Application of Six Sigma in Clothing SMEs: A case study

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Abstract The Six Sigma approach aims to improve the quality of products in order to ensure the customers satisfaction. It focuses on the improvement of the quality by reducing of process variation in order to improve its efficiency. Small- and medium sized enterprises (SMEs) face several quality problems in progress or in the end of the work process. Few studies have been reported about the application of Six Sigma in SME. The purpose of this paper is to propose a new model based on the integration of Define, Measure, Analyze, Improve, Control (DMAIC) and Plan, Do, Check, Act (PDCA) approach in order to improve the effectiveness of the Six Sigma structure in solving quality problem in clothing SMEs. An example is given to illustrate the application of the proposed model to fix the parameters of a laying carriage in order to minimize tissue cutting defect

Keywords— Six Sigma, DMAIC, PDCA, Clothing SME.

I. INTRODUCTION

The Six Sigma methodology was developed by Motorola in USA in 1980. It aims to identify and eliminate defects or failures in business processes or systems by focusing on those process performance characteristics in order to assure the customers satisfaction [1]. With the statistical and non-statistical tools and techniques, Six Sigma aims to eliminate process variation and by this way it improves process performance and capability [2], and set this goal so that the process variability is kept in the range of ±6 Sigma [3]

Tunisian small- and medium sized enterprises (SMEs), precisely clothing SMEs face several problems of quality, in addition to other problems such as: Lack of adequate financial resources and manpower, lack of time to achieve the project, wrong choice of objectives, unacceptability of the culture of change and lack of knowledge about Six Sigma tools. For this reasons, the application of this Six Sigma approach still limited for large enterprises. In fact it requires investing in training and hiring of experts. In addition, the use of the complex tools remains difficult for small- and medium sized enterprises (SME) because it requires an adapted model to implement the approach successfully. The purpose of this paper is to present a framework to implement a Six Sigma approach in clothing SME. A simple model is developed to facilitate this application. This model is based on the combination of the DMAIC (Define, Measure, Improve, Analyze, and Control) approach and PDCA (Plan, Do, Check, Act) cycle to relate Six Sigma initiatives to process improvement.

II. LITERATURE

A. Brief review of Six Sigma

The Six Sigma methodology was developed by Motorola in USA in 1980. It aims to identify and eliminate defects or failures in business processes or systems by focusing on those process performance characteristics in order to assure the customers satisfaction [1]. With the statistical and non-statistical tools and techniques, Six Sigma aims to eliminate process variation and by this way it improves process performance and capability [2], and set this goal so that the process variability is kept in the range of ±6 Sigma [3]

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B. Review on Six Sigma implementation in SMEs

Small and medium-sized enterprises are companies whose size is defined by the number of employees and turnover, which must not exceed certain limits. According to the European Union, the category of micro, small and medium-sized enterprises (SMEs) consists of companies with less than 250 employees and an annual turnover not exceeding 50 million euro [15]. They are considered as the suppliers of large companies. Rowland (2004) noted that the traditional Six Sigma approach with Black Belt is not desirable in SMEs [16]. Snee and Hoerl (2003) presented the main obstacle to implementing of Six Sigma which consists in that the Six Sigma experts have formerly structured models that are not applicable for SME [1]. The result of the pilot survey presented in the work of Antony 2007 in UK manufacturing SMEs, which is primarily based on descriptive statistics, shows that many of the SMEs are not aware of Six Sigma. For its successful implementation in SME, management involvement and participation, and linking Six Sigma to customers and to business strategy are the most critical factors for the successful deployment of Six Sigma in SMEs [17]. In the same context, Kumar 2007 presented several critical success factors for the implementation in SMEs. The findings of his study revealed that management involvement and commitment, poor training and resource availability were ranked as the highest impeding factors during the implementation of the Six Sigma project [18]. Furthermore, DeRuntz and Meier (2010) show that the success of the Six Sigma implementation depends on adopting clear strategies, motivating employees and training stakeholders and involving the top management [19]. The result of the survey in our study in Tunisian Clothing SME shows that: The involvement and commitment of top management Performance measurement and communication are the most critical factors for the successful deployment of Six Sigma in these SMEs [20].

III. RESEARCH METHODOLOGY

The structure of the methodology is based on the continuous improvement model DMAIC and the PDCA quality. The PDCA (Plan-Do-Check-Act), cycle is the basic procedure of TQM. It is a problem-solving model in the context of quality management [12] [13]. A general description of the methodology and the process flow chart is given in figure 1.

In particular the five phases in Six Sigma methodology, representing (DMAIC) approach were deeply studied, with used tools.

In our recent study, we have determined the tools most used and known of Six Sigma in clothing SME by a survey. We have focused on the clothing industries in Tunisia with an employee’s number between 10 and 300 people, with a turnover not exceeding 30,000 dinars and operating in 4 activities: Technical articles industries, Knitted articles industries, Denim articles industries and mixed articles industries (Table 1).

In our research we are interested in SMEs because they represent the major part of the Tunisian industrial and because large companies usually have more material resources.

The first step consists in identifying the most used techniques and tools, for implementation of Six Sigma in 85 Small and medium Tunisian clothing industries. A questionnaire was distributed to the selected companies situated in different regions in Tunisia. In order to improve the accuracy of the results, the questionnaire was followed by interviews with CEO of these companies.

To rate the application and the knowledge of methods, tools, techniques and indicators, the respondents were asked to rank on a Likert Scale of 1–5, were:

- 0 indicates: unknown
- 1 indicates: Known
- 3 indicates: known and partially used
- 5 indicates: known used continuously
The collected data was then analyzed using Microsoft Excel.

![Flow diagram of methodology adopted](image)

**TABLE I**

DISTRIBUTION OF CLOTHING INDUSTRIES ACCORDING TO THEIR ACTIVITIES

| Activity                  | number | Certified ISO 9001 |
|---------------------------|--------|-------------------|
| Technical articles industries | 77     | 2                 |
| Knitted articles industries      | 110    | 3                 |
| Denim articles industries          | 85     | 0                 |
| mixed articles industries        | 505    | 3                 |
| Total                              | 777    | 8                 |

Tools, techniques or indicators with highest average score means that they are the most known and used ones.

In Table 2, it can be seen the result of the most common unknown, known and used techniques by apparel manufacturing SMEs. Installation of balancing production line (4.2), the calculation of the cycle time (3.9), the Visual Management (2.9) and the 5S (2.8). They are essential and easy to use. All organizations have installed the balancing production line continuously or partially. Most of apparel manufacturing SMEs don’t know the customer satisfaction evaluation methods such as Kano, CTQ, and VOC. Kai Zen, SMED, VSM, Six Sigma and
TPM, are well-known methods but not yet applied. These methods ensure continuous improvement of the production and the quality but require trainings to efficiently achieve their goals.

Our study shows that: 47% of companies that do not know the Six Sigma method, 43% of companies that know the method 5% of companies that applied this method partially and 5% of companies that applied this method continuously.

The structure of the methodology is based on the continuous improvement model DMAIC and the PDCA quality.

| Tools, techniques and indicators | Average score |
|----------------------------------|---------------|
| Installation of balancing production line | 4.2 |
| calculate the cycle time | 3.9 |
| Visual Management | 2.9 |
| 5S | 2.8 |
| training | 2.5 |
| Acceptance of Six Sigma Culture | 2.3 |
| Just In Time | 1.9 |
| PDCA | 1.9 |
| KANBAN | 1.6 |
| Identification of bottlenecks | 1.5 |
| Kai Zen,Pareto | 1.16 |
| SMED | 0.9 |
| VSM | 0.8 |
| Six Sigma | 0.7 |
| TPM,FMEA | 0.6 |
| VOC, CTQ, KANO | 0.4 |

The PDCA (Plan-Do-Check-Act), cycle is the basic procedure of TQM. It is a problem-solving model in the context of quality management [22] [23]. In fact, it was considered as a well-established framework for process improvement where it focuses on continuous learning and knowledge creation [24]. We choose the PDCA cycle because it is similar to the steps in Six Sigma projects (DMAIC), [13] [24], and it adds the rigour of project life-cycle (PLC) to the implementation and close-out of Six Sigma projects. So that, we called it PDCA-applied-to-DMAIC. The principal is described by figure 2. The established framework PDCA is applied to each DMAIC steps to improve continuously the process, focusing on continuous learning and knowledge creation [24].
Present study was carried out in a clothing SME. The clothing SME contains a cut unit and an assembly unit. The problem is that cut pieces with the existing laying carriage parameters don’t comply with the requested measures. In order to solve the former problem, a study was carried out to adjust of the laying carriage parameters (speed, tension) to ensure the correct superposition of the fabric ply mat. The unconformity rate of the cut pieces is huge due to the high variation in these parameters. That’s why; it is of a great importance to need to fix these parameters in order to reduce the unconformity.

A. Define
This phase consists in defining the problem and the customer requirements. In order to precisely target the expectations and the requirement of the client. The Critical To Quality (CTQ) essential elements are determined. Figure 3 shows the results of the CTQ diagram of the wristband product. After conducting several brainstorming sessions; we have concluded that the measurement defect is the most significant issue.

B. Measure
In this step data on measurable indicators of production processes are collected. The objective is to determine this sigma of the process which internally can give an idea about the process capability index and hence its performances. The process capability analysis was performed to find out actual state of the process. The set of the possible values is divided into five states (Table 3) with the recommended actions relative to each state [25].
The variation of the process capability is shown in figure 4. The company was operating at a baseline capability of 0.2, the $Z_{-\sigma}$ is equal to 0.7 and existing DPMO level of the process 780,000, which is remarkably high and this shows that there are lot of opportunities for improvement in the process.

TABLE III

INTERPRETATION RULES OF THE CAPABILITY INDEX CP

| Cp     | Interpretation          | Recommendation                          |
|--------|-------------------------|-----------------------------------------|
| Cp <1.67 | Highly capable       | No concerns                             |
| 1.33 <Cp ≤1.67     | Capable               | Comfortable situation                   |
| 1.00 <Cp ≤1.33     | Almost capable         | Possibility of non-conforming products  |
| 0.67< Cp ≤1.00     | Incapable             | Existence of Possibility of non-        |
|                   |                        | conforming products                     |
| Cp ≤0.67           | Chaotic               | Shutdown, analysis of causes and        |
|                    |                        | corrections actions                      |

C. Analyze

The analysis phase examines the collected data in order to generate a prioritized list of source of variation [26]. Using the result of the step "Measure", it’s possible to determine the root causes and identify the significant process parameters of the defect. The cause and effect diagram (as shown in Figure 5) was drawn to find out the causes of ”Measurement defect”. Cause and effect diagram shows that the most important causes that affect the measurement defect are: the incorrect speed and tension setting, the change of these parameters by the operator, and the information lack of these parameters used for each fabric color. At this stage, it was essential to identify significant parameters so that they can be properly tuned for each fabric color.

![Process capability analysis for laying carriage](image)

Figure 4  Process capability analysis for laying carriage before implementing DMAIC methodology

![Cause and effect diagram](image)

Fig. 5  Cause and effect diagram
D. Improve

In the improve phase, we decided to carry out a designed experiment. The design of experiments was done to find out the optimum value of the vital few parameters found out after a two-sample t-test [27]. A 2*2 experiment was designed, i.e., an experiment with two levels (maximum value, minimum value) for each factor. Table 4 shows the four tests carried out to fix the values of the optimum carriage laying parameters. For each test, the Cp level given by these parameters values was calculated.

| Test | Speed | Tension | Cp   |
|------|-------|---------|------|
| 1    | 100   | 80      | 0.4  |
| 2    | 100   | 40      | 0.2  |
| 3    | 25    | 80      | 0.31 |
| 4    | 25    | 40      | 0.35 |

Table 4 shows the four tests carried out for this objective. Minitab was used to determine the optimum combinations speed and tension as given in figure 6. The optimum values of the speed and tension vary from 50 to 100, and 40 to 60 respectively. It is more practical and easier to work with equation than the flowchart of fig. 5 to know the optimum of combination (tension speed). Using curve fitting technique, the function tension as a function of speed can be easily determined. Then, the user can manipulate only one variable (speed) to achieve the maximum Cp. The tension can be calculated using equation (1) when needed:

\[ f(x) = a \cdot x^b + c \]

Coefficients (with 95% confidence bounds): x: speed ; f: tension

\[ a = -4.043e+07 \quad (-7.207e+07, -8.796e+06) \]

\[ b = -3.705 \quad (-3.905, -3.505) \]

\[ c = 61.35 \quad (61.03, 61.68) \]

Using equation 1 or figure 5, we have set the tension and speed values of the laying carriage for each fabric ply mat color. In order to validate the obtained results of the improve phase, a confirmatory test was implemented by using the optimal values of the combination speed and tension and the measuring again the cut pieces. In figure 6 shows, it can be seen the new process capability of the laying carriage after.

Table 5 presents the significant improvements after implementation of Sigma methodology. The key metrics used for comparing the results after implementing the Six Sigma framework included Z-Sigma, Process Capability Cp, Defects per million opportunities (DPMO), and standard deviation of process.
TABLE V

| Key metrics used | Before improvement | After improvement |
|------------------|--------------------|-------------------|
| Z-Sigma          | 0.7                | 2                 |
| Cp               | 0.2                | 1.47              |
| DPMO             | 780,000            | 308,000           |
| Process standard deviation | 0.38              | 0.056             |

Application of Six Sigma project brought up the sigma level for 0.7 to 2 with DPMO level of 308,000 and capability of 1.47, which is substantial for a clothing SME.

E. Control

The main purpose of the Six Sigma methodology is not only improving the process performance but also having the improved results sustained in the long run. The standardization of the optimal parameters setting have been fully integrated into the training regime and the process documentation, the information related to company performance was sharing with its employees. A regular audit of parameters setting was carried out.

The cut unit process had been chosen in the chain manufacturing unit because it represents the first source of measurement defect. The success of Six Sigma application in this case study can definitely encourage the other clothing units to use Six Sigma as a quality tool to reduce the losses in their processes to ensure customer satisfaction.

IV. CONCLUSION

In this paper, a new model was developed by integrating DMAIC and PDCA approach into the Six Sigma methodology in order to find out the sources of measurement defects cut unit and improve its index capability.

Analysis of the results shows that the speed and tension of laying carriage are the tow parameters responsible for this defect.

A 2^2 experiment was performed and the optimum combinations of these parameters were extracted. The new set of this optimum combination was applied for the laying carriage and yields to improve sigma from 0.7 to 2 and Cp from 0.2 to 1.47.
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