

Application of Quality Control Tools in Carpet Industry: A Case Study

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Abstract

In today's highly competitive industrial development, quality performs an extremely significant role. A case study has been implemented in a carpet industry to improve the quality of carpet pieces. The objectives of this study were to minimize the number of customer complaints, decrease the gap with the best competitors, and increase customer purchasing orders for all products by application of advanced quality tools. Random samples of 4 products were selected for performing random inspection and doing comparison with the main competitors. Criteria of the comparison were indicated by the customer and the comparison results were sent to all competitors. Quality tools such as Pareto chart, Spider plot diagram and Affinity diagram have been implemented to assess and improve the quality of the products. MAC company has found that all missing points leading to increasing performance gap with competitor C were nearly fixed and so the improvement led to increasing the percentage of customer purchase orders of all products by 27 %.

Keywords: Quality, Quality control tools, Carpet, Carpet industry, Case study

Introduction

Carpet industry represents one of the most important businesses both in Egypt and worldwide, as well as it is one of the oldest industries. Competition between carpet companies has been dramatically and rapidly increased because of the increase in the number of organizations that produce the same products, competitor behavior, and product features. In this dynamic market situation, competitiveness, highly changeable and complex business environment, organizations are continuing facing the changes, globalization, fast technological advances, and competition [1,2]. To stay competitive in a business based on the development of complex systems and processes, there is a high demand for continuous improvement of quality to ensure that potential incompatible cases are noticed as early as possible in the development stage. Organizations must be able to achieve the requirements and expectations of customers such as high product quality, faster delivery and competitive cost which are the critical for customer's satisfaction. Moreover, organizations need to apply a comprehensive concept and method on managing those requirements [3]. As well as, organizations also need to apply a comprehensive concept on how they can maintain the level of satisfaction of their customer by delivering best quality of their products and services. Additionally, organizations need to establish a strategy that will focus on business activities improvement to overcome the competition as well as improved the competitive advantage [4]. The highly increasing demand for both efficiency and quality in product development requires best-in-class ways for evaluating the relevant product development processes at a primary phase. Companies must not only meet customer demands, but they also need to plan for exceeding their expectations to gain customers' loyalty and trust. In addition to the above, companies should pay due attention not only to incompatible cases correction, but also to continuous process development. Failing to meet this continuous development, would potentially risk these companies' continuity and existence in the market due to the fierce competition.

Benchmarking in a business means measuring your company's quality, performance and growth by analyzing the processes and procedures of others. Competitive benchmarking is one of the most important types of benchmarking and is about setting certain goals based on what your competitors are doing. By studying the practices and standards of similar businesses to match or, ideally, exceed the industry status quo, your business can gain a competitive edge. A business can use benchmarking to measure numerous areas of their operations against internal and external standards. Benchmarking became one of the most used competitive techniques. It is widely used as a tool to improve performance, eliminate the process of trial and error, and enhance efficiency of developing new products [5]. Benchmarking approach was used in this study to understand what competitors are doing that makes them successful, as well as areas where they falter. By adapting competitors' best practices to your organization needs and deviating from the things customers don't like. Panwar *et al.* [6] observed the adoption and application of benchmarking in automotive companies. They performed a survey for 300 respondents. The results revealed that benchmarking is an effective approach to raise performance and gain knowledge of competitors. In recent times, Kerandi *et al.* [7] observed the relationship between benchmarking and its impacts on organizational performance in commercial banks in Kenya using random sampling technique. They concluded that practicing of benchmarking helps in performance improvement. In a study of the same caliber, [8] studied the relationship between benchmarking and process improvement mechanism, and its impacts on performance improvement of municipalities in the Eastern Cape Province. A questionnaire was used as an instrument to collect data from 100 respondents. The results showed that benchmarking positively affects performance of the municipalities in the Eastern Cape Province. In addition to the above studies, Al-Tarawneh [9] investigated the effect of using benchmarking in the Jordanian banking sector, where he distributed questionnaires to 12 different commercial banks. The findings revealed that benchmarking helps managers to make decisions and this is reflected by the enhanced organizational performance. Moreover, the empirical study by Hwang *et al.* [10] used a survey on the Singapore construction industry to study the relationship between application of performance measurement and benchmarking. The study found that benchmarking represents only 10 % in the field. They concluded that competitive nature of the industry and sensitivity issues influenced the obtained results. In a more recent study, Adewunmi *et al.* [11] examined the benchmarking challenges in Nigerian facilities management. They found that implementation of benchmarking faces many obstacles such as, lack of understanding of the exercise of benchmarking, unwillingness to change, weakness of data from other organizations and poor execution of the benchmarking exercise. The studies conducted by Attiany [12] and Hashim *et al.* [13] found a significant impact of benchmarking practices on organizational performance.

Quality plays a very important role in these today's highly competitive environment. It is not only vital to minimize the wastage but also to fulfill customer's expectations, continuous cost reductions and continuous improvements [14]. In addition, an essential goal of quality control is to fulfill customer requirements by delivering products free of defects. Furthermore, quality control aims to exceed customer expectations in order to increase their loyalty and build good reputation in the market. Analysis of process consists of four tools including cause and effect, Pareto diagram, scatter plot, and flow chart. Cause and effect diagram was developed by Dr. Kaoru Ishikawa in 1943. It is occasionally labeled Ishikawa diagram or fishbone because the shape of the diagram looks like the skeleton of a fish, as it is designed to identify quality problems based on their degree of importance [15]. Two quality control tools (Pareto analysis and cause & effect diagram) were used in study [16] to minimize the rejection of casting components in an automobile industry. In [17,18] found that, the diversity of quality tools has been applied to TQM programs in various industries. It is also used in other improvement methodologies such as in ISO 9,000, Six Sigma, and national quality awards. The necessity of quality tools in continuous improvement can be seen in several studies and the research interest to quality tools and techniques is at the increasing trend. Dahlggaard-Park *et al.* [19], study the quality movement under the subject total quality management and business excellence, found the increasing trend of the article's publication related to techniques and tools from 1987 until 2011. Kumar [20], conducted case study to minimize the refusal of castings depending on quality control tools (QC) in North India. According to the study, the yearly saving is Rs. 10 lakhs. Quality tools such as the cause and effect diagram, histogram, Pareto diagram and check sheet were also implemented to capture the causes of difficulties related to quality [21]. In automotive assembly lines, quality tools were used in a case study [22] to minimize the imperfections. Another case study was implemented by Fouad H.K. The main purpose of a study conducted by Kumar and Bagri [23] was achieving a continuous improvement of the processes on Mindarika Private Limited. In their study, a quality tool like the histogram has been used to identify the main reason of problems related to lever combination switch. The authors then drew the cause-and-effect diagram according to these causes of the problem and took the appropriate action plan for improving productivity at certain levels. The benefits

from process improvements that an organization gains include quality improvement, cost reduction because of less rejection, market dominance through customer satisfaction by better quality and lower prices, improved business and improved productivity [24]. Productivity has been improved in a case study conducted by [25]. In this study, a very useful quality tool like Pareto chart was employed to help define the problems in the process. Ishikawa diagram was also designed to analyze the problems via establishing effective brainstorming meeting. Control chart was drawn to show if the process was stable or not to take the appropriate action plan. Data was collected and a control chart has been drawn again, which has shown that all samples were in-control, so quality improvement has been occurred achieved.

MAC Carpet Company was established in 1980 with a capital of 1 million dollars. At present time MAC is considered the world number 1 producer and the leader in carpet industry. MAC Carpet Company faced a big problem with one of the most important customers because of lacking the product quality which directly led to increase the gap with the best competitor and as a result of this, MAC company's purchase orders decreased. The company instantly took the appropriate action and used the suitable methodology to eliminate the unsatisfied cases. The quality team made strenuous efforts for solving the study problem. Therefore, the essential goal of this study was to decrease the gap ratio with the best competitor and increase the of customer purchase orders for all products. In this research, the percentage of the gap between the company performance and best practice performance has been reduced from 21 to 5 %. Therefore, the application of quality control tools in the carpet manufacturing industry has led to an increase in the percentage of customer purchase orders for all products by 27 %. The study will be highly beneficial for carpet industry.

Materials and methods

MAC Carpet Company uses CHROMOJET digital printing in production processes. The CHROMOJET family of digital printing systems is appropriate for all types of pile products in a range of 300 up to 1,500 g/sqm. The printing machine is usually equipped with 8 to 16 individual colors. Special machines may have up to 48 colors. For printing, these colors are pressurized (1 - 3 bar) and supplied directly to the jets, which are electromagnetically opened and closed up to 1,200 times per second. The jets inject the dye with surgical precision deep into the face of the pile, without any machine parts touching the fabric surface (**Figure 1**). Floor covering products like wall-to-wall carpets, rugs, carpet tiles, and mats are one of its most important applications [26].



Figure 1 CHROMOJET Machine.

Competitive benchmarking was implemented by identifying the product criteria required to measure the performance of competitors. The criteria for product evaluation were identified by the customer and were as follow performance, serviceability, durability, reliability, and conformance. The customer selected random batches from well-known products for all suppliers. The customer put into consideration that the selected samples were from the same type, size and production date in order to ensure that there was no variation during the evaluation. The samples were numbered and distinguished by different marks, in order to be confidential and to avoid any errors. The selected samples were evaluated according to these criteria and were tested by third-part auditor. Competitors received the evaluation reports from the customer and each supplier implemented a comparison with the best competitor. Quality team of MAC Company received the evaluation report and planned to evaluate the performance of the processes of all departments. Brainstorming approach was used for generating ideas to improve the incompatible cases. Affinity diagram was used to help join the large amounts of data by finding relationships between thoughts or ideas and to organize facts, opinions, and issues into taxonomies in order to help diagnose complex problems and identify common issues. Collected Data from affinity diagram compared to other companies (best practice) and determine an appropriate and realistic goal for improvement. Laying out the data in an easy-to-digest format (e.g. graphs or charts) can give a holistic picture of any gaps in your performance and how far you will need to go to meet your desired benchmark. Holota *et al.* [27] studied the choice of material used for manufacturing of clutch plates using graphical analysis. For analysis of used materials and specified parameters were chosen method of radar chart. Radar chart shows visually and quantitatively individually parameters used for the selection of material. The correct selection of the material has effect on the effectiveness and efficiency of manufacturing of clutch plate. Therefore, Spider plot diagram was used in this study to measure the gap with the best practice and to detect the points of weakness which need to be improved. The steps of spider plot diagram implementation were as follow:

Identifying the product dimensions which will be used in competitive benchmarking with the best practice according to **Table 1**.

Table 1 Symbols of dimensions.

Criteria/Dimensions	Performance	Serviceability	Durability	Reliability	Conformance
Symbols	A	B	C	D	E

Evaluating the dimensions by third part laboratory and sending the results to MAC Company according to **Table 2**.

Table 2 Supplier evaluation report.

Criteria/Dimensions	Performance	Serviceability	Durability	Reliability	Conformance
MAC Company	-	-	-	-	-
Best Practice	-	-	-	-	-

Drawing the spider plot diagram

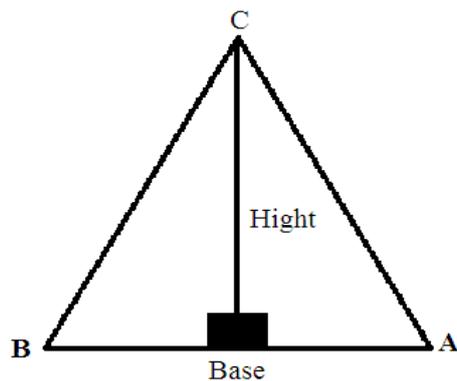


Figure 2 Area of a triangle.

According to **Figure 2**, area of a triangle = $\frac{1}{2}$ (Base * Height), and as:

- Sin 0 = 0,
- Sin30 = 0.5,
- Sin45 = $\frac{1}{\sqrt{2}}$,
- Sin60 = $\frac{\sqrt{3}}{2}$, and
- Sin90 = 1

So, Area of a triangle = $\frac{1}{2}$ AB* h

- Sin A = h/ AC
- H = Sin A * AC
- Area = $\frac{1}{2}$ AB* Sin A * AC
- = $\frac{1}{2}$ Sin A * AB* AC

According to **Table 3**, the value of angle “O”

Table 3 Value of angle according to dimensions number.

No .of Dimensions/Determinants	Value of angle O
3 Dimensions/Determinants	$\frac{360}{3} = 120^\circ$
4 Dimensions/Determinants	$\frac{360}{4} = 90^\circ$
5 Dimensions/Determinants	$\frac{360}{5} = 72^\circ$
6 Dimensions/Determinants	$\frac{360}{6} = 60^\circ$
7 Dimensions/Determinants	$\frac{360}{7} = 51.25^\circ$
8 Dimensions/Determinants	$\frac{360}{8} = 45^\circ$
9 Dimensions/Determinants	$\frac{360}{9} = 40^\circ$
10 Dimensions/Determinants	$\frac{360}{10} = 36^\circ$

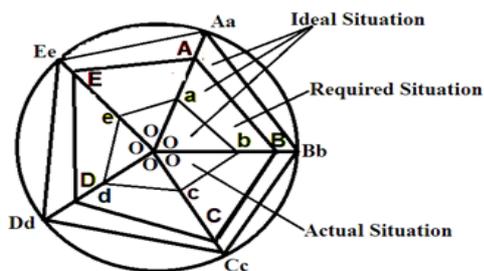


Figure 3 Spider plot diagram.

Area corresponding to the performance of the best practice =

$$\Delta_{O A B} + \Delta_{O B C} + \Delta_{O C D} + \Delta_{O D E} + \Delta_{O E A} = 0.5 \times \sin 72 (A \times B + B \times C + C \times D + D \times E + E \times A) = \text{Result 1}$$

Area corresponding to the performance of the Organization =

$$\Delta_{O a b} + \Delta_{O b c} + \Delta_{O c d} + \Delta_{O d e} + \Delta_{O e a} = 0.5 \times \sin 72 (a \times b + b \times c + c \times d + d \times e + e \times a) = \text{Result 2}$$

Area corresponding to the maximum performance =

$$\Delta_{O A a B b} + \Delta_{O B b C c} + \Delta_{O C c D d} + \Delta_{O D d E e} + \Delta_{O E e A a} = 0.5 \times \sin 72 (A \times a \times B \times b + B \times b \times C \times c + C \times c \times D \times d + D \times d \times E \times e + E \times e \times A \times a) = \text{Result 3}$$

Area corresponding to the performance of the actual situation of the organization in the Pareto chart

- Total Area 360 Degree
- Result 3 360
- Result 2 X_1
- $X_1 = (360 \times \text{Result 2}) / \text{Result 3}$

Area corresponding to the performance of the best practice compared to the organization in the Pareto chart

- Total Area 360 Degree
- Result 3 360
- Result 1 X_2
- $X_2 = (360 \times \text{Result 1}) / \text{Result 3}$

MAC Carpet Company depends on one of the most important customer in European markets. It produces more than 1 million carpets for this customer monthly. The customer evaluates all suppliers monthly and distributes purchase orders based on this evaluation. MAC Company’s competitors developed their processes and performances to obtain a ratio from these huge productivities and to compete MAC Company. MAC Company noticed shortage in its required quantities compared to those required from competitor C. **Table 4** represents the customer purchase report which contains the total required quantities from products A, B, C, and D and includes the percentage identified for each supplier from those products according to the supplier evaluation report. Therefore, the main reason for this study was to perform competitive benchmarking with the best practice (competitor C).

Table 4 The percentage of required carpet pieces from each supplier.

Products	Total quantities required from each product	%of pieces				
		MAC Company	Competitor A	Competitor B	Competitor C	Competitor D
A	2,875,000	24 %	13 %	7 %	38 %	18 %
B	10,965,000	20 %	10 %	15 %	45 %	10 %
C	57,456,550	30 %	20 %	5 %	40 %	5 %
D	200,400,000	30 %	7 %	0 %	55 %	8 %

Figures 4 - 7 show Pareto charts for the required pieces percentage from product “A”, “B”, “C” and “D” for each supplier. As shown in the Pareto charts, competitor C obtained the highest required pieces percentage from product “A”, “B”, “C” and “D” compared to those required from others suppliers.

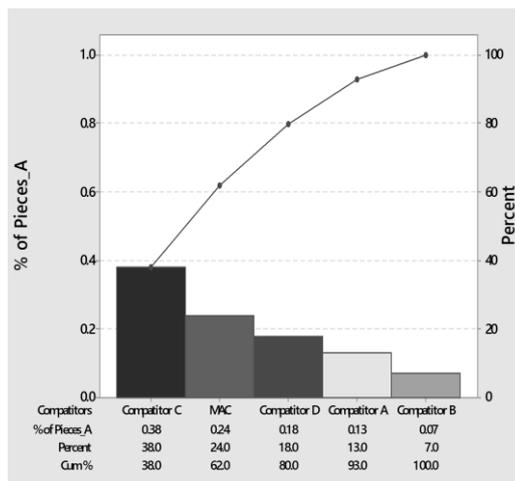


Figure 4 The percentage of required carpet pieces from product A.

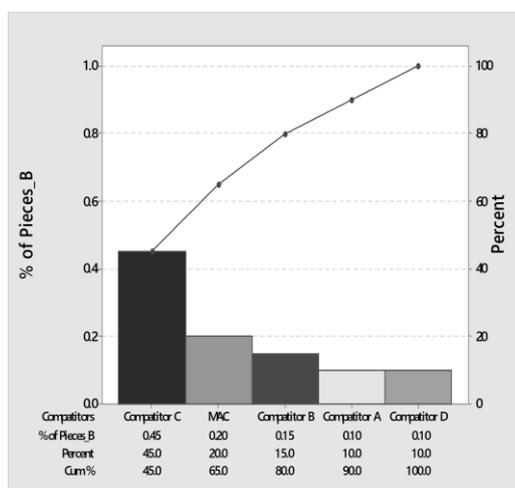


Figure 5 The percentage of required carpet pieces from product B.

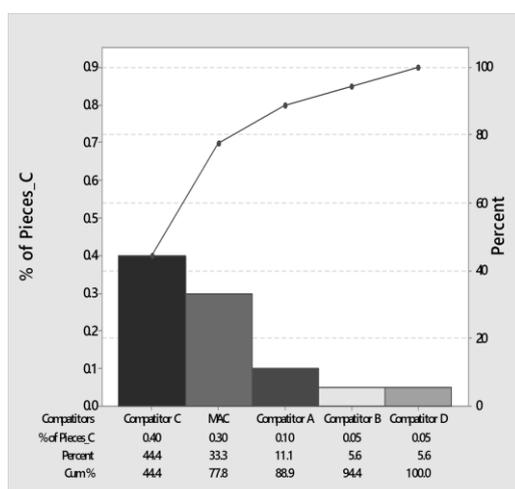


Figure 6 The percentage of required carpet pieces from product C.

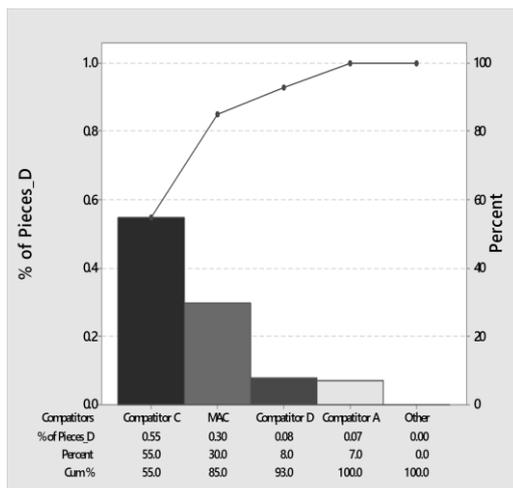


Figure 7 The percentage of required carpet pieces from product D.

As shown in **Figures 4 - 7**, competitor C obtained the highest percentage of required pieces for product A, B, C, and D. MAC Company requested from the customer to do a benchmarking with competitor C to detect the weakness points which were the main reason for increasing the gap and decreasing the performance with competitor C. Therefore, the study focused on performing a benchmarking by using quality tools to indicate the incompatible cases or processes which led to the study problem.

Results and discussion

MAC Company depended on the customer feedback reports to perform a comparison with Competitor C. Through this comparison, the company achieved the main goals of this study which were, decreasing the gap with competitor C and increasing the number of purchase orders. **Table 4** showed customer assessment for the product criteria used for doing a comparison with competitor C. Spider plot diagram was used in this section to measure the gap with competitor C before and after the improvement. The data was analyzed before the improvement and the results were as shown in **Table 5**.

Data analysis before improvement

Table 5 Customer assessment before improvement.

Criteria/Dimensions	Performance	Serviceability	Durability	Reliability	Conformance
MAC Company	7	7	6	5	8
Best Practice	9	9	8	7	9
Competitor C					

Spider plot diagram before improvement

- As no. of dimensions = 5
- So Angle (O) = $360/5 = 72^\circ$
- So the spider plot will be as shown in **Figure 5**

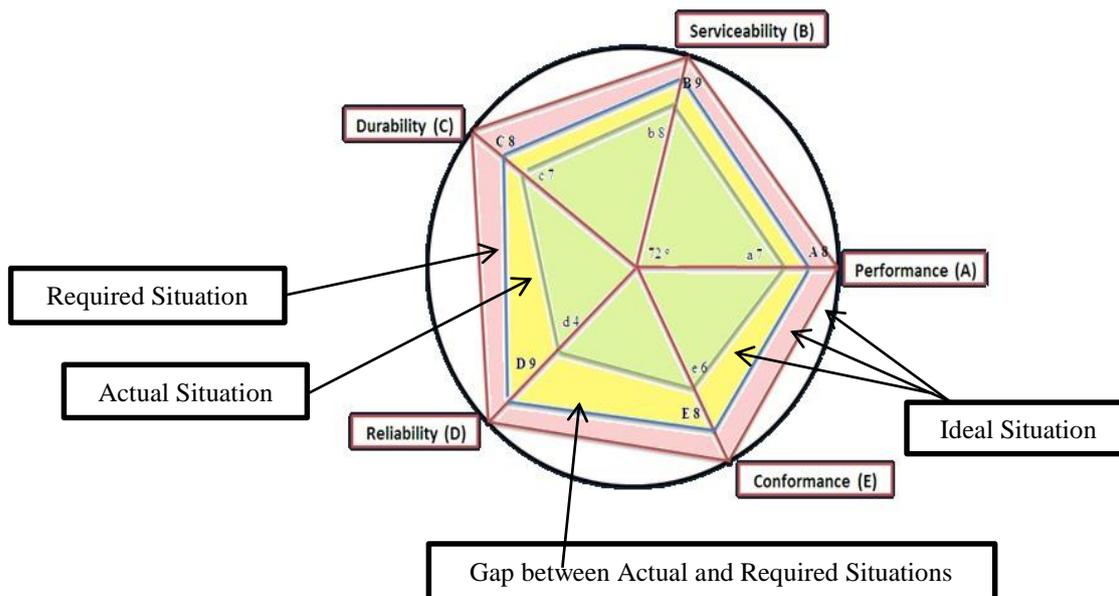


Figure 5 Spider plot diagram before improvement.

Figure 5 shows that, the highlighted in rose, yellow and lime areas represent the ideal situation and the highlighted in yellow and lime areas represent the area of best practice (competitor C). The highlighted in lime area is the size of MAC Company performance and the highlighted in yellow area represents the gap between MAC and Competitor C. The area of competitor C is bigger than the area of MAC. Therefore, the competitor C performance is better than the performance of MAC Company and so competitor C obtained purchase orders more than those of MAC Company.

Area corresponding to the performance of the organization =

$$\begin{aligned}
 & \triangle O E_6 A_7 + \triangle O D_4 E_6 + \triangle O C_7 D_4 + \triangle O B_8 C_7 + \triangle O A_7 B_8 \\
 & = 0.5 \times \sin 72^\circ (8 \times 7 + 8 \times 7 + 7 \times 4 + 4 \times 6 + 6 \times 7) = (0.5 \times \sin 72^\circ) (56 + 56 + 28 + 24 + 42) \\
 & = 0.5 \times \sin 72^\circ \times 206 = 97.95 = 98 \text{ cm}^2
 \end{aligned}$$

Area corresponding to the performance of the best practice =

$$\begin{aligned}
 & \triangle O E_8 A_8 + \triangle O D_9 E_8 + \triangle O C_8 D_9 + \triangle O B_9 C_8 + \triangle O A_8 B_9 \\
 & = 0.5 \times \sin 72^\circ (8 \times 9 + 9 \times 8 + 8 \times 9 + 9 \times 8 + 8 \times 8) = (0.5 \times \sin 72^\circ) (72 + 72 + 72 + 72 + 64) \\
 & = 0.5 \times \sin 72^\circ \times 352 = 167.38 = 167 \text{ cm}^2
 \end{aligned}$$

Area corresponding to the maximum performance =

$$\begin{aligned}
 & = 5 \times \triangle O A_{10} B_{10} = 5 \{ 0.5 \times \sin 72^\circ \times 10 \times 10 \} \\
 & = 5 \{ 0.5 \times \sin 72^\circ \times 100 \} = 237.76 = 237.8 \text{ cm}^2
 \end{aligned}$$

Area corresponding to the performance of the actual situation of the organization in the pie chart

- Total Area 360 Degree
- 237.8 360
- 98 X₁
- X₁ = 360 × 98 / (237.8)
- X₁ = 148.33

Area corresponding to the performance of the best practice compared to the organization in the pie chart

- Total Area 360 Degree
- 237.8 360
- 167 X₂
- X₂ = 360 × 167 / (237.8)
- X₂ = 252.8 = 253

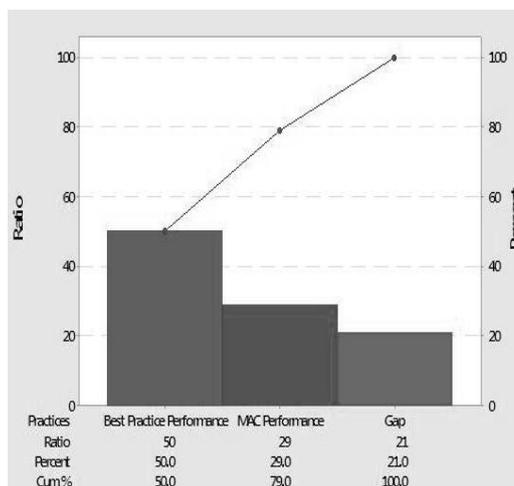


Figure 6 Ratio of gap between MAC Company performance and best practice before improvement.

After analyzing the above results and as shown in the **Figure 6**, the gap ratio was 21 % and this was due to the presence of many factors that may have an effect on increasing the gap ratio with the best practice (Competitor C). One of these factors which has a low score compared to the others factors were reliability. The quality team checked the main reasons for decreasing the reliability score of the company devices with the best practice score. The main target for using spider plot diagram in this research was to identify the reasons for decreasing the gap with the best practice. Spider plot diagram showed the gap size with the best practice accurately and the criteria that must be improved to decrease and delete the gap size with the competitor C. One of the most advanced quality tools (Affinity diagram) was used to gather large amounts of data (Opinion-Ideas-Issues) and organize them into groups based on their natural relationships as shown in **Table 6**.

Improvement stage

MAC Company started to analyze and investigate the principle causes of increasing the gap with competitor C and made a quick improvement. The quality team depended on implementing a lot of meetings with all concerned departments and focused on using brainstorming and affinity diagram quality tools to generate ideas and development methods. The quality team and concerned departments discussed the main reasons for this problem and specified ideas which were the reasons for increasing the gap with competitor C, and then the ideas were classified into related groups. The header cards were then created for each group, and the final step was to draw the finished affinity diagram after placing the header cards above each group of ideas as shown in **Table 6**.

Table 6 Affinity diagram for idea generation.

Step1 - Generate ideas		
Brainstorming was the first step to produce ideas, opinions or issues.		
Step 2 - Display the Ideas		
Misunderstanding of Customer Requirements		Wrong test method was used
	Results were wrongly registered	
Doing the test in abnormal environmental conditions		A problem in Quality Control Laboratory
	Contamination during the transportation period	
A problem during the transportation period		Testing method was not updated
	The tools used during the testing were not calibrated	
Products were exposed to a high temperature		Technicians were not qualified and well trained
	Selected samples for testing were not cover delivered batches	
The materials used in testing were expired		
Wrong warehousing method for product		Contamination during the warehousing period
	Products were exposed to a very low temperature	
Power failure during the test		
	Q.C MSs were not calibrated	
Products were exposed to a heavy rain		Customer requirements were not clarified
	Wrong warehousing method for material used	

Step 3 - Sort Ideas Into Related Groups		
Misunderstanding of Customer Requirements	Products were exposed to a high temperature	A problem during the transportation period
Wrong warehousing method for material used	Products were exposed to a heavy rain	Contamination during the transportation period
Used test method was not updated	Products were exposed to a very low temperature	
The tools used during the testing was not calibrated	Contamination during the warehousing period	
Customer requirements were not clarified	Wrong warehousing method for product	
The materials used in testing were expired		
Doing the test in abnormal environmental conditions		
Power failure during the test		
Selected samples for testing were not cover delivered batches		
Results were wrongly registered		
Wrong test method was used		
Technicians were not qualified and well trained		
Q.C MSs were not calibrated		

Step 4 - Create Header Cards		
Quality Control Laboratory issues	Warehousing issues	Transportation issues

Step 5 - Draw the Finished Affinity Diagram (place a header card above each group of ideas)		
Quality Control Laboratory issues	Warehousing issues	Transportation issues
Misunderstanding of Customer Requirements	Products were exposed to a high temperature	A problem during the transportation period
Wrong warehousing method for material used	Products were exposed to a heavy rain	Contamination during the transportation period
Used test method was not updated	Products were exposed to a very low temperature	
The tools used during the testing was not calibrated	Contamination during the warehousing period	
Customer requirements were not clarified	Wrong warehousing method for product	
The materials used in testing were expired		
Doing the test in abnormal environmental conditions		
Power failure during the test		
Selected samples for testing were not cover delivered batches		
Results were wrongly registered		
Wrong test method was used		
Technicians were not qualified and well trained		
Q.C MSs were not calibrated		

Affinity diagram observations showed that, three main issues were suggested as the reasons for this problem. After investigating the procedures of each issue, it became clear to the quality team that the procedures of the quality control related to MAC Company laboratory were the essential reason for this problem. The quality team focused more on checking all processes related to testing, random sampling

and checking the reliability of gages used in measuring processes. Checking the reliability of the gages showed that there were some gages giving unreliable measurements and need improvement. The incompatible cases were discovered through checking the reliability of gages. Quality team exerted double effort to delete the nonconformity cases to improve the reliability of the gage.

Data analysis after improvement

After doing the improvement stage, the customer performed the inspection and testing on the random samples which were selected from the new production. The samples were also numbered and distinguished by different marks, in order to be confidential and to avoid any errors. The results were sent to all suppliers (MAC Company and MAC Company’s competitors). **Table 7** showed the customer assessment and feedback after improvement stage. The quality team drew the spider plot diagram to study the gap size after improvement stage as shown in **Figure 7**.

Table 7 Customer assessment after improvement.

Criteria/Dimensions	Performance	Serviceability	Durability	Reliability	Conformance
MAC Company	8	8	8	8	8
Best Practice Competitor C	8	9	8	9	8

Spider plot diagram after improvement

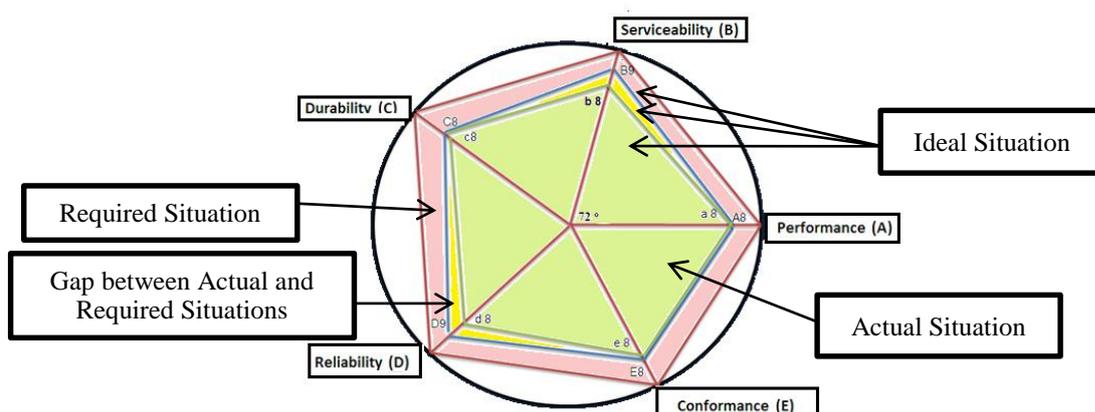


Figure 7 Spider plot diagram after improvement.

Area corresponding to the performance of the organization =

$$\Delta O A8 B8 + \Delta O B8 C8 + \Delta O C8 D8 + \Delta O D8 E8 + \Delta O E8 A8$$

$$= 0.5 \times \text{Sin}72 (8 \times 8 + 8 \times 8 + 8 \times 8 + 8 \times 8 + 8 \times 8) = 0.5 \times \text{Sin}72 (64 + 64 + 64 + 64 + 64)$$

$$= 0.5 \times \text{Sin}72 \times 320 = 152.16 = 152 \text{ cm}^2$$

Area corresponding to the performance of the best practice =

$$\Delta O A8 B9 + \Delta O B9 C8 + \Delta O C8 D9 + \Delta O D9 E8 + \Delta O E8 A8$$

$$= 0.5 \times \text{Sin}72 (8 \times 9 + 9 \times 8 + 8 \times 9 + 9 \times 8 + 8 \times 8) = 0.5 \times \text{Sin}72 (72 + 72 + 72 + 72 + 64)$$

$$= 0.5 \times \text{Sin}72 \times 352 = 167.38 = 167 \text{ cm}^2$$

Area corresponding to the maximum performance =

$$= 5 \times \Delta O A10 B10 = 5 \{ 0.5 \times \text{Sin} 72 \times (10 \times 10) \}$$

$$= 5 \{ 0.5 \times \text{Sin} 72 \times 100 \} = 237.76 = 237.8 \text{ cm}^2$$

Area corresponding to the performance of the actual situation of the organization in the pie chart

- Total Area 360 Degree
- 237.8 ————— 360
- 152 ————— X₁
- X₁ = (360×152) / 237.8
- X₁ = 230

Area corresponding to the performance of the best practice compared to the organization in the pie chart

- Total Area 360 Degree
- 237.8 ————— 360
- 167 ————— X₂
- X₂ = (360×167) / 237.8
- X₂ = 252

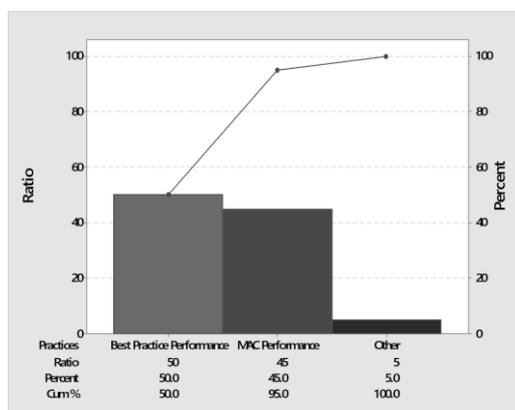


Figure 8 Ratio of gap between company performance and best practice after improvement.

MAC performance was affected by unreliable results of measurement systems and this led to increasing the gap with competitor C before improvement. As shown in **Figure 7**, the highlighted in light green area which represents the performance of MAC Company became almost equal to the area of the competitor C performance. Additionally, the size of highlighted in yellow area which represents the gap with competitor C decreased. Therefore, this benchmarking with the best practice helped MAC Company to improve its performance and increased the number of purchase orders. After analyzing the above results and as shown in the **Figure 8**, the gap ratio decreased to 5 % after the improvement and this was due to deleting non-conformity cases in quality control laboratory. **Table 8** showed a brief comparison between the performance of MAC Company before and after the improvement. The purchase orders of product A increased from 24 to 31 %, product B increased from 20 to 30 %, product C increased from 30 to 34 % and product D increased from 30 to 42 %.

Table 8 Comparison between the performance of MAC Company before and after the improvement.

Items	Data analysis before improvement	Data analysis after improvement
Gap ratio with the best practice	21 %	5 %
Percentage of customer purchase orders of product A	24 %	31 %
Percentage of customer purchase orders of product B	20 %	32 %
Percentage of customer purchase orders of product C	30 %	34 %
Percentage of customer purchase orders of product D	30 %	42 %

Conclusions

The essential goal of the study was to improve the quality of the product shipped to the customer. Quality tools were used in this paper to illustrate the steps of methodology in a simple presentation and helped the quality team to define and analyze the root causes of the problem. Spider plot diagram indicated and analyzed the gap ratio with the competitors in a simple manner. In addition to, the gap ratio became 5 % after it was 21 % before the improvement stage and the percentage of customer purchase orders for all products increased by 27 %. Process improvement measures were suggested and successively applied in operation. Therefore, meaningful benefits were gained in declining the defects of shipped products, as well as the costs of poor quality were saved. Quality tools like cause and effect diagram, histogram, Pareto diagram and check sheet were used in study [9] to find out the causes of the problems related quality. The major causes of rejection, i.e. seal ring pore, latex coating damage and mating ring chip were controlled by appropriate action and defects were reduced from 9.6 to 7.9 %.

Based on the study results, it is recommended to use quality tools to conduct further studies on other industry sectors such as clothes and plastic production to improve the performance. Moreover, quality tools can assist organizations to improve their processes and thus contribute to their effort to accomplish the process and business excellence. In addition to the above, quality tools can be utilized as a guiding reference for section heads, department managers and chemists to implement specific improvement studies in industrial organizations.

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