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Development of a Conceptual Model for Implementation of Six Sigma Concept in Manufacturing SMEs: The Indian Scenario

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Abstract: *About four million industrial undertakings in India are under small and medium-sized enterprises (SMEs) category and their contribution to the gross domestic product (GDP) of the nation is very much significant. However, the ever-increasing influx of foreign goods and services in Indian market, either imported or manufactured by multi-national companies (MNCs) within India has rendered many SMEs unviable to compete, especially in terms of cost. For survival and growth of SMEs, it has become highly imperative for them to adapt cost effective manufacturing strategies by eliminating defects from every one of the company's products, process, and business transactions. Defects or rejections from a process may be due to human element, equipment, or material. The focus of this paper is on human element since for most Indian SMEs human element is an important business asset and is an important process element. A study has been undertaken of a sample manufacturing SMEs to know which process elements, namely, human element, equipment, material have become causes of rejections. For this, a survey (personal interview and questionnaire) was conducted in about 73 local small manufacturing firms. The findings of the study point at the human element to be the major cause of rejections in SMEs. Based on the findings, a conceptual model is proposed for SMEs to take up Six Sigma as an improvement strategy. It is found from the existing literature that there is a little focus on the issue of implementing Six Sigma in Indian SMEs and on developing an implementation model. The conceptual model of Six Sigma implementation proposed in this paper from the viewpoint of human element is believed to help most small manufacturing firms to apply Six Sigma to their business processes and enable them to compete successfully in the globalised market. The model also takes into account the necessary process aspects such as process capability.*

Keywords: *Quality improvement strategy, SMEs, Six Sigma, implementation model, human element, process capability*

1. Introduction

Customers' awareness of the quality and cost of the product they buy or the service they are offered has increased significantly in recent years. With the growing influx of foreign companies entering the Indian business market, most Indian organisations are forced to adapt innovative manufacturing management strategies and quality management systems for better control and improvement of the manufacturing processes and business operations. However, only a few medium and large industries have shown the inclination to adopt innovative techniques and systems like reengineering, benchmarking, statistical quality control, supply-chain management, quality assurance and certification for international marketing of their products and services. A large portion of small and medium-sized enterprises (SMEs) that make up a huge supply base of large organisations are still unable to compete even in domestic market in terms of price and quality. The reasons for not using proven improvement strategies may be manifold including the lack of awareness of the new improvement strategies and techniques, non-committing top management, fear of huge investment, and employees' reluctance to change.

Many SMEs in India have obtained International Organisation for Standardisation (ISO) certificate for improving their processes, but they merely use the certificate as a marketing tool without serving the purpose. This paper proposes a conceptual framework for the implementation of Six Sigma approach in Indian manufacturing SMEs in order to reap the bottom-line benefits in terms of cost and quality criteria. A growing list of successful Six Sigma companies reveals that the positive margin impact on the bottom-line is on the order of 10% of revenues per year (Deshpande et al., 1999).

2. Indian SMEs And Their Uniqueness

SMEs are a very heterogeneous group. They include a wide variety of firms - village handicraft makers, small machine shops, component manufacturers, restaurants, and computer software firms - that possess a wide range of sophistication and skills. Ownership patterns range from proprietorship and partnership to companies and co-operatives. Due to their contribution to the national economy, the importance and emphasis on SMEs has been accentuated in the minds of policy makers, planners and the industry in the recent years.

SMEs may be defined in different ways by different countries. Most countries have adopted the benchmarks of employment. Some define them in terms of assets, a few in terms of sales and yet others, in terms of shareholders fund. In few countries, a hybrid definition is used such as employment as well as assets. In India, the term Small Scale Industries (SSI) is used far more often than SME and is based upon investment in assets. An SSI-unit is defined as one where investment in plant and machinery whether held on ownership terms or on lease or by hire purchase does not exceed Rs 10 million (1.00 USD = 44.49 Rs, approximately) (Government of India, 2006).

As of 2006-07 financial years, there are about 4.37 million small-scale units in India employing about 22.17 million people. The production of different goods and services from these units has been around Rs. 14 billion (i.e. around 40% share of output) (Pandey and Shivesh, 2007). Obviously, the contribution of this huge sector to the Indian economy cannot be overlooked. However, it has been estimated that most SSI units become sick and eventually shut down soon after their birth. The reason for this could be the output from such units not meeting the customer requirement over a period of time. The lack of understanding the quality and continuous improvement concepts in view of globalisation makes such units to lose their business. Many multinational companies (MNCs) take this opportunity to start up their business base in India leading to the death of many local SSI units.

Thus, it is high time for Indian SMEs to build capability in respect of knowledge of global products, and global quality and technical standards. In order to enhance the quality of the output of this sector on par with world-class organisations, there is a need to use continuous improvement strategies such as Six Sigma. Moreover, many of the large organisations are mandating Six Sigma to their supply bases (who are most likely the SMEs) as a condition of future business (Wessel and Burcher, 2004). However, implementation of strategies like Six Sigma may demand an investment, dedication of the best resources, training to employees, etc. which many SMEs may not be able to afford. Yet, there still exists a need for the Indian SME sector to look for this breakthrough business improvement strategy for survival and growth.

3. Literature Review

3.1 Process Capability

Six Sigma implementation in any manufacturing organisation starts with process capability study, which reveals the status of the process with regard to the number of rejections. Process capability refers to the ability of the process to meet technological or other requirements, to fulfill the demands put on it (Kureková, 2001). It provides a quantified value of the process variability with respect to the product requirements or specifications. This process variability indicates a measure of the uniformity of output (Montgomery, 2004), and the variability in the process output can happen due to the inherent variability of the process or some special causes.

Process capability study entails the measurement of the geometrical/functional parameters of the product turned out by the process and not the process itself (Montgomery, 2004). For a repeated process where the output data is assumed to follow normal distribution, process capability is obtained for one quality characteristic of the product at a time, and is expressed in terms of Process Capability Ratio (PCR), Cp. Mathematically,

$$\mathbf{C_p = (USL\text{-}LSL)/6\sigma} \text{ -------------- } (1)$$

where, USL and LSL are Upper Specification Limit and Lower Specification Limit respectively, and are specified by the customer or the design/development department of the organisation. The term (USL-LSL) is called tolerance band. Any or every process is required to operate within these limits. Products with quality characteristic(s) outside these limits are considered to be process fallouts or defects that must be rejected or reworked adding to the total cost.

A sigma, σ, represents the process standard deviation which is a measure of the spread in the output data (population) collected from the process, and the term 6σ is called *process spread*. The plotted data takes a form as shown in Figure 1. Graphically, one standard deviation is the horizontal distance between the process mean μ, and the point on the curve where it turns from convex to concave (Tennant, 2001).

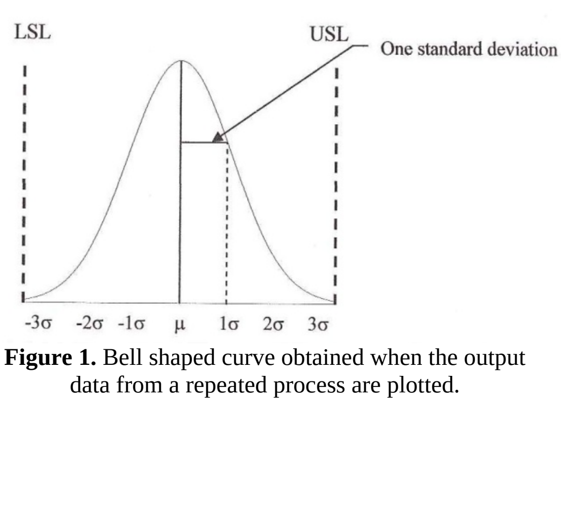

Figure 1. Bell shaped curve obtained when the output data from a repeated process are plotted.

The process capability ratio, $\mathbf{C_p}$ in equation (1) can be used to assess the process capability where the customer has specified both USL and LSL. There are situations where only one sided specification is given, either USL or LSL. In such cases, the $\mathbf{C_p}$ value, called the one-sided PCR, can be obtained using the relations given below (Montgomery, 2004):

$\mathbf{C_{pu}}$= (USL - μ)/3σ (when USL only is given) --------- (2),

$\mathbf{C_{pl}}$= (μ - LSL)/3σ (when LSL only is given) ---------- (3)

Ideally, the process mean μ should be on the target specified by the customer. If that is the case, the process is said to be a centered process. However, in actual processes, the mean will always be off, by some extent, from the target. Such processes are said to be off-centered processes. The process capability ratio $\mathbf{C_p}$ in equation (1) does not take into account where the process mean is located with respect to the specification limits. Thus, for an off-centered process, the process capability is given by another term, C_{pk}:

$\mathbf{C_{pk}}$ = minimum of $\mathbf{(C_{pu}, C_{pl})}$ ---------- (4)

Thus, $\mathbf{C_{pk}}$ is simply the one-sided PCR for the specification limit nearest to the process mean $\boldsymbol{\mu}$. For a centered process where the process mean and the customer target are the same, $C_p = C_{pk}$. If $C_{pk} < C_p$, the process is considered to be off-center (Montgomery, 2004). It is the responsibility of the process owners to bring the values of C_p and C_{pk} as close as possible and maintains a narrow *process spread* in order to reduce the rejection rate. This calls for reducing the value of 'σ' as low as possible in equations (1), (2), and (3). A Six Sigma process means the spread of the process is ±6σ on either side of the process mean and it outputs 99.9999998% of defect free products (Tennant, 2001), as shown in Figure 2.

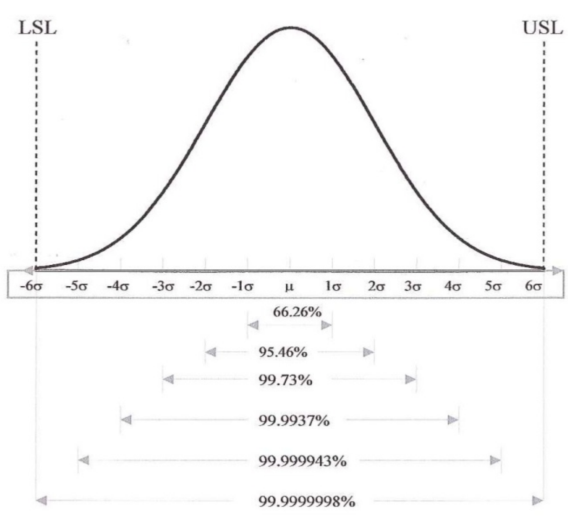

Figure 2. The 12σ spread of the normal curve for a repeated process controlled between -6σ to +6σ

However, processes vary and drift over many cycles of manufacturing. This variation typically falls between 1.4σ and 1.6σ (Harry and Schroeder, 2000; Europe.is six sigma, 2009). Thus, an adjustment is required to the process mean by offsetting normal distribution by 1.5σ on either side of the target. This shift of ±1.5σ of process mean from the target, would account for 99.9997% of good products (see Figure 3), or put other way, only 3.4 defects per million opportunities (DPMO).

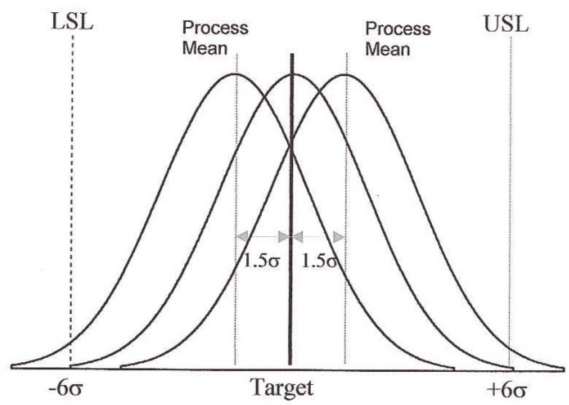

Figure 3. Normal curve when the process mean is shifted by 1.5σ on either side of the target specification

3.2 Six Sigma Concept

a) The Evolution

The roots of Six Sigma can be traced back to the early industrial era, during the eighteenth century in Europe (Europe is six sigma, 2009). Carl Frederick Gauss introduced it as a conceptual normal curve metric. The evolution of Six Sigma took one step ahead when Walter Shewhart developed an improvement methodology called PDCA (plan, do, check, act) cycle. And all quality management initiatives further are extensions and expansions of the PDCA cycle. He showed how three sigma deviations from the mean required a process correction. The Six Sigma model, Define-Measure-Analyse-Improve-Control (DMAIC) developed by Motorola way back in 1980s is an improved version of the PDCA cycle (Pande et al., 2003). The action step in PDCA model is equivalent to improve step in the DMAIC model that actually leads to improvement of quality in a manufacturing process and/or product.

Japanese people are known to have crossed many boundaries to perfect their technological achievements. So it was no wonder when they took it upon themselves to perfect the Six Sigma concept in true Japanese style. It all began when they took over a television-manufacturing unit of Motorola in 1970. The new management decided to change the way the operations were conducted. The Japanese management made sure that they placed a high emphasis on all the activities leading to production. Finally, because of their zealous approach they started manufacturing television sets with just 5% defects against the original records under

Motorola.

In 1985, engineer Bill Smith of Motorola coined the term Six Sigma and showed how significant the relationship is between a product's performance in the market and the adjustments required at the manufacturing side. The relationship is the lesser the number of non-conformities at each stage of production, the better is the performance. Smith's contributions in this regard paved the way for implementing Six Sigma in Motorola in four- stage approach known as Measure, Analyse, Improve and Control.

b) The Methodology

The choice of implementation of Six Sigma methodology depends on whether improvement is required on existing processes (Define-Measure-Analyse-Improve-Control) or on new process / product design creation (Define-Measure-Analyse-Design-Verify). These methodologies make Six Sigma stand in a different position from other quality initiatives such as total quality management (TQM). TQM, for example, does not have a universally accepted implementation method (Pande et al., 2003). In contrast to this, Six Sigma has two structured approaches for implementing as discussed in the next sections. Another uniqueness of Six Sigma is its focus on projects and their duration. Projects are typically completed in three to six months with significant savings to the organisation annually.

DMAIC

In Six Sigma, DMAIC methodology involves defining improvement goals, measuring the existing standards at baseline for future reference and analysing the relationship between defects and their causes. This Six Sigma methodology also entails improving processes to deliver consistent goal achievement in accordance with company strategy and consistent with customer demand. The analysis process of this Six Sigma methodology sets the stage for midway course correction, called improvement.

DMADV

The Define-Measure-Analyse-Verify-Design (DMADV) methodology applies to the creation of new processes for product development. The implementation in this case differs from the DMAIC methodology at the final two stages. Defining and measuring the design and product goals and capabilities are the first two stages. The next stage is analysing alternatives and evaluating to choose the best product design. The next stage consists of implementing the best design. The final stage entails verifying the design, pilot (or test) runs and testing implementation before the final presentation.

c) The Roles and Responsibilities

Six Sigma uses martial arts convention for naming some of its professional roles (Pande et al., 2003), as shown in Table 1

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Table 1. The roles and responsibilities in Six Sigma implementation

The Role	The Responsibility
Sponsor	Senior executive who sponsors the overall Six Sigma Initiative.
Champion	Middle- or senior-level executive who sponsors a specific Six Sigma project, ensuring that resources are available and cross-functional issues, if any, are resolved
Master Black Belt	Highly experienced and successful Black Belt who has managed several projects and is an expert in Six Sigma methods/tools. Responsible for coaching/mentoring/ training Black Belts and keeps Champion and Sponsor informed about the initiative on track.
Black Belt	Full-time professional who acts as a team leader on Six Sigma projects. Typically, this has four to five weeks of classroom training in methods, statistical tools, and (sometimes) team skills.
Green Belt	Part-time professional who participates on a Black Belt project team or leads smaller projects. Typically has two weeks of classroom training in methods and basic statistical tools.

Source: Abstracted from (Pande et al., 2003)

d) The Present Scenario

Over the past few years the word Six Sigma has become, and is still, a catchphrase in the corporate world. It has emerged as a quality program with a rigorous approach to achieve an excellence in the performance of an organisation (Breyfogle III and Meadows, 2001). Recent studies (Antony, 2005; Antony and Banuelas, 2002; Breyfogle III and Meadows, 2001; Deshpande et al., 1999) reveal that Six Sigma approach significantly improves the business process and affects the bottom-line savings thereby making an organisation to compete in the global market. The reports describe the success stories of many of the large organisations from America and Europe. Harry and Schroeder (2000) argue that Six Sigma produces superior financial results and improves a company's profitability dramatically.

Motorola was the first organisation that used the term Six Sigma and implemented it in the late 1980s for reducing the in-process defect level. By 1992, it could reduce the in-process defect levels by 150 times (Europe.is six sigma, 2009). Honeywell started its Six Sigma quality program in the early 1990s, and claimed to have saved more than $600 million a year by 1999 (Pande et al., 2003). A study conducted by Lucier and Seshadri (2001) showed how General Electric implemented Six Sigma and gained significant improvements in its key business performance areas. The company gained a saving of $2 billion in a span three years after implementing Six Sigma in 1996 (Antony and Banuelas, 2002). The benefits gained by companies such as Raytheon, Dow Chemical, DuPont, Texas Instruments, Johnson and Johnson, Toshiba, Boeing, etc. can be found in other studies (Buss and Ivey, 2001; de Feo and Bar-El, 2002; McClusky, 2000;

Weiner, 2004).

Many of the above mentioned success stories of implementing Six Sigma belong to large organisations, especially, multinational companies (MNCs), from American, European, Japanese, and German industries. Very few publications report about the implementation aspects of Six Sigma in SMEs. Criticisms on Six Sigma reveal that it is a high investment and resource intensive program that only big companies can afford (Caulcutt, 2001). However, since the complications associated with a small company or SME in terms of the size of the firm, nature of projects undertaken, team building, training needs, etc. are less compared to a large organisation, it can be argued that implementation of Six Sigma would be easier in SMEs, keeping aside the investment factor.

Notwithstanding, a few reports have proposed success factors, guidelines, tools and techniques, possible impeding factors to adopt Six Sigma in an SME context (anatomy, 2005; Antony et al., 2005; Wessel and Burcher 2004). Buss and Ivey (2001) cites two important reasons, among many, as to why most manufacturing SMEs in the United Kingdom (UK) have not undertaken Six Sigma projects. These reasons are unawareness about Six Sigma and lack of enough resources. However, with the advent of information technology, awareness about the recent process improvement strategies like Six Sigma is being created among many firms. A survey of selected SMEs in UK (Antony, 2005) has highlighted the suitable tools and techniques in practice in SMEs that have become Six Sigma. Another study by Wessel and Burcher (2004) reveals about an examination of a sample of German SMEs and suggests modifying the Six Sigma approach to be applicable and valuable in an SME environment. For this, ten factors have been proposed as ‘functional imperatives’ towards a general SME Six Sigma concept.

Though few large organisations in India (Tata Consultancy Services, Wipro, Infosys Technologies, TVS Motors, Maruti-Suzuki, BHEL) claim that they have implemented Six Sigma on project-by-project basis, there are no reports on the benefits gained by an Indian SME by implementing Six Sigma. For instance, Tiwari (2005) cites lack of knowledge in tools and techniques of Six Sigma, executives not investing their time in team meetings, trying to apply Six Sigma to every problem that can be solved without following Six Sigma approach, and project teams working under pressure to provide early results of benefits, as some of the reasons for the failure of Six Sigma in Indian context. Also, awareness about Six Sigma is not pervasive among many small manufacturing firms in India. Even though an awareness is there, it is at the executives’ level not at the lower employee levels. In recent days, a few reputed institutes in India like Indian Statistical Institute and Engineering Staff College of India are conducting seminars, conferences, workshops, intensive training programs on Six Sigma to create awareness as well as to convey the importance of implementing it.

From the review, it can be concluded that SMEs in India have not yet been tapped for the application of Six Sigma concept to improve their performance, productivity, and competitiveness for they contribute significantly to the economy of the nation. Also, large organisations that have adopted Six Sigma are mandating their supply base; many of them are SMEs, to adapt Six Sigma methodology. Moreover, the influx of goods from outside the country or an establishment of an MNC in India has forced SMEs to improve the quality of their products as well as cut down the costs. Thus, for survival and growth, Indian SMEs need to improve their businesses using strategies like Six Sigma.

4. Development of a Conceptual Model

A manufacturing process is considered to be formed of three basic elements, viz., man and methods, machine, and material. Obviously, one or all of these can be a cause of good or bad quality of the output. These elements are termed in this paper as Human element and methods, Equipment or Technology, and Materials. In most Indian manufacturing SMEs, the major asset is their human resource and the contribution of human element to achieve a desired quality level in the output is much significant than the other two. Hence they should focus more on this element for achieving a higher quality level of output, given a level of technology in place and materials from certified suppliers.

Hence, an attempt is made in this paper, through qualitative research, to analyse the role of human element in the output quality level of manufacturing SMEs. The reasons, if any, pertaining to human element that hinder achieving a desired output quality level are also highlighted. The results of the analysis are used to develop a conceptual model which establishes relationship between the basic elements of a manufacturing process and the process quality metrics. The process quality metrics form the basis to know the level of output quality in any manufacturing process. Corrective measures can then be initiated against those reasons pertaining to human element that are causing more rejections.

4.1 Survey Design

Before designing a survey questionnaire, the authors conducted personal interview of the heads of five renowned SMEs in the locality. Among the five firms, one was food processing unit, three engineering goods manufacturing units, and one garment manufacturing unit. The interview was general in nature and covered aspects such as globalisation, manufacturing SMEs, present quality of output of SMEs, quality improvement initiatives such as TQM, 5S, Kaizen, Suggestion schemes, and Six Sigma. The questions were framed with an intention to know if manufacturing SMEs are in need for strategies such as Six Sigma. And, if so, what makes such SMEs to look towards such improvement initiatives. The list of questions asked may be found in Annex-1. All the heads of the firms expressed their concern on the effects of globalisation for it has made them to rethink on their quality and cost strategies. They felt that quality approaches (such as Six Sigma) need to be implemented in SMEs for the survival and growth. But, when asked what Six Sigma is, their responses were in bits and pieces. Thus, to make Six Sigma work to fulfill the needs of such firms, the authors felt that a simple way of understanding Six Sigma concept and then applying it practically is essential.

By the analysis of the interview, the authors designed a questionnaire with two main objectives:

- to know the performance level of manufacturing SMEs of the locality in terms of rate of rejections,
- to know which of the three basic elements of a manufacturing process causes more rejections.

The target audience for the survey was selected from the database of District Industries Center (DIC- a statutory body) and North Karnataka Small Scale Industries Association (NKSSIA-a private association of SMEs in the locality covering eight districts). Of the eight districts, only two districts, namely Dharwad and Belgaum, are considered for the study since these two districts form the major industrial hub of North Karnataka. In all, 102 firms were selected randomly for the study (as SMEs). In thirty-seven firms of these, a quality management system was under practice.

One of the authors with a team of students of the research center personally visited the firms as all these firms were within a distance of 200 kilometers. Because of the time constraint and reluctance of few SMEs, the team could collect only 73 responses.

4.2 Findings of the study

It is found from the analysis of the survey responses that a fair degree of automation is in practice in most SMEs for producing the products. Also, the measuring equipment employed for quality checks at different stages (such as incoming material, in-process material and at the finished parts stage) are found to be fairly sophisticated. Most SMEs employ both online and offline techniques for this purpose. However, the output quality level from different processes of most SMEs is less than 3 sigma. This results in a rejection rate of more than 66,807 defects per million opportunities (DPMO). It can then be argued that defective outputs are due to the human element that plans the different manufacturing activities and operates various equipments. Table 2 gives a summary of the responses for causes of rejections in SMEs.

When a level of technology is in place and the materials from certified suppliers, the question is: what makes human element to contribute such a significant amount to rejections? What kind (or category) of human element has become the major contributor? How this problem is addressed and eliminated subsequently so as to reach Six Sigma level of defect reduction?

Table 2: Causes of rejections

Cause of rejections	Number of responses
Material	5
Machine	11
Human element	57
Total	73

4.3 A Conceptual Model for Implementation of Six Sigma Concept

An attempt is made to answer the above questions through developing a simple but effective conceptual model for easy understanding and application of Six Sigma approach in manufacturing SMEs. The model is conceived based on the *production system* concepts where men, machines, and materials go into a process as inputs and converted as outputs. To ensure the quality of the output, the model uses metrics such as process mean, process standard deviation, and process capability ratios (PCRs). If these metrics are not at the desired level, the model hints at identifying the reasons with a focus on the major process input (i.e., human element). The model is shown in Figure 4.

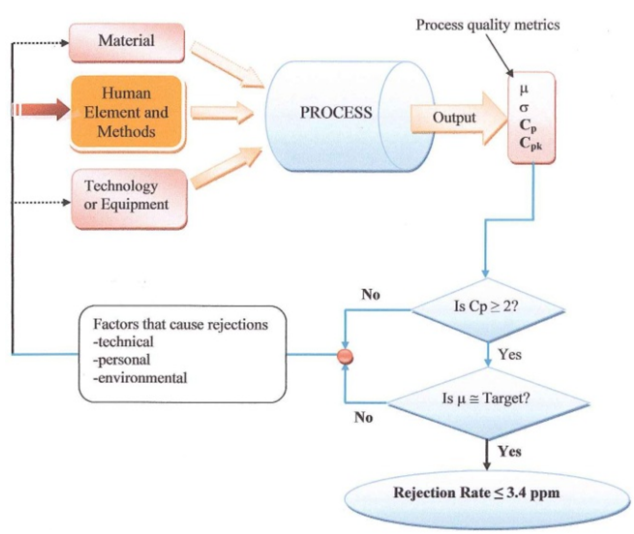

Figure 4: A conceptual model for implementation of Six Sigma concept

It is an established fact that at Six Sigma level, a process is capable of outputting only 3.4 defects per million opportunities (DPMO). That is, its capability of meeting the product specifications is very high implying a Process Capability (C_p) value equal to or more than 2. However, enough care must be exercised to see that the process mean (μ) is very close to or on the target specified.

The survey results in Table 3 indicate that few factors pertaining to human element are the major contributors towards rejections. Among all the factors, job knowledge and skills possessed by an employee are the roots of rejections. However, other factors also contribute considerably to rejections. Table 4 shows the summary of the general hindrances to Six Sigma implementation in a manufacturing SME.

Table 3: Factors pertaining to human element contributing to rejections

Factor	Number of responses
Job knowledge and Skills	24
Experience	11
Motivation	17
Personal problems	15
All the above	06
Total	73

Table 4: General hindrances to Six Sigma implementation in SMEs

Possible hindrances	Number of responses
Employee resistance	28
Investment in training	24
Non-committed top management	09
All the above	12
None of the above	---
Total	73

The overall summary of the analysis of survey is given below:

a) Most of the rejections in SMEs are due to the human element and methods of doing work which need to be addressed properly.

b) The employees are to be trained the tools and techniques of Six Sigma to acquire necessary skill level. Only those tools which are essential for an SME environment need to be taught. Not all SMEs require tools and techniques such as Design of experiments and Failure Mode and Effects Analysis. However, the training curriculum may include all the necessary tools which a Green Belt or Black Belt should know.

c) All the employees may be given Green Belt training except the key person who can be trained to a Black Belt level. One Black Belt can look after all the aspects of Six Sigma implementation in an SME owing to its small size. He can lead teams of Green Belts to implement Six Sigma project by project.

d) The investment for training or other purposes in Six Sigma implementation in SMEs is not that much high which large organisations invest. One or two key persons in an SME can have training in Black Belt certification from an external agency. These key persons in turn can train their employees in Green Belt aspects for successful implementation of Six Sigma.

e) Employee resistance can be handled by making them aware of the long-run benefits Six Sigma brings. They can be made involved and empowered in most of the activities of the organisation (SME), so that their morale goes high. Also, the benefits Six Sigma brings can be shared among those employees who take active participation in Six Sigma projects. Arrangements for counseling the employees to solve or to lessen their personal problems must also be made. All these efforts definitely motivate the employees.

5. Conclusion

Many SMEs are showing awareness about the growing business competition and the need to improve product or service quality by going for ISO certifications. However, most of them are using these certifications as a marketing tool without obtaining any bottom line benefits. It is found from the survey that most target SMEs are attempting to measure the process capability and improve their manufacturing processes overlooking the employee aspects. However, the technology with which most SMEs operate is moderately automated such as use of Computer Numerical Control (CNC) machine tools for production, and computerised measuring devices for measuring key quality characteristics. A preliminary survey of SMEs with moderate manufacturing automation shows among all the factors, job knowledge and skills possessed by an employee are the roots of rejections.

This paper highlighted the need for a cost-effective Six Sigma process improvement strategy. This would reduce the manufacturing cost by reducing percentage of defective products and improve product quality by appropriate training to employees.

A conceptual implementation model was proposed for easy understanding and application of Six Sigma in manufacturing SMEs. The model is conceived based on the production system concepts where men, machines, and materials go into a process as inputs and converted as outputs. To ensure the quality of the output, the proposed model uses metrics such as process mean, process standard deviation, and process capability ratios (PCRs). The process quality metrics form the basis to know the level of output quality in any manufacturing process. Corrective measures are then initiated against those reasons pertaining to human element that are causing more rejections. The model developed is under validation process through implementing it in a local manufacturing SME.

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Annex-1: Personal Interview Questions

1. How do you interpret the term 'globalisation'?
2. What is the effect of globalisation on Indian industries, especially on SMEs?
3. Do you agree with the statement "globalisation is favorable to the survival and growth of our SMEs"? If not, what would you like to say on this?
4. Do you think that the SMEs of this zone (North Karnataka) are capable of competing with their foreign counterparts? If not, what suggestions would you like to give?
5. Your views on 'using quality improvement initiatives such as Continuous Quality Improvement, TQM, Kaizen, 5S, Suggestion schemes, Six Sigma, etc. in the SMEs of this zone'.
6. In your opinion, what would be the urgent need/attention of SMEs in view of globalisation?
7. What are your suggestions to SMEs of this zone to make them to grow and sustain in the competitive market?

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