See the Unknown with **Monte Carlo Simulation**

Jenn Atlas

Global Market Development Manager

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Senior Marketing Manager

Welcome. The webinar will begin shortly.

AUDIO WEB: Please ensure you have your computer audio system activated and your speakers turned up.

Monte Carlo Simulation

with Process Optimization

Jennifer Atlas

Global Market Development

Meet the Presenter:

Jennifer Atlas

Global Market Development Manager

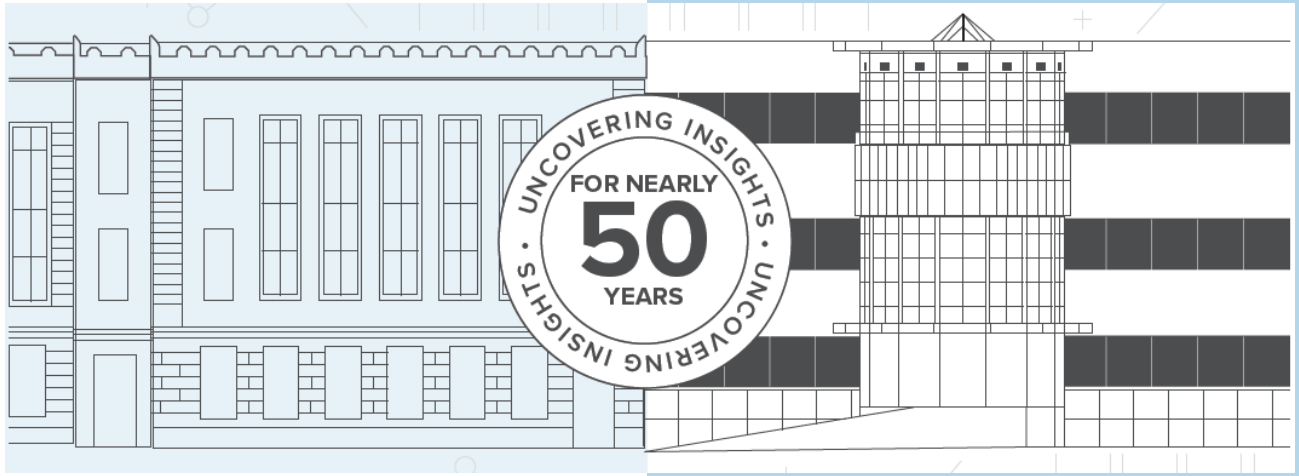
Jenn studies how organizations solve analytical problems to ensure that Minitab delivers on our commitment to make data analytics easier.

As a classically trained statistician, Jenn has worked, trained and consulted in the field of analytics for over 25 years.

Our History

1972

Three Penn State professors created Minitab Statistical Software to easily teach their students statistics. The software was rapidly adopted by other schools and revolutionized the way people teach and conduct data analysis.



2021

Today, Minitab continues to help discovery, innovation and transformation. Thousands of businesses and universities worldwide work with Minitab because of our unique ability to uncover insights and drive change through the power of data analysis.

Our Approach: More Than Business Analytics… Solutions Analytics

Solutions analytics is our integrated approach to providing software and services that enable organizations to make better decisions that drive business excellence.

Software

Data Analysis | Data Transformation | Predictive Modeling | Online Training | Project Ideation & Execution | Visual Business Tools

Minitab®

Powerful statistical software everyone can use

Minitab Connect™

Data access, automation, and governance for comprehensive insights

SPM®

Machine learning and predictive analytics software

Quality Trainer®

Master statistics and Minitab anywhere with online training

Minitab Engage™

Start, track, manage, and execute innovation and improvement initiatives

Minitab Workspace™

Visual tools to process and product excellence

Services

Training

Learn first-hand by attending public or customized trainings in your facilities according to your requirements.

Statistical Consulting

Personalized help with statistical challenges from collecting the right data to interpreting analysis more.

Support

Assistance with installation, implementation, version updates and license management.

Monte Carlo

Monte Carlo represents a broad class of computational algorithms that rely on repeated random sampling

Monte Carlo Simulation

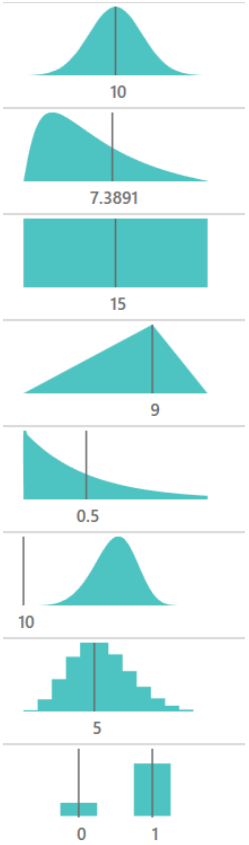
Accounts for risk in quantitative analysis and decision-making by providing a range of possible outcomes based on the model inputs and specifications.

Monte Carlo Simulation

More simply, it provides expected values for a response(s) given a set of equations.

It considers the uncertainty in the inputs in those equations to provide a better estimate of the true values that can result for a response.

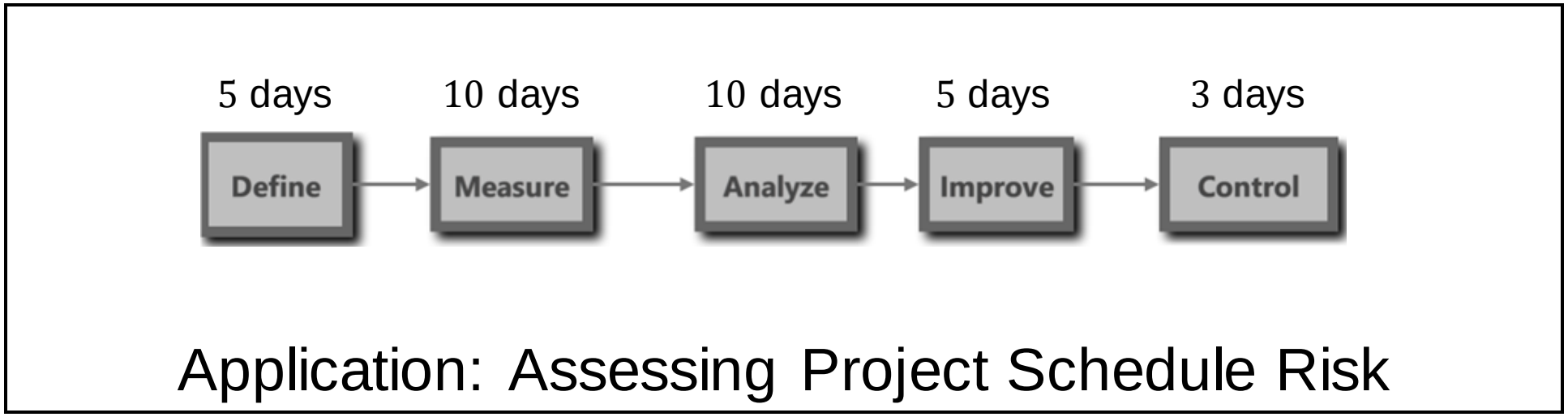
Quantifying Uncertainty in the Inputs: Probability Distributions



Normal
Lognormal
Uniform
Triangular
Exponential
Weibull
Poisson
Bernoulli

Application: Assessing Project Schedule Risk

- **Define: Define and Scope Project**
- **Measure: MSA and Project Baseline**
- **Analyze: Develop Y=f(X) Relationship**
- **Improve: Implement Proposed Improvements**
- **Control: Implement Control Strategy**



Application: Assessing Project Schedule Risk

Project Duration =

Define + Measure + Analyze + Improve + Control

5 days + 10 days + 10 days + 5 days + 3 days

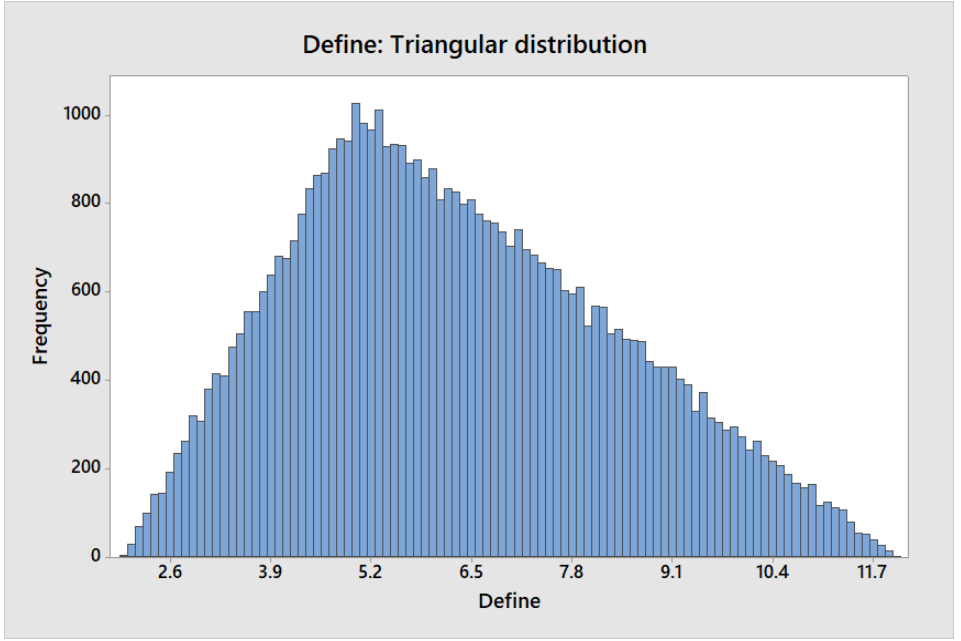
= **33** days

Project Duration =

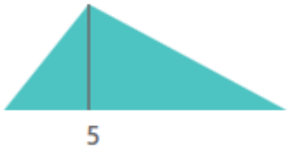
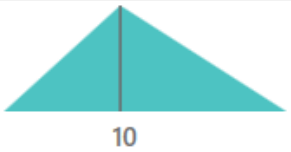
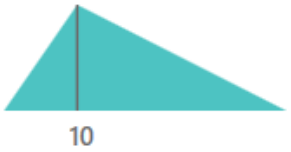
Define + Measure + Analyze + Improve + Control

A Triangular Distribution is defined by a lower bound, the mode and an upper bound

In this case: Triangular (2,5,12)



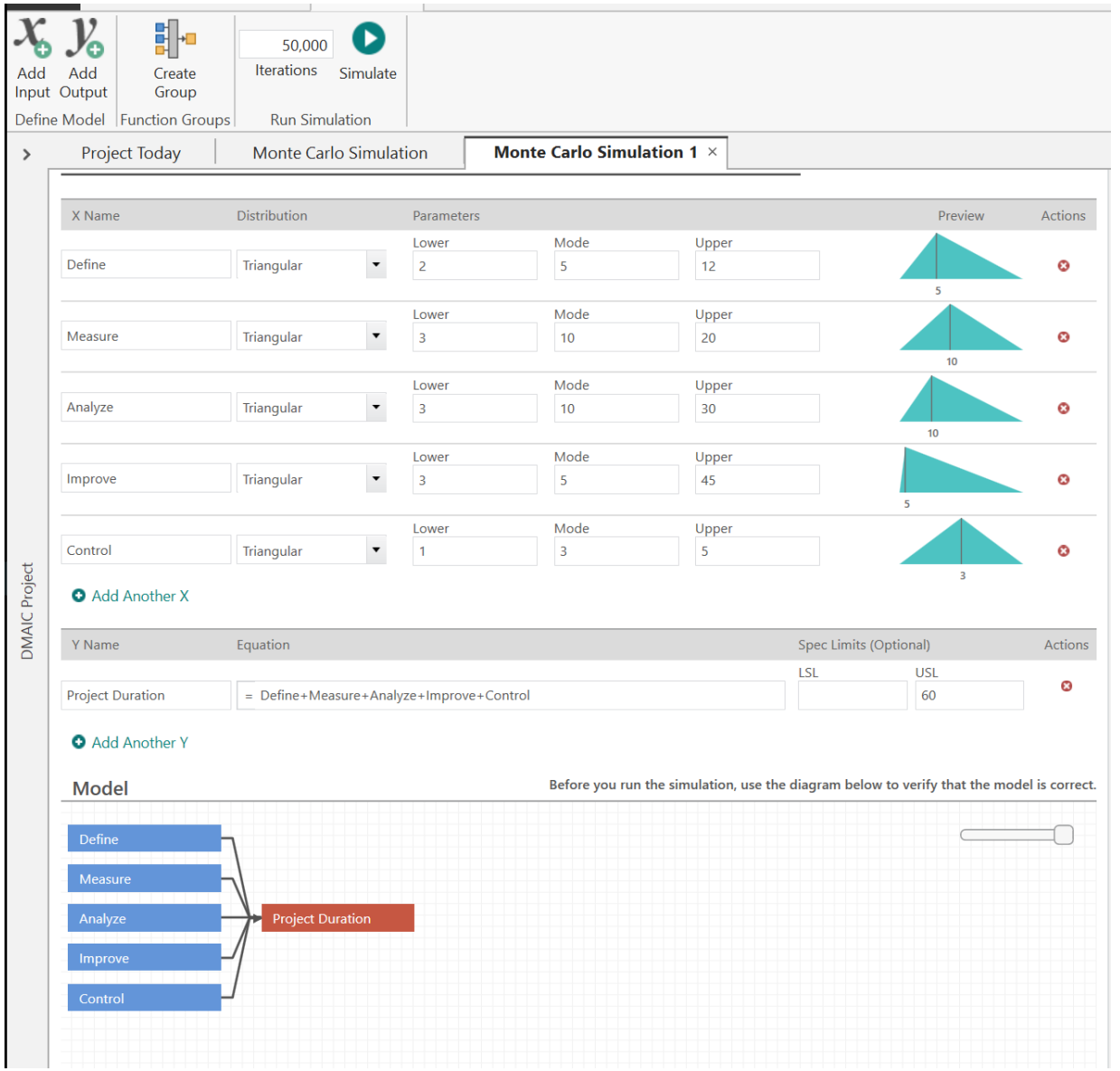
Define the Variation

X Name	Distribution	Parameters			Preview
		Lower	Mode	Upper	
Define	Triangular	2	5	12	 5
Measure	Triangular	3	10	20	 10
Analyze	Triangular	3	10	30	 10
Improve	Triangular	3	5	45	 5
Control	Triangular	1	3	5	 3

Estimate what percentage of projects are expected to go over 60 days

		LSL	USL
Project Duration	= Define+Measure+Analyze+Improve+Control		60

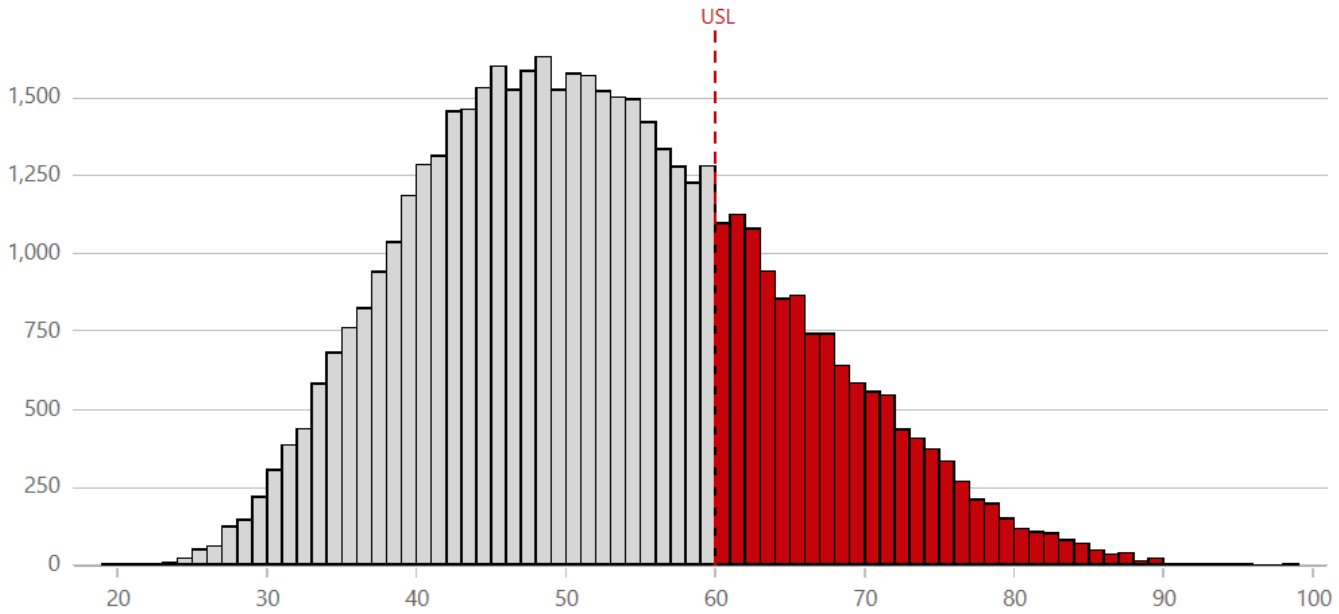
Estimate what percentage of projects are expected to last longer than 60 days



Results

Simulation Results

Project Duration



The simulation indicates that you can expect 25.91% of the *Project Duration* values to fall outside of the specification limits. This corresponds to a Cpk of 0.2299. A generally accepted minimum value of Cpk is 1.33

Process Performance (Cpk)

0.2299

% Out of Spec

25.91%

Summary Statistics

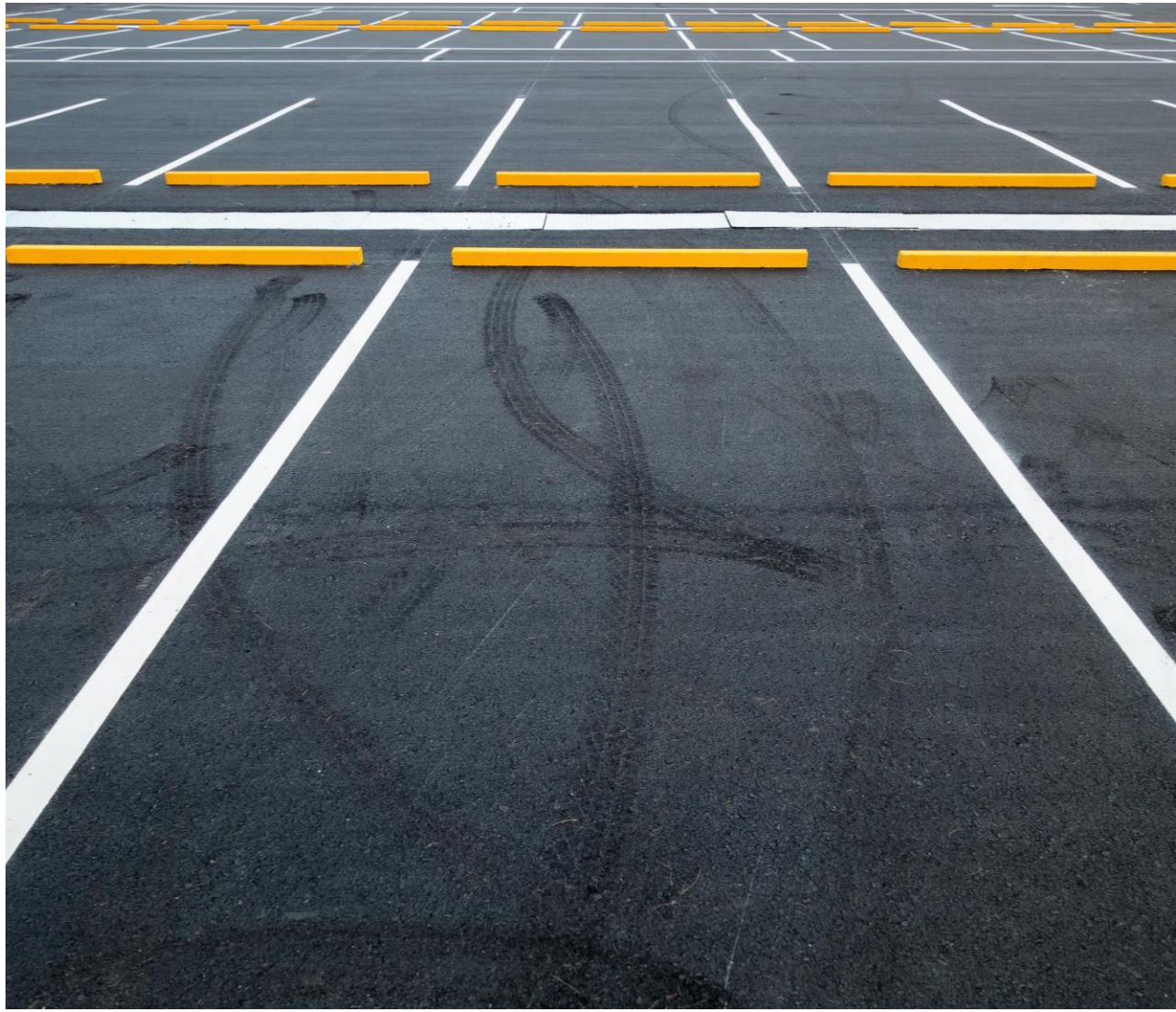
N	50,000
Mean	52.3063
Standard Deviation	11.9686

Better Estimates

Monte Carlo simulation can help with modeling, analyzing and improving confidence for measurements

Applications

- **Telecommunications**: Evaluate wireless network performance
- **Energy:** Predict output of a wind farm
- **Engineering:** Predict process capability in a fuel pump
- **Consumer Goods:** Predict viscosity in the manufacturing of a dish detergent
- **Finance:** Value a project by estimating future profits
- **Healthcare:** Predict claims processing times
- **Accident Reconstruction:** Evaluate road friction to calculate possible speeds

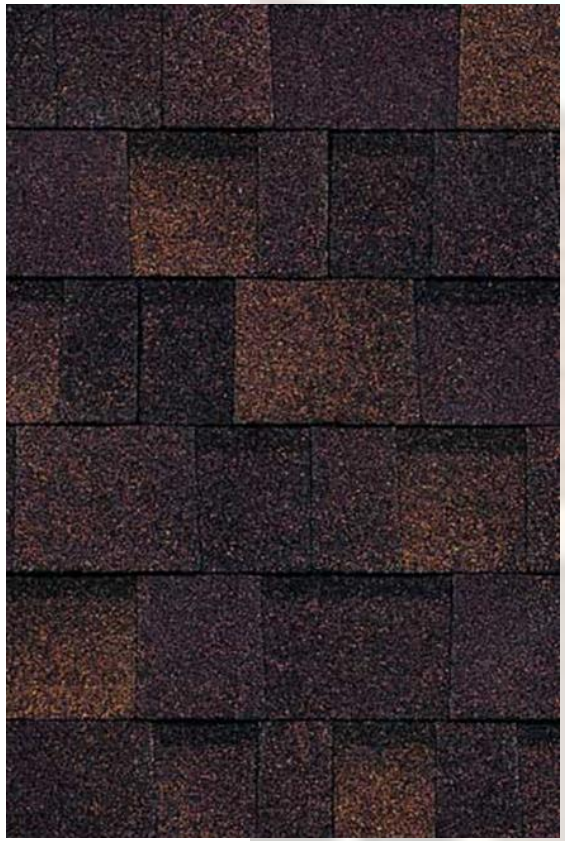


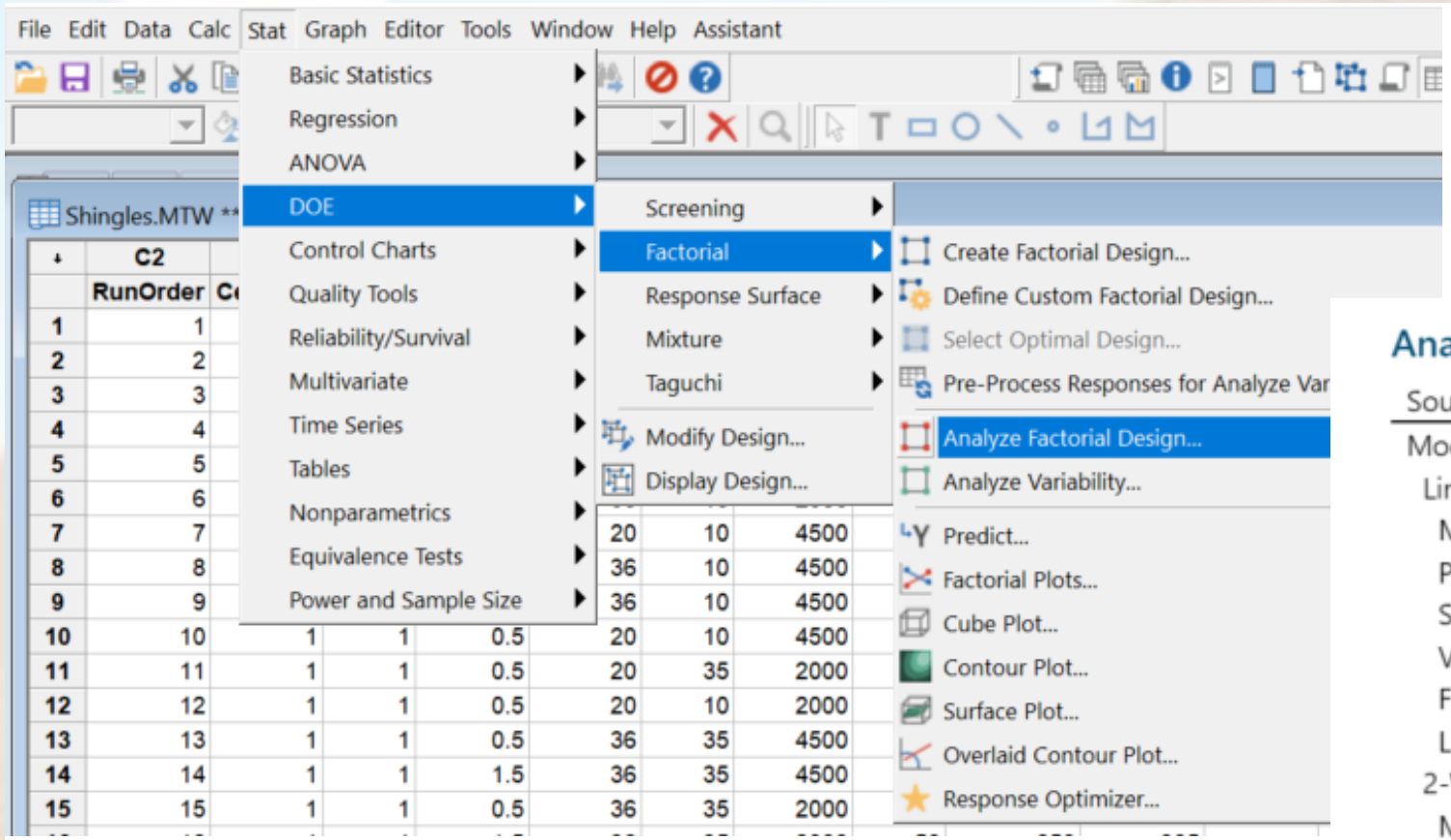
Example: Roofing Shingles

Response: Granule Loss

A Fractional Factorial Design in 6 factors:

1. Press: Application Pressure (in psi)
2. Moisture: Amount of moisture on the shingle
3. Sheet Tension (in pounds)
4. Coating Viscosity (in centipoise)
5. Percentage of Filler used in the granule mix
6. Line Speed (in feet/minute)





Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	40972.0	4552.4	77.82	0.000
Linear	6	39061.8	6510.3	111.29	0.000
Moisture	1	100.0	100.0	1.71	0.239
Press	1	22350.3	22350.3	382.06	0.000
SheetT	1	36.0	36.0	0.62	0.463
Viscosity	1	2070.3	2070.3	35.39	0.001
Filler%	1	12656.3	12656.3	216.35	0.000
LineSpeed	1	1849.0	1849.0	31.61	0.001
2-Way Interactions	3	1910.2	636.7	10.88	0.008
Moisture*Press	1	756.3	756.3	12.93	0.011
Moisture*SheetT	1	625.0	625.0	10.68	0.017
Moisture*LineSpeed	1	529.0	529.0	9.04	0.024
Error	6	351.0	58.5		
Total	15	41323.0			

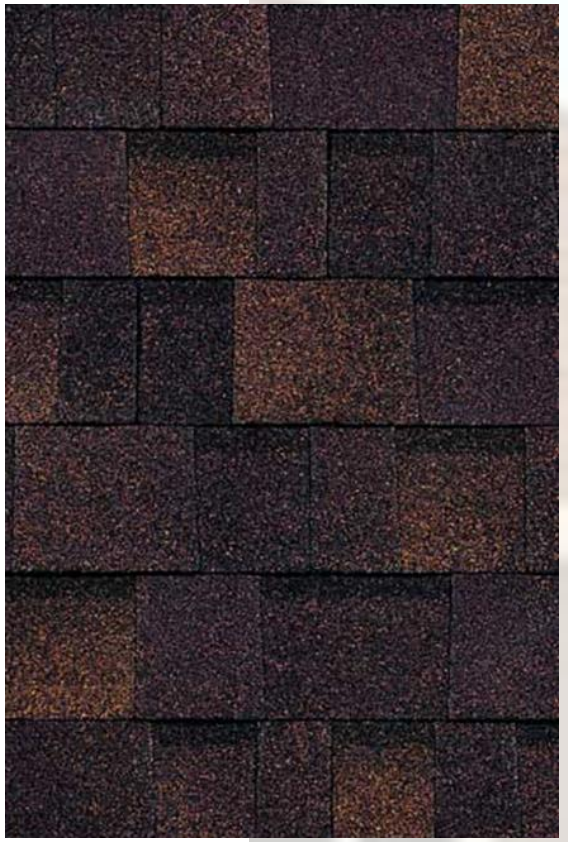
Minitab Model Fit

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
7.64853	99.15%	97.88%	93.96%

Regression Equation in Uncoded Units

GranLoss = 668.7 - 130.4 Moisture + 6.391 Press - 0.880 SheetT + 0.00910 Viscosity - 5.625 Filler% - 0.4450 LineSpeed - 1.719 Moisture*Press + 1.000 Moisture*SheetT + 0.2300 Moisture*LineSpeed

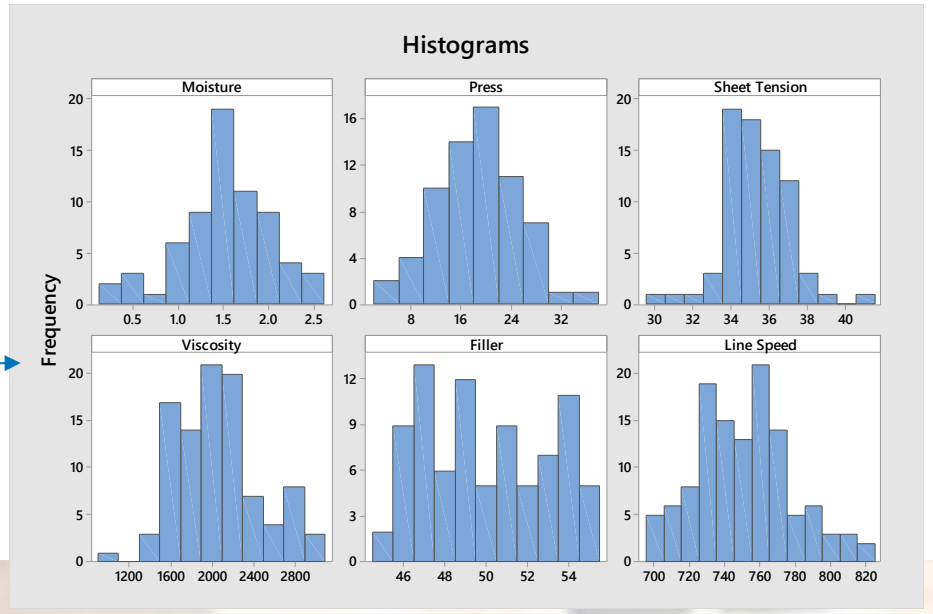


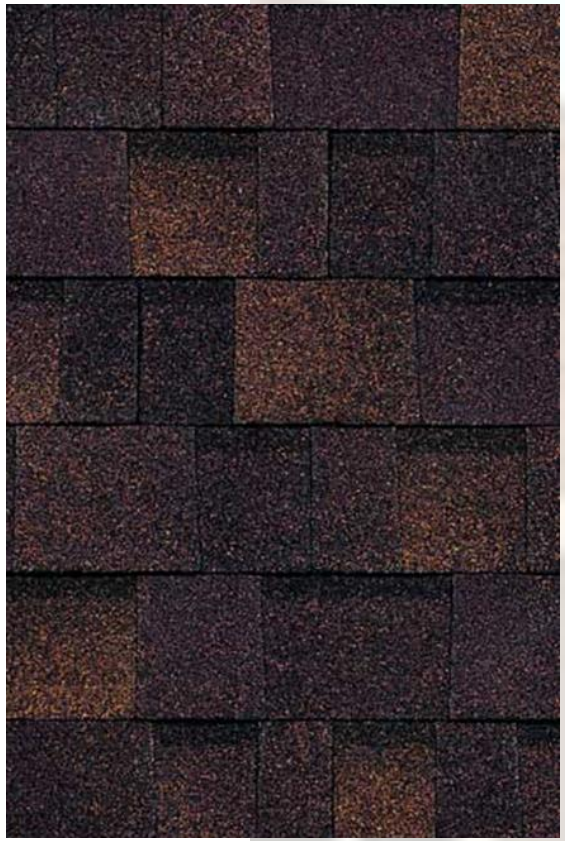
Input Distributions

Regression Equation in Uncoded Units

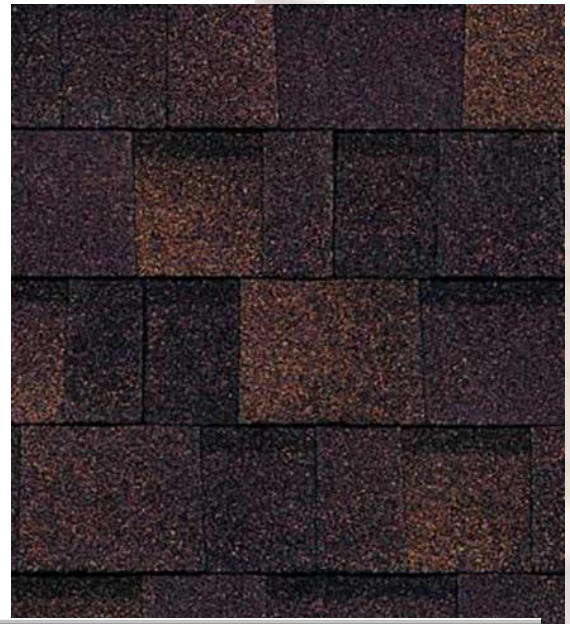
GranLoss = 541.0 - 53.9 Moisture + 4.672 Press + 1.50 SheetT + 0.00910 Viscosity
- 5.625 Filler% - 0.2150 LineSpeed - 0.859 Moisture*Press + 6.25 Moisture*SheetT
+ 0.1150 Moisture*LineSpeed

Mean	1.5276
StDev	0.5112





Minitab Statistical Software: Response Optimizer



Response Optimizer

Optimize up to 25 responses:

Response	Goal	Target
GranLoss	Minimize	

Response Optimizer: Setup

Response	Goal	Lower	Target	Upper	Weight	Importance
GranLoss	Minimize	190	190	280	1	1

Desirability functions for different

Help

Minimize the response

Hit a target value

Weight

		Moisture	Press	SheetT	Viscosit	Filler%	LineSpee
Optimal	High	1.50	36.0	35.0	4500.0	50.0	750.0
D: 0.9972	Cur	[0.50]	[20.0]	[35.0]	[2000.0]	[50.0]	[750.0]
Predict	Low	0.50	20.0	10.0	2000.0	40.0	650.0

GranLoss

Minimum

y = 190.250

d = 0.99722

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Minitab

Monte Carlo Simulation

Shingle Process

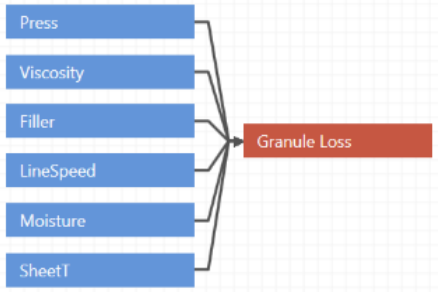
X Name	Distribution	Parameters				Preview
Press	Normal	Mean: 20	St Dev: 7			
Viscosity	Truncated Normal	Mean: 2,000	St Dev: 500	Lower: 1,400	Upper: 3,000	
Filler	Uniform	Lower: 45	Upper: 55			
LineSpeed	Normal	Mean: 750	St Dev: 25			
Moisture	Normal	Mean: 0.5	St Dev: 0.5			
SheetT	Normal	Mean: 35	St Dev: 1.75			

Y Name	Equation	Spec Limits (Optional)	
Granule Loss	668.7-130.4Moisture+6.391Press-0.880SheetT +0.00910Viscosity-5.625Filler-0.4450LineSpeed-1.719Moisture*Press+1.000Moisture*SheetT +0.2300Moisture*LineSpeed	LSL:	USL: 280

Model

Before you run the simulation, use the diagram below to verify that the mo

View: Model | Function



Input distributions

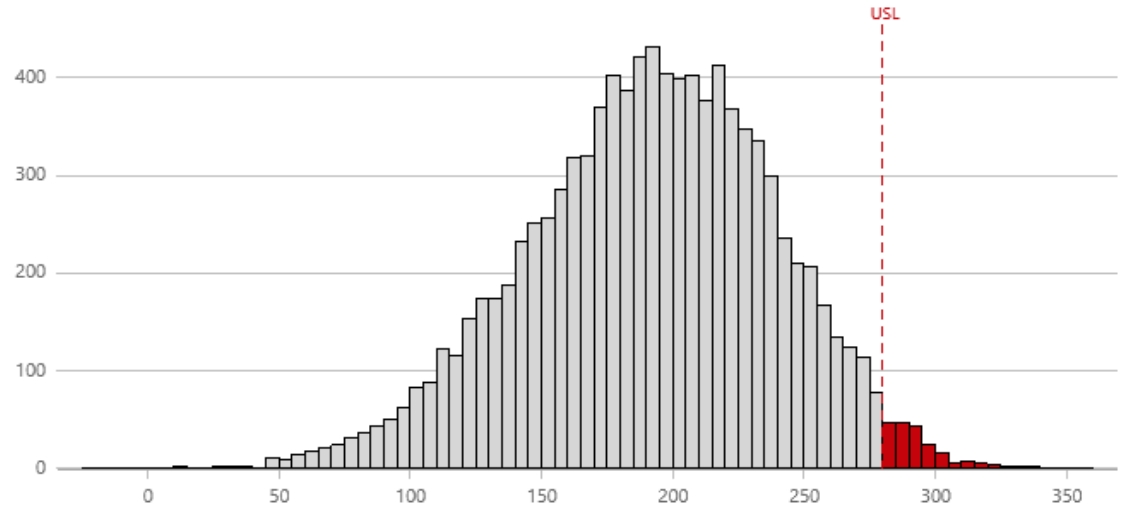
Transfer function(s)

Visual validation

Simulation Results

Shingle Process

Granule Loss



Process Performance (Ppk)

0.6677

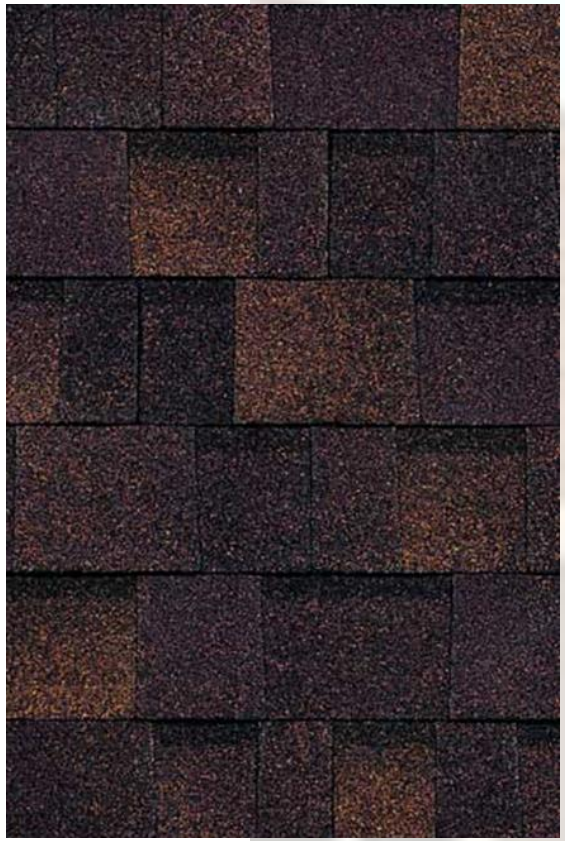
% Out of Spec

2.19%

Summary Statistics

N	10,000
Mean	191.136
Standard Deviation	48.0501

The simulation indicates that you can expect 2.19% of the *Granule Loss* values to fall outside of the specification limits. This corresponds to a Ppk of 0.6677. A generally accepted minimum value of Ppk is 1.33.



Next Steps

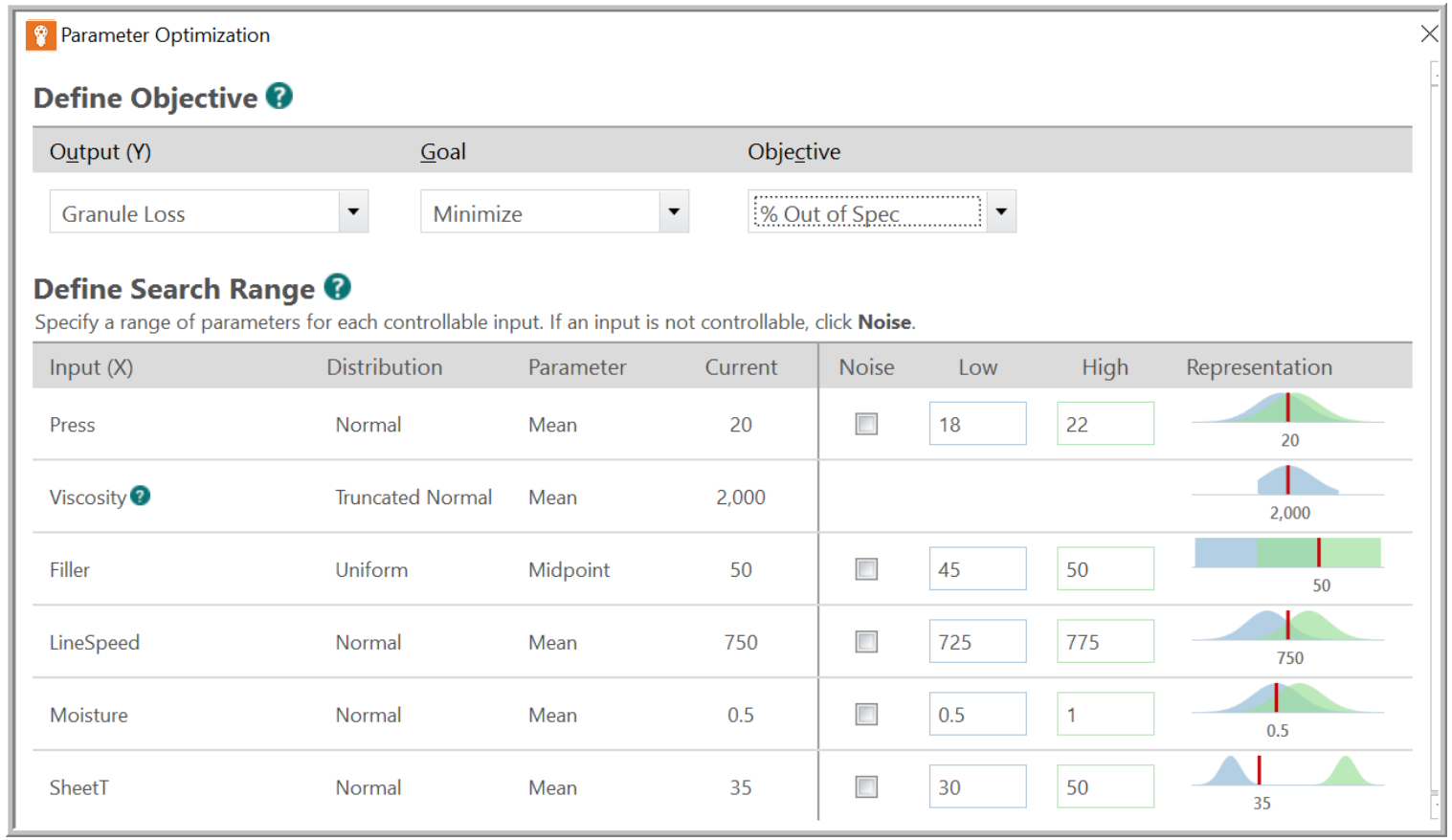
The Ppk is below the generally accepted value. To improve these results, you can perform **Parameter Optimization** to identify optimal settings for the inputs that you can control.

Parameter Optimization

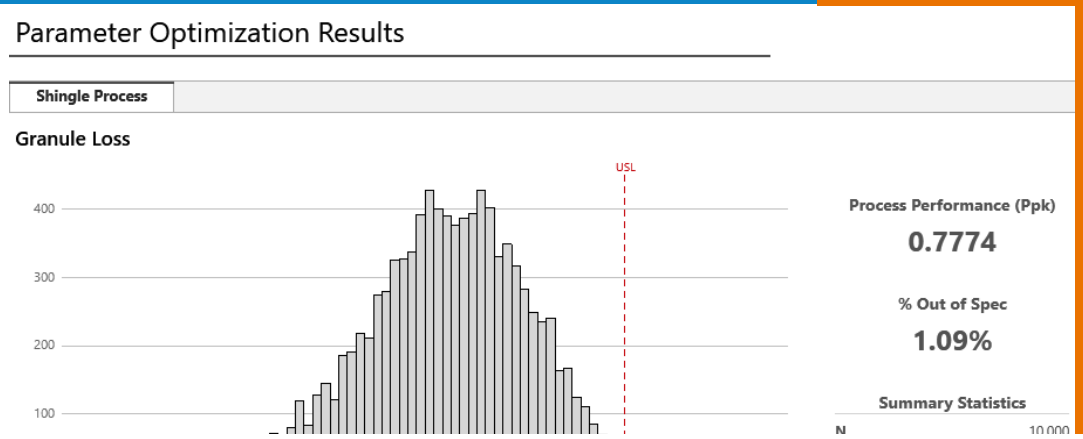
Parameter Optimization

Identifies settings for the controllable input parameters that result in a higher capability for the process using mathematical solutions and genetic algorithms.

Define Parameter Search Ranges



Parameter Optimization Results

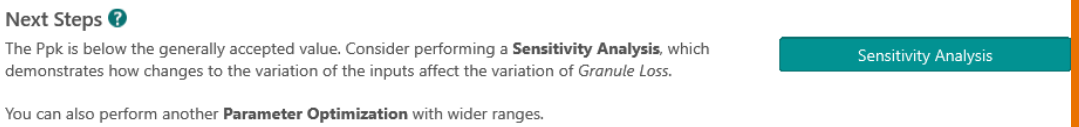


Assumptions

Optimization Goal: Minimize the % Out of Spec of Granule Loss

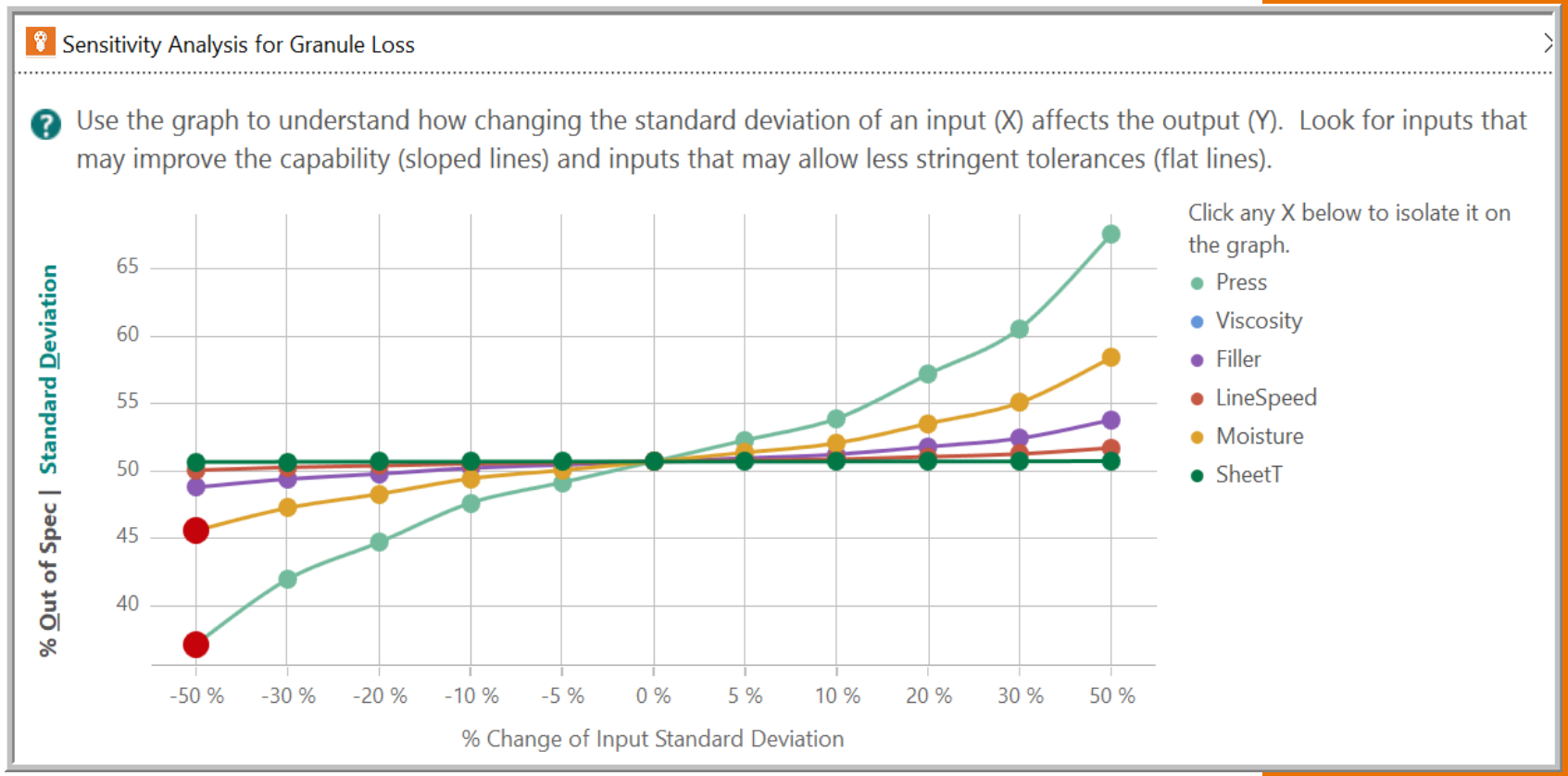
Inputs

Name	New Settings	Search Range		Previous Settings	Distribution
Press	(18.1478; 7)	Low: 18	High: 22	(20; 7)	Normal
Viscosity	(2,000; 500; 1,400; 3,000)	Low: —	High: —	(2,000; 500; 1,400; 3,000)	Truncated Normal
Filler	(44.9985; 54.9985)	Low: 45	High: 50	(45; 55)	Uniform
LineSpeed	(774.998; 25)	Low: 725	High: 775	(750; 25)	Normal
Moisture	(0.5; 0.25)	Low: —	High: —	(0.5; 0.25)	Normal
SheetT	(49.8073; 1.75)	Low: 30	High: 50	(35; 1.75)	Normal



Sensitivity Analysis

Allows you to see the effect of changing the standard deviation of the X's on the standard deviation or defect rate of Y.

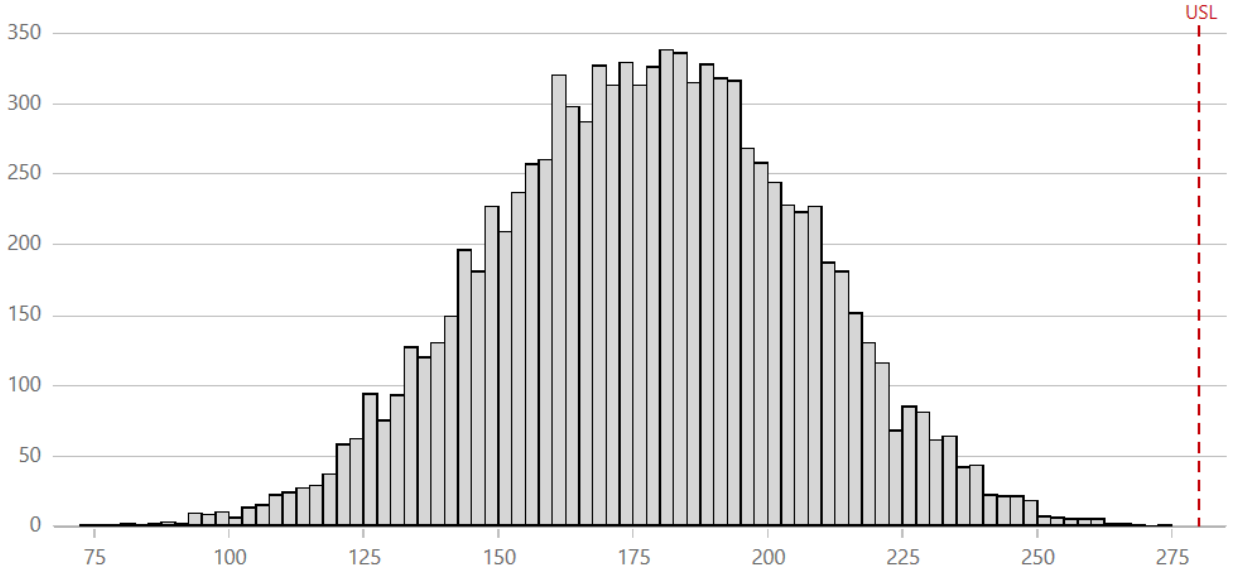


Sensitivity Analysis

Sensitivity Analysis Results

Shingle Process

Granule Loss



Using the new standard deviation values, the simulation indicates that you can expect 0.00% of the *Granule Loss* values to fall outside of the specification limits. This corresponds to a Ppk of 1.23. A generally accepted minimum value of Ppk is 1.33.

Process Performance (Ppk)

1.23

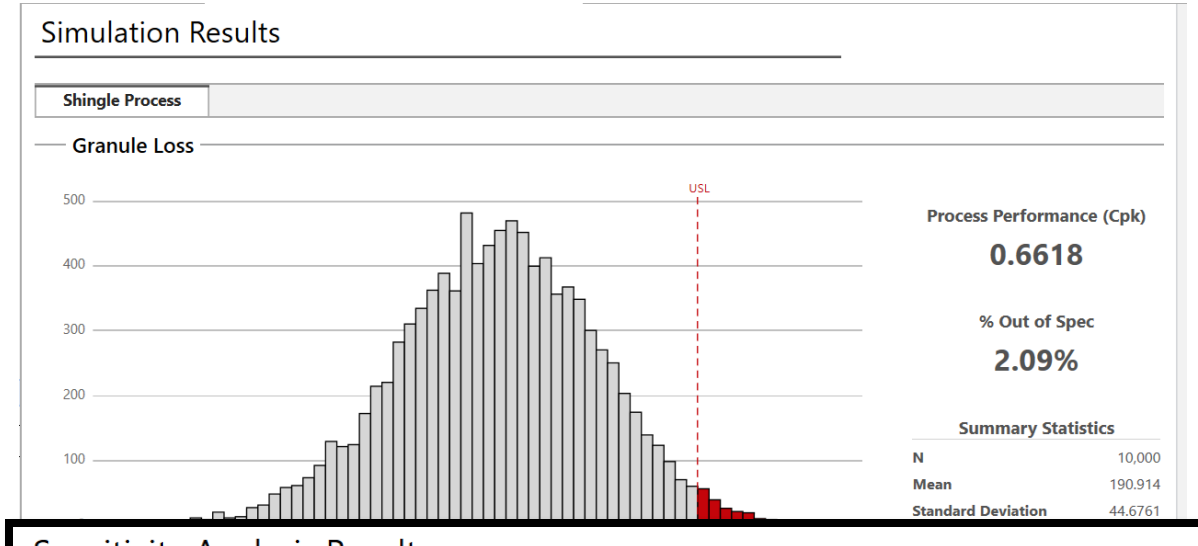
% Out of Spec

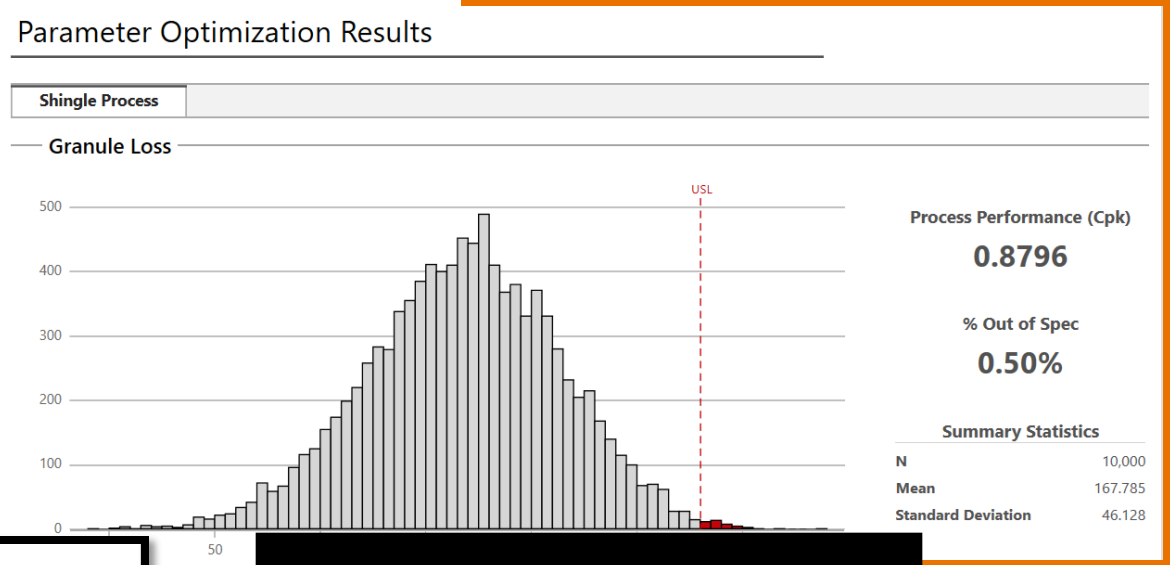
0.00%

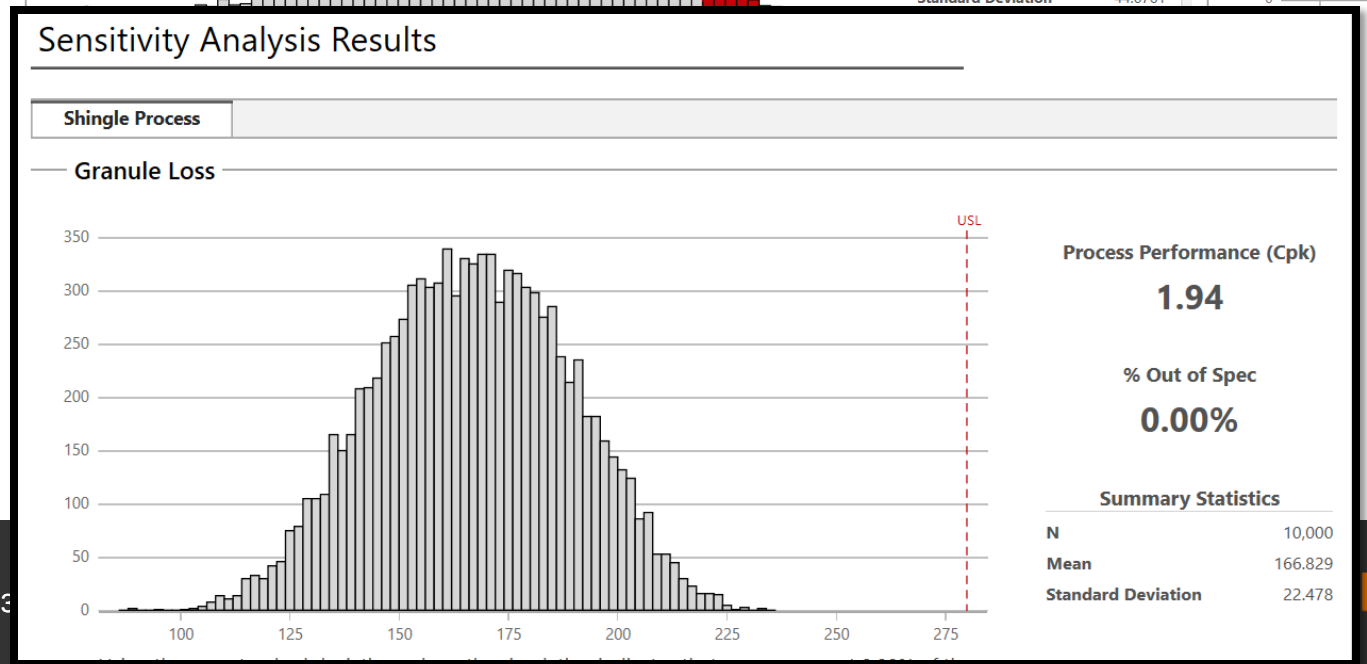
Summary Statistics

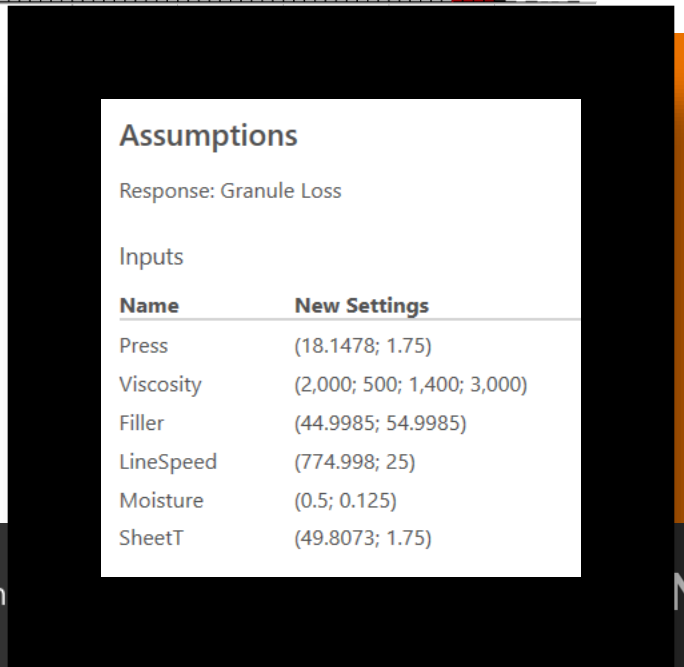
N	10,000
Mean	177.684
Standard Deviation	29.0869

Monte Carlo Simulation with Parameter Optimization and Sensitivity Analysis

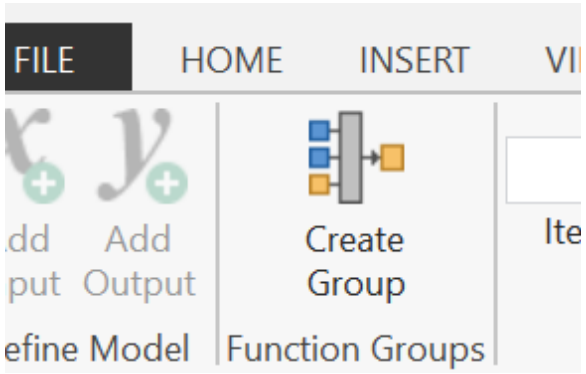


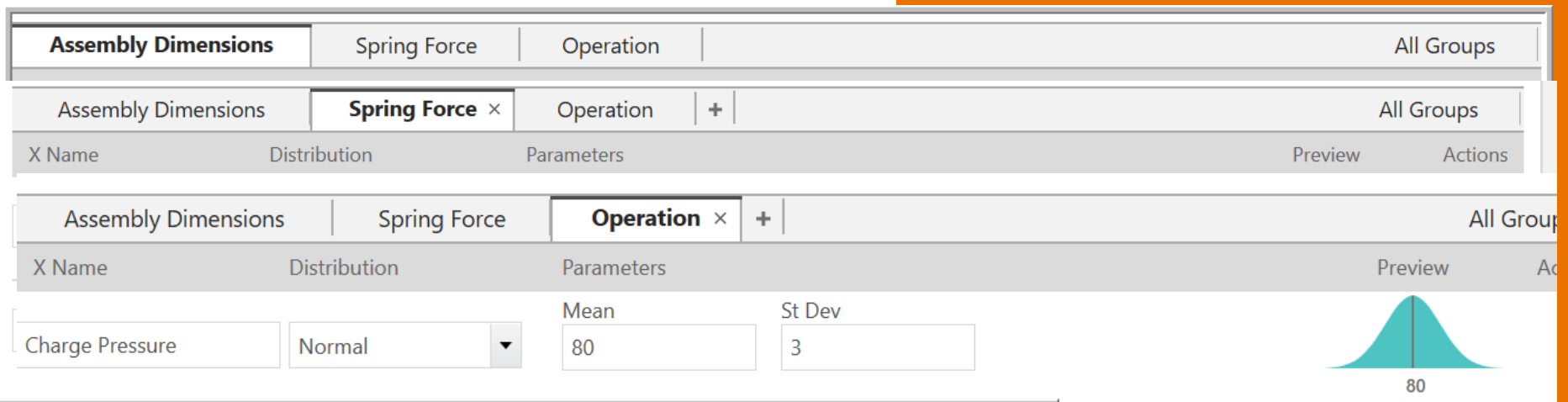


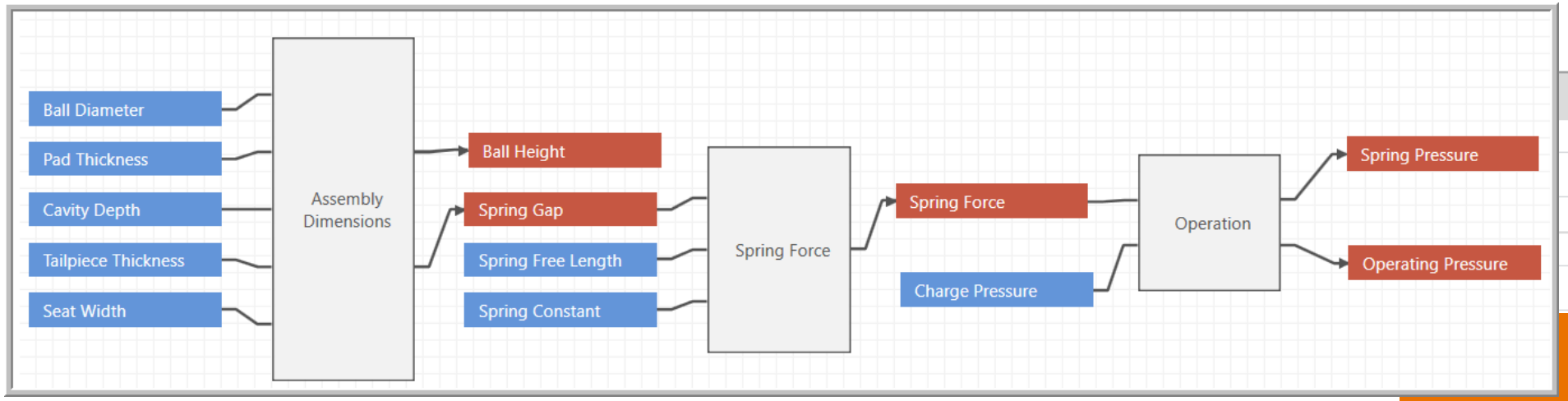


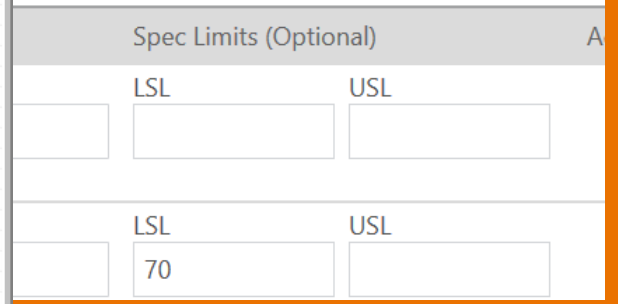


Easily Extensible









Improve Faster

- Minitab Statistical Software generated the transfer function via a designed experiment

- Minitab Workspace (and Minitab Engage) simulates and optimizes product results to ensure they meet specifications. Creating better estimates is easy with the Monte Carlo Simulation tool.

- The solutions make it easy to utilize y=f(x) equations, combined with the variability of your inputs to predict process capability and identify the best strategy for creating defect-free products.

Minitab Engage™

Minitab Engage is the only solution designed to start, track, manage and share innovation and improvement initiatives from idea generation through execution.

Accelerating growth and improving profitability begins with good ideas and ends with solid execution. Minitab Engage helps organizations build improvement and innovation programs, execute them with the help of problem-solving tools and proven project management methodologies, then track key performance metrics in real time to demonstrate ROI.

Visualize: Deliver Insights That Inspire Action

Monitor project status

Real time dashboards empower decision-making and strategic course correction.

Track KPIs with dynamic dashboards

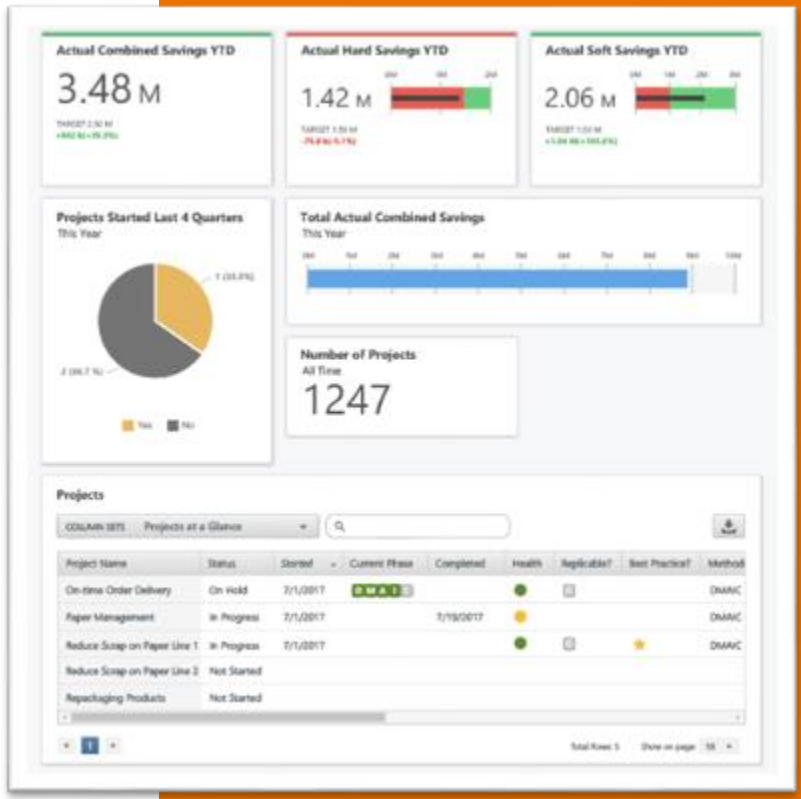
Visualize project status and performance metrics of your entire initiative or focus on specific projects, teams or divisions.

Generate presentation-ready reports

Keep stakeholders engaged by easily creating reports and dashboards

Recognize and replicate success

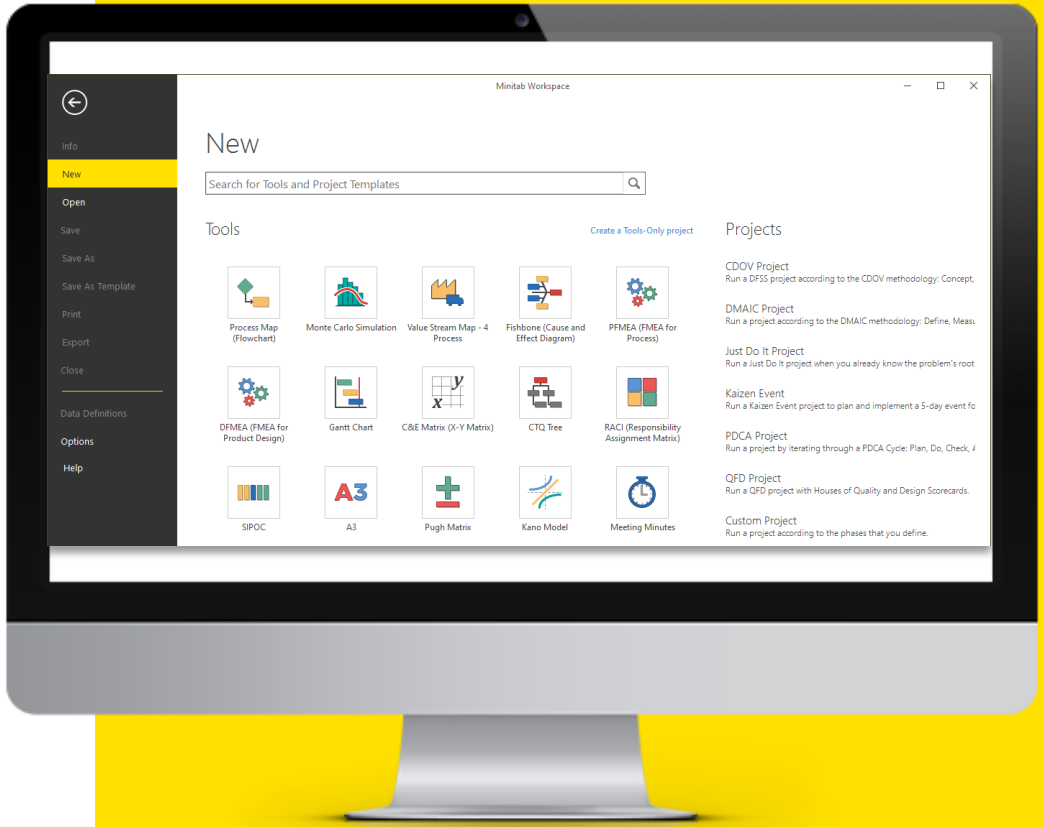
Inspire teams throughout the organization to replicate successful initiatives



Minitab Workspace®

The ultimate toolkit designed to elevate your work by helping you clearly visualize, optimize and map your business value better than ever before.

Powerful visual tools and forms are brought together in one intuitive interface that helps you create processes, identify improvement opportunities and make problems easier to solve. Combined they will help you achieve the greatest impact, elevate your work, gain buy-in and clearly communicate across teams with simple to use and understand visuals right at your fingertips.



Visual Tools for Better Business Productivity

Over 90+ powerful and functional tools and roadmaps all in one easy-to-use platform

Lean

- Value Stream Map
- A3
- Work Element Time Study
- 5S Audit
- Kanban & Supermarket Sizing
- Quick Changeover (QCO-SMED)
- Waste Analysis by Operation
- Gemba Walk Interview Sheet
- Force Field
- Value Stream Map Comparison
- Preventative Maintenance
- Cycle Time Bar Chart
- Kaizen Event Roadmap

Process Improvement

- Fishbone
- Process Map
- C&E Matrix
- Monte Carlo Simulation
- PFMEA
- SIPOC
- DOE Planning
- Funnel Report
- Pareto Chart
- Audit Plan
- Solution Implementation Checklist
- DMAIC Roadmap
- PDCA Roadmap

Product Development

- DFMEA
- Kano Model
- VOC Plan
- SWOT Analysis
- Critical To Tree
- House of Quality Matrix
- CDOV Roadmap

Project Management

- Gantt Chart
- Meeting Minutes
- Stakeholder Analysis
- RACI (Responsibliity Assignment Matrix)
- 30-60-90 Action Plan
- Project Risk Assessment

Decision-Making

- Impact vs. Effort Matrix
- Solution Desirability Matrix
- Project Prioritization Matrix
- Pairwise Comparison Matrix

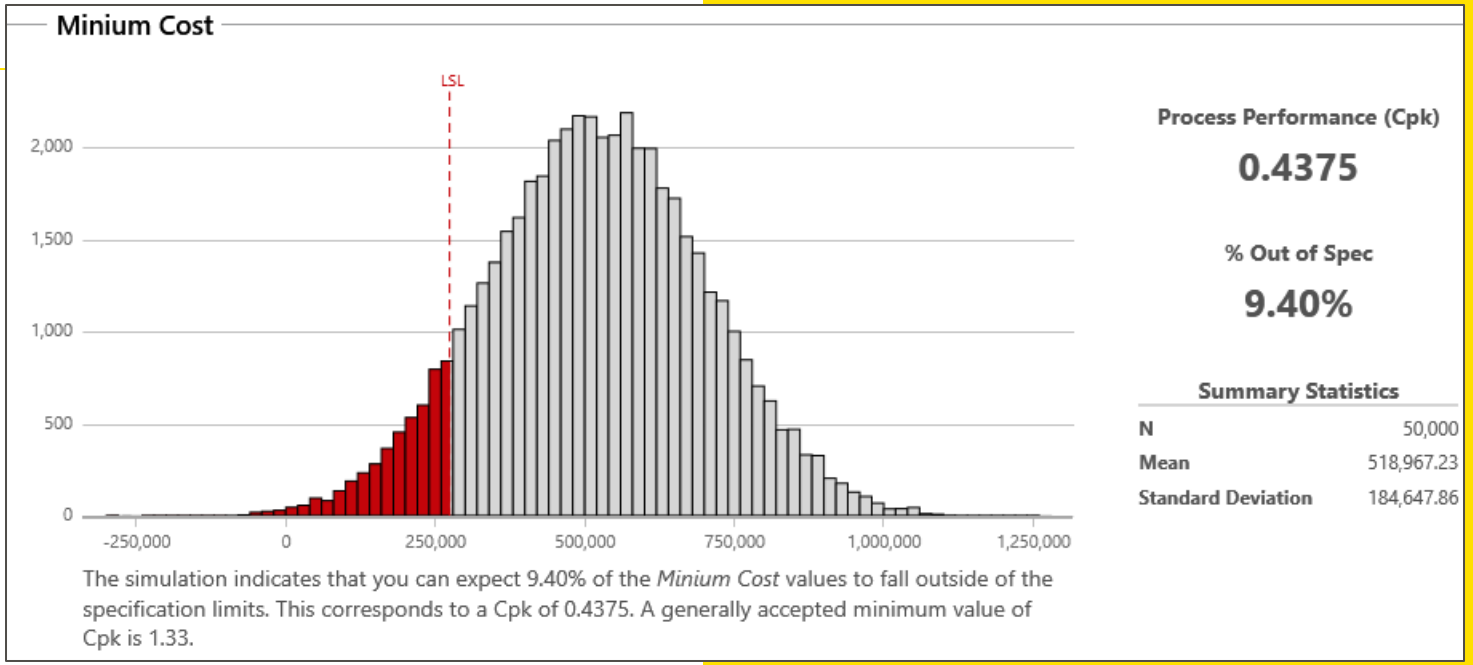
Root-Cause Analysis

- Idea Map
- Five Whys
- 4S
- 8P

Discover the Ultimate Toolkit

Monte Carlo Simulation

Simulate, forecast results and optimize any output with speed and efficiency.



Q&A

Thank You!

From all of us at