…We have a large reservoir of engineers (and scientists) with a vast background of engineering know-how. They need to learn statistical methods that can tap into the knowledge. Statistics used as a catalyst to engineering creation will, I believe, always result in the fastest and most economical progress…

George Box, 1992

Chapter 7

Taguchi Designs

Genichi Taguchi

- **An engineer who has developed an approach (Taguchi Methods) involving statistical planned experiments to reduce variation**
- **1950's: applied his approach in Japan**
- **1980's: introduced his ideas to US**
- **Many (in Japan and US) consider DEX and Taguchi Methods synonyms…**

What are Taguchi's Contributions?

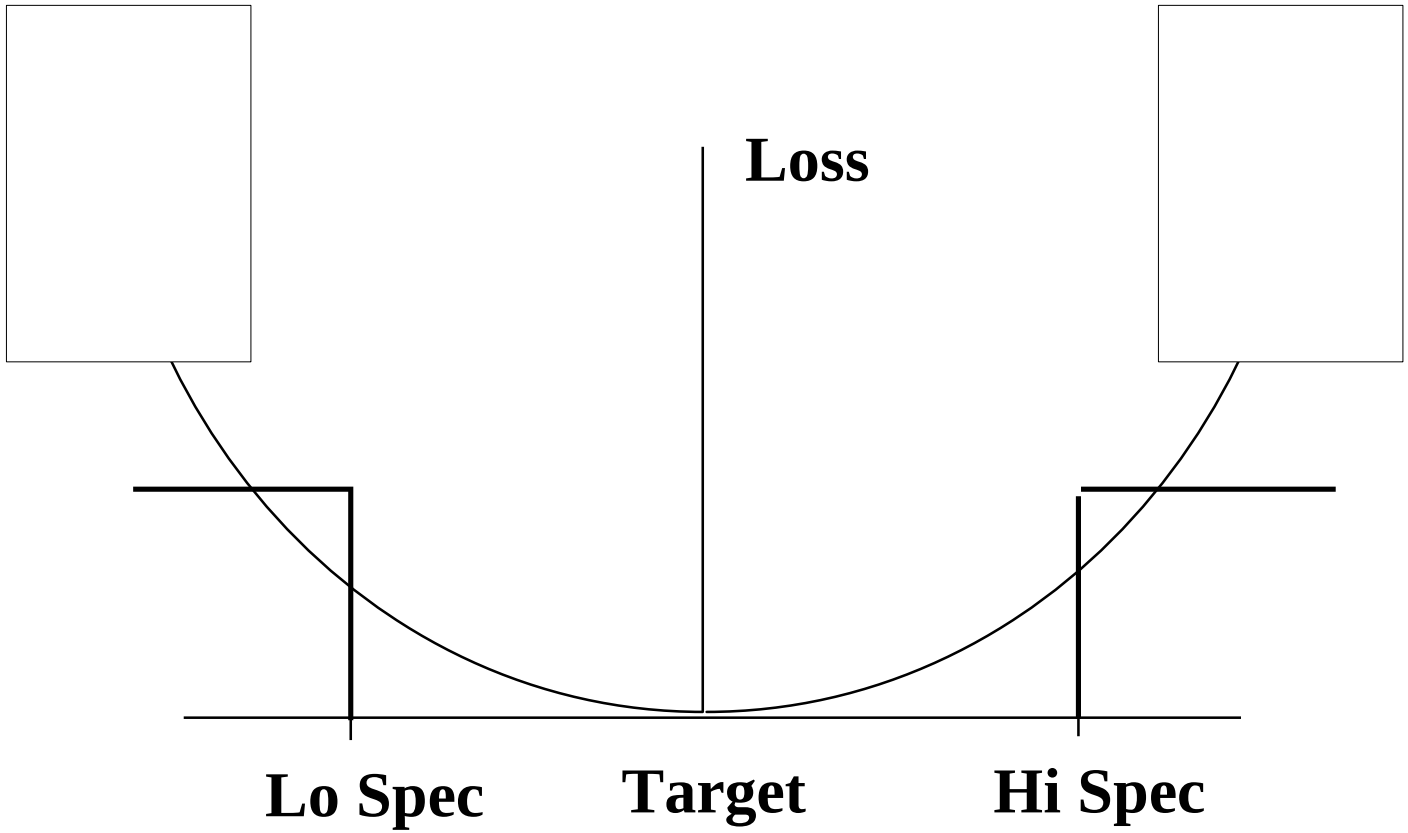
- **Quality Engineering Philosophy**
- **Methodology**
- **Experiment Design**
- **Analysis**

Taguchi focuses mostly on Off-Line Quality Control

Off-Line Quality Control =
Improving Quality and Reducing Total Cost in the Design Stage

Total Cost means cost to society so it includes the cost of problems in manufacturing and the cost of problems in the field.

The Quadratic Loss Function and the Typically Assumed Loss Function



The Design Process is Divided

- **System Design**
  - **Choose the sub-systems, mechanisms, form of the prototype.**
- **Parameter Design**
  - **Optimize the design, set up the design so that it improves quality and reduces cost**
- **Tolerance Design**
  - **Study the tradeoffs that must be made and determine what tolerances and grades of materials are necessary**

Taguchi's Contributions

- Quality Engineering Philosophy
- **Methodology**
- Experiment Design
- Analysis

Parameter Design (Robust Design)

- **Optimize the settings of the design to minimize its sensitivity to noise – ROBUSTNESS.**
- **Taguchi really opened a whole area that previously had been talked about only by a few very applied people.**
- **His methodology is heavily dependent on design of experiments, but he wanted to look at not just the mean but also the variance.**

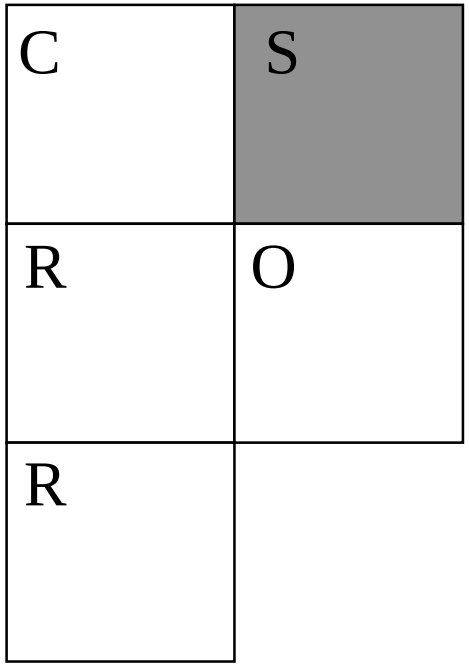
Classification of Factors

- **Control Factors–*Design factors* that are to be set at optimal levels to improve quality and reduce sensitivity to noise**
  - **Dimensions of parts, type of material, etc**
- **Noise Factors–Factors that represent the noise that is expected in production or in use**
  - **Dimensional variation**
  - **Operating Temperature**
- **Adjustment Factor – Affects the mean but not the variance of a response**
  - **Deposition time in silicon wafer fabrication**
- **Signal Factors – Set by the user to communicate desires of the user**
  - **Position of the gas pedal**

Taguchi's Contributions

- Quality Engineering Philosophy
- Methodology
- **Experiment Design**
- Analysis

Screening Designs
Taguchi Designs



Focus: Many Factors

Output: List of Important Factors, Best Settings, Good Model

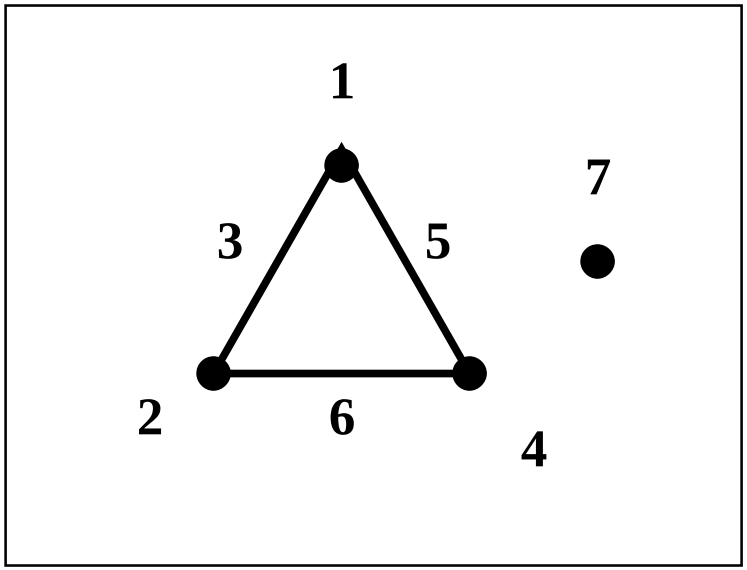
Alternative Notation

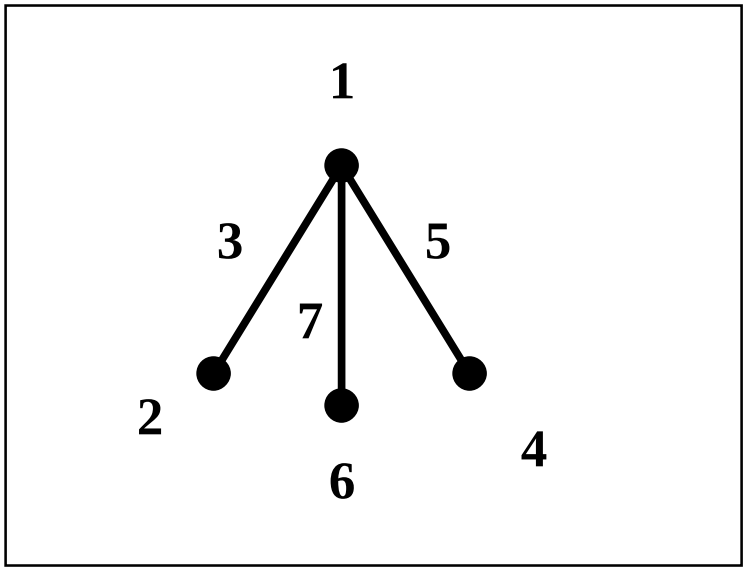
Std. Order	Fisher's Original X_1	X_2	X_3	Yates	Group Theory X_1	X_2	X_3	Taguchi *A*	*B*	*C*
1	–	–	–	1	0	0	0	1	1	1
2	+	–	–	*a*	1	0	0	2	1	1
3	–	+	–	*b*	0	1	0	1	2	1
4	+	+	–	*ab*	1	1	0	2	2	1
5	–	–	+	*c*	0	0	1	1	1	2
6	+	–	+	*ac*	1	0	1	2	1	2
7	–	+	+	*bc*	0	1	1	1	2	2
8	+	+	+	*abc*	1	1	1	2	2	2

L_8 array

1	2	3	4	5	6	7
1	1	1	1	1	1	1
1	1	1	2	2	2	2
1	2	2	1	1	2	2
1	2	2	2	2	1	1
2	1	2	1	2	1	2
2	1	2	2	1	2	1
2	2	1	1	2	2	1
2	2	1	2	1	1	2
C	B	-BC	A	-AC	-AB	-ABC

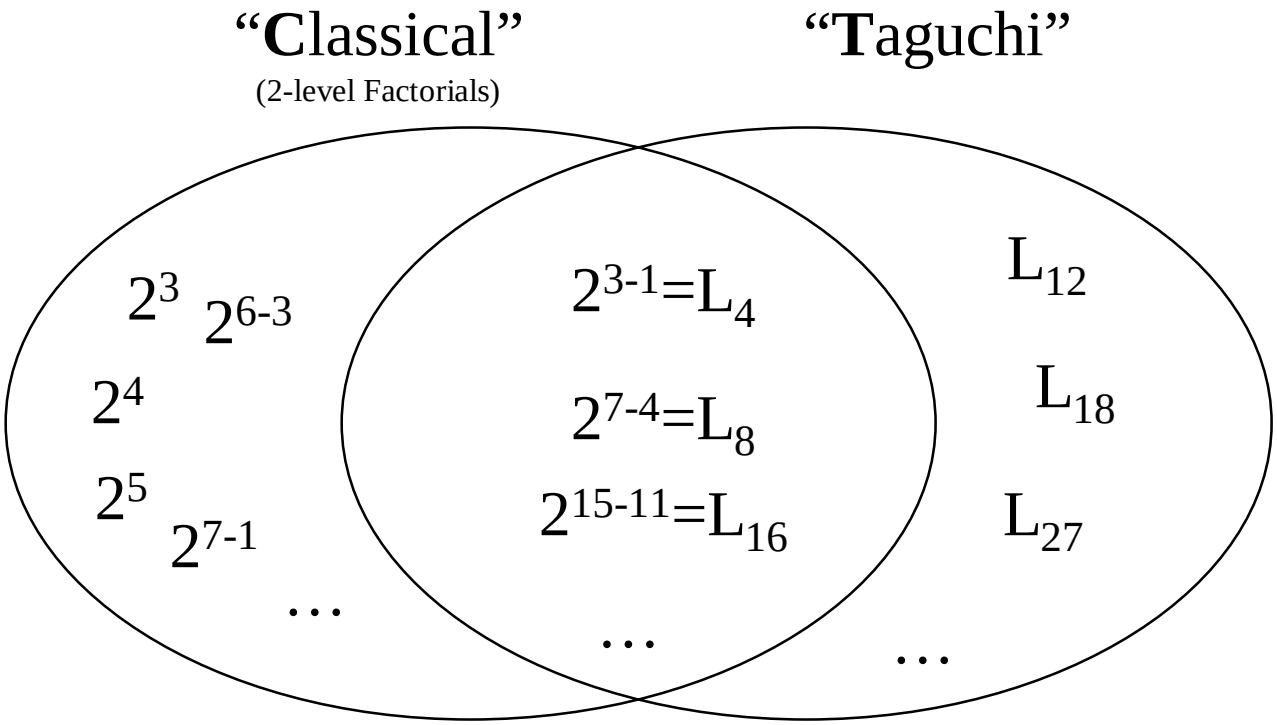
Linear Graphs for L_8 Array





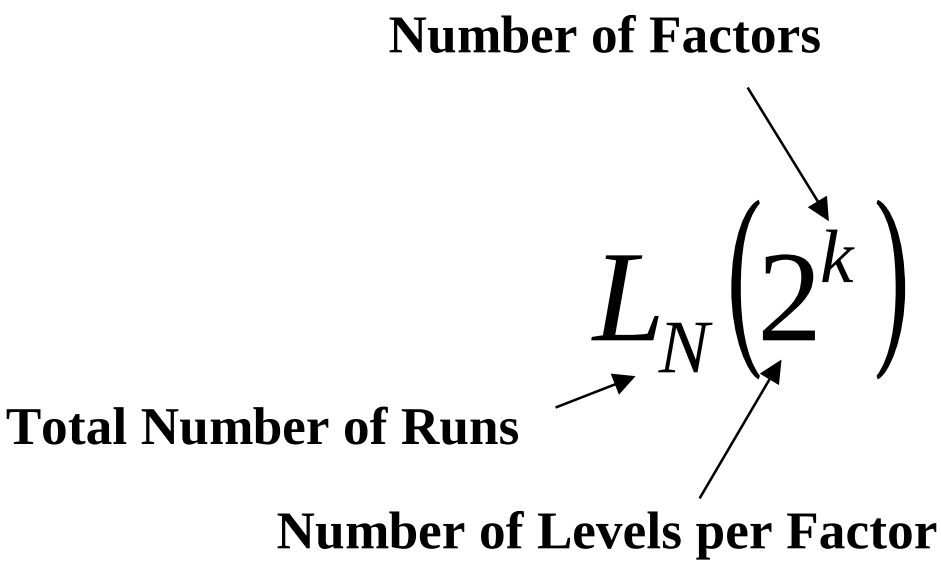
- **Main effects are assigned to columns at nodes in the plot.**
- **Interactions are assigned to the columns on the lines.**

Orthogonal Designs



Montgomery (1997), *Design and Analysis of Experiments*, P. 631

Taguchi Designs
Notation



Taguchi Orthogonal Array Tables

- **2-level (fractional factorial) arrays**
  - **$L_4(2^3)$. $L_8(2^7)$, $L_{16}(2^{15})$. $L_{32}(2^{31})$, $L_{64}(2^{63})$**
- **2-level array**
  - **$L_{12}(2^{11})$ (Plackett-Burman Design)**
- **3-level arrays**
  - **$L_9(3^4)$. $L_{27}(3^{13})$, $L_{81}(3^{40})$**
- **4-level arrays**
  - **$L_{16}(4^5)$. $L_{64}(4^{21})$**
- **5-level array**
  - **$L_{25}(5^6)$**
- **Mixed-level arrays**
  - **$L_{18}(2^1x3^7)$, $L_{32}(2^1x4^9)$, $L_{50}(2^1x5^{11})$**
  - **$L_{36}(2^{11}x3^{12})$, $L_{36}(2^3x3^{13})$, $L_{54}(2^1x3^{25})$**

Where is a list of Taguchi Designs?

- **DATAPLOT**
  - **L4.DAT**
  - **L8.DAT**
  - **L9.DAT**
  - **L12.DAT**
  - **L16.DAT**
  - **ETC.**
  - **TAGINDEX.DAT**

Comments on Taguchi Design Selection Method

- **Assumes most interactions are small and those that aren't are known ahead of time.**
  - **He claims that it is possible to eliminate these interactions either by correctly specifying the response and design factors or by using a sliding setting approach to those factor levels.**
- **Doesn't guarantee that we get highest resolution design.**
- **Instead of designing the experiment to investigate potential interactions, Taguchi prefers to use three-level factors to estimate curvature.**

Taguchi's Contributions

- Quality Engineering Philosophy
- Methodology
- Experiment Design
- **Analysis**

Analysis

- **Taguchi uses signal to noise ratios as response variables.**
  - **e.g.,**

$$SN_t = -10 \log\left(\frac{\bar{y}^2}{s^2}\right)$$

- **It is often more informative to analyze mean and standard deviation separately (sd), rather than combine into a signal to noise ratio**
  - **analyze sd in the same manner that we have previously analyzed the mean.**

- **Taguchi analysis techniques are often inefficient…**

We should support Taguchi's philosophy of quality engineering. However, we must rely on simpler, more efficient methods that are easier to learn and apply to carry this philosophy into practice…

You can use the techniques presented thus far in class to analyze Taguchi Designs.

More Screening Designs...

Wu and Hamada (2000), *Experiments*, Appendices 6C, 6D, 7A, and 7C

(See Pink Hand-Out)