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P2SL WHITE PAPER 1: BUILT IN QUALITY CYCLE

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Building quality into products is an application of the lean ideal: to deliver what customers, internal or external, value—and to do so with no waste. We understand waste to be cost drivers, the reduction of which does not reduce customer value. What fits that definition as regards building in quality? Inspection, rework, and longer project durations spring immediately to mind, all of which drive costs up. Customers value defect-free products, not inspection, rework or longer project durations. The question then is how to build in quality? In this white paper, we begin to answer that question by providing a basic process for building in quality, the BiQ cycle.

The PDCA, Plan-Do-Check-Act, cycle originated with Walter Shewhart (Shewhart, 1939) and was further developed and popularized by W. Edwards Deming (Deming, 1986) as a way of introducing scientific experimentation into business management; in other words, as a way to learn from experiments. This white paper introduces a different PDCA cycle, a method to learn from breakdowns.

Breakdowns are defined as unexpected outcomes of processes, and as such, they signal that there is something for us to learn. For example, suppose that we expected to produce a defect-free product B from following process A, but instead we produced a defective product, or had an accident, or broke a promise, or—more happily—had better results than we expected. All of these are unexpected outcomes, and all signal the need to learn. In this white paper, we apply the new PDCA cycle to building in quality.

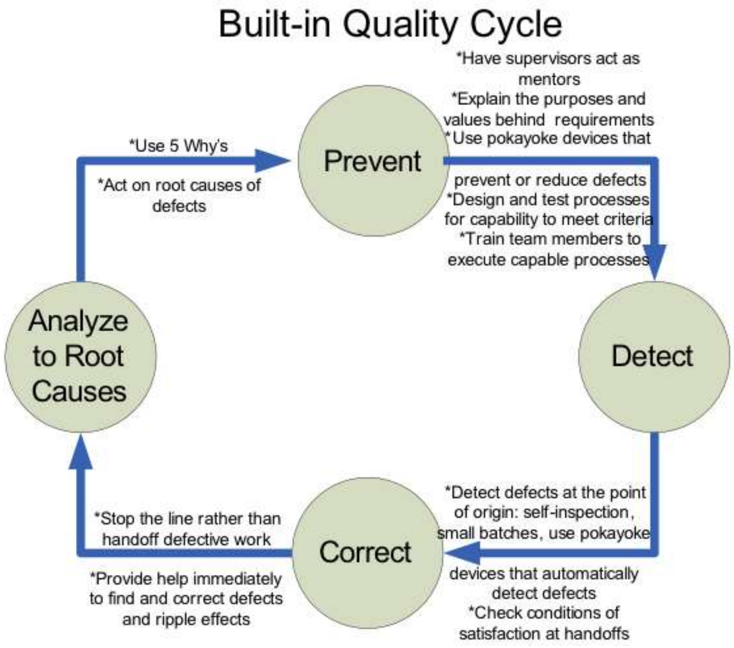

Figure 1: BiQ Cycle

The BiQ Cycle is Prevent-Detect-Correct-Analyze or PDCA$_B$. We want to prevent defects, but if they do occur, we want to detect the defect as close as possible to the point of origin in order to limit the damage. The next step is to take corrective action; understand the situation and decide if production can be resumed. When a standard process needs to be improved, analysis to root causes reveals possible countermeasures, which then must be tested in experiments to evaluate their effectiveness in preventing the defect.

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Before explaining how the two PDCA cycles are linked in this BiQ process, let's consider some of the methods that have been developed to support the steps in the cycle.

Prevent

- *Use poka yoke devices (mistake proofing) that reduce or prevent defects.* A drill bit marked to show the target depth of the hole to be drilled reduces the probability of a hole too deep or too shallow. A cylinder of the right length placed over the bit prevents the hole being drilled to the wrong depth. See Tommelein (2008) for more poka yoke examples and send us some to add to the collection at http://p2sl.berkeley.edu/pokayoke/.
- *Design and test processes for capability to meet criteria.* Processes can be designed and tested using virtual prototyping or physical prototyping. Discrete event simulation is one example of virtual prototyping. Use of building information models (BIM) is another. Physical prototyping is familiar in the construction industry as mock-ups, although more often used to test fabricated components than to test processes for fabricating the components. Introducing materiality usually reveals additional information about process performance. Repetitive processes can also be tested in first run studies; i.e., the first instance of the process being used on a project. For examples and further explanations, see Tommelein (1998) and Howell & Ballard (1999).
- *Explain the purposes and values behind requirements.* When craft workers understand the purpose of requirements and how that links to customer value, that reduces defects by motivating and directing attention. It also helps when craft workers understand in advance of doing their work how it will be inspected.
- *Have supervisors act as mentors.* Supervisors at every organizational level in a lean enterprise act as mentors to their direct reports, helping them learn how to carry out standard processes, and how to improve standard processes. The goal is for everyone in the organization to be continuously improving his or her own work.

Detect: Detect defects at the point of origin

- *Self-inspection obviously helps identify defects earlier. An inspection by the supervisor prior to release for quality control (QC) inspection is the next line of defense. Successive inspection is performed by the immediate customer, but their concern and competence may be limited.*
- Small batch production also is an obvious help in earlier identification of defects. This links to the first run studies mentioned earlier. If we define the first run as a small batch, perhaps a ten foot section of in situ concrete wall, we can test the capability of a process to produce defect-free product, and limit any defects to the small batch.
- If possible, we want to use poka yoke devices that prevent defects from occurring altogether, but if that is unachievable then use them to automatically detect defects or signal a (non-) defective state of the product. That reduces reliance on manual methods of inspection and assures early detection. Example: bolts that provide a visual signal that a desired torque has been achieved.

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Correct

- The first step in correction is to ‘stop the line’ rather than release bad product past your workstation. This may be done by the direct worker or his/her immediate supervisor. The second step is to determine where the defect originated, at the workstation where it was detected or upstream. The third step is to find out if the defect resulted from an inadequate standard process or from failure to follow the standard process. The fourth step is to decide if production can be resumed without risk of the defect happening again. All this needs to happen quickly. When the standard process was not followed, corrective action may consist of discarding or repairing the defective part and retraining the worker or external supplier, or simply reminding them to follow the standard process. When the standard process was followed and failed, the process must be improved before being used again. That requires analysis of the situation to find countermeasures.

Analyze to root causes

- The goal is to find countermeasures that will prevent reoccurrence of defects. When that is not feasible, the alternative is to reduce the probability that a defect reoccurs or reduce the negative impact of reoccurrence.
- The first step is to identify potential countermeasures.
  - 5 Whys may be sufficient to identify countermeasures or to reveal the need for other analytical tools such as failure modes and effects analysis (FMEA).
  - The expression “root cause analysis” is a bit misleading, as it suggests there is a single cause although the defect may have occurred as a result of a constellation of causes and preventing future occurrences of the constellation may be what is needed.
  - Another trap to avoid is to become so fixated on the problem as given that you fail to ask a more fundamental “why?”. An example from safety: a worker slipped on the icy top of a bathroom pod when attempting to release the crane hook. Initial questioning focused on how to prevent slipping; e.g., by preventing ice from forming. Then someone asked a more fundamental question: “Why are workers getting on top of loads?,” which prompted a search for ways to avoid putting workers at risk.

Figure 2: Shewhart/Deming PDCA Cycle

- Once a potential countermeasure is identified, we have a hypothesis to be tested: ‘If x does z in situation y, the defect will be avoided.’ Here the $PDCA_B$ BiQ cycle intersects with the Shewhart/Deming experimentation cycle, $PDCA_E$: Plan-Do-Check-Act.
  - “Plan” is forming the hypothesis; i.e., proposing a countermeasure to prevent the defect.
  - “Do” is doing the experiment.
  - “Check” is testing if the countermeasure was effective.
  - “Act,” in this case, is using the countermeasure to Prevent the defect from reoccurring.

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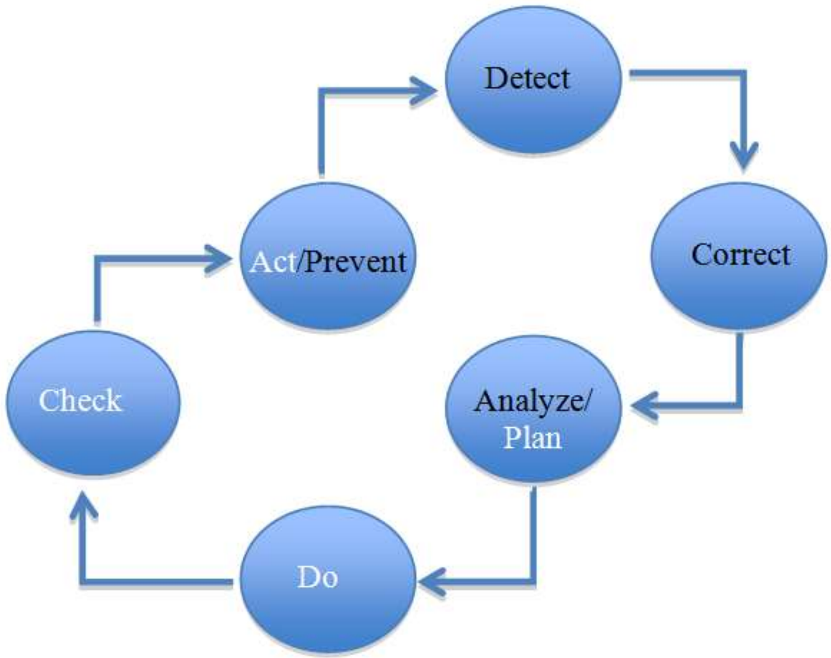

Figure 3: Combined $PDCA_B$ and $PDCA_E$ Cycles

A defect is detected (Detect), corrective action is taken (Correct), a possible countermeasure is identified through analysis (Analyze/Plan), the countermeasure is put into place (Do), the results are evaluated (Check), and then, possibly after multiple repetitions, the effective countermeasures are incorporated into standard practice and deployed throughout the organization to prevent future defects (Act/Prevent).

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