Design and Control of Quality

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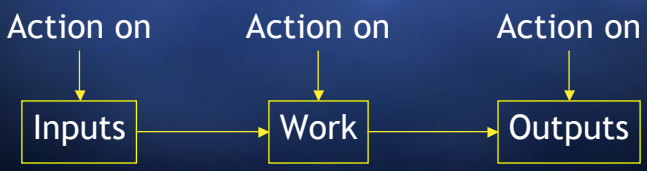
Quality Assurance

- Two kinds of people (Scholtes)
- Views on Outcomes:
  - Assurance that outcomes conform to requirements
  - Loss to Society (Taguchi)

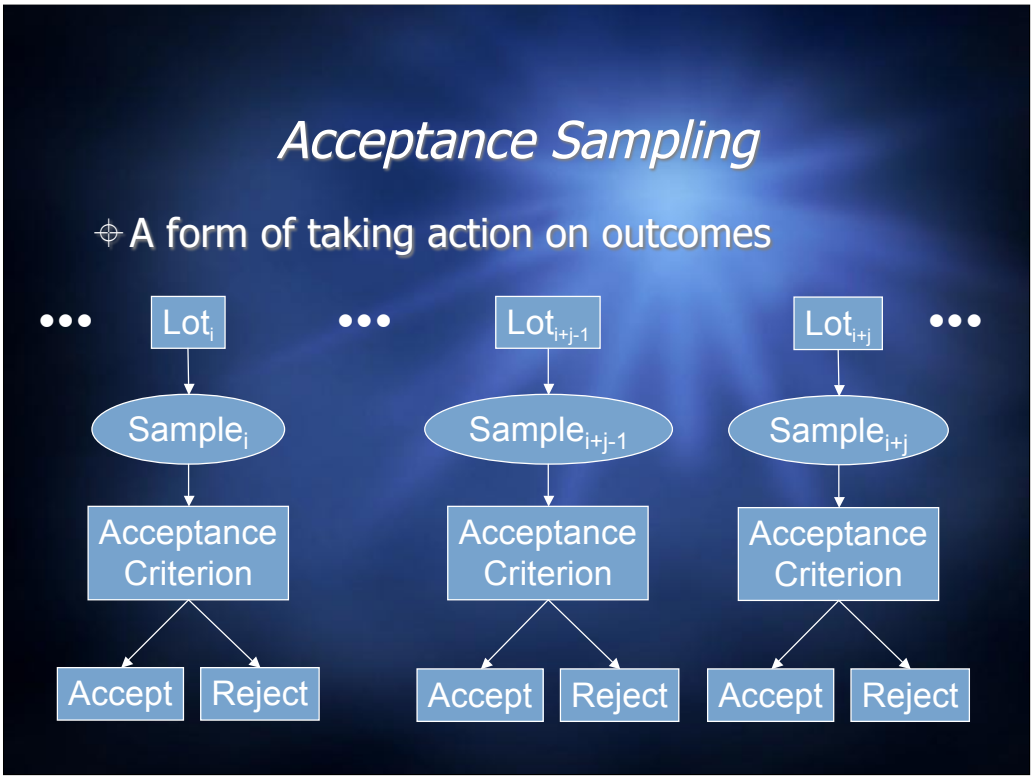
- I'd like to start by contrasting 2 views of variation in outcomes
- As Peter Scholtes used to say, there are 2 kinds of people in this world: Those who think there are two kinds of people in this world and those that don't
- The traditional view of variation has been that everything within specifications is (equally) good, and everything out of spec is bad; also known as a "goalpost view"
- Genichi Taguchi popularized a different view - that of (quadratic) loss to society; that loss becomes progressively greater the further you deviate from "target"
- Ex. Temperature in this room

Methods for Quality Assurance

- Take action on outcomes
- Take action on the process (means/context of production)
- Take action on inputs



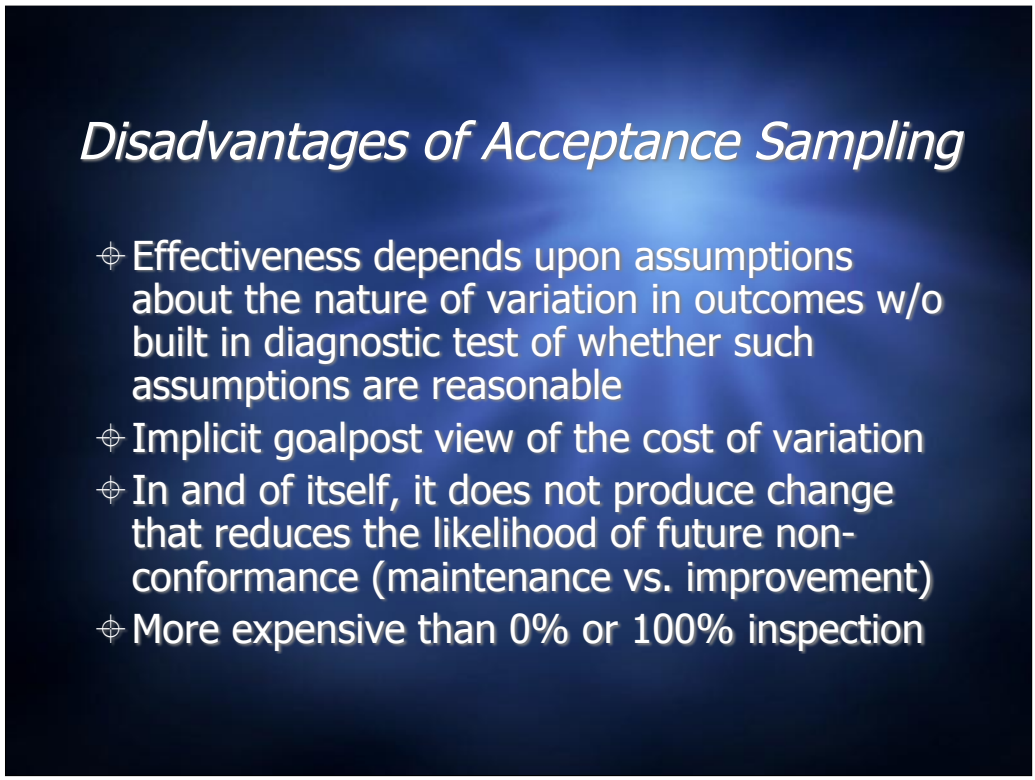
- Broadly speaking, we can frame efforts for Quality Assurance as taking action on outputs, action on the work required to produce the outputs and action on the inputs to that work



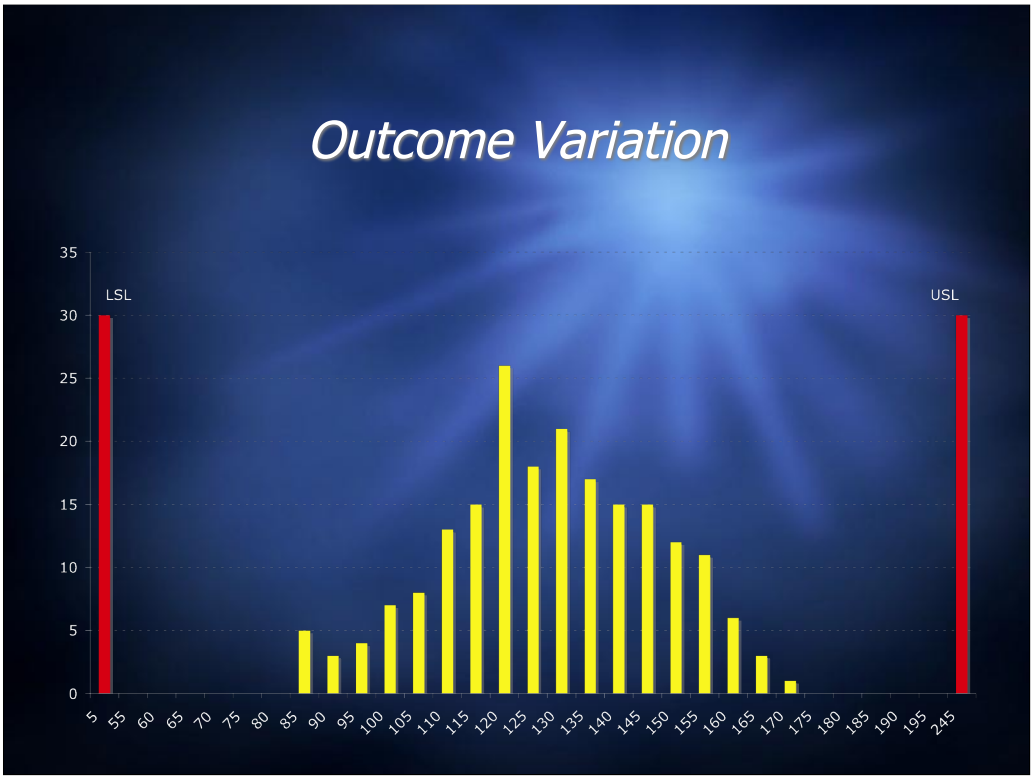
- Acceptance Sampling is a very common and, I assume, familiar approach to Quality Assurance
- MIL-STD-105 has driven a lot of acceptance sampling, although officially cancelled in 1995 and replaced by MIL-STD-1916
- The basic concept is that lots of goods are produced over time. Samples are taken from those lots with “measurements” made and lot classification based upon acceptance criteria
- Variety of sampling methods - simple random, stratified, sequential, …
- Aim = classify as efficiently as you can for given level of effectiveness (risk)

Advantages of Acceptance Sampling

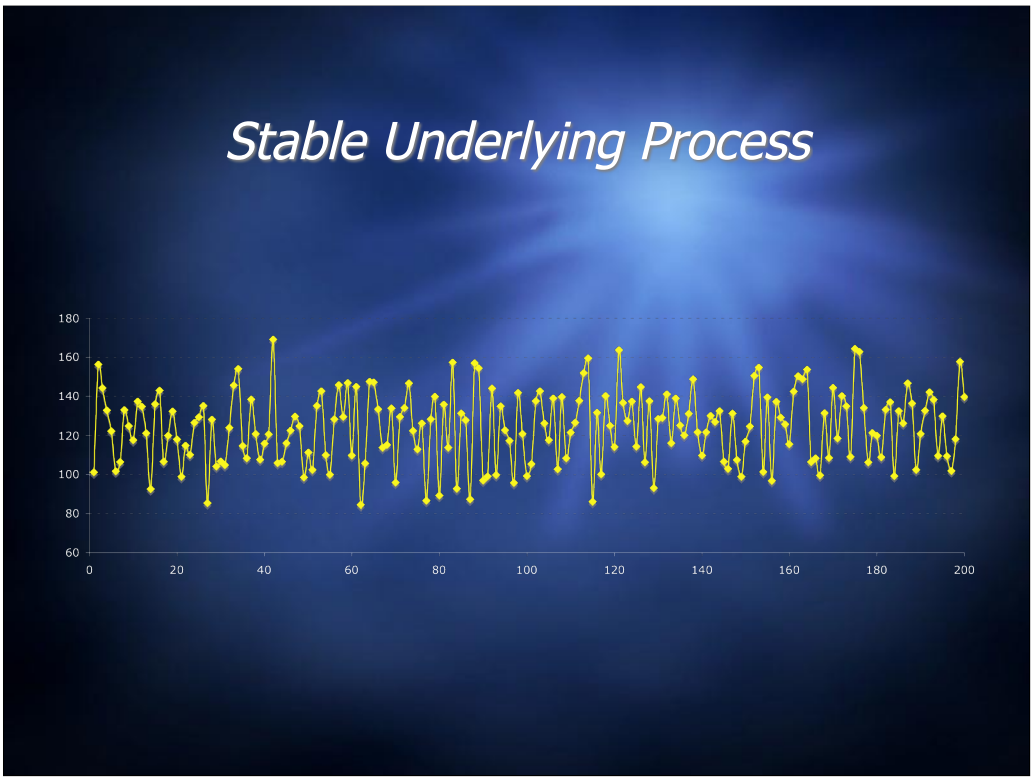
- Rules for application are largely context independent
  - Differences due to levels of risk, type of measurement etc., but not whether it's drugs, food or missiles being produced)
  - Approach may therefore be prescribed quite tightly and audited without much domain knowledge for judgment



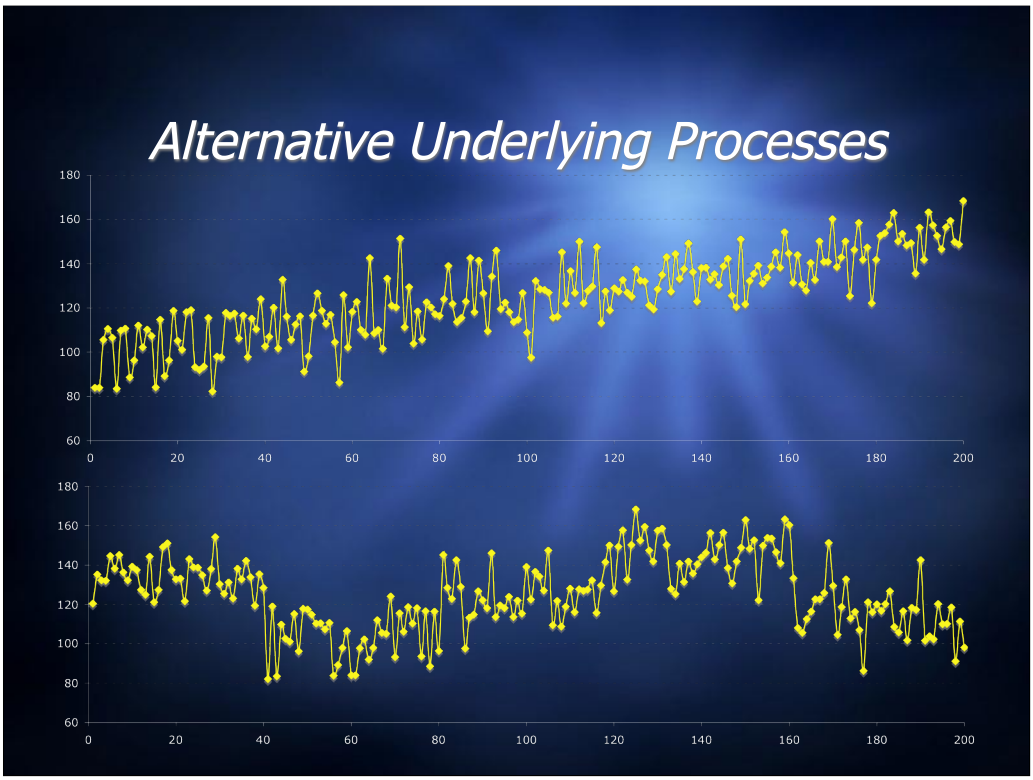
- [Read]
- Point 2 is true whether using #Pass<c or |X-bar - SL|/s>k criteria
- Let's first take a look at some differences in outcome variation to explore the first point a little further
- We'll also revisit the other points later



- This slide shows a summary of census data of a lot of 200 with upper & lower specification limits - Cpk = 2.14
- Clearly this lot should (and almost certainly would) be accepted
- Does this tell us anything about whether future lots are likely to be in spec?
- Is there anything more to be learnt?



- The outcomes on the previous slide could have arisen from a stable process, such as the one illustrated
- A stable process is one whose variation is judged to be the result of common causes
- Statistical control charts are required to make the judgment of stability reliably and consistently (beyond the scope of what I can cover today)



- Both of the processes illustrated also generate the set of outcomes summarized on page 7 - they would produce identical summary statistics once the time element has been “lost”
- How confident would you be that the future outcomes will be in compliance with specifications? Would it be different for the 3 processes? Confidence in your prediction is based upon?
- Most important point - view into the nature of variation over time (or space)
- Integral to learning about the causal relationships that provide a basis for rational prediction (and control) of future outcomes

Deming's k-p rules (simple case)

- Let p be the average fraction defective
- Let k_1 be the cost to inspect one unit
- Let k_2 be the cost of a defective unit 'down the line'
- $0<k_1/k_2<1$ is referred to as breakeven quality

- Returning to the last point on page 6, Deming developed the *k-p* rules
- The principles apply more broadly, but originally were developed where incoming parts/material could be inspected before entering your process at a cost per unit of k_1.
- If a defective part makes it past receiving inspection, it will be caught later in the process at (significantly higher) cost per unit of k_2.
- This can also be applied to inspection through the process, or prior to shipment where k_2 is the cost of a defect to your customer

Simple Cases

- Case 1: If the worst lot will still have $p<k_1/k_2$, 0% inspection yields minimum cost
- Case 2: If the best lot will still have $p>k_1/k_2$, 100% inspection yields minimum cost
- Case 3: If *p* is stable (i.e. the result of a process that's in a state of statistical control):
  - If $p<k_1/k_2$, 0% inspection yields minimum cost
  - If $p>k_1/k_2$, 100% inspection yields minimum cost
- Other cases, and some rationale in *OOTC* chapter 15. More theory in *Some Theory of Sampling*

- [Read]
- So, if you've heard a statement along the lines of "Anything other than 0% or 100% inspection just increases cost" attributed to Dr. Deming, this is the likely basis for that statement (with conditions!)
- Note that in case 3, it is assumed that the proportion defective is stable. In practice, a control chart would be required to make this judgment and/or as a part of learning/improvement to bring about a state of stability
- The formula providing the basis for these conclusions is expected cost for one stage acceptance sampling with lots of size *N* and sample size *n* where the lot is accepted if the count of defectives in the sample $r \le c$. Deming showed that the cost of inspection for such a scheme is:

$$E[Cost] = \frac{Nk_1}{1-p} - \frac{(N-n)k_2 \Pr(R \le c)}{1-p}\left(\frac{k_1}{k_2} - p\right)$$

- Other cases in chapter 15 of OOTC include that of *p* not being stable. My personal opinion is that for such a case, a control chart (such as a p-chart) should be used to learn and test actions aimed at improving to bring about stability. Judgment is for predicted *p*, and should have stability for prediction

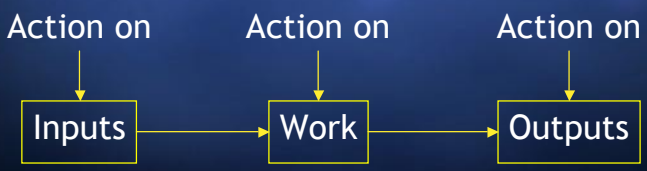
Point 3 of Deming's 14 Points for Management

- Cease dependence on inspection to achieve quality. Eliminate the need for inspection on a mass basis by building quality into the product in the first place

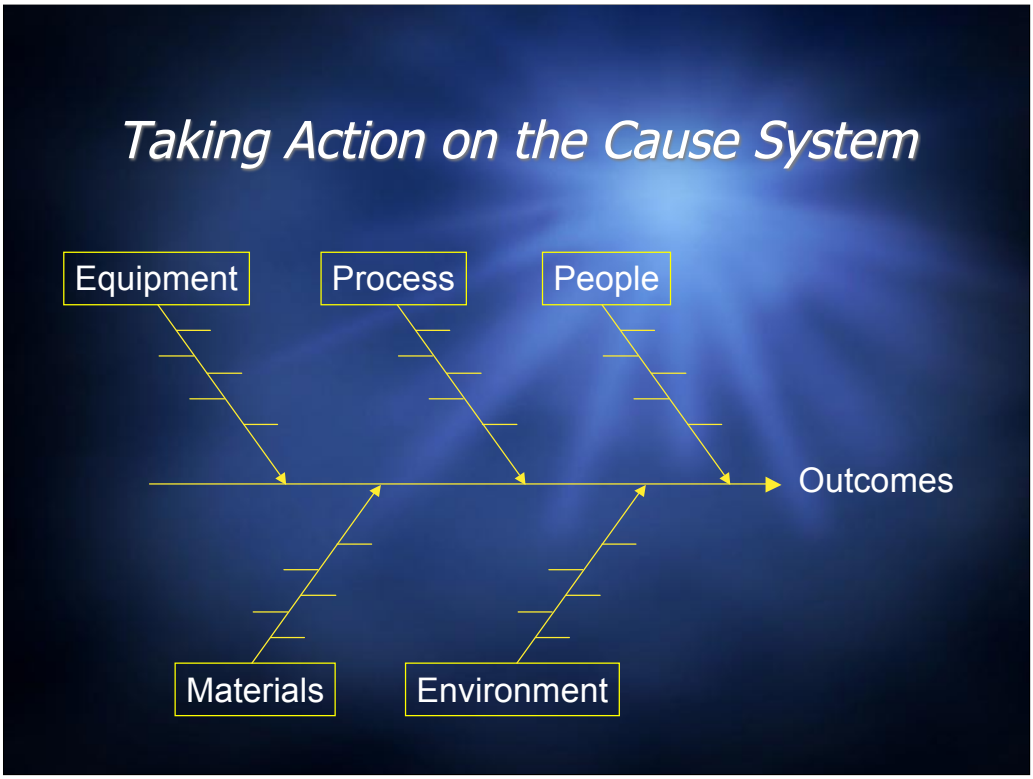
- One way of interpreting this is to work to decrease p to the point that it is smaller than k_1/k_2, whereby 0% inspection becomes the lowest cost choice
- Still just conformance level quality, though
- Some believe that Deming said "don't inspect". You can see from this statement that Deming was advocating that we take action on the inputs/process and in so doing, eliminate the need for taking action on outcomes to assure (conformance) quality
- It was also Dr. Deming's view that we should do better than just conform to requirements - he ascribed to Taguchi's loss to society view

Methods for Quality Assurance

- Take action on outcomes
- Take action on the process (means/context of production)
- Take action on inputs



- So, let's take a look at a framework for Action on the first 2 boxes



- At the level of the current system of production, taking action on the cause system can be both action on the means of production as well as its inputs
- This depends upon use of existing knowledge or development of knowledge of relationships between potential causes and variation in outcomes

Advantages of the Approach

- Leverage - cost effectiveness
- Level of Assurance that's possible
- More in depth knowledge development of the nature of variation in outcomes
- Rational basis for Prediction

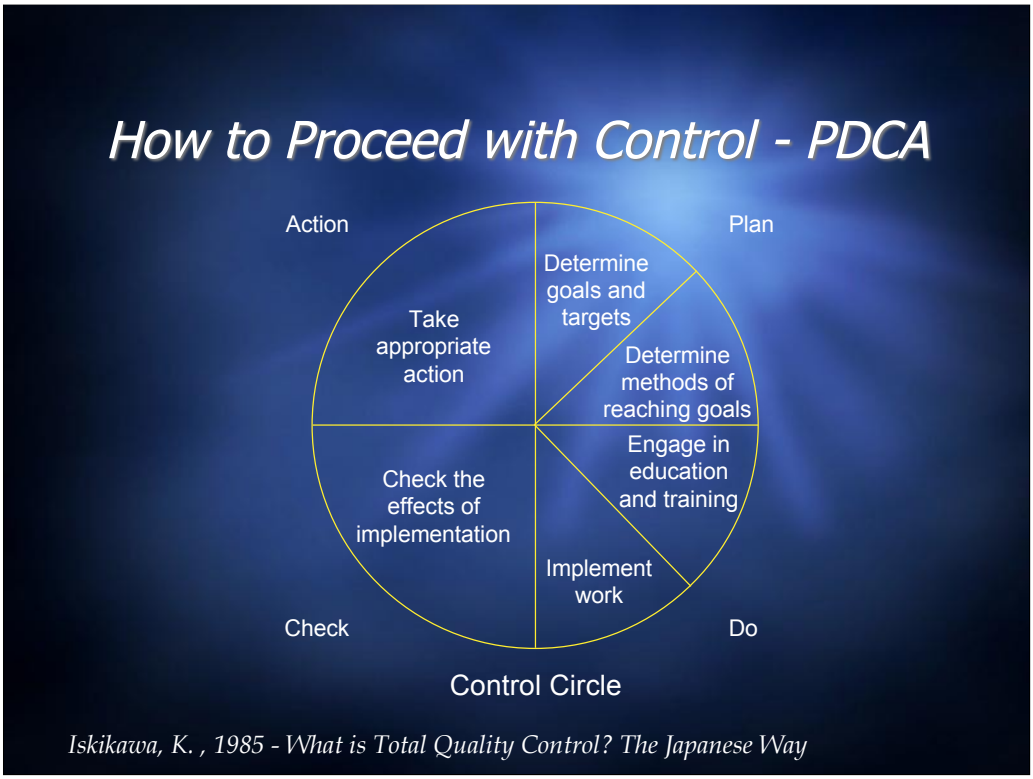
Disadvantages of the Approach

- Less 'prescriptively' simple
- Depends upon domain knowledge of cause & effect relationships (or requires development thereof)

Different Classes of Action on the Cause System

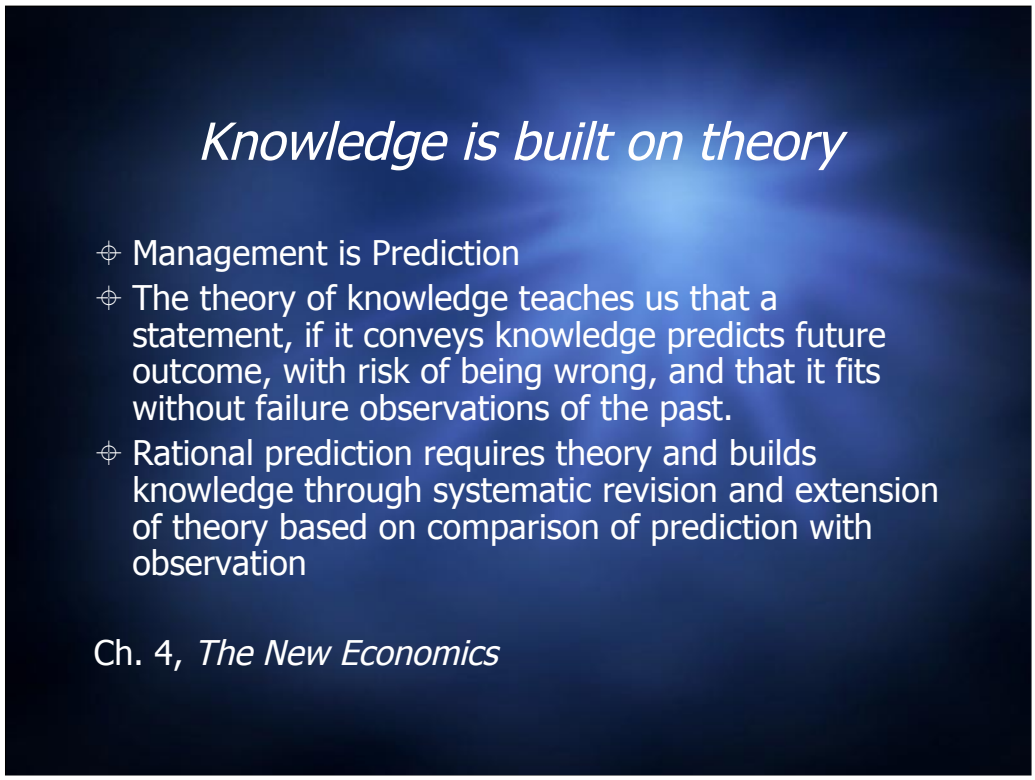
- Control Feedback - PDCA
- Simultaneous Deliberate Learning while making changes aimed at Improvement - PDSA

- The essence of control feedback schemes is that you know ahead of time that taking a given (control) action on a cause system factor will have a given (at least directional) effect on the outcome you want to control
- Adjusting the mixer valve for the bath/shower to reach desired temperature is a good example
- There's no need for (new) learning to occur (although it can, by accident)



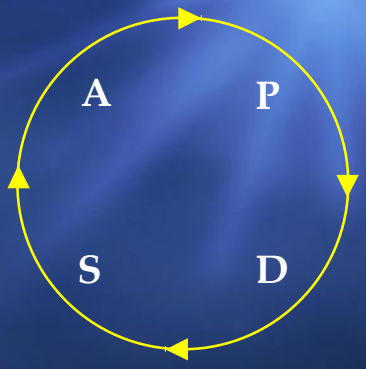
- Ishikawa described the cycle as follows, under the title *How to proceed with control*:
  - Dr. Taylor used to describe control with these words, “plan--do--see.” What does the word “see”mean? To Japanese middle school students, it simply means to look at, and that does not convey Taylor’s meaning. So we have rephrased it as follows: “plan--do--check--action” (PDCA). This is what we call the control circle, [see slide], and it must be made to move in the right direction. I have found it advisable to redefine this circle by dividing it into six categories, which have proven successful.

- What happens in “Check”?
  - Comparison of the effects of implementation against your goal(s).
  - What happens if the goal(s) are not met?
- Adaptation - Control theory view - the focus is solely on application of existing knowledge towards goals. Learning is not an explicit or deliberate component of the PDCA framework



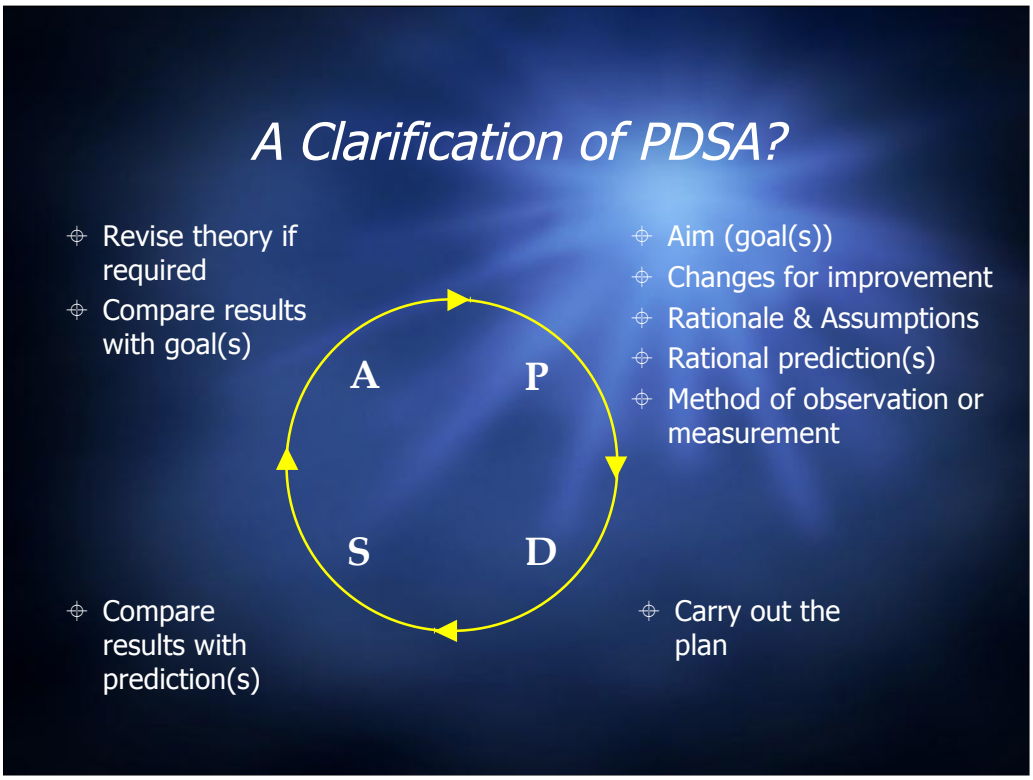
- Deming said that "Management is Prediction" as every plan, however simple, involves prediction (at least implicitly)
- In order for a statement to qualify as containing knowledge under this definition, it must satisfy two conditions
  - It must provide a satisfactory explanation of past experience, in other words an explanation which is not contradicted by past experience
  - It must predict future outcomes in such a way that experience in the future may contradict the explanation
- Rational prediction - qualifier
- This leads us to the Plan-Do-Study-Act cycle, which Deming viewed as fundamentally different from PDCA (although PDCA is frequently referred to as the "Deming Cycle"):

Reaction to "that corruption..."



A flow diagram for learning and for improvement of a product or of a process.
Page 132, *The New Economics, 2ed.*

- In his seminars from late 1989, Deming provided a versions of what he called *The Shewhart Cycle for Learning and Improvement* which were of the form shown here from *The New Economics, 2ed*, (1993). This was developed in reaction to having described PDCA as a "corruption".
- Does this convey the essential elements for *learning and improvement*?
  - Improvement: movement towards an intended end (goal)
  - Learning: revision of knowledge through test in use
- In the clarifying text immediately surrounding the PDSA cycle, Deming refers to the comparison of rational prediction with observation or measurement in the study phase indirectly in use of the term *expectations*:
  - Step 3. STUDY. Study the results. Do they correspond with hopes and expectations? If not, what went wrong?
- Results that are contrary to expectations (prediction) is what prompts the need to revise your theory or learn - a creative Act



The PDSA cycle starts in the *Planning* stage with consideration of the question "What are we trying to accomplish?*" to establish the context and aim for improvement . The Plan consists of four components:

1. Changes which can be made that we predict will bring about the improvement
2. The reasons we believe the changes will bring improvement, any assumptions we are making and the reasoning behind the assumptions - this is our theory, no matter how tentative or improbable
3. Prediction of what results we will get from carrying out the planned changes, based on our theory
4. A method of observation or measurement that can be used to see whether the actual results of carrying out the plan were as predicted

In the *Do* stage, the planned change(s) is carried out and the results are observed or measured

The *Study* stage involves comparison of the results observed in the Do stage with the predictions made in the Planning stage. There are two possibilities:

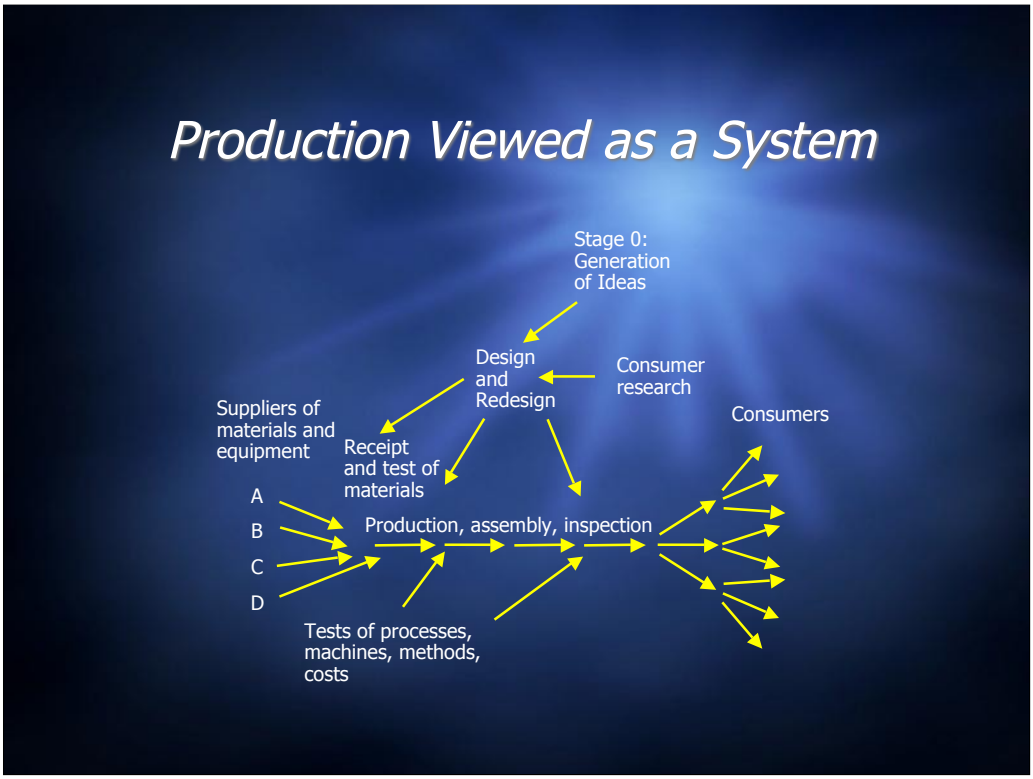
1. The observed results and predictions do not correspond. This provides an opportunity to learn since we have cause to revise the theory used as a basis for the plan. It could be that the reasoning behind the prediction that the planned changes would bring about improvement is in need of revision. It could be that the reasoning behind the assumptions that were made is in need of revision.
2. The observed results and predictions do correspond. We do not have cause to revise the theory used for the plan, which increases our degree of belief in the theory's usefulness. It does not, however, prove the theory to be true since the future may always present cause for revision

In the *Act* stage the theory is revised (acted upon), if such a need were indicated in the Study stage, thereby providing a new foundation for any future cycles. The results achieved are also considered relative to the aim established in the Planning stage to determine whether further opportunity for improvment is needed. If so, the next PDSA cycle starts with an answer to "What are we trying to accomplish?" that has adapted to past performance.

This framework can be used for learning about cause and effect relationships (p.14 Inputs & Work) and simultaneously take actions aimed at improvement. In doing so, much higher levels of Quality Assurance are possible than when just acting on outcomes. It also provides the evidence required for justification/audit. It can be used to just get to the point of dependably conforming to requirements, but is also key to continual improvement within a Taguchi view of loss.

Stepping up a level, …

* This question is taken from the API *Model for Improvement*



- This provides a view of the organization's work as a process. The intent is for this picture to represent a high level learning and improvement cycle.
- Ishikawa and Imai both use the terms PDCA cycle and Deming cycle interchangeably, but identify Deming in particular with its application at the level of *Production Viewed as a System*
- PDSA can be seen as being applied here at different levels:
  - As described earlier in learning about (and taking action on) input and production causes of outcome variation
  - At the level of the system as a whole
- Deming linked taking such a view to Joy in Work - knowing what one's job is - who depends on you and upon whom you depend is a purposeful view in which one may take pride. This is in stark contrast to the view of responsibility which can come through a traditional pyramidal organization chart (job=please the boss). It also illustrates an interdependency between *Appreciation for a System* and *Psychology* in *The System of Profound Knowledge*

Summary

- For conformance quality, 0% or 100% inspection (k-p rules) for lowest cost
- Importance of understanding the nature of variation over time
- Systematic application of PDSA to build knowledge and simultaneously take action aimed at improvement

Questions & Comments

- References:
  - *The New Economics, 2ed.* - W. Edwards Deming
  - *Out of the Crisis* - W. Edwards Deming
  - *Some Theory of Sampling* - W. Edwards Deming
  - *Kaizen: The Key to Japan's Competitive Success* - Masaaki Imai
  - *What is Total Quality Control? The Japanese Way* - Kaoru Ishikawa