Implementing Design for Manufacturability in a Large Company

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Abstract

Design for Manufacturability (DFM) methods have been understood for more than a decade. Still, few large companies have been able to exploit the power of DFM for long-term advantage. The authors share lessons they have learned over the past decade from implementing technical and social components of DFM in General Motors.

Introduction

Today, large companies operate in a global economy, in an environment of diverse languages, cultures and laws. A global company may have several engineering organizations, each operating in a different country. Strategic alliances and supply chains often span international borders. Some large companies operate in only one country, but this situation is the exception, not the norm.

Large companies typically have concurrent product developments in various states of completion, and some of them may be joint programs by two or more engineering organizations. These companies are usually organized in functional compartments, which hinders cross-functional communication and drives duplication. Functional managers are routinely groomed for promotion, which can cause frequent leadership turnover in functional organizations. To preserve continuity and consistency, large organizations often develop formal "business processes." The environment in a large company can be perilous for leaders wanting to implement a major change, and rapid change is seldom possible.

The theme of this paper is implementing DFM in an organizational setting that exhibits the aforementioned attributes. The authors assume that readers are familiar with DFM methods and the benefits of using them.

Alternate Perspectives

In the late 1980s, a popular topic of research and professional conferences was "Socio-Technical Systems Theory." The main premise of Socio-Technical Systems Theory is that every manufacturing system can be viewed from two distinct but related points of view: social and technical. The technical viewpoint emphasizes structures, processes, skills and tools. The social viewpoint emphasizes expectations, motivation, relationships and behaviors.

Some people naturally gravitate to one side of this issue or the other. The third dimension of the Myers Briggs Type Indicator, "thinker-feeler," captures this preference. "Thinkers" prefer the technical view, while "feelers" prefer the social view. Both views are valid because they identify issues that must be resolved for any system (such as product engineering) to be effective. Consequently, this paper is organized in two major sections. The first section deals primarily with the technical issues, explaining lessons and principles from the viewpoint of a "thinking" manager. The second section deals with the social issues, offering lessons from the viewpoint of a "feeling" observer. The authors are not psychologists; they are simply reporting observations regarding the effect of human nature on implementing DFM.

Section 1: A Manager's Technical Perspective on Implementing DFM

Motivation for DFM

DFM offers strategic benefits, but very few companies have been able to capture them in a sustained manner. Examples abound of products that achieved big gains in quality and cost through DFM methods. Many examples suggest that DFM stimulates creativity. Examples of applying DFM to successive generations of a product suggest that benefits are reliable and not exhausted during the first or second DFM process. If the use of DFM is so beneficial, why have companies been unable to exploit it for strategic advantage?

The answer lies in the pervasive changes that must be made to. A company must acquire skills, implement organizational changes and reengineer business processes. Perhaps, the most difficult change is creating expectations in design, engineering and manufacturing employees that DFM is normal and necessary to achieve superior product designs.

Peter Dewhurst once said, "Most problems with products are not within the components themselves. They occur at the interfaces between components[1]." For the record, the authors state that in their experience, *organizational interfaces cause more design problems than interfaces between components*. Engineers may unintentionally embed problems in their designs, because they did not consult with stakeholders from other functional organizations. Latent design problems that lie undiscovered until late in the design cycle can compromise timely market introduction, engineering cost and product cost. Opportunities lost through a communication deficit may never be known.

The authors want to emphasize that DFM is not and should not become an end in itself. DFM is a means to an end, and the desired end is product design capability. DFM in its simplest form is an engineering practice, similar to other practices already in use. When any practice is mandated, satisfying the mandate can become an end. If DFM were an end, then getting a check in the appropriate box would satisfy the mandate, but not necessarily the design goals. Mandates can backfire.

The authors believe that DFM is the most important means for people in different functional organizations to apply their collective knowledge to designing products. DFM energizes collaboration across functional organizations in four respects:

1. DFM empowers input to design engineering from other functional organizations
2. DFM collects diverse knowledge, which offers more design alternatives
3. DFM helps to identify and avoid problems downstream in manufacturing or customer use of the product
4. DFM mitigates problems with hand-offs between organizations

Principle 1: Integrate DFM into the Product Development Process

A large company should have a formal, documented process for designing and developing products. Any company without such a process should fill this void first. Integrating DFM in the product development process may require serious thought by knowledgeable people. The fruits of their labor should be documented so employees can learn what they will be expected to do.

There are four major tasks in DFM practice, which should be integrated into the product development process. They are:

1. Planning
2. Workshops, also known as Concept Development
3. Follow-up to workshops, also known as Concept Validation
4. Tracking and Measurement

Planning

In the Planning task, managers identify and schedule workshops to fit within the product development schedule. They specify major design goals, product content to be redesigned using DFM, workshop timing, and people assignments. Even if managers do not schedule a workshop for specific component interfaces, a product engineer can request a workshop if he/she thinks it would be beneficial.

The first step in planning is defining major design goals. Design for Assembly (DFA) automatically uses assembly labor, investment and part cost as design goals. But, a DFM workshop offers the opportunity to consider lead-time, quality, serviceability, environmental impact or a variety of other goals. Once design goals are established, each must be measured so the organization will know how successful it has been. A “DFM analysis” provides an early estimate of these measures.

The second step in planning is defining product content to be redesigned using DFM. Many products are so complex that redesigning every component is not practical. The best candidates for a DFM workshop include new parts, parts with high warranty costs, and parts that fare badly in benchmarking analyses.

The final two steps in planning are timing of workshops and assigning responsibility. The plan must consider program timing, and the workload of product engineers and DFM engineers. Once plans are complete, they are documented and distributed. This documentation will be invaluable for tracking performance to plan and measuring the benefits that accrue from applying DFM.

Workshops (Concept Development)

Substantial preparation precedes each workshop. The product development team leader organizes and hosts the workshop with support from the DFM engineer. A room must be reserved, and participants must be invited. The DFM engineer must gather data and complete an initial analysis. Properties to be used in the workshop must be collected. Preparation is crucial to successful execution of a workshop.

Follow-up (Concept Validation)

Following DFM workshops the product development team begins detailed design of the product. As this work progresses, the team may find it necessary to modify or refine the design because of newly identified opportunities or incorrect assumptions from the original workshop. The DFM engineer revises the DFM analysis and tracks changes.

Tracking and Measurement

The documented plans are used to verify whether all planned workshops have been completed. As the design progresses, some product development teams may have difficulty creating detailed designs consistent with workshop recommendations. The team periodically assesses risk, and when risk exceeds acceptable levels, managers execute contingency plans to ensure timely product introduction. Product engineers may execute follow-up workshops to formulate alternate designs.

When the design is completed, formal measures can be calculated and compared to design goals. These are described as "results measures" because they focus on the outcome, not the process. They document the improvement achieved from the old or initial design to the final design. Tangible improvements can be converted to financial measures, which can be totaled across the product or product family. In this manner, the benefits to the organization can be estimated and compared to the cost of DFM. This evidence will be invaluable in convincing top managers to allocate budget and maintain the DFM organization.

The DFM group must take care not to claim credit for great results. The engineering organization must perceive that the DFM group acts as a catalyst to make these improvements possible. Credit for achieving the design goals rests with the product development teams that carry the burden of responsibility for the design. Positioning DFM in this way will encourage cooperation and diffuse potential resentment toward the DFM group for accepting credit for results that belong to the entire team.

Principle 2: Integrate DFM into the Engineering Organization

The first question to address is why DFM support fits better in Engineering. The authors are aware of examples where the industrial or manufacturing engineering organizations provided DFM support. The authors are also aware of instances where DFM support was abruptly discontinued by these organizations.

A DFM support organization will be more stable if placed in Engineering. Engineering is responsible for product design, so Engineering should be more motivated to support DFM. DFM practice may address design goals outside Manufacturing. Manufacturing has a stake in the design because they must build the product, and consequently, they should be motivated to provide expert knowledge. However, Manufacturing has little incentive to coordinate the planning, facilitate workshops, perform analysis, track the design process and measure results, which are essential for ongoing support of DFM.

The company accomplishes DFM through dedicated people, appropriate tools and common practices. The dedicated people providing DFM services (DFM engineers) are specialists with facilitation and analytical skills as well as knowledge of the engineering disciplines they support. They use DFM tools frequently and apply them using a common process to ensure consistent application. Common processes also enable use of best practices as well as mobility of DFM engineers among engineering organizations.

Product development teams are responsible and accountable for product design. DFM engineers support these teams by providing DFM expertise, facilitating workshops and performing analyses.

DFM groups can utilize generic DFM tools such as Design for Assembly software, but generic tools may not be available for all important design goals. For example, GM uses proprietary DFM tools for body sheet metal and collision repair. Companies can develop proprietary DFM tools that are specific to their own needs and goals.

Evolution of DFM Practice in GM

General Motors experimented with design for assembly starting in 1983, but did not use it on a vehicle program until 1989. In 1990 GM established a corporate DFM Knowledge Center with the mission to implement DFM across GM.

Company leaders believed that product engineers could learn to use DFM tools, and that long-term support from a center of expertise would be unnecessary. The initial focus of the DFM Knowledge Center was teaching DFM software and assisting product development teams that were not yet self-sufficient. Managers chose this approach because they thought of DFM as a collection of analytical tools for product designers.

Ten years later, GM's perspective has changed. Managers acknowledge that direct use of DFM tools is ineffective for engineers. In today's economy, software is updated more frequently than vehicle designs. GM has found it more effective for DFM engineers to support overburdened product teams than to expect product engineers to perform DFM analyses themselves. The underlying belief that drives this approach is that DFM is a means for integrating the profound knowledge from various functional organizations. The analytical tools have become less important than power of integrating collective knowledge.

Intramural Communication

If a company has more than one engineering organization, each with its own DFM support, then some means of intramural communication would benefit the company. The usual term for such a group is *"community of practice."* The purpose of a community of DFM practice is to foster common methods, nurture relationships among practitioners, promote DFM engineering as desirable in a career path, share knowledge, and regulate qualifications for DFM engineers. Being common offers a plethora of advantages such as cost savings, workforce competence, career mobility and positive motivation.

GM's DFM Strategy Team maintains a strategic focus on DFM in the company whereas the DFA User Group and the DFM Sheet Metal User Group focus on tactical issues relating to the application of DFM practices in specific functional areas. Together with the corporate DFM Knowledge Center, these communities of practice unify GM's approach to DFM for Car, Truck, Powertrain and Body Engineering in North America, Europe, Latin America and the Asia.

Section 2: The Human/Social Perspective on Implementing DFM

Expectations, culture and attitude exert an enormous influence on organizational capability. For example, in the 1980s product engineers believed that they had adequate knowledge of manufacturing, although few of them had actually worked in a plant. The prevailing attitude was that Engineering designs the product, and Manufacturing builds it, regardless how difficult that may be. We now understand that this attitude is ineffective.

When confronted with the possibility that collaborating with manufacturing engineers, factory tradesmen and assembly operators could improve product designs, product engineers sometimes reacted negatively. Some avoided collaboration because they believed that they were already incorporating process knowledge in their designs.

Put this emotional backdrop into the perspective that DFM meant applying analytical tools such as DFM/A software, and there was no reason for them to believe collaboration to be either necessary or desirable. Many engineers believed they could do the analysis at their desk. Perhaps, the most difficult challenge associated with implementing DFM has been changing deeply held beliefs and replacing them with enthusiasm for collaboration. Emotional baggage can make the job of a DFM engineer more difficult.

A DFM engineer must be proficient with DFM tools, DFM methods and workshop facilitation in addition to speaking the jargon of product engineers. The DFM engineer must be sensitive to organizational issues as well as cultural issues and must be a good listener. These skills are necessary to command the respect needed to be an effective leader. Perhaps, the most important qualification for a DFM engineer is the ability to guide a team toward discovering a solution rather than solving the problem for them. A DFM engineer should function in a workshop as a facilitator and mediator, controlling the meeting and mediating disputes. Becoming involved in solving design problems in a workshop can render the DFM engineer ineffective in this important role because it may compromise ownership by the team.

What’s in it for ME?

Over time, many engineers have been victimized by well-meaning peers or managers who appear to offer help but have their own agenda. After being burned once or twice, most engineers tend to be cautious about offers of help. A skeptical product engineer may respond to an offer of DFM help with a question such as “what’s in it for me?”

The DFM organization, and DFM engineers in particular, must be prepared to answer such questions with a compelling explanation. During the period of time when attitudes and expectations must be reshaped to gain acceptance, the DFM engineer must function as an agent of organizational and behavioral change.

A DFM engineer can demonstrate value to the product development team by sharing the burden caused by applying DFM. A DFM engineer can:

- Collect data
- Perform DFM analysis
- Contact participants
- Send out meeting notices.
- Collect properties to be used in the workshop
- Facilitate workshops
- Collect documentation
- Publish reports and
- Track the results

This pattern of behavior helps to earn respect and generate repeat business for the DFM organization and the DFM engineer.

Ownership

Ownership is an emotionally held belief that connects an idea, such as a proposed design innovation, to one's self-image. Since self-image is so important to everyone, ownership provides powerful motivation to implement and prove the worthiness of an innovation. We may exhibit less effort to implement someone else's innovation because our self-image will not be damaged by failure. Ownership links implementation to ego.

This fundamental notion is applicable to DFM engineers. A product engineer who owns a design may be reluctant to accept ownership of someone else's solution. To accept ownership, a product engineer must understand an idea and believe that it can work. When leading a workshop to develop ideas, the entire team generates understanding and ownership, which fosters commitment to implementation. The DFM engineer supports the product engineer but makes it unmistakably clear that the product engineer and the team are fully responsible for the design.

A product engineer may want to influence a team's thinking due to a hidden agenda, and interference by a DFM engineer could lead to resentment. Although hidden agendas are frequently counterproductive, the human dynamics caused by a DFM engineer's interference can damage working relationships and make DFM practices less effective. The DFM Engineer's duty is to diffuse hidden agendas, expand the team's view, and consider more possibilities during brainstorming. Risk to relationships must be considered when confronting such situations.

Communities of Practice

Each GM community of DFM practice is composed of peers representing most (GM is striving for "all") of the engineering organizations in global GM. Because of their diversity, establishing relationships among members can be challenging. Our experience suggests that face-to-face meetings are essential to quickly establish relationships within a team. After the relationships have been established, communication through conference calls, web-based meeting techniques or teleconferencing become viable alternatives to time consuming and expensive travel.

Members of the DFM Strategy team are mid-level managers who are responsible for the DFM support groups in each engineering organization. The duties of this team includes:

- Changing attitudes regarding relationships across organizational boundaries (converting "not invented here" attitudes to "let's help each other")
- Aligning the priorities of their groups (with each other and with corporate objectives)
- Approving common tools and practices recommended by User groups
- Overseeing the DFM engineer certification process

Members of the User Groups are practicing DFM engineers. The duties of these teams include:

- Identifying, evaluating, negotiating and recommending common tools and methods to the Strategy Team for approval
- Assisting each other with insight, information and temporary assignments in each others' organizations
- Assisting each other to adapt common practices in local environments
- Learning from each other's experiences
- Networking to exchange views, explore opportunities and resolve differences

Beyond the stated duties, communities of practice help establish and nurture relationships among managers and practitioners. The networked environment makes DFM engineering desirable in a career path, which is important because finding qualified candidates for these positions can be difficult.

Global Integration

In the automobile industry, global integration has become necessary for long term survival. This industry is experiencing consolidation in which local companies are being acquired to utilize the strengths and expand economies of scale. The objectives of global communities of practice include sharing knowledge and achieving practical commonality without compromising independence. DFM can be a means to strengthen engineering organizations within the family.

Common methods and tools are important enablers for applying DFM practices across a decentralized company. Although language may be a barrier, use of common tools can help bridge this barrier. Methods and tools can encourage common thought patterns that simplify inter-organizational communication, which in turn enable sharing of innovative solutions to common engineering problems.

Decentralized engineering organizations introduce variation to engineering practices, and this variation can be a barrier to joint programs (product developments with two or more engineering organizations participating). Engineering organizations separated by international borders, large travel distances and diverse cultures experience variation in:

- Engineering processes (they do things differently)
- Organizational structure (job titles and duties do not correspond)
- Managerial enthusiasm (do DFM practices fit with engineering processes?)
- Culture that drives behavioral patterns for all employees

Cultural Norms influence behaviors in a variety of ways. Acceptable patterns of communication may affect understanding and knowledge transfer across organizations. Language can represent a major barrier to effective understanding, and body language can be misinterpreted. Personal relationships are essential in some cultures, while less important in others. Asian culture may drive teams to behave in ways that Americans do not understand, but Asian auto companies are living proof of how effective their team performance can be.

With this backdrop, how can we gain advantage through common DFM practices on a global scale? GM delegates the task of defining robust common practices to the User Groups. Where practices cannot be duplicated, the User Group can help each member's organization adapt the common practices to the local environment. Temporary assignments of DFM engineers from one group to another can improve communication. By delegating to the user groups, practitioners assume ownership of common practices and become committed to making them work effectively.

Conclusions

Attempting to implement DFM in a large, global company may seem impossibly difficult. However, GM's experience suggests that implementation is possible, and that the benefits make the journey worthwhile.

To successfully implement DFM, companies may need to initiate structural and organizational changes. Accomplishing such changes requires leadership, commitment and a reliable change management process.

Perhaps, even more difficult than the structural and organizational changes are the necessary changes in expectations, attitudes and behaviors that can make or break the implementation. Leaders must somehow address the soft skills and mental models that can cripple a change process before it has a chance to succeed.

In this paper, the authors have offered a glimpse of DFM in one company, General Motors. GM's model has not been static, but rather, has changed over time. The journey to implement DFM is not and may never be complete in GM. Further, what works for GM may not work for other companies. Leaders of large companies must develop their own vision and plan their own transformation based on their own culture, organization and business.

REFERENCES

1. Dewhurst, Peter, Industry Week, September 4, 1989