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Six Sigma Application to Food and Beverage Testing Services

Raid Al-Aomar, Aamir Al-Saberi, Mohammed Al-Ameri, Ahmad Al-Wahedi and Kelechukwu Eke
Department of Engineering Management Program, College of Engineering, Abu Dhabi University, 59911 Abu Dhabi, UAE

Abstract: This study presents the results of applying the Six Sigma DMAIC (Define, Measure, Analyze, Improve and Control) process to improve the testing services of food and beverages. The study illustrates the application of several Six Sigma graphical and analytical tools to characterize and measure the service process, diagnose potential problems and deficiencies and identify improvement actions. An effective measurement system was utilized to collect empirical data for various operations of the testing service. The collected data is utilized to assess the current process capability and sigma level. Multiple tools were used in the “Analyze” stage of DMAIC to identify the root causes of the problems and to propose and verify a set of improvement plans. The study has reported tangible improvement to the efficiency and the quality of the food and beverages testing process.

Key words: Six sigma, DMAIC process, food and beverage industry, testing services, improvement

INTRODUCTION

Food and beverage products are globally considered one of the most important consumables in the market (Dopson and Hayes, 2016). Such products are common and essentially used by the public on a daily basis. Thus, different government entities and consumer protection organizations relentlessly work to ensure the safety of food and beverages in the market especially in an open market such as the United Arab Emirates (UAE). In order to ensure the safety of its residents, the government had established a food and beverage laboratory 30 year ago to test all types of local and imported food and beverages and to make sure that are (Halal) products. Currently the laboratory has two buildings in Abu Dhabi and Al-Ain with several working units (Organic, Inorganic, Microbiology, Pesticide, etc.) and >100 analysts conducting tens of thousands of tests yearly.

The food and beverages testing service is part of government entity that was established to raise the quality level of the country’s exports as well as products traded locally. The entity protects the consumers and contributes to enabling a diversified economy. Today, the government operates across six key areas of activity related to provision of quality infrastructure:

- Standards
- Metrology infrastructure
- Testing infrastructure
- Conformity schemes and certification
- Consumer safety
- Legal metrology

With the increasing number of tests applied on samples of food and beverages, it has become hard for the analysts in the testing laboratory to complete the tests within the agreed time. This has affected the customer satisfaction of testing services and increased the risk of customers seeking alternative testing services. Thus, it has become of utmost importance to take a corrective action in order to enhance the performance of the testing process not only to retain customers but also to expand the services, increase customer satisfaction and become more cost effective.

Six Sigma methodology was selected for improving the food and beverage service process. It is globally considered as a proven quality method that is mainly characterized by being data-driven and solution-oriented. It arrives at effective solutions and recommends improvement actions that are based on measuring current and future process performance supported by various graphical ad statistical tools.

Six Sigma methodology is widely used in both manufacturing and service industries with many successful applications (Evans and Lindsay, 2015; Pyzdek and Keller, 2009). It improves process quality level by reducing service errors and product defects as well as process variability. Several references can provide further details on Six Sigma methods and applications (Harry and Schroeder, 2000; Keller, 2005).

Corresponding Author: Raid Al-Aomar, Department of Engineering Management Program, College of Engineering, Abu Dhabi University, 59911 Abu Dhabi, UAE

Six sigma improves quality and performance using the structured approach of DMAIC (Define-Measure-Analyze-Improve-Control). DMAIC is a problem-solving approach that ensures complete understanding of process steps, measures process capability at the process Critical-To-Quality metrics (CTQs), applies six sigma tools and analysis to improve process performance and implements methods to control the achieved improvement. Details of Six Sigma DMAIC process can be found in several references (Breyfogle *et al*., 2001; Wheeler, 2004; Keller, 2001).

In this study, the Six Sigma DMAIC methodology is applied to reduce the cycle time of the testing service process of food and beverages to a tolerable level. To this end, six sigma was adopted to reduce errors, delay and flow issue at key process steps, to improve analysts' productivity and to improve the overall testing process performance.

MATERIALS AND METHODS

The term six sigma was initially originated from statistical terminology related to the standard deviation as a measure of dispersion. It seeks process perfection by reducing process variation and the opportunities to drastically produce process defects to almost free of defects level (3.4 Defective Per Million Opportunities or 3.4 DPMO). Typically, six sigma projects follow two methodologies that are composed of five phases each:

- DMAIC is used for improving an existing process
- DMADV is used for designing new processes

The case presented in this study is based on DMAIC methodology to improve an existing process for testing the quality and safety of food and beverages.

The DMAIC process: DMAIC process represents the core of Six Sigma methodology for problem-solving and process improvement. It is in line with the commonly used deming cycle of plan-do-check-Act and the general problem solving techniques. Within the six sigma context, the process is more structured towards process re-engineering, data analysis and valid improvement and control actions. The DMAIC consists of the following five stages:

- Define: Describe the problem, the need for improvement, the voice of the customer and the critical to quality aspects
- Measure: Map the process, collect relevant data through a measurement system and determine as-is process capability
- Analyze: Analyze collected data, identify root causes of the problem and sources of variability, model relationships and select the vital few factors
- Improve: Set improvement actions through experimental design and optimization, verify improvement plans, run pilot tests, set an implementation plan
- Control: Set process controls that maintain the improved state using standards, monitor performance using Statistical Process Control (SPC) and improve the process continuously

RESULTS AND DISCUSSION

Dmaic application results: The five stages of the DMAIC process were applied to the food and beverages testing process. The following is a summary of DMAIC application. Several application details were removed for brevity.

Define stage: The following key quality aspects were identified based on a VOC survey:

- The customer shall get accurate/credible test results (Effectiveness)
- The customer shall get it within an acceptable time (Lead Time)
- The customer shall pay a reasonable fee (Cost)
- The service shall be provided to the customer in a way that appeals to him/her (Presentation).

The survey showed that the effectiveness of the service (the accuracy of test results) is already acceptable to customers. Also the lab is internationally accredited and continuously participates in activities that ensure results quality and credibility (such as proficiency testing, inter-laboratory comparison, audits, etc.). The cost of the testing service was not within the control of the improvement study as it is set by another government entity.

Thus, the six sigma project was mainly focused on two aspects (i.e., the service lead time and the presentation of the service to customers). Based on the VOC surveys, customers have raised multiple complaints about the service timeframe and the overall duration to get the service. The concern was more pressing for customers who are also service providers to other clients and they need to obtain the test results within a reasonable time to be able to provide a better service to their customers (i.e., other companies).

Other concerns were related to the complications in sending and confirming the receipts of service request and the difficulty to follow up on the sent applications.

Thus, the testing service duration (Lead time) was set as a Critical To Quality (CTQ) measure to guide the six sigma study with a recommendation to improve the presentation/customer service of the service process. Consequently, a six sigma project charter was developed and approved based on the results of the "Define" stage of DMAIC.

Measure stage: This stage of DMAIC was mainly focused on collecting data related to the duration of testing services. The lab is using a specialized Lab Information Management System (LIMS) to manage its operations. The software database has summaries of several measures of the testing service including the process lead time. Using this software, large samples of tested food and beverages were tracked and from their start at registration until the lab results are handed over to customers. The study has focused on recent data (i.e., tests conducted in 2015) with a total number of 4853 samples. Table 1 presents a sample of the data collected from LIMS. The system excludes weekends from the duration and shows the total duration in workdays taken to finish the sample testing.

The collected data was represented statistically and graphically. For example, Fig. 1 shows a histogram/distribution for collected data (testing times) with key summary statistics.

Based on the collected data, the as-is process measurement currently clearly illustrates the problem reported by customers. Customers are expecting to receive tests results within one week of registration. However, almost 69% of the test samples required >7 days to be completed and and handed over to customers. The corresponding short term sigma level is around one indicating low quality level and unacceptable process capability. This supports the identified problem in the Define stage of DMAIC and emphasizes the need for process improvement.

Analyze stage: This DMAIC stage was mainly focused on identifying the root causes of process delays and the sources of variations in the process. To this end, the collected process information and data were carefully analyzed using several graphical and statistical tools including process mapping, Pareto analysis, cause and effect diagram and SPC. Other advanced statistical techniques that can be alsused to analyze variability and model relationship include ANOVA and regression. The team has created a process map (Fig. 2) for the

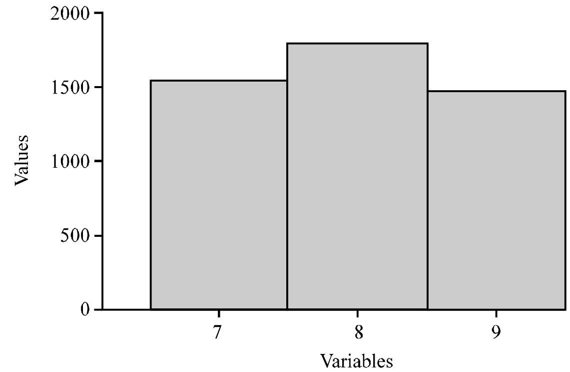

Fig. 1: Measured data distribution; summary statistics: N = 4853; Mean = 7.98661; SD = 0.79156; Min. 7; Max. = 9

Table 1: Sample of collected data

Samples	Log date	Report print date	Duration
A10067577001	4-Jan-15	13-Jan-15	7
A10067691001	4-Jan-15	14-Jan-15	8
A10067692001	4-Jan-15	15-Jan-15	9
A10067931001	4-Jan-15	15-Jan-15	9
A10067704001	4-Jan-15	14-Jan-15	8
A10068031002	4-Jan-15	14-Jan-15	8
A10068043001	4-Jan-15	13-Jan-15	7
A10068043002	4-Jan-15	13-Jan-15	7

service process to better understand the process structure and identify the steps contributing to process delays.

As shown in Fig. 2, the testing process starts when the customer submits a testing request or application. The customer needs to also submit the required documents, the samples to be tested and to pay the testing fees. The request then goes to the sample management team where it is reviewed and registered in LIMS. The samples are then distributed to the specialized lab unit according to the type and parameters of the required test. Once the sample reaches the testing unit, the analyst in charge performs the required tests and enters the results into LIMS. The test results are also checked by the supervisor in charge (decision maker) and a test report is then issued. Once the supervisor issues the report, the request is sent back to the sample management team in order to generate the reports and send them to customers. The process ends once the report is generated and received by the customer. A thorough look at the process map in Fig. 2 shows that the process is well controlled in terms of credibility and accuracy but time consuming.

To track the progress of testing process, the data was plotted using an SPC chart (X-bar and S charts) with a subgroup size of 100. As shown in Fig. 3, the values of S chart are all within control limits except for 1 point (subgroup 47 has a special cause that was known for the team related to the availability of spare parts). This indicates an almost stable process and shifts the attention

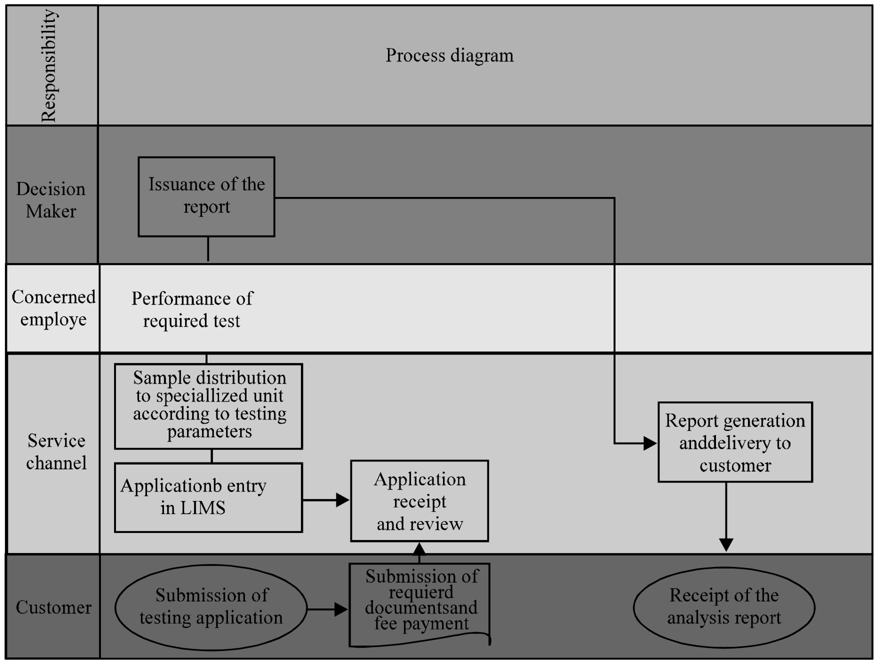

Fig. 2: Testing process map

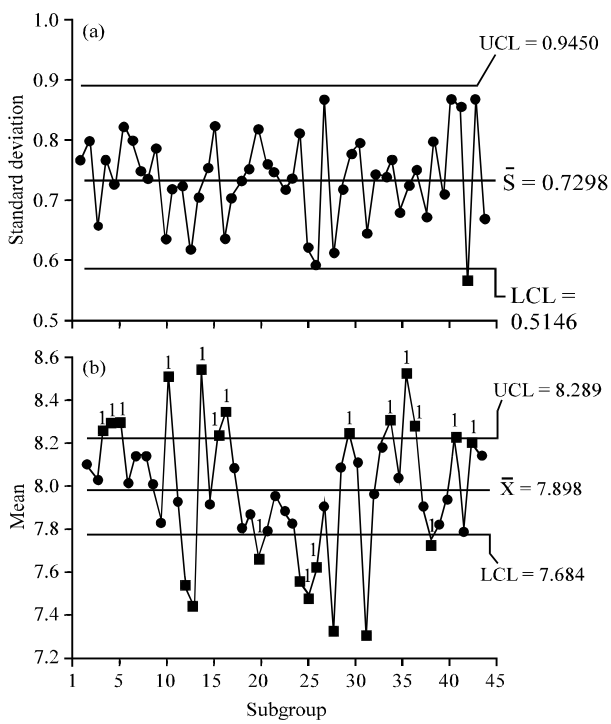

Fig. 3: Lead time control charts: a) S chart of F&B samples; b) Xbar chart of F&B samples

to the X-bar chart. Point 47 was removed after resolving the special cause and then S chart and X-bar chart are plotted again.

By a quick look to X-bar chart in Fig. 3, it is very clear that the process has settled to an out of control performance from both lower and upper control limits. The team is was not worried about points below the LCL as they indicate shorter processing times. Points above the UCL indicate special causes of long processing times which need further investigation and improvement.

The first task facing the team is to determine the root causes of process variability that keep pushing the processing time above the control limit. The second task is to set actions to eliminate sources of instability. To this end, the team has developed a Cause and Effect (C&E) diagram and run Pareto analysis.

To develop the CandE diagram, the team has investigated and identified different causes of delay in the testing process using the process map and classified these causes into the following four categories as shown in Fig. 4.

Manpower: The average age of employees is relatively high (approaching 50) which has potentially contributed to process delay. Also, it was found that the work pattern of some employee causes several delays in the testing process.

Machinery: Some testing pieces of equipment are relatively old and slow in reporting results compared to the new models. As an example, some tests which take

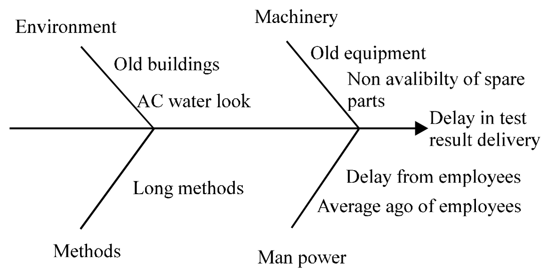

Fig. 4: Delay cause and effect diagram

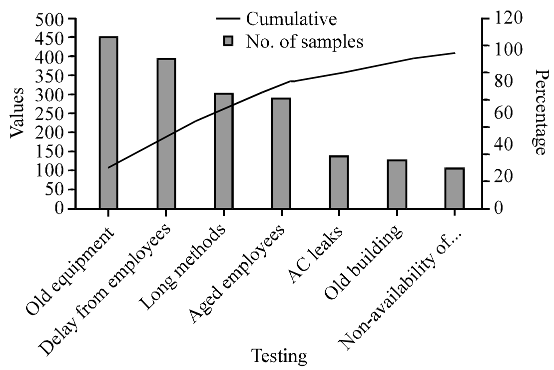

Fig. 5: Pareto analysis

72 h to report the results can be completed in 48 h using the new models. Also, the equipment spare parts are not always available in storage. This typically increases the equipment downtime and delays the overall testing process.

Methods: The work methods which are currently used for testing are not fully efficient with some redundancy and waste in the test procedure.

Environment: The building where the test lab is located is relatively old with less than perfect work environment. Also the ACs in the building are old and leak water in some cases which negatively affects the tests and contributes to process delay. A Pareto chart was also developed to further analyze and prioritize the identified seven causes from the CandE diagram and to differentiate the vital few from the trivial many. Results are shown in Fig. 5.

Based on Fig. 5, it was found that the first four causes represent 80% of the delayed samples. Thus, the vital few factors were identified as follows.

Old equipment: This was a major cause for the delay. Most of their problems were related to long warm up time before starting the testing process.

Delay from employees: Further investigation of this factor found out that the sample management team was a bottleneck as they receive and register all samples and then receive them back after testing and repeat the process before sending them to customers.

Long test methods: The currently used test methods are standard testing procedures that were not updated for a while. New and more efficient test methods can be used along with new testing equipment.

Aged employees: Further analysis to this factor found out that the majority of aged analysts are relatively slow and often slow in testing samples. Unlike young analysts, they do not prefer to run two tests simultaneously using two different test machines.

Improve stage: After analyzing the test data and identifying the causes of process delay, the team has set an aggressive improvement plan to reduce the average lead time to 6 days (i.e., exceeding customer expectations). Such improvement is expected to drastically increase the sigma level and the process capability. Starting with the first vital few factor in the Pareto chart (the delay caused by the sample management team), the procedure was enhanced to eliminate the redundancy in registering tests and sending them to test analysts. Once the testing team complete all tests then they should send the results directly to customers without the need to send them back to the sample management team. The LIMS system was enhanced to support such process changes. The system was set to directly send the final test report to the customer by email. Other process improvement actions that were set based on the other process factors include:

Updating current test methods to deliver test results faster without compromising test credibility and accuracy. Requesting new testing equipment that are compatible with the new test methods (shorter warm-up, faster processing and less downtime). A business case is prepared to compare the costs of new equipment to the expected benefit.

The aged employees were considered as experts. Their effort and time was redirected to deliver value in different fields other than direct testing such as training and R and D. It was proposed to transfer some of the aged employees to training department and recruit young test analysts. The aged employees will help develop specialized technical training programs for the new analysts. The training programs can also be provided to other government and private entities as an extra source of income.

Control stage: The team believes that all the efforts spent on improving the process will be sustained if the process is not controlled. Thus, the team has established a control plan to ensure stability and monitor performance. To this end effective standard operating procedures were developed, control charts are continually monitored and the LIMS was reconfigured to better manage and monitor the process. Examples of other control actions include:

- All the process steps shall be managed and monitored through system
- Each analyst will have his/her own inbox and all his/her assigned requests shall be shown to him/her with the specific deadlines
- A report is automatically generated and sent every morning to lab manager to notify him/her about all the pending samples in color coded rows. This will alert the manager of samples approaching their deadline to expedite the testing process
- The system shall generate an auto-email notification to the employee when the sample reaches 80% of its allocated time. This will help the analyst set the right priority to certain samples to avoid delays

CONCLUSION

The study presented a six sigma application to improve the process of food and beverage testing at a local firm in the UAE. Such service process is critical to the safety of local and imported food and beverages. The study has targeted the lead time of the testing service as a key customer satisfaction measure. The DMAIC process of six sigma was utilized to characterize the testing process, measure current performance, identify and analyze sources of delay, specify improvement actions and set an effective control plan. The study presented a briefing on several graphical and statistical tools used in the Six Sigma study. Implementing the recommendations of the study is expected to result in reduced process lead-time and improved process capability and Sigma level.

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