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IMPLEMENTATION OF SIMULATION IN SIX-SIGMA METHODOLOGY: AN APPLICATION IN A MANUFACTURING FIRM

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ABSTRACT
Simulation technique has been widely using by companies in contribution to improve their operations on business and manufacturing processes for several decades. On the other hand, Six-Sigma has evolved as a discipline and highly quantitative approach and introduced another way of thinking with regard to process or product improvement. Especially in recent times, the idea of taking advantage of the benefits of simulation technique and six-sigma discipline together has led various companies and academics towards investigation and implementation of simulation technique within the context of six-sigma methods. From this perspective, the objective of this study is to improve control processes of a manufacturing firm by the help of integration of simulation technique and six-sigma methodology. In this study, first, the control process has been analyzed by a time study and simulated as a model by using Oracle Crystal Ball simulation tool. Following, as-is scenario analysis has been conducted in the analyze phase of DMAIC methodology, and then the improved scenario generated according to the gaps of current situation (as-is scenario) has been analyzed in the improve phase (to-be analysis) by the help of analysis of inputs and outputs by Crystal ball using spreadsheet simulation modeling. As a result, it was seen that the waiting times between value-added operations were considerably high, consequently, it was revealed that the capacity of current situation can be improved according to the simulation findings of as-is scenario analysis. Therefore, it was demonstrated by simulation modeling of to-be scenario that the improvement in the capacity may be as high as %20.
Keywords: Simulation, six-sigma, DMAIC methodology, spreadsheet simulation modeling

1. INTRODUCTION AND BACKGROUND OF THE STUDY
The home appliances industry is a multi-billion dollar industry with its own characteristics. Some of the products that can be placed in the household appliances category range from automatic washers to ovens and refrigerators. Customers' expectations are high from the industry by demanding innovative products with advanced features with cheaper prices. Moreover, the companies have to get products to market quickly, at a lower cost while providing advanced quality and reliability. Hence, these firms have a significant challenge in increasing operational efficiency, while being responsive to customer demands in terms of high quality, reliability and lower prices to survive in highly competitive business environment.

The purpose of this study is to improve the efficiency and effectiveness of manufacturing stream of a firm which is one of the leading companies in the home appliances industry. The company focuses on many issues related to increasing quality and reliability of its products as well as decreasing its costs. From this perspective, objective can be more specified as to improve the controlling processes of a dishwasher unit's quality department of the firm in order to achieve higher use of existing capacity. In this respect, the six sigma methodology seems appropriate for accelerated process improvement which aims for virtually error-free business processes [1]. Six-sigma is often described as a problem solving methodology which typically focuses on identifying defects in the production and customer delivery phases, wherein the defects can be easily identified, but it costs extremely high to fix. Unlike the other Six-sigma initiatives which focus on production and delivery phases of a product, the Design for Six-Sigma (DFSS) techniques are better suited for identifying various defects and failures during the earlier phases of the product life cycle including marketing, R&D, and design rather than manufacturing or delivery processes [2,3]. As part of DFSS, Define-Measure-Analyze-Improve-Control (DMAIC) is employed as problem solving approach to reduce process variation and associated defects. DMAIC rely on a disciplined set of tools such as Pareto analysis in analyze phase or spreadsheets through the designing process [4].
Spreadsheets models offers great flexibility in wide application areas in addition to accounting for quality and cost variations across the different phases of the DMAIC processes. However, there are limitations on techniques like spreadsheets modelling due to their reliance on static and deterministic situations, which lack the dynamic environment of the processes. Simulation modelling for maintaining efficiency in the processes of product life cycle and for eliminating defects in production stage is recommended due to following reasons [5]; (1) accounting both random and structural variability, (2) providing data analysis to understand system's nature, (3) interactions between sub-systems, (4) studying alternatives and perform "what-if" analysis, and finally (5) quantifying different performance metrics to make better decisions prior to implementation phase. Hence, Monte Carlo Simulation and stochastic optimization have a critical role throughout DMAIC process [4]. In this sense, we obtained simulation modelling technique integrated into DMAIC processes as our methodology to improve the controlling processes of the dishwasher unit's quality department in order to achieve higher use of existing capacity. The following sections include a brief introduction of our methodology and application, then summarizing obtained results, and finally providing discussions and conclusions.

2. PROPOSED METHODOLOGY AND ITS APPLICATION

In order to achieve higher use of existing capacity by improving controlling processes of the quality department, the research methodology adopted for the study is Six Sigma DMAIC approach wherein simulation modeling can be used as a useful tool in different stages. DMAIC stages are as follows [6]:

Define: Problem selection and benefit analysis.
Measure: Translation of the problem into a measurable form, and measurement of the current situation, refined definition of objectives.
Analyze: Identification of influence factors and causes which are critical for quality of processes.
Improve: Design and implementation of adjustments to the process to improve system performance.
Control: Empirical verification of the results and adjustments of the processes and control system in order to those improvements are sustainable.

Simulation is an applicable tool for almost every stage of DMAIC due to its capability for understanding how a process or product varies and, therefore for identifying and testing potential improvements. Crystal Ball created by Oracle is an easy-to-use Excel add-in designed to help modelers from various fields including Six Sigma applications to perform Monte Carlo simulation. Some of the Six-Sigma applications using Crystal Ball are design development and optimization, tolerance and reliability analyses, project selection, and process simulation etc. [7]. Hence, we have employed spreadsheet-based Monte Carlo simulation (Crystal Ball) to use an effective tool in our DMAIC project to understand behavior and dynamics of our product controlling process in order to reveal potential increase in quality department in terms of production quantity. There are three types of processes in the quality department with different cycle times which are Type 1 controlling process

(30 min), Type 2 controlling process (145 min), and Type 3 controlling process (195 min). Each unit is controlled by just one type of the control processes. In addition to that, there are 8 stations in controlling area.
The application stages of our Six Sigma DMAIC project are as follows:

Define: The Define phase is used to identify problems, foresee possible process and improvement opportunities, and determine the project goals, project duration, and the requirements of internal and external customers. Define is mainly focused on customer and employee expectations to identify performance requirements. Therefore, some tools such as project charter, milestone diagram, SIPOC, and flow chart has been used in order to get deeper understanding of the process. These tools helped us to set project goals, customer expectations etc. In this stage, our foresight for possible improvement was Type 1 stations can be also employed to make Type 2 controls.

Measure: During the Measure phase, controlling processes, activities and staff were studied by a time study for two weeks which helped us to gather data to be used as inputs into our simulation model. The results of time study were also used to identify variables for simulation modeling. Our model includes 9 different variables range from Sampling time deviation to Cycle end time. The data gathered from this phase formed as basis for our spreadsheet simulation model.

Analyze: In Analyze phase, the results from the Measure phase were taken to highlight possible improvement areas and identify potential influence factors in the system. To analyze current system and determine the potential future capability of different processes, traditional analysis tools such as descriptive statistics and inferential statistics can be adequately used in the Design of Experiments environment. However, simulation is far better than traditional tool as it can accurately identify statistical validity and capability of the process in the system to understand and validate current situation (As-is) in the system by the help of easily and correctly defining variables within simulation environment. Hence, we have modeled simulation of our system (As-is) according to the data gathered in the Measure phase by using Crystal Ball simulation tool. In this phase, after coding our actual system as a simulation model, we have also conducted verification and validation analysis for our simulation model to ensure it captures our system right and works right. Then, the model gets ready to be run in an adequate number of replications which is selected as 1000 runs for our simulation model. According to the results of this phase, it is possible to see potential areas and gaps to improve in the current system.

Improve: In the improve phase, the results of Analyze phase are studied in order to create “what-if” scenarios. Then, we have performed “what if” scenarios and measures their impacts and feasibility in our current system by comparing them for different indicators. The main objective of this phase is to develop “to-be” scenario with the help of the results of Analyze phase. Finally, we have developed out “to-be” scenario and coded them as our new model, and then we have run our “to-be” scenario to conduct some statistical analysis such as ANOVA for determining its statistical validity.

Control: During the Control phase, it is required to verify project’s results empirically and to adjust process management and control system in order to see that improvements are sustainable. In our project, this phase was being mainly carried by the company firm. As part of Control phase, the firm continually monitors the implemented system for any trends or “out-of-control” situation. In addition to that, the impact of the changes is also being carefully tracked by the firm and they provide feedback for further analysis.

3. RESULTS OF THE APPLICATION

According to the simulation results of as-is analysis in Analyze phase, we have revealed that some of the stations dedicated to Type 1 process (Station 23, Station 24, Station 31 and Station 32) were not used fully in terms of capacity as shown in Figure 1. Therefore, we have assumed to use these stations for Type 2 processes and generated our To-be scenario. The results of simulation runs of to-be scenario in Improve phase, we have concluded that our to-be scenario improves the current system as

it can be seen in Figure 1. Improvements are % 20 increases in controlling process of all types of units and % 33 increases in controlling process of Type 2 units.

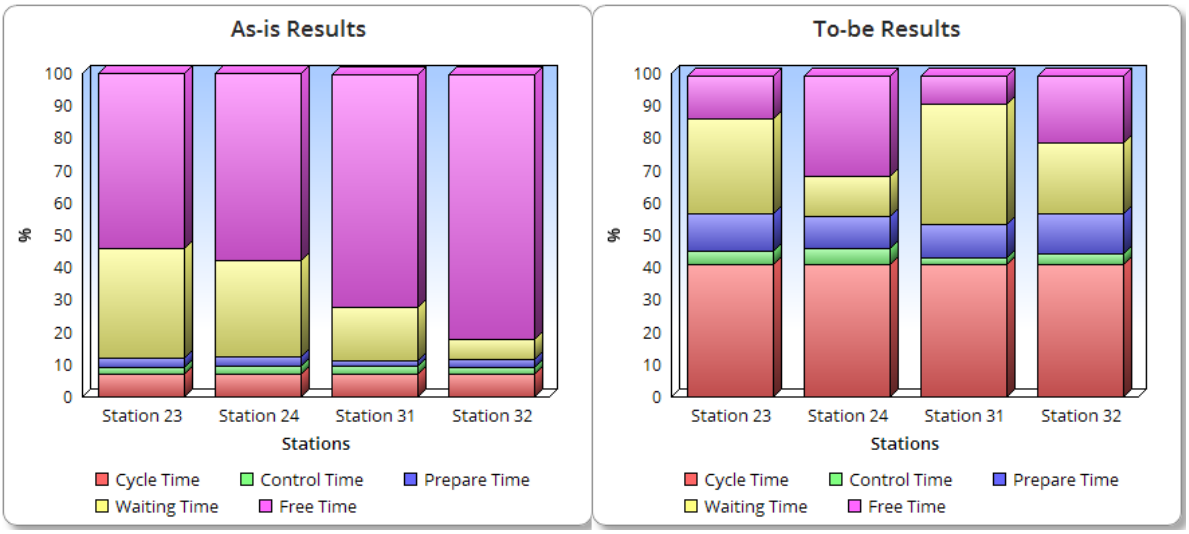

Figure 1: As-is and To-be results of different stations daily usage percentage

4. CONCLUSIONS

This study presents the application of DMAIC methodology and simulation technique in a manufacturing firm environment from home appliances industry. The objective of the study was improving the controlling processes of a dishwasher unit's quality department of the firm in order to achieve higher use of existing capacity. In this respect, we have approached our problem by using the systematics of DMAIC method and applied simulation technique in the phases of Analysis and Improve. In Analyze phase, the simulation has been employed to generate "as-is scenario" for revealing potential gaps and defectiveness point of the current system. Then, simulation model of the current system has been recoded according to "what-if" analysis to generate to-be scenario in the Improve phase. At the end, we have seen that the current system can be improved as high as %20 in terms of capacity, so that it was seen that new investments was not required to increase capacity in some point. In the light of this research, we can say that simulation is a good fit for DMAIC methodology as part of Design for Six-Sigma systematic especially in the phases of Analyze and Improve.

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