ROBUST DESIGN –
THE TAGUCHI PHILOSOPHY

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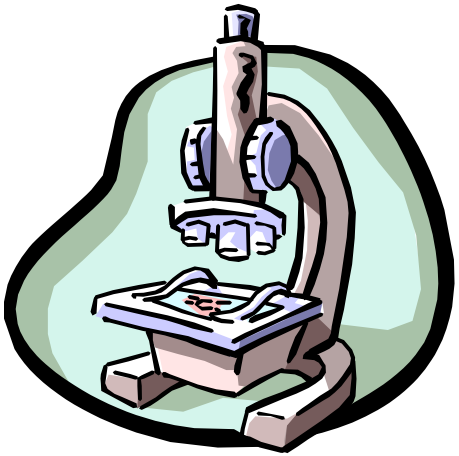
Robust Design – The Taguchi Philosophy

Overview

- Taguchi Design of Experiments
- Background of the Taguchi Method
- The Taguchi Process



Taguchi Design of Experiments

- Many factors/inputs/variables must be taken into consideration when making a product especially a brand new one
  - Ex. Baking a new cake without a recipe
- The Taguchi method is a structured approach for determining the ”best” combination of inputs to produce a product or service
  - Based on a Design of Experiments (DOE) methodology for determining parameter levels
- DOE is an important tool for designing processes and products
  - A method for quantitatively identifying the right inputs and parameter levels for making a high quality product or service
- Taguchi approaches design from a robust design perspective

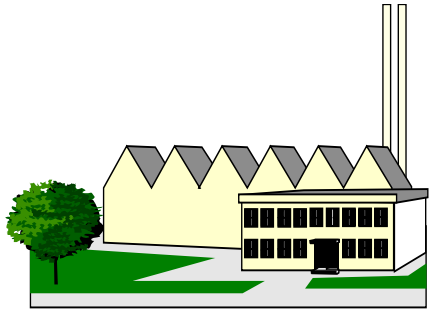
Robust Design (I)

- ”Products and services should be designed to be inherently defect free and of high quality”
  - Meet customers’ expectations also under non-ideal conditions
- Disturbances are events that cause the design performance to deviate from its target values
- Taguchi divide disturbances into three categories
  - **External disturbances**: variations in the environment where the product is used
  - **Internal disturbances**: ware and tare inside a specific unit
  - **Disturbances in the production process**: deviation from target values
- A three step method for achieving robust design (Taguchi)
  1. Concept design
  2. Parameter design
  3. Tolerance design
- The focus of Taguchi is on Parameter design

Robust Design (II)

1. Concept Design

- The process of examining competing technologies for producing a product - Includes choices of technology and process design
- A prototype design that can be produced and meets customers' needs under ideal conditions without disturbances



Robust Design (III)

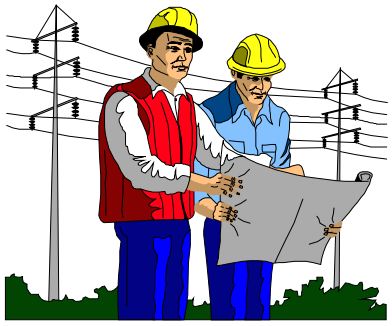
2. Parameter Design

- The selection of control factors (parameters) and their "optimal" levels
  - The objective is to make the design Robust!
- Control factors are those process variables management can influence.
  - Ex. the procedures used and the type and amount of training
  - Often a complex (non-linear) relationship between the control factors and product/design performance
- The "optimal" parameter levels can be determined through experimentation

Robust Design (IV)

3. Tolerance Design

- Development of specification limits
  - Necessary because there will always be some variation in the production process
  - Taguchi strongly advocates aiming for the target value not just settle for “inside the specification limits”!
- Occurs after the parameter design
- Often results in increased production costs
  - More expensive input material might have to be used to meet specifications



Background of the Taguchi Method

- Introduced by Dr. Genichi Taguchi (1980)
  - Comparable in importance to Statistical Process Control (SPC), the Deming approach and the Japanese concept of TQC
- Unique aspects of the Taguchi method
  - The Taguchi definition of quality
  - The Taguchi Quality Loss Function (QLF)
  - The concept of Robust Design

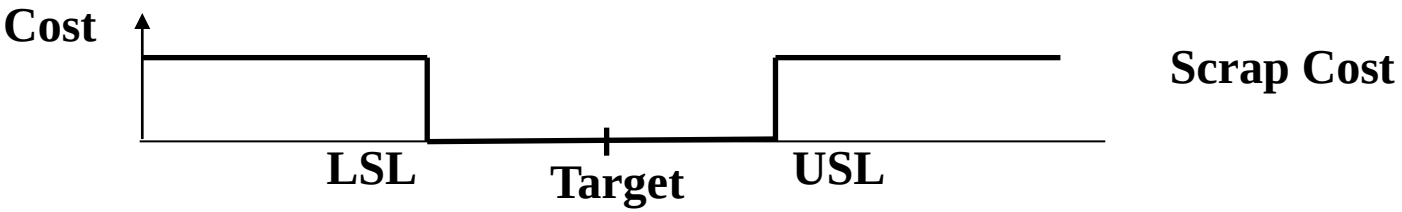
➢ **The Taguchi definition of quality**

- Ideal quality refers to a target value for determining the quality level
- Ideal quality is delivered if a product or service tangible performs its intended function throughout its projected life under reasonable operating conditions without harmful side effects
- Ideal quality is a function of customer perception and satisfaction
- Service quality is measured in terms of loss to society

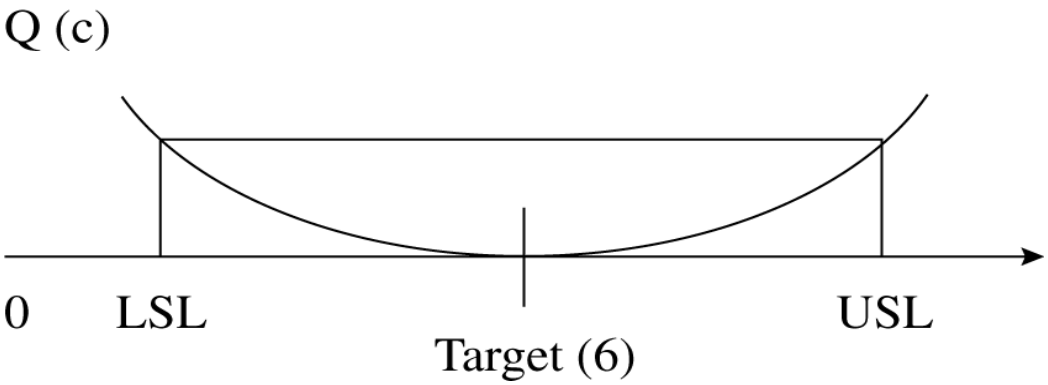
- The traditional definition is ”conformance to specifications”

The Taguchi Quality Loss Function (I)

- The traditional model for quality losses
  - No losses within the specification limits!



- The Taguchi loss function
  - the quality loss is zero only if we are on target



Computing The Taguchi QLF

Define

C = The unit repair cost when the deviation from target equals the maximum tolerance level

Δ = Tolerance interval (allowable parameter variation from target to SL)

T = Target value

Y = The actual metric value for a specific product

V = Deviation from target = Y-T

L(V) = Economic penalty incurred by the customer as a result of quality deviation from target (The quality loss)

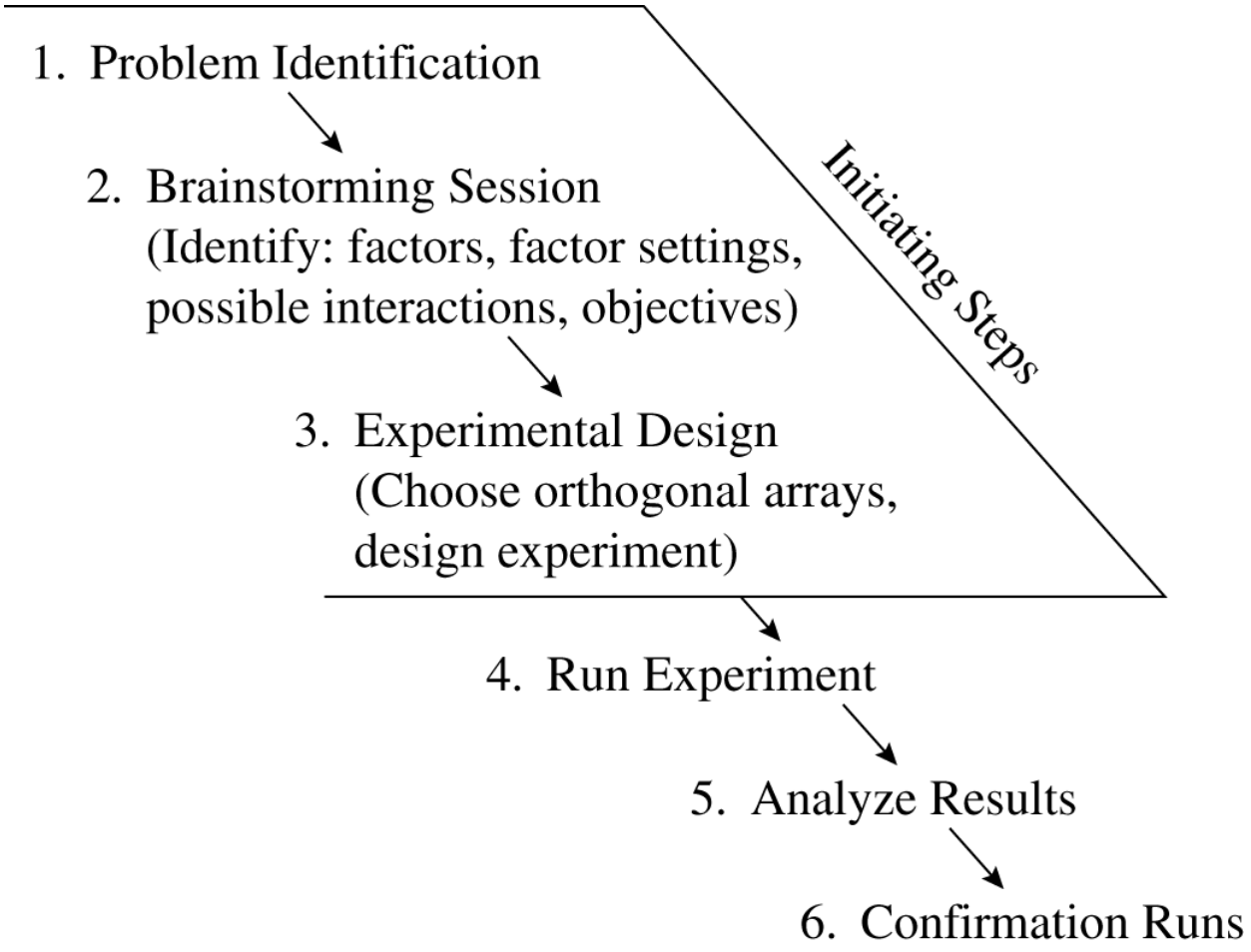
The Loss Function

$L(V) = C(V/\Delta)^2$

Example: The repair cost for an engine shaft is \$100. The shaft diameter is required to be 10 ± 1 mm. On average the produced shafts deviates 0.5 mm from target. Determine the mean quality loss per shaft using the Taguchi QLF.

Solution: $L(0.5) = C \cdot (V/\Delta)^2 = 100 \cdot (0.5/1)^2 = 100 \cdot 0.25 = \$25$ per unit

The Taguchi Process (I)



The Taguchi Process (II)

1. Problem Identification
   - Locate the problem source not just the symptom
2. Brainstorming Session
   - Attended at least by project leader/facilitator and workers involved in the process. Other participants may include managers and technical staff
   - The purpose is to identify critical variables for the quality of the product or service in question (referred to as factors by Taguchi)
     - **Control factors** – variables under management control
     - **Signal factors** – uncontrollable variation
   - Define different factor levels (three or four) and identify possible interaction between factors
   - Determine experiment objectives
     1. **Less-the-better** – keep the level of defectives as close to zero as possible
     2. **Nominal-is-best –** Outcome as close to target as possible
     3. **More-the-better** – max number of units per time unit or lot without defects

The Taguchi Process (III)

3. Experimental Design
   - Using factor levels and objectives determined via brainstorming
   - Taguchi advocates off-line-experimentation as a contrast to traditional on-line or in-process experimentation
   - Care should be taken to selecting number of trials, trial conditions, how to measure performance etc.
4. Experimentation
   - Various rigorous analysis approaches like ANOVA and Multiple Regression can be used but also simpler customized methods are available
5. Analysis
   - The experimentation provides ”best” levels for all factors
   - If interactions between factors are evident $\Rightarrow$ Either ignore or run a full factorial experiment
6. Conforming Experiments
   - The results should be validated by running experiments with all factors set to ”optimal” levels

The Taguchi Approach to DOE (I)

- Traditional Design of Experiments (DOE) focused on how different design factors affect the ***average*** result level
- Taguchi's perspective (robust design)
  - variation is more interesting to study than the average
  - Run experiments where controllable design factors ***and*** disturbing signal factors take on 2 or three levels.
- For each combination of the design variables a number of experiments are run covering all possible combinations of the signal variables.
  - ➔ Can estimate average effects and the variation different design factor levels imply
  - ➔ choose factor levels that minimize the sensitivity against disturbances

The Taguchi Approach to DOE (II)

- From every trial series we can obtain an average result level and a measure of the variation, si, i=1,2, … ,9. These values can then be used as a basis for choosing the combination of factor levels that provides the most robust design.