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Design for Six Sigma and Lean Manufacturing

Praveen Gupta

After initial success, Six Sigma methodology has become the strategy of many corporations. Before the advent of Six Sigma, as discovered by Motorola, initiatives such as design for manufacturability (DFM), cycle time reduction (or lean manufacturing) and waste reduction existed. Six Sigma methodology has evolved to incorporate DFM and lean manufacturing. What's interesting to note is that DFM and lean manufacturing have become post-Six Sigma initiatives, instead of prerequisites for implementing Six Sigma successfully.

Quality assurance has evolved from end-of-line inspection (product inspection) to on-line inspection, to process control (control charts), and to off-line inspection (DFM), quality management systems (ISO 9000) and Six Sigma (dramatic improvement). During this evolution, many tools, techniques and systems have been invented. Commonly known systems are pareto charts, cause-effect diagrams, control charts, design of experiments, Taguchi methods, zero defects, quality function deployment, Malcolm Baldrige National Quality Award Guidelines, Triz (Russian methods for systematic innovation), ISO 9000, QS-9000 and Six Sigma. Names like Walter Shewhart, Ed Deming, J.M. Juran, Armond Feigennbaum and Phil Crosby are legends in the quality assurance industry. However, Six Sigma was invented at Motorola within a framework that included DFM and lean manufacturing.

DFM is achieved through concurrent design of product and processes. Design for Six Sigma uses an integrated approach to design so that the product is manufacturable at the highest quality and lowest cost and satisfies all of the customer's requirements. DFM is important to implement because the majority of manufacturing defects occur due to design-related issues. The success in creating a manufacturable product depends upon clearly defined product goals reflecting physical and functional requirements of the customer. Products designed for Six Sigma using design for manufacturability processes will allow the following:

- virtually defect-free or robust product design
- waste-free manufacturing
- 100 percent usable purchased parts
- minimal maintenance and service
- total customer satisfaction.

In a design for Six Sigma environment, the product design team works with a cross functional team consisting of members from marketing, sales, quality, manufacturing, purchasing and even customers.

An excellent measure of a product designed for Six Sigma performance is Cp that is defined as follows:

$$Cp = \frac{\text{Design tolerance (Upper spec. limit – Lower spec. limit)}}{\text{Process capability } (6\,\sigma)}$$

If the Cp is equal to or greater than 2.0, the product design can be considered a Six Sigma design because, when transferred to production, it will most likely yield 99.9996 percent for each customer's critical characteristics.

For Six Sigma designs, the product design team should focus on the following considerations:

- fewest number of parts
- parts of known capability
- maximum design tolerances
- maximum operating margins
- minimal overstress.

The inventor of Six Sigma methodology at Motorola, Bill Smith, has stated that parts designed to the target conditions, with the above considerations and operating under normal conditions without overstress, will never fail.

Design for Six Sigma will also consider using tools such as quality function deployment for developing best-in-class products; failure modes and effects analysis (FMEA); creative methods such as Triz; design for assembly; simulation; design of experiments for optimization and Taguchi methods for robust designs.

Lean manufacturing is a way to specify value, arrange value-creating actions in the optimum sequence, conduct these activities without interruption and improve continually. Lean thinking is a way to do more with fewer resources to provide customers exactly what they want. The value is defined in terms of specific products with specific capabilities offered at a specific price to a customer. One identifies the value stream as a set of specific actions required to create value. Identifying the value stream for each product or service is a key step in lean thinking. Typically, the actions in the value stream can be grouped in one of the three categories:

- actions creating value
- actions creating value but unavoidable immediately
- actions creating value and avoidable immediately.

Having identified the value stream, the wasteful steps are eliminated and the remaining value-creating steps flow. Lean thinking can be considered to be out-of-the-box thinking. Nothing is taken for granted. Every step is questionable. One of the opportunities for change is reducing the batch size. Having a large batch size is a natural inclination for high-volume producers to justify longer set-up times. Lean thinking challenges the batch size by focusing on reduction in set-up time. Batch size impacts purchasing quantities, maintenance, set-up time, material flow and quality improvement.

One of the measurements of lean manufacturing is inventory levels. Inventory is a good measure of manufacturing woes, because a natural company reaction is to build more or buy more just in case of a shortage. Suddenly, the cost of carrying the inventory starts eating up the profits.

Managing inventory is like managing the material river, where the volume of water is dependent on the length, depth and width of the river. Similarly, in a manufacturing operation, inventory level is dependent on the number of process steps (length), unique part counts in designs (width) and organizational policies (depth). When one starts reducing the inventory level, the rocks, or the problems, start to appear. Continual improvement at a dramatic rate is a critical part of sustaining lean operations.

For parts manufactured with lean manufacturing and Six Sigma design, manufacturing engineers should focus on the following considerations:

- documentation
    - product design documentation
    - process manufacturing instructions
    - inspection and test procedures
    - repair and rework instructions
    - handling of nonconforming material
- processes of known capability
- simple and shortest process flow
- process reproducibility
- organizational policies.

Products designed for Six Sigma and built with lean thinking will be manufactured in a pull system and with virtual perfection. Ultimately, an organization’s goal is to produce the highest quality product at the lowest cost and minimal waste. In such an environment, endless improvement is realized using kaizen (continual), as well as kaikaku (dramatic), methods.