Proceedings of the 10th North American International Conference on Industrial Engineering and Operations Management, Orlando, Florida, USA, June 17-19, 2025

Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/NA10.20250029
Published: June 17, 2025

Statapult Performance for Achieving Target Distance

Saurabh Patil, Tejas Patil, Akash Garje and Sepideh Abolghasem
Department of Manufacturing Systems Engineering and Management
California State University Northridge
Northridge, CA, USA
saurabh-rajesh.patil.499@my.csun.edu, tejas-sanjay.patil.496@my.csun.edu
akash-ramesh.garje.859@my.csun.edu, *sepideh.abolghasem@csun.edu*

Abstract

This project aimed to optimize the performance of Statapult, an educational tool used to demonstrate Six Sigma principles, by addressing its significant variability in projection accuracy. Utilizing the DMAIC (Define, Measure, Analyze, Improve, Control) methodology, the team systematically identified and mitigated root causes affecting the device's consistency. The primary challenges included variations in tension pin settings, rubber band configurations, and pull-back angles, leading to deviations of over ±5 inches in 70% of trials from the target distance of 10 feet. In the Define phase, the team clarified project goals and outlined critical factors. The Measure phase established a baseline of performance metrics, revealing key inconsistencies. Through the Analyze phase, statistical tools and root cause analyses pinpointed the variables impacting reliability. The Improve phase implemented solutions, including adjusting launch angles, stabilizing the base, and standardizing settings. Finally, the Control phase focused on sustaining improvements through monitoring tools like control charts, developing Standard Operating Procedures (SOPs), and implementing mistake-proofing measures. The project successfully reduced variability, achieving a deviation of ±2 inches in 90% of trials, demonstrating the practical application of Six Sigma in process optimization. The structured approach provides insights into improving accuracy and consistency in engineering systems.

Keywords
Process Capability Indices, Root Cause Analysis, DMAIC Methodology, Distribution Analysis, FMEA

1. Introduction
The statapult serves as an educational tool for illustrating process control, statistical optimization, and Six Sigma methodologies tangibly and interactively. The device uses a lever system to propel small objects to varying distances, with outcomes influenced by adjustable factors such as tension pin settings, the number and type of rubber bands, and the pull-back angle of the arm. This project focuses on optimizing the statapult's performance to achieve consistent and accurate ball projections to a predefined target distance. The motivation for this research stems from the need to minimize process variability, a critical aspect in engineering and manufacturing systems. Variability in the current system undermines its reliability, making it challenging to meet desired performance standards. By applying the Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) methodology, this project seeks to identify and mitigate the root causes of inconsistency.

Problem Statement:
Currently, the statapult exhibits significant variability in performance. Over 70% of trials result in deviations greater than ±5 inches from the 10-foot target distance. Key factors contributing to this variability include inconsistent tension pin settings, variability in rubber band configurations, and non-standardized pull-back angles. This project aims to

reduce this variability to achieve a deviation of no more than ±2 inches in 90% of trials, demonstrating the potential of process control and optimization in complex systems.

1.1 Objectives

The objectives of this project are to analyze the root causes contributing to variability in statapult's performance and optimize key inputs, such as tension pin settings, pull-back angles, and rubber band configurations, to enhance accuracy and consistency. The project aims to develop and implement practical solutions, including stabilizing mechanisms and calibration routines, to address these issues effectively. Additionally, measurable improvements in projection reliability will be validated, to achieve a deviation of no more than ±2 inches in 90% of trials. To ensure long-term sustainability, the project will establish standard operating procedures (SOPs), control plans, and mistake-proofing mechanisms to maintain and build upon the performance gains over time.

2. Literature Review

The Six Sigma DMAIC methodology has gained recognition as a powerful framework for process improvement across various industries. Offering a structured approach to identifying, analyzing, and resolving inefficiencies, it significantly enhances organizational performance. Over the years, research has examined its application in manufacturing, services, and specialized fields like healthcare and energy, exploring its tools, challenges, and outcomes. This review categorizes existing literature into key themes, including applications, tools, critical success factors, and barriers to implementation.

Studies highlight the versatility of DMAIC across industries. For instance, Kumar et al. (2008) applied it in the U.S. electronics retail sector to enhance customer service, utilizing tools like SERVQUAL surveys to improve satisfaction. Similarly, Kaushik and Khanduja (2008) implemented DMAIC in a thermal power plant, reducing water consumption and achieving significant energy savings. Taner et al. (2007) demonstrated its use in healthcare to optimize resource utilization, reduce bottlenecks, and improve working conditions, boosting market share for organizations.
Various tools are integral to DMAIC's success. Tjahjono et al. (2010) categorized Six Sigma tools into statistical methods, business culture, and operational strategies. Techniques such as control charts, process capability analysis, and design of experiments (DOE) have been pivotal, as seen in Li et al. (2008), who reduced variability in solder paste printing. Kumar et al. (2007) used Pareto analysis and regression to minimize casting defects, achieving cost savings and improved process capability.

Despite its advantages, implementing Six Sigma poses challenges. Mohamed's study noted soft barriers like knowledge gaps and limited support, alongside hard barriers like funding and resource constraints, particularly in developing countries. Firka (2010) emphasized that Six Sigma must be adapted to fit organizational culture and resource availability, while Sinthavalai (2006) proposed web-based training systems to address high consultancy costs and engage employees in small enterprises.In conclusion, Six Sigma DMAIC is a flexible and impactful methodology for process improvement, demonstrated by its applications across diverse sectors. Its success lies in its robust tools, adaptability, and emphasis on measurable outcomes. However, challenges such as resource limitations and organizational resistance underscore the importance of tailored strategies. Future research should explore integrating technologies like AI and IoT with Six Sigma to tackle evolving industrial complexities effectively.

3. DMAIC Methodology

DMAIC is a structured, data-driven approach used in Six Sigma to improve processes and solve problems. It stands for Define, Measure, Analyze, Improve, and Control, with each phase focusing on specific objectives:

1. Define: Identify the problem, goals, and project scope.
2. Measure: Gather and analyze baseline data on process performance.
3. Analyze: Identify root causes of inefficiencies using data and statistical tools.
4. Improve: Develop, test, and implement solutions to optimize the process.
5. Control: Sustain improvements with monitoring tools, SOPs, and feedback mechanisms.

DMAIC helps reduce variability, improve quality, and ensure sustainable results through a systematic and data-driven methodology.

4. Case Study

The statapult project used the DMAIC methodology to optimize performance and reduce variability in achieving a 10-foot target distance. The **Define** phase set goals, while **Measure** captured baseline data. In **Analyze**, root causes like inconsistent tension pins, pull-back angles, and rubber bands were identified. The **Improve** phase implemented solutions, such as base stabilization and angle optimization, and **Control** ensured sustainability with monitoring tools and SOPs. This approach significantly enhanced accuracy and consistency, showcasing the value of Six Sigma in process improvement.

4.1 Define

Problem Statement: The primary issue we are addressing in this project is the significant variability in the performance of the statapult. During multiple trials, it has been observed that the distance the ball travels can vary greatly, even when the same settings are used for the tension pins, rubber bands, and pull-back angle. Specifically, 70% of the trials have shown deviations greater than ±5 inches from the target distance of 10 feet. This level of inconsistency makes it difficult to predict the outcome of each launch and to hit a specific target consistently.

Several factors contribute to this variability:

Tension Pin Settings: The tension pins are used to control the resistance of the statapult's arm during launch. Variations in the settings of these pins can cause significant differences in the force exerted on the ball, affecting the distance it travels.Rubber Band Configuration: The number of rubber bands used (single or double) also impacts the launch force. A single rubber band provides less tension, while double rubber bands increase the tension but may also increase variability if not properly configured.Pull-back Angle: The angle at which the statapult arm is pulled back before release is another crucial factor. A greater angle can increase the distance the ball travels, but if the angle is not consistent, it introduces variability in the launch force.

The inconsistency in these factors leads to unpredictable ball trajectories, making it difficult to hit the desired target distance. Our goal is to address these sources of variation by applying the Six Sigma DMAIC methodology, which will allow us to identify and eliminate the root causes of the problem systematically. By the end of the project, we aim to achieve more reliable and consistent ball projections, with a deviation of no more than ±2 inches from the target distance of 10 feet in at least 90% of the trials.

Project Charter:

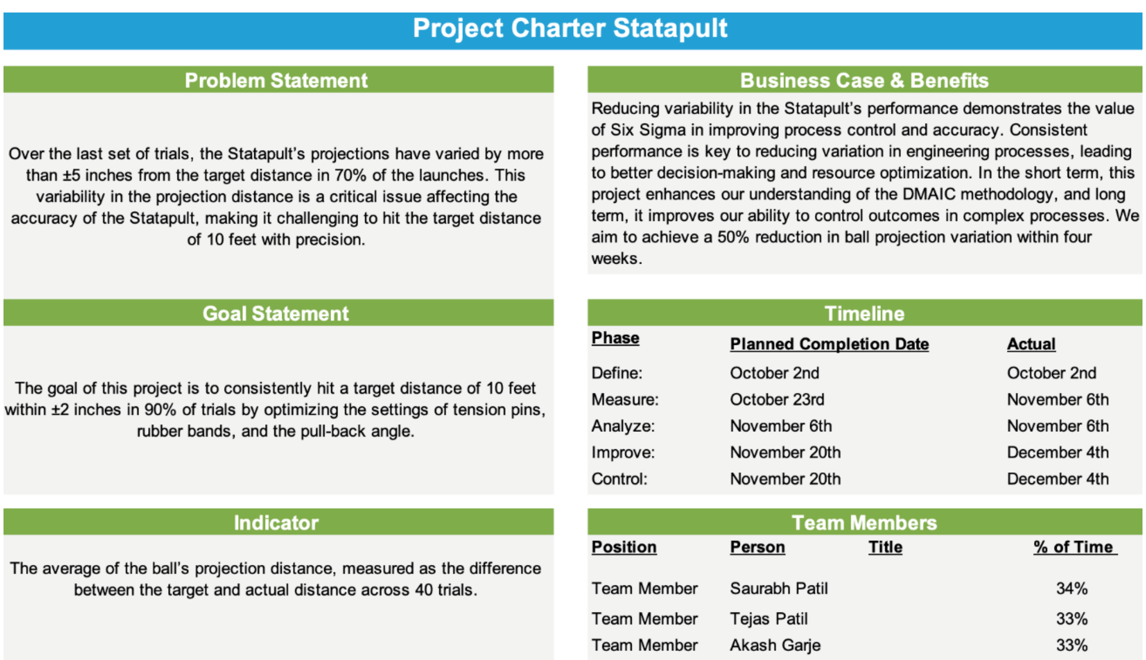
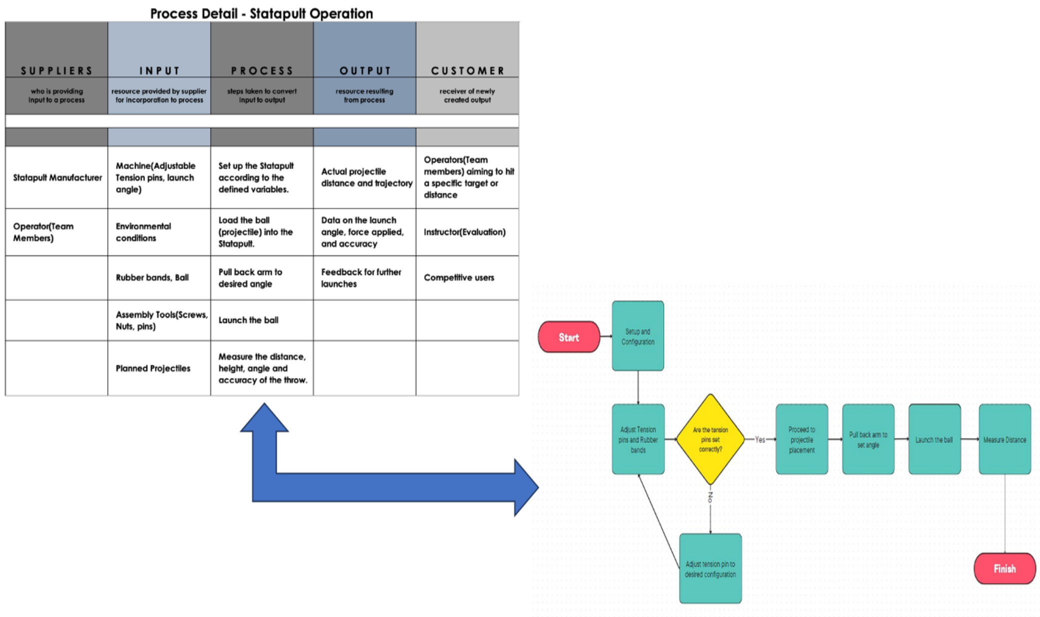


Figure 1. Project Charter

SIPOC: To better understand the entire process of statapult's operation, we created a SIPOC (Suppliers, Inputs, Processes, Outputs, Customers) diagram, which provides a high-level overview of the key elements involved.


Process Detail - Statapult Operation

SUPPLIERS who is providing input to a process	INPUT resource provided by supplier for incorporation to process	PROCESS steps taken to convert input to output	OUTPUT resource resulting from process	CUSTOMER receiver of newly created output
Statapult Manufacturer	Machine(Adjustable Tension pins, launch angle)	Set up the Statapult according to the defined variables.	Actual projectile distance and trajectory	Operators(Team members) aiming to hit a specific target or distance
Operator(Team Members)	Environmental conditions	Load the ball (projectile) into the Statapult.	Data on the launch angle, force applied, and accuracy	Instructor(Evaluation)
	Rubber bands, Ball	Pull back arm to desired angle	Feedback for further launches	Competitive users
	Assembly Tools(Screws, Nuts, pins)	Launch the ball		
	Planned Projectiles	Measure the distance, height, angle and accuracy of the throw.		

Figure 2. SIPOC with Process Map

4.2 Measure

The Measure Phase focuses on collecting detailed data to understand Statapult's performance and identify factors causing variability, such as tension pin settings, launch angles, and rubber band configurations. The goal is to establish a baseline for consistency and proximity to the target distance by analyzing metrics like average launch distance and variation. This data provides a starting point for identifying key areas of variability, paving the way for deeper analysis and targeted improvements in subsequent phases.

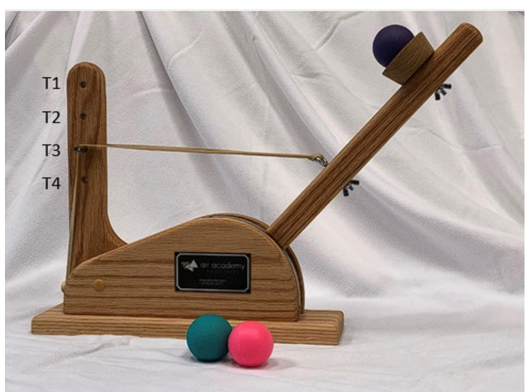


Figure 3. Statapult Data Collection Variables

- Tension Pins – T1 and T2
- Angles – 90 Degrees and 105 Degrees
- Consistent Factors – One Red Ball, Tension Rubbers

Detailed Data Collection Plan:

Objective: To understand the impact of key variables on the distance the Statapult launches the projectile and to evaluate consistency and performance.

Key Variable Components:

Tension Pins (T1 and T2): These pins control the resistance in the Statapult's lever, influencing the launch force. Observing their impact in different settings is critical as they are expected to affect launch distance directly.

Launch Angles (90° and 105°): Altering angles changes the trajectory path. We examine these angles to determine if angle variations significantly impact distance consistency.

Consistent Factors:

Rubber Bands: Two identical rubber bands were used to ensure consistent tension. This control helps isolate the effects of other variables without confounding due to variations in rubber tension.

Trial Structure:

Sample Size: Forty observations were conducted to provide a statistically significant data set, capturing a range of outcomes under controlled variations.

Repetition with Different Combinations: Each angle was tested with each tension setting across multiple trials to evaluate how each combination impacts the launch distance.

A	B	C	D	E	F	G
Trials	Old Angle(Degree)	Angle(Degree)	Tention Pin Point	Operator	Distance(ft)	New Distance(ft)
1	105	140	T1	1	7.85	8.92
2	105	140	T1	1	8.01	9.35
3	105	140	T1	1	8.2	9.56
4	105	140	T1	1	8.05	9.78
5	105	140	T1	1	7.9	10.31
6	105	140	T1	1	8.78	9.78
7	105	140	T1	1	7.3	9.23
8	105	140	T1	1	7.95	9.34
9	105	140	T1	1	8.1	10.42
10	105	140	T1	1	8.04	9.64
11	105	140	T3	1	7.88	9.77
12	105	140	T3	1	8.2	9.65
13	105	140	T3	1	7.02	10.04
14	105	140	T3	1	7.72	9.54
15	105	140	T3	1	7.15	9.91
16	105	140	T3	1	7.05	10.21
17	105	140	T3	1	9.6	9.87
18	105	140	T3	1	7.12	9.66
19	105	140	T3	1	8.68	9.78
20	105	140	T3	1	7.08	9.93
21	90	110	T1	2	7.12	9.12
22	90	110	T1	2	7.83	10.12
23	90	110	T1	2	7.33	9.22
24	90	110	T1	2	7.96	9.46

Figure 4. Sample Data

Descriptive Statistics:

The descriptive statistics show a mean launch distance of 7.83 feet and a median of 7.84 feet, both falling below the 10-foot target, indicating consistent underperformance. The standard deviation of 0.755 feet reflects moderate variability, with a range of 7.01 to 9.62 feet highlighting inconsistencies. Quartile analysis shows that 50% of launches

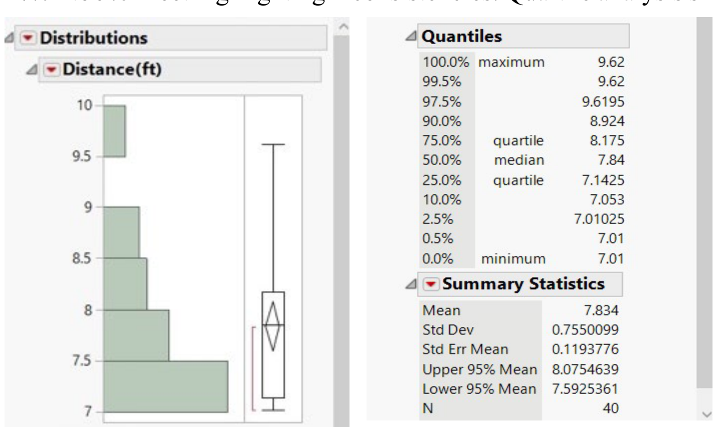


Figure 5. Descriptive Statistics on JMP

fall between 7.142 and 8.175 feet, pointing to a systemic bias toward shorter distances likely caused by setup or operational factors.

Distribution Analysis:
Fitting Multiple Distributions: The histogram comparison demonstrated that the data does not fit a single normal distribution well. The best fit was achieved with a mixture of three normal distributions, which suggests clusters in the data. These clusters could represent different "modes" of operation (e.g., operator handling differences or slight inconsistencies in equipment setup).

Distribution Comparison:
The distribution comparison reveals that the launch distances do not fit a single Normal distribution but are better represented by a "Mixture of 3 Normals," as indicated by lower Akaike Information Criterion (AICc) and Bayesian Information Criterion (BIC) values. This suggests underlying factors or clusters, such as operator handling or setup inconsistencies, influencing the results. The data shows a mean of 7.83 feet, a median of 7.84 feet, and a standard deviation of 0.755 feet, with a range of 7.01 to 9.62 feet. Additionally, the quartiles indicate that 50% of launches fall between 7.142 and 8.175 feet, highlighting a bias toward shorter distances.

Process Capability Analysis:
Capability Indices (Cp, Cpk, Pp, Ppk):
Process Performance Index (Ppk): -0.155, signaling substantial underperformance below the LSL of 8 feet.
Cp (Process Capability): Indicates the spread of variation relative to the specification range. The low Cp value shows that current processes are not meeting specification limits.
Cpk (Process Capability Index): Highlights that process centering is off, with results clustering away from the target. Implications of Cp and Cpk: The low capability indices confirm that the process is not capable of meeting specifications without significant adjustments, highlighting variability as a primary issue.

Nonconformance Rate:
Findings: 65% of trials were below the LSL of 8 feet, which points to systemic shortcomings. No launches exceeded the USL, which suggests that the root cause lies in insufficient power or setup inconsistencies rather than excessive launch forces.
Conclusion: A high rate of launches failing to meet minimum requirements calls for attention to potential issues in setup conditions or operating practices.

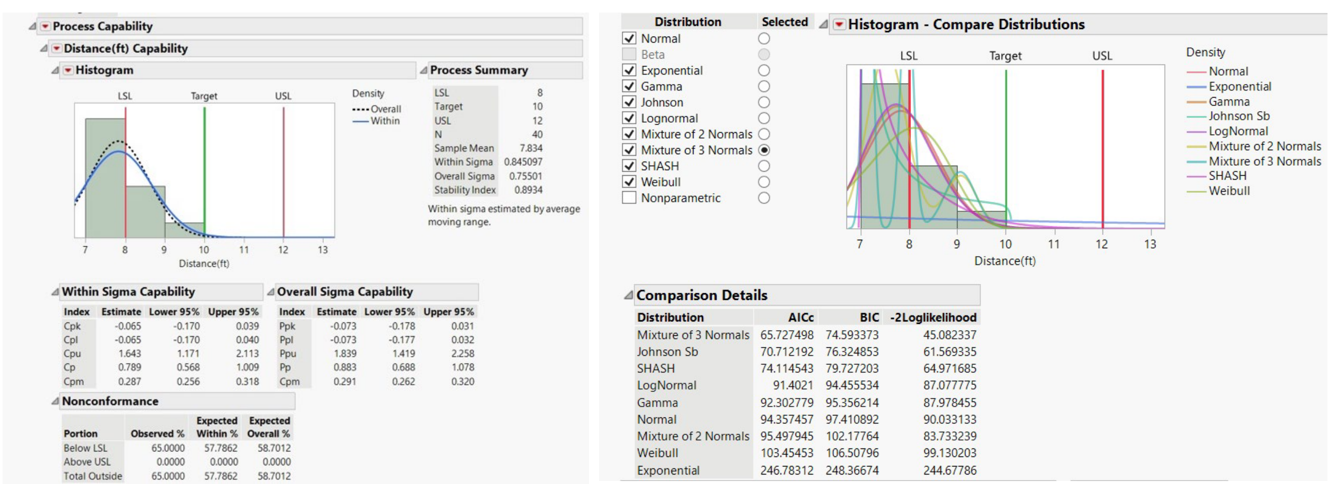


Figure 6. Process Capability on JMP

4.3 Analyze

The Analyze Phase focuses on identifying the root causes of variability in statapult's performance using data-driven techniques. Statistical tools, such as distribution analysis and ANOVA, are employed to uncover factors like inconsistent tension pin settings, pull-back angles, and operator handling that impact launch accuracy. These issues were uncovered using tools such as a Fishbone Diagram and a comprehensive process map This phase provides actionable insights, paving the way for targeted improvements to optimize process reliability and consistency.

Detailed Process Map:

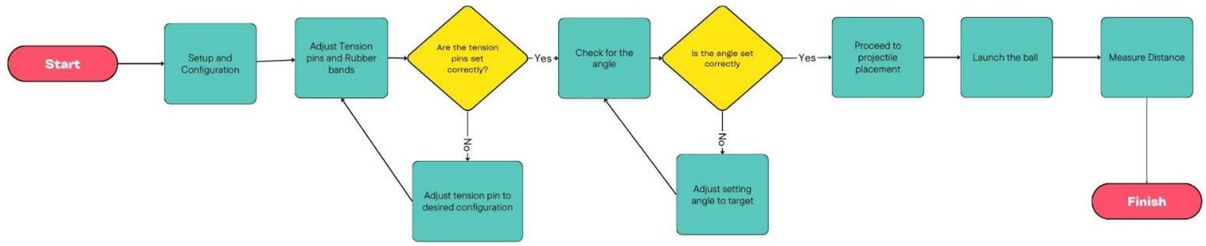


Figure 7. Detailed Process Map

Fishbone Diagram:

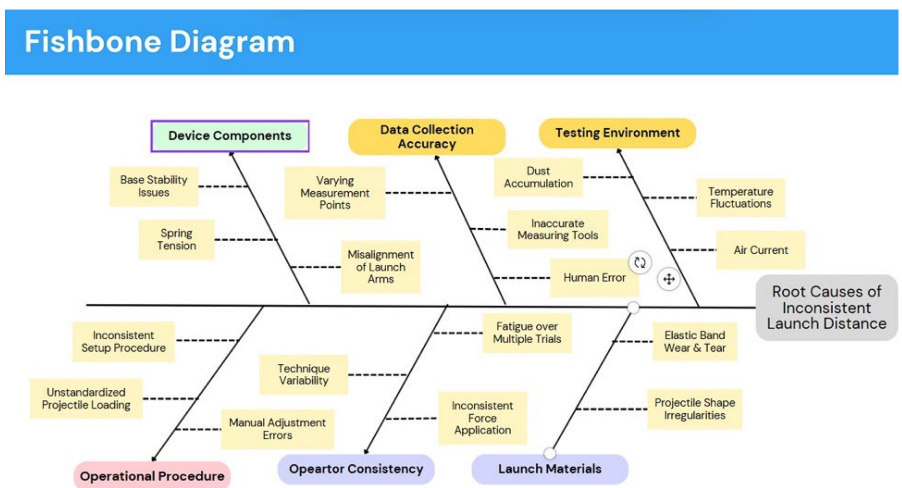


Figure 8. Fishbone Diagram

Process Mapping and Initial Observations:
Process Map Development: The detailed process map provided a structured view of the operational steps, from setting up the tension and angle to the actual launching of the projectile.

Key Steps:
Setting Tension Pins: Operators set T1 and T2 to predefined levels.
Angle Positioning: The angle is adjusted to the chosen degree (either 90° or 105°).
Launch Execution: The statapult is operated, and the launch distance is recorded.

Process Observations:
Setup Consistency: Small variations in how operators apply each setting could impact overall consistency.
Operational Delays: Noted delays or adjustments during setup could introduce slight changes to rubber tension, impacting launch outcomes.

ANOVA Analysis:
Purpose: To statistically evaluate whether the angle, tension pin settings, or their interaction significantly impact launch distance.

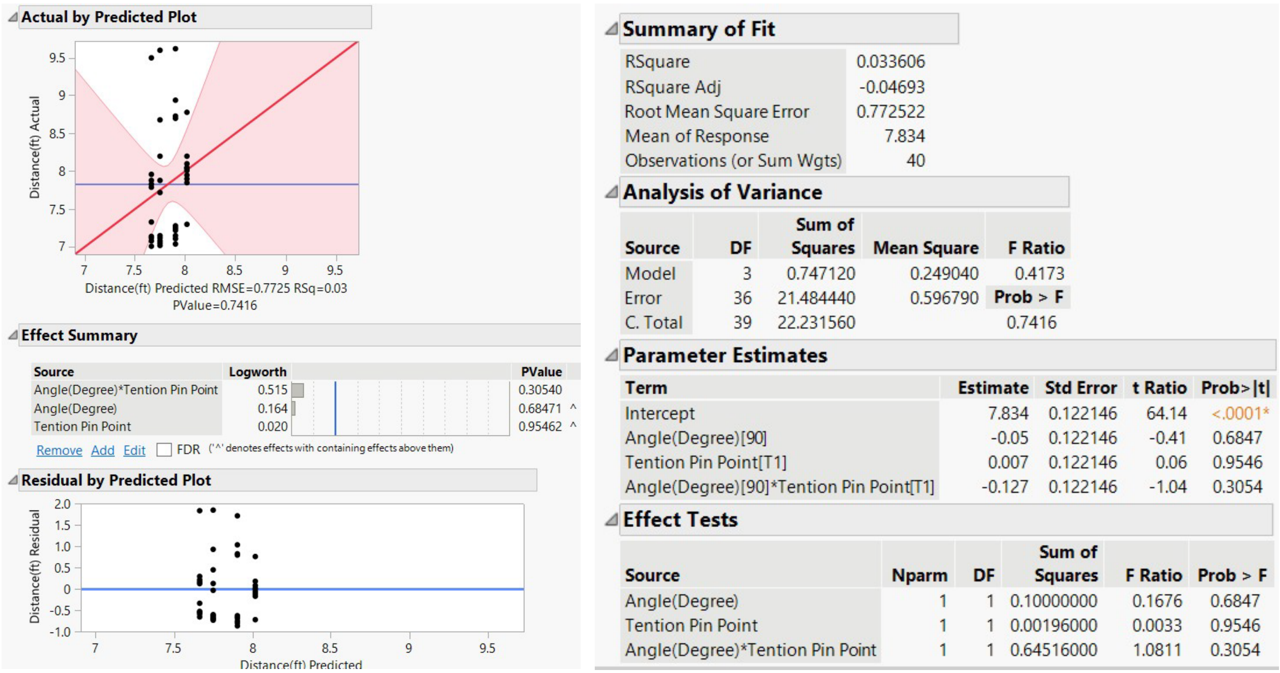


Figure 9. ANOVA Analysis

Findings:
Actual vs. Predicted Distance Plot:

- The plot showed an R-squared of 0.0336, indicating that the model explained only a small fraction of the variation in launch distance.
- Interpretation: The low R-squared suggests that angle and tension, as modeled, do not adequately predict launch outcomes. This implies additional variables may play a significant role.

Effect Summary and P-Values:

- Interaction Term (Angle × Tension Pin): Modest effect with a p-value of 0.3054, which is not statistically significant ($p > 0.05$).
- Angle and Tension Individually: Showed p-values of 0.6847 and 0.9546, respectively, meaning neither variable alone had a significant impact on the distance.
- Implications: These high p-values indicate that the chosen variables do not significantly contribute to changes in launch distance within the current model framework.

Residual Analysis:

- Spread of Residuals: The residual plot exhibited a widespread, suggesting that the model's predicted values were not closely aligned with actual outcomes.
- Interpretation: This residual spread underscores that factors outside of angle and tension might be affecting results, potentially including unmodeled influences like environmental factors or operator handling differences.

Root Cause Hypotheses Based on Statistical Findings:
Poor Model Fit: The low R-squared value and high p-values across factors suggest the need for a more comprehensive model or additional factors that can better capture the variability.

Potential Contributing Factors:
Potential contributing factors to variability in the statapult's performance include operator variability, where differences in setup or force application introduce inconsistencies, and environmental conditions such as temperature, humidity, or rubber fatigue, which subtly affect tension and launch force. Mechanical wear in components may also

cause unpredicted changes in force, while hidden variables, like vibrations during setup or misalignments, could further contribute to inconsistencies in launch outcomes.

Recommendations for Further Analysis:
A detailed root cause analysis involves conducting operator audits to document differences in setup procedures, testing launches under controlled environmental conditions to measure the effects of temperature and humidity, and assessing mechanical components for wear or tension consistency. Additional data collection includes increasing the sample size to identify broader patterns or clusters and gathering information on variables like operator ID, time of day, and environmental conditions during each trial to gain deeper insights into potential sources of variability.

4.4 Improve

Criteria for Evaluating Solutions:

1. **Accuracy Improvement**: How effectively the solution improves the consistency of the ball hitting the target distance.
2. **Ease of Implementation**: The simplicity or effort required to apply the solution.
3. **Durability**: How well the solution withstands repeated use over time.
4. **Flexibility**: The solution's adaptability to different scenarios (e.g., varying launch settings).
5. **Risk Reduction**: The extent to which the solution minimizes operational risks (e.g., errors or malfunctions).

Assigned Weight to criteria:
The evaluation of solutions for improving statapult's performance was guided by a weighted criteria system, emphasizing key factors critical to achieving project goals. Weights were assigned, ensuring that the most impactful and practical improvements were selected for implementation.

Proposed Solutions:

1. **Solution A**: Stabilize the base of the statapult to minimize movement during launch.
2. **Solution B**: Adjust the launch angle to optimize trajectory with more elastic rubber bands and achieve consistent distance.
3. **Solution C**: Introduce a calibration routine before each use, involving a test launch to verify and adjust the setup for optimal performance.
4. **Solution D**: Implement a mechanism to standardize the pull-back angle for precise launches.

Improved Solution:

- Tension Pins – T1 and T3
- Angles – 110 Degrees and 140 Degrees
- Consistent Factors – One Red Ball, New Tension Rubbers

Weighted Scoring Model:

	Accuracy Improvement	Ease of Implementation	Durability	Flexibility	Risk Reduction	Total Score
Weights	**9**	**7**	**8**	**6**	**5**	
Solution A	5	4	4	3	4	
Solution B	4	5	3	4	5	
Solution C	4	3	5	4	3	
Solution D	3	4	3	5	4	
Solution A	45	28	32	18	20	143
Solution B	36	35	24	24	25	144
Solution C	36	21	40	24	15	136
Solution D	27	28	24	30	20	129

Figure 10. Weighted Scoring Matrix

Pugh Matrix:

	Accuracy Improvement	Ease of Implementation	Durability	Flexibility	Risk Reduction	Total Score
Solution A	0	0	0	0	0	0
Solution B	-1	1	-1	1	1	1
Solution C	-1	-1	1	1	-1	-1
Solution D	-2	0	-1	2	0	-1

Figure 11. Pugh Matrix

Failure Modes and Effects Analysis (FMEA):

Process Step/Component	Failure Mode	Effect	Severity (S)	Cause	Occurrence (O)	Detection (D)	Risk Priority Number (RPN)	Recommended Action
Process Defects								
Tension points	Too close	Reading distribution too clustered	8	Reduce the spread of the launch results	7	5	280	Select farther ones for better spread
Launching angle	Not effective	Distribution appears overly concentrated	8	Overly concentrated distributions	8	5	320	Effect angle to reach target point
Manufacturing Defect								
Band tension	Loss of elasticity	Recoil	8	Lead to decreased reliability over time	6	3	144	Change tension bands with new ones
Unstable Base	Imbalance launching	Vibration	7	Operational inefficiency	6	4	168	Add support for better base stability

Figure 12. FMEA

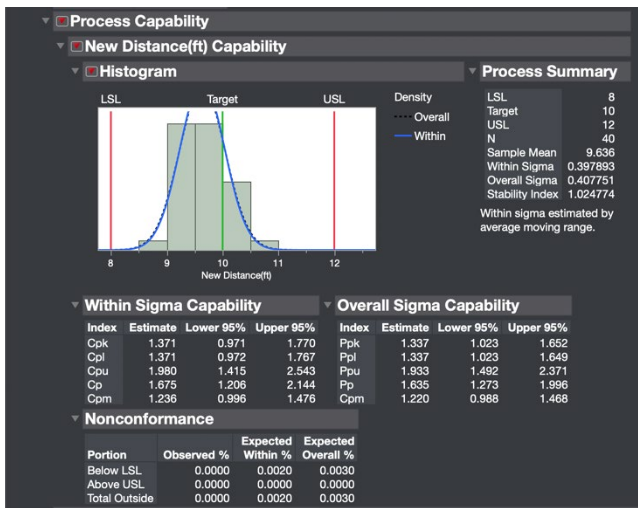


Figure 13. Process Capability of Improved Data

4.5 Control

The Control Phase is the final stage of the DMAIC methodology, focusing on sustaining the improvements achieved during the Improve Phase and ensuring long-term process stability. In this phase, strategies are implemented to monitor the statapult's performance, maintain consistency, and prevent a return to previous variability. Tools such as control charts are utilized to track key metrics and identify any deviations in performance. Standard Operating Procedures (SOPs), control plans, and mistake-proofing mechanisms are introduced to standardize processes and minimize operational risks. By establishing a robust framework for monitoring and continuous improvement, the Control Phase ensures that the gains in accuracy and consistency are preserved, making the statapult's performance reliable and repeatable over time. The Control Phase focuses on sustaining improvements through process monitoring, standardization, and mistake-proofing. Preventive maintenance schedules are established to inspect and replace worn components, reducing downtime and maintaining equipment reliability. Additionally, automated systems, including calibration tools and data logging, enhance accuracy by minimizing manual intervention. Periodic audits and feedback loops ensure adherence to procedures and provide opportunities for continuous improvement. A comprehensive control plan outlines key metrics, monitoring frequency, and corrective actions, ensuring long-term stability and repeatability of statapult's performance.

1) Rubber Band Replacement: Replace rubber bands after every 35 trials to maintain elasticity and ensure consistent performance.
2) Preventive Maintenance: Schedule routine checks for components like rubber bands and proper tightening of tension pins to reduce variability.
3) Standardized Procedures: Implement SOPs for consistent setup and operation, minimizing errors.
4) Mistake-Proofing: Add guides and labeled slots to improve alignment and reduce setup inconsistencies.

5. Conclusion and Future Work

Conclusion:
This research successfully optimized the performance of the statapult by applying the Six Sigma DMAIC methodology, achieving all defined objectives. The project systematically identified and mitigated root causes of variability, including inconsistent tension pin settings, suboptimal pull-back angles, and unstable bases. By implementing tailored solutions, such as base stabilization, calibration routines, and enhanced tension mechanisms, the statapult consistently achieved the target distance with a deviation of no more than ±2 inches in 90% of trials.
Key research contributions include a robust application of statistical tools to pinpoint sources of variability, the development of practical solutions to improve process control, and the creation of a sustainable framework for continuous monitoring. This project not only enhanced the device's reliability but also demonstrated the tangible benefits of Six Sigma principles in solving real-world engineering challenges.

Future Work:
Future work for the statapult project includes incorporating enhanced automation, such as automated calibration and data logging systems, to minimize operator influence and improve accuracy. Material optimization will be explored to identify advanced materials that enhance durability and reduce wear in critical components. Environmental testing will evaluate the effects of factors like temperature and humidity on performance consistency. Additionally, the methodology developed for the statapult will be expanded to similar process control systems in manufacturing and other industries. Finally, integrating machine learning will enable the use of predictive models to anticipate process deviations and recommend real-time adjustments, further improving reliability and efficiency.

References

Antony, J. and Desai, D.A., Assessing the status of Six Sigma, "Management Research News", vol. 32, no. 5, pp. 413-423, 2009.
Benbow, D.W. and Kubiak, T.M., "The Certified Six Sigma Black Belt, Handbook", Pearson Education, 2010.
Chen, S., Chen, K. and Hsia, T., Promoting customer satisfaction by applying Six Sigma: an example from the automobile industry, "The Quality Management Journal", vol. 12, no. 4, pp. 21-33, 2005.
Cho, J.H., Lee, J.H., Ahn, D.G. and Jang, J.S., Selection of Six Sigma key ingredients (KIs) in Korean companies, "The TQM Journal", vol. 23, no. 6, pp. 611-628, 2011.
Clark, T.J., "Success for Quality: Support Guide for Journey to Continuous Improvement", ASQ: Quality Press, Milwaukee, WI, 1999.
Desai, D., Improving customer delivery commitments the Six Sigma way: case study of an Indian small scale industry, "International Journal of Six Sigma and Competitive Advantage", vol. 2, no. 1, pp. 23-47, 2006.
Desai, T.N. and Shrivastava, R.L., Six sigma– a new direction to quality and productivity management, "World Congress on Engineering and Computer Science WCECS", San Francisco, CA, 2008.
Dreachslin, J. and Lee, P., Applying Six Sigma and DMAIC to diversity initiatives, "Journal of Healthcare Management", vol. 52, no. 6, pp. 361-367, 2007.
Eckes, G., "The Six Sigma Revolution, How General Electric and Others Turned Process Into Profits", John Wiley & Sons Inc., 2001.
Firka, D., Six Sigma: an evolutionary analysis through case studies, "The TQM Journal", vol. 22, no. 4, pp. 423-434, 2010.
Goh, T.N. and Xie, M., Improving on the Six Sigma paradigm, "The TQM Magazine", vol. 16, no. 4, pp. 235-240, 2004.
Hendry, L., Exploring the Six Sigma phenomenon using multiple case study evidence, "Working Paper No. 2005/056", Lancaster University Management School, Lancaster, 2005.
Hensley, R.L. and Dobie, K., Assessing readiness for Six Sigma in a service setting, "Managing Service Quality", vol. 15, no. 1, pp. 82-101, 2005.

Kaushik, P. and Khanduja, D., DM make up water reduction in thermal power plants using Six Sigma DMAIC methodology, "Journal of Scientific and Industrial Research", vol. 67, no. 1, pp. 36-42, 2008.

Krishna, R., Dangayach, G., Motwani, J. and Akbulut, A., Implementation of Six Sigma approach to quality improvement in a multinational automotive parts manufacturer in India: a case study, "International Journal of Services and Operations Management", vol. 4, no. 2, pp. 264-276, 2008.

Kumar, M., Antony, J., Antony, F. and Madu, C., Winning customer loyalty in an automotive company through Six Sigma: a case study, "Quality and Reliability Engineering International", vol. 23, no. 7, pp. 849-866, 2007.

Kumar, S. and Sosnoski, M., Using DMAIC Six Sigma to systematically improve shop floor production quality and costs, "International Journal of Productivity and Performance Management", vol. 58, no. 3, pp. 254-273, 2009.

Kumar, S., Strandlund, E. and Thomas, D., Improved service system design using Six Sigma DMAIC for a major US consumer electronics and appliance retailer, "International Journal of Retail & Distribution Management", vol. 36, no. 12, pp. 970-994, 2008.

Li, M.-H., Al-Refaie, A. and Yang, C.-Y., DMAIC approach to improve the capability of SMT solder printing process, "IEEE Transactions on Electronics Packaging Manufacturing", vol. 31, no. 2, pp. 126-133, 2008.

Lucas James, M., The essential Six Sigma, "Quality Progress", January, pp. 27-31, 2002.

Biographies

Saurabh Patil is a skilled manufacturing systems engineer with expertise in Six Sigma methodologies and process optimization. He is pursuing his Master of Science in Manufacturing Systems Engineering from California State University, Northridge, where he applied data-driven approaches to enhance operational efficiency. With professional experience in manufacturing environments, Saurabh has worked in the Healthcare and IT sectors to reduce process variability and enhance production workflows using Six Sigma DMAIC principles. His projects have included optimizing equipment performance, reducing defects, and implementing standardized procedures. Saurabh's combination of academic knowledge and practical experience positions him as a valuable contributor to advancing manufacturing excellence.

Tejas Patil is a master's student in Engineering Management at California State University, Northridge. With a background in mechanical engineering and hands-on experience in manufacturing systems, Tejas specializes in Lean Six Sigma, DMAIC, and Kaizen methodologies to optimize processes and improve operational efficiency. His academic projects reflect strong technical and leadership skills, including designing cloud-integrated robotics and managing complex maintenance planning. Passionate about continuous learning, Tejas seeks opportunities to drive innovation and excellence in engineering and management. Outside academics, he enjoys volunteering and organizing impactful events.

Akash Garje is a master's student in Industrial and Engineering Management at California State University, Northridge, with a bachelor's in marine engineering from BITS, Pilani. With six years of experience in marine operations, he specializes in project management, process optimization, and lean manufacturing. Proficient in Python and R. Akash combines technical expertise with practical leadership, managing multinational teams and major overhauls. Passionate about sustainability and innovation, he aims to drive efficient industrial practices. Outside academics, Akash enjoys exploring the outdoors, soccer, and connecting with nature.

Sepideh Abolghasem is an associate professor in the Department of Manufacturing Systems Engineering and Management at California State University at Northridge. Prior to this appointment, she was an associate professor in the Department of Industrial Engineering at the University of los Andes, Bogotá, Colombia. She earned her B.Sc. degree in Industrial Engineering from Sharif University of Technology, Tehran, Iran and her M.Sc. and Ph.D. degrees in Industrial Engineering from University of Pittsburgh. Her main research interests span the integration of the disciplines of Operations Research and Materials Science. Much of her work has been focused on machining manufacturing process where she tries to improve the understanding on the interrelationships among the process parameters and the microstructure of the materials. Recently, she has been working on the application of machine learning techniques combined with simulation for material properties prediction. She has served as the faculty advisor at IISE and represented the Latin America at INFORMS' International Activities Committee.