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Opportunities and Implications of Six Sigma for Bangladeshi Industries: Case Study on a Cable Manufacturing Organization

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I. Introduction

Six Sigma is a business process improvement strategy which essentially checks what a business is doing, what its customers want, what can be most effective process and what variation could be removed from that process to provide significantly improved consistency. This approach is a modern method for quality management aimed at minimizing the number of defects in any process. It is a philosophy which, in achieving its strategic aims, provides such stability of the processes that the defects are only a few in a million (Breyfogle et al., 2000, and Galabova & Nenkova, 2003). The Six Sigma is a unique means of quality measurement, which can be applied irrespectively of the type, complexity and diversity of the processes and products. The attention is focused on the processes, as the final results depend on what happens during the processes (Galabova & Nenkova, 2005). Six Sigma's core philosophy focuses mainly reducing variability. It relies on the assumption that the output of every process should fall within acceptable limits (Carrigan & Kujawa, 2006).

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Quality is specifically measured in terms of defect rates and is assessed from the customer's perspective. More formally, Six Sigma can be described as an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates (Linderman et al., 2003). The concept of Six Sigma was first introduced by MOTORALA Inc. during the later part of 1980s. Motorola developed and vigorously pursued the Six Sigma quality program by attributing much of its quality improvement to this program (McFadden, 1993). Since then many other companies have developed their own six-sigma programs, including General Electric, Texas Instruments, Eastman, Kodak etc.

Six Sigma concept helps measure the level of excellence in performance of any activity. This also measures the capability of the activity to perform defect free work. In fact, Six Sigma relies on normal distribution theory to predict defect rates of any activity being predicted. In addition to this, Six Sigma uses several statistical measures to analyze and interpret the data on processes and products. The best known of these measures is the Six Sigma goal of 3.4 parts per million opportunities or defects per million opportunities (PPMO or DPMO) defect rate. Interestingly, Six Sigma has evolved over years and become a customer-driven approach (Ravichandran, 2010). Historically a process was considered to be capable if specifications were $+/-$ 3 standard deviations from the mean, which would result in about 3 defects per thousand opportunities if the process remained centered. Six Sigma follows a much more stringent approach to defining process capabilities, and provides tools for mathematical computation of that capability. If a process is capable at six standard deviations, only 3.4 defects per million opportunities would occur (assuming a 1.5 standard deviation shift in the process mean) (Langabeer et al., 2009, and Sung, 2003). Six Sigma is a highly disciplined approach to decision making that helps people focus on improving process to make them as near perfect close to "zero defects" as possible (Stevenson, 2009).

II. Motivation Behind this Study

Six Sigma has become very popular throughout the whole world. There are several reasons for this popularity. Many companies, which were not quite successful in implementing previous management strategies such as TQC and TQM, are eager to introduce Six Sigma. It is viewed as a systematic, scientific, statistical and smarter (4s) approach for management innovation which is quite suitable for use in a knowledge-based information society. The essence of Six Sigma is the integration of four elements (customer, process, manpower and strategy) to provide management innovation (Montgomery, 2009). Six Sigma provides a scientific and statistical basis for quality assessment for all processes through measurement of quality levels. The six sigma methods allow us to draw comparisons among all processes, and tell how good a process is. Through this information, top-level management learns what path to follow to achieve process innovation, and customer satisfaction and to improve quality and process capability. Second, six sigma provides efficient man power cultivation and utilization. It employs a "belt system" in which the levels of mastery are classified as green belt, black belt, master black belt and champion (Stevenson, 2009). As a person in a company obtains certain training, he acquires a belt. Usually, a black belt is the leader of a project team and several green belts work together for the project team.

Motorola, GE, Allied Signal, IBM, DEC, Texas Instruments, Sony, Kodak, Nokia, Philips Electronics, LG, Samsung, Hyundai groups etc. implements six sigma philosophy (Pyzdek, 2004). But Bangladeshi industries are lack behind because of not yet implementing six sigma programs. So it is necessary to implement six sigma programs immediately to cope with others world-class industries. Lastly, six sigma provides flexibility in the new millennium of 3Cs, which are:

- Changes: Changing society
- Customer: Power is shifted to customer and customer demand is high
- Competition: Competition in quality and productivity.

The pace of change during the last decades has been unprecedented, and the speed of change in this new millennium is perhaps faster than ever before. Most notably, the power has shifted from producer to customer. The producer-oriented industrial society is over, and the customer-oriented information society has arrived. The customer has all the rights to order, select, and buy goods and services. Specially, in e-business, the customer has almighty power. Competition in quality and productivity has been ever increasing. Second-rate quality goods cannot survive anymore in the market. Six sigma with its 4S (systematic, scientific, statistical and smarter) approaches provides flexibility in managing a business unit. Six sigma improvement projects typically has one or more objectives such as reducing defects, reducing cost, reducing product and/or process variability, reducing delivery time, increasing productivity, or improving customer satisfaction.

III. Research Methodology

Bangladesh Cable Shilpa Limited (BCSL), a leading telecommunication cable manufacturer, has been considered as a case for implementing six sigma. Among other competitive companies, BCSL has been taken into account since the company already has their own standard quality procedure but has the potentiality for further improvements. With direct collaboration from the Production Planning & Quality Control Department, we have identified the steps of implementation procedures. Initially eight quality parameters have been identified in the targeted factory. The quality department has been working with two types of quality characteristics which are physical and electrical. We have studied all the properties before and after extrusion process to get defect rate of experimented eight specifications of the wire. In terms of length, the defect lengths have been cumulated to calculate the defect per million opportunities (DPMO). This research has advanced through analyzing the sigma level where DPMO has been utilized along with total defects and production.

a) Quality Parameters

Quality has been checked and inspected with respect to 8 criteria in 8 steps –

- Diameter (before insulation)
- Elongation
- Conductor loop resistance
- Insulation resistance
- Mutual capacitance
- Capacitance imbalance
- Dielectric strength
- Other (time loss, water tightness, etc)

b) Physical Characteristics

Bangladesh Cable Shilpa Ltd. usually produces four types of telecommunication wire according to the customer requirements. The physical characteristics of the wires are listed in Table 1. Those characteristics including nominal, minimum, and maximum conductor diameters and percentage of elongation are maintained to meet technical requirements. The specifications corresponding to these quality characteristics are different for each individual wire type.

Table 1 : Specifications of Physical Characteristics for Different Types of wire.

Wire Type	Nominal conductor Diameter (mm)	Minimum conductor Diameter (mm)	Maximum conductor Diameter (mm)	Elongation %
01	0.4	0.4	0.408	25-31
02	0.5	0.5	0.508	25-31
03	0.6	0.6	0.608	25-31
04	0.9	0.9	0.909	30-40

c) Electrical Characteristics

Five basic electrical characteristics shown in Table 2 are maintained strictly by BCSL to meet technical as well as quality requirements. These are Loop resistance, Insulation resistance, Mutual capacitance, Capacitance imbalance, and High voltage for in process products like Quad and 10 pairs sub unit as well as for semi finished and finished products. When any one of these specification limits is not met, the nonconforming portion is treated as defective. The major causes of nonconformities are identified through root cause analysis and corrective actions are taken to rectify the process. Defective portions are cut off. The nonconforming portions are to be reduced otherwise the process will not be within the six sigma limit and the company will have to count a significant loss.

d) Wire Specifications (After Extrusion)

Cores are filled with compound (petroleum jelly) and wrapped into non hygroscopic tapes and laminated sheath with aluminum tape and are insulated by black polyethylene. Conductor diameter have been calculated as 0.4, 0.5, 0.6, 0.9 mm as well as insulated wire diameter have been measured by digital micrometer. Tolerances of conductor are 0.004 mm and 0.03mm respectively. Elongation of conductor have been measured and stated in Table 3.

Table 2 : Specifications of Electrical Characteristics for Different Types of wire.

Wire Type	Conductor Diameter (mm)	Conductor Loop Resistance (max) (Ω/km)	Insulation Resistance (min) (MΩ.km)	Mutual Capacitance (max) (nF/km)	Capacitance Imbalance (max) (pF/km)	Dielectric Strength	
						Between Conductors & Screen	Between Conductors
01	0.4	295.0	5000	55	500	0.5 KV AC	1.5KV AC
02	0.5	187.0	5000	55	500	0.5 KV AC	1.5KV AC
03	0.6	130.0	5000	55	500	0.5 KV AC	1.5KV AC
04	0.9	56.6	5000	55	500	0.5 KV AC	1.5KV AC

Table 3 : Insulated wire specifications after extrusion.

SL. No.	Wire type	Insulation Material	Conduction Diameter (mm)	Insulated wire Diameter (mm)	Wall Thickness (mm)	Conduction Elongation %
1	0.40/0.72	Foam–skin	0.396-0.402	0.71-0.18	0.14-0.18	18-25
2	0.40/0.82	Solid PE	0.396-0.402	0.81-0.83	0.19-0.23	18-25
3	0.50/0.90	Foam–skin	0.494-0.502	0.89-0.93	0.19-0.23	20-28
4	0.50/1.02	Solid PE	0.494-0.502	1.00-1.13	0.24-0.28	20-28
5	0.60/1.10	Foam–skin	0.594-0.602	1.09-1.13	0.24-0.28	20-28
6	0.60/1.22	Solid PE	0.594-0.602	1.20-1.24	0.29-0.33	22-31
7	0.80/1.63	Solid PE	0.794-0.802	1.61-1.66	0.39-0.43	22-31
8	0.90/1.75	Solid PE	0.896-0.903	1.72-1.76	0.41-0.46	22-31
9	0.90/1.65	Foam–skin	0.894-0.903	1.63-1.66	0.33-0.38	22-31
10	0.90/1.60	Foam–skin	0.894-0.903	1.58-1.62	0.31-0.36	22-31

e) Defect Magnitude

From BCSL production target quantities of wire and defective length for eight quality parameters of five consecutive days have been tabulated in Table 4. The magnitudes have been recorded for the deviation in specified conformities supplied by the customer in physical properties (diameter, elongation) and electrical properties (loop and insulation resistance, Mutual capacitance, Capacitance imbalance, Dielectric strength) and others.

Table 4 : Defect quantity/day on November 2011.

Date/ November/ 2011	Target (km)	Diameter (mm)	Elongation (mm)	Loop resistance (Ω/km)	Insulation resistance (MΩ.km)	Mutual capacitance (nF/km)	Capacitance imbalance (pF/km)	Dielectric strength (KV AC)	Other	Total
13	4000	95	45	30	21	15	26	8	290	530
14	4000	83	59	68	27	26	6	4	310	583
15	4000	100	54	53	18	25	11	8	210	479
16	4000	78	86	28	26	35	16	14	240	523
17	4000	85	29	27	24	29	13	10	230	447
Total	20000	441	273	206	116	130	72	44	1280	2562

IV. Results and Discussions

Defects Per Million Opportunities (DPMO) is a measure of process performance. DPMO is the actual, observed number of defects, extrapolated to every 1,000,000 opportunities. Opportunities are actually the quality parameters against which the defects are identified i.e., they are the categories of defect types. DPMO is not the same as defective Parts Per Million (PPM) since it is possible that each unit (part) being appraised may be found to have multiple defects of the same type or may have multiple types of defects. A part is defective if it has one or more defects. The number of defectives can never exceed the number of defects. IF each part only has one characteristic that can be a defect, then DPMO and PPM will be the same. DPMO will always exceed or equal to PPM for a given yield or sigma level of performance ("Defects Per Million", 2012, "How is the defects", 2012, and "Process Sigma", 2012). DPMO can be expressed as:

$$DPMO = \frac{\text{number of defects} \times 1{,}000{,}000}{\text{number of units} \times \text{number of defect opportunities per unit}} \quad (1)$$

DPMO is calculated using equation 1:

Production capacity = 4000 km/day
Total Number of Defects = 2562 km
Defect Opportunities per unit = 8
Total cable produced during five days = 20000 km

So, the DPMO of the process is 16012.5.

A standard normal distribution table is taken look up the DPMO value to determine the equivalent standard deviation which produces that level of DPMO. Converting the quality metric DPMO to an equivalent first-time yield discloses the approximation P = (DPMO/ 10^6) = 1 – (16012.5/10^6) = 0.9839. Statistically converting this first-time yield provides the quantity Z = 2.14 in rounded form. Most of the processes tend to exhibit instability of 1.5 Sigma over time. Although statistical calculation indicates that 16012.5 defects/million are achieved when 2.14 process standard deviations (Sigma) are between the mean and the closest specification limit, the target is raised to 3.64 Sigma to accommodate adverse process shifts over time considering 1.5 Sigma process shift. Hence the Sigma level of the industry is 3.64.

V. Conclusion

Sigma level is a sign of quality level of the industry. Sigma level of BCSL is 3.64. In Six Sigma the goal is to achieve DPMO below 3.4. But the DPMO of BCSL is 16012.5. So this company's current process capability is not good enough to produce zero defects. Most of the companies of Bangladesh are not achieving their expected sigma level for lack of proper management, electricity, and skilled labor. Now a day's electricity problem is a vital issue in this country. The company was counting a huge amount of per hour cable loss due to the electricity problem.

Bangladesh is lack behind in quality sector as well as applying the quality tools like six sigma, TQM, KAIZEN, 5s etc. This paper has identified the current sigma level and quality position of the company. It can be recommended that the quality tools have to be properly implemented to make the processes more capable. DMAIC (an acronym for the procedural steps of Six Sigma: Define, Measure, Analyze, Improve, and Control) which is a key principle of Six Sigma can be applied to enhance the quality level of the company.

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