From Manufacturing to Design – and Back Again

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Until recently, manufacturers generally assumed that design should precede manufacturing in priority and prestige as well as in time. Today, however, there is growing recognition that design and manufacturing really are interdependent activities that work best when they maintain a continuous exchange of knowledge and insight. Companies in a wide array of industries are discovering that when manufacturing managers, engineers, and workers collaborate actively with designers, they can greatly improve the quality and reliability of products, reduce time to market, and provide greater customer satisfaction.

Substantial as these developments have been, they do not go nearly far enough. In this article, we argue that manufacturing has a great deal more to contribute to product development than is currently recognized. Besides improving the design of established products, manufacturing has the potential to affect the parameters of future product design and thus to enable – rather than constrain – new product development. To tap that potential, managers must reverse traditional notions about linear flows and place manufacturing (especially manufacturing capability) before product development.

Getting It Right

A number of leading-edge manufacturers have been giving their manufacturing capabilities considerable prominence with excellent results. We believe the following examples represent an emerging trend:

• **Honda** is recognized as a leader in both automotive technology and manufacturing equipment design. Honda's dual thrusts are not coincidental: years before it gained prominence in the auto industry, the company realized that it had to leverage as much competitive advantage as it could out of its manufacturing facilities and its engineering talent. The company made explicit efforts to foreshorten the familiar „S" curve of the product life cycle. Rather than wait until it had achieved volume production of a given motorcycle (later, car) to improve the efficiency of its manufacturing processes, Honda pushed for simultaneous introduction of new products and new ways to manufacture them. Its goal, though simple, was nonetheless ambitious: to beat competitors two ways – by bringing more technically advanced products to market sooner and by introducing manufacturing processes that could not be easily copied.

• **Boeing** and **Airbus** take justifiable pride in their capacity to design commercial aircraft. Both companies have made enormous investments in understanding how to design, fabricate, and assemble aircraft out of aluminum and other lightweight metals. Over the past decade, however, both firms have also come to recognize that nontraditional materials (e.g., graphite composites and thermoplastics) and nontraditional processes (such as automated lamination) are likely to prove essential to the development of new generations of aircraft. In other words, dramatic changes in materials and processes hold the promise for substantial expansion in the range of product „possibilities" – but only if some person or group in the organization is capable of recognizing the promise and translating it into product possibilities. In Boeing, Manufacturing has been among the most vocal and consistent advocates of new materials and processes.

• **Telco,** a truck manufacturer, invested heavily in achieving an intimate understanding of its own processes, as well as in capabilities for designing its own machines and press tools and in laser-cutting and CNC-machining technology. The knowledge of manufacturing processes that Telco acquired and the flexible production capability it created enabled the company's designers to expand its range of products very rapidly from medium trucks to heavy vehicles to pickup trucks and sports utility vehicles – all produced in the same factory! (For the complete Telco story, see *Prism,* first quarter, 1992.)

• **Sony's** successful strategy of rapid, incremental evolution in products and product families (such as the Walkman and Discman series) rests heavily on a discipline of continuous design-for-manufacturability (DFM). DFM teams carry on a dialogue that spans initial design, upgrades, and renewals of the original product. The benefits of that dialogue – and the organization that sustains them – are evident not only in the continuous improvement of the products, but in the rapid transfer of insight from one domain to another. For example, advances in miniaturization came about through an active collaboration between designers and manufacturing engineers, with the latter taking the lead nearly as often as the former. In other words, when harnessed together by a strategy of rapid, incremental evolution, Sony's design and manufacturing organizations have increased both the scope of product offerings and the efficiency with which those products are produced.

• Finally, there is the case of a large, decentralized electronics company, composed of a number of small, autonomous, product-based divisions, that prided itself on its market leadership in product technology. Although the company was aggressively advancing new product technology, it took a more cautious approach to the development of process technology. Indeed, it limited development of manufacturing technology to purchases of „off-the-shelf" equipment. Worse: new production equipment had to be approved and paid for by the product development organization, a practice that ensured slow, incremental change in process technology.

Manufacturing engineers seemed to have little option but to maintain existing equipment, to concentrate on routine „firefighting," and to hope that when a new generation of products moved into stable production they could begin to experiment with newer and more efficient process technologies. One process engineer summed up the sentiments of his colleagues: „Most of our manufacturing innovation has gone into making their designs manufacturable."

However, in the mid-1980s, manufacturing engineers in several divisions of the company began to hear exciting news about a new approach to printed circuit board assembly – a technique called surface mount technology (SMT). SMT techniques promised to give a dramatic boost to miniaturization (by more than doubling the number of components that could be placed on a given circuit board) and to achieve substantial increases in the quality and productivity of circuit board assembly.

Despite their excitement, the manufacturing engineers had a difficult time convincing their counterparts in Product Design that the new technology was worth the effort or the expense. Although the design engineers relished the idea of dramatic reductions in board size and increases in board functionality, many were skeptical about the capabilities of the technology – and they were nervous about the risks involved in incorporating a new process before its economic benefits had been demonstrated clearly and unequivocally. Moreover, product designers and their managers were frankly suspicious about the technical capabilities of the SMT proponents in manufacturing. Besides the skepticism of product developers, the SMT proponents faced accounting rules that understated the potential cost savings associated with the new process and budgeting procedures that forced individual product lines to shoulder the costs of equipment that would serve many other present and future products.

Nonetheless, after a long period of experimentation (which included the surreptitious replacement of SMT boards for conventional ones in several products), a coalition of manufacturing engineers and manufacturing managers – spanning several divisions – mobilized a successful campaign to gain corporate acceptance of SMT. Executives in several key divisions were persuaded to take the plunge with the new process technology. Their investments paid off handsomely. Several product lines captured market share through the introduction of smaller and more powerful SMT-based versions. And the payoffs multiplied as designers in those divisions began to embrace SMT and to develop unprecedented applications of the technology. In this case, a breakthrough in manufacturing technology had two significant impacts: it opened the doors for new product designs, and it stimulated a broad reevaluation of the contributions of manufacturing knowledge to organizational competitiveness. But, as this story also illustrates, breakthroughs of this kind are often blocked by organizational and cultural barriers.

Rethinking Design and Manufacturing

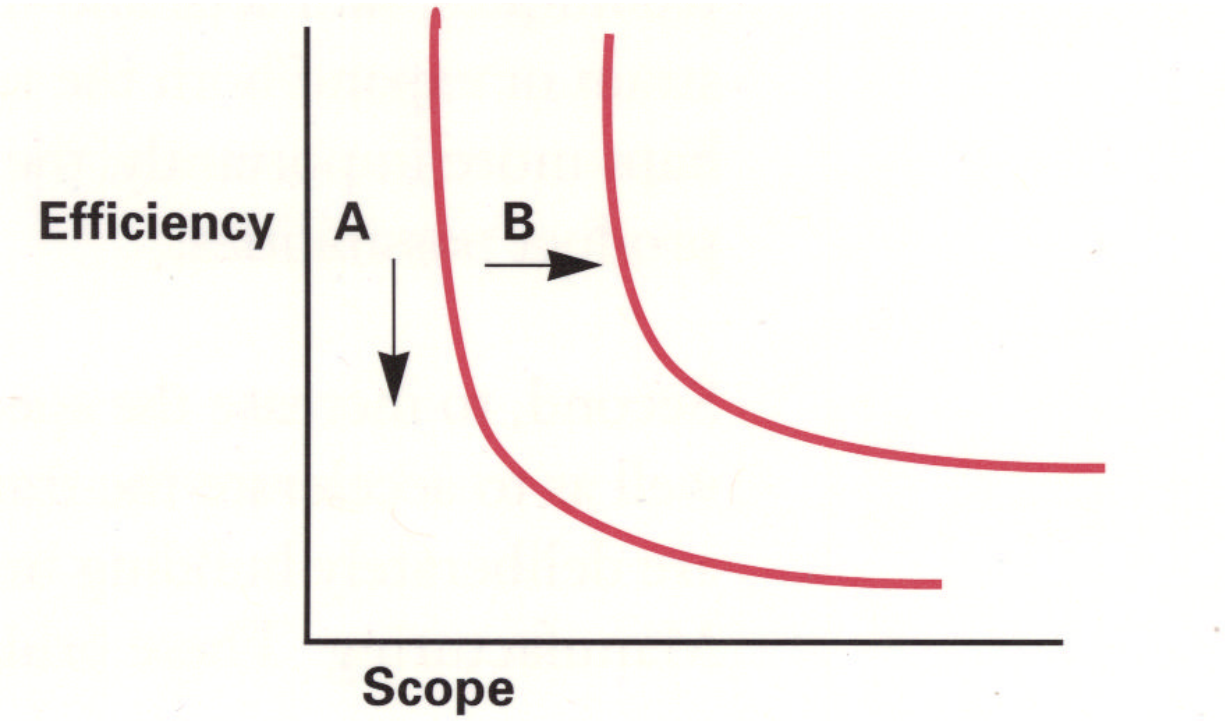
The examples sketched above share three common underlying themes. First, to break out of a self-limiting cycle, these firms have chosen to search out materials and manufacturing processes that can expand the range of product possibilities. In other words, there is a growing recognition that although Design and Manufacturing are distinctly different functions, they have a tendency to shape each other over time. The design of a product may precede its manufacture, but over time investments in manufacturing equipment, techniques, skill sets, and organization can either constrain or expand both the range of products and, perhaps more importantly, the way designers think about product possibilities.

Second, to increase the speed of product evolution, as well as to accelerate the transfer of knowledge, firms are deliberately building bridges between Design and Manufacturing. These bridges – like the continuous DFM teams in Sony or the less-formal but still successful „insurgent" manufacturing coalition in the decentralized electronics company – span time (e.g., simultaneous product and process design), they span space (e.g., collocation of product and process engineers), and they span structure (e.g., cross-functional teams with common budgets, objectives, and reporting lines). For instance, program managers are now responsible for bringing different types of functional expertise to bear on common objectives. Efforts at DFM and concurrent engineering are ensuring that product and process engineers not only report to the same management, but also gain a much more intimate understanding of one another's jobs. These are deliberate attempts to eliminate the temporal, spatial, structural, and even the intellectual and political gaps between Design and Manufacturing.

Third, these firms are – whether boldly or cautiously – challenging the notion that there is an inevitable tradeoff between efficiency and scope in manufacturing. That is, conventional thinking suggests that as firms seek to expand the scope of products they produce with a given manufacturing base, they have a tendency to slide down the efficiency curve (Curve „A" in Exhibit 1). Companies like Honda, Telco, Hewlett-Packard, and Motorola are testing that conventional thinking by investing in advanced manufacturing technology and deeper manufacturing skills in an effort to push the entire curve (Curve „B" in Exhibit 1) to the right – thus sustaining efficiencies of scale while broadening the scope of production capabilities.

Exhibit 1

Sustaining Efficiency While Expanding Scope



Clearly, these firms are saying in practice, if not in words, that manufacturing has a great deal to contribute to product development, not only in improving present performance but in expanding and enhancing options for the future. However, these efforts alone cannot ensure that manufacturing knowledge will be fully exploited as a source of long-term competitiveness. Extraordinary measures may sometimes be needed. To that end, companies need to take a closer look at issues of knowledge, power, and value.

Knowledge. Efforts to codify and incorporate manufacturing knowledge into design rules for product development are core features of DFM. They recognize that the knowledge residing in the manufacturing organization ought to „flow back" and help developers design manufacturable products. However, it is crucial to consider what kind of knowledge is being transferred. If, for example, the manufacturing knowledge flowing back into the design activity is historical knowledge – i.e., knowledge derived solely from past practice – then it may very well constrain the range of possible products the design organization develops. As long as the manufacturing knowledge being communicated is bounded by past investments in plant and equipment, by established procedures and routines, and by institutionalized assumptions about the capabilities of the production organization, the benefits of structural change will be limited at best. Designs may become more manufacturable, but the range of possible products will still be constrained by current manufacturing capabilities.

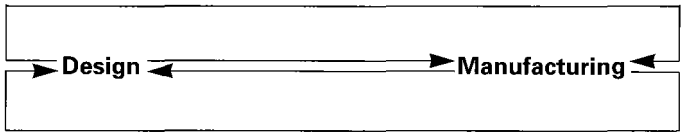
One way to loosen the constraints imposed by Manufacturing on the range of possible products is by investing in future manufacturing capabilities. That is, most firms are well aware that their capacity to deliver new products to market is constrained by their ability to make – or at least to prototype – those products. So, they invest in manufacturing capabilities that Design and Marketing identify as important. But a few managers question whether their manufacturing capabilities don't also constrain the range of products they could make in the medium or long-term future.

We contend that it is essential to look upon manufacturing as an activity and an organization that can not only respond to the demands of new products but also stimulate product innovation and change (Exhibit 2).

In this respect, assembled goods industries could benefit by emulating continuous process industries, such as petrochemicals. Here the process and the product are so closely intertwined that they are virtually indistinguishable; investments in understanding and improving the process routinely expand the range of product possibilities. Thus, for example, by devoting focused attention to their core manufacturing processes, firms as diverse as Alcoa, Allegheny-Ludlum, Dow Chemical, and Kyocera have built strong reputations in product innovation and development. Organizations in assembled goods industries can obtain similar results by dedicating themselves to achieving an equally intimate understanding of their own processes.

Exhibit 2

From Design to Manufacturing and Back Again



Power and Value. This brings us to the influence of Manufacturing on organizational decision-making and the perceived value of manufacturing knowledge as a resource in the conduct of design. A manufacturing organization may contain tremendously valuable knowledge, but if it cannot affect the design activity, the value of that knowledge is greatly diminished. In order for knowledge to add value, its value has to be recognized and used. In order to be recognized and used, that knowledge must be backed by power – which Manufacturing often lacks.

Unfortunately, it is painfully evident from our research on change in manufacturing organizations – as well as the authors' direct involvement in change-oriented programs at the Massachusetts Institute of Technology and at large manufacturing companies – that the obstacles to fully empowering Manufacturing are many and complex. It is important to recognize that the value attached to knowledge about manufacturing correlates with the power of Manufacturing as a function. For example, in our earlier discussion of the electronics company introducing SMT, both the entrenched skepticism of product designers and the tremendous difficulty manufacturing engineers had in acquiring funds reflected the relative lack of prestige of the Manufacturing function. In fact, the coalition of manufacturing managers and engineers was as much an effort to gain access to influence – to attach clout to their knowledge – as it was to advertise the benefits of SMT.

Far too often, the knowledge held by people in Manufacturing is perceived as not just different in kind but inferior in value to the knowledge held elsewhere in the organization. This is to a considerable extent reflected in differences in status, pay, and promotional opportunities between product engineers and manufacturing engineers. Clearly, there is a need to demonstrate that the different kinds of knowledge that reside in Design and Manufacturing are equally valuable to the long-term competitiveness of the manufacturing firm.

The Leadership Challenge

The fundamental leadership challenge will be to achieve not simply a new balance of emphasis or power between Design and Manufacturing, but a new relationship. In this respect, it will be critical to recognize and reward what is distinctive about Design and Manufacturing – or product and process, respectively – while at the same time finding newer, more creative, and more powerful ways to bridge the distance between them.

The new relationship between Design and Manufacturing is founded on three basic changes:

• The involvement of manufacturing technicians in the product development process and the involvement of product designers in the development of new manufacturing processes

• The recognition by both Design and Manufacturing groups that each must apply its knowledge to improving current products and to increasing the degree of freedom each can provide to the other for the future

• The recognition that while each party is both expected and enabled to develop its own unique excellence (through the creation of separate divisions for product development and manufacturing technology development), the fates of these potentially competing centers are bound together at the bottom by cross-functional teams and at the top by the strategy of the firm

The idea that design must precede manufacture is not „wrong" by any means, and it certainly does fit with prevailing Western notions of time as a linear and directional flow. But as we have tried to show, it can also be an extremely restrictive idea. It can blind us to the possibility that investments in manufacturing capabilities may expand the array of future products. Moreover, it can limit manufacturing to short-term and reactive adjustments in existing processes – thus reducing the likelihood that people in manufacturing will recognize, much less generate, innovations that provide real competitive advantage. In this sense, it can channel even the most dedicated efforts at continuous improvement into narrow refinements of existing processes – at the expense of discovering new ones.

To extract from the manufacturing function knowledge that can serve future competitive purposes – including the expansion of new product „possibilities" – it is essential to recognize what is distinctive about manufacturing knowledge, capture it, and convert it to something that is usable without sacrificing the very thing or things that make it distinctive. In other words, if we consider knowledge about product different from knowledge about

process, and if we attach value to both types of knowledge, then we must recognize and value the difference.

However, even as we argue for greater attention to manufacturing and the potential contributions of manufacturing knowledge, we also recognize the challenge of balancing Manufacturing and Design. That is why throughout this article we have tried to caution against a simple about-face in the ordering of Design and Manufacturing. Earlier we suggested that assembled goods industries emulate continuous process industries by increasing their commitment to process innovation; here, we caution that firms in continuous process industries have found that an overzealous focus on process can curb new product development. The goal, therefore, must be to enlarge knowledge in both Design and Manufacturing – recognizing that each expands through its interaction with the other.

Next Steps

Clearly, we believe manufacturing – and process innovation more generally – to hold the potential for tremendous contributions to enterprise competitiveness. The biggest and as yet untapped benefits of process innovation are to be had in the domain of product development. However, a great deal more needs to be done to render these ideas practical.

To that end, we offer a set of questions for senior executives to ponder as they think about the future relationship between Design and Manufacturing in their own organizations. Most broadly, executives should consider the interplay between their product and their process strategies. They should ask:

1. How do our existing manufacturing capabilities limit or constrain product design? What portion of these constraints is truly unchangeable and what portion is bureaucratic, procedural, cultural, and/or political?

2. Will our next-generation (or generation-after-next) products require radically new materials or processes? If so, what are we doing now to prepare our manufacturing organization to incorporate those new materials or procedures?

3. How much do our product designers actually understand about the manufacturing process, its capabilities, its leading-edge practices, and next-generation materials and processes?

4. How much of the reluctance to experiment with (or even to become familiar with) manufacturing and process technology is driven by real (as opposed to assumed) assessments of costs and benefits? By product strategies that ignore the potential for process-based product innovation? By history, politics, and culture?

5. Do our accounting practices unduly limit or misdirect investments in process knowledge and innovation? What might be more instructive or revealing measures of return on investment in process knowledge?

6. Do our staffing, compensation, and career development practices contribute to an undervaluation of process knowledge?

7. What exactly are the unwritten rules of product design?

Uncovering the answers to these questions can be an important step toward realizing the potential benefits of truly integrated and collaborative Design and Manufacturing.

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