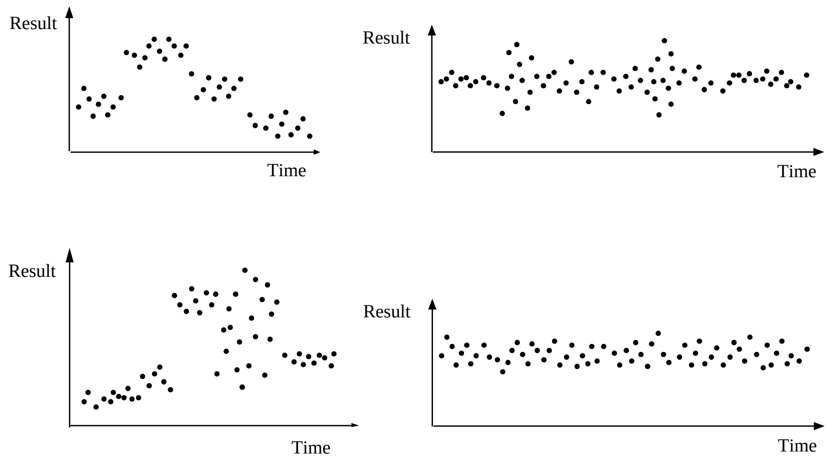
Location and Spread



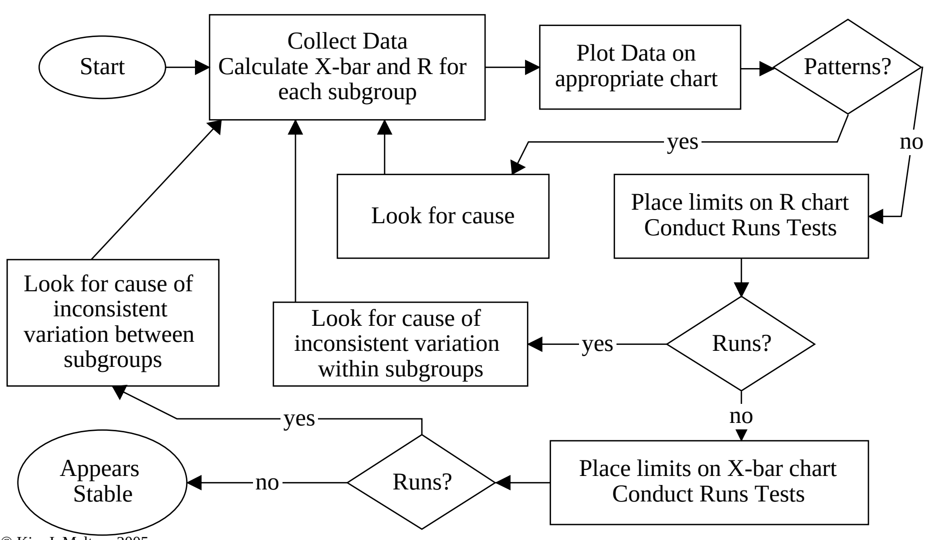
Insurance Quotes

An insurance company staffs quote lines so that independent agents can call in for quotes on insurance. The following data represent the time (in seconds) for one operator to respond to five consecutive calls from the same state. One subgroup (of five observations) is collected each day.

The Data

Day	------ Quote Times (In Seconds) ------					X-Bar	R
1	197	190	162	159	194	180.4	38
2	200	192	177	227	180	195.2	50
3	186	178	209	197	190	192.0	31
4	206	168	209	208	182	194.6	41
5	182	175	158	207	226	189.6	68
6	195	179	216	213	193	199.2	37
7	197	195	213	198	217	204.0	22
8	208	248	193	158	177	196.8	90
9	184	166	224	186	180	188.0	58
10	203	185	212	214	161	195.0	53
11	189	183	207	176	207	192.4	31
12	223	175	196	213	200	201.4	48
13	200	168	193	233	164	191.6	69
14	186	161	179	155	203	176.8	48
15	199	218	211	217	230	215.0	31
					Totals	2912	715

X-bar and R charts



Using Excel to Calculate X-Bar and R

Assume that the data for the first subgroup are in cells B2, C2, D2, E2, and F2

If you want to put X-Bar for this subgroup in cell I2, then click on cell I2 and type:

=average(B2:F2)

If you want to put R for this subgroup in cell J2, then click on cell J2 and type:

=max(B2:F2)-min(B2:F2)

Copy the formulas down the column to find the corresponding values for each subgroup

Control Limits

R Chart

$$LCL_R = D_3\overline{R}$$

$$CL_R = \overline{R}$$

$$UCL_R = D_4\overline{R}$$

$\overline{X}$ Chart

$$LCL_{\overline{X}} = \overline{\overline{X}} - A_2\overline{R}$$

$$CL_{\overline{X}} = \overline{\overline{X}}$$

$$UCL_{\overline{X}} = \overline{\overline{X}} + A_2\overline{R}$$

If the **process** appears to be stable, then: $\hat{\mu} = \overline{\overline{X}}$ $\quad \hat{\sigma} = \frac{\overline{R}}{d_2}$

Interpreting Results When the Process is Judged to be Stable

- Recall that control limits deal with the expected range of variation for the characteristic plotted on the control chart.
- Therefore, the limits on the X-bar chart deal with the expected range of variation for subgroup averages.
- Natural process limits, expected ranges for the individual values, can be calculated as:

$$\hat{\mu} \pm 3\hat{\sigma} \text{ where } \hat{\mu} = \overline{\overline{X}} \text{ and } \hat{\sigma} = \frac{\overline{R}}{d_2}$$

Limits

- Control Limits (LCL and UCL)
  - calculated from data collected from the process
  - used to assess stability of the process
  - related to the characteristic plotted (e.g., X-Bar or R)
- Natural Process Limits (LNPL and UNPL)
  - only calculated if the process appears to be stable
  - related to measurements for individual items
  - provides information about range of measurements for individual items that can be expected
- Specification Limits - "Specs" (LSL and USL)
  - determined by the user based on desired or needed measurements for an item
  - related to desired (acceptable) range of measurements for individual items

Call Center Goals

- Suppose that management of the Insurance company wants quotes times to be between two minutes and four minutes. (They believe any times below two minutes will be rushed and unfriendly, and times above four minutes would discourage future business.)
- With the current process, what proportion of the calls would you expect to take more than four minutes?

Call Center Ads

Suppose the manager wants to create an ad telling people how quickly they can provide a quote. The manager wants to include a statement along the lines of:

"If you call us, our agent will provide you with a quote in less than ________ minutes."

What number should be placed in the blank?

Process Capability

- To talk about capability of a process, we must have stability
- Capability refers to the “voice of the process”
- The capability of the process tells the range of values that can be expected for the measurements of some process characteristic
- Specifications (specs) provide a “voice of the customer.”
- Capability indexes are a fairly common way of communicating the relationship between specifications and process performance.
- Capability indexes attempt to compare the “voice of the process” with the “voice of the customer.”

Two Approaches to Talking about Capability

- Approach 1:
  – Comparison of Engineering Tolerances to Natural Tolerances
    - Engineering Tolerances refer to the specifications for the characteristic
      ET = USL - LSL
    - Natural Tolerances refer to the natural process limits for the characteristic
      NT = UNPL - LNPL (where natural process limits are calculated as $\mu \pm 3\sigma$ and σ is estimated by $Rbar/d_2$ from a stable process)
  – If NT < ET, we say the process is capable
  – If NT < ET and the natural process limits are within the specification limits, we say the process is capable and meeting spec.

Capable but Not Meeting Specs???

When capability is described in terms of the amount of variation (without looking at location), a process with very little variation could consistently produce unacceptable product.

Example:

Nails are sold by weight, but builders need to know how many nails are contained in boxes of a given weight. Suppose a builder specifies that each box of nails should contain 990 to 1010 nails (i.e., 1000 ± 10).

The producer has reduced the variation in the weight of nails to the point where there is only a difference of 1 to 4 nails from one box to another—but, boxes actually contain 983 to 987 nails.

Capability (cont.)

- Approach 2:
  - Capability Indexes
    - C_p tells us if the natural variation is smaller than the allowed variation. C_p does not look at process location; therefore it is possible to have a 'good' C_p and be making large amounts of unacceptable product.
    - C_{pk} tells us if the natural variation is 'small enough' and 'far enough' from the specifications for most product to meet specs for the characteristic. C_{pk} cannot be larger than C_p.

Capability Formulas

$$C_p = \frac{USL - LSL}{6\sigma} = \frac{ET}{NT}$$

$$C_{pk} = \min \left\{ \frac{USL - \bar{\bar{X}}}{3\sigma}, \frac{\bar{\bar{X}} - LSL}{3\sigma} \right\}$$

If the process is centered between the specs:

$$C_{pk} = \frac{\left| \bar{\bar{X}} - \text{nearest spec} \right|}{3\sigma}$$

Histogram Patterns