Using Six-Sigma DMAIC Methodology to Systematically Improve the Performance of Physical Plants at an Educational Institute

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Abstract

The purpose of this paper is to systematically improve the performance of engineering assets. This has been achieved using the six-sigma DMAIC methodology: define, measure, analyze, improve and control. Other tools have been used such as fishbone diagram, Pareto-chart, six-hats, quality function deployment, multiple criteria decision making. The methodology was tested by implementing it at the physical plant department at an educational institute in UAE. Primary historical data were collected for the period 2016-2017, and secondary data were collected by distributing questionnaire. It was found that the main identified problems are poor service quality in air-conditioning and Internet. These problems are related to the lack of preventive maintenance strategy, low level of competence and skills, poor quality of spare parts, low labor efficiency and effectiveness. A set of relevant solutions were identified. Implementing six-sigma DMAIC methodology helps organizations sustain best performance and customer satisfaction which result in achieving organizational excellence.

Keywords
Six-sigma, DMAIC methodology, balanced scorecard, preventive maintenance

1. Introduction

The comfort and satisfaction of the occupants of buildings in hot countries like UAE become very important. Indoor environments quality becomes more important than before because people spend more time in their offices, and other types of buildings. These stakeholders are expecting high quality services in these facilities that should meet and exceed their requirements and expectations. Analyzing stakeholder's requirements and expectations can result in identifying the main common problems they are facing and provide solutions which may result in improving performance and stakeholder's satisfaction. Six-Sigma define, measure, analyze, improve and control (DMAIC) improvement methodology has been used as a continuous improvement tool for many years (Alsyouf, Al-Aomar, Al-Hamed, & Qiu, 2011; Alsyouf, Kumar, Al-Ashi, & Al-Hammadi, 2018; Shahada & Alsyouf, 2012; Shamsuzzaman, Alzeraif, Alsyouf, & Khoo, 2018; Zugelder, 2012) However, despite their wide use in the manufacturing industry, their application in the service industry has been limited (Dieterich et al., 2017). Although DMAIC methodology was used in educational institutes, however, it was not used for measuring and improving the performance of the physical plants of educational facilities. Therefore, the main purpose of this study is to investigate how to continuously improve the performance of physical plants at educational institutes using six-sigma DMAIC methodology. The structure of this paper is sequenced as follow: section II presents the methodology used, section III shows the results and discussion, and section IV represents the conclusion.

2. Methodology

The study used the six-sigma DMAIC improvement methodology that consists of five phases: define, measure, analyze, improve, and control. Each phase comprises several steps that use relevant engineering tools, taking into account that these tools can differ from one case to another as follow:

1. Define
In this phase a definition of the goals, main problem, boundaries, timeframe, and constraints are discussed.

2. Measure
The main objective of this phase is to understand and evaluate the current performance of the system by conducting surveys, interviews and collecting data to measure relevant Key Performance Indicators, (KPI's). here both quantitative and qualitative data can be used.

3. Analyze
In this phase, efforts are focused on identifying critical problems and finding, validating, and overcoming their root causes. Moreover, this phase aids in identifying the gap between the current performance and the ideal performance targets. Several relevant statistical and industrial engineering tools can be used in this context such as: cause and effect (fishbone) diagram, and Pareto charts.

4. Improve
In this phase the objective is to develop several solutions for the identified problems and judge if the solutions are within the given constraints. Then, checking the feasibility of suggested solutions and helping in choosing the most critical (suggestion) to be implemented.

5. Control
The main goal of the control phase is to ensure that the improvement suggestions that are selected in the previous step will lead to the planned and expected results and can be sustained over time. Taking into account that control phase, in most cases, will be after implementing the selected alternative, and may take long time to be proved.

3. Results

This section represents the results of implementing the DMAIC methodology at the physical plants of one educational institute in United Arab Emirates.

3.1 Define

In this phase it was decided to investigate the performance of the physical plant department that provides maintenance services to the university facilities and buildings that consist of units such as class rooms, offices, meeting rooms, labs, food courts, theaters, students' dorms, and housing of the faculty members and their families. The goal is assessing the satisfaction of relevant stakeholders and provides effective solutions. However, it will not be possible to assess collect data from all university facilities, therefore we focused on four buildings which are: M9 (Faculty office and class rooms), W13 (female dormitories), M13 (male dormitories) and Al-Khawarizmi block B (faculty members housing).

3.2 Measure

It is very important to understand the baseline and current performance by assessing the level of stakeholders' satisfaction. Therefore, an on-line survey was designed and conducted to assess the stakeholders' satisfaction with respect to the performance of the physical plant department at the university that has about 15000 students and about 650 faculty members. Furthermore, a detailed maintenance survey was distributed to the 65 employees who are serving with the physical plan department. A total of 631 answers were received from the on-line survey, and 39 answered the

maintenance survey. As a result, it was found that the most frequent problems that are facing the respondents are related to Air Condition, (475 complaints) and then Internet (235 complaints), see Fig. 1. These two categories represent the highest categories. About 71 percent of the respondents are not satisfied with the maintenance services provided by the physical plant. For example, about 26 percent of the respondents said that it takes more than one operating day to receive a response about their service requests. On the other hand, the results of the maintenance survey showed that about 86 percent of the operators have more than 10 years of experience. And about 81 percent believe that they have the needed qualifications. However, about 58 percent answered that they are using old equipment and about 53 percent believe that the spare parts are not available when needed.

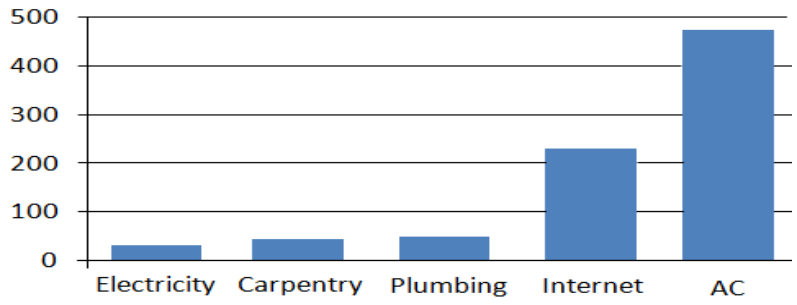

Figure 1. Type and frequency of problems in the facilities in 2017

Similarly, relevant historical data were collected from the physical plant department for 2016-2017 for the specific buildings identified in define phase. It was found that the number of service requests per month has increased, i.e. almost doubled, in year 2017 which is noticed to be highest in September and October when the students and faculty members are back from their summer vacation, see Fig. 2.

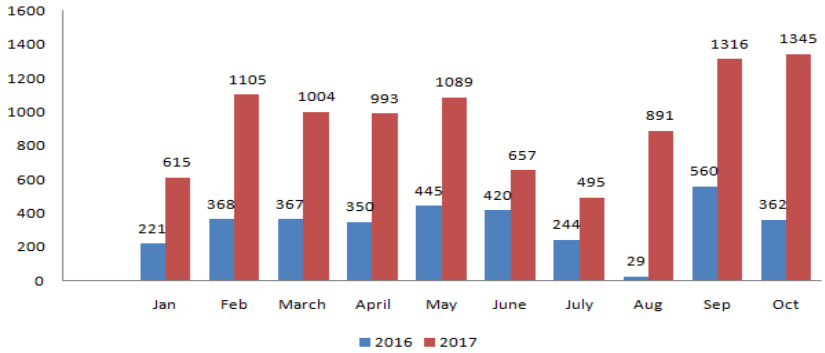

Figure 2. Number of complaints per month

Also, when analyzing the complains with respect to their category it was found that most of the complains were related to air condition problems, which emphasized the survey results, as shown in Fig. 3.

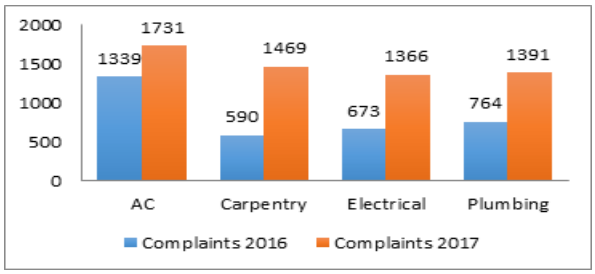

Figure 3. Number of Complaints with respect to category

Figure 4 shows the number of complaints with respect to building type. It can be seen that most of the complaints are coming from W13 and M13 that represent the female and male dormitories, respectively. This means more attention should be given to these two buildings to investigate the problems encountered and try to find solutions.

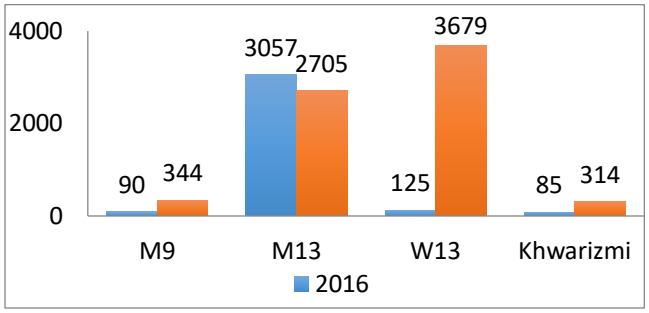

Figure 4. The number of complaints with respect to building type

Also we measured the efficiency and effectiveness of the operators where the efficiency is measured by dividing the expected time estimated to close the order over the actual time. Based on the data collected about all complains received in year 2017 up till September for all buildings, Fig 5 shows the efficiency results, it can be seen that lowest efficiency is with technician who are dealing with the AC. while the highest efficiency was with the electrical technicians.

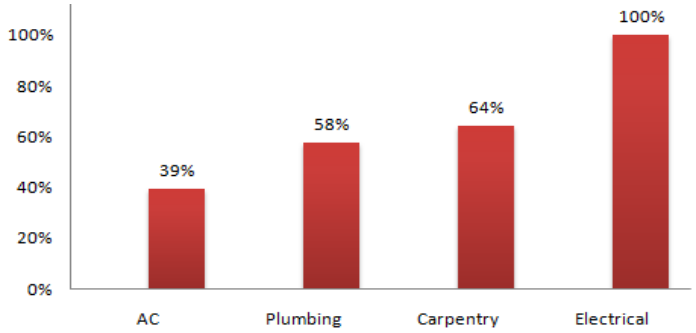

Figure 5. Technicians efficiency in year 2017

The technicians' effectiveness was measured by dividing the number of completed tasks over all tasks during same period of time. As shown in Fig. 6, the lowest effectiveness was in AC, too. while the highest was in plumbing.

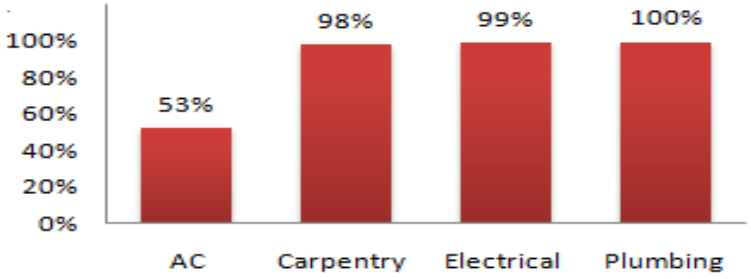

Figure 6. Technicians effectiveness in year 2017

3.3 Analyze

Based on the results obtained from the measure phase, it is clear that there are two major problems that affect the stakeholders' satisfaction, which are related to air conditioning (AC) and internet services. Regarding the AC problems, based on the results of AC experts interview it was found that the most frequent AC failures are improper

operation, poor maintenance, faulty installation and poor service procedures; as well most of failures happen due to the refrigerant cooling gas charging, if the compressor was charged more than the required amount which does not match with the manufacturer's specifications this may probably cause leakage, frozen pipes and low airflow. Other failures may happen due to fuses, circuit boards and distribution panels. Moreover, some users keep on turning the air condition on and off as well keeping the windows opened which will cause serious damage for central boards and thermostat.

For the Internet problems, the fishbone diagram was used as a tool with help of Information Technology (IT) experts at the university. Consequently, it was possible to identify the main causes that lead to internet problems as shown in Fig. 7

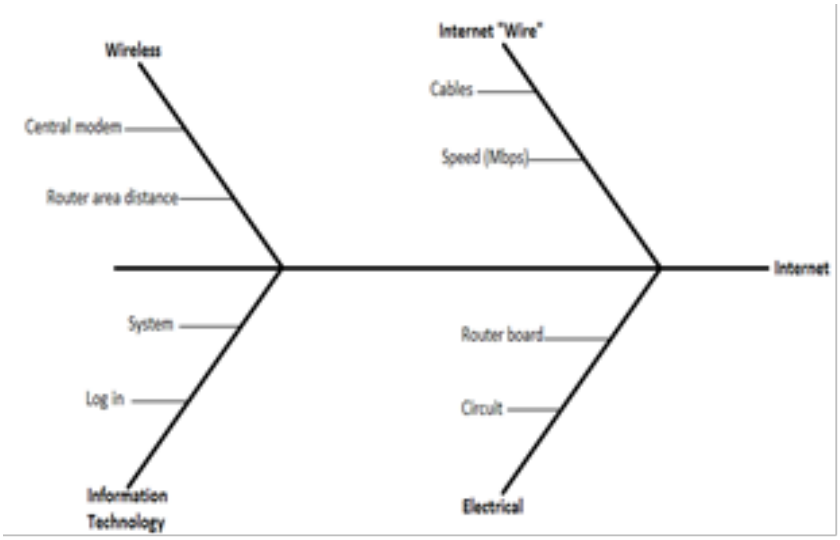

Figure 7. Internet cause and effect diagram

As a result of more investigation, analysis, and extensive discussions with experts in the physical plant department the following relevant problems were identified:

Problem 1: Low Quality of spare parts.

The company that provides the AC maintenance services used to get low quality spare parts for the air-conditioning system which gives short life cycle of the parts and they used to wear-out very fast. This resulted in more failures and the maintenance technicians have to act in a "firefighting" mode which resulted in more stressful, working environment with less time for planned maintenance task, more time needed to response to received maintenance requests, and finally less customer satisfaction.

Problem 2:Weak Training and Education Courses.

It was found that rate of leaving the work at the company that is providing the AC maintenance services is very high, which resulted in low performance. In addition, the operators are not getting enough training and education courses which affected their effectiveness and the work done and reduced stakeholder's satisfaction with the maintenance jobs done.

3.4 Improve

In this phase we suggested various recommendations and solutions to improve the performance at the university that if implemented may increase the satisfaction. We used the "six thinking hats" approach which tries to reach to improved solutions using various views and perspectives. The six thinking hats approach is an effective management

tool that makes a person to think outside the limits of limited mindedness of thinking and fixed positions, see (De Bono, 1985). The six hats approach is based on the following concepts:

- Blue hat: it focuses on the process by thinking about what should be done to manage and control the process so that it can be improved by organizing our thinking.
- White hat: it focuses on the facts like identifying what data and information are needed; being neutral and objective when analyzing the data; finding what do I know and what do I need to find out; and finally how will I get the information I need.
- Red hat: here the focus is on our intuition and feelings; what is my feeling right now? can my feeling change?
- Yellow hat: it focuses on the benefits; what are the positive sides of an idea? Why this idea is useful? logical reasons should be given.
- Black hat: it focuses on cautions; what are the difficulties, weaknesses, and dangers; what are the potential risks and problems? Logical reasons should be given.
- Green hat: here the focus is on creativity; one should search for solutions to overcome barrier; think outside the box to find innovative and creative solutions to the difficulties that are identified in the black hat phase.

We used the quality function deployment (QFD) as a tool to generate solutions based on the stakeholders' requirements. The survey was used as a tool to collect data about stakeholder's complaints and requirements. Consequently, the following needs and complains were identified and used as what in the QFD:

- AC is too cold or too hot
- Internet is too slow
- We encounter frequent failures
- More than two days to respond to a service request
- The problem was not solved well
- No response all
- The AC unit is too old
- Rooms smells bad
- Operators are not qualified
- I cannot communicate with operators

Using the QFD tool, see Fig. 8, all the "what" were analyzed and relevant solutions "How" were suggested to solve or mitigate the complains received based on the results of interviews with expert engineers who work in the physical plants department.

Legend: ● Strong Relationship, ○ Moderate Relationship, ▲ Weak Relationship	Fix thermostate or replace	upgrade internet services	Monthly maintenance check up	Increase workforce	Qualified maintenance team	Increase operator utilization	Central Air-conditioning	High performance ventelation	Training courses	Increase education and wilingness
Hows / *Whats*										
AC too cold or hot	●		○		▲		○			
Internet is too slow		●	▲			▲				
Frequent failures	▲		●	▲	○	▲			○	
More than 2 days to respond				●	○	●				
Problem was not solved well			▲		●	○			●	
No response at all				●	▲	●				
Split units are old			○				●	○		
Room smells bad			▲	▲	●		●	●		
Operators not qualified					▲				●	●
I can not communicate with operator					▲				○	●

Figure 8. Example of quality function deployment results

In the following we list possible final suggestions and recommendations to improve the performance:

1. Conduct monthly planned maintenance check-up.
2. Invest on new cooling system such as central AC.
3. Shift from "Corrective maintenance" to "preventive maintenance" to prevent breakdowns from happening.
4. Invest on new condition monitoring technologies such as vibration analysis, infra-red cameras, acoustic sound analysis.
5. Use high quality long life cycle spare parts.
6. Increase operator's skills and competence by hiring the right person.
7. Implement training and education courses to increase willingness of operators.

Finally, multiple criteria decision making (MCDM) can be used as tool to select the most suitable recommendation.

3.5 Control

Monitoring the current state is a must, monitoring will help to control an improvement and reduce failures as much as possible to achieve the main goal which is stakeholder's satisfaction.

4. Conclusion

This study will increase stakeholder's satisfaction by meeting their expectations and reduce number of breakdowns and failures that they are facing, as a result of using DMAIC methodology and other industrial tools; we are the first of kind who used this methodology in assessing and improving the performance of the physical plants, by developing feasible solutions and chose the right solution that can be implemented with the lowest cost and shortest time, this paper shows that DMAIC methodology can fit in any organization not only in manufacturing and enterprises, it is a strategic planning method to provide the best measurements of the current situation and as well generate unlimited solutions.

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Biographies

Imad Alsyouf is an associate professor of Industrial Engineering, employed by University of Sharjah, UAE. He is the director of the university Sustainability Office and founder and coordinator of the Sustainable Engineering Asset Management (SEAM) Research Group. He has produced more than 30 conference and journal papers. He has about 27 years of industrial and academic experience in various positions in Jordan, Sweden and UAE. His research interests include reliability, quality, maintenance, and optimization. He has developed and taught more than 25 post and undergrad courses. He delivered training courses in Kaizen, TQM, and organizational excellence.

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