You're Only As Agile As Your Customers Think

by B. Joseph Pine II

Abstract

Rather than embrace the full promise of agile manufacturing, some organizations merely use it to introduce and produce an ever-increasing number of stock-keeping units (SKUs) in the markets they serve. For some, it has become a way of forestalling true customization, trying desperately to maintain the mindset of Mass Production in the face of rapidly fragmenting markets.

This is unfortunate, for *variety is not the same as customization*. Variety is still producing a product and putting it in finished goods inventory *in the hope* that some customer will come along and desire it. In contrast, it is only customization if it is produced *in response* to a *particular* customer's desires. Being agile may help manufacturers become more cost-efficient in introducing more and more variety, but unless Agility is directed at mass customizing in response to actual demand, customers will not think you're agile—only bursting with options. Complexity and costs on the shop floor will only be replaced by confusion and chagrin on the shopping floor.

Instead, customizers figure out exactly what individual customers need (often through direct collaboration), and then produce it, generally using design tools that eliminate the problem of too much choice. And *mass* customizers do so efficiently, at a price customers are willing to pay and at a cost that allows for profitable margins. Mass Customization is not being everything to everybody; rather, it is doing *only and exactly* what each customer wants, when they want it. Indeed, most mass customizers find that—although there may be a significant up-front investment in developing the products, processes, and technologies required—mass customized products can cost nearly the same as mass produced ones. And for some, they actually cost less, particularly when markets become fragmented enough that mass production techniques can no longer effectively predict what customers desire.

Because of these tremendous advantages, Mass Customization is moving from being at the frontier to fast becoming an imperative in industry after industry. It is, in fact, the next logical step in the evolution of business competition. But it is not the last step. Once a company achieves the Mass Customization business model through the activities of development, linking, modularization, and renewal, it then can create a markedly higher degree of inventive capability, one that builds upon mass customization techniques to enable the rapid, constant, efficient creation of new, innovative products—not just customized versions of existing products. Companies that do this embrace a business model that could be termed "Continuous Invention."

Introduction

Like it or not, customers (whether consumers or businesses) are becoming more demanding about getting exactly what they need, while increasing competitive intensity—arising in

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particular from the globalization and convergence of industries—dictates that costs keep decreasing as well. Where companies used to pursue *either* a low cost *or* a high differentiation strategy, today companies find they must adopt strategies embracing *both* efficiency *and* customization. Instead of mass producing standardized goods or incurring high costs to produce great variety, companies are in fact discovering that they can combine the best of both strategies to *mass customize* their offerings. They must, in short, *mass* produce individually *customized* goods.

A Few Exemplars

Many companies are already effectively meeting this challenge. Levi Strauss & Co., for example, has created Personal Pair™ jeans, which (for only about a $10 premium) are tailored to individual consumers along four dimensions: waist, hips, rise, and inseam. The enabling PC-based technology (developed by Custom Clothing Technology Corp. of Newton, Massachusetts, since purchased by Levi's) selects a piece of stock inventory to ensure the consumer likes the fit and then transmits the custom order to Levi's factory in Mountain City, Tennessee for production. In-store or at-home delivery generally takes less than two weeks. In creating Personal Pair, Levi's increased its number of manufacturable sizes by two orders of magnitude: from about 40 to more than 4000, with five additional options on color/finish and two more on leg cut.

But that level of customization is nothing compared to what some other companies are doing. Consider window manufacturer Andersen Corp., of Bayport, Minnesota, which has millions and very possibly billions of possible window configurations and saw the number of unique end items actually shipped explode from 10,000 in 1980 to more than 200,000 in 1996. To handle this rapidly increasing level of customization, Andersen developed a multimedia system called the Window of Knowledge™. The system features an icon structure of more than 50,000 possible window components to let distributors collaborate with end customers in *designing their own* windows and interactively see exactly how potential designs would look—with such added touches as videos of beautiful, cloud-swept vistas viewed through the online windows. This rather sophisticated design tool automatically generates error-free quotations and manufacturing specifications and transmits completed orders directly to Andersen's factory.

While the goods created by both Andersen and Levi's are sold to consumers, Mass Customization has made just as much of an inroad—if not more so—in industrial applications. For example, ChemStation, of Dayton, Ohio, mass customizes industrial soap for factory floors, car washes, restaurants, and other commercial outlets. It independently analyzes each customer's needs and then uses its patented "H7" technology and exclusive process to customize the concentration strength, PH-level, enzyme concentration, foaminess, color, odor, and so forth, for that customer. These unique formulations are delivered in bulk into ChemStation's own plastic storage tanks—with the ChemStation logo emblazoned on the front for all to see—that are provided to customer sites to completely eliminate the need for drums. The company further enhances its overall service simply by ensuring that customers never run out of their particular formulation. By constantly monitoring its tanks at customer sites and thereby learning each customer's usage pattern, the company presciently replenishes inventory before a customer ever has to ask—eliminating any need for the customer to create or even review orders.

As just one more example of the many manufacturers that have embraced Mass Customization, consider the case of Ross Controls, a seventy-year-old Troy, Michigan-based manufacturer of pneumatic valves and other air control systems used in heavy industrial processes in such industries as automobile, aluminum, steel, and forestry. Through its "ROSS/FLEX" process, Ross learns about its customers' business needs so it can collaborate with them on precisely tailored designs. It then quickly and efficiently produces customized valve systems that meet each customer's needs, often starting with a series of prototypes before finding the one design that can be replicated across the customer's various production lines. By integrating its efficient customization capabilities with the ability to learn about each customer's needs over time, Ross develops a connection to them that grows with every successive interaction.

To make this happen the company instituted an *integrator* position that productively combines marketing, engineering, and manufacturing functions into one person. The integrator's primary task is to "mine the knowledge" of his assigned customers to resolve their own manufacturing process problems. Interestingly, because the integrator's responsibilities are so antithetical to the normal engineer's way of working—one person must talk with customers, engineer the valve designs, and then determine the manufacturing specifications (including the tool paths for the CNC machines)—Ross found that it had to hire new engineers from college *who had not yet learned that engineers were supposed to only do engineering*, not all that marketing and manufacturing "stuff" as well.

To What End Agile Manufacturing?

What these four companies are doing is, of course, very different from traditional Mass Production, which aims to standardize products to be placed in finished goods inventory while stabilizing processes for efficient production. Surprisingly, it is also quite different from how many companies that have abandoned mass production processes leverage agile manufacturing. Rather than embrace the full promise of agile manufacturing, some organizations merely use it to introduce and produce an ever-increasing number of stock-keeping units (SKUs) in the markets they serve. For some, it has become a way of forestalling true customization, trying desperately to maintain the mindset of Mass Production in the face of rapidly fragmenting markets.

This is unfortunate, for *variety is not the same as customization*. Variety is still producing a product and putting it in finished goods inventory *in the hope* that some customer will come along and desire it. In contrast, it is only customization if it is produced *in response* to a *particular* customer's desires. Variety is about giving more customers more choices in the hope that they can find something close to what they need. But so often companies overwhelm customers with so much proliferation that they throw up their hands at having to go through a lengthy decision-making process with little or no support, and simply walk away.

It is important to realize that fundamentally *customers do not want choice; they just want exactly what they want*. Being agile may help manufacturers become more cost-efficient in introducing more and more variety, but unless Agility is directed at mass customizing in response to actual demand, customers will not think you're agile—only bursting with options. Complexity and costs on the shop floor will only be replaced by confusion and chagrin on the shopping floor.

Instead, customizers figure out exactly what individual customers need (often through direct collaboration), and then produce it, generally using design tools (like Andersen's Window of Knowledge) that eliminate the problem of too much choice. And *mass* customizers do so efficiently, at a price customers are willing to pay and at a cost that allows for profitable margins. Mass Customization is not being everything to everybody; rather, it is doing *only and exactly* what each customer wants, when they want it. Indeed, most mass customizers find that—although there may be a significant up-front investment in developing the products, processes, and technologies required—mass customized products can cost nearly the same as mass produced ones. And for some, they actually cost less, particularly when markets become fragmented enough that mass production techniques can no longer effectively predict what customers desire.

Further, most customers are willing to pay a premium (often 10-50%) simply because customized products *have greater value* than standardized ones—they more closely match each individual's needs. Margins, therefore, often increase greatly, especially once a company realizes the gains from the elimination of the carrying costs of finished goods inventory, having customers not walk away when they can't get what they want, and not having to put some product on sale because no one wanted it. Think of the financial gains in your company that could be realized through the elimination of finished goods inventory alone.

Mass Customization: The New Imperative

Because of these tremendous advantages, Mass Customization is moving from being at the frontier to fast becoming an imperative in industry after industry. It is, in fact, the next logical step in the evolution of business competition.

This can be seen clearly through the framework given in the Figure 1, *The Evolution of Business Competition*.[1] To understand the model, first recognize that product change (meaning the degree to which a good or service changes over time, or for

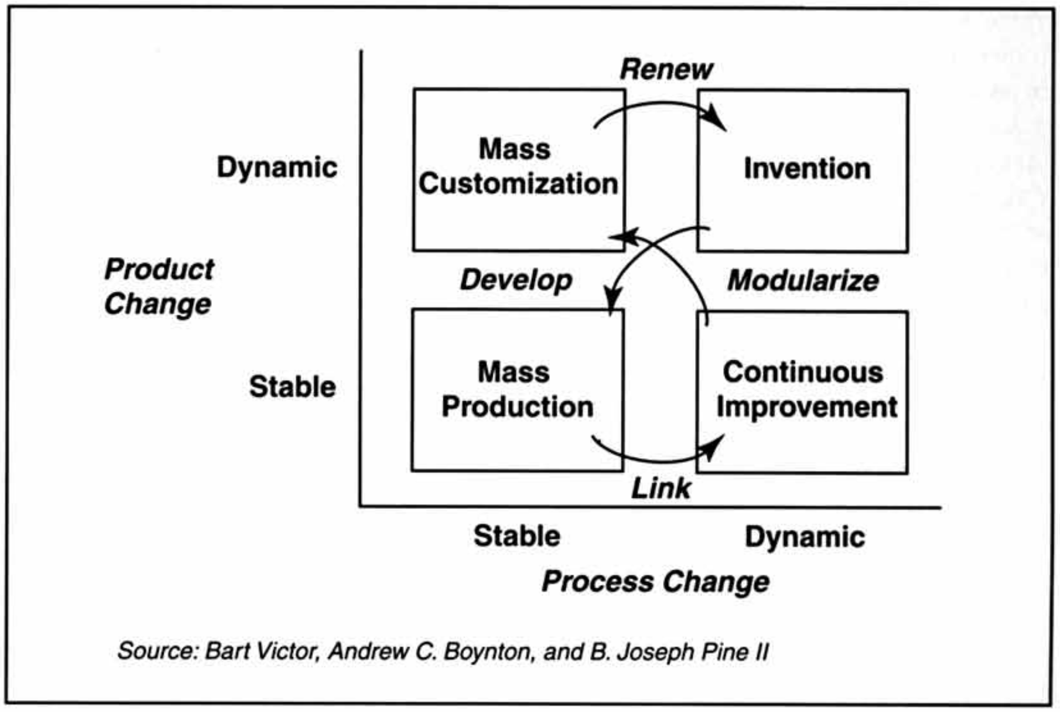

Figure 1: The evolution of business competition.

individual customers) can be either *stable*—slow, evolutionary, predictable—or *dynamic*—much more erratic, unpredictable, or revolutionary, and, at its limit, resulting in a different product every time one is produced. Similarly, process change—how an organization goes about producing the good or delivering the service—can be either stable or dynamic (where at its limit a different process is executed every time). This, then, defines the four generic *business models* that companies choose—consciously or otherwise—based on their particular configuration of products and processes.

The *Invention* model includes craft producers, entrepreneurs, R&D units of large companies, and others that compete on high differentiation. These organizations constantly create new products as well as the processes by which they are produced; both product and process change is very dynamic. For centuries, all businesses were craft producers (often craftsmen) that basically followed the Invention model—if a customer wanted something an artisan didn't know how to make (either a new product or customized version of a current one), he might still offer to make it and then figure out how. Should the craft producer try to make the same thing twice, it always comes out at least slightly different because the production process has never been stabilized. By its very nature, the Invention model has constantly changing products and processes, and its practitioners—true inventors—often tinker and experiment, tweak and then start over, just to see what new output emerges.

With the advent of the Industrial Evolution, and in particular Henry Ford's development of the assembly line, came the capability for *Mass Production*—the exact the opposite of the Invention model. Here, everything is stable: these organizations find the one best way to produce a given product and then move down the learning curve as fast as possible to do it. Both product and process change comes only very slowly to ensure fixed costs are recouped. Every once in a while (typically 4-5 years or longer) mass producers would have to depend upon some other Invention organization (usually its own R&D labs) for a new product idea that would be brought down to the Mass Production organization to be mass produced. In their heart of hearts, mass producers want to stabilize everything—establish the *one best way* to do everything—and then duplicate that one path over and over again. If they had their way, most manufacturing managers would produce a single standard item via one set-up and then run the production line until the cash cows came home.

Mass producers were thus very dependent on Invention organizations to create new products, and Invention organizations were often dependent on mass producers to provide a ready market for their highly differentiated creations.[2] This synergy between Mass Production and Invention organizations worked very well for a very long time; it was at the heart of America's economic success during the twentieth century. So much so that it became a basic "law" of business that companies had to choose between *either* low costs *or* high differentiation—that one organization could never do both, because each required such different business models.

What Japanese companies (in particular but not exclusively) discovered was that if they continually improved their processes, they could achieve *both* lower costs *and* higher quality than the typical mass producer. By embracing dynamic process change, they moved to a new business model and gained a significant advantage over their competitors. This was so different from the old ways of doing things that it took American companies a long time to uncover the business model's true nature. Now, most companies subscribe—at least in principle, if not fully in practice—to *Continuous Improvement* (or *Lean Production*, if you prefer) and incorporate such innovations as statistical process control, total quality management, just-in-time inventory, cross-functional teams, and customer satisfaction measurements, to name just a few. At its ideal, organizations following this model have a process life cycle of one execution; every execution is different—and better—from the last. Yet the output change remains relatively stable; Japanese producers in particular had less variety than their American counterparts when they first invaded the latter's domestic markets. This tends to change over time as cross-functional process teams—the basic structure of Continuous Improvement organizations—set their sights on setup and changeover time, improving the organization's capabilities for greater variety.

While companies everywhere seem to be making great strides in quality by embracing Continuous Improvement, many firms are already moving beyond mere variety to the *Mass Customization* business model.[3] Here, stable but very flexible and responsive processes provide a dynamic flow of products, enabling companies to achieve *both* low costs *and* individual customization. In this business model, the organization's primary thrust is to identify and fulfill the individual wants and needs of each and every customer. Ideally, the product life cycle is one unit: every product is different from the last—and exactly suited to that particular customer's needs.

Organizations can move between business models, and their products and processes may be scattered across multiple approaches, but *there is a definite order to the sequence* that must take place to reach Mass Customization. The first such movement, from Invention to Mass Production, is the well-known activity of *development*. It requires articulating and stabilizing the product and process, making each definable and repeatable for high-volume, low-cost production.

The resulting Mass Production organization has historically been very hierarchical and bureaucratic, with very little information flow between functions. To equip the organization for Continuous Improvement, these vertically separated functions must be *linked* (the second move) through cross-functional teams, information sharing, and a horizontal process focus. The islands of automation that grew up within each function must come together to provide one common base of data from which each views the process. Further, the organization must link with its suppliers (value chain integration, versus the old vertical integration) so they have the same information about what is going on in the marketplace and can respond just-in-time with the components necessary to satisfy market needs. The result is a set of tightly coupled, high-quality processes capable of being continuously improved,[4] yielding a high degree of customer satisfaction—the key measurement of continuous improvers.

The third move, to Mass Customization, requires that goods and services be *modularized* to provide individual combinations for each customer. This lets companies to efficiently deliver individual modules of customer value—whether it be a particular jean fit, a specific pitch of window, a certain PH factor in industrial soap, or an exacting pneumatic valve connection—within the structure of a modular architecture. The architecture determines what universe of benefits the company intends to provide customers and, within that universe, what specific permutations of functionality will be provided at this time, to this particular customer. These permutations are, in turn, defined by a modular schema that specifies what types of modules can be used and what linkage system will connect them together to create specific products for specific customers.

To understand modularity think of Lego® building blocks. What can you build with Lego's? The answer, of course, is *anything you want*—because of the large number of different kinds of blocks and a simple, elegant system of tabs and holes that enables them to be easily snapped together. Every Mass Customization architecture needs to standardize these two basic elements: a set of modules and a linkage system to dynamically connect them together. Without standardization here, no company can hope to efficiently customize anywhere. Modularity, once again, is *the key* to mass customizing any good or service.[5]

In addition to customizing the actual product itself, the most robust Mass Customization implementations, as demonstrated with the examples above, break apart and modularize the tightly coupled *processes* created by Continuous Improvement. Specific, stabilized process modules are then free to dynamically link with other process modules as required to create the end-to-end value chain that will best satisfy each customer. The result is a dynamic—rather than static—network of linkages between people and processes loosely coupled to deliver mass customized goods.

The Cycle That Truly Counts

Mass Customization organizations also have to be able to *renew* themselves, to realize when they cannot satisfy a particular customer or cannot go after a particular market opportunity with their current universe of customization. This, the fourth and final move in Figure 1, causes them to "go back" and re-invent a new product module, a new process, or link to an organization inside or outside of the firm to provide the new capability required. And at times, firms may have to overthrow their entire product or process architecture—before their competitors do—and re-invent one that will once again provide a distinct competitive advantage.

Although the organization will never again want to "live" in Mass Production, it does have to go through the activities outlined above—the figure-8 pattern through the framework—for each new product, process, or organization module created in Invention. Each one still has to be developed and stabilized, linked to the rest of the organization and made of high quality, and finally made to fit the modular architecture. The organization is *mass customizing*, not just pursuing a end-state of mass customization or "living" in any one business model; the figure-8 cycle of Developing-Linking-Modularizing-Renewing never ends. The result? Customers experience the constant enhancement of capabilities over time.

Mass Customization, then, is not the ultimate. Rather, organizations must manage the ongoing cycle of successive transitions between each business model—not make a one-time selection of any particular model. Consider, for example, one of the early pioneers of Mass Customization, the Motorola Paging Products Group in Boynton Beach, Florida. During the 1980s, Motorola moved beyond the traditional mass production of electronic products to embrace a Continuous Improvement mindset. It implemented many quality and cycle-time improvement programs, with the company's vaunted Six Sigma program (which strove to reduce defects to 3.4 parts per million) becoming the most well-known. But when Japanese competition significantly stepped up the competitive requirements with their own Continuous Improvement activities, the Paging Group went beyond the competition to Mass Customization at an organizational level.

Motorola put together a project that, in just 18 months, created an (almost) fully automated manufacturing system that could produce any one of 29 million different combinations of pagers in Boynton Beach within an hour and a half of the order being taken via a sales representative's laptop computer anywhere in the country. This drastically changed the nature of competition in the industry. Motorola became the sole surviving American producer of pagers and commanded a worldwide market share of more than 40 percent. And it didn't stop there.

Since that original project—code-named Bandit to encourage its members to "steal" from any source inside or outside of the company to create the best possible manufacturing system—the Paging Group moved far beyond its original capabilities. It created what it calls the Fusion Manufacturing System because it unifies and integrates engineering, manufacturing, and marketing into one enterprise system that, at an operations level, enables it to accomplish all of the transitions shown in Figure 1[6]. With this information technology infrastructure in place, the Paging Group engineers can invent new module designs on a computer-aided design system (renewal), simulate the performance of that "virtual" design using various electronic tools (development), ensure that the manufacturing processes exist with sufficient raw materials inventory and capacity to physically create the module in concert with the rest of the manufacturing processes (linking), build the complete product specifications and dynamic manufacturing instructions online (modularization), and, finally, send them to the Fusion Factory for production. As a testament to how far Motorola has come: One of the company's customers (a vice-president of a paging services firm) related how his people collaborated with the Paging Group to design a new feature peculiar to their consumers' needs. The Motorola engineers left on Friday afternoon with an agreed-to description of the feature and came back Monday morning with working pagers! *And there were no yellow wires in the back*; these pagers were produced on the exact same assembly line as the company's production pagers. Although Motorola's engineers may not realize it, the system they put together enables them to go through the figure-8 pattern to renew over a weekend.

Unfortunately, the figure-8 pattern cannot be shortcut effectively. Invention organizations cannot go directly to Continuous Improvement precisely because they have not yet stabilized their processes. As all those intimately familiar with Total Quality Management techniques know, unless a process is definable and repeatable, it cannot be continuously improved because it can never be determined whether the results of the next execution derive from the improvements or from the natural variability of a process that has not been locked down via the activities of development. Similarly, one cannot go directly from Mass Production to Mass Customization. While both use stable processes, the Mass Production organization is so hierarchical and compartmentalized, its focus so inward, and its processes so rigid and ossified, that it cannot possibly be modularized without first linking the organization together to focus (sometimes for the first time in decades) outward on the marketplace and begin incorporating flexibility and responsiveness into the processes through Continuous Improvement.

One clear result of the success of Japanese competitors and others that embraced the Continuous Improvement model was the tremendous force for change it became. Not just at particular companies like Motorola, but company after company in industry after industry *had* to increase their quality and lower their costs in order to compete in the face of a clearly superior business model to Mass Production. But a second result, perhaps less clear but of equal importance, is that all of this improvement *taught customers to become more demanding*. Once they discovered they could get both low costs and high quality from one company, they stopped putting up with poor service from others and began demanding that companies provide goods and services exactly as promised. Indeed, these two effects were reinforcing, driving each other to greater and greater levels, until today in most industries Continuous Improvement only gets companies into the game[7]. Quality is no longer a differentiator.

We are nowhere near that point yet with customization, but companies in the next decade will be faced with *the same precise predicament*. Once customers—again, whether consumers or businesses—begin to see that they can get products made just for them that almost exactly match their needs at a price they are willing to pay, you can believe that they are going to ask for it elsewhere. And that's precisely why Mass Customization is becoming an imperative.

The Ultimate Advantage of Mass Customizing

But implementing Mass Customization not only offers better products to customers but opportunities for stronger relationships as well. By interacting with each customer on a personal basis *for the purpose of customizing products just for him*, companies can better learn the wants, needs, and preferences of each. The more the customer teaches the company about his *unique* needs, the better it can provide exactly what he wants—when, where, and how he wants it—and the more difficult it will be for him to be enticed away by a competitor. Company and customer thus enter into a *learning relationship* that grows and deepens over time—and thereby create a singularly powerful competitive advantage[8].

The beauty of Mass Customization is that the modular architecture enables this to be done incrementally, one module at a time, at very low costs. Instead of massive development efforts—which often end up with a large share of the time spent re-inventing what someone else somewhere has already done—new modules can be created and dynamically linked into an existing architecture with a fraction of the effort. This is exactly what Motorola does so well with its Fusion Factory, or what Ross does every time they work with a customer to determine how its pneumatic valves can enable that customer to realize strategic value. They don't completely reinvent a new pager or a new valve; they work from existing designs to reuse 80-90% (or even 95 or 99%) of what they've used before, and then spend their truly creative work only on what *has* to be innovated to meet that particular customer's needs.

Continuous Invention

This will be crucial to where business competition will go in the future. Reconsider Figure 1, and note that it takes us from Craft to Mass Production with the Industrial Revolution, from Mass Production to Continuous Improvement with the quality revolution of the past few decades, and then on to Mass Customization in recent years of increasing market fragmentation and customer demands. But it doesn't stop there: business competition will not cease its evolution once this new business model is mastered. Rather, as one can surmise from Figure 1, it will *go back* to Invention. The next logical step in business competition is a markedly higher degree of inventive capability, one that builds upon mass customization techniques to enable the rapid, constant, efficient creation of new, innovative products—not just customized versions of existing products—or what my partner at Strategic Horizons LLP, Jim Gilmore, has termed "Continuous Invention."

For mass-customized variations within a given product architecture, virtually instantaneous development cycles with efficient production are already a reality[9]. However, it may be science fiction to think of instantaneously creating the architectures themselves, inventing new product categories, or even developing major innovations for well-established products. But there are a number of promising lines of research and practice that will, now and in the future, yield marked improvements in this direction. Three possibilities stand out.

Modular Design: Component modularity, based on physical elements, is already being widely used to develop architectures for mass customizing products. Taking it up a level, Susan Walsh Sanderson of Rensselaer Polytechnic Institute has demonstrated how design modularity—what she calls "virtual" design—can modularize *functional elements* to reuse them across product families[10]. Higher and higher levels of modularity will yield greater and greater degrees of innovativeness. One can envision certain classes of "functionalities" being reused across very different products, with tools in place to make their reuse quick, efficient, and effective.

Essential to design modularity is incorporating more and more of the product essence inside of information technology, as Motorola has made great strides in doing with its Fusion Factory. A key tenet of mass customization is *anything that can be digitized can be customized.* Once something resides in the realm of bits—ones and zeroes—it can be instantly changed on demand to a different, but still meaningful, set of ones and zeroes. In some cases the product itself can be digitized, such as with greeting cards, sheet music, and other information-based goods (not to mention telecommunications, insurance, and financial services that are all fundamentally information-based). In other cases, as with Motorola pagers, the specifications for the product design and its manufacture can be digitized for almost instant instantiation in a physical, customized product. In the future, as information technology continues to advance, greater and greater functionality will be digitizable, yielding virtual design and something that could easily deserve the label of Continuous Invention.

Invention Databases and Expert Systems: Many functions, however, cannot be digitized or even modularized, and may never be. Many stubborn development problems, for example, require resolving fundamental engineering contradictions for which there are no easy solutions. But what if you could attack it from every possible angle, quickly apply various inventive principles and physical effects to the problem at hand, have an expert system suggest alternatives, and learn by analogy from thousands of innovative creations?

That is exactly what one software product, called *Invention Machine Lab* from Invention Machine Corp. of Cambridge, Massachusetts, is already on the market to do[11]. It has three modules. The first, IM:Principles, helps developers find solutions to engineering contradictions by presenting inventive principles gleaned from analyzing more than 2.5 million patents. The second module, IM:Effects, contains a knowledge base of more than 1,350 physical, geometric, and science-engineering effects to assist users in understanding the ramifications of alternative approaches. And the third, IM: Prediction, helps developers predict the possible technological evolution of their invention to lead them down the path of creating entirely new products. Motorola, for example, has licensed more than 1,000 copies of Invention Machine Lab to speed the creation of new, innovative products from its various R&D labs.

Collaborative Technologies: Technologies such as groupware, liveboards, argumentation spreadsheets, and rapid prototyping are but a shadow of what will come as these technologies merge into collaborative environments. The new generation of collaborative technologies will have two effects on product development processes: they will enable many activities to be done that could never have been done before, and they will allow activities that could be done to be completed much faster, more efficiently, and more effectively[12].

Included in this latter group will be the ability, through virtual reality and other simulation technologies, to rapidly examine and test new product concepts without having to build the physical components. Combined with design modularity, the potential time savings in the testing phase of new product development are enormous. As just one example of what possibilities are fast becoming achievable, professors at the University of Illinois at Chicago have created a virtual reality system they call CAVE (for Cave Automatic Virtual Environment, a reference to Plato's cave) that enables researches to walk around—without bulky headsets—three-dimensional representations of products[13]. General Motors, Caterpillar, and other companies are already using CAVE in their new product development activities.

The Future Landscape

Of course, technology will not solve all invention or collaboration issues, and not all innovations are amenable to digitization or modular design. No matter what technologies or techniques are developed in the future, many development projects—and certainly the most important and the most inventive among them—will still take significant amounts of time to complete. And while development times for most anything can be greatly lowered from where they are today, they often cannot be "rushed" without detrimental consequences[14]. There is more than wine that cannot be sold before its time.

But nonetheless, there is still a tremendous amount of progress that can be made in the direction of Continuous Invention. With new systems, technologies, and techniques one can indeed envision the day not too far in the future—some time in the twenty-first century—when the development and life cycle times of major new platforms such as automobiles and computers are measured in months, consumer electronics products in weeks, and many products in days or hours. Like many mass-customized products today, custom variations created in minutes will be commonplace. And if there is any problem with achieving these numbers, it will come—as it should—from customer acceptance issues, not from the inability of producers to do it.

For those agile manufacturers that wish to become continuous inventors, the path is clear. It begins by embracing the principles of Mass Customization.[15]

Notes

1. The origins of this framework were developed by Bart Victor and Andy Boynton of the University of North Carolina (visiting the International Institute for Management Development in Switzerland at the time of this writing) and extended in collaboration with Joe Pine. It evolved considerably over time to become a very robust way of looking at the world of business competition. To trace that evolution, see Boynton and Victor, "Beyond Flexibility: Building and Managing the Dynamically Stable Organization," pp. 53-66; Pine, *Mass Customization: The New Frontier in Business Competition,* pp. 215-221; Boynton, Victor, and Pine, "New Competitive Strategies: Challenges To Organizations And Information Technology," pp. 40-64; Pine, Victor and Boynton, "Making Mass Customization Work," pp. 108-119; Pine, Victor and Boynton, "Aligning IT with New Competitive Strategies," pp. 73-96; and, finally, Victor and Boynton, *Invented Here: Maximizing Your Organization's Internal Growth and Profitability.*

2. The idea that Mass Production and Invention organizations were dependent on each other was first articulated by MIT Professor Michael Piore of the Sloan School of Management. He noticed that mass producers were utterly dependent on specialized machine makers to provide them with the customized machinery required to make an assembly line efficient. It was applying this insight to the framework that led to discovering the figure-8 path that leads from Invention, through Mass Production and Continuous Improvement, to Mass Customization, and back again to Invention. For discussions on the concept of "industrial dualism" see Piore, "Dualism as a Response to Flux and Uncertainty" and "The Technological Foundations of Dualism and Discontinuity," in Berger and Piore, 1980.
3. For a fuller description of the differences between Continuous Improvement and Mass Customization, and of the difficulty in making this transformation, see Pine "Challenges to Total Quality Management in Manufacturing," in Cortada and Woods, *The Quality Yearbook*, pp. 69-75.
4. In fact, process improvement is rarely if ever constant; rather, it is episodic. As explained by Tyre and Orlikowski, 1993, a burst of activity is followed by a time of gradual stability, followed by another burst once new challenges surface (or unresolved problems become too great to ignore). In essence, those organizations that have mastered Continuous Improvement really "bounce" between that model and more stable Mass Production on an episodic basis.
5. There are at least six different ways of modularizing and a myriad ways of doing each depending on a company's particular circumstances; see Pine, *Mass Customization*, pp. 196-212. Other good resources on this are Ulrich and Eppinger, 1995; Galsworth, 1994; Suzue and Kohdate, 1990; Sanchez and Mahoney, 1996; and Baldwin and Clark, 1997. The six types of modularity discussed in *Mass Customization* are based on earlier work by Ulrich and one of his students.
6. For a complete description of Motorola's Fusion Factory, see Strobel and Johnson, 1993. Since this article was written, it appears that Motorola went too far with the automation of its current architecture of pagers and has had trouble responding to demand for features outside of that modular architecture. As good as its Paging Products Group is—and it is among the best of mass customizers—its current experience is a testament to the need discussed earlier to renew not just capabilities but architectures as well (what can be called macro-renewal).
7. Note that this is the exact same thing that happened in the movement from Craft to Mass Production. Once customers got used to having low costs in automobiles and textiles, they began demanding it across other industries (including service industries, for whom back offices became the equivalent of assembly lines). As a result, thousands upon thousands of craft producers went out of business, and millions of craftsmen became assembly-line workers, just as many people have been reengineered and downsized out of their jobs in the past two decades because of the inability of their companies to provide what their customers wanted at a price they were willing to pay.
8. For more information on learning relationships, see Pine et al, *Harvard Business Review*, March-April 1995. Robust details on one-to-one marketing can be found in Peppers and Rogers' fine books, *The One to One Future: Building Relationships One Customer at a Time* and *Enterprise One-to-One: Tools for Competing in the Interactive Age.*
9. See von Braun, 1990 and 1991, for a rather interesting and thought-provoking argument that decreasing the life cycles of new products can be very detrimental for a company's health. While his argument is inherently sound, it assumes that there is always a natural limit to how quickly new products can be developed, and therefore to how low life cycles can go. I believe that this assumption is false, thanks to such techniques as are discussed here. However, it is clear through von Braun's work that such an environment will become increasingly turbulent with potentially large ups and downs in revenue and profits (as new products attract customers to buy before they might otherwise purchase, reducing revenue in the future).

10. See Sanderson, 1991.
11. See Mattimore, 1993 and Choi, 1996. According to the latter, the Invention Machine Lab "codifies the invention principles behind some two million international patents and the inventive techniques of some of the world's greatest inventors."
12. Of course, the time it takes to do new activities will detract from the time savings of doing old activities faster. Whether it's supposedly leisure time at home, working time at the office, or either/both on the road, we continually find new things to do as technology frees up time on the more mundane tasks.
13 See Cruz-Neira, et al, 1992, and Bylinsky, 1994.
14. See Utterback, et al, 1992.
15. This article draws upon material from the book, *Agile Product Development for Mass Customization: How to Develop and Deliver Products for Mass Customization, Niche Markets, JIT, Build-to-Order, and Flexible Manufacturing*, by David M. Anderson, with an introduction by B. Joseph Pine II (New York, McGraw-Hill, 1997).

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Key Words

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