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Agile Manufacturing: Beyond Lean?

Overview

Agility has become the *buzzword d'jour* and the latest synonym for good. What most people are calling agile, however, is actually included in the existing concepts of flexible and lean. To make matters worse, these terms have all been used in so many ways that they have lost much of their original distinction. There is still, however, a meaning of *agile* that has proven its competitive power and applies as well to manufacturing as to any other enterprise.

Agility wins wars

Somewhere around 400 b.c., Sun Tzu [33] wrote:

> According to my assessment, even if you have many more troops than others, how can that help you win?

What is he talking about? If size and strength are not the keys to victory, what is? Down through the years, agility has evolved as one answer to that question. The modern usage of the word dates back to attempts in the early 1950s to understand what made a fighter aircraft superior in air-to-air combat. The first concepts defined fighter performance in terms of its ability to change altitude, airspeed, or direction, and energy-maneuverability (EM) plots were generated

showing where one competitor or the other had an advantage. Although EM gave a pilot useful insights, there were some disturbing exceptions. In Korea, for example, the American F-86 won handily over the Soviet MiG-15, even though the MiG had an advantage in turn and climb performance in certain flight regimes. After the war, when we had the opportunity to examine MiGs first hand, it was discovered that although the Soviet aircraft could sometimes turn tighter than the F-86, it was very sluggish and a canopy that restricted the pilot's view. The American jet had a bubble canopy, which provided better visibility, and boosted hydraulic controls—power steering for fighters—which meant that the MiG rarely had an opportunity to use its theoretically better maneuverability.

To explain this phenomenon, Air Force strategists coined the term *agility*, defined as the ability to change maneuver state, the time derivative of maneuverability. Maneuverability referred to maximum turn rate, for example 7 gs, that is, seven times the acceleration of gravity. Agility, however, indicated how fast an aircraft could go from pulling, say, six gs to the left to 6 to the right. Such abrupt changes of maneuver are typical of how pilots actually fight in combat. Pilots reported that a more agile aircraft seemed to flit around the sky and rarely presented a good target.

Up to this point, agility might seem like something useful only for fighters and soccer players. But military philosophers quickly took the concept further. One of the principle authors of EM theory, USAF Col John R. Boyd, noted that the true effects of agility were on the opponent's mind. A pilot in the less agile

(although perhaps more maneuverable) fighter, soon became frustrated and disoriented. This presented the more agile pilot with fleeting, but exploitable, firing opportunities. Boyd, a keen student of military history, made the connection between fighter agility and victory in other forms of combat. Japanese samurai, for instance, had known that by operating at a faster and more irregular mental tempo, they could cause gaps, *suki*, in their opponents' attention [20]. Several hundred years later, Rommel employed a similar strategy, believing that "in the consequent unpredictable fighting, his own swiftness of action and the training of his troops would bring victory." [8, 28] By 1978, Boyd was interpreting these observations in terms of decision cycles: Opponents in a conflict can be viewed as cycling through four distinctive but indistinct stages: *observation*, absorbing information from the environment by all possible means, and where the F-86's canopy gave it an advantage; *orientation*, placing this information in context; *decision*, selecting a subsequent course of action; and *action*, attempting to carry it out [2, 23, 27]. Note that the performance of the hardware only affects the last item, act, while mental processes, sparked by observation, account for the other three. After studying battles from Sun Tzu to Vietnam, and in particular the German blitzkrieg and its later Israeli refinements, Boyd observed that:

> Observe, Orient, Decide, and Act more inconspicuously, more quickly, and with more irregularity
>
> ... permits one to:
>
> Generate uncertainty, confusion, disorder, panic, chaos, ..., to shatter cohesion, produce paralysis, and bring about collapse

This is how small armies beat big ones, and it broadened the concept of agility from air-to-air combat to any form of conflict. In Bosnia, US pilots are finding the OODA loop concept as useful today as it proved in the Gulf. [18] And indeed, it is now generally accepted as a primary principle of strategy by the military services:

> Agility is the ability of friendly forces to react faster than the enemy and is a prerequisite for seizing and holding the initiative. [35]

Is agility only for warriors?

Business is conflict, but it is not war, despite all the nonsense that has recently been written on the subject. The primary difference, from the standpoint of strategy, is the customer. Competitors in business do not fight each other; they compete for the attention (and money) of the customer. You can use Sun Tzu all you want, but if your customer buys a competitor's product anyway, you lose. Oddly enough, however, the notion of agility applies to business with as much impact as it does to war. There is considerable evidence, cited in Stalk and Hout [32], Schonberger [30], Romm [27], Meyer [15], Peters [23], and Richards [26], that the more agile company, in the Boyd sense of streamlined decision cycles, enjoys a decisive competitive advantage. But again, this was a concept well-known to the Japanese. In the famous H-Y War, Honda turned back a challenge by motorcycle rival Yamaha not by matching that company's manufacturing expansion but by introducing three times as many new models in the ensuing 18 months [32]. Honda's strategy built on a long tradition in Japan: The notion of agility was raised

to a high degree of perfection in *The Book of Five Rings*, by the 17th century samurai, Miyamoto Musashi [19, 20]:

> In the path of victory, taking the initiative at all costs is the most important thing.
>
> If you consciously try to thwart opponents, you are already late.
>
> Use an advantageous rhythm to arrest the powerful determination of the adversary's motivation (compare to OODA Loops)

Like Boyd, Musashi emphasized that the physical aspects of conflict, while important, are secondary to the mental. And of course, the Japanese are well known for continually shortening their development and manufacturing cycles.

Agility and manufacturing

So what would agile manufacturing be? The term apparently comes from the Agile Manufacturing Enterprise Forum (AMEF) at Lehigh University, formed to continue (with $5 million of DoD funding) the efforts of a 1991 Iacocca Institute study [31]. Their definition of agility is reasonable, although the use of the word "respond" suggests an overly passive orientation [26]:

> Agility is the ability of an enterprise to thrive in a competitive environment of continuous and unanticipated change. To respond quickly to rapidly changing markets driven by customer valuing of products and services. [13]

Certainly no competent strategist would argue against any enterprise, manufacturing or otherwise, becoming more agile. However, the AMEF has had less success in distinguishing agile manufacturing from the admittedly related forms of flexible, virtual, and lean, leading some to question whether there is anything to be gained by yet one more buzzword. We will explore these concepts in the next several sections, and then return to agility in its strategic sense.

Is *flexible* the same as *agile*?

There is such a thing as flexible manufacturing, which refers to the ability to produce different products on the same production line, although some definitions restrict the meaning to products within the same general family [34]. In this sense, *agility* might be the ability to switch rapidly among the various product lines, a concept also referred to as *mobility* [34]. Flexible manufacturing in its various forms is well understood in some industries, and in fact, once a system achieves a level of flexibility it often becomes possible to extend the concept, allowing products to be designed, as well as built, in a lot size of one. Some manufacturers have created direct links to customers so that orders and even designs for products can be transmitted electronically. This is becoming commonplace in the garment industry, and is beginning to spread to the automotive sector, where Toyota and Saturn have goals of delivering a car built with a customer's options in less than a week .

There are caveats. Originally, *flexible* meant robots, on the presumption that one needed automated, programmable devices in order to manufacture different types of product on the same line. One might expect that once the process of automation is complete, the system would automatically demonstrate the virtues of flexibility, if not agility, but this has not proven to be the case. Data have indicated that automated lines tend to be less flexible in terms of product mix, perhaps reflecting the cost and time needed to acquire, modify, and program the machines

[12, 34]. Perversely, such lines can become highly "agile" within a very narrow product range.

While technology does play a role, it is generally recognized today that the best way to become flexible is to begin by reducing certain non-essential activities, setup times in particular, so that the system can produce very small lot sizes of different (but often related) products and still maintain competitive prices [11, 17]. One of the most agile automobile manufacturers, Toyota, installed only about one-third the industry average level of automation in its latest plant [7].

All of this suggests that if implemented properly, an enterprise can achieve the flexibility to compete in the marketplace and, because it is not performing unnecessary activities, can switch between products rapidly enough to be considered agile, at least from the standpoint of the production floor. Conversely, just automating what we have today is unlikely to produce either flexibility or agility, and the infrastructure and internal focus that often accompany large automation projects can bog down decision cycles and slow the enterprise's play in the marketplace, as General Motors' $30-billion fiasco demonstrated so conclusively in the 1980s [12].

Is *virtual* the same as *agile*?

Generally, a virtual company is a true company in that it carries out all the functions necessary to exploit a particular set of business opportunities [3, 4, 9]. It is *virtual* in the sense that large pieces, such as marketing, design, manufacturing, legal, accounting, etc. are carried out by legally distinct units that have come

together just for this opportunity, and will probably go their separate ways once it is over. The classic example is motion picture production . The core company may be as small as the producer him/herself, a secretary and perhaps a few administrative assistants. Everybody else on the set is likely to be an independent contractor or work for any of a number of specialized companies. Yet, for the duration of the picture, they form a real company. Can all business be done, and done better, by virtual organizations? The concept is new, so evidence is anecdotal, but a sizable crowd of management gurus appears to be heading in that direction [3, 4, 5, 9, 24, 25].

The reason given by business theorists to go virtual is, simply, to become agile. *Business Week*, for example, began its cover story on virtual companies with "Big companies can't react fast enough." [3] In this sense, virtual is a modular technique that a company might use to increase its agility. It should be noted, however, that there are highly agile companies that do not seem particularly virtual, although one might argue that they could become even more agile by becoming more virtual. The virtual concept is not a panacea for manufacturers, however, since it is hard to imagine how a fat virtual company would have much of a competitive advantage (i.e., What is gained by having useless functions performed by a legally distinct entity?)

As an aside, a virtual company should not be confused with virtual manufacturing, which refers to simulation of the manufacturing process so that decisions can be made before incurring the cost and risk of altering the factory

floor. Virtual manufacturing defined in this way is classic simulation, and is neither virtual nor manufacturing. Of course, one could invent a meaning of "virtual manufacturing" that is both virtual, like a virtual machine or virtual memory in computer science or like a virtual company, and which can also manufacture products. But it is probably too late for that now.

What about *lean production* and *reengineering*?

These are closely related concepts that are frequently associated with agility [16]. One of the things that keeps companies from executing rapid OODA loops is waste, in particular, performing functions that do not need to be performed. Reengineering is a process for identifying and eliminating such functions [10, 11, 14]. Thus the fashionable term "business process reengineering" is a little misleading, since the focus of reengineering is on simplifying the overall company system by eliminating processes, not improving them [11]. The term was popularized, perhaps invented, by Michael Hammer in what is still the greatest title in modern management literature: "Reengineering Work: Don't Automate, Obliterate." [10] Eliminating inventory, undoubtedly the best known illustration, is a prerequisite for converting to a just-in-time production system, which experience suggests is required for agility [6, 21, 29].

But reengineering can do more than eliminate unnecessary activities from the current system. It can attack and simplify the company's underlying structure. Many companies have accumulated strong hierarchies of non-programmatic functions, such as engineering, manufacturing, materiel, finance, and marketing. If

decisions must go up and down these stovepipes, you will have slower OODA loops than a more streamlined competitor. This will be true regardless of how much you have simplified and improved your manufacturing processes. For this reason, every known case of successful reengineering has, at some point, stripped out several layers of management and taken the bulk of decision making away from functional hierarchies. The late Mike Walsh, when he began the spectacular turnaround at Union Pacific, eliminated six layers of management [22]. And, as Jack Welch, CEO of GE, put it in his 1993 Annual Report:

> With the drag and nonsense of boundaries, management layers, bureaucracy, and formality cleared, the organization automatically accelerates.

Thus we can say that reengineering is a technique for improving the overall health of a system, and decision cycle time—agility—is one of the primary ways to measure it [30]. Cost structure and quality are two others, and a successful reengineering effort will improve them all. The end result is usually called a lean enterprise or lean production [36]. Examples abound: Chrysler today is enjoying a resurgence because it has drastically reduced its design and production cycles and is introducing one new, high quality car after another, a strategy also recently adopted by Chevrolet. In 1994, *Consumer Reports* selected the Dodge Intrepid as tops in its class, the first time in recent memory the magazine had so rated a domestic design.

Some of the proponents of agile manufacturing appear to overlook the corresponding goals of lean production. For example, *Industry Week* ran an article entitled "Agile Manufacturing: Stepping Beyond Lean Production." [31] They

noted that "lean production is regarded by many as simply an enhancement of mass-production methods." Flexibility, they claim, will inevitably suffer under lean production. Perhaps, but it will not be because the advocates of lean production have ignored that possibility:

> The lean producer combines the advantages of craft and mass production, while avoiding the high cost of the former and the rigidity of the latter ... Lean producers (in contrast to mass producers) set their sights explicitly on perfection: continually declining costs, zero defects, zero inventories, and *endless product variety.* [36] (emphasis added)

And in fact, the leanest modern producers, companies like Toyota and Motorola, are among the most flexible.

So, what *is* agile manufacturing?

It probably would have been better to have called the Toyota Production System agile manufacturing rather than lean production from the beginning. At this stage it is proving difficult to find anything in the AMEF usage that is not included in a more complete understanding of lean production. It is also becoming hard to see any payoff in continuing doctrinal debates on the concepts discussed in this paper.

But let's be honest: The practitioners of lean production, reengineering, flexible manufacturing or whatever do sometimes concentrate on the mechanics of the factory floor and lose sight of customers and competitors [1]. The canonical work on lean production, *The Machine That Changed The World,* does have a chapter on dealing with customers, but it merely suggests how to run a lean showroom [36].

In fact, it is worse than that. Trying to become lean without an equal emphasis on improving interaction with the world outside can be dangerous. This was the point of the canopy on the F-86 and why strategists emphasize observation and other mental aspects of competition. The principle applies to manufacturing as well. The fact is that the value or quality of a process cannot be determined purely by examining it within the context of the organization itself. The term "value added" should be used with great caution. Ultimately, only the customer, not manufacturing engineers, determine whether any value was added during production. How much "value," for example is added during production of unsold inventory?

This is a special case of a general principle of strategy stated by Boyd as: You cannot determine the character or nature of a system within itself, and attempts to do so will generate confusion and disorder [2]. For some reason, and this is as true in business as in war, organizations confronted by more agile competitors often exhibit this same confusion and disorder. Stalk & Hout observe that the less agile competitor often fails to understand the nature of the attack or even that one is taking place [32].

Consider the case of a warrior who, although working hard and doing all the right exercises, is so befuddled that he or she cannot ever quite decide in time what to do next. Our warrior may have all the physical equipment for agility, and be as fast and limber as any black belt, but the result is predictable: getting the stuffing beat out of him or her on a regular basis. In just this way, a focus on agile

manufacturing misses the point. Your production processes may be agile in any sense you like, but if your enterprise is not creating products and services that customers want to buy, more than they want to buy those of the competition, you will soon be stockpiling inventory quicker and more efficiently than anybody else. If you are truly into just-in-time, you'll soon build nothing at all. Some agility.

Recall back to our opening discussion that military strategists designed their concept of agility, with its emphasis on observation and orientation, to avoid exactly this sort of problem. Why not take advantage of 25 centuries of success? So perhaps there is a useful concept of agile manufacturer, something like:

> A lean producer that has extended the concept to improve its ability to function as an open system (observe), change its worldview accordingly (orient), and make timely and effective decisions.

or, put another way,

> An agile manufacturer is an agile organization in the competitive, OODA Loop sense, who also happens to be a manufacturer.

Similarly, we should broaden the idea of waste beyond its internal sense of cost to anything that interferes with OODA loops, which, for manufacturers, implies providing value, as the customer and only the customer determines it, more quickly than the competition.

Epilogue

Which brings us back to Sun Tzu. He insisted in our opening quote that one does not guarantee victory through brute strength. So what did he like? Agility, of course, as in the following (to which I have made only one slight change):

> The condition of a competitive manufacturer is that its essential factor is speed, taking advantage of others' failure to catch up, going by routes they do not expect, attacking where they are not on guard.

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