMA BY GIANTS
Identified by company, the yearly revenues, the Six Sigma costs investment per year and the financial benefits (savings) [Six Sigma website (76)]

Table-3.1-Six Sigma cost and saving by companies [six sigma website (76)]

<table>
<thead>
<tr>
<th>Year</th>
<th>Revenue ($B)</th>
<th>Invested ($B)</th>
<th>% Revenue Invested</th>
<th>Savings ($B)</th>
<th>% Revenue Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorola</td>
<td>356.9(e)</td>
<td>ND</td>
<td>-</td>
<td>16</td>
<td>4.5</td>
</tr>
<tr>
<td>1986-2001</td>
<td>ND</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allied Signal</td>
<td>15.1</td>
<td>ND</td>
<td>-</td>
<td>0.5</td>
<td>3.3</td>
</tr>
<tr>
<td>1998</td>
<td>15.1</td>
<td>ND</td>
<td>-</td>
<td>0.5</td>
<td>3.3</td>
</tr>
<tr>
<td>GE</td>
<td>382.1</td>
<td>1.6</td>
<td>0.4</td>
<td>4.4</td>
<td>1.2</td>
</tr>
<tr>
<td>1996-1999</td>
<td>ND</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honeywell</td>
<td>72.3</td>
<td>ND</td>
<td>-</td>
<td>1.8</td>
<td>2.4</td>
</tr>
<tr>
<td>1998-2000</td>
<td>ND</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ford</td>
<td>43.9</td>
<td>ND</td>
<td>-</td>
<td>1</td>
<td>2.3</td>
</tr>
<tr>
<td>2000-2002</td>
<td>ND</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key:
$B = $ Billions, United States
(e) = Estimated, Yearly Revenue 1986-1992 Could Not Be Found
ND = Not Disclosed
Note: Numbers Are Rounded To The Nearest Tenth

Wipro is the first Indian company to adopt Six Sigma. Today, Wipro has one of the most mature Six Sigma programs in the industry ensuring that 91% of the projects are completed on schedule, much above the industry average of 55% [Wipro website (77)].

The results of achieving Six Sigma are rapid and overwhelming at Wipro. Its unique methodology provides Six Sigma knowledge and skills to the client, enabling the client to create ownership, generate results and sustain success. The
maturity of Wipro’s quality processes takes the benefits to another level, ensuring that the customers benefit from:

1. 30-40% lower total cost of ownership
2. 20-30% higher productivity
3. On-time deliveries (93% projects completed on time)
4. Lower field defect rates (67% lower than industry average). The performance enhancement enabled the client to have an improved product with the overriding Benefit that the end customer perception of the quality of the client’s product is Improved [Sharma and Pandla, 2001].

3.5. SIX SIGMA POTENTIAL

To be able to optimize the benefits of Six Sigma it is important that the work in all areas of the organisation utilizes the mind set of Six Sigma [Snee et al. 2005]. There is data indicating that there are significant benefits to gain by including the nonmanufacturing activities, since these activities are only about 70% efficient.

As General Electric continued to develop the Six Sigma system originally created at Motorola, they realized that the potential of Six Sigma was far greater than the current applications on their manufacturing processes. Six Sigma could be applied to all type of processes including finance, administration and new product development. Use of Six Sigma significantly reduces barriers between functions. This ensures that the root causes for variation or bottle necks are truly eliminated and not moved along in the system. [Pande et al. 2000]
In addition, it is important that the application of Six Sigma is adjusted to the needs of the specific organization. Pande states that “there are many Six Sigma Ways” and emphasises that following a fixed script will make sure that the implementation falls short [Pande et al.2001]. For example with an ISO9000 implementation, there are no formal Six Sigma standards or certifying institutions that guide about the implementation. The knowledge from the organisation must be used and it is impossible to “copy and paste” an implemented Six Sigma from another company, no matter how similar the processes or organization seems to be [Klefsjo and Bergman 2004].

The use of knowledge within the organization is very important from the Six Sigma perspective as well as other strategies. Internal staff is fundamental to the success of Six Sigma. Pyzdek provides an overview of the skill and quality required for the staff employed to facilitate implantation and long term application of Six Sigma within an organization. (detailed description shown in Table 3.2)

Table 3.2-Overview of Six Sigma Green, Black and Master Black Belt Qualifications

Source- The Six Sigma handbook, Pyzdek (2003)

<table>
<thead>
<tr>
<th>GREEN BELT</th>
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**Roles**- Project leaders, Capable of forming and managing teams and projects from concept to completion.

**Requirements**- 5 days formal classroom training that covers:
- Project management
- Quality management tools
### Quality control tools
- Problem solving
- Descriptive data analysis

### BLACK BELT

**Roles** - Technically oriented individuals held in high regard by their peers, actively involved in the process of change and development.

**Requirements**
- Candidates may come from a wide range of disciplines. Do not need to be formally trained statisticians or analysts. Expected to master a wide variety of technical tools quickly. University level mathematics is useful. Training in statistical methods a plus or even a prerequisite. Approximately 160 hours of classroom instruction one on one project coaching from Master Black Belts or consultants. Must be computer literate. Proficient with one or more operating systems.
- Proficient in the use of one or more advanced statistical analysis software packages.
- Black Belts help Green Belts define their projects prior to the training, assist Green Belts in their projects after the training.

### MASTER BLACK BELT

**Roles** - Highest level of technical and organizational proficiency. Provide technical leadership to the Six Sigma program.

**Responsibility** -
Able to assist Black Belts in applying the methods correctly in unusual situations, especially advanced statistical methods. Statistical training should be conducted only by qualified Master Black Belts or equivalently skilled consultants. Must know everything the Black Belts knows. Must possess excellent communication and teaching skills. Must have deep understanding of the mathematical theory, coaching skills to help Black Belts and program organization at the enterprise level.

For many large corporations like General Electric, Six Sigma has become the centre of nearly every business activity, and a very important step to ensure long-term competitiveness.

In today’s highly competitive environment, it is also becoming increasingly important for SMEs. Furthermore, the success of large corporations’ quality programs is critically dependent on the supply of high quality goods and services from suppliers, which are most likely to be SMEs. Thus, a logical consequence is that large organizations encourage the application of well-proven QM approaches among their suppliers, underlining the fact that modern economies operate as complex networks of firms.

Consequently, the competitiveness of SMEs affects the competitive position of an economy as a whole. In today’s crowded markets, firms cannot afford to stand still, waste resources by adopting a trial-and-error approach to formulating a strategic direction, and deliver poor quality products or services.

However, many small companies have stopped their quality journey rather than pursuing further continuous improvement efforts. Small businesses must understand the need to go beyond the quality system stage and work towards a
total approach for quality [Yusof and Aspinwall, 2000]. Nevertheless, the adoption of Six Sigma is not restricted to their relationship with larger firms. It is rather an opportunity for a development towards a stronger focus on customer requirements and higher profitability.

SMEs require consulting services which differ significantly from those usually found in the marketplace for larger corporations. SMEs require consultants and trainers offering modular services, which allow the addition or subtraction of elements without compromising the entirety of the concept and without risking the success for their target group.

In summary, Six Sigma can be seen as the current stage of evolution in the field of QM with a core focus on profitability improvement and strategic value leveling, but still based in the fundamentals of traditional TQM. A general six sigma concept for SMEs needs to be adjusted to the core requirements of ISO 9000 to enable a certification, which represents a major difference to six sigma programmes in large corporations.

Unfortunately, there is no research work available on six sigma specifically focusing on SMEs. There is, therefore, a need to perform primary research in the area of six sigma applications in SMEs. Available research work in the literature provides general suggestions for a six sigma design to be applied and adjusted to SME requirements.