Cooking recipe => V.05 / 2018
Quality by Design - Design of Experiments

Course doc.
&
Orientating

By Stefan Moser
info@stefan-moser.com

Problem - Formulation
- Why?
- What?
- When?
- Who?
- How?
- Where?

Project-management-Quality by Design
- Why you?
- Who is involved? Stakeholds / Shareholder
- What is needed? Res. / Time / money / People
- What is really important?
- What happens if you do nothing, what changes
- How much harm is done if you succeed (in time and budget?)

Define, Measure, Analyze, Improve, Control, Budget, Resources, Time-line, Function

Frame / boundaries
- What are the focus?
- What are the boundaries?
- How does the process look?
- What does the process out?
- What are the main inputs?
- What are the main outcomes
- What is derived?
- What is qualified/expected
- Are there problems?

SIPOC, Boundary Diagram

Factors
- Which ones you never touched?
- What are the important ones?
- How to prioritize?
- What is already known?
- How to generate consent?
- What data type is your factor?
- Is the factor measurable?
- Is your factor capable according the MSA

Ishikawa / 7M, Brainstorm, Brainmap, Cluster, MVDA

Factors => Responses
- qualitive => quantitive
- topic related
- significant
- capable (MSA)
- continious?

QFD, Kano, Must-be, Attract, Must-be?

Choose the right design

Design & Objective
- Complexity can't be reduced. Find the Space of interest & therefore the needed mathematics
- Quadratic approximation

USL, LSL, Linear approximation, Area of interest

Include existing Data
- Balanced
- Symetrical
- Orthogonal
- Corn points

Choose Objective I
- Degree of obsession compl.
- knowledge existing
- estimate time, ressources, moneys
- cost per experiment
- availability of machinery

Linear, Interaction, Squared

- keep investigation as small and simple as possible
- Don't an estimate variance and variability

Choose objective II -> Workheet
- keep it simple
- think of flexibility
- document Tools which are used

Use corn points to:
- Estimate pol. 2. Grade
- Calc. Lack of Fit
- check reproducibility

choose combination of investigation that are complementary and modular

Robustness, Think in steps if possible

Raw data analysis

Review replicates
- Ok: Variance of corn points / replicates $r \leq 20\%$
- : Variance of corn point / replicates way to big. Name of unknown side factors?

Exp. No

Check histogram of Responses
- Perfect?
- Left Skew by transform to log
- Right Skew by transform to log / log
- Bimodal
- Exponential Dist. by transform to Exponential

Response is attributive data? Set more levels? Learn other signal-type

Problem ahead Kurtosis Test!

Geometric Design Quality
- confoundings
- bad scaling
- Typing errors
- wrong / unsupported model terms
- Copy / paste errors
- Less Orthogonal
- less Symmetry
- less Balanced

Correlation Matrix, check condition No., Skew Design

Data analysis

Data Analysis I Summary plot
- Regression
- Coefficients
- Residuals & precision
- Replicate - plot

Data Analysis II Summary plot
- Model - pruning
- Main Error I
- Main Error II
- Main Error III
- Main Error IV
- Main Error V
- Main Error VI

Reasons for bad models

Model - Response - Outcome
- not sufficient
- sufficient
- check Design Matr.
- Complement Design
- Have Investigation space?
- verify models
- find Optimum

Main - Error I
- Sorting
- Typing errors
- Labelling errors
- Join / match
- copy/paste

Main Error II
- bad replicates
- measurement not capable
- mix up of Exp.
- copy/paste errors

Main Error III
- Histogram
- Skew => log transform
- Bi-modal find more representative levels
- Curve maybe unexpected x² terms?

Main Error IV
- Pruning
- Wrong pruning
- none significant terms
- wrong factors
- outlier
- wrong or not applied transformation

Main Error V
- Interaction
- missing Interaction term
- Complement Design

Main Error VI
- none Linear effect
- check main effect plot
- add additional Experiments
- complement Design

Result - Quality - satisfactory?

Find the optima
- Define factor range
- Define Y and Z Responses
- weight responses
- find a compromis
- Use Simplex evaluation to present the possibilities/ies
- Use desirability to reflect the voice of customer

Simplex evaluation

Visualize the result
- Venn-diag.
- Responses
- Factors
- Trios
- Compromis
- desirability
- weight
- Compare results
- new possibilities
- new insights
- collaborators
- components
- Limits

Test the solution
- Sweet spot
- Monte Carlo Simulation
- calculate DPMO
- Log D
- Loss function

Calculate the tolerances
- Probability map
- manhattan distance
- Prove acceptable region
- From the robust region find the space where tolerances as safe as possible as wide as possible and as narrow as necessary?
- robust edges
- hypercube edges
- Tolerance - Confidence - Reduction - Tolerance
- Sobol

Limits of a model
- model not valid outside
- Area of interest
- model valid inside
- Every model includes
- Factor precision error
- Response precision error
- Influence of uncontrolled factors „noise"
- Influence of the environment „noise"
- noise of unknown factors
- upscale errors based on estimates

„Essentially, all models are wrong, but some are useful" G.E.P. Box

test the robustness?

Robustness - Outcome I
- in Specification
- model
- Outcome Ok

hints
- factors do still have some influence
- you know where to adjust if necessary

Robustness - Outcome II
- in Specification
- model
- Outcome Ok

hints
- bad outcome factors don't influence results?

Robustness - Outcome III
- in Specification
- model
- Outcome Ok

hints
- special reason outlier
- the model will tell you what factor is responsible?

Robustness - Outcome IV
- in Specification
- model
- Outcome Ok

hints
- factors are estimated
- wrong factors
- weak model
- process not understanded

Close the project?

Document your success
- count the costs
- count the benefits
- point out the improvements
- explain / highlight the structure
- lessons learned

help others to apply the knowledge
- Contour Plot
- Control charts
- SOP

Close the project official
- Otherwise it will stick to you forever
- Goal
- Celebrate and set a clear end to the topic &
- Combine a rollout and hand over the responsibility to the process owner

Interpret Investigation results
- What is desired
- Consider Model quality Q_2
- Consider Model validity
- Use common sense?
- Don't expect things to change if you try again! With good model quality

contour plot

Have in mind contour plots don't include the model precision => $y = mx + b + \varepsilon$ [noise]

Look out 4 compromis
- Find the overlap! venn-diagram
- green: OK
- yellow: N.ok
- Still no precision included!
- Sweet spot plot

MOSER STEFAN PROCESS OPTIMIZATION
"Consultancy, Analysis & Training"

STEFAN MOSER Dipl.-Ing. FH
Weberweg 3 • D-83131 Nußdorf am Inn
Mobile: +49 (0) 170 811 240 3
Email: info@ stefan-moser.com
www.stefan-moser.com