Design for Six Sigma

You need more than standard Six Sigma approaches to optimize your product or service development

by **Douglas P. Mader**

Many organizations believe design for Six Sigma (DFSS) is a design process when really it is not. DFSS is an enhancement to an existing new product development (NPD) process that provides more structure and a better way to manage the deliverables, resources and trade-offs.

DFSS is the means by which we employ strategies, tactics and tools to enhance an existing design process to achieve entitlement performance. It integrates qualitative and quantitative tools and key performance measures that allow progressive organizations to manage an NPD process more effectively to optimize several competing key drivers, such as cost, quality and time to market.

A typical NPD process might include several high-level development phases, such as the seven-step systems engineering model: needs assessment, concept design, preliminary design, detail design, process design and construction, manufacturing and end of life. Most organizations have instituted management reviews called checkpoints or tollgates throughout these design phases to allow the organization to assess risks, monitor progress and ensure transitions from each phase to the succeeding phase are warranted.

Focus on risk management in the early phases

Because quantitative measures of performance may not exist until the physical product is prototyped or the service is piloted in the later design phases, all that exists early in the NPD process is the risk of future problems. This is why progressive organizations focus on risk management in the early phases of an NPD process rather than on the application of traditional quantitative quality tools.

DFSS opportunities should be categorized by the size of the effort. Macro opportunities involve the design and development of an entirely new product or service or the major redesign of an existing one. Micro opportunities are smaller in scope and likely pertain to the execution of a subtask within a macro opportunity.

To address macro opportunities, most organizations develop their own NPD process based on the seven-step systems engineering model. Modern implementations of DFSS consist of integrating DFSS deliverables into the checkpoint criteria for the macro level NPD process, training the management team on how to resource and guide the effort, and using a structured approach to the application of DFSS principles at the micro level.

At the macro level, there is no consistent standard for integrating DFSS into an existing NPD process because NPD processes are as widely varied as the products and services they generate. My company, SigmaPro, works with its clients to map their NPD processes and develop a custom approach that uses best practices from the organization and incorporates DFSS deliverables into the checkpoint criteria.

Management training is addressed before technical training because many of the issues pertaining to performance of the NPD process are not technical in nature. Once DFSS criteria have been integrated into the NPD process, the management team has been fully trained and the appropriate design projects or applications have been selected, we launch technical training at the micro level. Our technical training is centered around a four-step methodology that provides a general approach to the application of DFSS at the project level and subtasks within a design project.

The ICOV approach

The DFSS approach we use at the micro level consists of four major steps, known as ICOV (see Figure 1):

1. Identify.
2. Characterize.
3. Optimize.
4. Validate.

Identify. This stage consists of two major steps. The first is to develop a clear understanding of customer requirements for the micro level design activities, in which the definition of the customer can include internal and external customers and other stakeholders. We also take into consideration the business's financial goals, such as development cost and schedule. The needs and wants are collectively known as CTXs or "critical to (whatever the particular need or want is)." These CTXs are then translated into architecture requirements, specifications, performance criteria or other objective measures for the activity.

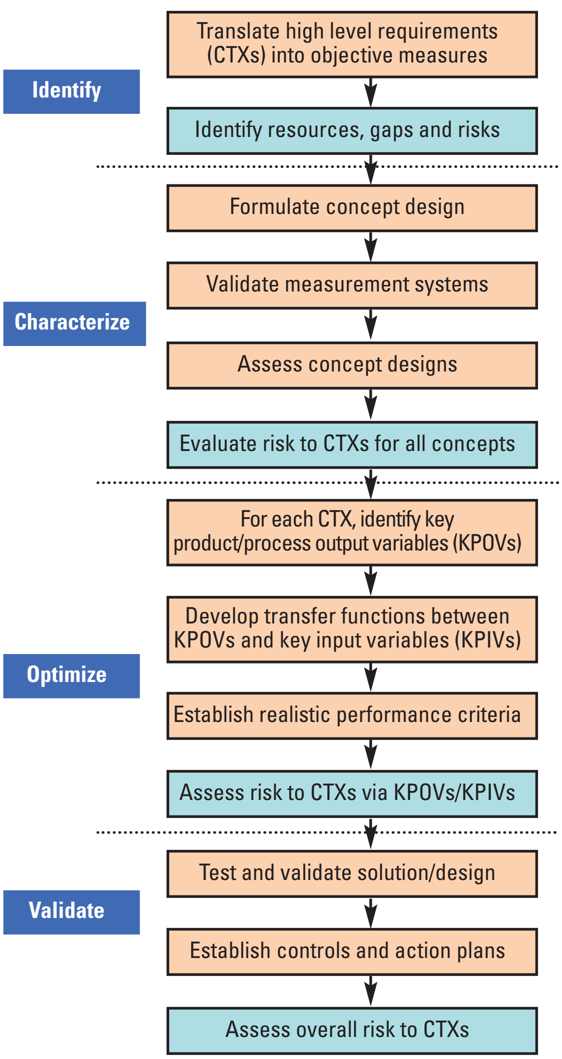
The next step is to identify what resources are needed to achieve the requirements identified in step one. Consider technology, manpower, supplier, process and business constraints. Then create an effective plan to achieve the CTXs. Common deliverables for this stage include a feasibility study, definition of the customer, needs analysis, financial or cost analysis, system operational requirements, functional requirements and advance product planning.

Characterize. In this stage we

develop, test and validate design concepts. Once we have identified the CTXs and determined the required level of performance, the designer or team may have several competing solutions or concepts. Pugh concept selection methods and enhanced quality function deployment (EQFD) matrices are often coupled with failure mode and effects analyses (FMEA) and cause and effect matrices to help organize the information pertaining to concept selection. Several other common tools employed in this stage include architecture block diagrams, functional flow diagrams, specification trees, functional hierarchy diagrams and process mapping.

If we have several competing concepts, we need to determine the measurement systems that will allow us to test the performance of the system for important design attributes. For product design attributes, we use statistical measurement capability methodologies, such as gage repeatability and reproducibility, and risk analysis. A common mistake DFSS practitioners make, however, is to assume we are only referring to hardware tests in this important step. In fact, subjective testing methods such as choice modeling, focus groups and customer interviews are equally as important as hardware testing.

FIGURE 1 Identify, Characterize, Optimize And Validate Strategy



For services, we need to find measurement systems, such as customer satisfaction, recommend rates, repurchase rates and perceptions of value, that allow us to measure performance subjectively. Tools such as surveys and process mapping coupled with FMEAs are extremely useful. Once we have determined the measurement systems that will give us the information we need regarding the performance of the design, we implement the concept testing process and evaluate the risk with regard to the CTXs. We can then make a decision to proceed or to revisit the design concepts.

Optimize. In this stage we make sure we have optimized the design with regard to customer and business requirements. For each CTX, the designer or team should identify the key product or process output variables (KPOVs) that relate to the desired performance. Once the KPOVs are identified, the next step is to find the key process or product input variables (KPIVs) that we can control in order to optimize the KPOVs.

To quantify the relationship between KPOVs and their associated KPIVs, we develop transfer function models. These models provide information on how we can change the KPIVs to optimize the performance of the KPOVs and, therefore, the design.

For the construction of transfer function models, we have two alternatives. If we have a physics based equation, we can use calculus based methods to predict the mean, variance and capability for a KPOV based on the means, variances and capabilities of the KPIVs. Unfortunately, this method is extremely difficult even for simple problems and is rarely used.

The second method is to build empirical prediction equations using regression or other mathematical methods based on simulation or experimental results. Empirical prediction models allow us to predict the mean, variance and capability of a KPOV based on the means, variances and capabilities of the KPIVs.

Monte Carlo simulation is typically used for hardware scenarios, and discrete event simulation is used for service scenarios. Engineers often have simulation engines that are adept at modeling physical systems, and these tools have been standard practice for some time. Only recently, with the development of integrated process mapping and simulation tools, have similar methods become available to service designers.

After we develop transfer functions and optimize the system, we need to establish realistic performance criteria for the product or process. In other words, we establish the criteria that will be used to assess whether the process or product fulfills the customer's requirements. Then we estimate our risks to the desired performance of the CTXs using knowledge of the KPIVs, transfer functions and the predicted performance of the KPOVs.

A key question to ask is how well the system fulfills the customer wants and needs. If we can demonstrate the optimized design fulfills customer and business requirements, we will also want to assess whether the design possesses adequate quality levels at an appropriate cost. Common tools employed in this stage include EQFD, FMEA, cause and effect matrices, statistical decision making, statistical tolerancing, risk analysis, designed experiments, simulation and optimization, and probabilistic design.

Validate. In this stage we test and validate the optimized design. We confirm the performance, capability and reliability of the product, process or service. The key is to make sure we have good test systems to validate the design. Some of the tests may be subjective in nature. Upon validation of the system through objective and subjective testing, the designer or team should establish control and action plans. This involves the extension of risk management from the conceptual design into the production or operations environment.

> **The power of DFSS is in the organization of the tools into a coherent strategy that aligns with the NPD process, not the individual tools themselves.**

Statistical process control, error proofing, reliability, maintenance validations, sampling, test plans, test coverage, process FMEAs and measurement capability are all tools needed to complete this stage.

The design team should then make an overall assessment of the risks and potential impact on the CTXs.

Old tools, new strategy

The majority of the tools used in the ICOV methodology have been employed for a number of years. Thus, DFSS is a strategy for the deployment of tools that are not necessarily new. The power of DFSS is in the organization of the tools into a coherent strategy that aligns with the NPD process, not in the individual tools themselves. This structured application of the tools allows for a much higher rate of success when compared to current approaches. One of the past difficulties in NPD improvement is that people have focused on the application of discrete tools and not on how those tools align with and support the objectives of the overall NPD process.

DFSS is not limited to the design and development of products and processes. The majority of the tools, concepts and methods in the DFSS approach can be applied to service industries and processes and to industrial products and processes.

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