Competitive Advantage Through Design

Rajendra S. Sisodia

Whether by intention or by default, design is always a strategic activity.
Robert Potts
Design Director, Ciba-Corning

At a time when almost every business practice is undergoing a thorough reengineering process, many companies are discovering the value of going back to basics in one crucial area: design. Management, preoccupied during much of the 1980s with a set of concerns that were far removed from creating value for customers, is rediscovering the power of that fundamental building block of all commercial success: the interaction between a customer and a product, tangible or intangible. The quality of that interaction is overwhelmingly driven by two things: product and process design.

As with most rediscoveries, however, this is a back-to-basics movement with an important twist. Design previously meant merely function and aesthetics; today, it is a highly complex, multifaceted function. When fully understood and applied, the new principles of design can lead to exciting results:

- Empirical studies have shown that an additional dollar spent at the design stage leads to an average of $47 dollars in incremental profits downstream.
- According to the Industrial Designers Society of America (IDSA), the average company realizes sales of $2,500 for every dollar spent on design. For companies with revenues over $1 billion, the average rises to $4,000.
- Over 80% of a product's production costs are locked in at the design stage, even though only a tiny fraction of that is actually spent on design. After many companies spent enormous amounts of money during the 1980s automating factories to reduce costs and improve quality, it has become painfully clear that no amount of factory automation can compensate for poor product design. According to estimates by Dataquest Inc., a product change that costs just $1,000 at the design stage can cost up to $10 million during the final production stage.

In spite of these impressive numbers, the clear fact is that the majority of companies do a very poor job of harnessing the true power of design. For instance, some companies have proven adept at designing for manufacture and assembly, but they have created products that are dull and unresponsive. Others have learned the value of incorporating intelligence into their products, but in the process have designed complex products that are nearly impossible to produce efficiently and with high quality.

THE EMERGING DESIGN REALTIES

To a significant extent, the new design realities are being propelled by advances in information technology, which have completely

The strategic value of design is now being recognized by increasing numbers of companies. The author maintains that enormous benefits can be gained from taking a comprehensive, integrated, and strategic approach to the design function.

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altered the process of designing; software packages from companies such as Silicon Graphics and Alias are capable of speedily rendering images of products that are virtually indistinguishable from photographs. Such photorealistic images of nonexistent products go a long way in facilitating communication between designers, marketers, and engineers. Without such communication, concurrent engineering—a clear necessity for any manufacturing today—would be impossible.

With 3-D graphics, companies are able to involve more people in the design process, as well as get products to market faster. In the not-too-distant future, technologies such as holography and virtual reality will further blur the line between the tangible and the conceptual. The impact of these developments will be especially crucial in linking the design function to the market.

Information technology has also given designers increased degrees of freedom in shaping product forms. For example, as more and more functions are embedded onto single integrated circuits in products running the gamut from toasters to computers, the need for numerous mechanical controls has declined. Unconstrained by the need for extensive functional controls and freed from many of the trade-offs implicit under the electromechanical paradigm, designers are free to create products with personality, humor, and even a touch of whimsy (for example, Apple Computer, Inc.'s new product due out next year called Newton).

Information technology has allowed creators to infuse products with intelligence and responsiveness. As society moves toward more distributed intelligence, more and more inanimate objects will be thinking machines. This realization must lead designers of even the most mundane products to contemplate the implications of adding intelligence and connectivity to their products.

Design freedom has become crucial at a time when it is very difficult for products to sustain functional differentiation; through reverse engineering, innovations can be rapidly adopted by competitors. Customers, however, increasingly take a holistic view of products: they view them not merely as bundles of attributes, but as a gestalt. Marketplace success is driven by what is now called product integrity, which has two components: internal integrity (whether a product functions well as a system) and external integrity (the fit between customer expectations and actual experience).[1]

Mazda Motor Corp. has touted this design philosophy in its advertising under the label "kansei engineering." Ken-ichi Yamamoto, Mazda's president, has described this design approach as follows:

> "In the past, we could quantify our goals of product development by specifying numbers such as lightness, cost, and engine horsepower. However, today's customers are not satisfied with such numbers any more. They are now talking about certain differences which they can sense while driving, even if they cannot articulate the differences. They say that [a certain] car is different, even if its performance in acceleration and braking is exactly the same as other cars. This is what I call "feeling" or "sensibility."[2]

The same philosophy pervades products far less complex than automobiles.

SUCCESS BY DESIGN

The recognization of these emerging realities is already so strong that it is being predicted that "design (will be) to the '90s what finance was to the '80s and marketing to the '70s: It is the corporate buzzword for the new decade."[3] But design is proving to be far more than a buzzword. The ability of a vibrant design tradition to confer lasting competitive advantage on companies has been demonstrated time and again. A number of companies owe their survival, turnaround, and widespread success to their allegiance to the new design principles.

THE DESIGN STRATEGY BEHIND THE MAZDA MIATA*

In Mazda's original positioning niche for what eventually became the Miata, the company planned to develop a low priced sporty model, one highly differentiated from its base model. In the targeted price range (approximately $14,000), cars such as Toyota Corolla Coupe and the Nissan NX lacked differentiation from base cars; among differentiated cars, such as the Mazda RX-7, Nissan 300 ZX, and Porsche 944, prices were much higher. There was clearly a market gap if Mazda could create—at reasonable costs—a distinctive, appealing car.

Internally, the project was designed as an "offline 55 program," meaning that it was a project that was loosely structured and deemed to have only a slightly better than 50% chance of commercialization. Mazda uses a number of such initiatives, halfway between its "online" projects (e.g., periodic updates of existing models) and basic research (e.g., concept cars). The charge for offline projects is to develop new products to respond to emerging (rather than existing) markets, as well as to pioneer new management and production processes that Mazda might later adopt.

Resource requirements are driven by product complexity and differentiation. Mazda kept the basics of the car very simple, since its differentiation was already determined to be high. This kept resource requirements within reasonable bounds, an important consideration given the Miata's planned pricing strategy. The car was designed to be globally standardized, use a small variety of major components, and was to be sold in only a few combinations of options.

An innovative organizational structure was used during the development phase. The project teams were 45% smaller than usual for Mazda, and their membership was voluntary and exclusive to the project. In another departure from previous practice, team members remained on the project until the car was launched. All members were given less specialized, broader responsibilities. Communication between members was frequent and informal.

The design teams were given an extraordinary degree of freedom to express themselves with the product. (Three teams were working concurrently and independently; one in California and two in Japan.) The California team used unorthodox creative approaches, such as writing brief stories featuring the car they were trying to create. Sharing such stories gave the group a consistent, holistic version of what they were trying to accomplish.

The design process was a lean one, facilitated by the frequent use of computer simulation for testing. Only 60 physical prototypes were built, versus an industry average of 100 (each prototype costs from $300,000 to $600,000); this shaved six months off the developmental lead time. The project also consumed 40% fewer engineering hours than average.

With the runaway success of the Miata—the product as well as the process—all other Mazda projects since have adopted similar approaches. Extensive "clinic" testing, in which customers are brought in to test early prototypes, was stopped after the Miata, illustrating the difficulty of doing market research in a new product environment with long lead times. At Mazda, design teams are given an unusual degree of creative flexibility. The results so far, measured in marketplace success, have been striking.

*Based on a presentation by Tom Matano and Kentaro Nobeoka, "The Visual Material from the Archive of Mazda Miata," made at the Third International Forum on Design Management Research and Education, Harvard Business School, May 1991.

Once again, consider Mazda. Five years ago, Mazda's market position was rapidly eroding. Its entire product line, from the 323 to the 626 to the 929, could be described in two words: dull and unoriginal. The 626 was a poor copy of the Honda Accord and the Toyota Camry. The 929 was a luxury car without distinctiveness—a sure recipe for failure. Its designers clearly were "inspired" by the Acura Legend, though once again the outcome was a yawner.

Then came a remarkable turnaround in the company's fortunes, led by the success of the Mazda Miata MX5 (see "The Design Strategy Behind the Mazda Miata"). The company embraced high-concept design with gusto, and it has since produced a remarkable string of new car introductions: the MPV minivan, innovative new 626 and 929 sedans, and the high-performance RX7. As a result of its success, the company has announced the formation of a new luxury car division, Amati, which will compete head-on with Acura, Lexus, and Infiniti. Ken-ichi Yamamoto has stated the company's new philosophy as a desire to be "number one on a few people's lists, rather than number two or three on many lists." Mazda has been one of the very few automotive success stories of the current recession; since the launch of the Miata, its US market share has risen from 2% to more than 3%.

Other examples can be seen in a variety of industries. A fanatical devotion to quality and design (the two are almost inextricably linked) has catapulted Rubbermaid, Inc. from a low-profile producer in a frankly boring industry to one of the most admired companies in the US. Samsonite Corp. has shot to world leadership in molded luggage through innovative design. Consider just two of its models: its Oyster suitcase is rugged, lightweight, and inexpensive to produce; the Piggyback doubles as a suitcase and a built-in luggage trolley.

The Black & Decker Corp. has made a highly successful foray from the garage to the kitchen and beyond largely through design: after acquiring GE's housewares business, the company redesigned all the products, including the successful Spacemaker line. The result: a full line of premium, hot-selling complementarily designed under-the-cabinet appliances that have restored growth and profitability to a previously lackluster market.

The computer industry provides especially interesting examples of success through design. As the underlying technologies have become widely available and more like commodities, successful companies have used design as the primary way to differentiate themselves. Consider these four examples:

- Apple has been a design leader throughout its short history; the company is rightly renowned for its ability to confer a degree of wit and humor to its products. For example, its newly announced "personal digital assistant," called Newton, incorporates design touches that create the sound of rustling paper when pages are turned; when a user crosses out an entry on the screen, it crumples up and gets "tossed" into a trashcan. The effect comes complete with sound effects and animation.

  Apple's recent successful transition from a low-volume, high-margin strategy to one based on rapid market-share gains was made possible by redesigning all of its products for manufacturability and added value. This allowed the company to cut prices dramatically for machines that were far superior to the ones they replaced.
- Hewlett-Packard Co.'s tremendous success in the laser printer market, followed by success in other peripheral markets, has been made possible by product designs that are simple, easy to manufacture and maintain, and almost breakdown-proof. The company has set a blistering pace for its competitors, consistently improving on its products, which are already market leaders. Its laser-printer market share is nearly 60%, more than five times higher than that of its nearest competitor—even though the company uses the same Canon "engine" that many of its competitors do.
- Logitech, Inc. has created a major business out of a small niche market by designing an attractive and innovative series of "mouse" products for computer users, ranging from mouses for children, for left-handed users, wireless mouses, colorful mouses, even mouses that are not mouselike at all (e.g., trackballs). At a time when a fully functional Taiwan-made mouse can be purchased for less than $10, Logitech is able to command prices over five times that figure. Two of its mouse products were honored in a recent *Business Week*/IDSA-sponsored competition. The company is now leveraging its design strengths to enter other, larger peripheral markets such as hand-held scanners and digital cameras.
- On the software side, Microsoft Corp.'s runaway success with its Windows graphical interface is clear testimony to the power of design

THE NEW DESIGN PRINCIPLES

Higher-order design principles may be divided into three categories: product and process basics, responsiveness factors, and custom factors.

Product Basics

The basic requirements of good product design are timeless and well known: function, aesthetics, and reliability. Function does not imply designing products to serve the largest combination of needs. Some multifunction products may reflect design overkill and often confuse the customer. (The Swiss Army Knife is an exception.) Less can often be more in designing products. This is increasingly being realized by electronics companies that are retreating from an everything-but-the-kitchen-sink design philosophy for all their products to one that emphasizes robust and easy function.

Sony Corp. has launched videocassette recorders with minimalist controls; AT&T Co.'s new digital answering machine is highly successful, even though it lacks advanced but seldom-used features of many other machines. Another increasingly important consideration is universal design; as the population ages, products have to be designed so they can be easily and safely used by all consumers, including the elderly and the disabled. Examples include walk-in, soft bathtubs, easy-to-open detergent boxes, and kitchen utensils with large rubber grips.

Products certainly must conform to customers' sense of the aesthetic. Increasingly, products such as small appliances are being bought with an eye to style and appearance. This requires manufacturers to strive for a high degree of integrity and thematic consistency in their design elements within and even across product lines. Honda Motor Co. achieves such consistency across product lines as diverse as cars, power equipment, lawnmowers, garden tools, and motorcycles. The objective of design should be to invoke in consumers something akin to "product lust."

Reliability is probably the single most important factor for consumers. Products that do not consistently deliver what the customer expects cannot offset that shortcoming with outstanding performance on other criteria. The SERVQUAL studies on service quality (sponsored by the Marketing Science Institute) have shown that this is even truer for services: in nine studies across six service industries, customers consistently ranked reliability to be the most important dimension of quality.

The preoccupation with reliability is really an expression of the customer's desire to maximize product uptime. This translates to the need to design products not only to minimize breakdowns but also to permit speedy repair. Primarily, this involves designing for modularity. When modules are made to be self-diagnosing, companies can gain a crucial competitive edge.

Early Honda Accords were otherwise well designed, but certain items were placed in extremely inaccessible locations. (For example, the entire engine had to be dismounted to replace a burnt-out alternator.) On the other hand, Hewlett-Packard designed all the wear-and-tear items in its LaserJet printer into a cartridge, which can be replaced in seconds. A useful rule of thumb is to make the degree of component accessibility proportional to the breakdown rate for that component, or inversely proportional to the mean time between failures.

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Modularity can be a strategic advantage in the current climate of thrifty consumption, even when such products are purchased by affluent consumers. While it is already being applied to commercial products, such as computers and copiers, it can easily be applied to smaller-ticket products. Modular design with self-diagnosing modules can dramatically reduce the costs of setting up and running a product service network; uptime can be maximized with minimal investments in inventory or in highly skilled repair technicians.

Process Basics

The lack of early coordination between design and engineering can lead to products that are difficult to manufacture. In fact, such neglect can doom potentially outstanding products. For example, the Danish company Bang & Olufson has long been admired for outstanding product design. The company's high-quality electronic entertainment equipment is good enough to be placed in museums. However, the company's products are assembled in a tedious process: workers use pliers to insert individ-

RETHINKING HOW PRODUCTS ARE MANUFACTURED AND ASSEMBLED

Poorly designed products require painstaking and lengthy assembly by highly trained workers; well-designed products, on the other hand, can be snapped together in minutes by novice assemblers. The latter can be achieved without compromising product quality or features; in fact, such products are usually higher in quality and more reliable.

Several companies have achieved dramatic design breakthroughs through the use of an expert system called Design for Manufacture and Assembly (DFMA). Developed by Professors Boothroyd and Dewhurst of the University of Rhode Island, this expert system has been used by IBM, NCR, Motorola, Hoover, Ford, and others, usually with striking results.

Motorola first tested DFMA on a small product—a battery charger for its Radius portable-radio line.[6] Using the DFMA manual-assembly efficiency rating, Motorola found that its products ranged from a 2% rating to 15%. By applying DFMA concepts, it raised average efficiency to 40%. Assembly time was reduced 94%, and assembly defects were lowered by 50%. The number of parts was reduced by 85%, while the number of fasteners was now zero. Direct material costs declined 50%.

Although Motorola hadn't approached DFMA as a quality improvement program, it in fact achieved much higher quality levels as well. As important as the cost reductions and quality improvements, the company found that DFMA led to the breakdown of communication barriers between designers and engineers. As a result, numerous other products were reengineered.

IBM redesigned its Proprinter so that it had 79% fewer parts and no fasteners in the final assembly. Assembly time was reduced from 90 minutes to three minutes. Because labor costs were reduced to the point of being irrelevant, IBM was able to bring Proprinter manufacturing back to the US.

NCR used DFMA to redesign a sophisticated electronic cash register so that its 15 parts (down from 75) can be assembled blindfolded by an unskilled worker in less than two minutes. Ford Motor Co. estimates a saving of $1 billion from DFMA. Such a design philosophy goes a long way toward restoring the global competitiveness of the manufacturing sector in developed countries.

The principles behind DFMA are straightforward: first, simplify the structure (reduce the number of parts, by eliminating some and combining others) to simplify the assembly process. The approach leads to more complicated individual parts (which can usually be easily mass produced) and a simpler product structure. The expert system is based on enormous quantities of research data on manufacturing intelligence, material properties, and machining rates.

One of the secondary impacts of applying DFMA is that companies need not deploy robots at all in the assembly process. Since robots are much easier to deploy in activities such as painting and welding and are an expensive solution for mechanical assembly, this is a key advantage.

ual transistors into circuit boards. As a result, the company's products are extremely expensive, and it has been steadily losing money and market share.

Engineering must be given veto power over needlessly complex designs. In some instances, however, manufacturing complexity can be an advantage. Gillette Co. pioneered a sophisticated micro-laser welding process to create its Sensor blades, at a development cost of over $200 million. This has now become a significant entry barrier for private-label blade makers. Of course, Gillette remains susceptible to a competitor that is able to design similar performance characteristics into a blade without such a complicated manufacturing process.

The use of approaches such as design for manufacture and assembly is fast approaching a strategic necessity; no company can hope to compete globally (or even locally) for long without making full use of such methodologies (see "Rethinking How Products Are Manufactured and Assembled" in box above).

Responsiveness Factors

Responsiveness, as defined here, includes the dimensions of product intelligence, connectivity, and integration. Product intelligence has several aspects. High-value products should be made self-diagnosing through the extensive use of sensors. When feasible, these sensors should be linked to an automatic data interpretation and reporting system.

For instance, Fuji-Xerox in Japan has developed a copying machine that runs a detailed set of diagnostic tests every 50 copies; it analyzes these results using a built-in expert system. If it anticipates a problem, the machine automatically dials up a service center and schedules a preventive maintenance visit; this alerts the service department as to what parts are likely to be replaced.

Such a design and service philosophy is becoming widespread: the General Electric Co. has a similar system for some of its medical diagnostic systems; Otis Elevator uses such a built-in design process with some of its elevators. AT&T has taken a similar design approach to its Definity G3 communication system.

Design for intelligence also means intelligent product performance. Consider the extensive use of fuzzy logic systems by some Japanese manufacturers. By using this technique, they have designed a variety of "smart" products, including smooth-shifting automatic transmissions, fast and always-available elevators, energy-efficient air conditioners, and one-button washing machines that choose an optimal wash cycle from 600 possibilities.

Belatedly, US companies are climbing aboard the fuzzy bandwagon. From such early niche applications as targeting for F-16 fighters, companies are now using fuzzy logic in applications such as engine control, information-retrieval systems, and efficient appliance operation. With rapidly declining prices for automatic sensors, such built-in intelligence is fast becoming a prerequisite for market success. Many products already possess the computing power; the typical car sold today has the computing horsepower of an IBM XT. Adding more capabilities does not add greatly to costs.

Products must be able to work as an embedded part of a system, and sometimes one that may not in fact yet exist. Hewlett-Packard's 95LX palmtop computer was designed with a built-in infrared communications system. This feature, little noted at the time, is now becoming increasingly significant. Using special software, for example, two owners of such devices can instantly exchange "electronic business cards" and other information simply by bringing the units together. In a similar vein, Nintendo's base game system has included the capability to be upgraded for nongame uses; it has been used for banking and other services for years in Japan.

Custom Factors

In some industries, expandability, upgradability, and recyclability are becoming very significant factors. Products that allow customers an accessible entry point—but that will not be relegated to rapid obsolescence—can give a company a competitive edge. The most important reason for IBM-compatible computing's explosive growth over the past decade has been its architecture and modular design. Within the industry, ALR, Inc. has achieved a successful niche by positioning its computers as being even easier to upgrade than others. They allow for pin-compatibility with more advanced microprocessors. Intel Corp. has recently initiated a strategy of introducing several generations of upgrade chips and has encouraged manufacturers of motherboards to include vacant slots for such future developments.

Customers are increasingly looking for products that are recyclable and environment-friendly. To respond to this, companies must choose materials, components, and supplies that are less hazardous, as they are doing now with air-conditioning coolants. It is very important that the substance of their actions match the promise and rhetoric of their advertising and public relations efforts.

Companies must also set up the mechanism whereby recycling can take place, allowing customers access to drop-off points and even paying them for the discarded products. The aluminum industry, which achieved over 50% recycling a few years ago, is a good industry for others to emulate.

The notion of design for disassembly has been used by a number of companies, including BMW and U.K. Kettle. In the latter case, key issues involved in the kettle design included two-way snap-fit and break points, coding of all parts, using labels of similar material to facilitate separation when recycling, and the total absence of fasteners.[4] The product has been very successful; it was so well designed that the Museum of Modern Art was its first customer.

CONCLUSION

Over the past several years, design has emerged from being a misunderstood and

Design for intelligence also means intelligent product performance.

underappreciated support function to one that has assumed a central role and critical importance. In an era of fast-moving global competitors, design confers on companies the ability to differentiate their products from others.

The emerging role for designers is one in which they serve as integrators, being ultimately responsible for creating products with internal as well as external (i.e., customer) integrity and reconciling the often-conflicting demands that marketing and engineering may place on a project.[5] Designers today use remarkably sophisticated visualization software that facilitates communication between designers, marketers, customers, and engineers: expert systems now rationalize and streamline design for producibility without sacrificing function or aesthetic appeal. Coming in the not-too distant future: virtual reality systems in which products can not only be seen before they are produced but also held and manipulated.

Despite all this information technology, design remains at its core a physical activity, and the creation of physical prototypes is integral to a successful design effort. Here, too, technology is fast changing the designer's world. Stereolithography machines, capable of converting a 3-D drawing into a plastic prototype, are becoming faster and more affordable. In Singapore, such machines are being used in a variety of ways, from designing knee prostheses to designing gold jewelry. Soon, such machines should be able to facilitate die-casting directly from the prototype, speeding up the process even further.

Design's tremendous strategic value and ability to leverage small investments into huge profit impacts are clear, but companies continue to spend enormous amounts of money on advertising and on short-run sales promotions. If corporations were to reallocate some of that funding into design (and the redesign of existing products), the payoff would be great.

Most design firms are compensated through up-front fees. Given the increasingly strategic role that design has come to play, it is time to explore different arrangements to provide adequate incentives for superlative work. For example, design firms could be given a stake in the success of the product through revenue-sharing arrangements.

These days, many design firms do not even call themselves design firms. Rather, they define themselves as being in the "technology commercialization" business. Given the enormous significance of design, such a designation is quite appropriate.

Notes

[1] K. Clark and T. Fujimoto, "The Power of Product Integrity," *Harvard Business Review* (November-December 1990), pp. 107–118.

[2] K. Yamamoto, *Nikkan Jidosha Shinbun* (*Daily Automotive News*) (October 13, 1987), p.1.

[3] *Business Week* Special Issue: Innovation—The Global Race (June 15, 1990).

[4] D. Sykes, "The Visual Material from the Archive of the U.K. Kettle Project," presentation made at the Third International Forum on Design Management Research and Education, Harvard Business School, May 1991.

[5] T. Fujimoto, "Product Integrity and Role of Designers-as-Integrator," *Design Management Journal* 2; no. 2 (Spring 1991), pp. 29–34.

[6] T. L. Welter, "Motorola Gets a Charge Out of DFMA," *Industry Week* (September 3, 1990), pp. 75–76.