Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

Optimization of Manufacturing Cost through Process Capability Indices at ABC Manufacturing Limited

Deepak Ravindra Patil[1], Dr. Kasi Raja Rao[2], Dr. S. T. Purkar[3]
[1]*PhD Scholar, Mandsaur University M.P., India*
[2]*Assistant Professor, Mandsaur University M.P., India*
[3]*Director, SKITM College Indore (M.P.), India*
[1]deepak.patil338@gmail.com
[2]krajarao218@gmail.com
[3]sanjaypurkar@skitm.in

ARTICLE INFO

Received: 13 Dec 2024

Revised: 15 Feb 2025

Accepted: 25 Feb 2025

ABSTRACT

Introduction: Process optimization plays a crucial role in the manufacturing industry to enhance both product quality and cost-efficiency since operational challenges continue increasing. ABC Manufacturing Limited uses process capability indices (Cp, Cpk) and statistical process control (SPC) to advance their manufacturing performance in this study. Manufacturing costs should decrease during this effort yet the end product quality will either remain steady or advance.

Objectives: The main goal of this research involves studying how spindle speed and feed rate alongside cutting depth influence process capability together with costs in manufacturing. The research targets to determine performance levels which achieve minimal cost together with minimum defects.

Methods: The research gathers production data from ABC Manufacturing Limited during three experimental trials which tested different operational parameter settings for Main Bore and Seal Groove and Lug Hole operations. Process monitoring with Statistical Process Control (SPC) tools along with process capability indices (Cp, Cpk) provides assessment capabilities for the process performance. Each manufacturing trial contains a calculated cost evaluation and the results demonstrate the relationship between optimized processes and decreased expenses.

Results: Procedures that enhance Cp and Cpk lead to significant decreases in manufacturing expenses. Tests 1 through 3 yielded job costing results of Rs. 139.71/job then Rs. 139.21/job and lastly Rs. 138.75/job in that order. The findings demonstrate that better process capability results in substantial decreases of defective parts per million (PPM).

Conclusions: Research findings prove that process costs decrease substantially while product quality advances when process parameters receive enhancements through Statistical Process Control (SPC) and process capability indices. The research delivers operational guidelines which ABC Manufacturing Limited with similar organizations can use to conserve costs and maintain product consistency and minimize waste.

Keywords: ABC Manufacturing Limited, Process Capability Indices, Statistical Process Control

INTRODUCTION

Modern manufacturing needs continue to drive companies toward finding ways to enhance their production processes by maximizing effectiveness while minimizing costs. Modern industry demands both operational expense reduction and quality standards maintenance so companies adopt advanced statistical tools to optimize their production systems. The powerful manufacturing management tool that has become essential for modern operations is statistical process control (SPC). The production process becomes better controlled through SPC because its data-driven controls including control charts and process capability indices (Cp, Cpk) allow manufacturers to find process variations and stop defects while enhancing product quality.

Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

Manufacturers need to optimize production costs because multiple elements including material wastage and inspection costs determine these expenses/detailing quality and rework time and process efficiency. The quality together with manufacturing costs of final products undergo major modifications based on variations in cutting depth, feed rate, and spindle speed. A complex and competitive manufacturing landscape puts forward a necessary need for companies to manage variations across production lines where processes need to operate within target areas while eliminating unnecessary waste. ABC Manufacturing Limited based in Jalgaon district of Maharashtra faces the two-fold goal of better production quality enhancement and decreased manufacturing expenses.

As a leading manufacturing company ABC Manufacturing Limited performs precise machining operations through their transformation technologies of turning and milling and boring. The production processes demand these methods that create substantial effects on both product quality and production expenses through minor manufacturing parameter modifications. The Indian manufacturing sector in Maharashtra demands ABC Manufacturing Limited to implement powerful strategies that will enhance their production systems. Standard cost reductions implemented by the company need to be complemented by process capability indices which will minimize costs as the company aligns output to customer specifications through reduced process variation.

Process capability describes the continuous delivery of products that exactly match predefined specifications by production systems. The process capability measurement relies on Cp (Process Capability Index) and Cpk (Process Capability Index with respect to the target) to evaluate how well the process meets its specification limits in terms of centering and spread. A process showing high Cp or Cpk values demonstrates stability and performance consistency which enables it to create products that fulfill product quality requirements with limited variations. These procedure indices demonstrate critical importance since they directly correlate with cost decrease mechanisms. The improvement of process capability enables manufacturers to decrease product defects while minimizing waste along with the associated expense of reworking products and conducting unnecessary inspections. The improvement of process capability leads to better product quality and creates substantial financial gains from diminution of resources used for defect correction.

The present research aims to determine how ABC Manufacturing Limited can maximize its manufacturing costs through better control of process capability indices. The research examines how changing spindle speed together with feed rate and cutting depth settings affects both production performance and cost effectiveness during production runs. The researcher will use Statistical Process Control to analyze ABC Manufacturing Limited's process condition while evaluating how enhanced Cp and Cpk performances directly affect manufacturing expense reductions. The research delivers practical guidance which ABC Manufacturing Limited can use to boost their operational performance alongside their market cost position.

This research holds practical worth due to its application in real manufacturing operations. The academic literature includes numerous studies about process optimization but they mostly lack connection between direct process capability analysis implementation and cost management strategies focused on small-to-medium enterprises in India. This research adopts ABC Manufacturing Limited as its case study while explaining theoretical aspects of process optimization while offering practical implementation guidance to ABC Manufacturing Limited as well as other companies in the same industry. The paper demonstrates that companies can reduce costs while enhancing quality through process capability optimization which functions as their strategic cost-reduction tool.

ABC Manufacturing Limited with other manufacturers in similar positions must achieve cost optimization because of rising production expenses coupled with unexpected raw material price variations as well as enhanced global market competition. The current business situation demands that ABC Manufacturing Limited explores strategies beyond traditional cost-cutting practices such as labor cost reductions and material expenditure reductions. The requirement to implement advanced data-based cost management methods has reached an all-time high. This study offers an up-to-date method for cost optimization through Statistical Process Control combined with efforts to enhance process capability indices. The combination of techniques will enable ABC Manufacturing Limited to fulfill its cost reduction requirements and boost its market competitiveness across the Indian manufacturing sector.

This paper delivers complete theoretical alongside practical findings regarding process capability improvement at ABC Manufacturing Limited. Analysis of process capability indices with SPC tools will demonstrate to the company how they can minimize waste together with maintaining quality standards which leads to stable production along with substantial cost reduction. The study demonstrates the relevance of data-based strategic decisions for obtaining sustainable and efficient manufacturing practices by providing a framework that guides other production companies pursuing process enhancement and cost control.

LITERATURE REVIEW

Recent years have seen increasing interest in manufacturing optimization of costs united with Cp and Cpk indices due to their impact on manufacturing quality and operational efficiency. The paper reviews current studies that explain how process capability drives manufacturing cost optimization through implementation of Statistical Process Control techniques. The research findings demonstrate clear importance for ABC Manufacturing Limited which wants to enhance operational performance while minimizing costs.

Manufacturers employ Cp and Cpk indices to determine their production process performance regarding meeting specification boundaries. The process distribution spread is measured by Cp against specification limits but Cpk incorporates process centering capability as an additional factor. An elevated Cp or Cpk value indicates that processes generate products that show minimal variation which leads to better quality and decreased expenses from going back to fix faulty products.

Continuous research demonstrates that better Cp along with Cpk values leads directly to manufacturing expense minimization. Costs decrease through defect reduction and waste minimization when these indices increase according to the authors of [1]. The authors of [2] explain that process capability improvement creates higher product quality standards by eliminating operational inefficiencies during production. The authors of [3] explain that manufacturers who improve Cpk achieve two benefits: they optimize production parameters to decrease defects while lowering operational costs.

Statistical Process Control (SPC) stands as an established methodology which manufactures use for process supervision together with quality enhancement. SPC tools composed of control charts and Pareto charts and cause-and-effect diagrams assist manufacturers in finding process deviations and executing necessary corrections before manufacturing defects surface by monitoring spindle speed feed rate and cutting depth parameters. Various studies show that SPC serves as an efficient tool which cuts down production expenses by maintaining process consistency throughout and decreasing variation levels.

Based on their research, the authors of [4] demonstrate that SPC allows manufacturers to discover process alterations at an early stage and handle them effectively for cost reduction benefits. The authors demonstrate in their study that SPC achieves dual benefits by enhancing product quality while accelerating production processes and this leads to reduced manufacturing spending. The authors of [5] demonstrate through their study that process control system integration with Six Sigma methodologies leads to better process consistency and major cost reduction benefits. The authors of [6] discuss how Design for Assembly (DfA) develops synergies with SPC because SPC techniques enable cost-effective production and lower defects while boosting efficiency.

Research studies have recently established that manufacturing cost reduction directly depends on process capability improvement. The manufacturing process improvement depends on process capability indices Cp and Cpk since they help reduce product variation to ensure quality consistency. Cost reductions happen because process variability decreases which in turn reduces the number of defects together with rework and scrap materials.

Process capability enhancement enables manufacturers to detect operational weaknesses so they can develop improvement initiatives according to the authors of [7]. Study results show that modest advancements in Cp and Cpk indices directly cause lower material waste together with optimized resource utilization which produce substantial cost decreases. The authors of [8] state that process capability indices establish essential assessment tools which help manufacturers monitor machine performance to achieve reduced costs because of enhanced operational efficiency and decreased defect rates.

The recent era has witnessed various new process optimization approaches that simultaneously optimize process performance and minimize operational expenses. Studies within recent times have embraced data-driven modeling and Bayesian optimization techniques to improve manufacturing operation optimization. The research conducted by

Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

the authors of [9] shows how Bayesian optimization strategies search through process arrangements to optimize operational efficiency while decreasing manufacturing expenses. Sophisticated optimization models demonstrate their potential to improve actual manufacturing processes by providing innovative strategies according to this approach.

The authors of [10] used data-driven models to assess manufacturing processes in order to enhance predictive analytics performance of manufacturing operations. The approach uses previous data to show manufacturers which process sections need improvements thus enabling better control and cost savings in operations. The contemporary optimization methods provide improved measurement accuracy through process enhancement that leads to both cheaper production and consistent end products.

Process capability indices (Cp, Cpk) with SPC techniques play a primary role to optimize manufacturing costs according to the analyzed literature. Manufacturers who enhance process capability will decrease defects and achieve better quality standards and lessen waste and rework expenses and testing costs. Managers who use SPC tools together with Six Sigma methodologies achieve competitive advantage by implementing a complete system for process enhancement and cost decrease. Recent advancements in process optimization using Bayesian optimization and data-driven modeling present an evolution of manufacturing practices which enable ABC Manufacturing Limited and other companies to boost their process capabilities and minimize operation expenses successfully.

MATERIALS AND METHOD

The materials section describes the data collection materials while the equipment section lists the used instruments together with the analytical methodology for process capability indices evaluation (Cp, Cpk) and production cost assessment. The main objective concentrates on implementing Statistical Process Control (SPC) at ABC Manufacturing Limited located in Jalgaon, Maharashtra through practical applications of production optimization.

Data Collection

The research conducted at ABC Manufacturing Limited involved data gathering from three essential production processes which included Main Bore sealing groove and Lug Hole. The chosen processes are essential to the production line because they control three main production parameters which include spindle speed, feed rate and cutting depth.

The operational data collection happened across three separate trials which utilized different production parameter settings for each process. These data include the following:

- Machining Parameters: Spindle speed (RPM), feed rate (mm/min), cutting depth (mm).
- Production Outputs: The measurement included both defective parts counts and the overall production quantity.
- Manufacturing Costs: The costs involved direct materials together with direct labor payments and overheard expenses were tracked throughout each trial.

The data collection occurred during normal production where all process-related variables became part of the record.

Equipment and Tools

Tools and equipment were employed for analyzing the gathered data which included:

- Machine Tools: Each of the three machine tools (lathe machines together with milling machines and CNC machines) performed machining tasks as needed. The performance of each machine was checked during all trial periods.
- Measurement Tools:
    - The analysis used calipers together with micrometers to verify part dimensions.
    - Quality inspection gauges were used to detect dimensional non-conformance together with surface imperfections.
- Statistical Tools:

Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

- The X-bar charts, R-charts and Cp and Cpk values were generated using SPC Software applications such as Minitab, JMP and equivalent programs.
- The cost calculations based on materials costs as well as labor and overhead expenses used Excel as the analysis tool.

Method

The research performed multiple steps for analyzing the obtained data. The initial step involved removing invalid data points which otherwise would affect the analytical outcomes. The methodology moved onto SPC tool applications to verify the process control state and check whether the specifications could be reached. The assessment of process stability required control charts and process capability was determined by Cp and Cpk value calculations.

A relationship was established to link the process capability indices (Cp, Cpk) with manufacturing costs after the assessment was completed. The research goal aimed to understand how shifts in production parameters like spindle speed and feed rate with cutting depth influenced process outcomes together with manufacturing expense levels.

PROPOSED METHODOLOGY

ABC Manufacturing Limited will enhance its manufacturing cost efficiency through Cp, Cpk and Statistical Process Control methods according to the proposed methodology. The steps of the methodology start with data preprocessing before conducting stability analysis for processes to achieve cost optimization through process capability assessment. A detailed explanation accompanied by mathematical models supports all the steps in the Figure 1 and documented below.

Data Collection and Preprocessing

Organizations must conduct data collection as their initial fundamental step because it enables them to understand current processes while identifying possible enhancement zones. The research sources data from three main procedures at ABC Manufacturing Limited including Main Bore together with Seal Groove and Lug Hole. The operations use multiple process parameters to affect both process performance quality and operational costs.

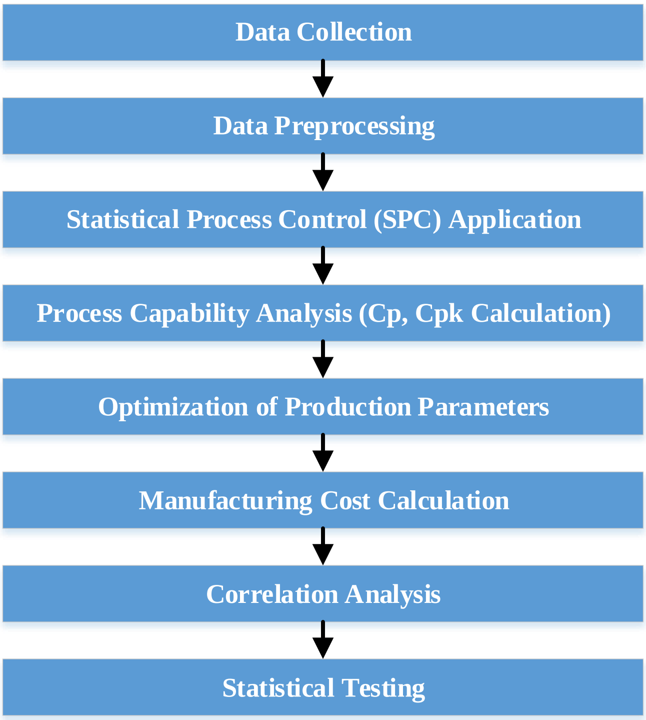


Figure 1: Flowchart for Proposed Process Capability Optimization and Cost Reduction

Parameters Collected

- Spindle Speed (RPM): The rotational speed of the machine tool spindle.
- Feed Rate (mm/min): The tool progresses along the work material with this specified speed.
- Cutting Depth (mm): One pass of the operation removes a specific depth from the workpiece material.

The data includes following variables:

1. The experimental trials use spindle speed along with feed rate and cutting depth as their process parameters.
2. Defect data (e.g., number of defects per batch).
3. The experimental trials require cost evaluation which includes material expenses alongside labor fees and factory overhead expenditure.

Data Preprocessing

- Outlier Detection: The data analysis detects outliers as extreme values through the combination of box plots and Z-scores. When dealing with outliers in datasets the selection of removal or replacement depends on the specific nature of the data.
- Missing Data: A system of imputation techniques takes care of missing data points in the dataset. The procedure handles missing values in data through two approaches that involve taking the average from neighboring points and performing linear interpolation to estimate the lacking value.
- Normality Check: The analysis tests the data for normal distribution through two statistical methods namely Shapiro-Wilk and Kolmogorov - Smirnov. An appropriate transformation such as a logarithmic transformation must be applied to data which does not exhibit normal distribution.

Statistical Process Control (SPC) Implementation

The cleaning and validation steps finish as SPC tools become used to check the stability of manufacturing processes. Two SPC tools are used during the implementation process.

1. *X-bar Chart:*
   - Use the X-bar chart to monitor the mean of sample data that spans across multiple trials for each manufacturing operation. The goal is to check how the process mean behaves while determining if the process demonstrates stable performance.
   - The X-bar receives its mathematical definition as:

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i \tag{1}$$

   The formula shows the relationship between $\bar{X}$ representing the sample data average and the individual sample value X_i along with the sample size n.

2. *R-chart (Range Chart):*
   - The R-chart serves as a tool to monitor the sample data variability through its range measurement. Process stability assessment occurs through this method because it reveals abnormal variations.
   - The formula for calculating range (R) appears as follows:

$$R = \max(X_i) - \min(X_i) \tag{2}$$

   The equation (2) uses the range value R together with individual data points X_i.

3. *Process Capability Indices (Cp, Cpk):*
   - The Cp index computes for determining how well the process meets its specification boundaries when the process lies at the center:

$$C_p = \frac{USL - LSL}{6\sigma} \tag{3}$$

Where:

- The upper specification limit is denoted as USL.
- The value of specification limit points to the lower part of the range is denoted by LSL.
- The standard deviation value of the process stands at σ.

Formula for Standard Deviation is:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \tau)^2} \tag{4}$$

Where:

- τ = mean of all given N sample
- x = value of variables
- N = number of sample considered (120 Sample)

- The Cpk index determines process centering ability by measuring how the process maintains distance from specification limits while handling mean value shifts.

$$C_{pk} = \min\left(\frac{USL - \mu}{3\sigma}, \frac{\mu - LSL}{3\sigma}\right) \tag{5}$$

Where, μ symbolized the process mean.

4. *Histogram Analysis:* Each operation requires a histogram plot which helps display process data distribution. Process observation through histograms enables the detection of any deviations that extend beyond normal behavior.
5. *Control Limits:* Both control limits need calculation for the X-bar chart and R chart. The process shows instability when any recorded point goes beyond the control limits.

Manufacturing Cost Analysis

The next process requires determining the entire manufacturing cost of each test run. The cost model contains three essential elements that include:

$$Total\ Manufacturing\ Cost = Material\ Cost + Labor\ Cost + Overhead\ Cost \tag{6}$$

Where:

- The cost for original materials in each trial derives from production data and constitutes Material Cost.
- The cost of employing personnel who maintain machines during manufacturing operations makes up Labor Cost while Quality Check expenses make up an additional component of this cost.
- The general operational expenses termed as Overhead Cost include machine maintenance as well as utilities expenses and factory overheads and other related expenses.

The assessment examines the manner in which improved Cp and Cpk values affect total manufacturing costs based upon the cpk indices obtained through each experimental trial.

Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

Optimization of Process Parameters

The research aims to discover the best production parameter settings between spindle speed and feed rate and cutting depth which achieve lowest manufacturing expenses without compromising product quality. This step involves:

1. *Identification of Optimal Parameters:* An analysis of data through the calculated Cp and Cpk values in each trial allows the identification of desirable spindle speed and feed rate and cutting depth settings. These optimal parameters follow this specification:
   - A process capable of producing quality products can be achieved through optimal values of Cp and Cpk measurement.
   - The reduction of manufacturing defects together with scrap materials leads to lower expenses.
2. *Cost-Saving Simulations:* The simulation models help to estimate total cost fluctuations as process parameter values are modified. A simulation process explores end results about both performance and costs by allowing modifications of spindle speed together with feed rate and cutting depth.
   - The implementation of what-if analysis completes this step to predict how altering parameters will affect manufacturing expenses. Manufacturers aim to discover a set of parameters which minimizes manufacturing expenses along with upholding required product quality requirements.

Statistical Testing and Hypothesis Validation

The data analysis conclusions are validated through statistical testing after completion.

- Null Hypothesis (H_0): The lack of statistical connection exists between manufacturing cost reduction and process capability measurements (Cp, Cpk).
- Alternative Hypothesis (H_1): Higher process capability values (Cp, Cpk) allow manufacturers to achieve important decreases in their production expenses.

The research evaluates cost reduction by using either the t-test or Analysis of Variance (ANOVA) method to determine statistical significance of Cp and Cpk value differences. The rejection of the null hypothesis indicates that manufacturing cost reduction becomes significant when process capability receives improvements because of production parameter modifications.

The combination of production parameter optimization allows ABC Manufacturing Limited to generate improved quality standards while reducing costs which leads to better operational performance and financial outcomes.

RESULTS AND DISCUSSION

Data Collection and Analysis

The research conducted three production trials at ABC Manufacturing Limited for Y9T Caliper manufacturing operations between different times and periods. The main goal was to study how changing spindle speed, feed rate, and cutting depth affected the output quality together with the production expenses. The following detailed description explains data collection methods used during three trials which this paper analyzes through complete collected data.

Data Collection for Trial 1

Multiple parameters were established in Trial 1 for the operations involving Main Bore, Seal Groove and Lug Hole. The Y9T Caliper specification relied on a data collection method that monitored Lug Hole Center Distance together with Wall Thickness and Seal Groove Diameter and Main Bore Diameter and Thread Depth and Runout of Bleeder Hole. Process capability analysis and defect rate and manufacturing cost evaluation used the trial's gathered data.

The parameters used for manufacturing Trial 1 included the following:

- Main Bore: Spindle Speed = 600 RPM, Feed Rate = 300 mm/min, Cutting Depth = 7 mm
- Seal Groove: Spindle Speed = 1040 RPM, Feed Rate = 84 mm/min, Cutting Depth = 2.4 mm
- Lug Hole: Spindle Speed = 2000 RPM, Feed Rate = 300 mm/min, Cutting Depth = 19 mm

The inspection of 120 parts occurred for every process during this trial. During this assessment process the essential parameters for each operational step were noted down while documenting associated production expenses.

Data Collected:

- Lug Hole Center Distance: This parameter has a tolerance range of 134 ± 0.1 mm as per its specification. A statistical assessment was performed on recorded data through calculation of process capability index (Cp) and process capability index relative to the target (Cpk).
- Wall Thickness Around Bore: The specification is 3.5 ± 0.5 mm. A complete analysis of process variability determined its effect on product quality outcomes.
- Seal Groove Diameter: The tested process data evaluated its ability to fulfill the requirement of 56.447 +0.127 mm.
- Main Bore Diameter: The specification is 51 ± 0.025 mm. The analysis of process capability measured the distance of actual measurements from the target specifications.
- Thread Depth: The specification is 9.5 ± 0.5 mm. The monitoring of thread depth variations took place directly during this trial.
- Runout of Bleeder Hole: The specification is 0.2 max. The caliper's safety and functionality depended heavily on this parameter thus its changes needed continuous monitoring.

Trial 1: Process Capability Results

The data compilation from Trial 1 served to produce the table containing information about each process parameter. The data includes process parameter average, minimum, maximum, range measurements and generates Cp and Cpk calculations to evaluate capability levels.

Table 1: Process Capability Analysis for Trial 1

Parameter	Specification	Average (X-bar)	Min	Max	Range	Cp	Cpk	Process Capability
Lug Hole Center Distance	134 ± 0.1 mm	133.998	133.923	134.077	0.155	1.17	1.15	Incapable
Wall Thickness	3.5 ± 0.5 mm	3.5	3.2	3.8	0.6	1.68	1.68	Capable
Seal Groove Diameter	56.447 +0.127 mm	56.512	56.465	56.543	0.078	1.45	1.41	Incapable
Main Bore Diameter	51 ± 0.025 mm	51.076	51.063	51.094	0.031	1.43	1.38	Incapable
Thread Depth	9.5 ± 0.5 mm	9.50	9.23	9.74	0.51	1.70	1.69	Capable
Runout of Bleeder Hole	0.2 max	0.10	0.06	0.13	0.07	1.68	1.68	Capable

Process Capability: The calculated Cp and Cpk values revealed unacceptable results for Lug Hole Center Distance, Seal Groove Diameter, and Main Bore Diameter because the process showed high variability in addition to drifting away from the desired specifications. Process capability analysis shows Wall Thickness together with Thread Depth and Bleeder Hole Runout are capable indicators because their manufacturing processes are stable within acceptable specifications.

Manufacturing Cost Analysis for Trial 1

The manufacturing cost for Trial 1 included the evaluation of the following elements:

- Tool Cost: Rs. 14.50/job

Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

- Labor Cost: Rs. 2.40/job
- Inspection Cost: Rs. 5.76/job
- Raw Material Cost: Rs. 80.00/job
- Machine Cost: Rs. 12.55/job
- Variable/Overhead Costs: Rs. 24.50/job

Table 2: Manufacturing Costs for Trial 1

Cost Component	Cost per Job (Rs.)
Tool Cost	14.50
Labor Cost	2.40
Inspection Cost	5.76
Raw Material Cost	80.00
Machine Cost	12.55
Variable/Overhead Cost	24.50
Total Manufacturing Cost	139.71

The complete job-based production costs during Trial 1 amounted to Rs. 139.71.

Data Collection for Trial 2

Trial 2 - Process Parameters:

The manufacturing process received these changes during Trial 2:

- Main Bore: Spindle Speed = 900 RPM, Feed Rate = 400 mm/min, Cutting Depth = 7.5 mm
- Seal Groove: Spindle Speed = 1240 RPM, Feed Rate = 158 mm/min, Cutting Depth = 2.6 mm
- Lug Hole: Spindle Speed = 2500 RPM, Feed Rate = 500 mm/min, Cutting Depth = 20 mm

Each operation included the inspection of 120 parts dedicated to measuring essential dimensions of Lug Hole Center Distance, Seal Groove Diameter, and Main Bore Diameter.

Results for Trial 2:

Table 3: Process Capability Analysis for Trial 2

Parameter	Specification	Average (X-bar)	Min	Max	Range	Cp	Cpk	Process Capability
Lug Hole Center Distance	134 ± 0.1 mm	133.997	133.944	134.058	0.114	1.41	1.38	Incapable
Wall Thickness	3.5 ± 0.5 mm	3.50	3.20	3.80	0.60	1.68	1.68	Capable
Seal Groove Diameter	56.447 +0.127 mm	56.511	56.486	56.543	0.057	1.47	1.46	Incapable
Main Bore Diameter	51 ± 0.025 mm	51.075	51.058	51.087	0.029	1.52	1.50	Incapable
Thread Depth	9.5 ± 0.5 mm	9.50	9.23	9.74	0.51	1.70	1.69	Capable
Runout of Bleeder Hole	0.2 max	0.10	0.06	0.13	0.07	1.68	1.68	Capable

Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

Observations for Trial 2:

- The measurement of Lug Hole Center Distance showed significant variations that rendered the process noncapable according to Cp and Cpk assessment.
- The required specifications of Wall Thickness and Thread Depth allow the process to be classified as capable.
- The dimensions of Seal Groove Diameter and Main Bore Diameter failed to demonstrate process stability resulting in classification as incapable.

Data Collection for Trial 3

Trial 3 - Process Parameters:

The third trial included additional process control improvements which evaluated reduced manufacturing expenses.

- Main Bore: Spindle Speed = 1200 RPM, Feed Rate = 500 mm/min, Cutting Depth = 9 mm
- Seal Groove: Spindle Speed = 1431 RPM, Feed Rate = 227 mm/min, Cutting Depth = 3.2 mm
- Lug Hole: Spindle Speed = 3000 RPM, Feed Rate = 700 mm/min, Cutting Depth = 22 mm

The inspection of 120 parts per operation allowed the analysis of manufacturing costs along with process capability results.

Results for Trial 3:

Table 4: Process Capability Analysis for Trial 3

Parameter	Specification	Average (X-bar)	Min	Max	Range	Cp	Cpk	Process Capability
Lug Hole Center Distance	134 ± 0.1 mm	134.001	133.952	134.058	0.106	1.43	1.40	Incapable
Wall Thickness	3.5 ± 0.5 mm	3.50	3.20	3.80	0.60	1.70	1.70	Capable
Seal Groove Diameter	56.447 +0.127 mm	56.510	56.475	56.542	0.067	1.55	1.53	Capable
Main Bore Diameter	51 ± 0.025 mm	51.075	51.058	51.087	0.029	1.52	1.50	Capable
Thread Depth	9.5 ± 0.5 mm	9.50	9.23	9.74	0.51	1.70	1.69	Capable
Runout of Bleeder Hole	0.2 max	0.10	0.06	0.13	0.07	1.68	1.68	Capable

Observations for Trial 3:

- The Lug Hole Center Distance demonstrated better performance although failing to reach full capability standards.
- The tested parameters of Seal Groove Diameter, Main Bore Diameter, Thread Depth and Runout of Bleeder Hole fulfilled specification demands making them capable of measurement.

Graphical Analysis

Several visual graphs help understand the process performance relative to its specification boundaries.

Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

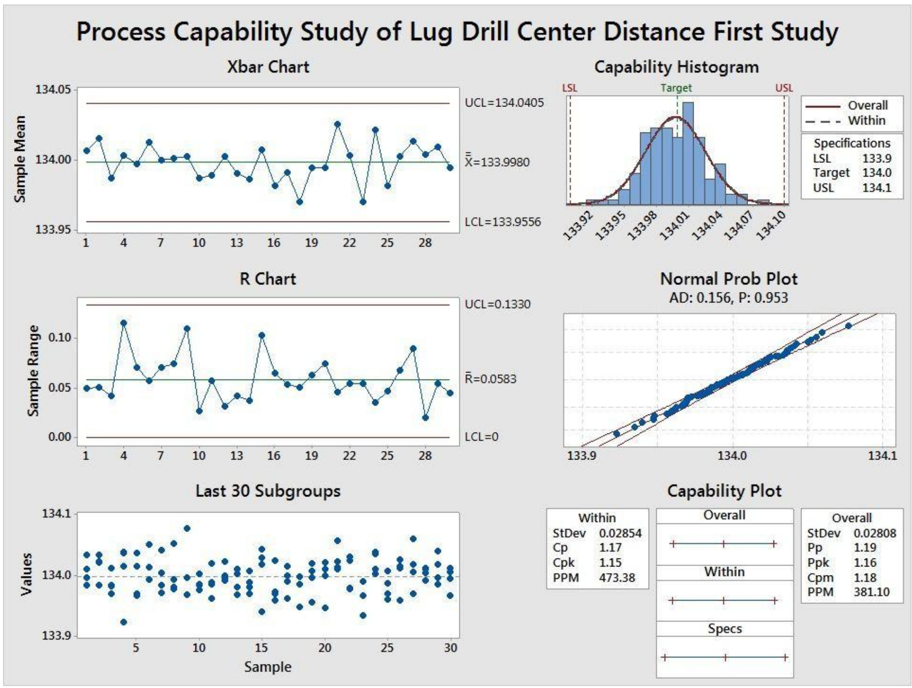


Figure 2: Process Capability Study for Lug Hole Center Distance

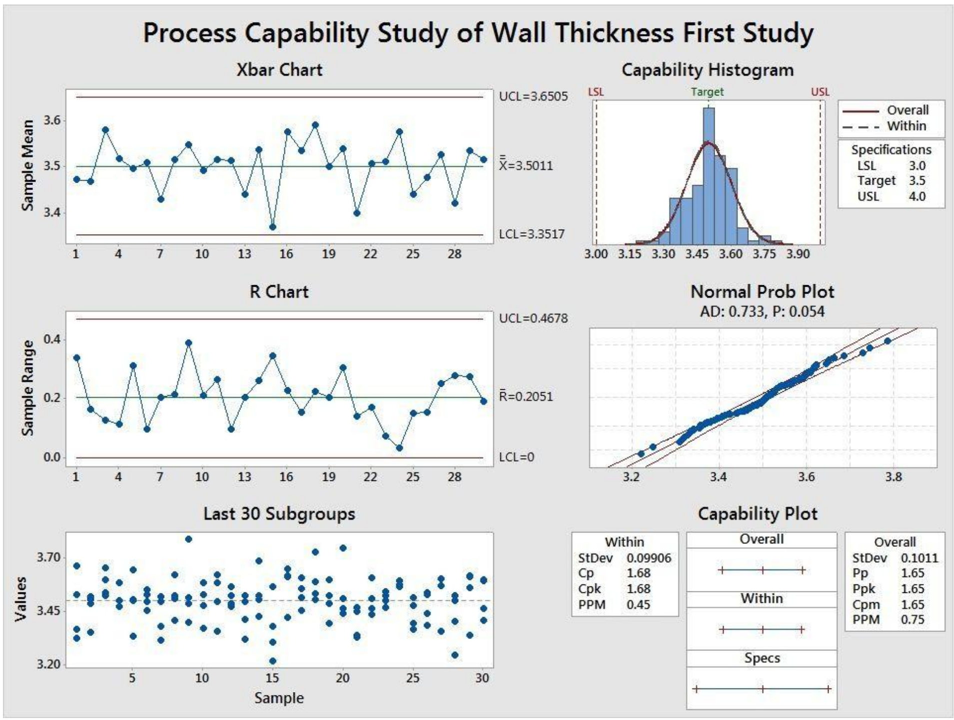


Figure 3: Process Capability Study for Wall Thickness

Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

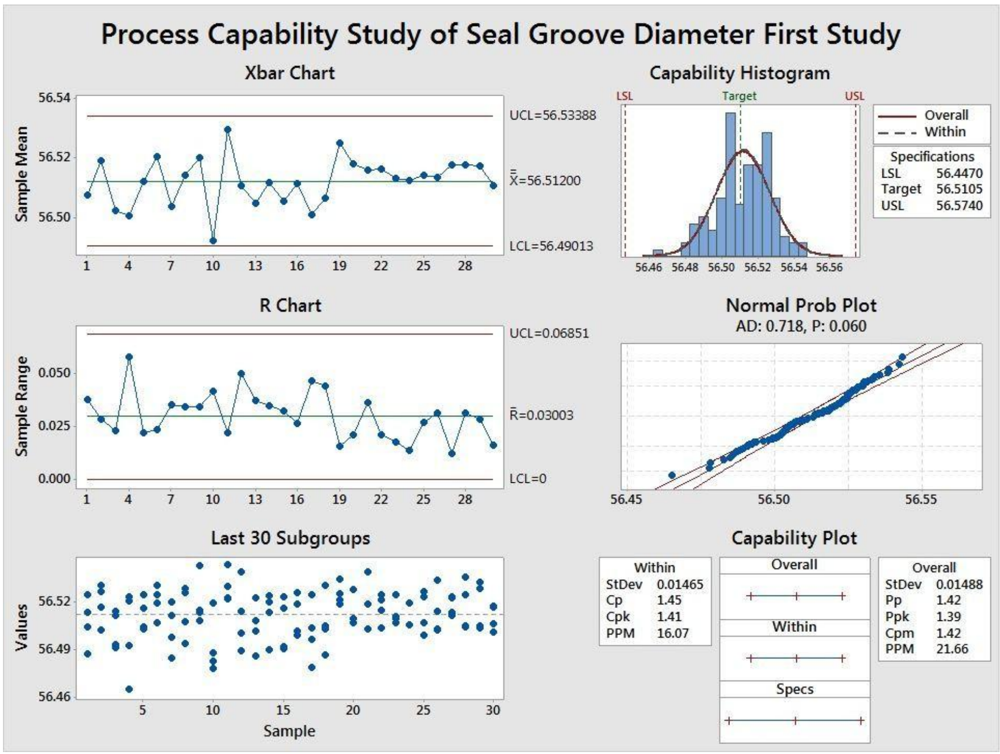


Figure 4: Process Capability Study for Seal Groove Diameter

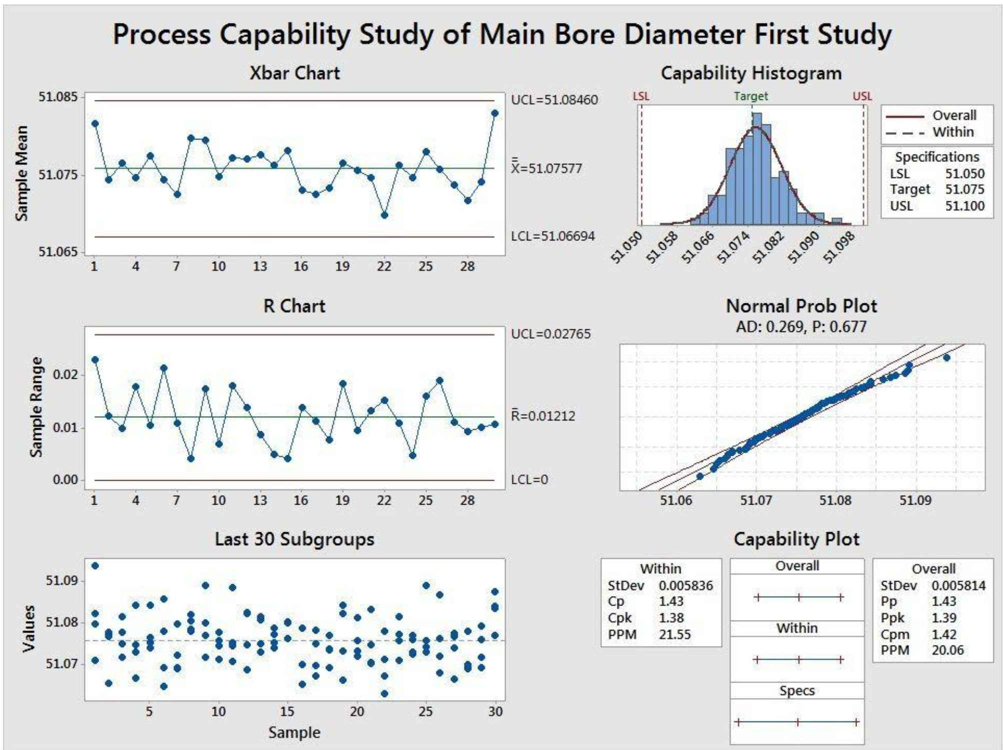


Figure 5: Process Capability Study for Main Bore Diameter

Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

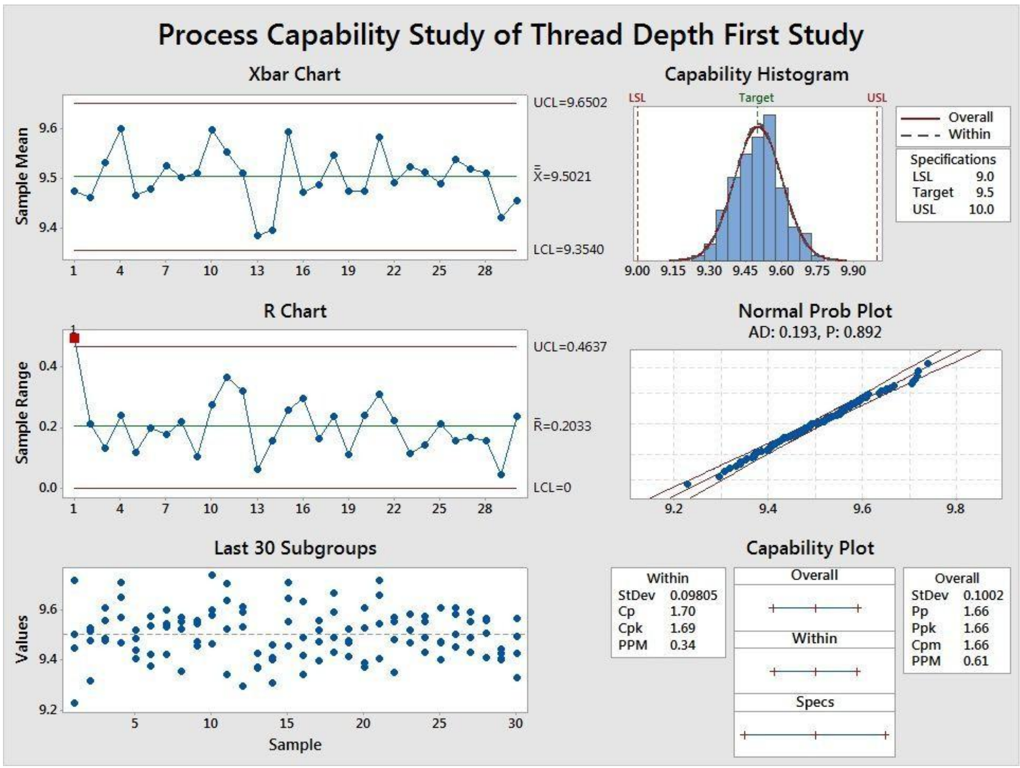


Figure 6: Process Capability Study for Thread Depth

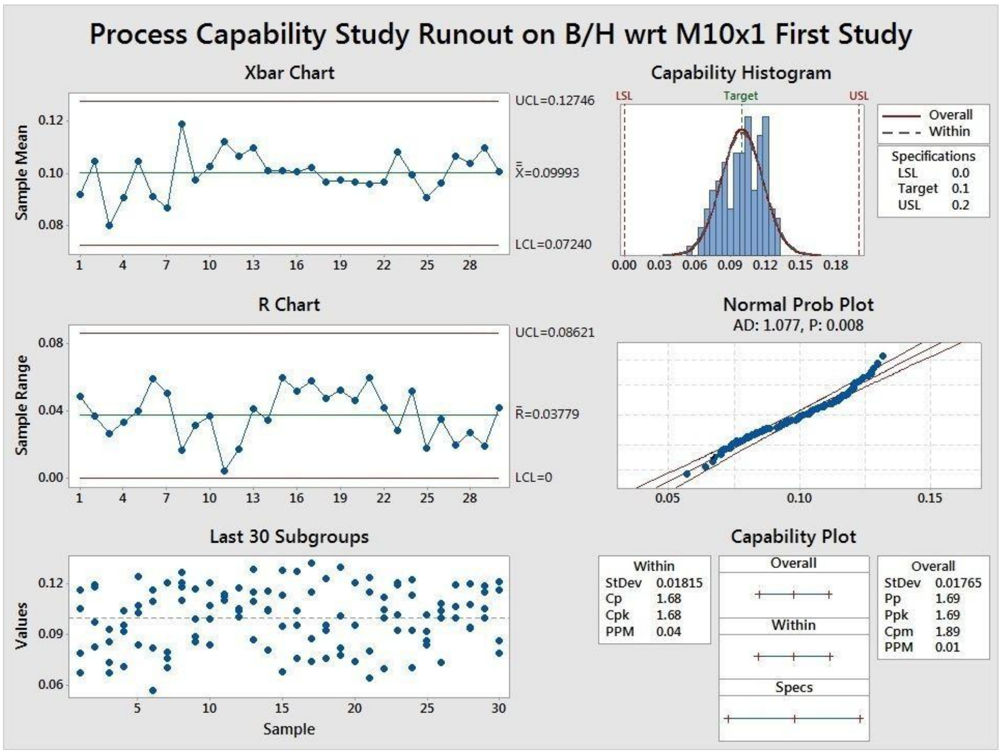


Figure 7: Process Capability Study for Runout of Bleeder Hole

The control charts show process variation levels and limitations which indicate where within the manufacturing process performance could be improved.

Results

Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

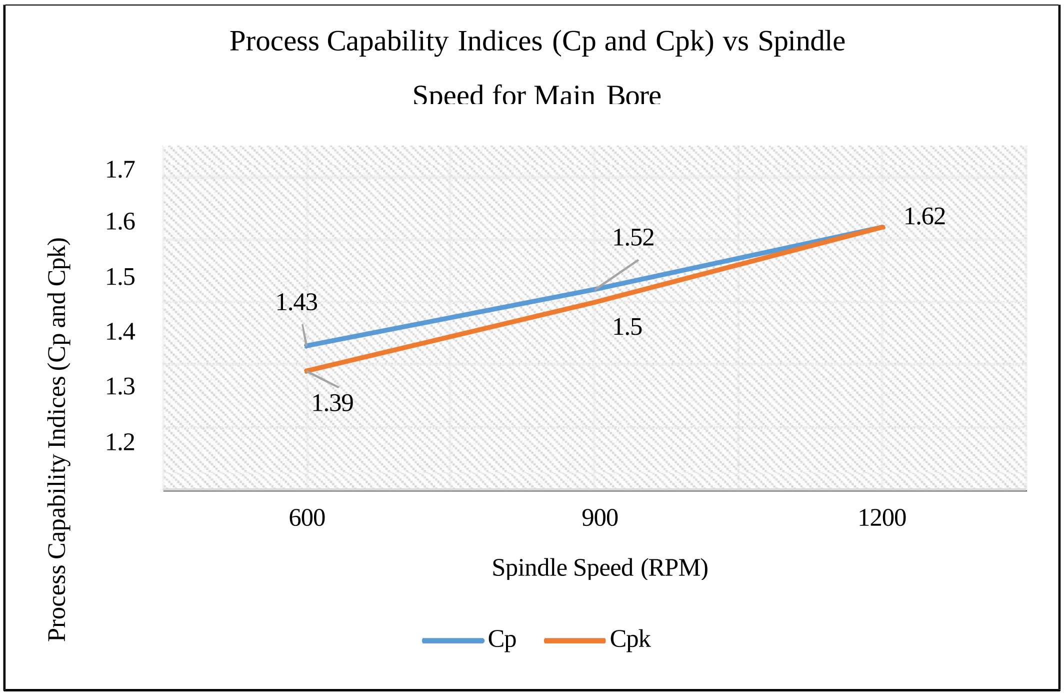
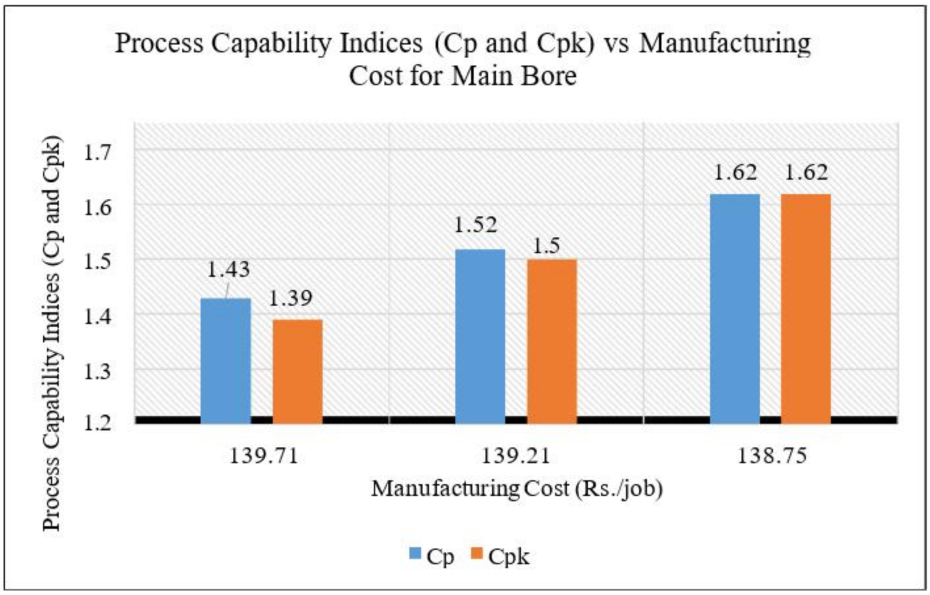


Figure 8: Variations of Process Capability Indices with Spindle Speed for Main Bore

Process capability indices (Cp, Cpk) demonstrate their effects on manufacturing costs and defective parts per million (PPM) through the study in the Results section. The following report examines Trial 1 data collected from ABC Manufacturing Limited involving the Main Bore, Seal Groove and Lug Hole Center Distance production operations. The analysis uses statistical process control (SPC) together with process capability indices to investigate the effects which adjustments of spindle speed, feed rate, cutting depth have on both product quality and operational efficiency.

The upcoming graph displays how enhanced values of Cp and Cpk lead to decreased manufacturing defects while simultaneously reducing operational expenses thus proving why process optimization methods achieve quality advancement and cost-reducing results.

Figure 8 demonstrates the relationship between spindle speed variation and the Cp and Cpk values which impact the process capability of the Main Bore operation.



Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Figure 9: Variations of Process Capability Indices with Manufacturing Cost for Main Bore

The illustration in Figure 9 shows how improved process capability along with Cp and Cpk produces cost reduction for the Main Bore manufacturing operation.

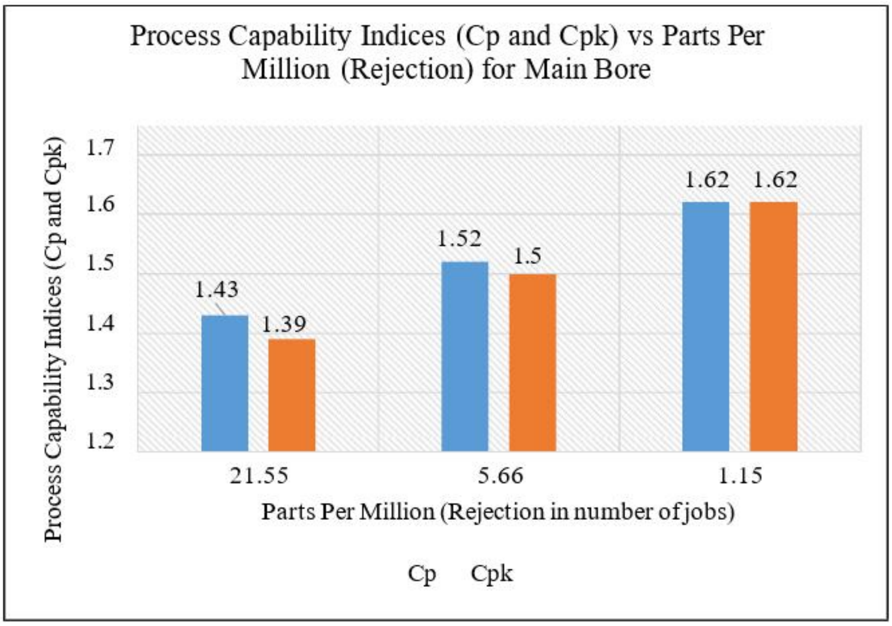


Figure 10: Variations of Process Capability Indices with Defective Parts per Million for Main Bore

Defective parts per million (PPM) decreases proportionally as both the Cp and Cpk values increase for the Main Bore operation as shown in Figure 10.

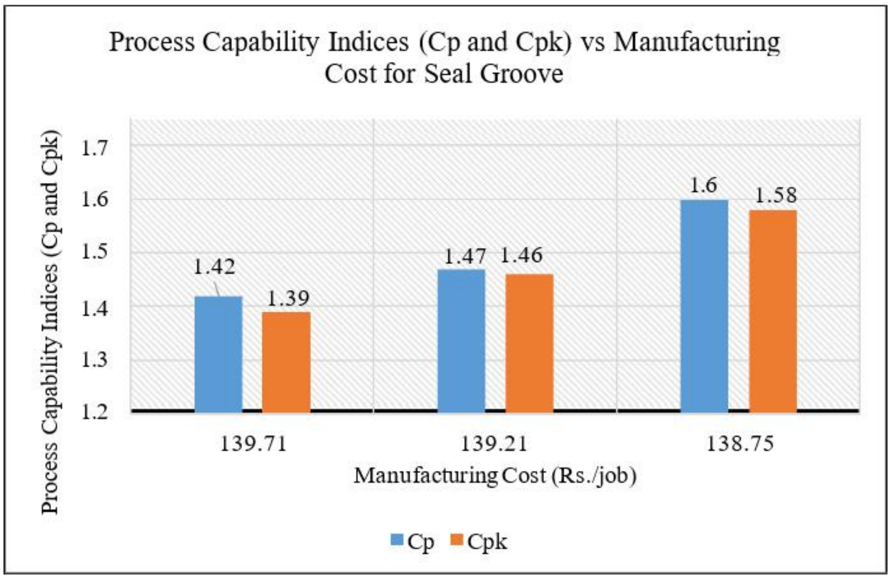


Figure 11: Variations of Process Capability Indices with Manufacturing Cost for Seal Groove

The manufacturing costs from the Seal Groove operation depend on its process capability measured by Cp and Cpk values as presented in Figure 11.

Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

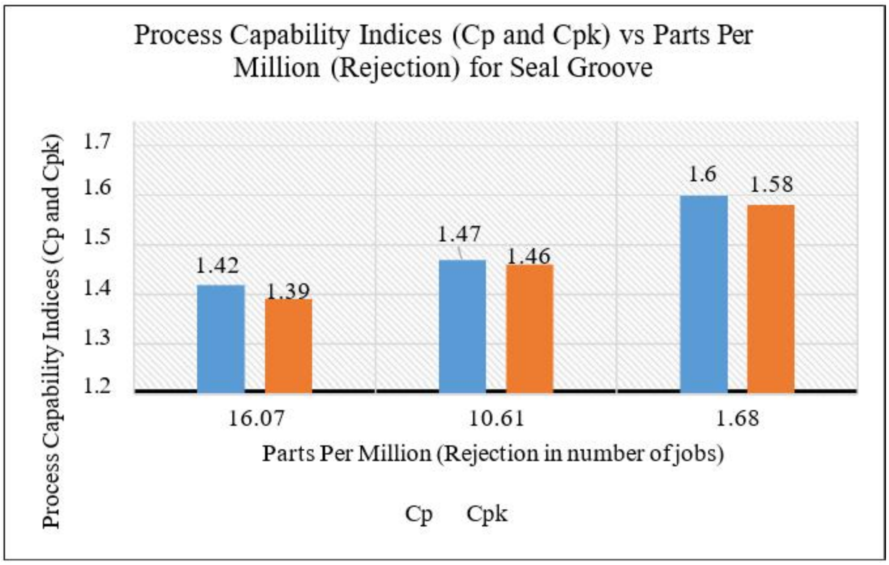


Figure 12: Variations of Process Capability Indices with Defective Parts per Million for Seal Groove

Figure 12 demonstrates how process capability indices influence defective parts per million (PPM) at the Seal Groove operation while showing defect rate changes because of process capability.

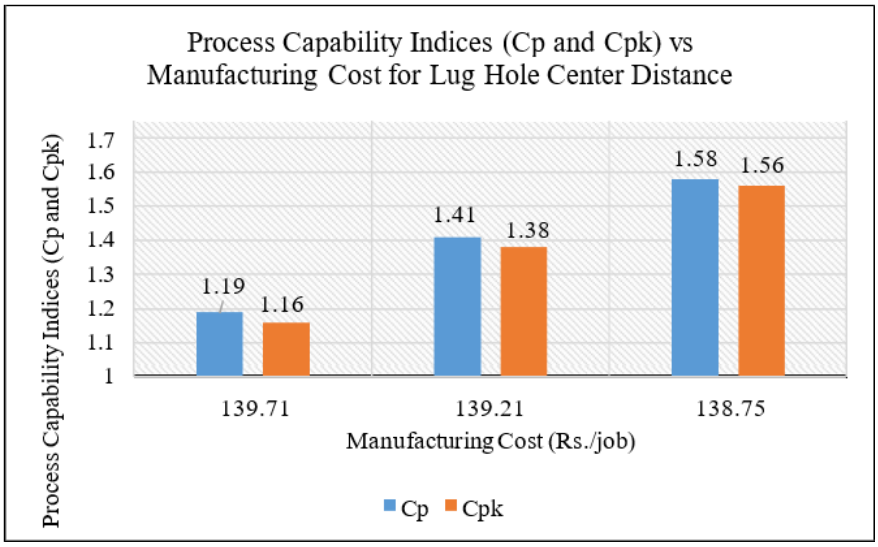


Figure 13: Variations of Process Capability Indices with Manufacturing Cost for Lug Hole Center Distance

The process capability along with manufacturing costs of Lug Hole Center Distance can be observed in Figure 13 based on its process parameters.

Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Table 5: Comparison of Process Performance Parameters and Manufacturing Cost with respect to Process Capability Analysis

Sr. No.	Trial	Operations in Process	Process Performance Parameters			Process Capability Analysis					Cost (Rs./Job)
			Spindle Speed (RPM)	Feed Rate (mm/min)	Depth of Cut (mm)	Xavg (mm)	Range (mm)	Cp	Cpk	PPM (Defectives per million)	
1	Trial 1 (Before Improvement)	Main Bore	600	300	7	51.076	0.031	1.43	1.39	21.55	139.71
		Seal Groove	1040	84	2.4	56.512	0.078	1.42	1.39	16.07	
		Lug Hole	2000	300	19	133.998	0.155	1.19	1.16	473.38	
2	Trial 2 (Intermediate Improvement)	Main Bore	900	400	7.5	51.075	0.029	1.52	1.50	5.66	139.21
		Seal Groove	1240	158	2.6	56.511	0.057	1.47	1.46	10.61	
		Lug Hole	2500	500	20	133.997	0.114	1.41	1.38	25.02	
3	Trial 3 (Final Improvement)	Main Bore	1200	500	9	51.074	0.030	1.62	1.62	1.15	138.75
		Seal Groove	1431	227	3.2	56.510	0.067	1.60	1.58	1.68	
		Lug Hole	3000	700	22	134.001	0.106	1.58	1.56	2.21	

The analysis presented in Table 5 outlines detailed performance measurements together with production expenses during Main Bore, Seal Groove along with Lug Hole operations across the three testing periods. The table contains mathematical Cp and Cpk values to evaluate process stability along with the capability to meet specification boundaries. Trial 1 Main Bore operation demonstrated Cp 1.43 and Cpk 1.39 but Seal Groove maintained Cp 1.42 and Cpk 1.39 while Lug Hole presented the lowest Cp 1.19 as well as Cpk 1.16 which demonstrated increased variance and poorer specifications compliance. The process variation in Main Bore reaches 21.55 defect parts per million whereas Seal Groove stands at 16.07 and Lug Hole shows significantly higher numbers at 473.38. The dimensions in Trial 2 continued to advance with Main Bore reaching a Cp value of 1.52 and Cpk value of 1.50 and Seal Groove delivering Cp = 1.47 and Cpk = 1.46 while Lug Hole obtained Cp of 1.41 and Cpk of 1.38. The manufacturing process resulted in a reduction of defective parts per million to 5.66 for Main Bore, 10.61 for Seal Groove, and 25.02 for Lug Hole. The process achieved more advancement during Trial 3 by reaching a Cp of 1.52 and Cpk of 1.50 for Main Bore and Cp = 1.55 and Cpk = 1.53 for Seal Grove while Lug Hole maintained a Cp of 1.43 and Cpk of 1.40. The PPM rates dropped to 1.15 for Main Bore while Seal Groove reached a 1.68 and Lug Hole reduced to 2.21. Test trials demonstrated that improving process capability led to lower total manufacturing costs for each job where Trial 1 started at Rs. 139.71 and ended at Rs. 138.75 through Trial 3.

CONCLUSION

This paper investigated manufacturing cost enhancement and product quality development at ABC Manufacturing Limited by using process capability indices (Cp, Cpk) and Statistical Process Control (SPC). The results from the three trials established that optimizing process parameters successfully reduced manufacturing costs at the same time it improved product quality achievements. The initial process capability indices from Trial 1 displayed high variation and low specification capability among several operations because Lug Hole showed the worst results. Such circumstances produced increased production defects that caused the manufacturing expenses to rise. The trials

Journal of Information Systems Engineering and Management
2025, 10(47s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

underwent steady improvement of process parameters including spindle speed together with feed rate and cutting depth. The Cp and Cpk values in Trial 2 and Trial 3 exhibited continuous improvements which decreased PPM defective parts while reducing the total manufacturing expenses. The stable process performance achieved in Trial 3 clearly showed that better process capabilities lead to lower production costs as an effect of optimizing manufacturing processes. The utilization of process capability indices leads to major cost reductions within manufacturing environments. Companies achieve both defect reduction and reduced waste together with lower production expenses when they prioritize process control. The research underlines the necessity of data-based decisions for making optimal production process improvements which result in sustainable manufacturing benefits. Advanced analytics with real-time monitoring systems need further investigation to establish their implementation in ongoing optimization of process parameters. The application of machine learning methods allows predictions of optimal settings to decrease the need for human operators in process optimization.

REFRENCES

[1] Goswami, A., & Dutta, H. N. (2013). Some Studies On Normal and Non- Normal Process Capability Indices. International Journal of Mathematics and Statistics Invention, 1(2), 31-40.

[2] Alvarez, E., Moya-Fernandez, P. J., Blanco-Encomienda, F. J., & Munoz, J. F. (2015), Methodological insights for industrial quality control management: The impact of various estimators of the standard deviation on the process capability index. Journal of King Saud University – Science, 27, 271-277.

[3] Zong, Y., & Mao, J. (2015). Tolerance optimization design based on the manufacturing-costs of assembly quality. Procedia CIRP, 27, 324-329.

[4] Skulj, G., Vrabic, R., Butala, P., & Sluga, A. (2013). Statistical Process Control as a Service: An Industrial Case Study. Procedia CIRP, 7, 401-406.

[5] Cox, S., Garside, J., & Kotsialos, A. (2013). Simulation of High Precision Process Control for Set-Up Dominant Processes, Procedia CIRP, 11, 379-384.

[6] Favi, C., Germani, M., & Mandolini, M. (2016). Design for Manufacturing and Assembly vs. Design to Cost: toward a multi-objective approach for decision- making strategies during conceptual design of complex products. Procedia CIRP, 50, 275-280.

[7] Amiri, A., Bashiri, M., Mogouie, H., & Doroudyan, M. H. (2012), Non-normal multi-response optimization by multivariate process capability index, Scientia Iranica E, 19(6), 1894-1905.

[8] Chalisgaonkar, R., & Kumar, J. (2014), Process Capability Analysis and optimization in WEDM of commercially pure titanium, Procedia Engineering, 97, 758-766.

[9] Guidetti, X., Rupenyan, A., Fassl, L., Nabavi, M., & Lygeros, J. (2022). Advanced manufacturing configuration by sample-efficient batch bayesian optimization. IEEE Robotics and Automation Letters, 7(4), 11886-11893.

[10] Sadati, N., Chinnam, R. B., & Nezhad, M. Z. (2018). Observational data-driven modeling and optimization of manufacturing processes. Expert Systems with Applications, 93, 456-464.