



The slide features a central illustration of four stylized human figures in orange, teal, and blue, working together to assemble large puzzle pieces. The puzzle pieces are arranged in a circular pattern, with some pieces already in place and others being moved into position. The background is white with faint geometric shapes like circles and lines. The title and presenter information are displayed in orange and white text boxes at the top.

Product Sensitivity Analysis Using Design Of Experiments

Perry K. Parendo

 Minnesota
Section
ASQ Excellence Through Quality™

QUALITY CULTURE
FOR
SUSTAINED SUCCESS

MINNESOTA
QUALITY CONFERENCE
November 9 & 10, 2021
Earle Brown Heritage Center
Brooklyn Center, MN

About the presenter

- Experience
 - Corporate
 - Large and Small projects
 - Including International
 - Consulting
 - Leader and team member
- Education
 - BSME (University of Minnesota)



MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 2 of 22

What this presentation will cover

- Product Development Flow
- The Point Solution Problem
- Design of Experiments Solution



MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 3 of 22

Product Development Flow

What happens?



Product Development Flow

- Requirements
- Concept
- Proof of concept
- Key variables
- Sensitivity analysis
- Learning/ recommendations
- Final Design
- Validation

Avoid jumping ahead

Applies to product and process design

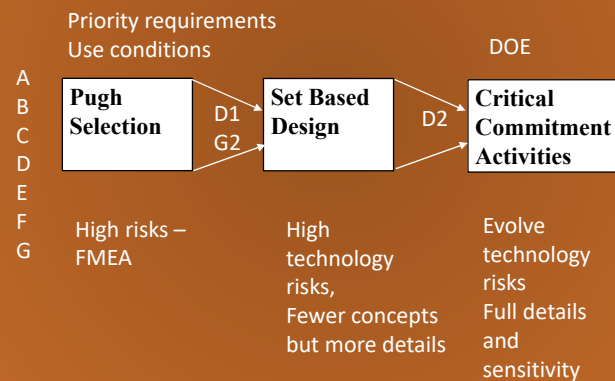


MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 5 of 22

Convergent/ Divergent Concept



MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 6 of 22



The Point Solution Problem

- Missing Potential
 - Stuck at preliminary design
- Likely no stability
- Likely more expensive than needed
- Can it be scaled?
- Impact on validation and end of development schedule
- Impacts Design Culture/ Behaviors



MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 8 of 22

Stability

- Consistency
- With material variation
- With design variation
- With process variation
- With environment variation

- Know of places to open tolerances
- Know where to improve process controls

Can also look at cost and schedule sensitivity



MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 9 of 22



Intro to DOE Solution

- A tool to identify relationships between multiple input and multiple output variables
- Common window is 3-7 inputs but phased approach is common
- Outputs – unlimited, but solution becomes less intuitive with larger quantities
 - Include competing requirements
 - Always a cost trade off
- Additional depth is important to increase confidence
 - Residual analysis is core approach which also provides additional learning



MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 11 of 22

Typical DOE Test Table

Test #	Variable			Response			
	A	B	C	1	2	3	4
1	-	-	-				
2	+	-	-				
3	-	+	-				
4	+	+	-				
5	-	-	+				
6	+	-	+				
7	-	+	+				
8	+	+	+				

This is the most simple case. Can add more inputs and outputs. Do not have to test every combination.

This case is often evaluated at 3 conditions, leading to 27 tests.



MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 12 of 22

Dealing with Sensitivity Information

- Based on the sensitivity, can we determine a new solution
- A balance of the levels we previously tested at
 - Do not need to select corners of the cube. We can pick the interior
- For example, if we did a temperature of 70 and 150, maybe we can determine a level of 90 may be our “sweet spot”



MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 13 of 22

Design of Experiments (DOE)

- How do we find an ideal sweet spot?
- Simultaneous, strategic changing of variable settings and multiple output measurements
- Confident prediction to speed decision making

May be useful for feasibility but certainly an advantage for development

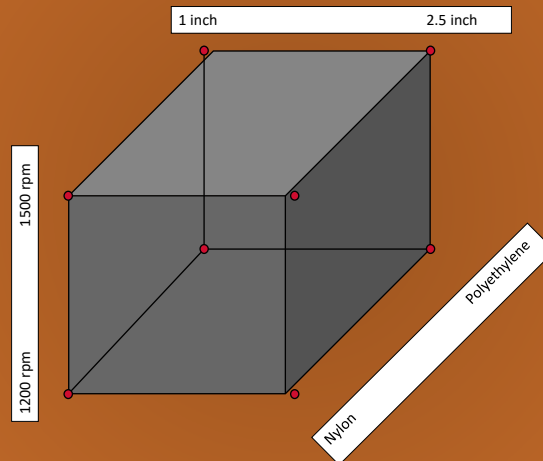


MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 14 of 22

Design of Experiments - Product

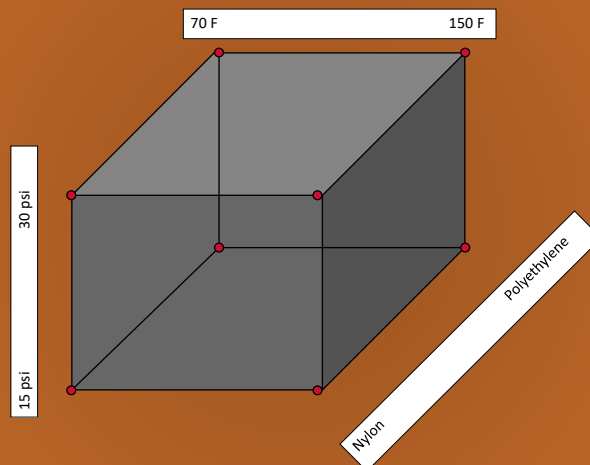


MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 15 of 22

Design of Experiments - Process



MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 16 of 22

DOE Testing

- DOE can explore extremes and avoid all of the middle values
 - Interpolation often matches quite well

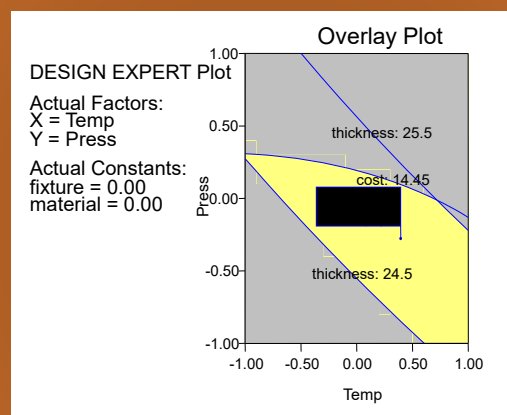


MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 17 of 22

Optimization



MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 18 of 22

Example Equation

- $Y = z + a[A] + b[B] + c[C] + d[A*B]$
- $Y = z + 15[A] + 8[B] + 1[C] + 8[A*B]$
 - A is key variable
 - C tolerance can be opened up



MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 19 of 22

Next Step

- Another test?
 - Change ranges
 - New variables to replace less important ones
 - Add responses/ outputs
- Finalize design
 - Confirm and then move to validation



MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 20 of 22

Key takeaways

- As we advance our designs, knowledge and understanding shapes our decisions
 - More knowledge means more predictability
- If we stop with a preliminary design, the instability causes development delays and cost impacts.
- Doing sensitivity analysis well, accelerates the end of the development process



MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 21 of 22

Thank you for attending!!!



For more information feel free to
contact me:

Perry K. Parendo

Perry@PerrysSolutions.com

Note: If you choose to print this presentation, consider choosing Grayscale in order to
avoid printing the background color and wasting ink.



MINNESOTA QUALITY
CONFERENCE

Product Sensitivity Analysis Using Design Of Experiments

Slide 22 of 22