Implementing Six Sigma to Improve A/C Repair Requests Turnaround

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Abstract

The paper was to collect and analyze the turnaround time of A/C Services requests at a maintenance firm which is located in Saudi Arabia. The year 2018 was selected for this study, and the average turnaround time was 5 days. Also, to provide solutions and recommendations to improve the process of the A/C Services request in the company. Significant solutions and recommendations that will reduce the turnaround time were addressed and discussed in this paper. Study identified that the time wasting of routine processes are the root cause of the problem, also the company inventory and warehouse of spare parts can't cover all repairs and at the same time the orders take a long time.

Keywords
Six Sigma, HVAC, HVAC System, Air-Condition, Turnaround, Time, Spare, Parts, Optimization, Saving, Inventory, Quantity, Warehouse, Store, Maintenance, Critical, Equipment, Saudi, Arabia.

1. INTRODUCTION

1.1 Background of the case company

The subject company of this case study is a maintenance company who has a contract to provide A/C Services for a compound consisting of 2,000 pulse housing units. This contract is one of several long form contracts that the company has. For this contract the company has assigned 20 A/C Technicians, 2 maintenance planners and one project manager. Moreover, the company provides 11 vehicles that are assigned to the technicians and the project manager. The compound is located in the eastern province of Saudi Arabia. The name of the company is not mentioned to avoid any legal matter.

1.2 Background of the study

A/C Service is one of the important services in the hot weather countries where the air-conditioner is essential nowadays. Additional hours for a repair request processing is not appreciated by the customers. The process for a services request starts by a call from the customer to the call center. The call center operator initiates the services request in the system with very brief details about the A/C issue. Then, the service request details are printed on the work control center where the shift supervisor reviews the request and assigns it to the available technician after he calls the customer to get the confirmation of his availability at the house. Once the technician is assigned to a request, he will visit the customer's house to check and diagnose the issue. If spare parts are required, technicians will report back to the planning team and request the required material. Then, the technicians collect the material from the warehouse, they go back to the house to fix the a/c issue. After the repair is completed, the technicians go back to the work control to report the completion of the request.
Planning activities in the A/C request process is taking a significant time which leads to increased turnaround time of the repair request. This definitely affects the customers' satisfaction level as it takes more time to repair and put back the A/C to operation.

1.3 Problem statement

Turnaround time for A/C maintenance tickets is taking a long time. For 2018, the average turnaround time was more than 5 days. There are two types of activities in the process. They are work control activities and repair activities. This study focuses on the work control activities.
The current process of A/C repair request goes through the following steps (Figure 1):

1. Customer call for maintenance
2. Call Center operator issue the maintenance request (ticket)
3. Workcontrol will assign it to a A/C Technician to visit the site and diagnose the issue and fix the issue if no material is required
4. If material is required, Technicians will report back to the planning team and request for the required material.
5. A/C Technician will collect the material from the warehouse.
6. A/C Technician will go back to the house and fix the issue.
7. Report the request completed to the planning.

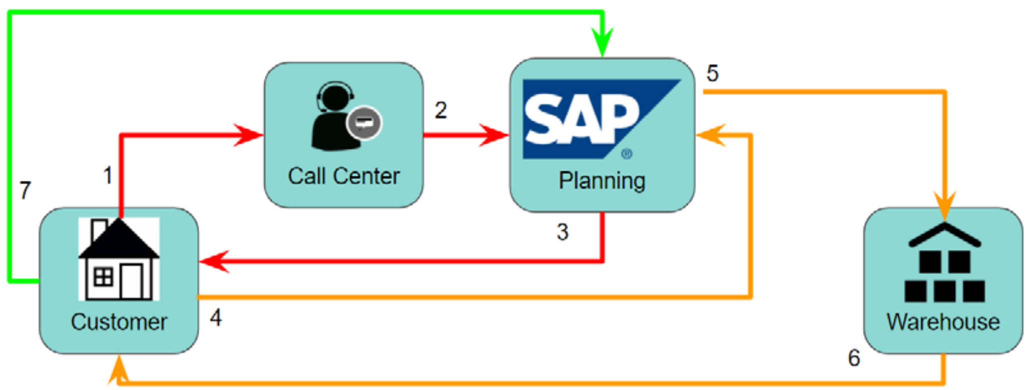


Figure 1: Process diagram of the A/C services requests

1.4 Objective
The objective of the project is to recognize the root cause and reduce the turnaround time by using DMAIC process, improving method of work, or other potential solutions.

1.5 Significance of the study
The team believes that this study will significantly improve the process of the A/C Services request in the company by providing solutions and recommendations that will reduce the turnaround time. Moreover, this will positively affect the customer satisfaction level at the compound.

1.6 Scope of the study
The scope of this study is to collect and analyze the turnaround time of A/C Services requests during the year 2018. Also, to provide solutions and recommendations to improve the process of the A/C Services request in the company by providing solutions and recommendations that will reduce the turnaround time.

1.7 Data Collection
The data were collected from the SAP historical data for 2018. 2018 was selected because the customers' behavior have not been affected by the COVID-19 pandemic. It was noted that the number of the services have been reduced due to the pandemic's precautions as the customers avoid having strangers interning their houses. Table 1 shows a sample of the data from the month of January 2018.

2. LITERATURE REVIEW
2.1 Overview of Six Sigma
Quality is becoming more important for many organizations in different business sectors. It can be used as a competitive tool to give an advantage to an organization by making customers happy. Having a robust quality strategy can be a major factor in long term success. Six Sigma is a project-oriented approach that uses statistics to reduce variability, remove defects, and eliminate wastes from products, processes, and transactions (Montgomery and Woodall, 2008). Since 1980, there has been a rapid growth in the use of statistical methods for quality not only in the United States, but around the world. Part of this can be attributed to the loss of business suffered by US companies during the 1970's, with one company estimating losing nearly $1,000,000 per hour in 1980.

Table 1: Sample of the data from the month of January 2018

Description	Start Date (Release Date)	End Date (Teco Date)	Actual Repair Hours	Actual Repair (Days)	Turnaround Time (Days)	Time Spent On Other Process	Cost Sar
A/C is not working tell 053727820 (Repea	1/1/2018	1/2/2018	2	0.25	2	1.75	SAR 74.00
Change the AC filters 6775607	1/1/2018	1/1/2018	2	0.25	1	0.75	SAR 74.00
A/C heater is not working tell 6775874	1/1/2018	1/1/2018	2	0.25	1	0.75	SAR 74.00
Check and repair the A/C	1/1/2018	1/2/2018	2	0.25	2	1.75	SAR 74.00
NEED AC SERVICE	1/1/2018	1/2/2018	2	0.25	2	1.75	SAR 74.00
NEED AC SERVICE	1/1/2018	1/2/2018	2	0.25	2	1.75	SAR 74.00
check and repair the a/c is not working	1/1/2018	1/8/2018	0	0	8	8	SAR 0.00
checkand repair a/c is noisy tell 673123	1/1/2018	1/3/2018	2	0.25	3	2.75	SAR 74.00
A/C is not working (2) tell 6730743 0531	1/1/2018	1/1/2018	2	0.25	1	0.75	SAR 74.00
a/c is not cooling tell 6774415	1/1/2018	1/1/2018	2	0.25	1	0.75	SAR 74.00
a/c is not cooling 0531216468	1/1/2018	1/8/2018	2	0.25	8	7.75	SAR 74.00
clean filter a/c tell 6775460	1/1/2018	1/4/2018	2	0.25	4	3.75	SAR 74.00
replace a/c filter - 6775372	1/1/2018	1/7/2018	2	0.25	7	6.75	SAR 74.00

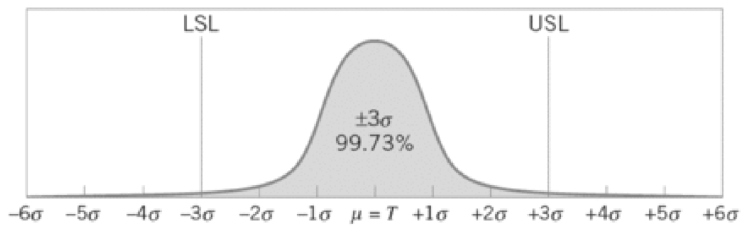
One of the first quality systems to emerge was total quality management (TQM). TQM achieved only moderate success for a plethora of reasons. Some general reasons that are cited are lack of top-down, high-level management commitment, inadequate use of statistical methods, and general, non-specific, objectives (Montgomery and Woodall, 2008). Six Sigma is another quality system that has been far more successful than TQM. The main reason for this is the focus on projects that positively impact the bottom line. These types of projects tend to get the attention of upper management, which causes a trickle down effect that pulls in all necessary parties to the project. The level of training is usually deeper and more extensive as well, resulting in the techniques actually being used.

Many recognize Bill Smith, a Motorola engineer, as the father of Six Sigma. Bill developed a Six Sigma program in 1986 in order to improve quality and reduce defects in Motorola’s products. The CEO recognized this program as a revolutionary tool to help the company and began applying Six Sigma throughout the company, the main focus being on manufacturing processes and systems. This proved tremendously successful. Between 1987 and 1993, it is estimated that Motorola reduced defects by 94% on semiconductor devices (Montgomery and Woodall, 2008). Other companies soon began adopting similar forms of Six Sigma programs.

The main focus of Six Sigma is reducing variability in key product quality characteristics around a specified target value at which, failure or defects are extremely unlikely. In order to do this, Motorola sets their specification limits at least six standard deviations from the target, resulting in about two parts per billion non-comforming. Under this concept, an assumption was made that once this level is reached, the mean was still subject to disturbances that could cause it to shift by as much as 1.5 standard deviations. This would result in up to 3.4 parts per million non-conforming to specifications.

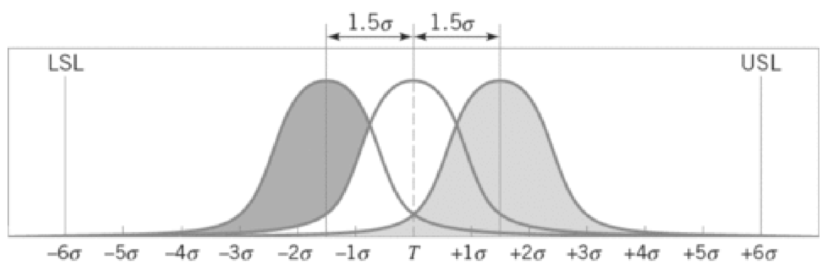
The drifting mean is a source of controversy. Some have argued that there is an inconsistency in that we can only make predictions about process performance when the process is stable. If the mean is truly drifting, a prediction of 3.4 ppm may be unreliable since the mean could shift more than the allowed 1.5 standard deviations. The common rebuttal is that Six Sigma is at best an approximation that is a useful way to think about and quantify the process performance. The 3.4 ppm metric is recognized as a distraction, while the true focus is on the reduction of variability and elimination of wastes.

Companies involved in a Six Sigma effort use specially trained individuals to guide the project. From high to low, they are Master Black Belts, Black Belts, and Green Belts. Black Belts usually have at least 4 weeks of training involving concurrent work on a Six Sigma Project. Green Belts are trained by Black Belts for about 1 or 2 weeks and assist major project teams.



Spec. Limit	Percent Inside Specs	ppm Defective
±1 Sigma	68.27	317300
±2 Sigma	95.45	45500
±3 Sigma	99.73	2700
±4 Sigma	99.9937	63
±5 Sigma	99.999943	0.57
±6 Sigma	99.9999998	0.002

(*a*) Normal distribution centered at the target (*T*)



Spec. Limit	Percent inside specs	ppm Defective
±1 Sigma	30.23	697700
±2 Sigma	69.13	608700
±3 Sigma	93.32	66810
±4 Sigma	99.3790	6210
±5 Sigma	99.97670	233
±6 Sigma	99.999660	3.4

(*b*) Normal distribution with the mean shifted by ±1.5σ from the target

Figure 2. Motorola Six Sigma Concept (Montgomery, 2008)

A common tool for Six Sigma is DMAIC (Define, Measure, Analyze, Improve, Control). This is a structured problem-solving procedure widely used in quality and process improvements. The structure strongly encourages creative thinking about the problem and the solution within the definition of the product or process. DMAIC is successful because it focuses on the effective use of statistical tools.

Project selection is an integral component of Six Sigma. A project should represent a possible breakthrough that can result in a major improvement in the product or service. A key to evaluating projects is the financial benefit to the business. This must be clearly identified and the projects must be well aligned with corporate business objectives at all levels. Aligning projects with both business-unit goals and corporate-level metrics helps ensure that best projects are selected.

The Define step of DMAIC is used to identify a project and verify it represents legitimate breakthrough potential. This involves creating a project charter. A project charter is a short document containing a description of the project, along with key dates, measures of successes, benefits, and team members for the project. This stage typically lasts 2-4 days. The Measure step evaluates the current state or the process. Team members collect data and cost to get a baseline for the beginning of the project. Previous data can be used but it is best to gather current data. At the end of the Measure step, the team should update the project charter, re-examine the project goals and scope, and re-evaluate team makeup.

The next step, Analyze, uses data from the Measure step to determine sources of variability. The objective in this step is to identify potential causes of defects, quality problems, customer issues, and waste. You will generally see statistical steps such as graphical data displays, control charts, and hypothesis testing.

In the Improve step, the team uses creative thinking thinking about the specific changes that can be made that will improve the performance of the process. Many tools are in the Improve step, like mistake-proofing, redesigning, and reducing bottlenecks. The goal is to develop a solution to the problem and trial it. The final step, Control, completes all remaining work on the project and makes sure the new process is sustained. The team will start quantifying the benefit of the project to see the true benefit. This should include a validation check after a few months to ensure the new process is still in place and there are no new issues as a result. For continued success of Six Sigma, it is important to incorporate a broader array of statistical methods. There are an increasing number of applications where more sophisticated statistical methods are required in Six Sigma applications. Six Sigma has been used in great success in improving quality in applications around the world.

2.2 LSS Maintenance

Six Sigma is a technique used to eliminate and prevent any possible inconsistencies in products/processes and try to reduce process failures. In order to make the process run smoothly, all equipment must be in the best possible condition, the equipment must be maintained, and the workers need to be trained properly (Paprocka et al., 2020). Sensors can be added to the machines even after they're made that can track noise, vibrations, position of key elements, among other things. This information can be used for off-site analysis during the operation of the device. Using the collected data, this method is an extension of the Six Sigma concept for monitoring and continuous control in order to prevent inconsistencies in processes and resulting products. Machine maintenance can limit the amount of unpredicted production stoppages. The tasks of maintenance include corrective maintenance, preventive maintenance, and predictive maintenance (Liu et al., 2018). Corrective actions are more of a reactive step, repairing damaged machine elements, while preventive and predictive actions are proactive steps. These proactive steps tend to save money and reduce any unplanned production stoppages.

2.3 Six Sigma in Service

Service quality is becoming more important for companies trying to stand out from their competition. In an ever-evolving world, products are becoming more of a package of goods and services rather than the good alone. While consumers needs are always changing, the most consistent findings of service quality research are:

- Service quality is more difficult for the consumer to evaluate than product quality
- Service quality perceptions result from a comparison of consumer expectations with actual service performance
- Quality evaluations are not based solely on the outcome of a service but also involve evaluation of the delivery process

One of the biggest myths about six sigma is that it is only good for manufacturing processes (Kumar et al., 2008). Six sigma can be used in many sectors, not just manufacturing, such as human resources, finances, and even the service industry. In these non-conventional sectors, there are several critical factors that can determine if six sigma is successful. Top management needs to be committed to six sigma, the culture of the entire company needs to adjust properly, and the six sigma initiatives must be focused on the customer (Chakrabarty and Tan, 2007).

The service industry has some difficulties with implementing six sigma. Within the service industry, it is harder to collect data because the majority of it is subjective not objective. It is also more difficult to control and measure six sigma in the service industry based on what can arise from various sub-processes (Hensley and Dobie, 2005). There are also higher costs to train workers in six sigma which can make it tough for small and medium sized companies to adopt six sigma. Wessel and Burcher detailed ten imperatives for these companies. These include making sure all projects benefit the bottom line, implementing a one day training program, allowing quality leaders to handle the six sigma projects, and combining the efforts of six sigma and ISO 9000 (Wessel and Burcher, 2004).

2.4 Overview of Using Six Sigma to Reduce Turn-round Variability

Many industries are trying to reduce turn-round time for their parts. Good maintenance and repair is essential in the aerospace industry. The cost of repair and overhaul is huge and if it is not taken care of in a timely manner, can cause significant financial strain on the company. Looking at a case study (Thomas et al, 2013) on an aerospace company, a Monte Carlo simulation method was used along with Six Sigma to assess the most economical strategy to repair and maintain specific components. Monte Carlo simulation is used in many different industries, such as banking, engineering, and medical. The method is the use of pseudo random numbers to guess when failures could occur in a system. This makes it ideally suited for predicting machine failures. The study showed a drastic short-term improvement in cost reduction. Over a 70,000 hour operational period, overall maintenance cost dropped by $11,000,000. This proves that there is a benefit to combining Monte Carlo simulation to Six Sigma methodologies.

3. Results and Discussion

In this chapter we will discuss six sigma phases (DMAIC) with company performance. Root causes are one of the important parts of any problem, so the results will lead us to get the remedy.

3.1 Define Phase

The definition of a project, including the designation of who is responsible for what progress by when. By definition, those applying six sigma methods must answer some or all of these questions in the first phase of their system improvement or new system design projects. Also, according to what may be regarded as a defining principle of six sigma, projects must be cost-justified or they should not be completed. Often in practice, the needed cost justification must be established by the end of the "define" phase. The most relevant strategies associated with answering these questions relate to identifying so-called "subsystems" and their associated key input variables (KIVs) and key output variables (KOVs). Therefore, we have to begin with an explanation of the concept of systems and subsystems. Then, the format for documenting the conclusions of the defined phase is discussed, and strategies are briefly defined to help in the identification of subsystems and associated goals for KOVs.

3.1.1 Company Business

The subject company has a business of fixing cooling systems in Saudi Arabia. It has a team of technicians and its own inventory. The procedure of the work is: If the company hasn't the material in its own inventory so they have to purchase from the warehouses, if they failed to find it in all warehouses, so they have to order it. The Pareto Chart (Figure 3) shows the total amount of spending time around tickets becomes higher.

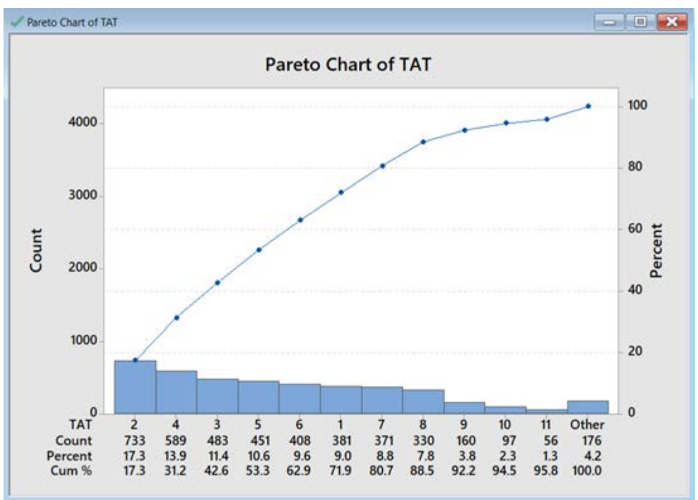


Figure 3. Pareto Chart time around ticket

3.1.2 Problem Statement

The time around ticket has high category bars in (Figure 3) that means there is a lot of time-wasting.

3.1.3 Project Objective Statement

The objective of the project is to improve the company's performance to avoid time wasting.

3.1.4 Systems and Subsystems

A system is an entity with inputs and outputs. A "subsystem" is itself a system that is wholly contained in a more major system. The subsystem may share some inputs and outputs with its parent system. Figure 4 shows three subsystems inside a system. The main motivation for the "define phase" is to identify specific subsystems and to focus attention on them. In this case, we have the main system that receives calling processing and fixing with series subsystems when the orders from warehouses or from another country. Compressors fail frequently to find it in the company inventory. The company must make a list of the customers A/C unit's type. That will give the company a list of all materials that will be needed in the future.

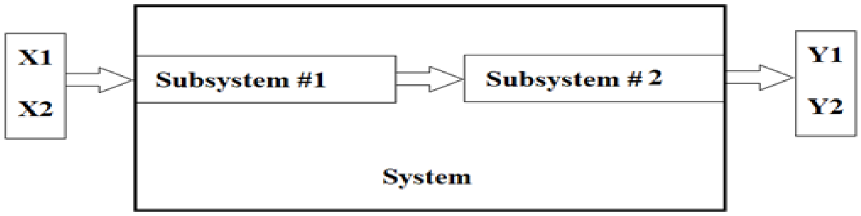


Figure 4. Example of subsystems inside a system

3.1.5 Process Map Analysis

The Analyze phase begins with a good look at the detailed process map. It is a planning and management tool that describes the flow of work visually. The main purpose of process map analysis is to improve efficiency. It provides insight into a process, helps teams brainstorm various ideas for process improvement, increases communication among the team and provides process documentation. Process mapping is used to identify bottlenecks, repetition, and delays. It also helps to define the process boundaries, process ownership, and process responsibilities.

3.1.6 The benefits of process map analysis

- Increase the understanding of a process
- Analyze how a process can be improved
- Improve communication among the individuals engaged in the same process
- Provide process documentation
- Plan projects effectively.

3.1.7 Graphical Analysis

This Histogram of start date shows (Figure 5) that the relation between calls with time is bell shape with mean is 43291 and the standard deviation is 92.72. We can notice the calls start in January then increase month by month until July and August (peak value) then start decreasing until December. The company works in summer more than winter. The Histogram (Figure 6) is the relationship between times spent on the other process and frequency. Its bell shape with mean is 4.597 and standard deviation is 3.279. Also it gives us a clear picture about how many times requests received.

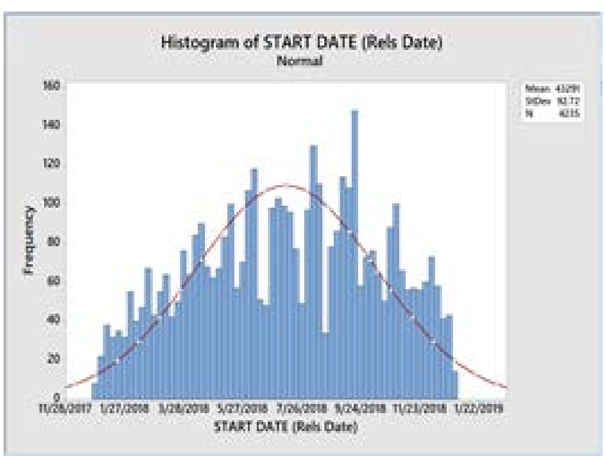


Figure 5. Histogram of start date

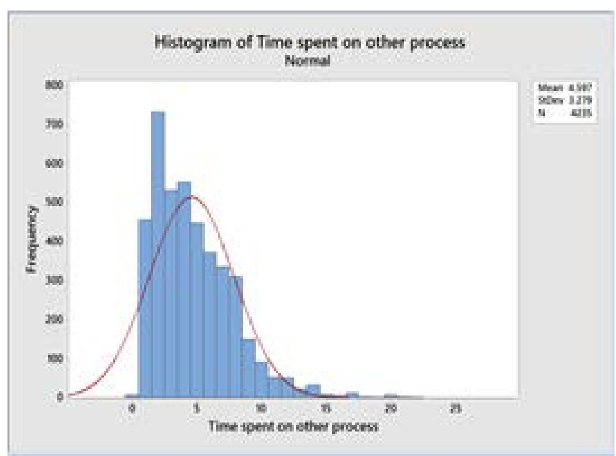


Figure 6. Histogram of TAT with frequency

3.2 Measure Phase

2018 Data was collected from a company with seven categories. We have to measure the time spending in every step so we can focus on the problem. The key objective of the Measure phase is to understand the Voice of the Customer

(VOC), to translate the customer feedback into measurable design requirements.

Table 2: Sample of the DATA

Description	Start Date (Release Date)	End Date (Teco Date)	Actual Hours	Actual Work (Days)	Tat	Time Spent On Other Process	Cost Sar
check and repair window A/C	12/25/2017	1/2/2018	0	0	9	9	SAR 0.00
check and repair window A/C 05316	12/26/2017	1/2/2018	0	0	8	8	SAR 0.00
check and repair window A/C	12/26/2017	1/4/2018	0	0	10	10	SAR 0.00
Change the A/C filters	12/26/2017	1/3/2018	2	0.25	9	8.75	SAR 74.00
Repair broken return Duct 535188014	12/27/2017	1/3/2018	0	0	8	8	SAR 0.00
check and provide new filter a/c is dama	12/28/2017	1/4/2018	0	0	8	8	SAR 0.00
replace 2 AC filters 6776453	12/30/2017	1/7/2018	2	0.25	9	8.75	SAR 74.00
check AC and clean filters 536921903	12/30/2017	1/7/2018	0	0	9	9	SAR 0.00
Check and repair the AC is leaking	12/31/2017	1/7/2018	2	0.25	8	7.75	SAR 74.00

3.2.1 A/C Technicians' Survey

Project team has conducted a short survey to the company's A/C Technicians to understand the process deficiencies and root causes of the long turnaround time of the A/C Service requests. These survey's questions give us a clear picture about company performance and can see the gap of wasting time throwing the answers. The survey result shows that the average daily request that can be completed from the first visit to the house are only 2 requests out of the average 4 requests that the A/C Technician can attend. Also, the result shows that the majority of the requests need material or spare parts. Moreover, material and spare parts are available only for 50% or less of the requests that need material or spare parts.

Table 3: A/C Technicians' Survey Result

No.	**Question**	**Multiple Choices**	**Result (# of Tech selected the answer)**
1	Average daily requests can be attended by a technician	2 or less requests	2
		4 requests	12
		More than 4 requests	6
2	Average daily requests can be completed from the first visit	Zero requests	3
		2 requests	10
		More than 2 requests	7
3	Average daily requests needs material or spare parts	1 or less requests	0
		2 requests	0
		3 requests	5
		4 or more requests	15
4	Average daily requests needs material or spare parts that are not available on the inventory or the warehouse	1 or less requests	1
		2 requests	3
		3 requests	14
		4 or more requests	2

3.2.3 Cost of rework

The Cost of Poor Quality (COPQ) is the cost caused through producing defects, is a commonly used concept. Within the total amount of quality cost, however, COPQ represents only a certain proportion. Costs do not result from only producing and fixing failures; a high amount of costs comes from ensuring that good products are produced. This article explains the cost of quality as a more comprehensive concept covering the cost of poor quality and the cost of good quality. In short, any cost that would not have been expended if quality were perfect contributes to the cost of quality. In this case the cost of poor quality affects Internal and external costs resulting from failing to meet the customer requirements.

3.2.2 Project Timeline / SIPOC Flow Diagram

Table 4. SIPOC Diagram

S	I	P	O	C
SUPPLIERS	INPUTS	PROCESS	OUTPUTS	CUSTOMERS
Who supplies the material input?	What resources are needed or provided by the supplier?	What steps or activities are carried out to create value for the customer?	What products or services are created by (or result from) the process?	Who are the customers?
A/C Services provider company 20 A/C Technicians 2 maintenance planners one project manager 11 vehicles	A/C Services Spare Parts & Material Fast respond Fast repair	Receiving the calls Assigning it to an A/C Tech. Schedule the site visit Troubleshooting & diagnose the problem Identify the required spare parts Order & collect the required spare parts and material Repair the equipment Report the issue and close the request	A/C Services Spare Parts & Material	A compound consisting of 2,000 pulse housing residents

3.2.4 Cost of Poor Quality: Internal Failure Costs

Internal failure costs are costs that are caused by products or services not conforming to requirements or customer/user needs and are found before delivery of products and services to external customers. They would have otherwise led to the customer not being satisfied. Deficiencies are caused both by errors in products and inefficiencies in processes. Examples include the costs for:

1. Rework
2. Delays
3. Re-designing
4. Shortages
5. Failure analysis
6. Re-testing
7. Downgrading
8. Downtime
9. Lack of flexibility and adaptability

3.2.5 Cost of Poor Quality: External Failure Costs

External failure costs are costs that are caused by deficiencies found after delivery of products and services to external customers, which lead to customer dissatisfaction. Examples include the costs for:

1. Complaints
2. Repairing goods and redoing services
3. Warranties
4. Customers' bad will
5. Losses due to sales reductions
6. Environmental costs

3.2.6 Cost of Good Quality: Prevention Costs

Prevention costs are costs of all activities that are designed to prevent poor quality from arising in products or services. Examples include the costs for:

1. Quality planning
2. Supplier evaluation
3. New product review
4. Error proofing
5. Capability evaluations
6. Quality improvement team meetings
7. Quality improvement projects
8. Quality education and training

3.2.7 Cost of Good Quality: Appraisal Costs

Appraisal costs are costs that occur because of the need to control products and services to ensure a high quality level in all stages, conformance to quality standards and performance requirements. Examples include the costs for:

1. Checking and testing purchased goods and services
2. In-process and final inspection/test
3. Field testing
4. Product, process or service audits
5. Calibration of measuring and test equipment

The total quality costs are then the sum of these costs. They represent the difference between the actual cost of a product or service and the potential (reduced) cost given no substandard service or no defective products. Many of the costs of quality are hidden and difficult to identify by formal measurement systems. The iceberg model (Figure 7) is very often used to illustrate this matter: Only a minority of the costs of poor and good quality are obvious – appear above the surface of the water. But there is a huge potential for reducing costs under the water. Identifying and improving these costs will significantly reduce the costs of doing business.

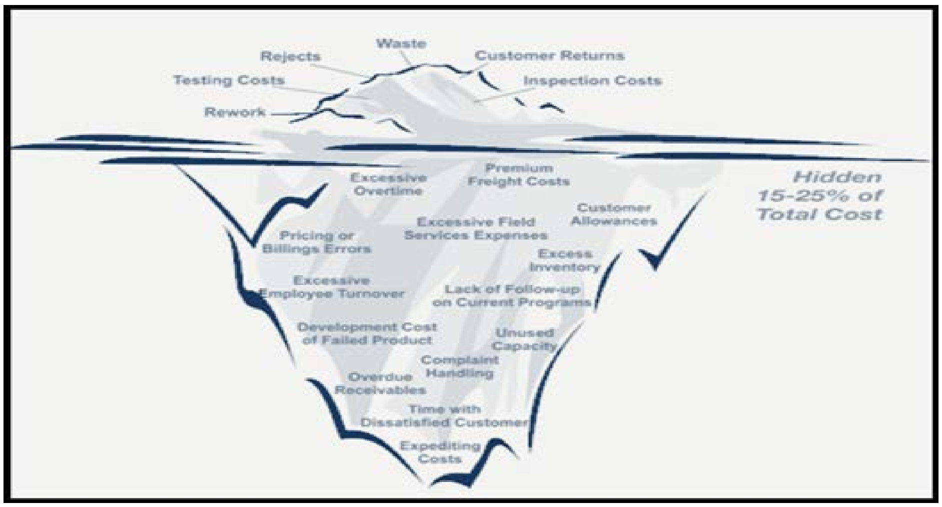


Figure 7. The Iceberg Model of Cost of Quality (http://www.kaizenfs.com/process-engineering)

3.3 Analyze Phase

The Analyze phase of DMAIC helps project teams identify problems in the production process that cause product defects. This phase of Six Sigma methodology is loaded with tools to help spot the problems in the production process and to determine if these problems are the root causes of defects.

3.3.1 Identifying Possible Causes

The Analyze stage focuses on the data gathered in the Measure phase of DMAIC to identify the cause of product defects. In typical Six Sigma fashion, identifying possible causes of defects is not left to hunches or guesswork. Six Sigma provides a host of tools to help identify the possible cause:

3.3.2 Cause and Effect Diagram

This graphical tool (Figure 8) helps the team identify the cause of the problem, not just the symptoms. This diagram enables a team to focus on the content of the problem rather than its history or the individual interests of team members. The problem is stated at the right side of the diagram. The project team works to the left by filling in and examining potential causes of problems such as materials, people and methods.

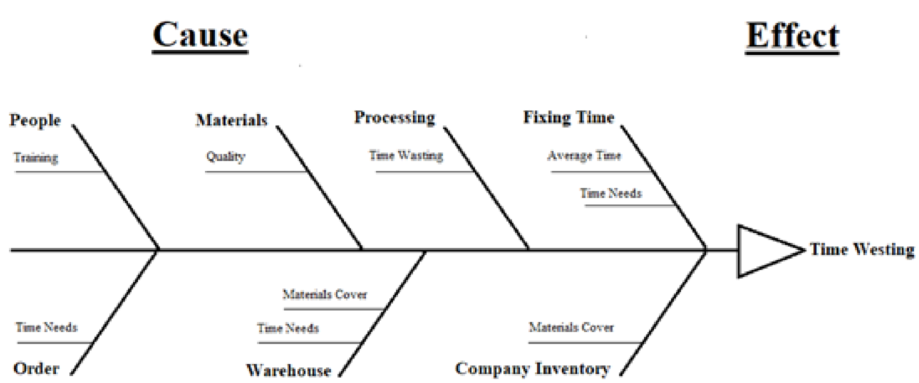


Figure 8. Cause and effect diagram

From Figure 8 we compute the main reasons of time wasting
1. People: Do the technicians have good training?
2. Materials: Is the company using good types of materials?
3. Processes: Is the company using a long routine process?
4. Fixing Time: Is the time around tickets long?
5. Company Inventory: Is it covering the work Martials?
6. Warehouse: Is the warehouse cover most of the main materials to reduce orders?
7. Orders: Does the order take a lot of time? And who can we reduce the orders time?

3.3.4 Finding the Root Cause

The survey of 20 A/C Technicians that we did, orders and process took a long time, so we identified that the time wasting of routine processes are the root cause of the problem, also the company inventory and warehouse can't cover all repairs, and at the same time the orders take a long time.

3.3.5 Design of experiments (DOE)

Is defined as a branch of applied statistics that deals with planning, conducting, analyzing, and interpreting controlled tests to evaluate the factors that control the value of a parameter or group of parameters. In this case we have input variables (People, Materials, Processing, Fixing Time, Company Inventory, Warehouse, and Orders). On the other hand the output is high and low cost. From figure 9. We notice a lot of start dates with result zero actual work. The red line means the regression is positive. But in Figure 10 the regression is negative, that is mean high work low cost.

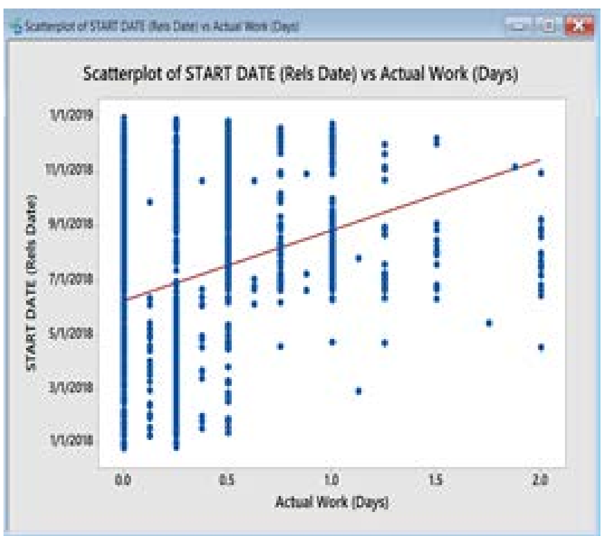


Figure 9. Scatterplot start date vs actual work

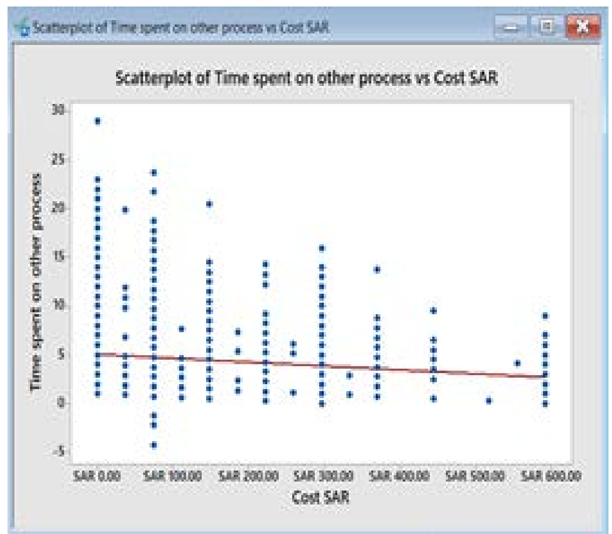


Figure 10. Scatterplot TAT vs cost

3.3.6 Why Why analysis

To solve a problem, we need to identify the root cause and then eliminate it. Therefore, the main goal of this is to drill down to the bottom of the problem to find out the problem of occurrence or root cause and thereby preventing its recurrence. By repeatedly asking the question "Why" (five is a good rule of thumb), you can peel away the layers of symptoms which can lead to the root cause of a problem. Very often the ostensible reason for a problem will lead you to another question. Although this technique is called "5 Whys," you may find that you will need to ask the question fewer or more times than five before you find the issue related to a problem.

When Is 5 Whys Most Useful?
1. When problems involve human factors or interactions.
2. In day-to-day business life; can be used within or without a Six Sigma project.

How to Complete the 5 Whys:
1. Write down the specific problem. Writing the issue helps you formalize the problem and describe it completely. It also helps a team focus on the same problem.
2. Ask **why** the problem happens and write the answer down below the problem.

3. If the answer you just provided doesn't identify the root cause of the problem that you wrote down in Step 1, ask **why** again and write that answer down.
4. Loop back to step 3 until the team is in agreement that the problem's root cause is identified. Again, this may take fewer or more times than five Whys.

3.4 Improve Phase

The goal of the improve phase is to test sources of variation to determine which of these actually cause process variation in the customer Critical to Quality (CTQ). After the project team analyzed the problem, it determined that the four major impacts are routine time-wasting on processing, company inventory, warehouse, and ordering time of unavailable spare parts. So they have to focus on some issues that can help to solve the problems.

3.4.1 Routine Time Wasting on processing

In this case, we solve this problem by using the Company Tablet application so we can reduce the time-wasting in reporting and ordering the spare parts. So the technicians can report the findings and order the required spare parts at the site by using the company tablet application. Then they can directly collect them from the warehouse. Also, throw the tablet applications the team can communicate with customers or with the company. At the same time, the teams can do the reports without going back to the company. By implementing this recommendation, the average turnaround time could be reduced by more than 40%. Because the analysis shows that actual repair time is 3.2 hours only while the remaining time goes for the processing. Moreover, we have measured the time required to travel from the site location to the shop and the warehouse, and it was found that 20 minutes.

3.4.2 Company inventory, warehouse and orders time

In this case, it is highly recommended to use Supply Chain Management to ensure that the inventory will not be zero at any time for the fast moving spare parts and material. Also, the supply chain management system shall be interfaced with the tablet application that will be available with the A/C technician at the job site. There is a company system and subsystem, as mentioned in the defined phase. The subsystem is for the warehouses and for the unavailable material and parts' ordering. These systems shall be interacted with the tablet application that will be available with the A/C technician at the job site. Supply chain management can give us a great framework to provide all materials in time. This strategy will depend on our own inventory. More depending on inventory means less depending on warehouses or orders.

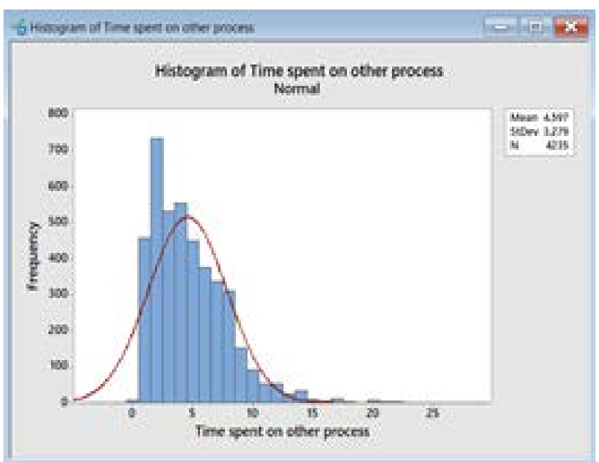


Figure 11. Histogram of date after implementing the recommendations

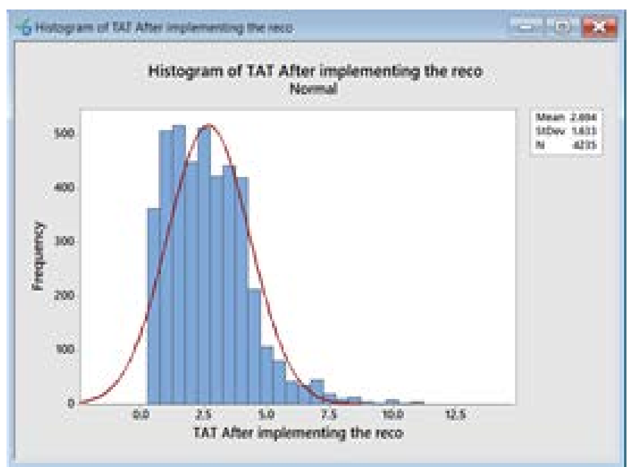


Figure 12. Histogram of Turnaround time with frequency after implementing the recommendations

3.5 Control Phase

In this Phase, we have to sustain the improvements that we did and to make sure the problems will not come back again. There are several issues that I have to understand and put a plan to watch. Let us start with People (technicians) who need training classes every specific period that give them great skills. These classes should be on work, communication, politeness and appearance. The other issue is the materials manufacture level type, so good type that means A/C will work for a long time with great performance that will lead to good satisfaction from the customer. Even fixing time is very important when it takes a short time better than a long time. Keep in mind when the technician follows the roles of doing the procedure so we will reduce fixing time. Company inventory is another important part of the company. In this case, we need to build a supply chain management department to control the inventory. That gives reliability on doing the work without needing to warehouse or order. Supply chain management will support the company in reducing the cost and provides all types of materials that we need in perfect time. The last one is Time Processing, this is more important than the others. We don't need to complicate or process a long process. The flexible and short process is the type that we need. The company-specific tablet with installed SAP logo application will help the teams to do their work with great performance.

4. Conclusion

A/C Services in hot countries like Saudi Arabia are very important and sensitive because of the need for air conditioning equipment during summer. The ambient temperature reaches more than 120 degrees Fahrenheit, so the fixing time should be at the same day. The customer will not believe in any type of explanations of delay of the services. The objective of the project is to recognize the root cause and reduce the turnaround time by using DMAIC process, improving method of work, or other potential solutions. The data was collected from the maintenance historical data for 2018. The problem was defined that the Turnaround time for A/C maintenance tickets is taking a long time. For 2018, the average turnaround time was more than 5 days. There are two types of activities in the process. They are work control activities and repair activities. This study focuses on the work control activities. The project team has analyzed the data and requests' processing steps; four major impacts were determined that caused time-wasting on the processing. They are manual routine, spare parts inventory, warehouse, and orders time for non-stocked material. Significant solutions and recommendations that will reduce the turnaround time were addressed and discussed in this paper. It is recommended that using an automated process for scheduling and assigning the maintenance requests by utilizing Tablet's application to reduce the time-wasting in the manual processing. Moreover, the required material and spare parts can be ordered by the technicians at the job site using this tablet's application. Also, it is recommended to link this system with the other subsystems such as the warehouse system and spare parts vendors' systems. As a result, the turnaround time could be reduced by 50% if the recommended system is implemented.

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