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A Systematic Review of Seven Core Quality Control Tools and Their Applications in Manufacturing Process Improvement

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Abstract

This paper provides a comprehensive analysis of the seven basic quality control tools and their applications in addressing problems within manufacturing industries. The tools examined include cause-and-effect diagrams, check sheets, control charts, histograms, Pareto charts, scatter diagrams, and flowcharts. Each tool is discussed in detail, focusing on its purpose, theoretical foundations, and practical applications in quality management. The study emphasizes how these tools support systematic identification, analysis, and resolution of production challenges, thereby improving process efficiency, reducing defects, and enhancing overall product quality. By demonstrating their versatility and effectiveness, the paper highlights the relevance of these tools as essential components of continuous improvement strategies in modern manufacturing.

Keywords: Quality Control Tools; Manufacturing Industries; Problem Solving; Process Improvement; Applications

INTRODUCTION

In contemporary competitive markets, quality management remains a defining element in determining organizational success. High standards in products and services not only satisfy customers but also strengthen a company's ability to remain viable in globalized economies. Achieving this requires systematic approaches that minimize variation in processes, maintain operational consistency, and instill trust in outputs. Central to these efforts are quality control tools, which provide structured methods for monitoring, analyzing, and improving performance across both manufacturing and service industries.

The conceptual foundation for modern quality control was notably advanced by Kaoru Ishikawa (1990), whose introduction of seven fundamental tools including Check Sheets, Trend Analysis Graphs, Histograms, Pareto Charts, Cause and Effect Diagrams, Scatter Diagrams, and Control Charts transformed practical quality management. Developed initially for Japanese industrial contexts, these tools were intentionally designed for ease of adoption through self learning and workplace training. Their influence extends far beyond their origins, forming the bedrock for systematic problem identification, root cause analysis, and targeted process improvement. Complementary perspectives have been provided by leading scholars such as Besterfield (2013), Frayman (2002), Jones (2000), and Montgomery (2017), whose works expand the theoretical and applied understanding of quality management systems.

Empirical research consistently underscores the utility of these tools in diverse operational environments. Bambharoliya (2015) demonstrated their capacity to reduce product rejection rates in a small scale manufacturing setting, leading to measurable improvements in customer satisfaction. Similarly, Muhammad (2015) integrated Ishikawa's framework into a DMAIC process consisting of Define, Measure, Analyze, Improve, and Control stages to address defects in fan production, reinforcing the premise that many industrial quality challenges can be resolved with these fundamental techniques. In the manufacturing sector, Ayenigba (2025) applied statistical quality control to enhance dimensional accuracy in soap production, achieving greater product uniformity. In a related study, Ayenigba and Ajao (2024) demonstrated the adaptability of such methods in the water packaging industry, using them to monitor both production efficiency and post production marketing processes.

Each of Ishikawa's tools offers distinct analytical capabilities, enabling practitioners to approach quality problems from multiple dimensions. For example, the Cause and Effect diagram has been used effectively by Grima *et al* (2021) to classify defect sources in printed circuit board assembly, while Chaudhuri *et al* (2019) employed histograms to reveal process patterns and assess manufacturing capabilities. Pareto analysis, applied by Soković *et al* (2018), has proven valuable in prioritizing quality issues for maximum impact. Beyond manufacturing, control charts have been successfully implemented in service environments, as illustrated by Hu *et al* (2020), to track and maintain service quality over time.

Given the enduring relevance and adaptability of these tools, this paper systematically examines the seven classical quality control methods. The review emphasizes their practical application across sectors, outlines the specific contexts in which each is most effective, and synthesizes evidence of their continued importance in meeting contemporary quality standards in both product based and service oriented industries.

MATERIALS AND METHODS

The present investigation adopted a structured literature review to examine scholarly and industry-based research on the seven fundamental quality control tools that are frequently employed in manufacturing environments to resolve quality-related challenges. This approach was selected to enable a comprehensive assessment and integration of existing knowledge, facilitating the recognition of patterns in usage, recurring application contexts, and the documented advantages of these tools.

The review concentrated on the principal quality control instruments, namely Pareto Charts, Cause and Effect Diagrams, Control Charts, Histograms, Check Sheets, Scatter Diagrams, and Flowcharts. Studies included in the analysis were examined in detail to collect information on a set of core variables, which comprised the specific tools applied, the nature of manufacturing quality problems targeted, obstacles encountered during implementation, and the results achieved.

All extracted information was systematically categorized to reveal trends in the effectiveness and suitability of each tool, as well as to identify any interdependencies between different methods. Following this, thematic analysis was employed to distill recurring concepts and insights, thereby clarifying the ways in which these quality control techniques contribute to measurable improvements in manufacturing quality performance.

RESULTS AND DISCUSSION

This section presents a detailed synthesis of the seven foundational quality control tools, offering both theoretical perspectives and practical insights into their application. In order to bridge the gap between conceptual understanding and operational practice, the discussion is enriched with real world examples and documented case studies drawn from diverse industrial contexts, including manufacturing, service delivery, and related operational environments. These examples serve to illustrate not only the technical use of each tool but also the measurable impact they can have on process improvement, defect reduction, and overall quality enhancement.

The review considers the evolution, methodological principles, and operational roles of each tool, highlighting situations in which their application has yielded tangible benefits. Attention is also given to the challenges encountered during implementation and the strategies adopted to overcome them, thereby providing a balanced perspective on both strengths and limitations. By comparing applications across sectors, the discussion emphasizes the versatility of these tools and their adaptability to varying process complexities and organizational objectives.

The seven tools examined in this analysis are Pareto Charts, Cause and Effect Diagrams, Control Charts, Histograms, Check Sheets, Scatter Diagrams, and Flowcharts. Each is discussed in relation to its conceptual basis, steps for effective application, and documented outcomes from empirical studies, thereby equipping the reader with a clear understanding of their role in modern quality management practices.

Application of Cause-And-Effect Diagram in Process Control

The production department of a tyre manufacturing company undertook an investigation to determine the primary causes of defects in its output. A structured brainstorming session was organized, during which team members identified potential factors contributing to the problem and classified them using a Cause and Effect diagram. This categorization followed the well-established “6M” approach in quality management, which groups causes under six headings: Measurements, Materials, Personnel, Environment, Methods, and Machine. The classified data, presented in the accompanying table, served as the foundation for subsequent analysis in this study (American Society for Quality, 2024).

Table 1: Potential causes of tyre defects classified using the 6M framework (American Society for Quality, 2024).

Measurements	Material	Manpower	Environment	Methods	Machines
Compound variability	Rubber quality	Operator training	Vibration isolation	Finishing techniques	Extruder maintenance
Uniformity testing	Synthetic materials	Safety procedures	Contamination control	Curing process	Mold defects
Specification adherence	Steel cord durability	Labor turnover	Temperature control	Mixing process	Mixer breakdowns

The data above was analyzed with Minitab and the Fish-bone diagram in the Figure below was created.

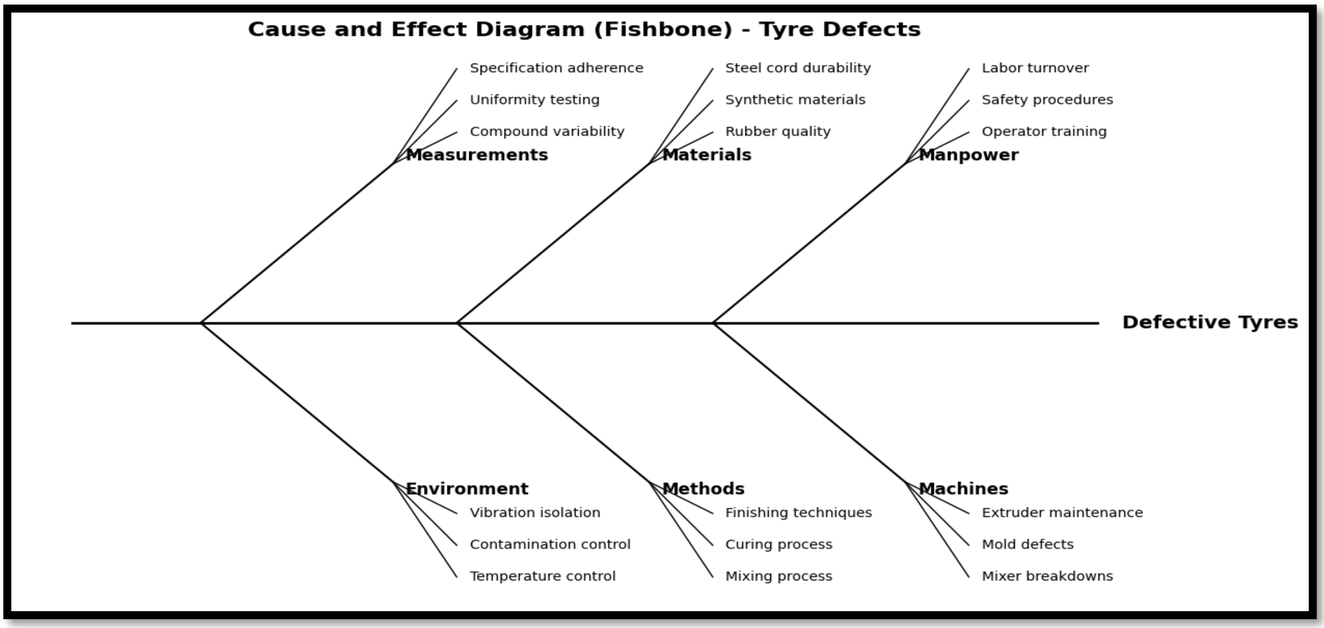


Figure 1: Cause-and-Effect Diagram Depicting Root Causes of Defective Tyres in Manufacturing

From this, we can see that it is easy to identify the causes of the effect (Faulty Tyres).

Application of Check Sheets in Process Control

Over the course of a defined observation phase, Jordan Steel Plc, the leading steel manufacturing enterprise in Jordan, adopted a structured monitoring procedure to evaluate communication efficiency within its operations. The process involved systematic logging of all instances in which call-related interactions failed or experienced disruption. Each event was recorded in a tally register designed to classify the occurrence by type and to note its frequency.

This record-keeping approach ensured that the dataset reflected both the specific nature of the communication breakdowns and their recurrence during the monitoring interval. By capturing these details with precision, the company generated an evidence-based profile of operational communication challenges. This dataset subsequently provided management with a reliable basis for detecting recurring patterns and prioritizing corrective actions. The resulting analysis enabled decision makers to design targeted interventions grounded in observed operational realities, rather than relying on subjective impressions.

Table 2: Recorded frequency of communication-related failures at Jordan Steel Plc during the observation period

Category	Repetition	Frequency
Tensile strength	ǀǀǀǀ ǀǀ⧵ǀ ⧵ǀǀ ⧵ǀǀ ⧵ǀǀ ⧵ǀ ǀǀǀǀ ǀǀǀ	28
Yield Strength	ǀ⧵ǀǀǀ	5
Elongation Percent	ǀǀǀ	3
Effective diameter	ǀǀ	2
Effective Weight	ǀ	1

Al-Hadeethi (2015).

From the Check sheet above, we can see that the type of defect that occurred the most is in Tensile strength (28) and the least which is Effective weight (1).

Application of Control Charts in Process Control

Variable control chart

The data used in this study were sourced from the Quality Control Department of Unilever Brothers PLC, Aba Plant. The dataset consists of measurements collected in January 2024, covering the length of Sunlight soap bars produced in 20 batches.

Table 3: Lengths of Sunlight Soap Produced by Unilever Brothers PLC

Batch No.	Observation 1 (cm)	Observation 2 (cm)	Observation 3 (cm)	Observation 4 (cm)	Observation 5 (cm)	$\bar{X}$	R
1	9.2	9.2	8.6	8.8	9.0	**8.96**	**0.6**
2	9.4	8.7	8.8	9.2	9.0	**9.02**	**0.7**
3	9.0	8.9	8.8	9.3	8.9	**8.98**	**0.5**
4	9.1	9.1	9.0	9.2	8.8	**9.04**	**0.4**
5	8.8	9.0	9.2	8.7	8.8	**8.90**	**0.5**
6	8.6	9.4	8.7	9.0	9.1	**8.96**	**0.8**
7	9.6	9.4	8.7	8.8	8.7	**9.04**	**0.9**
8	9.0	9.2	9.0	8.9	8.8	**8.98**	**0.4**
9	9.4	9.0	9.2	8.7	8.9	**9.04**	**0.7**
10	9.5	9.3	9.2	8.7	8.9	**9.12**	**0.8**
11	9.1	9.0	9.4	9.2	8.6	**9.06**	**0.8**
12	9.1	8.8	9.0	8.9	8.8	**8.92**	**0.3**
13	9.0	8.7	9.5	9.2	8.9	**9.06**	**0.8**
14	8.8	8.7	8.8	9.3	8.8	**8.88**	**0.6**
15	9.2	8.9	9.0	8.7	9.1	**8.98**	**0.5**
16	8.6	9.1	8.9	8.8	9.0	**8.88**	**0.5**
17	9.0	9.0	9.1	8.7	9.5	**9.06**	**0.8**
18	9.1	8.9	8.7	8.9	9.0	**8.92**	**0.4**
19	8.9	9.4	8.8	8.8	9.0	**8.98**	**0.6**
20	9.4	9.0	9.2	9.4	8.6	**9.12**	**0.8**
						8.995	**0.62**

Ayenigba (2025)

To evaluate process stability in the production of Sunlight Soap, statistical process control charts were developed, specifically the $\bar{X}$ chart and the Range chart. Data used for chart construction were obtained from the measurements summarized in Table 2. The computations and graphical outputs were produced within the Google Colab environment, which enabled both data processing and visualization. The resulting control charts are displayed in Figures 2 and 3, corresponding to the $\bar{X}$ and R charts respectively.

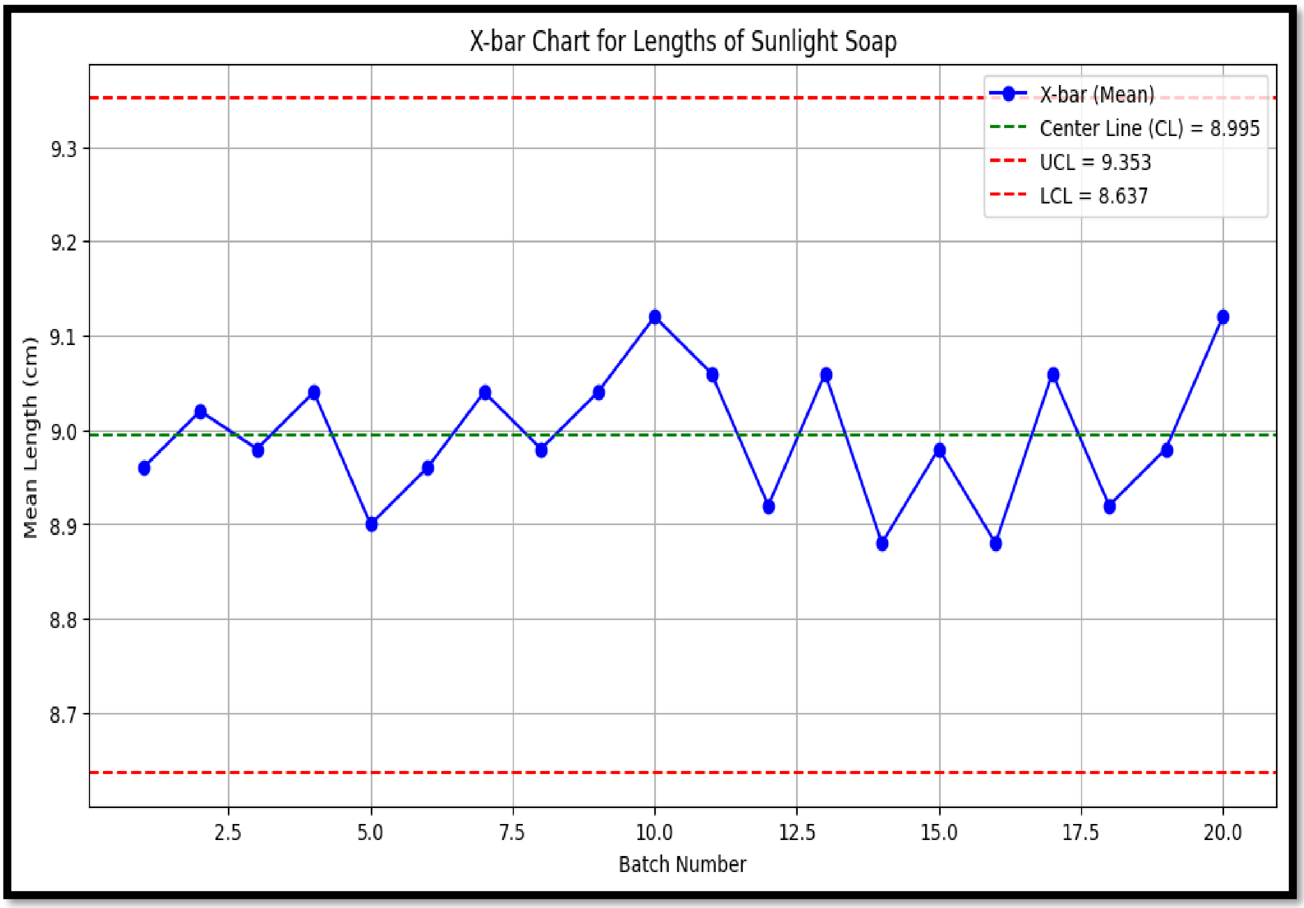


Figure 2: $\bar{\mathbf{X}}$ $\boldsymbol{Chart\ for\ length\ of\ Sunlight\ soap}$

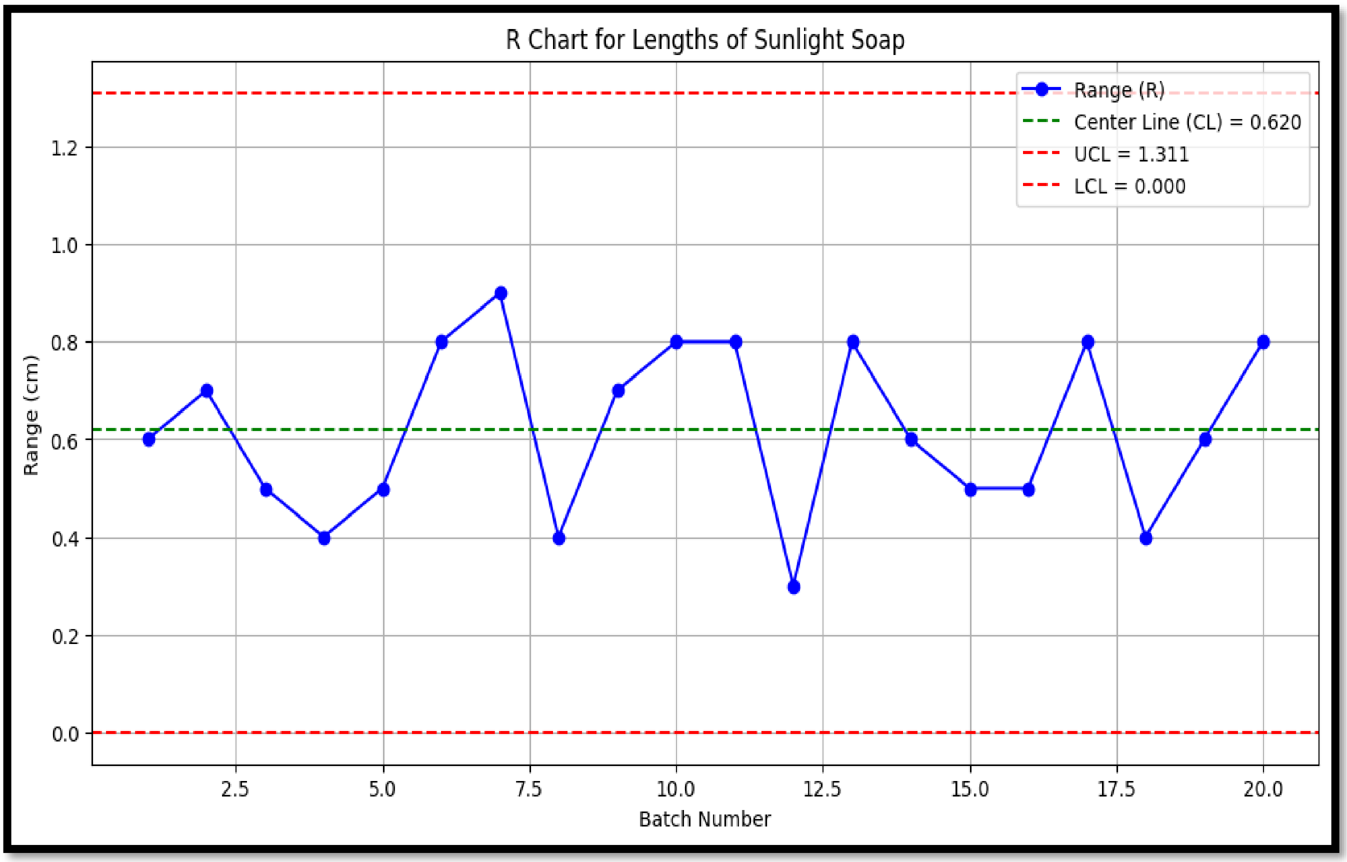


Figure 2: **R** ***Chart for length of Sunlight soap***

Table 4: Runs Test For: $\bar{X}$ *and R Chart*

Statistic	**Z-Value**	**P-Value**	**Conclusion ($\alpha = 0.05$**
$\bar{\mathbf{X}}$	1.207	1.000	Random(fail to reject H_0)
R	0.781	0.706	Random(fail to reject H_0)

The $\bar{X}$ and R charts for Sunlight Soap height show all points within control limits, with run tests confirming random distribution. No trends, cycles, or clustering were detected, indicating the process is statistically stable with variations arising only from common causes.

Attribute Control Chart

A data set drawn from DeVor (2017, p. 431) served as the basis for this study. The dataset consists of defect counts recorded for samples of 100 instrument panels each, gathered over a sequence of 30 consecutive production shifts. This information was employed to demonstrate the development of an initial or trial proportion defective chart, commonly referred to as a p chart. The purpose of constructing the chart was to evaluate whether the process proportion of defective units remained stable and within statistically acceptable limits throughout the observed production period.

Table 5: Defect counts for 30 samples of 100 instrument panels

Sample number	Number of Defectives
1	7
2	8
3	6
4	8
5	6
6	8
7	3
8	5
9	9
10	7
11	7
12	9
13	8
14	7
15	8
16	1
17	10
18	5
19	12
20	11
21	8
22	10
23	4
24	10

Sample number	Number of Defectives
25	7
26	7
27	9
28	8
29	10
30	10

(Jones, 2000)

The data was analyzed on Minitab and the result is given below

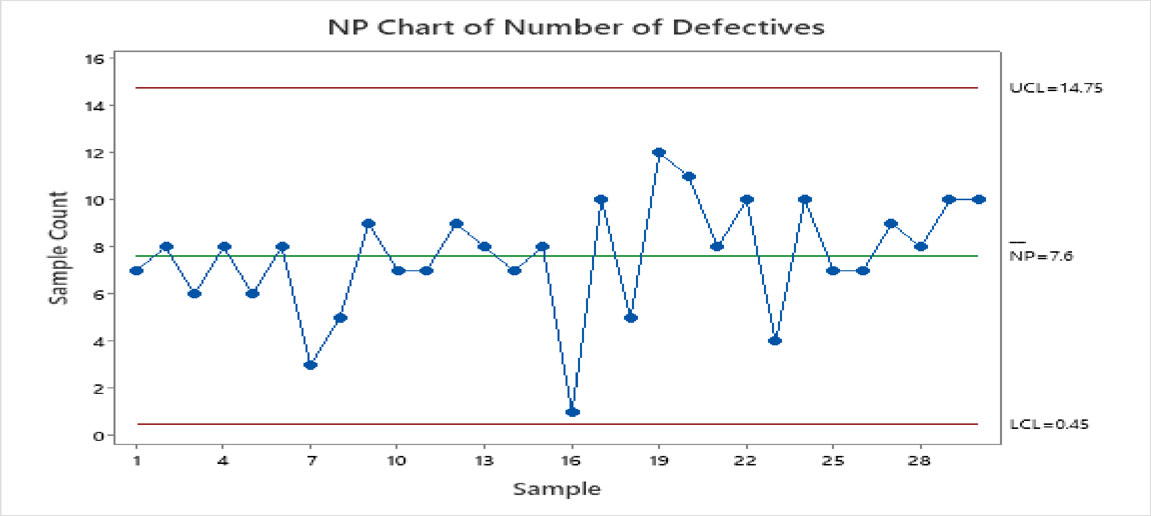
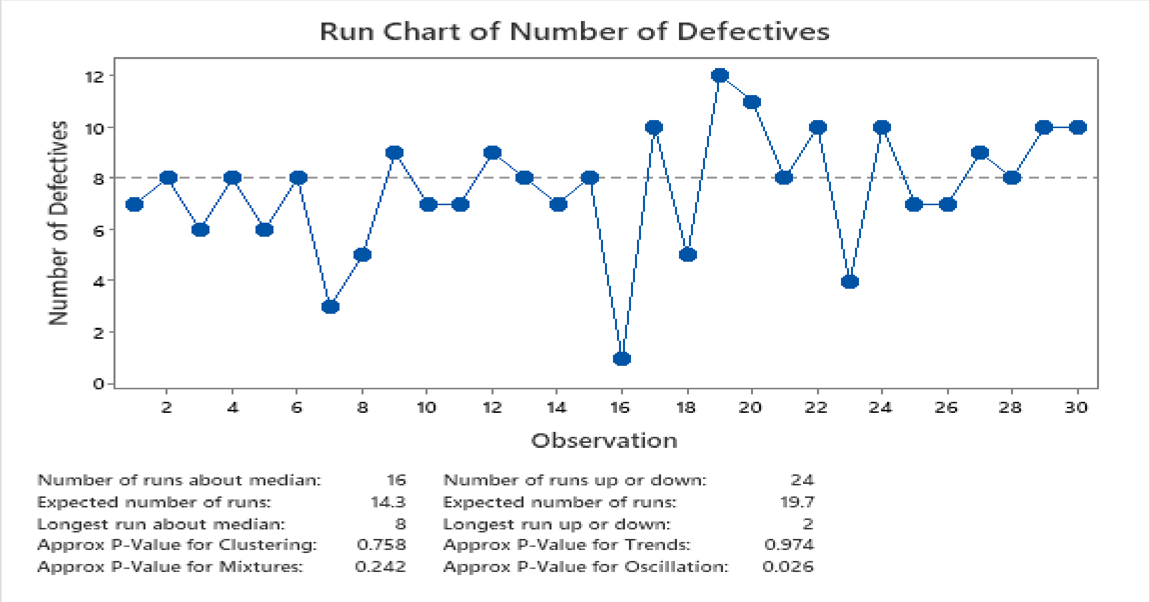


Figure 3: NP Chart of Number of Defectived



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Number of runs about median:       16    Number of runs up or down:        24
Expected number of runs:         14.3    Expected number of runs:        19.7
Longest run about median:           8    Longest run up or down:            2
Approx P-Value for Clustering:  0.758    Approx P-Value for Trends:     0.974
Approx P-Value for Mixtures:    0.242    Approx P-Value for Oscillation: 0.026
```

Figure 4: Run Chart of Number of Defectives

Findings from both graphical assessments indicate that the process remains within statistical control parameters.

Application of Histogram In Process Control

The dataset presented below contains the recorded results of tensile strength evaluations conducted on steel bars produced by Jason Steel Plc. Al-Hadeethi (2015).

Table 6: Frequency of tensile Strength

Tensile strength	Frequency
529.3	3
547.9	3
566.5	4
585.1	2
603.7	10
622.3	14
640.9	25
659.5	10
678.1	14
696.7	13
715.3	6
733.9	11
752.5	14
771.1	5
789.7	6

The data is then analyzed with Minitab and the histogram is illustrated in the figure below,

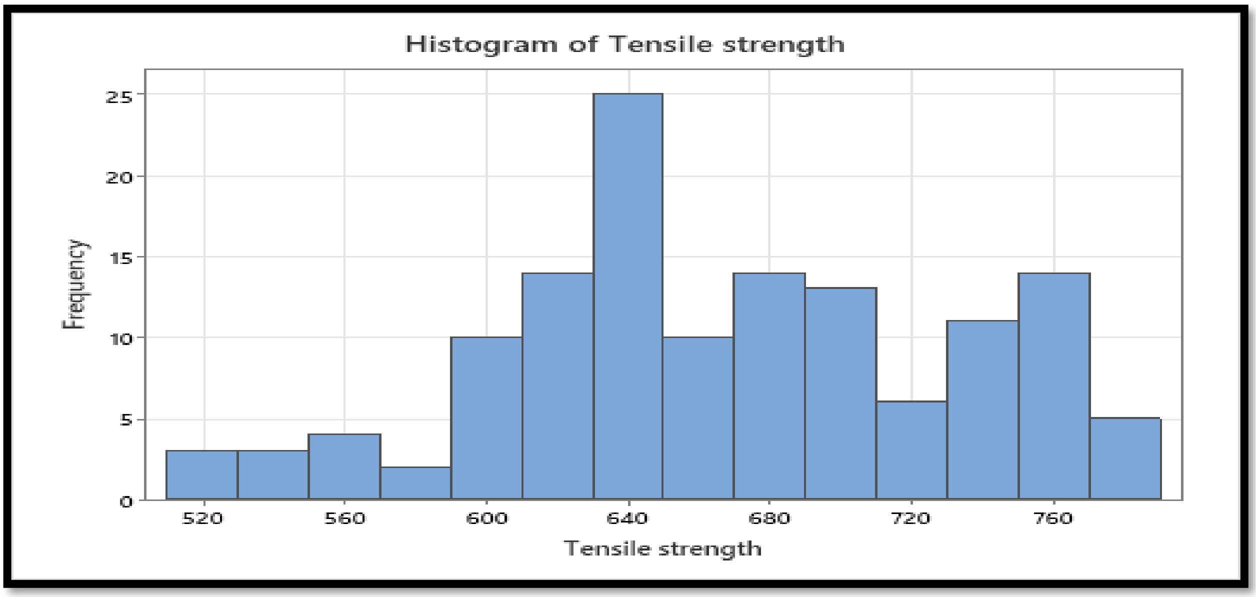

Figure 5: Histogram of Tensile Strength

From the histogram, we can see that the tensile strength of 640.9 recorded the most occurrences.

Application of Pareto Diagram in Process Control

Based on quality control records from tensile testing at Jordan Steel PLC, a tailored frequency distribution chart was created. This chart illustrates the principal measurement outcomes for the company's steel products, derived from systematically documented inspection results. The corresponding dataset is provided in the table for detailed reference. Al-Hadeethi (2015).

Table 7: Application of Pareto Diagram in Process Control at Jordan Steel PLC

Defects category	**Repetition**	**Frequency**
Tensile strength	∣∣∣∣ ⧹∣∣ ⧹∣∣ ⧹∣∣ ∣⧹∣ ⧹∣∣∣ ∣∣∣∣ ∣∣∣	28
Yield Strength	⧹∣∣∣	5
Elongation Percent	∣∣∣	3
Effective diameter	∣∣	2
Effective Weight	∣	1

The cumulative percentages is then calculated

Defects category	**Repetition**	**Frequency**	**Cumulative Frequency**	**Percentage**	**Cumulative Percent**
Tensile strength	NN NN ╲ǀǀǀ ǀǀǀǀ ǀǀǀǀ ǀǀǀ	28	28	72%	72%
Yield Strength	╲ǀǀǀǀ	5	33	85%	85%
Elongation Percent	ǀǀǀ	3	36	92%	92%
Effective diameter	ǀǀ	2	38	97%	97%
Effective Weight	ǀ	1	39	100%	100%

The data is then analyzed on Minitab and the result is given below

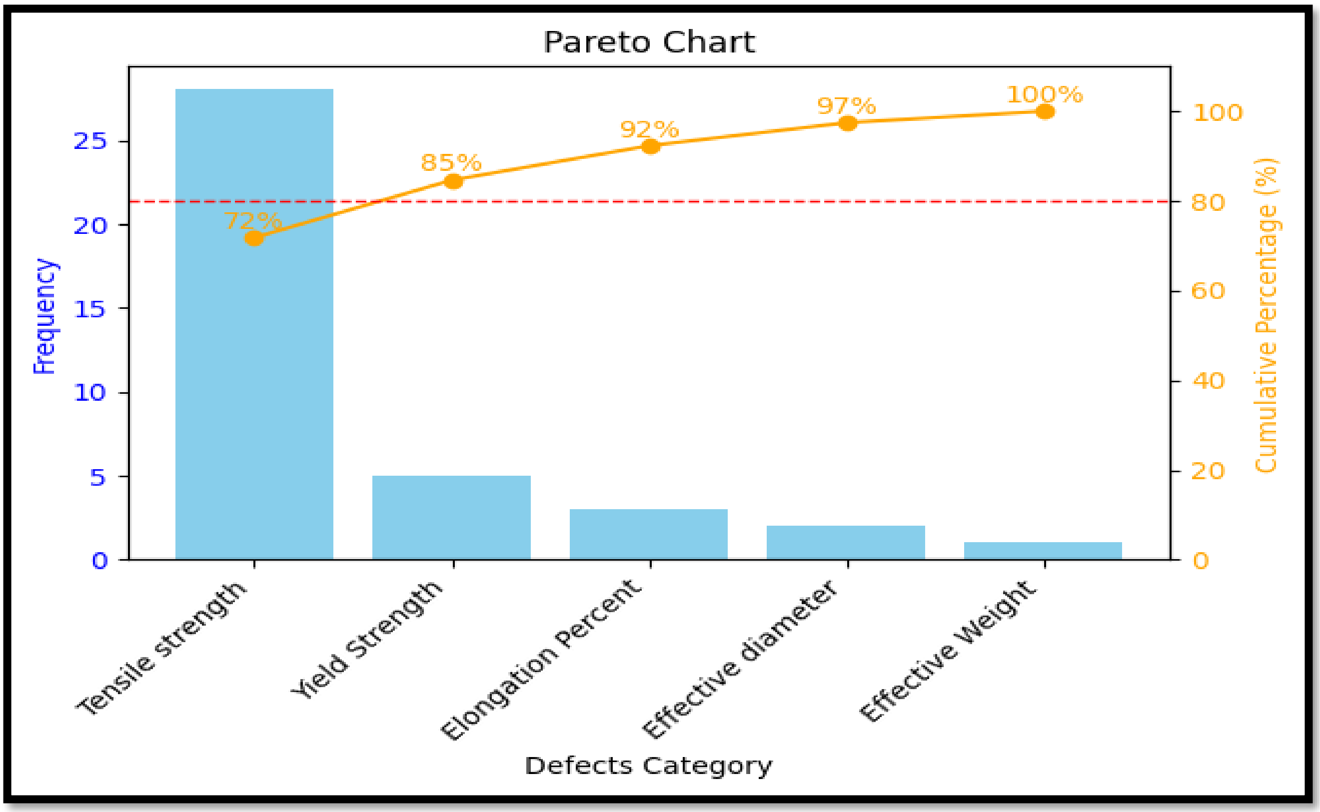

Figure 6: Pareto Chart - Defects in Tensile Testing at Jordan Steel PLC

The Pareto analysis reveals that defects related to tensile strength constitute the largest share, comprising roughly 72 percent of all recorded defects. Applying the 80/20 principle, represented by the dashed reference line, it is evident that tensile strength and yield strength combined account for about 85 percent of the total defects. This distribution indicates that targeted quality improvement initiatives should primarily focus on these two defect categories to achieve the most significant impact.

Application of Scatter Diagram in Process Control

A neighborhood ice cream vendor seeks to determine whether a statistically significant association exists between its daily sales and the midday temperature. To investigate this, the business has recorded ice cream sales alongside the corresponding noon temperature for each of the past twelve days.

Table 8: Daily Ice Cream Sales vs. Midday Temperature

Temperature	Ice Cream Sales($)
14.2°	215
16.4°	325
11.9°	185
15.2°	332
18.5°	406
22.1°	522
19.4°	412
25.1°	614
23.4°	544
18.1°	421
22.6°	445
17.2°	408

https://www.mathsisfun.com/data/scatter-xy-plots.html

The data above is analyzed and scatter diagram is illustrated below,

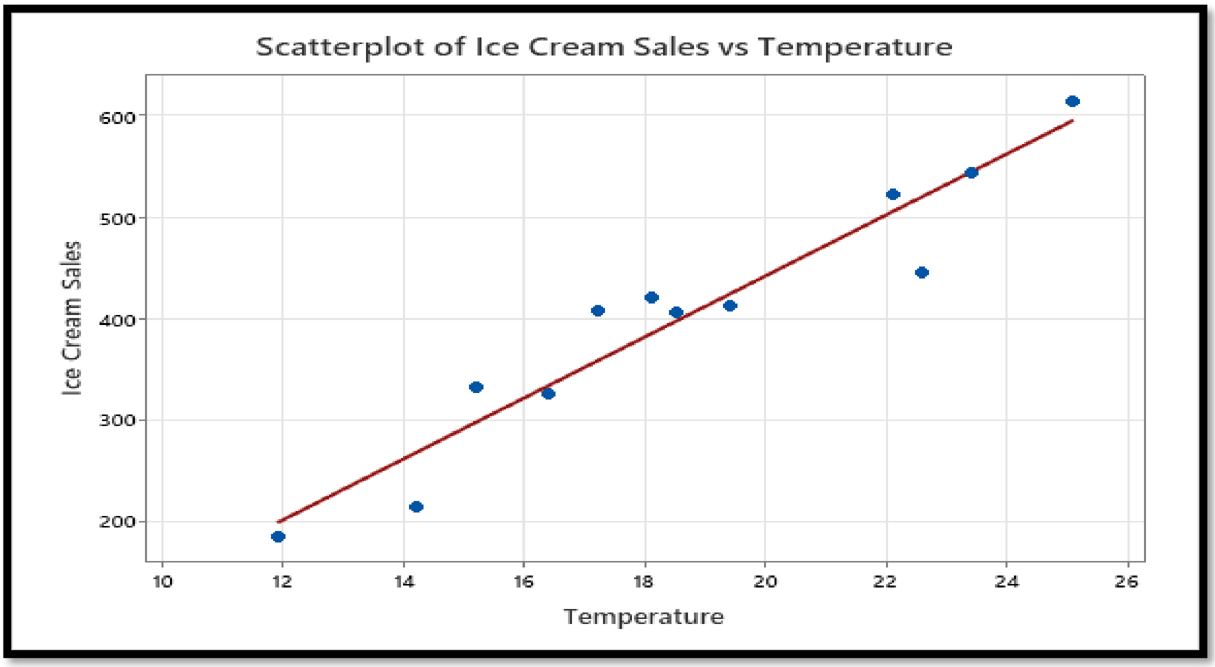

Figure 7: Daily Ice Cream Sales vs. Midday Temperature

From the Scatter Diagram, it is now easy to see that warmer weather leads to more sales, but the relationship is not perfect.

Application of Flowchart in Process Control

In industrial operations such as paper manufacturing, flowcharts illustrate each stage from raw material handling to final product packaging, helping identify critical checkpoints for quality control and process optimization (Domtar, 2021).

The following flowchart depicts the paper manufacturing process beginning with raw material delivery and pulp preparation, progressing through paper forming, drying, and calendering. A quality check step assesses product conformity, directing defective output for rework or allowing the process to proceed. Optional coating and final drying steps precede cutting and packaging, culminating in the finished product ready for distribution.

Figure 8: Flowchart of Packaging of Dye

CONCLUSION

Quality control is crucial for the success and competitiveness of organizations across manufacturing industries. This comprehensive review examined the seven basic quality control tools and highlighted the enduring value of well-established techniques like control charts, sampling plans, TQM, and SPC for identifying process variations and detecting defects. However, the complexities of modern manufacturing and evolving customer expectations necessitate innovative approaches.

This review provides a comprehensive decision making for selecting suitable quality control tools and strategies based on factors like product complexity, production volumes, regulations, and organizational maturity. Successful implementation requires clear quality objectives, employee training, cross-functional collaboration, continuous monitoring and adaptation, and embracing digital transformation. By adopting this comprehensive, forward-looking approach, organizations can minimize defects, reduce costs, enhance customer satisfaction, and maintain a competitive edge while driving continuous improvement in products and services.

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