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New product development process

1.1 Introduction

The development of new products is a major competitive issue as consumers continuously demand new and improved products. One outcome of this competitive landscape is the need for shorter product life cycles while still achieving ever increasing expectations for product quality and performance measures. This has required companies to significantly enhance their capabilities to better identify true customer wants, translate them into quantifiable product functional requirements, quickly develop, evaluate, and integrate new design concepts to meet them, and then effectively bring these concepts to market through new product offerings.

Several companies (e.g., Apple, General Electric (GE), Samsung, Toyota, General Motors (GM), Ford) have made great strides improving the effectiveness of new product development. For example, many companies have created processes to quickly gather voice of the customer information via surveys, customer clinics, or other sources. Samsung, for instance, has a well-designed system of scorecards and tool application checklists to manage risk and cycle time from the voice of the customer through the launch of products that meet customer and business process demands (Creveling et al., 2003). In addition, advances in computer simulation and modeling techniques permit manufacturers to evaluate many design concept alternatives, thereby resolving many potential problems at minimal costs. This also allows one to minimize assumptions and simplifications that reduce the accuracy of the answer (Tennant, 2002). Finally, even when there is a need to construct physical prototypes, the cost has been lowered through rapid prototyping processes.

Probabilistic Design for Optimization and Robustness for Engineers, First Edition.
Bryan Dodson, Patrick C. Hammett and René Klerx.

Companion website: http://www.wiley.com/go/robustness_for_engineers

An interesting outcome of reducing the costs of data collection and analysis (for voice of the customer, simulation modeling, or physical testing) has been an increase in these activities. This has subsequently resulted in a deeper and broader understanding of customers and their interactions with products. This expanding knowledge base further allows a greater proliferation of product choices to satisfy increasingly diverse and sophisticated consumers.

Still, product development undoubtedly entails tremendous challenges. Many companies struggle with products that are slower to market than planned, fail to meet cost objectives, or are saddled with late design changes. Although no single recipe exists for product development success, one common thread is the ability to effectively integrate engineering resources within product and process design along with sales, marketing, manufacturing, and most importantly the end user.

Design for Six Sigma (DfSS) is a methodology that emphasizes the consideration of variability in the design process, resulting in products and processes that are insensitive to variation from manufacturing, the environment, and the consumer. The role of DfSS within new product development is to become an enabler of better integration of these resources to provide a deeper knowledge of product performance drivers and capabilities. An excellent example may be observed through GE, which has aligned the tools and best practices of DfSS within their product development process (Creveling et al., 2003). This chapter discusses the major phases of new product development with an emphasis on the roles engineers and DfSS resources play in effectively launching new products.

1.2 Phases of new product development

The time to develop a new product often depends on product complexity, which typically is a function of the technology readiness level (Assistant Secretary of Defense for Research and Engineering, 2011), the number of components, and the difficulties associated with manufacturing. In the case of an automobile, product development typically requires at least 2 years depending on the extent of the redesign. For example, if a manufacturer uses an existing powertrain and interior body frame, the development time may be reduced to less than 2 years. Product development times in aerospace industries typically range from 3 to 4 years, while the electronics industry is much faster with lead times of 6–12 months depending on the complexity of the product.

Although the total time for new product development will vary by design complexity and technological availability, the basic steps involved are common. Clark & Fujimoto (1991) and others (Tennant, 2002; Clausing, 1994) have provided basic descriptions of the product development process. The general phases (or steps) of new product development include concept development, product planning, product engineering design and verification, process engineering, and manufacturing validation as shown in Figure 1.1. The ideal situation for employing DfSS is to integrate it within these steps. To do so, one must acquire true customer needs and then apply the discipline of DfSS within the phases to efficiently transform customer needs into

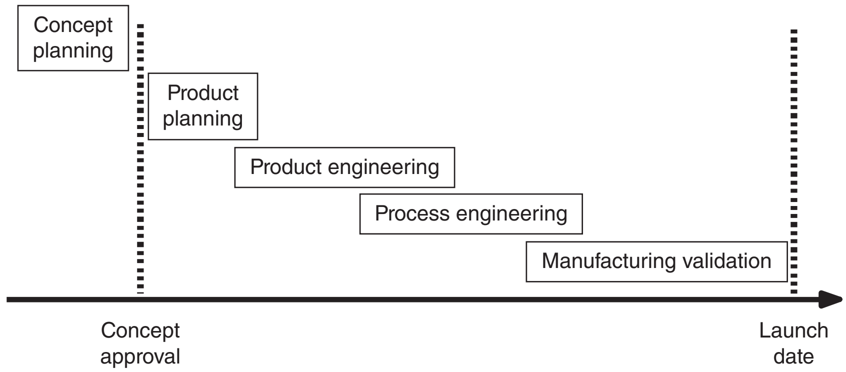

Figure 1.1 The phases of product development.

desirable products and services. DfSS and product development are complementary to each other and they can be implemented in parallel (Yang & El-Haik, 2003).

The following sections describe these phases in greater detail and discuss the roles of engineers and the integration of DfSS methods to improve their effectiveness.

1.2.1 Phase I—concept planning

During concept planning, manufacturers gather information on future market needs (voice of the customer), technological possibilities, and economic feasibility of various product designs. Many companies begin concept planning by expressing the character or image of their product in verbal, abstract terms using basic questions such as:

- Who shall use the product? (Target customers, cost of the product).
- What should the product do? (Performance and technical functions).
- What should the product have? (Appearance, packaging, key features, and options).

In defining a product concept, manufacturers often conduct three key assessments. These include assessing the voice of the customer, capabilities of the competition, and technological capabilities within the company.

The primary step in the development of a new product is the determination of the customer's wants and needs. Obtaining the voice of the customer traditionally has been the responsibility of Sales and Marketing who may conduct market studies, customer surveys, interviews, or use past sales data to identify market needs and trends. Although marketing is primarily responsible for customer research, under a DfSS framework, companies include more technical specialists such as product engineers in voice of the customer studies. The inclusion of technical specialists often accomplishes two objectives. First, product designers gain a better perspective of customer desires by mitigating the marketing filter. Second, technology specialists often are better suited to interpret emerging desires because of their deeper understanding of new technologies in development or existing ones in other industries that could be applied to their products.

To gain insight into consumer purchasing influences, Kano's method of analysis is a useful tool (Berger et al., 1993). Successful applications of Kano's methods require skill and experience. Translating customer wants and needs into product decisions remains a mix of art, science, and sometimes just good fortune.

To further assess the market, many companies conduct benchmarking studies of their competitors. Benchmarking is the continuous process of comparing one's own products, services, and processes against those of leading competitors. Although manufacturers typically benchmark direct competitors, they occasionally examine leaders in other industries. For example, car and bicycle manufacturers may benchmark airplane designs for ideas on how to make their products more aerodynamic, or for methods to improve internal processes.

To analyze complex products, today's manufacturers may even purchase their competitors' products and disassemble them down to evaluate the design. Here, companies are concerned with the inner workings of a product and how it is manufactured rather than its external appearance. Many companies set up "war rooms" where they make displays of competitor product components allowing internal engineers to review other designs and activate the creative process. In many cases, these war rooms provide a tremendous catalyst for making improvements. While one has to be careful to prevent benchmarking from leading to "look-alike" products, it can be a valuable tool to generate new ideas, which undoubtedly is necessary for continuous improvement of a product design.

The culmination of the concept and initial planning phase is often referred to as concept approval. This is an important date, because it typically is when financial resources are committed to bringing the product to market. While a company may reject a new product later in development, concept approval is generally "*when the clock starts ticking*."

1.2.2 Phase II—product planning

Once a concept is approved, a manufacturer must translate it into more concrete assumptions and detailed product specifications. In the language of DfSS, this involves the translation of customer requirements into product functional requirements, product attributes, and product features. This invariably consists of trade-offs between cost, functionality, and usability. Consider the design of an automotive body for a family sedan. Market studies may show that consumers want not only a strong rigid body for safety and handling, but also a vehicle with high gas mileage at a competitive cost. These few reasonable requests quickly create numerous design possibilities with each solution having its own set of advantages and disadvantages. For example, a manufacturer might choose to replace steel body panels with aluminum alloy panels because aluminum has a better strength to weight ratio. However, aluminum is generally more expensive than steel. It also can be more difficult to manufacture into certain shapes creating styling challenges. Under the DfSS framework, a manufacturer must establish a set of performance targets for the functional requirements and then select a design which best meets them using a balanced scorecard approach (Yang & El-Haik, 2003).

Among the key activities that occur during product planning are styling, product architecture, and material and component selection. These activities are discussed in the following sections.

Styling and system architecture

Styling and system architecture are analogous to skin and bones. Styling represents the exterior appearance or exposed view of the product. Product architecture represents the structure and organization of internal components within a design system. In the design of a computer, stylists are concerned with the size, shape, and color of the monitor and computer box. Product architecture would be concerned with the positioning of the hard drive and external devices inside the computer box to improve functionality and lower manufacturing costs. Even in this simple example, the importance of integrating styling and architecture into a final design package becomes apparent. For example, in designing a tower computer box, the stylist might dictate the location and order of the external connections based on expected customer use, assuming the tower will be placed on the floor. Since USB connections are used more often than other devices, they may be placed closest to the top. In this example, stylist dictates the architecture.

Typically, companies do not use engineers to lead styling. For example, automotive manufacturers often utilize art and graphics specialists. These specialists are better trained at designing more appealing products. Still, while these non-engineers may drive styling, product design engineers remain essential to ensure product functionality and identify various manufacturing and cost limitations.

The authority of stylists or designers on the final product varies by company. Some companies rely heavily on designers and then expect engineers to determine how to make the design work. For others, product engineering may place a greater emphasis on how the product will function prior to determining how it looks (“form follows function”). Successful product developers clearly recognize that both styling and architecture must have similar levels of authority to effectively work together.

Material and component selection

Another critical role of engineers during new product development is material and component selection. New product development involves numerous choices between different types of material, new versus existing technology, in-house versus supplier parts, and various levels of sophistication for a particular technology. In all cases, engineers must consider the cost implications, effects on other components, and product concept objectives. Ultimately, companies must try to maximize value, where value represents the relationship between price and functionality (or quality); in other words, the amount a customer is willing to pay for a feature or function of a product.

During component selection, organizations identify advantages and limitations. For example, in the design of a mountain bike tire, engineers must decide how wide to make the tire while achieving weight targets and absorbing a specified level of road stress. One critical step in conducting such engineering is to understand the stresses that might incur under riding conditions. For example, a typical rider may only need to handle stresses incurred on gravel roads and jumps of less than one foot. If a manufacturer overdesigns their bicycle with excessively durable tires relative to the expectations of their target customers, they will produce an unnecessarily expensive product. While some customers may consistently ask for greater functionality, purchasing behaviors routinely suggest acceptance limits, often related to product prices.

1.2.3 Phase III—product engineering design and verification

Product engineering involves the execution of the product concept and planning phase. Product engineers construct detailed designs of the end product and its various components, including design verification. Here, many of the early engineering activities such as product architecture and component selection are reassessed during this phase as engineers add detail to the loose objectives identified in prior phases. Functional requirements are cascaded down from the system level to subsystems and eventually components. For example, the functional requirements of an automobile include safety and acceleration. Acceleration cascades down to the engine in terms of horsepower. Engine horsepower continues to cascade down to the piston and other components.

During process planning, a vehicle manufacturer may only decide between aluminum and steel for their doors. During product engineering, more detailed questions are addressed such as whether the door window should go directly into the roof panel or whether it goes into a header attached to the door itself. Furthermore, if an organization decides to use a door header, they then would need to determine whether the header should be a separate assembly attached to the lower door or integrated into the lower stamped door. Figure 1.2 illustrates three basic door design differences.

Once determining the basic system architecture, product engineering designs components and evaluates them against design criteria or functional requirements.

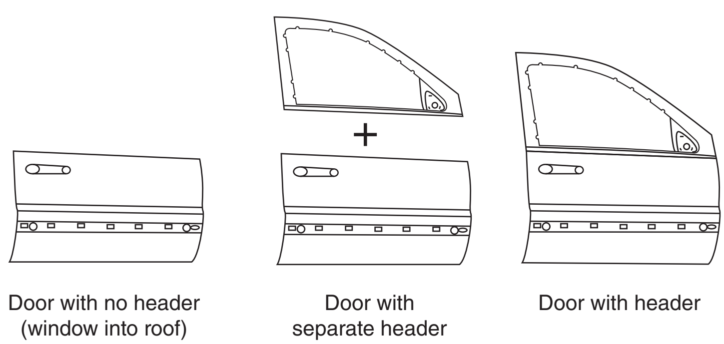

Figure 1.2 Door design alternatives.

Ideally this is done through engineering knowledge, including computer simulations. In cases where there are no engineering models, prototypes or replica are required for testing against design criteria or functional requirements. These criteria include both internal objectives and government standards such as safety and environmental regulations.

One way to consider multiple alternatives is through set-based concurrent engineering (Morgan & Liker, 2006). This approach involves considering a broad range of alternatives and systematically narrowing the sets to a final, often superior, choice. After finalizing the design plan, computerized drawings are created to convey the exact dimensions and requirements for each component. One important issue is to design interfaces that allow manufacturing to effectively assemble individual components. In developing drawings, product design engineers usually specify allowable variations (known as tolerances) for these interface dimensions in which the product design may vary and still be able to meet final product quality objectives. Considering more than one alternative also reduces risk when the technological readiness level is a concern.

To design a complex product, companies must develop various levels of specialization or rely on other organizations. In vehicle manufacturing, most companies divide their engineering groups by major subsystems such as body, chassis, electrical systems, and engine. Even within a major subsystem like body engineering, additional layers of specialists exist for internal and exterior body structures. Further specialization occurs at the working level where one engineer may focus on designing doors and another may specialize in hoods.

While this narrow specialization enhances engineering expertise, it also makes resource coordination and component design integration more difficult. Ultimately, organizations must constantly strive to balance the development of engineering specialists with cross-trained engineers to effectively integrate related subsystems. Toyota combines a strong functional organization (headed by general managers) with the deep specialization of a chief engineer (Morgan & Liker, 2006). This structure allows the chief engineer to focus on the customer and the integration of the overall product, whereas the general managers concentrate on their specialized systems and developing expertise among their engineers.

To enable coordination and integration, downstream resources such as process engineers and manufacturing personnel must have a channel of communication to provide insight into potential design problems. Poor integration often leads to late changes in designs. These engineering changes may result from lack of understanding of customer requirements, insufficient product knowledge, insufficient process knowledge, or errors of omission.

DfSS aims to mitigate the lack of understanding of customer requirements by more systematically gathering the voice of the customer and then translating this information into a set of comprehensive product design requirements with appropriate target and acceptance limits for functional performance measures. Ford (FMEA Handbook, 2004) and SKF (Re et al., 2014) cascade the requirements between system levels with the use of boundary diagrams. Boundary diagrams clearly define inputs, outputs, and responsibility for each level of a design.

Other late engineering changes may be related to insufficient product or process knowledge. These changes often result from skipping or compressing evaluation cycles due to pressures to reduce product development timing and costs. Organizations cannot test every possible occurrence that could lead to a product failure. Advancements in computer simulation and modeling are helping to mitigate this issue. Still, the creation of effective physical testing and experiments in the field of use along with the usage of methods like experimental design will continue to play a critical role in cases where engineering knowledge is lacking.

Another type of design error ("errors of omission") occurs when a product engineer misses a requirement or fails to resolve a historical problem. Repeating historical problems often is related to companies not effectively maintaining component design histories that categorize problems from prior models. As a result, design problems are repeated, especially if experienced engineers retire or change positions.

To reduce the errors of omission, design engineers must effectively communicate with both upstream functions (marketing and planning) and downstream functions such as process engineering (design of processes to build components) and manufacturing (physically making or assembly of components). Communicating with downstream development processes is particularly important because engineering changes usually increase in cost as the start of regular production approaches. Although all companies experience some engineering changes, the number and severity of these changes relative to product launch dates often separate the leading product developers from others. Developers that are not World Class have an increasing number of engineering changes culminating during validation and then spiking again after launch. This is illustrated in Figure 1.3. In contrast, world class developers typically identify problems earlier and resolve issues by the start of product introduction.

Ford (FMEA Handbook, 2004) and SKF (Re et al., 2014) use a chain of documents to store and reuse knowledge. The house of quality translates customer desires into engineering functions. These functions become the outputs of the boundary diagram. The boundary diagram is augmented with a parameter diagram, which lists the sources of variation. These sources of variation become failure causes in the design Failure

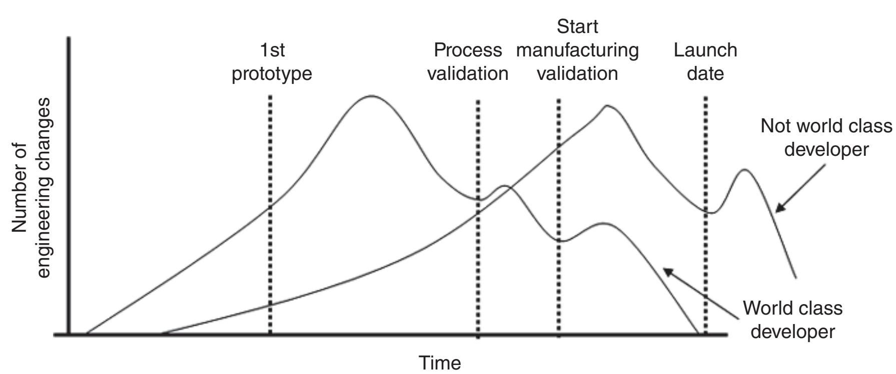

Figure 1.3 Engineering changes relative to start of production.

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Mode and Effects Analysis (FMEA). The design controls in the design FMEA become the verification plan. The design FMEA also identifies potential characteristics critical to the design function and to safety. The critical characteristics are either confirmed or removed in the process FMEA based on the manufacturing capability. The critical characteristics information form summarizes the confirmed critical characteristics from the process FMEA, and becomes the foundation for the manufacturing control plan. This entire chain of documents exists at each level of the design, and is updated on a continuous basis. This ensures all design and manufacturing knowledge is retained in an easy-to-use format that is easily reused with future designs.

While requirements are cascaded from the system level to the component level, the opposite is true for verification. Component designs are verified first, then the subsystems that include the components are verified, and finally, the system design is verified. Computer models and engineering knowledge play an important role in verification. Verification is only required where there is a lack of engineering understanding, which includes any assumptions that may have been made when using engineering models or equations. Historically, a design, build, test cycle has been repeated until an acceptable performance level is achieved. The methods described in this text combined with computer engineering tools can be used to break this cycle. Ideally, an optimal design is obtained with a single iteration.

1.2.4 Phase IV—process engineering

During the process engineering phase, organizations translate component design information into manufacturing processes. Process engineering consists of numerous specialists in a variety of manufacturing fields such as casting, stamping, machining, injection molding, bonding, and welding. These activities might include designing cutting tools, new fixtures, and process control software, in addition to training workers and developing standard operating procedures. For example, if a vehicle manufacturer wants to produce a hood, they would need to construct new tooling. Tooling generally refers to the equipment that interfaces directly with the product. In the hood example, process engineers would take design drawings of the hood inner and outer components and develop stamping dies (tools) that produce these components using stamping presses. Process engineers might also design new measurement fixtures to check the quality of the stamped hood panels. Assembly process engineers then would be responsible for designing and developing hemming and any subsequent welding operations, which are used to join the hood inner panel to the hood outer panel and attach any additional components such as latches.

One difference between product and process engineering is organizations typically develop manufacturing processes for a longer life cycle. With the exception of certain tools like dies and molds, which are often designed specifically for a particular component, manufacturing processes are usually capable of producing a variety of products. For example, welding robots may simply require reprogramming if a manufacturer changes component designs. In fact, organizations purposely design flexibility into manufacturing processes so changes can be made to product designs without purchasing new tools or machines. In redesigning processes, organizations prefer to only change the exterior tooling rather than purchase new equipment. As a result, many organizations contract independent firms to design and build their manufacturing processes. The effect of this approach is that internal process engineers may serve as liaisons rather than process design specialists. Still, process engineers provide a critical link between the production factory, product designers, and external engineering resources.

The criticality of the process engineering function within the product development process often depends on the experience using a particular technology. For example, vehicle manufacturers have used resistance spot welding for years and are able to design welders to assemble components relatively quickly. In contrast, a manufacturer may decide to switch from resistance welding to laser welding to improve the quality of the weld. This switch likely will create unknown challenges requiring more process development time for testing, debugging, and validation.

In developing a process, manufacturers must assess the effects of various process input variables on product outputs. Product output characteristics, such as the length or diameter, typically are controlled by a number of input parameters specific to a particular manufacturing process. These parameters may be relatively simple to control like adjusting the machine cutting speed or more difficult such as controlling material flow during a metal forming operation. For more complex processes, establishing a relationship between inputs and output variables is substantially more difficult. Here, more sophistical analysis methods are needed. In addition, process engineers must also consider the robustness of the relationships and design processes accordingly.

Robustness of the manufacturing process makes the production more uniform despite variability (Clausing, 1994). This ultimately leads to both improved quality and lower manufacturing cost. A robust process is where an output variable is insensitive to the variation of an input variable over its operating range. The wider the robust range for an input variable, the easier it is to control during normal production. For every process, it is important to clearly document what will happen, how it will behave, how long will it take, and how much will it cost when various input adjustments are made to continuously improve robustness of the process (Nevins et al., 1989).

Product design engineers should consider the capability of the manufacturing process when creating designs. The following chapters describe how to predict output variation from knowledge of input variation. This knowledge can be used to ensure the planned manufacturing operations have adequate capability, and to trade tolerances between parameters to minimize product cost.

1.2.5 Phase V—manufacturing validation and ramp-up

After designing components and developing processes, organizations begin preparing for full-scale commercial production. One might think that at this point engineering is complete and meeting production launch date is the responsibility of the production department. This, however, is not the case. Product and process designs often are not completely finalized until after manufacturing validation, where problems may arise when assembling components at regular production line rates. These problems result from an inability to meet and verify original design requirements by the start of manufacturing validation, or the failure to build products under regular production conditions.

In the first case, some product launches must deal with components that have yet to meet all design specifications by the start of validation. This, in turn, hinders the ability for downstream functions to properly evaluate the assembly of a component to its mating parts. Of course, some components are late because of excessively tight specifications that are not necessary to meet final product customer and functional requirements. Here, the resolution requires better processes for establishing and linking requirements.

A second set of validation problems results from differences between making components in a controlled environment versus regular production conditions. During process engineering evaluations, manufacturers may hand load parts into machines. In regular production, however, these parts may need to be loaded automatically using conveyors and pick-and-place devices. In some cases, the effects of automation may result in unforeseen issues. In many cases, manufacturers will be unable to solve all of their problems by the product launch date, resulting in temporary extra inspection and repairs. As a result, the validation process may continue after the product launch date.

This period after the start of regular production is often known as ramp-up. Generally, this ramp-up period is considered as the time from production launch until a manufacturer is producing at full production line rate. Depending on the success of the development process, ramp-up may entail only a few days. In some cases, the multitude of problems results in ramp-up lasting for several months.

1.3 Patterns of new product development

It should be apparent from the prior discussion of the product development phases that the integration of resources and joint problem solving skills is critical to new product development. Product designers need to consider marketing concerns as well as the potential effect of designs on process engineering and manufacturing. Quality is a function of design.

The product development process historically has been done as a series of sequential activities by various product development functions. Figure 1.4 compares the level of activity of each function relative to launch dates for a sequential development approach. Here, process engineering does not start until after the design is nearly complete. This has led many to characterize this process as an "over-the-wall" process. In other words, rather than designers communicating closely with process engineers, designs are handed over, and designers begin work on the next project. The problem with this approach is that many design errors or problems are not uncovered until later in the process, where engineering change and rework costs are significantly higher.

In response to the limitations of sequential development, organizations have recognized the importance of overlapping development functions. Consider product and process engineering working in parallel. The parallel approach heightens the importance of coordination and communication. Product engineering must comprehend implications of their designs for manufacturability, and process engineering must

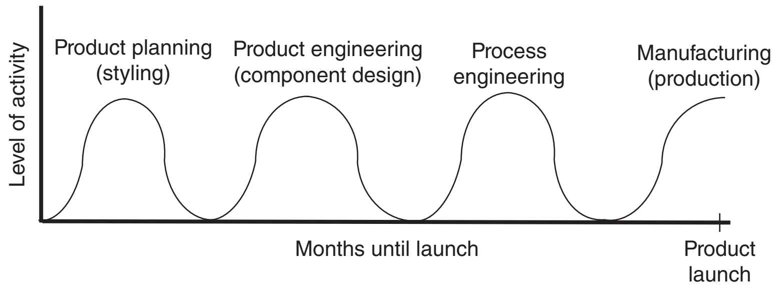

Figure 1.4 Sequential development (over-the-wall design).

clarify constraints and opportunities in the process and develop a good measure of flexibility to cope with the changes inherent in the product design process (Clark & Fujimoto, 1991). This greatly reduces lead time for development to better respond to changing market conditions. This approach is often known as concurrent or simultaneous development as illustrated in Figure 1.5. Under this approach, the development phases have significantly more overlap and thus require greater communication across resources.

While most organizations have some overlap in their development functions, the degree of overlap or concurrency may vary. For example, some organizations have their design engineers that not only solicit input from production departments, but also maintain authority and control over all design-related decisions. In contrast, some organizations give downstream functions such as process engineering and production, the authority to reject a particular design if they feel it cannot be manufactured effectively. Process designers at Toyota, for instance, use a "Lessons Learned Book." For instance, they have a Fender Die Design Book, which gives them a very detailed definition of what can be done (e.g., intervals of acceptable curvature radii for angles). Product design yields to these requirements. Of course, die design may develop a new technology or process to make the design feasible and revise the Lessons Learned Book (Ward et al., 1995). For another example, SKF encourages all engineers to understand the capability of manufacturing operations, and to release drawings with tolerances that can be achieved. SKF also models design outputs as a function of design inputs, and optimizes designs to be insensitive to variation in design inputs.

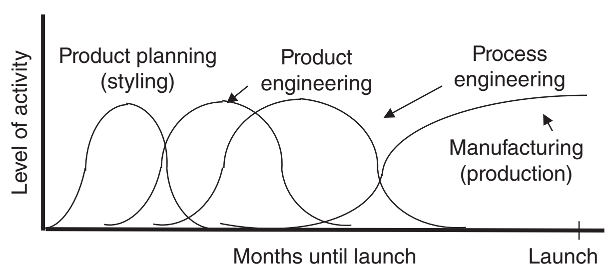

Figure 1.5 Concurrent product development.

One key to the integration of engineering resources is the organizational management structure. If new product managers have sufficient power and authority to make design changes and enhance communication channels, they can help insure better cooperation. However, if the new product manager is primarily a coordinator between product, process, and manufacturing departments, then new projects often have difficulty in making trade-offs and compromises between functions.

1.4 New product development and Design for Six Sigma

One way to enhance the capabilities of product development is to incorporate a DfSS approach or at least incorporate common DfSS tools into the product development process. DfSS involves a systematic approach to designing products to meet and exceed customer requirements while balancing internal business objectives for quality, cost, and timing. In short, it is a rigorous, systematic approach to develop higher value products in less time with less cost.

A key distinguishing features of DfSS are its focus on prevention of problems by designing optimal, robust processes that are less sensitive to typical operating conditions. Though often not obvious, an inherent lack of robustness in product design is a primary cause of manufacturing expenses. The "robustness" of products is more a function of good design, than manufacturing control, however, stringent the manufacturing process (Taguchi & Clausing, 1990). DfSS tools and methods are most effective during the phases from concept development to manufacturing validation. In contrast, once a product enters the later stages of manufacturing validation through regular production, problems become significantly more costly to correct, but of course they are much easier to identify. Here, the use of conventional quality problem solving and Six Sigma tools and methods such as the DMAIC process (Define, Measure, Analyze, Improve, Control) often is more effective for continuous improvement and achieving operational excellence. Figure 1.6 illustrates these differences.

As we discuss the link between DfSS and new product development, we may note that many of the individual tools and methods associated with it have been in existence long before DfSS became an established method embedded within new product development. In fact, the DfSS approach has a strong overlap with the push for "systems engineering." DfSS tools have been routinely employed, but not so stated (Vanek et al., 2008). Still, the adoption of DfSS methods provide a new opportunity to better link and apply many of these pre-existing tools to meet customer needs and reduce product costs.

1.4.1 DfSS core objectives

The core objective of DfSS is to create a more desirable design. This includes:

- Aligning products with customer requirements and desires.
- Reducing the product development cycle time with better knowledge reuse and by eliminating the build, test, fix cycle.

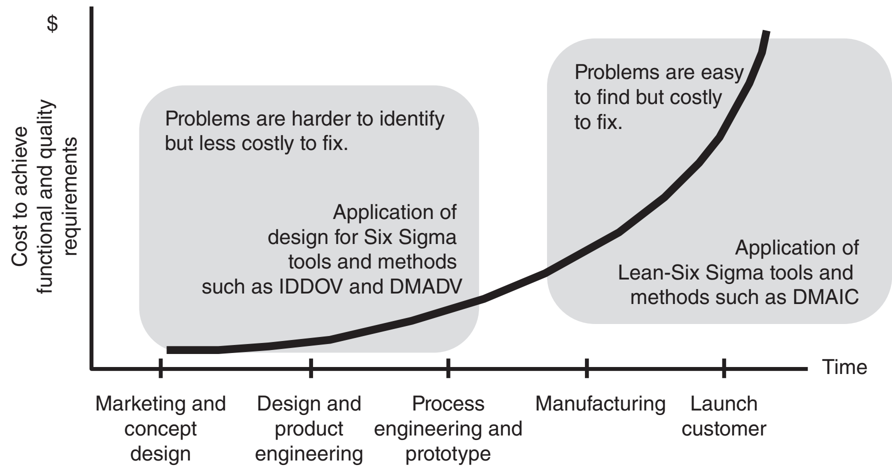

Figure 1.6 DMAIC versus DfSS.

- Designing products that are more robust to component, process, and user variation.
- Designing more reliable products.
- Designing products that are less costly and easier to produce.
- Enabling predictive versus reactive quality.

In terms of alignment, DfSS aims to give customers what they really want. This means not just what they say, but what they are willing to pay for. Alignment to customer requirements is also a never ending process as customers constantly raise their expectations or shift their preferences as new products become available.

Design for robustness involves delivering products and processes that are insensitive to the inevitable variability in manufacturing and use. While no product may be completely protected against all variation in processing or customer usage patterns, robustness may be quantified. Later in this book, we discuss several techniques to measure and quantify robustness.

While developing more robust and reliable products, which are essential, this must be done at a competitive cost. Critical to meeting cost targets is the ability to continuously develop products that are easier to manufacture than their predecessors. DfSS tools and methods may be used to evaluate and optimize design and process alternatives.

Finally, the adoption of DfSS stresses a shift from reactive to predictive quality. In a reactive world, requirements evolve often based on customer dissatisfaction or the inability of subsystems or components to meet cascaded specifications. Here, organizations employ build and test trials to determine a design solution, and then inspect in quality at the final product level. In contrast, a DfSS approach seeks to actively determine the voice of the customer and flow down requirements into a design solution. DfSS also stresses the use of simulation and modeling for initial evaluation and then the use of variation modeling for optimizing process parameters. In terms of quality, the objective is to design in quality and limit the amount of physical inspection for separating conforming from nonconforming product.

Given the broad objectives of DfSS, one must measure the overall quality of a design holistically. As such, we support the use of a total system desirability index that may include customer, functional, design, and processing requirements.

1.4.2 DfSS methodology

Several methods have been proposed to implement DfSS. For example, GM uses IDDOV (Identify-Define-Design-Optimize-Validate; Heincke, 2006); Ford prefers DCOV (Define-Characterize-Optimize-Validate; Stamatis 2004); while GE follows DMADV (Define-Measure-Analyze-Design-Verify; Snee & Hoerl, 2003). Other methods include DMEDI (Define-Measure-Explore-Develop-Implement; Costa, 2005), ICOV (Mader, 2003), and DCCDI (Define-Customer-Concept-Design-Implement; Tennant, 2002). Among these, we will illustrate DfSS using IDDOV.

The IDDOV process begins with the Identify and Define phase in alignment with the initial phases of new product development. Here, one gathers and prioritizes information on voice of the customer and functional requirements (design neutral requirements which quantify design performance and allow for creative solutions). These requirements flow down into the design phase where concepts are generated and selected. Design concept generation and selection in the context of DfSS starts at the system level, and is repeated at each level used within the end product. DfSS is also a useful tool when designing manufacturing processes.

Concept generation involves identifying new concepts and design alternatives, often by activating creativity through systematic or open innovation methods. Concept selection is done by comparing various alternatives against pre-established requirements and selecting the best overall option. Once a design concept is selected, computer-aided design and various other tools are used to create an actual product (either virtually or physically). At this point, the Optimize phase of DfSS begins to identify best settings for inputs using the robust design methods described in later chapters. This includes establishing target values and robust ranges for components and process settings along with the required tolerances and specifications to meet customer and functional requirements. Finally, the Verification & Validation phase is conducted to verify design intent, confirm that the product meets its requirements, and validate manufacturability.

A useful visual to show the integration of the IDDOV process with some common DfSS tools is the Systems V-diagram shown in Figure 1.7. The first mention of the V-diagram was found in Rook (1986), where it was introduced as a software project management tool illustrating the concept of verification of the process and products at established milestones (Kasser, 2010). The V-diagram was later introduced to the systems engineering community (Forsberg & Mooz, 1991). A key take away from this visual is that requirements flow down into a design solution via the IDD phases and then performance and quality measures flow up through the OV phases. A design

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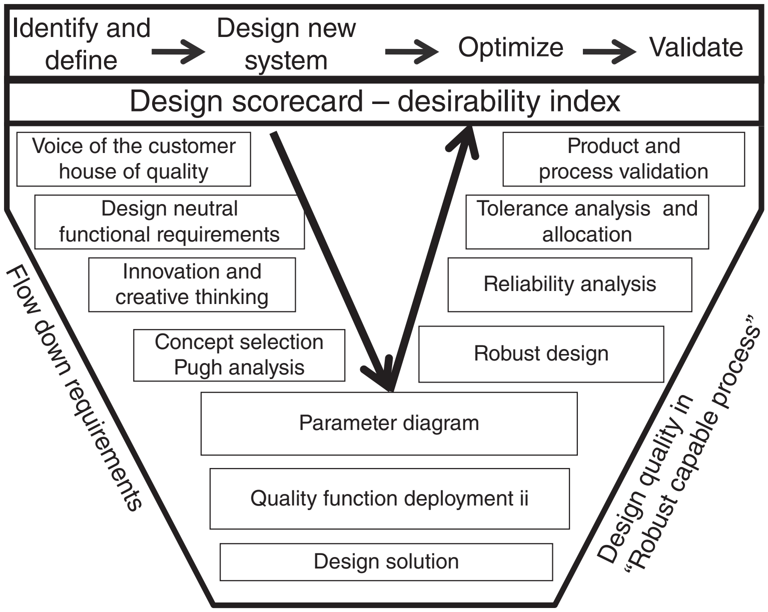

Figure 1.7 DfSS systems V-diagram.

scorecard with a desirability index may be used to measure the progress throughout (see Chapter 6 for additional details). It is important to note that the tools listed in the V-diagram are used for each level in the system.

1.4.3 Embedded DfSS

Similar to the conventional Six Sigma DMAIC approach, DfSS involves applying a structured, data driven methodology to solve high-impact problems and improve product performance. Among the quantifiable measures of DfSS successes may include:

- Shorter product development lead time.
- Lower total cost for product including engineering, materials, manufacturing, assembly, and shipping.
- Higher customer satisfaction ratings at launch and during the product life.
- Lower long-term production and operation costs.
- Higher reliability.

Unlike DMAIC, DfSS tools and methods often are embedded within an organization's existing new product development rather than applied as stand-alone improvement projects. Among "DfSS projects" led by Green or Black Belts, they often only contain either the IDD phases or IOV phases. As such, DfSS projects may be sub-classified as either IDD (Identify-Define-Design) or IOV (Identify Problem-Optimize-Validate) rather than full IDDOV. The power of DfSS is the organization of the tools into a coherent strategy that aligns with the product development process, not the individual tools themselves (Mader, 2003).

Several factors support the need to integrate DfSS within existing new product development. First, product development requires a substantial amount of company resources (both financial and resource time). Successful DfSS implementation should not be done in addition to normal activity but rather as an enabler to more effective product development. As the old adage says, "there's never enough time to do it right the first time, but there is always enough time to do it again." In fact, a popular view of DfSS is that it is not necessarily a new way of doing traditional development activities, but rather a more comprehensive, scientific, and data driven approach to make product decisions.

Since applying DfSS often occurs by incorporating the tools within an existing product development process, several challenges naturally arise. For instance, DfSS project applications typically span across multiple functions and organizations, thus the process owner may be unclear. Here, an organization must be careful to clearly identify roles and responsibilities related to a DfSS implementation. As noted by Soderborg (2004) of Ford Motor Company, DfSS implementation challenges often are more hindered by organizational and cultural change barriers than lack of technical skills to identify design improvements.

1.5 Summary

Developing an effective process to introduce new products clearly is a competitive weapon. A well-organized and efficient product development process is necessary to avoid cost overruns, late products, or product introductions with major quality problems. Although no single recipe exists for success, the ability of an organization to effectively integrate their engineering resources undoubtedly plays a central role. Engineers are trained to solve complex, practical problems. Rarely is this ability of greater value to a manufacturer than in the introduction of a new product. They simply need the tools and support to do so. The purpose of this book is to describe various methods and tools to more effectively develop new products.

Exercises

1 Choose a product or service recently launched in either your own organization or an organization closely related to your experience. Recall the process by which the new product or service was introduced. (For those with limited product development experience, look at media reviews for a new product.)

(a) How well does this process align with the framework methodology discussed in this chapter? How does it differ?

(b) What is the level of overlap between the various stages of design (level of concurrent engineering)?

(c) Identify real or potential failures of the product/service and try to attribute the cause of this failure to a product development stage. Then, identify the extent to which a DfSS approach may have reduced or eliminated such failures.

2 Go to a nearby college or university and observe the various customers using "Backpacks." Note the different types of backpacks in use, and the classes or segments of customers using them, and the uses to which backpacks are put.

(a) Identify the product features involved in a typical backpack.

(b) Roughly segment the backpack types and also the customer base.

(c) What are the needs associated with each customer base in addition to the typical "basic" backpack? Which features delight and which annoy? Brainstorm and rank your own list. Identify new features that may overcome weaknesses for each customer type.

3 Consider the process of cooking a formal meal, such as for a party.

(a) How robust is this process? Recall experiences of unreliable delivery of a meal and determine the cause of failure.

(b) How much of the problem is due to human error and what fail-safe devices could be introduced to prevent this? What fail-safe devices are already in use?

(c) If you were completely redesigning the process, what changes would you implement to make the process more robust?