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Improving the Performance of Production Operations through Statistical Quality Control: Case Study in South Mineral Water Company in Basra

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ABSTRACT

High-quality services and products give organizations a competitive advantage. Good quality reduces correction costs, waste, complaints and returns on defective products, and most importantly, it achieves customer satisfaction. Quality is the most important factor that affects the performance of an organization's production operations compared to its competitors. The main objective of this study is to use some statistical tools such as (X-bar Chart), which is one of the process control charts. In addition to using the ANOVA technique, this is among the statistical instruments employed to measure and analyses variance and identify sources of discrepancies between group averages. These tools were used in this study to monitor and control the quality of the production process to ensure that the products meet the required quality standards, and to identify and correct any problems or deviations from those standards as early as possible in the production process. The data collected from South Mineral Water Company was processed using the manual method as well as the Excel program. The research concluded that there was a variation in the level of water volumes inside the bottles within the sample as well as between the study samples, and after using the Tukey HSD equation, the largest difference between the variations was identified, which was between the average of observations 3 and 4, which had a value of 12.74.

Keywords: Mean X-bar Chart, Control Chart, Variance, ANOVA, One-Way variance analysis, Quality, Operation Performance.

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INTRODUCTION

Enhancing process performance is an international issue, and firms have a choice when it comes to quality because it's one of the key differentiators and competitive differentiators. In order to remain in the competitive circle, organizations sought to improve their production processes, and this calls for taking a set of measures to improve the quality of the product. Therefore, organizations should make use of all available resources efficiently and effectively, in order to meet the needs of customers who demand perfection and there is no room for error. On the other hand, quality is the most clearly dimension of what the process does, but it is relatively easy to evaluate the production process by the customer (Hadi & Sabeeh, 2021, p. 647).

Making customers happy requires finding new ways to exceed their expectations, which is a requirement for today's business world. For these reasons, manufacturing companies should build new ideas and processes, and one of the ways and methods that help the organization improve the quality of its operations is to reduce variation in the production process and know its source to reduce defects.

Through the use of ANOVA technology and quality control charts, the company under study can confirm the presence of statistically significant differences between products. Statistical quality control tools are an effective tool for making decisions because they enable users to test significant relationships between sample data that fall into different categories and sort the data into categories to see if this sorting explains some of the variation in the sample data.

RESEARCH METHODOLOGY

Due to the importance of research methodology in studies and its importance in supporting the researcher's work, we will address in this aspect both the significance and goals of the study, the research hypotheses, and the methodology employed in the study.

First: The problem of research

The research's issue is the high rates of variation in the product, which leads to an increase in loss. The problem of the study can be formulated through the following main questions:

1. Can statistical tools be applied to control product quality in the company under study?
2. Does applying statistical tools to control product quality in the company under study help improve the performance of production operations?

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Second: The importance of research

The importance of the research is based on the following basic points:

1. The significance of statistics underpins the research's worth tools to control the quality of products, and how to use them to detect variation and thus reduce it, which in turn leads to improving the performance of operations.
2. The great importance of this research stems from making the researched company have a prominent position in the field of competition within the production sector, by focusing on product quality as one of the strategic objectives.
3. Contributing to providing a theoretical framework for current research variables through what was collected from the ideas of thinkers and researchers in these fields.

Third: The objectives of research

In light of defining the research problem and its importance, the research aims to achieve the following points:

1. Use statistical tools (ANOVA, Mean X-bar Chart) to measure and analyze the variation in product quality levels of the researched company manually and using the Excel software.
2. Finding out if there is a statistically significant difference between the samples is an additional objective. If there are variations, we must identify the specific locations within the samples where these variations occur and ascertain the reasons behind them.
3. To test, apply the F_{test} theories.

Fourth: The hypotheses of research

Ho: The average outcomes of water bottle volume to the four observations are equal.

H1: The average outcomes of water bottle volume to the four observations are not equal.

LITERATURE REVIEW

Operations performance

Because operations management has the power to "make or break" a company, operations performance is crucial for any kind of organization. This is due to the operations function's size, which in most companies' accounts for the majority of their assets and personnel, as well as the fact that it allows for competitiveness by enabling the organization to grow its

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capabilities and respond to customers, both of which avert future competition (Slack et. al, 2010, p. 34).

Writers and researchers have mentioned many concepts for operations performance. According to some of them, it's an operations strategy that establishes a framework of competitive priorities that efficiently and effectively produces high value for the client. Three methods are considered by operations managers when making decisions to meet competitive priorities: differentiation, lowest cost, and response (Heizer & Render, 2011, p. 66). According to some, an organization's ability to carry out its operations function—which is dependent on knowledge and experience and involves offering a variety of high-quality services that are promptly delivered at a low cost—helps it establish a sustainable competitive advantage (Russell & Taylor, 2011, p. 24).

Improving of Operation Performance

The basics of improving performance are improving results through available resources, especially human resources, processes and organizations (Van Tiem, et al., 2012, p. 9). Therefore, whenever the improvement process begins, the scope of the improvement project should be determined, and which processes will be affected. Available information about existing processes can help determine the scope. The objectives of the organization are a significant factor in defining the scope of the improvement project (Martinsuo & Blomqvist, 2010, p. 9). For example, manufacturing companies that have improved the performance of their operations obtain a reduction in the costs of their products, delivery is on time and the level of quality is raised, and what is most important is always thinking and working on continuous improvement (De Gracia, 2014, p. 9). Companies always strive, significantly and continuously, to improve the efficiency of their business and reduce costs, which in turn leads to increased profits. By simplifying operational procedures and focusing on product quality, companies can reduce complexity in specific areas, increase revenues while reducing costs, and can also achieve long-term structural improvements (Böttcher & Neuhaus, 2015, p. 1).

Dimensions of Operation Performance

Authors and researchers have given many different names to performance indicators due to their different scientific backgrounds. Some call it competitive priority, competitive advantages, Operations performance objectives, others call it after performance or after competition. All these terms have the same meaning. Regardless of the name, recent literature

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in production and operations management suggests that process performance indicators are key objectives. Organizations strive to achieve these goals for the sake of business continuity and the ability to remain competitive. The dimensions of operations performance according to (Slack et. al, 2010: p46) are (quality, cost, speed, and flexibility).

- **Quality:** Quality is defined, according to the American Society for Quality (ASQ; www.asq.org), as "The sum of the attributes and characteristics of a product or service that affect its ability to satisfy stated or unstated customer needs.". As for Slack, (Slack et. al, 2010: p46), he defined it as consistently meeting customer expectations, in other words: "doing things right.". However, quality has been defined by some writers as being dependent on the user, as quality "is from the customer's point of view." Higher quality means better performance, nicer features, and other (sometimes expensive) improvements. As for others in the book, they defined quality from the point of view of production managers. Quality depends on manufacturing. They believe that quality means conforming to specifications and "making it right the first time." (Heizer et al., 2017: p216). (Groover, 2002: p633) mentioned that the dimensions of product quality are: (Performance, Features, Aesthetic appeal, Conformance, Reliability, Durability, Serviceability and Perceived quality)
- **Cost:** Organizations competing on the basis of cost always strive to reduce or eliminate all waste. Previously, organizations of this type manufactured standardized products for large markets. Currently, the entire cost structure is being scrutinized to find an opportunity to reduce these costs, not just labor wages. Production and automation in large quantities may or may not be an effective alternative in terms of reducing costs. Lean production systems achieve lower costs through controlled processes (Russell & Taylor, 2011: p19).
- **Speed:** The meaning of speed as a competitive advantage is that companies use it to overcome their competitors, and it represents the time it takes to process products until they become a final product, that is, from the beginning of production processes to their end, that is, from the time the customer submits an order for the product or service, until the point at which the client receives it (Slack & Lewis, 2011, p. 48). In companies that want to implement a strategy based on speed, managers work with great focus on the steps and time required to provide a service or produce a product. They then carefully analyze each step to determine the possibility of saving time without compromising quality (Krajewski, et al., 2013, p. 31).

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- **Flexibility:** It expresses the extent and speed of companies' response to changes in the different types of new products requested by the customer or changes in the volume of production (Kumar & Suresh, 2008, p. 13). There are different types of flexibility, including: **mix flexibility** (the ability to diversify products that result in a wide range of products or services), **changeover flexibility** (the ability to produce a new product in the shortest possible time), and **volume flexibility** (the ability to produce in the sizes required by the customer) (Bozarth & Handfield, 2013, p. 27). As a result of the great and rapid development that the world is witnessing, customer desires to change and diversify rapidly, as do the ways to satisfy them. As a result, flexibility is an important competitive advantage in current and future markets, embodied in the ability to adapt and offer different products in different quantities. Resilience generally reflects the ability to adapt to a wide range of potential environments and is a necessary condition for long-term survival (Abdul Hadi, 2011, p. 30).

Statistical Quality Control

Statistical quality control is a set of statistical tools used for quality control, and these statistical techniques are applied to ensure that processes meet specifications (Heizer et al., 2017, p. 246). It is an important way to test and evaluate products, and the information contained in that data is used to manage, control, and improve processes and products. Also, through statistical tools, all functions within the organization can communicate everything related to quality. (Montgomery, 2009, p. 61). Statistical quality control consists of three categories (Reid & Sanders, 2019, p. 173):

- **Descriptive. statistics:** Applied to characterize attributes and connections of quality. For example: measures of dispersion, which include (standard deviation and analysis of variance like ANOVA technique), measures of central tendency example (mean, median, mode, and range, and measures of data distribution).
- **Statistical process control:** In this category, a random sample is taken and examined from the process outputs to determine that the process produces products according to the required and pre-determined standards. In short, it determines whether the process is working properly or not. Statistical control is divided into two groups: Variable charts, which deal with characteristics that can be measured such as (length, volume, weight, density, etc.). The charts of this group are (Mean x-bar chart, Range (R) chart). The second group is attribute charts, which deal with the characteristics and qualities

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of product quality that can be calculated, such as (color, taste, new, old, …etc.), to which the answer is yes or no. The charts of this group are (P-chart, c- chart).

- **Acceptance sampling:** In this category, a random examination of a sample of products occurs. This examination is on raw materials and finished products, and a decision is made whether the entire batch will be accepted or rejected based on the results of the examination.

APPLYING TOOLS OF STATISTICAL QUALITY CONTROL

Mean x-bar chart

It is one of the variable control charts used to monitor the measurable properties of products. Used this type of control charts to keep an eye on the data's mean, or central tendency, as well as its variability with respect to standard deviation. When the observed values are out of control, this gives an indication that the process is not under control. Production stops, and employees try to find the cause of the problem and solve it (Reid & Sanders, 2019:178). To develop a x-bar chart, firstly must create the central line of the diagram. In order to accomplish this, we compute the average of them. The sample size is usually small, containing approximately 4 or 5 observations. Each sample has its own average. The middle line of the chart is then calculated as the average of all sample means. To establish the upper and lower control limits of the diagram, we use the following formulas (Heizer et al., 2017, p. 250):

$$\bar{\bar{x}} = \mu \qquad (1)$$

$$\text{Upper control limit (UCL)} = \bar{\bar{x}} + z\,\sigma_{\bar{x}} \qquad (2)$$

$$\text{Lower control limit (LCL)} = \bar{\bar{x}} - z\,\sigma_{\bar{x}} \qquad (3)$$

where?

$\bar{\bar{x}}$=The average of the sample means

z=Number of normal standard deviations (2 for 95.45% confidence, 3 for 99.73%)

$\sigma_{\bar{x}}$ =Standard deviation of the sample means = $\sigma / \sqrt{n}$

σ=Population (process) standard deviation

n=Sample size

The South Mineral Water Company in Basra is one of the Iraqi companies that works hard to raise the level of quality of its product. In order to reach these advanced levels of quality, this must be ensured and the use of Mean x-bar chart can contribute to controlling the quality of its

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product. Therefore, ten samples were taken from water bottles, and each sample contains four observations, as shown in Table (1).

Table 1: *Bottle volume in milliliter*

Sample No.	Observations (bottle volume in milliliter)			
	1	2	3	4
1	500.1	480	474.9	477.9
2	483.6	495.9	475.5	480.5
3	482.1	479.1	478.2	474.9
4	498.6	475.5	472.2	487.9
5	472.2	475.8	480.3	498.9
6	478.2	480.3	474.2	480.9
7	472.5	486.3	471.3	475.8
8	474.6	478.2	480.6	500.2
9	481.2	479.4	450.9	479.5
10	469.2	475.8	471.2	500.2

Source: Prepared by the researcher based on data from the company's quality department

To build the chart for the above data manually, we first calculate the average for each sample, and then the three control limits, noting that the sigma for process is 8.5, as shown below.

Table 2: *Sample average of Bottle volume*

Sample No.	Observations (bottle volume in milliliter)				Average
	1	2	3	4	
1	500.1	480	474.9	477.9	483.225
2	483.6	495.9	475.5	480.5	483.875
3	482.1	479.1	478.2	474.9	478.575
4	498.6	475.5	472.2	487.9	483.55
5	472.2	475.8	480.3	498.9	481.8
6	478.2	480.3	474.2	480.9	478.4
7	472.5	486.3	471.3	475.8	476.475
8	474.6	478.2	480.6	500.2	483.4
9	481.2	479.4	450.9	479.5	472.75
10	469.2	475.8	471.2	500.2	479.1
Sum					**4801.15**

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Prepared by the researcher

$$\bar{\bar{x}} = 4801.15 / 10 = 480.12$$

$$\sigma_{\bar{x}} = \sigma / \sqrt{n} = 8.5 / \sqrt{4} = 4.25$$

$$\text{Upper control limit (UCL)} = \bar{\bar{x}} + z\,\sigma_{\bar{x}} = 480.12 + (3*4.25) = 489.12$$

$$\text{Lower control limit (LCL)} = \bar{\bar{x}} - z\,\sigma_{\bar{x}} = 480.12 - (3*4.25) = 467.37$$

The result of the control chart is shown in the following figure:

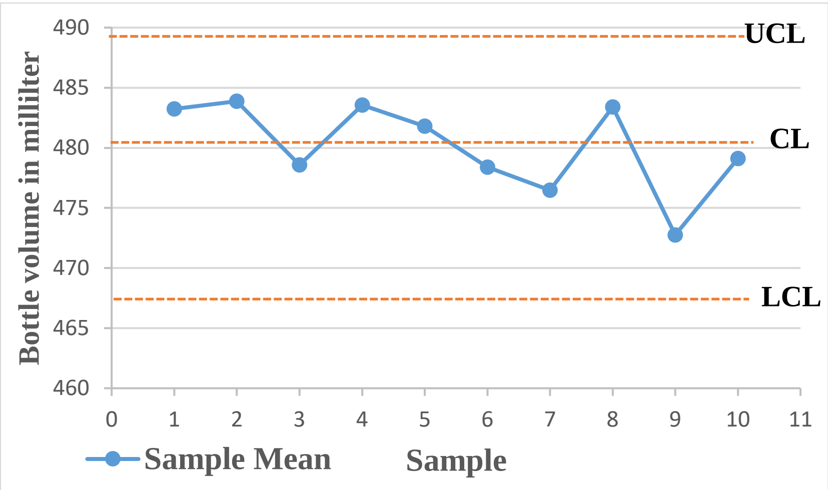

Figure 1: Mean (x-Bar) Chart of process

We note from the above chart, that all samples are within the limits of control, which means that the production process is controlled. We also see the extent to which the data is dispersed from its mean, and the next part of the practical side of the research is devoted to calculating this dispersion, and one of the measures of dispersion was used, which is variance. It can also be calculated using Excel as follows:

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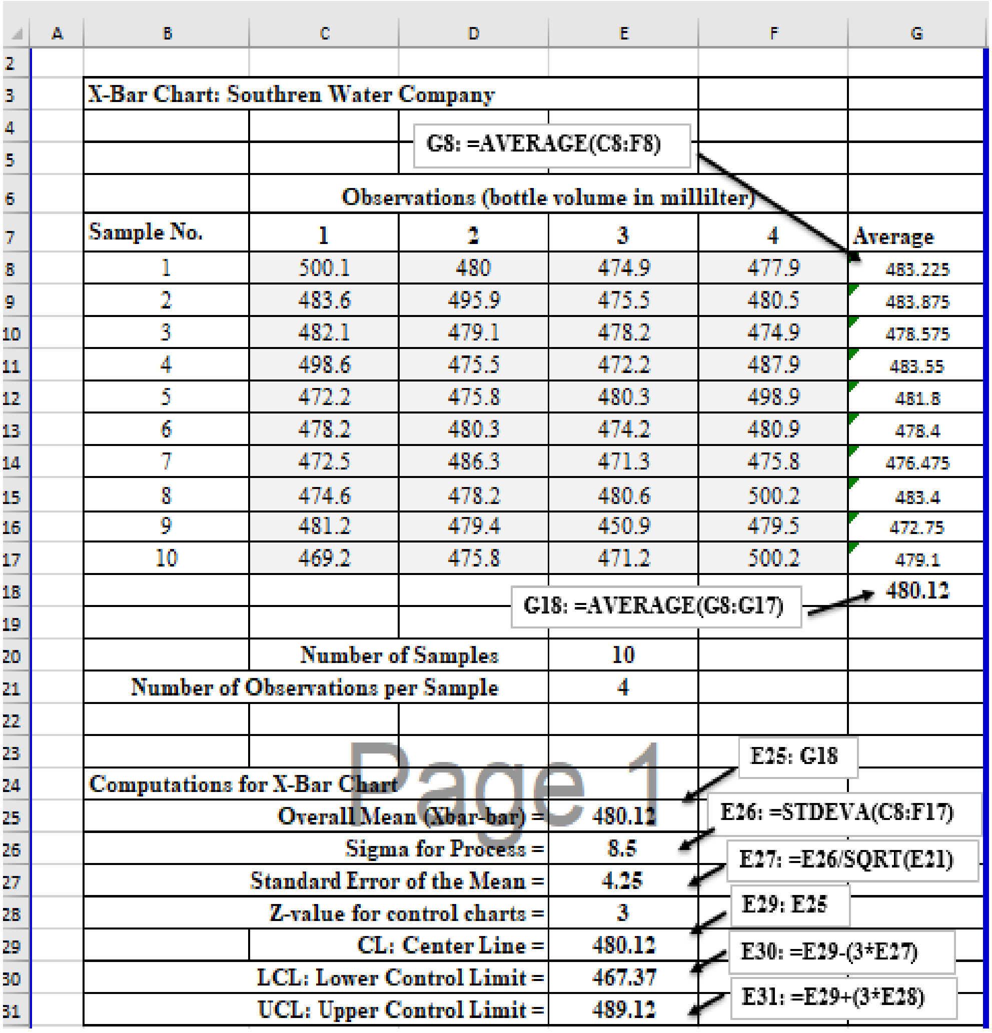

X-Bar Chart: Southren Water Company

Observations (bottle volume in millilter)

Sample No.	1	2	3	4	Average
1	500.1	480	474.9	477.9	483.225
2	483.6	495.9	475.5	480.5	483.875
3	482.1	479.1	478.2	474.9	478.575
4	498.6	475.5	472.2	487.9	483.55
5	472.2	475.8	480.3	498.9	481.8
6	478.2	480.3	474.2	480.9	478.4
7	472.5	486.3	471.3	475.8	476.475
8	474.6	478.2	480.6	500.2	483.4
9	481.2	479.4	450.9	479.5	472.75
10	469.2	475.8	471.2	500.2	479.1
					480.12

Number of Samples	10
Number of Observations per Sample	4

Computations for X-Bar Chart

Overall Mean (Xbar-bar) =	480.12
Sigma for Process =	8.5
Standard Error of the Mean =	4.25
Z-value for control charts =	3
CL: Center Line =	480.12
LCL: Lower Control Limit =	467.37
UCL: Upper Control Limit =	489.12

Figure 2: X-Bar chart of the process created in Excel

Recognized from the figure above that using Excel is better than the manual solution, as it reduces time, reduces effort, and gives more accurate results.

Variance Analysis

It is a statistical tool used to measure the dispersion of possible values around expected values. We look at the sources of variation in the process. They are two types of variation sources. The frequent or random causes of variation are the first kind. an example of which are soft drink bottles. We observe that the amount of drink in each bottle varies slightly from bottle to bottle. Some are filled slightly higher and others are slightly lowered. These kinds of variations are rather typical. Due to minute variations in the materials, labor, equipment, tools, and other components, no two items are quite the same. They cannot be prevented during the process and are not differentiated or identifiable. The second type of variance, assignable variance causes,

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also known as special causes, includes any variance-causing factors that can be identified and eliminated. Examples of these reasons are a lack of employee training, a machine that needs repair, or raw materials that are of poor quality (Krajewski, et al., 2013: p168).

To measure the variation in the sizes of mineral water bottles of the company under study, we use the ANOVA technique.

ANOVA Technique

The analysis of variance (ANOVA) approach is one statistical method used to find variations in group means. Finding differences in group means when there is one parametric dependent variable and one or more independent variables is done statistically (Sawyer & Steven, 2009). Analysis of variance is also used to look at the link between a dependent variable and one or more independent variables, or numerous independent variables. It is usually descriptive and ignores the type of relationship that exists between the independent and dependent variables. Different types of analysis of variance exist, including one- and two-factor analyses. In this study, one-way analysis of variance, or ANOVA, was used.
First, the ANOVA technique is used to see if there are general variance in the samples means (Mouritsen, et. al, 2016). Using the following equations, determine the variance manually (Panneerselvam & Sivasankaran, 2014):

Total Variance (TV). = Within Group Variation (WGV). + Between Groups Variation (BGV)

The Total Variance (TV) equation came from the following equation:

$$\mathbf{TV} = \sum_{i=1}^{k} \sum_{j=1}^{n} (\mathbf{Xij} - \mathbf{T\mu})^2$$

Similarly, two further equations for Between Groups Variation (BGV) and Within Group Variation (WGV) can be found.

$$\mathbf{WGV} = \sum_{i=1}^{k} \sum_{j=1}^{n} (\mathbf{Xij} - \mathbf{\mu i})^2$$

$$\mathbf{BGV} = \sum_{i=1}^{k} (\mathbf{\mu i} - \mathbf{T\mu})^2$$

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Table 3: *Sample information of Bottle volume*

Using ANOVA to check out the bottle volume				
Sample No.	**Observations (bottle volume in milliliter)**			
	1	**2**	**3**	**4**
1	500.1	480	474.9	477.9
2	483.6	495.9	475.5	480.5
3	482.1	479.1	478.2	474.9
4	498.6	475.5	472.2	487.9
5	472.2	475.8	480.3	498.9
6	478.2	480.3	474.2	480.9
7	472.5	486.3	471.3	475.8
8	474.6	478.2	480.6	500.2
9	481.2	479.4	450.9	479.5
10	469.2	475.8	471.2	500.2
Sum	**4812.3**	**4806.3**	**4729.3**	**4856.7**
Mean (□)	**481.23**	**480.63**	**472.93**	**485.67**
Total Main of Samples (Tµ)=∑µ / K			**19204.6/40**	**480.12**
Group sample size (n)				**10**
Sample size (N)				**40**
Groups number (K)				**4**

From the data of the table above, which shows 40 observations for ten samples, The total variance (TV) is the variance in all the values of the 40 observations as a result of the fact that all the values in the table are not equal. The values of observations do not match within samples. This difference is called within-group variation (WGV). Ultimately, there is an obvious difference between the ten samples since their average is not equal. The term "between-group variance" (BGV) refers to this variation.

We apply variance equations to the data in Table 3 to manually quantify and examine the variation in the standard of quality production process level, utilizing the ANOVA technique. 10 samples were used, each sample containing 4 observations.

$$\mathbf{TV}=(500.1-480.12)^2 + (480-480.12)^2 + (474.9-480.12)^2 + (477.9-480.12)^2 + (483.6-480.12)^2 + (495.9-480.12)^2 + (475.5-480.12)^2 + (480.5-480.12)^2 + (482.1-480.12)^2 + (479.1-480.12)^2 + (478.2-480.12)^2 + (474.9-480.12)^2 + (498.6-480.12)^2 + (475.5-480.12)^2 + (472.2-480.12)^2 + (487.9-480.12)^2 + (472.2-480.12)^2 + (475.8-480.12)^2 + (480.3-480.12)^2 + (498.9-480.12)^2 + (478.2-480.12)^2 + (480.3-480.12)^2 + (474.2-480.12)^2 + (480.9-480.12)^2 +$$

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$(472.5\text{-}480.12)^2 + (486.3\text{-}480.12)^2 + (471.3\text{-}480.12)^2 + (475.8\text{-}480.12)^2 + (474.6\text{-}480.12)^2 + (478.2\text{-}480.12)^2 + (480.6\text{-}480.12)^2 + (500.2\text{-}480.12)^2 +$

$(481.2\text{-}480.12)^2 + (479.4\text{-}480.12)^2 + (450.9\text{-}480.12)^2 + (479.5\text{-}480.12)^2 + (469.2\text{-}480.12)^2 + (475.8\text{-}480.12)^2 + (471.2\text{-}480.12)^2 + (500.2\text{-}480.12)^2$

=3816.351

BGV= $n \sum_{i=1}^{k} (\mu i - T\mu)^2$

$= 10\,[(483.225- 480.12)^2 + (483.875- 480.12)^2 + (478.575- 480.12)^2 + (483.55- 480.12)^2 + (481.8- 480.12)^2 + (478.4- 480.12)^2 + (476.475- 480.12)^2 (483.4- 480.12)^2 + (472.75- 480.12)^2 + (479.1- 480.12)^2]$

= 839.907

WGV= TV – BGV

= 3816.351- 839.907= 2976.444

Based on the above, the following table (variance analysis table) can be used, which shows the necessary steps to calculate the F value:

Table 4: *Methods for Calculating F*

Source of Variance	Sum of squares (SS)	Df	Mean squares (MS)	F Calculated	F Tabulated (Sig.)
Between Groups	$SS_B = n \sum_{i=1}^{k} (\mu i - T\mu)^2$	**K – 1**	S_B^2	S_B^2 / S_W^2	$F_{\alpha (K-1), (N-K)}$
Within Groups (Error)	SS_W = TV – BGV	**N – K**	S_W^2		
Total	$SS_T = \sum_{i=1}^{k} \sum_{j=1}^{n} (Xij - T\mu)^2$	**N – 1**			

Source: www.jmasi.com

We will investigate the following hypotheses using this data:

Null Hypothesis

Ho: The average outcomes of water bottle volume to the four observation are equal.

$$H_0: \mu 1 = \mu 2 = \mu 3 = \mu 4$$

It will reject the alternative hypothesis **(H1)** if it turns out to be valid.

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Alternative Hypothesis: .

H1: The average outcomes of water bottle volume to the four observations are not equal.

$$H1: \mu1 \neq \mu2 \neq \mu3 \neq \mu4$$

Since all means are equal, the null hypothesis can be tested as follows:

$$H_o: \mu1 = \mu2 = \mu3 = \mu4$$

The ANOVA variance analysis method computes two critical parameters: the value of F Critical or Tabulated (F_{Tabul}) and the value of F Calculated (F_{Calcu}) or F. The null hypothesis will be rejected if the value of (F_{Calcu}) is greater than the value of (F_{Tabul}), and it will be accepted otherwise. The decision-making rule is as follows:

Reject Ho if $F_{Calcu} > F_{Tabul}$; accept H1 otherwise.

MS_B = BGV /K - 1 = 839.907 / 4 - 1= 279.969

MS_W = WGV / N - K = 2976.444 / 40 - 4 = 82.679

F = MS_B / MS_W = 279.969 / 82.679 = 3.386217

Table 5: *F's Calculated Result*

Variance's Source	Squares' Sum (SS)	df	Mean squares (MS)	F_{Calcu}	F_{Tabul} (Sig.)
Between Groups	279.969	3	279.969	3.386217	2.866266
Within Groups (Error)	82.679	36	82.679		
Total	3816.351	39			

Source: Getting the researcher ready using the equations in Table (4)

Based on the given table, we may infer the following:

Calculated Value of (F_{Calcu}) = 3.386217

Tabulated Value of (F_{Tabul}) = 2.866266

The calculated F value (F_{Calcu}) is greater than the tabulated F value (F_{Tabul}). Consequently, the alternative hypothesis—that is, that the average values for the four observations and the volume of water in the containers are not equal—is accepted and the null hypothesis is rejected at the significance level of $\alpha = 0.05$.

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We identify differences both within and between groups using Excel's data analysis feature. The computed (F_{Calcu}) and (F_{Tabul}), as indicated by the steps of the solution in the following table:

Using ANOVA to check out the volume of water in the bottle

Sample No.	Observations 1	2	3	4
1	500.1	480	474.9	477.9
2	483.6	495.9	475.5	480.5
3	482.1	479.1	478.2	474.9
4	498.6	475.5	472.2	487.9
5	472.2	475.8	480.3	498.9
6	478.2	480.3	474.2	480.9
7	472.5	486.3	471.3	475.8
8	474.6	478.2	480.6	500.2
9	481.2	479.4	450.9	479.5
10	469.2	475.8	471.2	500.2
Sum	**4812.3**	**4806.3**	**4729.3**	**4856.7**
Mean (μ)	**481.23**	**480.63**	**472.93**	**485.67**
Total Main of Samples (Tμ)=∑μ / K			**19204.6/40**	**480.115**

[1] Click the Tools menue and then Data_Analysis to activate the Analysis ToolPak
[2] Choose the "Anova: Single Factor" opition and fill in the dialog box as follows:-

INPUT Input Range: Highlight (or enter) the range C5:F14
Grouped by: Columns
Labels in First Row: Click OK with mouse
Alpha: Enter the required signficance level (leave at 5%)

OUTPUT Output Range: Click OK with mouse
Enter a suitable output cell, e.g B27

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	10	4812.3	481.23	113.309
Column 2	10	4806.3	480.63	38.729
Column 3	10	4729.3	472.93	71.61344
Column 4	10	4856.7	485.67	107.0646

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	839.91	3	279.969	3.386217	0.0284	2.8663
Within Groups	2976.4	36	82.679			
Total	3816.4	39				

Figure 3: Results of the analysis of variance for the volume of water in the bottle

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Source: Prepared by the researcher and based on the data of the qualitative department of the researched company and the Excel program

Given that the group means differ statistically significantly, post hoc analysis is required to determine the cause of these discrepancies. Make use of the Honestly Significant Difference test (HSD). Which is employed if each group's sample size is the same:

Formula Tukey HSD: -

$$HSD_{\alpha} = q_{\alpha} \sqrt{MS_W / n} = 3.958 \sqrt{82.67 / 10} = 2.94$$

qα = 3.96 The intersection of the row that equals the (df=20) and the column that equals the number of groups (K=4) yields the Tukey tabulated value corresponding to the 0.05 level of significance.

After subtracting some from the means, we compare the absolute value of the result with the HSDα value to identify the groups that were responsible for the disparities. It is indicated that there are no differences if the difference between the means is less than the HSDα value. When the difference between the means exceeds the HSDα value, it signifies that there are variations in the means, and the lowest mean is the cause of the difference, as illustrated below:

Table 6: *The outcome of the observations' mean differences*

No.	Variation in Means		Difference Result (Absolute)	HSD_{α} Value	Final Result
	Observations	Means Variation			
1.	1 – 2	481.23 - 480.63	0.6	**2.94**	No Difference
2.	1 – 3	481.23 - 472.93	8.3		**Difference**
3.	1 – 4	481.23 - 485.67	4.44		**Difference**
4.	2 – 3	480.63 - 472.93	7.7		**Difference**
5.	2 – 4	480.63 - 485.67	5.04		**Difference**
6.	3 – 4	472.93 - 485.67	12.74		**Difference**

Source: Preparing the researcher.

The largest difference between the means of observations 3 and 4 may be seen in the above table. The difference between the means of observations 1 and 3 is the next to arrive, followed by the difference between the means of observations 2 and 3, then 2 and 4, and lastly, the lowest difference between the means of observations 1 and 4.

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CONCLUSION AND RECOMMENDATIONS

This research shed light on the most important quality problems facing the company under study, which is the deviation in the volumes of bottled water, as it was found that there is a discrepancy, which in turn leads to high levels of waste and poor quality, which negatively affects the increase in costs that reduce profits, especially in the presence of intense competition in this sector. Industry in the same geographical area. Statistical control tools were used for the process (x-bar chart) using the two manual methods and using the software Excel, a distinct dispersion of the data values from their average appeared. To measure this dispersion, the ANOVA technique was used, which revealed a clear difference in the volumes of water bottled and for the ten samples. This came through F_{Calcu} value being greater than F_{Tabul} value. Consequently, the null hypothesis (The average outcomes of water bottle volume to the four observation are equal) was rejected at the significance level of $\alpha = 0.05$, and the alternative hypothesis was accepted, which is (the means of the four observations are not equal). To find out the reasons for the discrepancy in the production process, we used the Tukey HSD test (honestly significant difference test), in order that the cause of these variations was in observation No. 3, which had the lowest means. Therefore, the company should find out the reasons for the dispersion of data in this observation and try to correct the course.

In light of what was discussed within the theoretical and practical framework, we recommend that the management of the company under study use statistical control tools to detect deviations in quality. In addition to enrolling employees in training courses, especially those working in the quality department, on how to use statistical tools in both Excel and SPSS to benefit from the multiple features of these electronic programs, and that these courses take the form of continuity and serious follow-up by the company’s senior management.

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