Application of Taguchi Tool in Egyptian Manufacturing Companies: A Case Study

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Sarah Elsayed Elshazly
Lecturer, department of business administration, faculty of commerce and business administration, Helwan university

Salaheldin Ismail Salaheldin
Correspondence: Salaheldin Ismail, Prof of Operations Management, Department of Business Admin. College of Commerce & Business Administration, Helwan University

Mai Shawky Gamaleldin
Lecturer, department of business administration, faculty of commerce and business administration, Helwan university

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Mai Shawky Gamaleldin
Lecturer, department of business administration, faculty of commerce and business administration, Helwan university

ABSTRACT

Regardless of the crucial role of quality in business competitiveness and globalization, quality is typically assessed from the customer perspective, with limited emphasis on quality during production and its impact on achieving operational excellence.

This research addresses the existing knowledge gap by examining Taguchi Tool which is known as: Quality loss function (QLF) in manufacturing companies, with the objective of attaining operational excellence and optimizing production efficiency levels.

The study investigated QLF within the Refrigerators Production Division at a leading Electronic Appliances Company in Egypt. This sector holds considerable significance for the Egyptian economy due to its capacity to absorb employment and its anticipated role in import substitution and export contribution.

The Taguchi Function was employed to validate the implementation of the QLF, focusing on elucidating and predicting the strength and direction of the correlation between quality and its parameters. This approach facilitates the quantification of design quality and the identification of its tolerances.

A random sample was utilized over a fifteen-days production period, with data reported and analyzed using appropriate charts that illustrate the distribution of actual values relative to target values. Additionally, calculations were made for the average, range, and standard deviation of the sample under consideration.

The findings indicate a significant positive relationship between deviations from the target quality level and the cost of quality loss. These results possess both practical and academic relevance.

Introduction

Most of scholars and practitioners in the field of Operations Management agreed that the concept of quality has evolved over time, transitioning from a focus on total quality of products to a more comprehensive understanding of quality as it pertains to the organization as a whole. Quality is influenced by pre-production, production, and post-production processes, necessitating the control and enhancement of all activities at both managerial and technical levels (Antunes, M. G. et al.,2018).

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Customers tend to prefer engaging with companies in whom they have full trust and confidence that their conditions, requirements, and motivations are consistently met. This trust is contingent upon the assurance that these companies are implementing effective quality improvement measures.

Consequently, the objective of this research is to investigate the implementation of a product quality loss function. The Refrigerators Production Division at a leading Electronic Appliances Company in Egypt has been selected as the site for this study to examine how the implementation of continuous improvement measures impacts overall product quality.

Research Problem

The focus of the current research is the Egyptian industrial environment, which is characterized by inadequate implementation of improvement techniques such as the quality loss function (Taguchi Function). This issue became evident during field visits to various industrial companies, particularly to the Refrigerators Production Division at a leading Electronic Appliances Company in Egypt. This study was conducted over a period of six months, from February 15, 2024, to August 14, 2024. During these visits, questions and data were extracted from the factory`s records with the assistance of the operations manager and the quality control manager. To better understand the nature and scope of the problem, it is important to note the following challenges faced by this factory:

a. The quality loss function is not considered in the production of refrigerators in accordance with established design standards.

b. The infrequency of customer complaints has led to a lack of attention to the quality loss function (The number and dates of complaints were recorded at the factory`s system).
The research problem is framed within this context. The current study aims to address several questions and provide meaningful answers at both theoretical and practical levels, specifically:

1. Whether the application of the quality loss function to refrigerators production is feasible, as well as its implications for the company's losses and its effects on customers and society.

2. If a comparison can be drawn between the quality loss function and various statistical approaches, thereby enabling the company to assess the impact of a single unit loss on the overall product.

3. Whether to implement empirical design research and conduct experimental product trials in order to achieve an optimal total product.

Research objectives

This research aims to analyze and evaluate the implementation of the quality loss function at this leading Electronic Appliances Company in Egypt, with a particular focus on the Refrigerators Production Division. The study seeks to achieve the following objectives:

(1) Identifying a theoretical framework and appropriate statistical methodologies suitable for application within the industrial sector in Egypt.

(2) Presenting both the theoretical and practical framework of the Taguchi quality loss function to enhance product design.

(3) Utilizing the Taguchi loss function to identify and rectify deviations that may arise during monitoring and evaluation processes.

(4) Proposing a series of managerial implications that summarize the appropriate actions for decision-makers to undertake in order to enhance performance in the production division under examination.

Research Sample and Duration

The Refrigerators Production Division at this leading Electronic Appliances Company in Egypt plays a significant role in contributing to the national economy through its diverse range of products. The selection of Refrigerators segment is based on the following reasons:

- The revenue in the Refrigerators market in Egypt amounts to US$0.96bn in 2024.
- This market is projected to experience an annual growth rate of 10.34% (CAGR 2024-2029).
- When compared globally, in China generates the highest revenue in this segment, reaching US$32,170m in 2024.
- In terms of per household revenue, in Egypt generates US$41.24 units in 2024.
- Looking ahead, the volume in the Refrigerators market is expected to reach 2.2m pieces by 2029 in Egypt.
- Furthermore, the segment is anticipated to exhibit a volume growth of 6.6% in 2025.
- The average volume per household in the Refrigerators market is projected to be 0.07pieces in 2024 in Egypt.
- The demand for energy-efficient refrigerators in Egypt has been steadily increasing as consumers prioritize sustainability and cost savings (https://www.statista.com/outlook/cmo/household-appliances/major-appliances/refrigerators/egypt).

This research was focused on the motor production line within the Refrigerators Production Division. The study was conducted over a period of six months, from February 15, 2024, to August 14, 2024.

Literature Review

The Quality Loss Function, commonly referred to as the Taguchi Tool or Taguchi Method, represents a highly effective approach for resolving organizational challenges (Sirega,K. et al., 2020). This methodology aids organizations in enhancing product quality by minimizing process variations. It ensures reliability in products and processes during the production phase, enabling manufacturers to produce higher quality goods at lower costs and in reduced timeframes (Wu et al., 2022).

Consequently, the Taguchi Method is employed to achieve superior quality and product enhancement through cost-effective experimentation in the early stages of production, while also considering societal losses, such as customer dissatisfaction. It utilizes a Quality Loss Function to quantify the quality loss resulting from variations in product functionality. The Quality Loss Function is a mathematical model that assesses quality loss in monetary terms, arising from deviations from target specifications (De Almeida et al., 2020). It serves as a graphical representation of loss, illustrating a phenomenon that impacts the value of a company's products (Sun et al., 2020). This approach underscores the significance of integrating quality and dependability into the design phase prior to manufacturing (De Almeida et al., 2020). Thus, the Quality Loss Function is a statistical method developed by Taguchi aimed at enhancing product quality.

The function is typically represented as:

L(y)=k(y−T)2L(y) = k(y - T)^2L(y)=k(y−T)2

where:

L(y)L(y)L(y) is the quality loss,

yyy is the actual value of the quality characteristic,

TTT is the target value,

kkk is a constant that reflects the cost associated with the deviation from the target.

The functionality of the quality loss function indicates that losses increase exponentially as the quality characteristic deviates from the target, thereby encouraging precise and consistent manufacturing processes.

The significance and advantages of the quality loss function are reflected in its capacity to reduce deviations from target values, which aims to enhance quality and minimize costs within a shorter timeframe, while simultaneously improving the quality of additive manufacturing by eliminating variations. It aspires to develop processes and products that are free from external influences and employs experimental design during the development phase (De Almeida et al., 2020). This methodology is compatible with human-centered quality evaluation techniques and facilitates the identification of common objectives (Zanjirani et al., 2019). The quality loss function holds substantial significance as it quantifies the cost associated with failing to meet a specified quality level (Sun et al., 2020). By emphasizing the eradication of variability, Taguchi has demonstrated that this strategy can aid designers in creating products that perform effectively even under varying conditions. The application of the quality loss function can result in enhanced quality and reduced manufacturing costs. Furthermore, the Taguchi loss function has partly contributed to the increasing focus on continuous improvement across the business landscape.

The objectives of the quality loss function encompass both desirable and undesirable deviations between target values and actual results, aiming to enhance quality and decrease costs within a reduced timeframe. Consequently, the primary objectives are (Uluskan, M., 2020; Wu, 2020):

-Minimizing variability to ensure consistent product quality and performance. This objective is crucial in industries where precision and reliability are paramount.

-Reducing costs associated with poor quality, including rework, scrap, and warranty claims.

-Enhancing customer satisfaction by consistently meeting or exceeding expectations. This emphasis on quality fosters brand loyalty and contributes to the long-term success of the business.

Moreover, the quality loss function strives to enhance the quality of additive manufacturing by removing variations. It seeks to establish processes and products that are devoid of external influences and utilizes experimental design throughout the development phase. The method aligns with human-centered quality evaluation approaches and aids in identifying shared objectives. The Taguchi technique is notable for its time and cost efficiency, durability, and ease of explanation; however, it is limited to the optimal combination of factors and levels (Pan, Z.et al., 2020).

In a similar context, quality improvement has become a primary concern in this process. Many managers continue to utilize decision-making models that evaluate projects based on measures of short-term profitability. It is essential to assess both the costs and financial benefits of these quality improvement initiatives, as they can serve as critical inputs for decision-making models (Margavio, 1994).

Manufacturers' concerns regarding quality can be categorized into two components: quality of design and quality of conformance.

The quality of design pertains to the translation of customer expectations regarding product usage into functional specifications and design specifications. Functional specifications define the capabilities of the product, delineating what is anticipated to be achieved. In contrast, design specifications convert these functional specifications into the physical characteristics of the proposed product.

Quality of conformance becomes a critical consideration during the manufacturing process. In this context, design specifications are transformed into manufacturing specifications and ultimately culminate in a final product. Quality of conformance is concerned with the extent to which the final product adheres to its design specifications and, in turn, fulfills customer satisfaction. It is in this evaluation of quality of conformance that managerial efforts are primarily concentrated. Additionally, the costs associated with quality of conformance are referred to by accountants as quality costs. To enhance the control of these quality costs, managers have categorized them into four distinct types (Devadasan, 1995): prevention costs, appraisal costs, internal failure costs, and external failure costs.

Prevention costs encompass all expenditures aimed at preventing errors across all functions within an organization. These costs include quality planning costs, new product review costs, process control costs, quality audit costs, supplier quality evaluation costs, and training costs.

Appraisal costs refer to the expenses incurred to identify inferior quality products prior to their shipment to customers. Typically, appraisal costs include expenses related to incoming inspection and testing, in-process inspection and testing, final inspection and testing, calibration of testing equipment, and the inspection and testing of materials and services.

Internal failure costs arise from defects identified before the product is shipped to customers. Such costs encompass expenses related to scrap, loss, rework, failure analysis, 100 percent sorting inspection, re-inspection and re-testing, and downgrading.

External failure costs, on the other hand, are associated with defects discovered after the product has been shipped to customers. These may comprise warranty charges, complaint adjustments, returned materials, and allowances (Banihashemi,A. 2021).

The following figure (1) illustrates the relationships between various quality costs and offers a model for understanding quality costs.

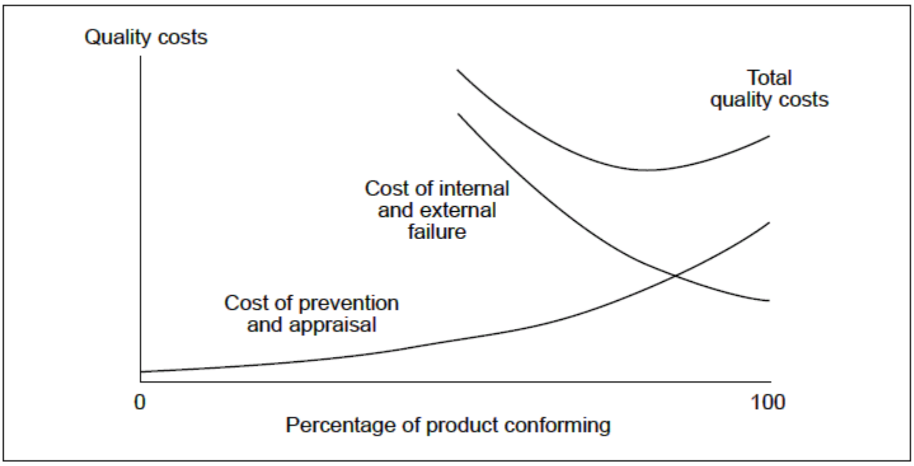

Figure (1):Kim, S., & Nakhai, B. (2008). The dynamics of quality costs in continuous improvement. International Journal of Quality & Reliability Management, 25(8), 842–859

1. An inverse relationship exists between appraisal costs plus prevention costs and failure costs.

2. A direct relationship is observed between appraisal costs plus prevention costs and quality.

3. An inverse relationship is established between failure costs and quality (Chen,C.H. & Chou, C.Y. 2022).

Based on these relationships, an organization's capacity to make informed decisions regarding quality enhancement, quality cost reduction, and productivity improvement will be significantly augmented.

The objective of quality cost management is to achieve the minimum point on the total quality cost curve (the aggregate of the appraisal/prevention curve and the internal/external failure cost curve). This acknowledges the trade-off between appraisal and prevention costs, as well as internal and external failure costs. As appraisal and prevention costs increase, both internal and external failure costs typically decrease. However, a threshold is reached beyond which additional expenditures on appraisal and prevention do not sufficiently diminish failure costs to reduce total quality costs.

In practice, identifying this point of lowest total cost presents considerable challenges. These challenges arise from various factors, the most notable of which is the difficulty in measuring the external failure costs associated with lost sales or diminished customer goodwill (Lofthouse, T. 1999).

The cost associated with lost customer goodwill does not conform to traditional accounting metrics. Accountants typically quantify costs based on expenditures incurred by the organization. In contrast, this external failure cost reflects potential revenue that the organization did not realize due to lost sales. Such costs are often absent from conventional accounting measures. Nonetheless, the primary emphasis of quality improvements is to mitigate this opportunity cost, commonly referred to as the cost of poor quality or quality losses (Margavio, 1994).

This measurement dilemma can be addressed through the application of the Taguchi loss function, which serves to estimate external failure costs, including the primary component of lost sales. The following figure (2) explains Taguchi loss function.

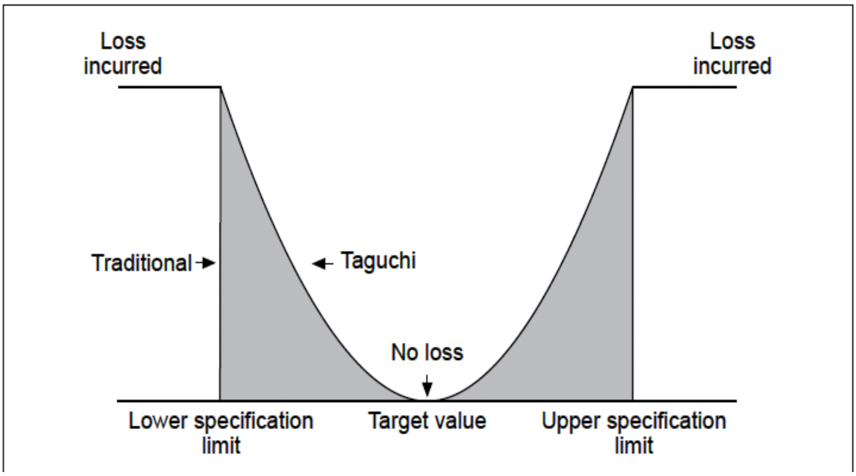

Figure (2): Krajewski L. J., Ritzman L. P. , Malhotra M. K., (2013) ' Operations Management : Processes And Supply Chains' Global Edition , (10th Edi.) , Pearson Education Limited , P.201

The Taguchi loss function, when applied to the manufacturing sector, quantifies the societal detriment arising from a product that fails to perform as anticipated.

The Taguchi function provides managers with a methodology for quantifying these often intangible costs, enabling a more rigorous evaluation of quality improvement initiatives and an assessment of the project's effect on the overall quality cost management.

While the cost associated with customer rejection is challenging to ascertain, it can be estimated by analyzing the components of external failure costs, which include: the costs of addressing customer complaints, the investigation of warranty claims, warranty repairs and replacements, product recalls, product liability, and returns and allowances. Many of these expenditures are readily available in accounting records. Further insights into external failure quality costs can be obtained through customer surveys, market share analysis, and product demand statistics (Mahla et al. 2022).

The principles underlying the Taguchi approach can be encapsulated in two key statements:

(1) Quality should be evaluated based on the deviation from a specified target value rather than mere conformance to predetermined tolerance limits.

(2) Quality cannot merely be ensured through inspection and rework; it must be inherently integrated through the appropriate design of both the process and the product.

Taguchi posited that variation in product specifications is the principal cause of product rejection. The remedy for this quality loss is the reduction of variation, with the goal of achieving zero variation and zero defects (Margavio, 1994).

The Taguchi methodology for minimizing product variation encompasses a two-step process:

(1) Fabricate the product optimally most of the time (reducing deviation from the target).

(2) Ensure all products are produced as identically as possible (minimizing variation among products).

The Taguchi quality loss function establishes a financial metric for user dissatisfaction correlated with a product's performance as it deviates from the target value. Consequently, both average performance and variation emerge as critical quality measures. Opting for a product design or manufacturing process that is resilient to uncontrolled sources of variation significantly enhances quality (Mahla et al. 2022). The traditional methodology for calculating the cost of quality is predicated on the number of parts that are rejected and subsequently reworked. This approach to quality evaluation is limited in its capacity to differentiate between two samples that may both fall within specification limits but exhibit divergent distributions of targeted properties. Typically, a product is deemed functionally acceptable if the values of specified parameters reside within the range established by the Upper Acceptance Limit (UAL) and Lower Acceptance Limit (LAL). Under these circumstances, societal loss is not assumed, and the product progresses to subsequent processes. However, if the product falls outside these established limits, it may either be discarded or subjected to salvage operations. Consequently, all efforts are directed toward controlling the manufacturing process to ensure the product remains within these boundaries (Pan, Z.et al., 2020).

However, according to Taguchi, there is no clear-cut delineation in real-world scenarios. Performance begins to gradually deteriorate as design parameters deviate from their optimal values. Consequently, he proposed that the loss function be assessed by the deviation from the ideal value (Peace, G. 1993).

More significantly, the loss function assumes the following basic quadratic form:

$L(y) = k\,(x - m)^2$

where L represents the loss in monetary terms, m denotes the point at which the characteristic should be set, x indicates the actual setting of the characteristic, and k is a constant that depends on the magnitude of the characteristic and the monetary unit involved.

K can also be expressed as O/δ^2

where O is the monetary loss incurred due to deviations from the specification range of quality, and δ represents the tolerance specification from the target quality parameter. From the quadratic loss function, it is evident that total loss increases parabolically as deviation from the target value occurs. This loss symbolizes a continuous function, signifying that merely producing a product within specification limits is insufficient to assert that the product is of good quality. Good quality is now redefined as maintaining the product characteristics on target with minimal variation.

The Taguchi approach focuses on developing products that consistently meet the target value. Therefore, the most critical aspect of Taguchi's quality control philosophy is the minimization of variation around this target value.

The Figure/formula enables a design team to conduct cost-benefit analyses of alternative designs, each yielding different average losses and associated costs (Lofthouse, 1999).

A significant point of emphasis is that quality is intrinsically linked to monetary loss, rather than to other factors or conditions. Although actual losses may manifest as a loss of product functionality or may involve other detriments such as pollution, time wastage, noise, etc., the overarching effect ultimately results in a financial loss.

There are several shortcomings associated with the traditional approach to quality, which is reactive in nature:

1. Improvement activities are prioritized based on easily identifiable metrics such as failures and rework, as well as negative feedback from customers following the occurrence of problems.

2. Customer requirements, needs, and expectations are not utilized proactively to guide quality improvement, and increased customer satisfaction and loyalty are not incorporated into performance measures.

3. Performance measurement and high-level management decisions typically rely on traditional accounting information, which is inadequate for monitoring and directing quality improvements.

Indirect costs associated with customer dissatisfaction and loss-of-reputation are frequently omitted from financial assessments. Customer dissatisfaction costs arise when a customer chooses not to repurchase a product due to dissatisfaction with its

overall performance. Conversely, loss-of-reputation costs occur when a customer opts not to purchase any products from the manufacturer based on a negative experience with a single product. The latter scenario reflects the customer's perception of the company as a whole rather than an evaluation of the individual product (Perona, 1998).
In more detail, the quality loss method, when compared with traditional approaches (Chandra, 2001), exhibits the following characteristics:

1. It demonstrates a greater market orientation in the evaluation of nonconformance, enabling a more systematic consideration of the impacts on customer satisfaction.
2. It allows for a differential assessment of the income effects associated with specific investments in the quality system, thereby acknowledging the opportunity costs linked to potential future profits that may be lost.

Key features of Taguchi methods include (Omachonu, 2004):

1. The integration of quality considerations at the design stage, recognizing that even rigorous inspection procedures cannot fully rectify flaws stemming from inadequate design.
2. An increased emphasis on the quality of design rather than reliance on inspection.
3. A focus on “robust design,” which entails creating products that remain unaffected by disruptions during either production or service.
4. The application of statistical procedures exclusively during the design phase, at appropriate stages, thereby eliminating their use during the production phase.
5. A reliance on models informed by the philosophy of "loss to society" rather than solely on statistical techniques during production.

Top management has often been reluctant to provide sustained support for quality initiatives, as they struggle to discern their impact on financial reports. Moreover, demonstrating the effect of quality improvements on customer satisfaction and loyalty poses significant challenges.

Failure costs associated with customer dissatisfaction, frequently referred to as the hidden costs of quality due to their challenging nature in terms of measurement or estimation, can amount to a substantial 20 percent of the cost of sales.

Taguchi's quality loss function offers a framework for quantifying all dimensions of external failure costs, including hidden costs. Taguchi's model posits that:

". . . if management decides not to incur the voluntary expenses of reducing the variation, it involuntarily will incur several times that amount in the form of warranty costs, lost contribution because of customer ill will, and so forth" (Moen, 1998).

Research Methodology

The methodology adopted in this research identifies a case study and analyzes it by gathering data from a sample that has been manufactured under normal manufacturing conditions and then analyzing the data.

The detailed methodology is as follows:

Identify an output batch and choose a random sample of 150 parts or components for the analysis.

Draw a chart for the average (mean) of the 150 random samples using the following equations:

$R=(\sum R)/n$

$X = \sum x/n$

$UCL = X + A2 \times R$

$CL=X$

$LCL = X + A2 \times R$

Draw a chart for the range for the 150 random samples to identify the cases the fall outside the normal range (deviation) using the following equations:

$UCL = R \times D4$

CL=R

LCL = R x D3

Draw a histogram for the 150 random samples to identify the percentage of output falling outside the upper and lower specification limits after finding the ranges and frequencies for each operation.

Implement the Quality Loss Function for each 150 random samples. The following equations shall be used:

QLF without standard deviation: $L(y) = k (y-m)^2$.

Where m= Target Value,

Y= Actual Value,

K= Constant Factor,

$K = C/d^2$,

C = Loss associated with one output that occurs on the, specification limit assuming that the loss on the target value = 0 (Replacement or maintenance cost).

d^2 = Tolerance specification (distance) from the target value.

QLF with standard deviation: $L = K * ((y - m)^2 + \delta^2)$

Where m= Target Value,

Y= Average Value,

δ = Standard deviation for sample.

Draw the Quality Loss Function to explain the deviation of the average value from the target value.

Case Study

Applying the Quality Loss Function requires identification of the details of the manufacturing operations to produce motor of refrigerators (research sample) that require the following procedures during the analysis.

The Quality Control of the Refrigerators company shall Test the samples from each output batch by taking 10 units on a 15 days period.

Calculating the average and range for the sample for using it to draw the average and range charts to determine whether the operation is within tolerance limits or not.

Drawing a histogram to determine the occurrence of any output beyond the upper and lower specification limits.

Analyzing the data using Taguchi's Quality Loss Function and comparing it with average chart and range chart and identifying the differences.

In the case study for the motor refrigerator under consideration the following data were recorded for the number of the motors selected:

Day	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	Average	Range (R)
1	400	401	401	402	400	401	400	401	401	402	400.8	2
2	400	401	400	405	405	400	401	400	405	405	402.2	5
3	400	399	399	400	401	400	399	399	400	401	399.8	2
4	399	399	400	400	401	399	399	400	400	401	399.8	2
5	402	404	402	401	400	402	404	402	401	400	401.8	4
6	400	401	402	401	400	400	401	402	401	400	400.8	2
7	398	398	399	400	401	398	398	399	400	401	399.2	3
8	400	401	402	400	401	400	401	402	400	401	400.8	2
9	401	398	409	400	400	401	398	409	400	400	401.6	11
10	400	401	400	401	399	400	401	400	401	399	400.2	2
11	399	401	400	399	402	399	401	400	399	402	400.2	3
12	402	400	401	402	403	402	400	401	402	403	401.6	3
13	402	399	400	401	400	402	399	400	401	400	400.4	3
14	398	401	402	399	400	398	401	402	399	400	400	4
15	399	400	401	402	403	399	400	401	402	403	401	4
Total											6010.2	52

Table (1): Range and Average calculations.

Based on the above data, it can be calculated the upper and lower specification limits as follows:

$R = (\sum R)/n = 52/15 = 3.466$

$X = \sum x/n = 6010.2/15=400.68$

$UCL = X + A2 \times R = 400.68+(0.223\times3.466)= 401.452$

$CL=X = 400.68$

$LCL = X - A2 \times R = 400.68-(0.223\times3.466)= 399.907$

Based on the above the following Figure(3) can be plotted:

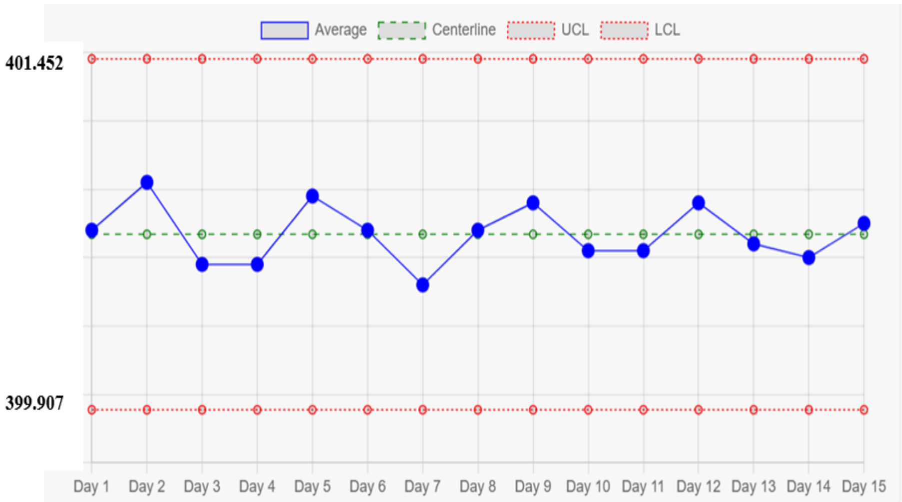

Figure (3) : the Average of the Number of Motors

The aforementioned chart suggests that the manufacturing process for the motor refrigerators is subjected to statistical control, as evidenced by the samples falling within the upper and lower specification limits and exhibiting a distribution around the target value.

The range Figure can be drawn based on the following equations:

$UCL = R \times D4 = 3.466 \times 2.282= 7.909$

$CL=R = 3.466$

$LCL = R \times D3 = 3.466x\ 0= 0$

Based on the above the Figure(4) for the range

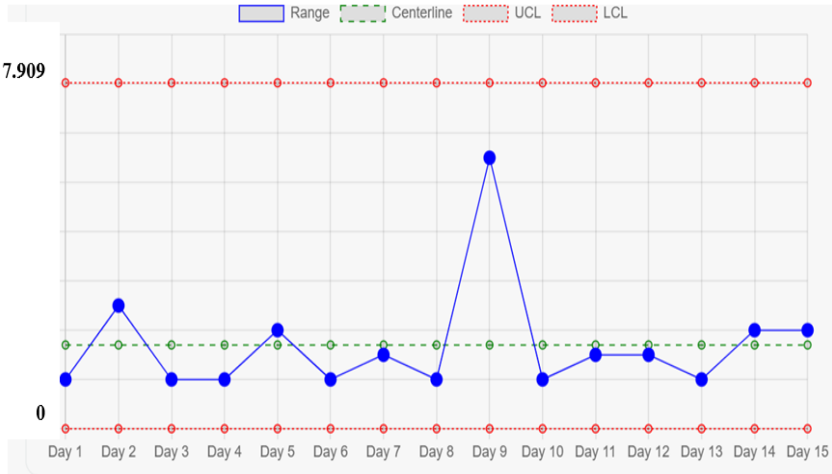

Figure (4): the Range of the Number of Motors

The above chart indicates that the deviation for the above operation is also accepted as it falls within the specification limits. The following table (2) shows the sample class limits and their frequencies are arranged in sequence of classes:

Class Limits	Class Center	Frequency
398-399	398.5	8
399-400	399.5	22
400-401	400.5	48
401-402	401.5	39
402-403	402.5	22
403-404	403.5	4
404-405	404.5	2
405-406	405.5	4
406-407	406.5	0
407-408	407.5	0
408-409	408.5	0
409-4010	409.5	1
Total		150

Table (2): Frequency calculations

The following histogram shows the frequency distribution for the sample.

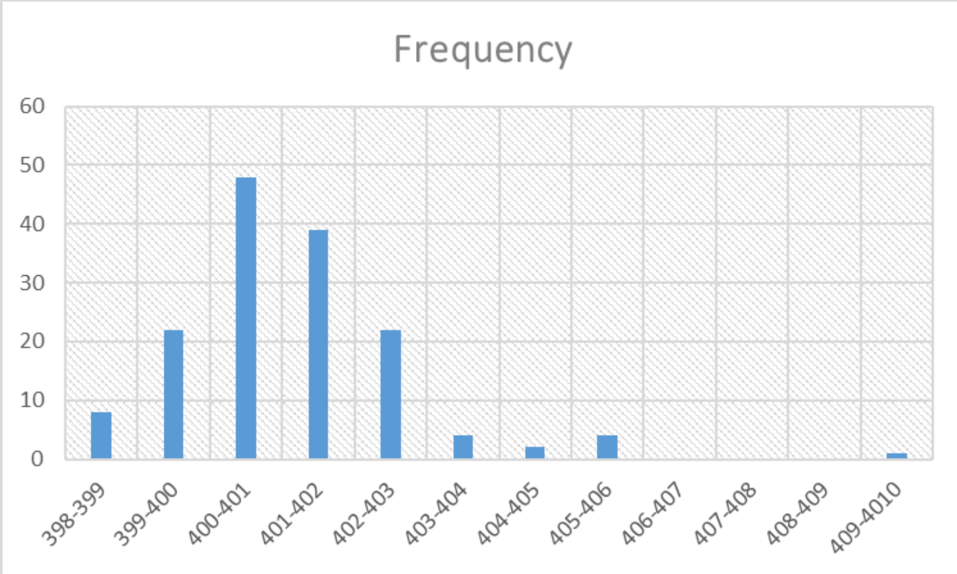

Figure (5): Frequency Distribution for the Average of the Number of Motors

Figures 3 and 4 above demonstrate that the samples cluster around the mean value, suggesting a statistically controlled operation. However, Figure 5 reveals a notable degree of deviation and a right-skewed distribution due to the occurrence of some samples falling beyond the upper cut limit.

In order to identify the quality loss to the society, it will be used the Quality Loss Function:

$L(y) = k\,(y\text{-}m)^2 = (2099 \text{ (in 100 EGP)} / (6)^2) * (400.68\text{-}400)^2$

m= Target Value=400,

Y= Actual Value=400.68

$K = C/d^2$

C = Replacement Cost = 2099 (in 100 EGP).

d^2 = Tolerance specification (distance) from the target value=6

L(y) = 20.9 (in 100 EGP) per unit.

From the above, the loss per unit is = 20.9 (Loss in 100 EGP), K=58.305

Standard deviation δ = 0.851

The effect of this deviation from the target value is = $L(y) = K * ((y - m)^2 + \delta^2)$.

$L(y) = 58.305\ ((0.68)^2 + (0.851)^2) = 69.185$ (in 100 EGP).

From the above, it is noticed that the amount of deviation from the target value has increased the loss by an amount = 69.185 -20.9 = 48.285 (Loss in 100 EGP). The previous results are depicted in the following Figure:

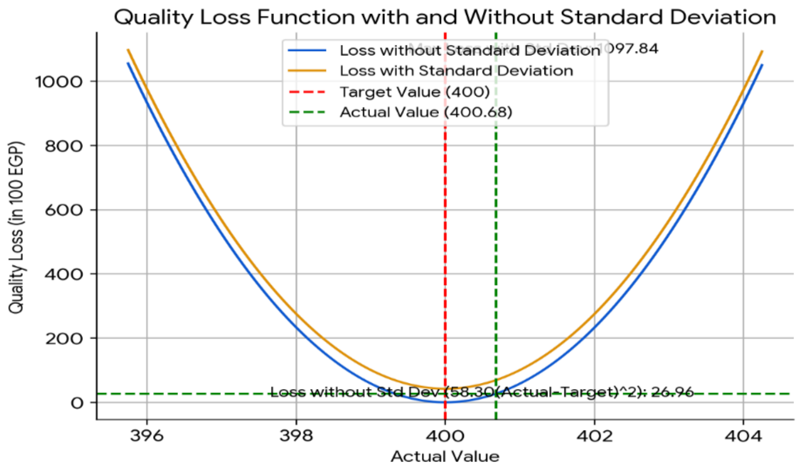

Figure (6): The amount of deviation from the target value.

Key points from the Figure:

Target Value: The vertical line at 400 represents the ideal value for the quality characteristic.

Actual Value: The point at 400.68 indicates the measured value of the quality characteristic, which deviates slightly from the target.

Loss Function: The parabolic curve represents the QLF, showing how the loss increases as the deviation from the target value increases.

Initial Loss: The point on the curve corresponding to the actual value (400.68) indicates the initial loss per unit, which is approximately 20.9 (in 100 EGP).

Increased Loss due to Variability: The point higher on the curve, representing the loss considering the standard deviation (0.851), shows the increased loss per unit, which is approximately 69.185 (in 100 EGP).

Interpretation:

Figure (6) visually demonstrates the concept of quality loss and the impact of variability. It highlights that even small deviations from the target value can lead to significant economic losses. Additionally, the variability in the process, as measured by the standard deviation, further amplifies the loss.

Main Findings

(1)The quality loss function focuses on optimizing product procedures to achieve high product quality and reduce design costs.

(2)The Taguchi function captures the customer sensitivity to deviations that hinder meeting their requirements.

(3)The Taguchi function facilitates economical acceptance by evaluating variations and determining the desired value.

(4)The Taguchi function takes into account all production costs, which have a long-term impact on the company's competitive ability.

(5)Each quality function should strive to minimize deviations from the target value.

(6)The Taguchi approach emphasizes product design improvement and identifies factors that can be easily controlled. This helps to minimize the product's response to deviations and maintain an average response within the target value.

Based on the above findings, the following action plan will be conducted.

Main Findings	Objective	Action steps
1-Quality Loss Function Optimization	-Concentrate on all product procedures to achieve high quality products and reduce design costs.	-Conduct a thorough review of current product procedures. -Identify processes where quality can be improved and design costs can be reduced. -Set a target for reducing design

Main Findings	Objective	Action steps
		costs by 2% while maintaining or enhancing product quality.
2-Taguchi Function Integration	-Understand customer sensitivity to deviations and align design parameters accordingly.	-Calculate the L(Y) value to quantify customer sensitivity. -Implement changes in design based on customer preferences identified through Taguchi methods. -Aim to reduce customer dissatisfaction by 4% through targeted design adjustments.
3-Economic Evaluation and Targeted Value	-Determine cost-effective quality improvement strategies and align with customer expectations	-Analyze variations in product design and production processes. -Evaluate the economic impact of these variations. -Set specific cost reduction targets in production processes based on Taguchi evaluations.
4-Production Cost Consideration	-Enhance competitiveness by considering all production costs.	-Conduct a comprehensive analysis of all production costs. -Identify areas where cost reductions can be made without compromising quality. -Aim to reduce overall production costs by 5% over the next quarter.
5-Focus on Targeted Value	-Minimize deviations from targeted values to meet customer requirements.	-Implement quality control measures to reduce deviations. -Monitor and adjust processes to ensure alignment with targeted values. -Aim to reduce quality-related defects by 7% over the next six months.
6-Product Design Enhancement	-Improve product design and reduce sensitivity to variations.	-Identify easily controlled factors affecting product design. -Implement design improvements to reduce responses to variations. -Maintain an average product response within target values to increase customer satisfaction.

Key Performance Indicators (KPIs) for Assessment:

-Reduction in design costs: 2%

-Customer dissatisfaction reduction: 4%

-Production cost reduction: 5%

-Reduction in quality-related defects: 7%

Based on the aforementioned comprehensive action plan and a regular evaluation of key performance indicators, the company can proficiently execute quality enhancement initiatives, leading to cost reduction and competitive advantage in the market.

Managerial Implications

The findings of this research have significant implications for both academics and practitioners.

For academics, this research introduces the role of the Taguchi loss function in quality deployment. Typically disregarded by academics, this study classifies the factors influencing production into controlled and non-controlled variables and validates the methodology by which the Taguchi loss function can reduce production deviations. Additionally, this research emphasizes the role of information systems and data on products and daily production levels in the context of the Taguchi loss function.

For practitioners, the Taguchi loss function, which utilizes statistical methods, offers a more efficient approach to quality control and minimizing quality loss. Practitioners can apply the Taguchi method in diverse manufacturing contexts to achieve production excellence and reduce costs in a price-sensitive market that experiences rising inflation rates for materials and production resources. Furthermore, by highlighting the role of the Taguchi loss function, this research underscores the importance of staff training and equipment maintenance. In summary, this research emphasizes the significance of coordination among various departments within an organization to minimize quality loss. "Taguchi Techniques for Supply Chain Optimization in Egyptian Industries"

"Sustainable Manufacturing Practices in Egypt: A Taguchi Methodology Perspective"

Avenues for Further Research

-Overcoming Implementation Challenges of Taguchi Methods in Egyptian Manufacturing.

-Comparative Analysis of Quality Improvement Tools in Egyptian Manufacturing: Taguchi vs. Traditional Methods.

-Success Stories: Case Studies of Taguchi Method Applications in Egyptian Industry"

-Integrating Taguchi Methods with Industry 4.0 Technologies in Egyptian Manufacturing.

-Driving Customer Satisfaction and Innovation: Taguchi Strategies for Egyptian Manufacturers.

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