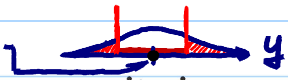
Strategies for Variation Reduction → quality improvement

1. ***Sampling inspection***: passive, sometimes last resort.
   ↳ 抽樣調查

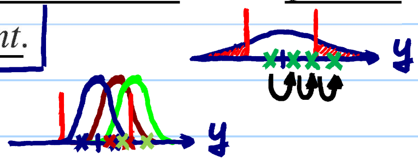
   target



However, SPC might not identify what is the cause

2. ***Control charting and process monitoring***: can remove special causes. If the process is stable, it can be *followed* by using a *designed experiment*.

SPC → for system changing over time (in control, out of control)
⇒ detect the appearance of unstable conditions



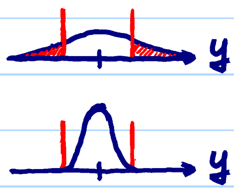
3. ***Blocking, covariate adjustment***: passive measures but useful in reducing variability, not for removing root causes.

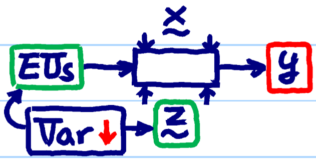
not a method that can reduce total variation in normal usage. But, when possible, block factors → noise factors

variation affecting treatment comparison in data analysis

4. ***Reducing variation in noise factors***: effective as it may reduce variation in the response but can be expensive. Better approach is to change control factor settings (*cheaper* and *easier* to do) by exploiting control-by-noise interactions, i.e., use robust parameter design!

have a better control on the variation of EUs & $\underset{\sim}{z}$





treatment effects

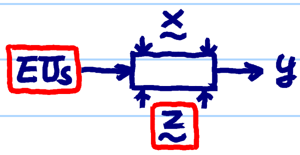
$$Y = X_1\beta_1 + \varepsilon$$
$$Y = X_1\beta_1 + \underbrace{X_2\beta_2}_{\text{block effects}} + \varepsilon'$$
$$Var(\varepsilon) \geq Var(\varepsilon')$$

❖ **Reading**: textbook, 11.2

Types of Noise Factors

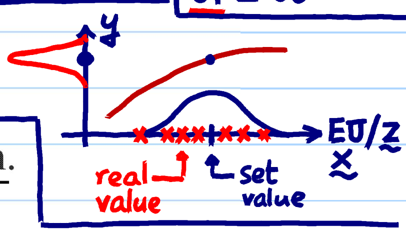
① they are EUs or $\underset{\sim}{z}$
② they are sources of "large" variation in y

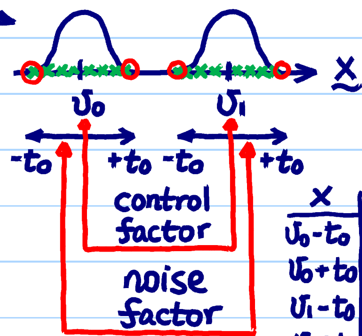
1. Variation in process parameters.
   check LN p.10-9~10 $\boxed{z}$ ← $\boxed{x}$ cannot be well controlled → $\underset{\sim}{x}_c$, $\underset{\sim}{x}_N$ ← $\boxed{z}$
2. Variation in product parameters.
   $\boxed{\text{EUs}}$ ← e.g. $v_0 \pm t_0$ (spec), $v_1 \pm t_0$



3. Environmental variation.
4. Load Factors.

$\boxed{z}$ → 3., 4.

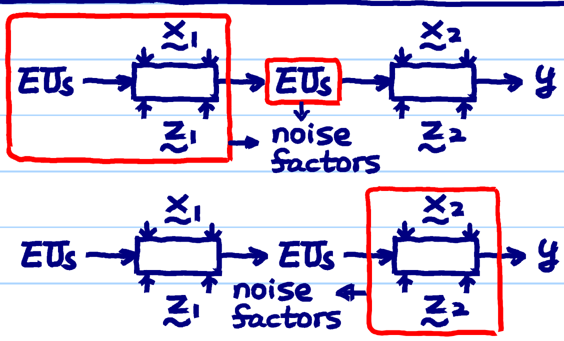




x	C	N
$v_0 - t_0$	v_0	−
$v_0 + t_0$	v_0	+
$v_1 - t_0$	v_1	−
$v_1 + t_0$	v_1	+

5. Upstream variation.
6. Downstream or user conditions.
   cf.
7. Unit-to-unit and spatial variation. → blocks
8. Variation over time. ← short
9. Degradation. ← long
   cf

can be surrogate variables of the true noise factors



- **Traditional design uses 7 and 8.**

❖ **Reading**: textbook, 11.3 → replicates

Variation Reduction Through RPD

In normal usage

- Suppose y (or $E(y)$) $= f(\mathbf{x}, \mathbf{z})$, $\mathbf{x}$ control factors and $\mathbf{z}$ noise factors. If $\mathbf{x}$ and $\mathbf{z}$ interact in their effects on y, then the $var_{\mathbf{z}}(y)$ can be reduced either by ① reducing $var(\mathbf{z})$ (i.e., method 4 in LNp.10-6) or by ② changing the $\mathbf{x}$ values (i.e., RPD).

- An example:

treat z as r.v. with $E(z)=0$

$Var_z(y|x) = (\beta+\gamma x_2)^2 \cdot Var(z) + \sigma^2$

$E_z(y|x) = \mu + \alpha x_1$

$$
\begin{aligned}
y &= \mu + \alpha x_1 + \overset{\text{N ME}}{\beta z} + \overset{\text{C×N interaction}}{\gamma x_2 z} + \varepsilon, \\
&= \mu + \alpha x_1 + (\beta + \gamma x_2) \underset{\text{r.v.}}{z} + \varepsilon.
\end{aligned}
$$

In exp't

$E(y) = \mu + \alpha x_1 + \beta z + \gamma x_2 z$

$Var(y) = \sigma^2$

By choosing an appropriate value of x_2 to reduce the coefficient $\beta + \gamma x_2$, the impact of z on y can be reduced. Since β and γ are unknown, this can be achieved by using the control-by-noise interaction plots or other methods to be presented later.

$Var_z(y|x)$