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ASP, The Art and Science of Practice: Taking the Measure of Lean: Efficiency and Effectiveness, Part I

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As a long-time (29 years and counting) researcher and writer about lean, I gave no thought to addressing lean efficiency and effectiveness until data began to show trouble in lean land. I saw that big, "best-managed" companies had mixed, long-term lean results, most of which were not good. The main measure of merit in my "leanness" research is the common one, inventory—a measure that is visible and countable in lean action zones and is readily available up the hierarchy as a standard, audited metric for publicly traded companies. Despite that, I have found the inventory metric to be subject to misunderstanding and misuse. In this two-part paper, I address the merits, uses, and abuses of this metric in terms of lean efficiency and lean effectiveness. With exceptions, inventory works well as a dominant, gratifying lean result and as a low-level indicator of lean efficiency. However, examples from five companies show inventory to be equivocal as an upper-management-level marker of lean effectiveness.

Key words: lean manufacturing; lean services; lean metrics; efficiency and effectiveness; performance management.
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We all know the difference between efficiency and effectiveness. Efficiency operates at a here-and-now detail level; effectiveness pertains to longer-range echoes of the details. How might this distinction apply to lean manufacturing and lean management? This is largely a moot question—as long as companies are doing well in their lean journeys.

Well, they aren't doing well. I began to see that in the mid-1990s during the early stages of my research, which I've called my "leanness studies." In these studies, I tracked publicly held companies' long-term (at least 15 years) inventory turnover trends. The data, which I initially collected for a few US companies and which grew over the years to many hundreds of global companies, show more disappointing trends than positive ones. These companies are the larger, presumably better-managed ones—the companies that are most likely to have an ongoing lean effort.

I consider lean's foremost objective to be quick customer response, which is sought everywhere along the value chain and pertains to all next-process customers as well as to the final user. Nearly every worthwhile lean activity shortens the time lag between process pairs. This allows quick reaction to any kind of problem while the causal trail is fresh and before mistakes can accumulate as off-target or defective inventory. This customer view of lean contrasts with other common views, as noted in the box below.

Common definitions of lean revolve around its methodologies, such as reducing wastes, mapping flows, and separating value-adding from non-value-adding activities. In this paper, we shift the emphasis from means toward ends. Among lean's ends, reduced cycle time stands out: a successful lean implementation is almost certain to deliver quicker response to the next-process customer, and beyond. Lean, which we previously called just-in-time (JIT), is unique in its overarching emphasis on reduction of cycle time—with quality considered as a valued enabler, and greater flexibility and lower cost as valued by-products.

Presenting lean (JIT) mainly as a vehicle for delivering quick response to the customer has strategic advantages. It helps to align lean with dominant customer-based concerns of marketing and to gain the active support of competitively focused senior officers.

With wait-time reduction as the goal, lean efficiency is easily measured: just time the interval. In practice, timing can be cumbersome. Nearly equivalent results come from just counting the number of units waiting: the people who are in line with you at the bank, or the number of widgets in queue before the drill press.

Lean efficiency, however, does not account for the importance of queued-up entities. Consider a road blockage, which is a common, unlean traffic condition. Clearing the road so that cars can get their drivers home for dinner in 10 minutes is of little importance compared with clearing it so that fire trucks can get to a fire in 10 minutes. In auto assembly, a container of 100 lug nuts that are awaiting their turn for fastening wheels to hubs is inconsequential when compared to a rack holding 100 wheels waiting similarly. In short, whether measured in clock time or units in queue, lean efficiency does not consider the time value of the entities waiting for service or use.

A well-rounded lean endeavor thrives on lean efficiency and the simple, direct evidence of it. It values lean effectiveness, accounting for both time and value, for higher-level oversight. However, as we shall see, for the purposes of performance management, the lean-efficiency metrics serve their action-zone managers well, whereas the lean-effectiveness metrics sometimes get lost among too many other business-level measures.

In preparing this paper, the closer I looked at the roles and limitations of lean metrics, the more issues they exposed. Thus, the scope of the paper kept broadening. The question of how to best measure lean led to my exploration of these issues:

- how accounting gamesmanship can contaminate a common lean metric;
- the valued role of visual displays of the metrics;
- how companies armed with lean-efficiency metrics can enjoy beneficial tendencies toward self-management of lean activities, which in turn points to less planning and control of lean at higher levels;
- the application of the metrics in operations versus externally in supply and distribution.

I've woven these topics into part I of this paper, along with graphical data and other helpful information from Cooper Industries and Hormel Foods.

Part II includes more detail on lean in supply and distribution, and the following issues:

- how lean metrics are properly employed in the service of continuous process improvement and strategic management;
- the close link between lean-based and quality-focused process improvement;
- the controversy over the use of inventory reduction as a goal, as opposed to a result.

Examples from three additional companies—Federal-Mogul, Toyota, and Walmart—enhance the discussion in part II.

Most of this paper centers on lean metrics for goods, given the intangible nature of services and the difficulties in developing robust lean-service metrics. We will continue by probing lean effectiveness in more detail, using the Cooper and Hormel examples.

Lean Effectiveness

Effectiveness, in general, and lean effectiveness, in particular, cannot reliably be judged in the short term. As we will see later, lean efficiency can be judged reliably, although it need not require much judging.

For its longer-term role in overseeing the lean journey, senior management needs relevant summary information. But what metric, aggregated sufficiently for executive consumption, can reliably be attributed to lean? Sales revenue? Market share? Return on investment? Earnings per share? Labor productivity? All these should benefit as results of lean, but they are also affected by a host of other factors: a more attractive, better-advertised, and better-priced product line; fortuitous plant closures and consolidations, mergers and acquisitions; successful entry into new global markets and favorable exchange rates; mistakes by competitors; and plain luck. Executives need clarity; they typically get muddled signals. Can inventory turnover, geared to the time value of waiting, shine through the muddle?

The metric's two components spill right out of audited financial statements, hallowed ground for company officers and boards. Inventory turnover is the cost of goods sold from the income statement divided by the value of inventory from the balance sheet. Both the numerator and denominator are in hard-numbered value (i.e., monetary) terms. Further, by Little's law (Factory Physics 2008), inventory is a function of wait time—or lead time, flow time,

throughput time, or cycle time, all of which have about the same meaning. Thus, rising inventory turnover is, by the authority of Little, a close surrogate for improving leanness—although that authority is hardly needed inasmuch as inventory is a fairly convincing, visually prominent lean indicator.

Lean Effectiveness at Cooper Industries

In my search through approximately 1,350 graphs in the leanness database, that of Cooper Industries (see Figure 1) stood out as an impressive, positive example. (The database comprises at least 15 years of inventory turnover graphs for publicly traded companies in 37 countries. Each year, I update the graphs with another year's data from audited financial reports for each company. My primary aim in this longitudinal research is to shed light on these companies' capabilities to sustain a lean trend over the long term.) The very long upward trend in inventory turns at a high rate, as Figure 1 shows, is a mark of lean effectiveness at Cooper. No action is required of senior managers other than to participate in recognition and celebration events. (To assess lean effectiveness, I have taken "long trend" to mean a double-digit number of years—enough to test the staying power of lean, given changes in management, technologies, competitive thrusts, and so on. Bayou and de Korvin 2008, in their research on measuring leanness, use only three years as the time horizon.)

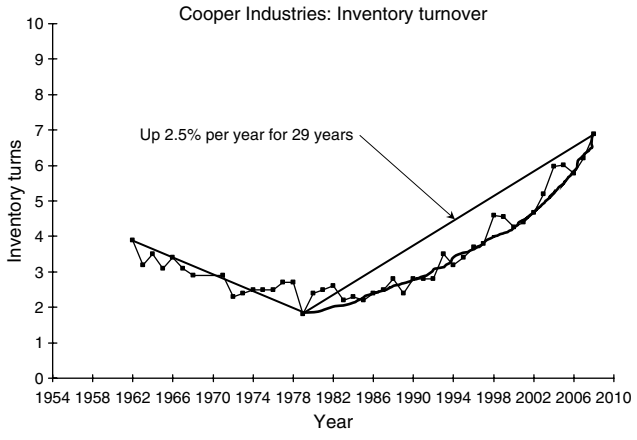

Figure 1: This graph shows the downward, then improving, long-term inventory turnover trend for Cooper Industries, as well as its improving *rate* of improvement in the indicated 29-year period.

To learn more about what Cooper Industries had been doing right, I interviewed a company officer and studied the firm's annual reports and website. I learned about Cooper's strong emphasis on cash flow in recent years. Its executives should have been gratified by what the graph in Figure 1 shows: 29 years of increased working capital generated through disinvestment in inventory, at an average rate of 2.5 percent per year—at compound interest. Because, as I also learned, Cooper is engaged in company-wide lean, its management might also have viewed the improvement in lean terms: time compression, providing 29 years of cementing ever-stronger provider–user ties along the value chain, also at something similar to compound interest.

> Explanation: Just as wealth grows year to year by compound interest in an interest-earning account, so should tightening lean linkages with suppliers or customers yield codependency benefits, compounded year upon year.
>
> Analogy: If you have sporadic contacts with someone, you have an acquaintance; if your contacts are moderately frequent and extend for some months, you have a friend; if you and that person interact almost daily and for years, you have a best friend with all the understanding, trust, and reliance that builds over that lengthening time span.

Cooper's inventory trend also caught my eye for its concave upward shape, showing the company has improved its *rate* of improvement. What factors might explain that upward accelerating trend? Could mergers, acquisitions, and divestitures have something to do with it? Perhaps so. As a Cooper executive explained, the company's product portfolio has evolved through the years from that of a conglomerate to a more focused producer of electrical products, tools, and hardware. That shift might explain much of the rise in turns from the early 1980s through much of the 1990s. In more recent years, as I learned, Cooper management has given emphasis to lean and six sigma, which might explain the steepening rate of improvement.

Ralph Keller, president of the Association for Manufacturing Excellence, has been persistently pointing out that lean practices are overly focused on in-plant processes, when greater lean benefits reside in the supply pipelines. Many manufacturers, he says,

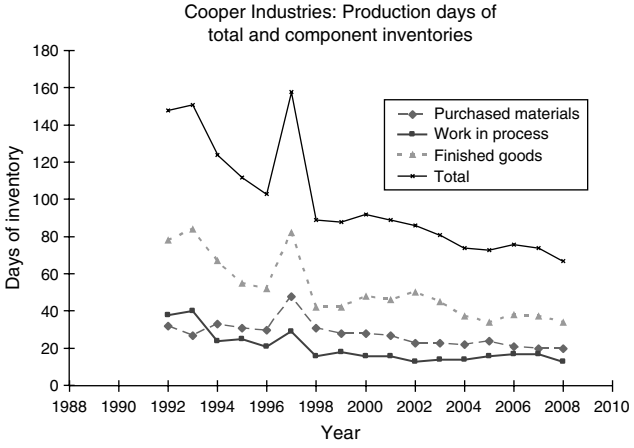

Figure 2: The four trend lines show declining production days of total inventories, purchased materials, work in process, and finished goods for Cooper Industries.

"are seeing the direct-labor portion of their cost of goods sold [dropping to] single-digit percentages while purchased components and materials often account for over 60 percent . . ." (Keller 2009, p. 5).

Do Keller's comments apply to Cooper? I went back to my leanness database to look at the components of Cooper's inventory (see Figure 2) for the period 1992–2008. (For many of the companies in the database, I've accumulated a second set of more detailed graphs that break down total inventory into purchased, in-process, and finished inventories.) Here, the data are in production days of inventory rather than turnover. (Executives often prefer the "days of" form, which marries with days of accounts receivable and accounts payable to equal days of working capital.) We see that in those 16 years, Cooper's days' inventory have declined in all three components. Shrinking both work in process (WIP) and finished goods by more than 50 percent suggests success in synchronizing production and shipping to customers' demands. Reduction of purchased inventory by about one-third also indicates synchronization upstream to suppliers, which may be partly a result of Cooper's strategic sourcing and vendor-base rationalization efforts. Thus, downplaying acquisitions and divestitures, Cooper looks to be an achiever in lean supply chain management, lean operations, and collaborative lean with customers.

Caution: Component inventory trends (see Figure 2) seem to offer superior guidance on the effectiveness of the lean pursuit, pinpointing which of the three areas (i.e., purchased materials, work in process, finished goods) needs attention. For accounting reasons, it is not that simple.

Most people among the "lean literate" know about distortive effects of conventional cost accounting—that the system rewards low unit-cost production of goods, even when the goods are made in large "unlean" lots far in advance of sale and even when little or no demand for them exists. But that's old news. These days, one must know something about lean accounting, aimed at correcting accounting's faults while improving performance management—topics with which I've long been involved.

One tendency that I've found especially detrimental, and not only to lean, is that management fixations on generating cash flow can deteriorate into accounting gamesmanship: The easy way to look good is to get inventory off your company's books and onto those of suppliers and customers. This says nothing about the reality of excess inventory and the ills that go with it. You are still paying for those ills, although your books falsely say you are doing well. Your suppliers and customers are trying to do the opposite—get the inventory off their books and onto yours. Companies need to redirect some of their lean management toward subduing the game playing and, through collaboration, intensively fixing root causes. In Cooper's case, the numbers alone do not tell if Cooper has been exercising its big-company clout to push its inventories onto the balance sheets of its suppliers and customers. Because I know the company only from a researcher's distance, I can only give Cooper the benefit of the doubt at this time.

Hormel: Confused Lean-Effectiveness Signals

In Figure 3, we see the opposite of Cooper. Hormel's turns have worsened at a rate of minus 1.6 percent per year for 40 years, with inventory growth that is eating away at Hormel's working capital. (This situation is not because Spam, Hormel's iconic product, has made inroads all over the world only to take up larder space in the just-in-case mode; Spam is not a major revenue item for the company.) Hormel executives should be concerned, although a company officer points to

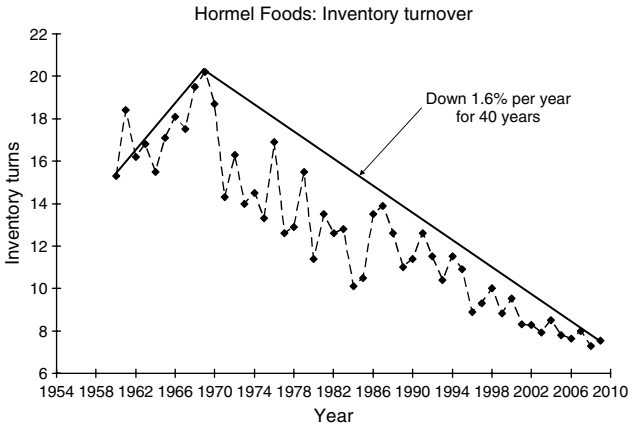

Figure 3: After improving for a few years in the 1960s, Hormel's inventory turnover trend is shown in sharp decline for four decades.

a mitigating reason: Hormel has been transitioning-away from bulk meats with their short shelf lives for years. The evolution (also evidenced in inventory graphs for other leading meat processors, but not shown in this paper) is toward more inventory-intensive products—high value-added items involving precooking processes and special shelf-life–friendly packaging.

Still, this is the meat business, in which product aging and bacterial contamination can be ruinous. More than most industries, meat producers should be ardent about lean's mandate to shrink or check the growth of inventories—its own and those of suppliers and customers. My database includes Hormel's component inventory trends only for the period of 1997–2009. I find that raw and in-process (RIP) inventories, lumped together in company documents, show an unclear up-and-down pattern. Finished packaged meats have trended upward from a low of 21 production days to a current 28 days—a trend that is clearly not good.

The Cooper Industries and Hormel examples show that inventory trends should be viewed as a good starting point in assessing lean effectiveness. Executives—and consultants and researchers—need to read between the (trend) lines. Two additional company examples are discussed in part II of this paper. For now, let us probe lean efficiency, which, in contrast to lean effectiveness, has mostly straightforward application and benefits.

Lean Efficiency

Lean efficiency comes from local acts: reducing wait times for customers in want of goods or services, or reducing time in queue or storage before use at the next process for a physical item. That kind of time-based efficiency is at the core of most lean activities.

Time in queue, although it is lean's main focus because of its customer sensitivity, has disadvantages when compared to number in queue. The number of units in an active zone queue or in storage is quick and easy to determine, just by counting. In manufacturing, wholesaling, and retailing, inventory counting routines are elements of good management and are legally required by accounting and tax laws. Kanban, a lean basic (Schonberger 1983), sets an upper limit on number of units between one process and the next, making kanban both a formal queue limiter and a queue-variation limiter.

Time in queue, as a lean-efficiency metric, has another deficiency: it lacks in-place visibility. In contrast, number in queue stands out visually. Anyone in or walking by the work place—operators, supervisors, stock handlers, technical support, controllers, executives, or customers—may, at a glance, reckon number in queue. Any kind of interference, such as late arrival of materials or defective work, shows up in its own way, but also in the form of lengthened queues. Thus, the simple, visual observation of number in queue is like a snapshot of the process-improvement whole.

However, a casual snapshot has little impact. The queue condition must be formalized through other elements of visual management, such as posting a kanban number. I'm impressed when I see progress put on display with before and after photos and diagrams, supported, for example, by Pareto charts that show causal factors and verbiage on their correction. Add to that a graph showing progressive reduction of the queue (a shrinking kanban quantity), and the scene impressively takes on the appearance of systematic lean-based improvement.

When indicators of lean efficiency are widely on display, lean acquires the potential for self-management at low levels: visually prominent queue numbers and progress graphs become motivators for engaging the workforce in queue reduction, and they offer perpetual targets for improvement. Ideally, well-trained low-level lean teams generate most of the improvements

and self-plot each result. The graph is self-rewarding when there are continual improvements, self-scolding when there are not.

Role of Management and Professional Staff

Done well, all this reduces the need for managing lean through layers of goal setting and managerial follow-through. Ah, but I don't think it is often done well. More commonly, the visual elegance of lean efficiency is compromised by a hierarchy of planners and controllers taking charge. Such management overkill may partially explain lean's common tendency to falter. Schonberger (2008) provides research-based evidence of this tendency.

I believe that there are two main reasons why managers and professional and technical staff tend to dominate lean activities. The first is weak training. The workforce, because it lacks the necessary training, is not charged with using its experience, hands-on common sense, and constant in-process awareness in the cause of continuous improvement and lean efficiency. In the second reason, proclivities, action-oriented managers, and staff are rightfully concerned that process improvement and lean succeed, have the expertise to take charge of the improvements themselves, value the additions to their career development and résumés, and relish the glow that comes with each implementation. Whatever the reasons, their involvement is too sporadic (their activities center on intermittent projects), expensive (they are high salaried), and limited (in military terms, there are "not enough boots on the ground").

What are the proper roles of intermediate managers and staff? The trainer of racehorses provides an apt metaphor: the trainer marshals resources (horses, facilities, stable team, food, jockeys, etc.); launches activities, ensuring thorough and systematic training; keeps up with best practices; and provides ready access and wise counsel. The trainer feeds, grooms, times, flatters, celebrates—but doesn't personally race the horses; finally, the trainer keeps the owners informed but waives them off unwise interference.

Summary: Part I

I see lean as still an immature adolescent. We sort of know what it's supposed to do, but we don't have a good handle on how to control it. Good performance measures would help a lot. We have them at the efficiency level: the current-state measures are wait times and queue times (cycle times, in lean lingo) and inventory counts. We obtain improvement measures, which show trends, simply by subtraction: prior mean number in the queue minus current number. In application, these measures are visually, numerically, and motivationally cogent.

At the effectiveness level, lean is less easily assessed. Great-looking inventory trend data, averaged and aggregated for an entire business unit or company, are buffeted by a host of factors other than lean effectiveness. In looking for meaning among the trend lines, executives must probe the externalities and decide if they make a difference. In executive lingo, built into US financial regulations, it is a question of "materiality" of those externalities.

There are still more of the externalities. In part II of this paper, I deepen and broaden the quest for lean effectiveness measures using examples from Toyota, Federal-Mogul, and Walmart.

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ASP, The Art and Science of Practice: Taking the Measure of Lean: Efficiency and Effectiveness, Part II

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In part I of this two-part paper, I stated that lean's dominant purpose should be seen as cycle-time (wait-time) reduction, which—counted in units of inventory, its close relative—is visually prominent and easily measured at low (efficiency) levels and high (effectiveness) levels in the hierarchy. Part II continues with observations on lean's strategic value; additional cautions about uses of inventory trends at the executive level; examination of lean metrics in retailing, wholesaling, and services; and lean's relationship to quality and other elements of continuous-process improvement. More data from my "leanness studies" offer support for my observations.

Throughout much of my involvement in the still-evolving lean era, I have kept in mind the milestone article, "Time—The Next Source of Competitive Advantage" (Stalk 1988), and the follow-on book (Stalk and Hout 1990). These two works articulated the strategic advantages of quick, flexible response, which had endowed Japanese industry with a distinct competitive advantage. Seeing the "Japanese miracle" in operational terms—just-in-time production and supply with total quality control—was fine for implementation purposes. However, getting and holding the attention of senior leaders, the target audience of the article and book, required understanding of its strategic importance: that the "miracle" was largely about time compression, and that time compression is highly customer sensitive and therefore competitively vital.

The Stalk and Hout book includes case-study examples at Honda, Toyota, Harley-Davidson, Milliken, Federal Express, and Walmart. I use Toyota and Walmart as examples; Federal-Mogul serves as a third example.

To begin part II, we consider lean and its performance measures in the greater realm of continuous process improvement. Following this broad introductory topic, the discussion turns to lean and quality issues at Toyota; the negative effects of erratic long-term inventory trends, using Federal-Mogul as an example; the high rank of inventory as a lean-effectiveness metric in retailing and distribution, featuring Walmart; and finally, excessive use of inventory reduction as a goal.

Lean and Process Improvement

In their pursuit of process improvement, companies may direct their energies toward cycle times, quality, supply chains, flexibility, safety, dependability, and (or) orderliness. We can identify each of these as a separable set of methodologies: lean, total quality (or six sigma), supply chain management, agility, behavior-based safety, total productive maintenance, and 5S. All are interrelated and make up most of continuous process improvement.

Process improvement is more than just another management initiative. I am persuaded that it is an essential of good management in any organization. Wherever it is active, the organization's officers will sometimes need to assess whether the proper benefits are being attained. An executive cannot tell just by roaming the work sites and hearing about and seeing lean-efficiency successes and deficiencies—a practice familiar to lean practitioners, and one popularized earlier by the acronym MBWA—management by wandering around (Peters and Waterman 1982). Doing so is worthwhile. It keeps the executive "in the game," with freshened awareness, and demonstrates high-level interest and support. The evidence, such as graphs of shorter queues, less rework, and quicker setups and changeovers, may look great, but how does it all add up? And compared to what? The senior staff will want answers in summary form—the kinds of aggregated competitive measures they are used to and can quickly consider.

Given the fragmented nature of process improvement, few satisfactory ways to express progress in executive-level terms are available. Such measures as quick changeover, smaller lots, and space compression—and, on the quality side, defectives, rework, and scrap—do not roll up well for consumption in the executive suite. In the case of goods, although not human services, two that are consumable at senior levels are inventory turnover for lean and warranty costs for quality. Both indicators have high-level appeal because they are standardized, customer and marketing sensitive, and monetarily derived. In human services, the lack of standard financial measures of lean or quality requires that each organization devise its own, for example, mystery-shopper reports in retailing, length of stay for hospitals, late arrivals for airlines, and customer satisfaction surveys for any service entity.

Whether in goods or services, no company is a champion in all aspects of process improvement. As companies make changes, including to their senior-management teams, process improvement becomes strained and in need of renewal. Toyota is a case in point, especially in regard to the lean and quality dimensions of process improvement.

Lean and Quality Erosion at Toyota

We know two things for certain about Toyota: it has suffered considerable real and reputational angst over issues about the quality and safety of its automobiles. And, as Figure 1 shows, it has experienced a long and deep plunge in inventory turnover, the most common indicator of lean performance. Its turns had risen to a stratospheric 23 in 1988; it then got stuck around that point for five years before sinking for 16 years—all the way to 12 turns. Are the two Toyota issues—slipping quality and leanness—related? It seems likely.

To a strong lean advocate at any company, a many-year worsening trend in inventory turnover should be upsetting (except when obvious extenuating circumstances exist). For this to have happened at Toyota, long esteemed as a developer and continuing master of lean manufacturing, is astonishing to the outside lean advocate. However, Toyota insiders would have

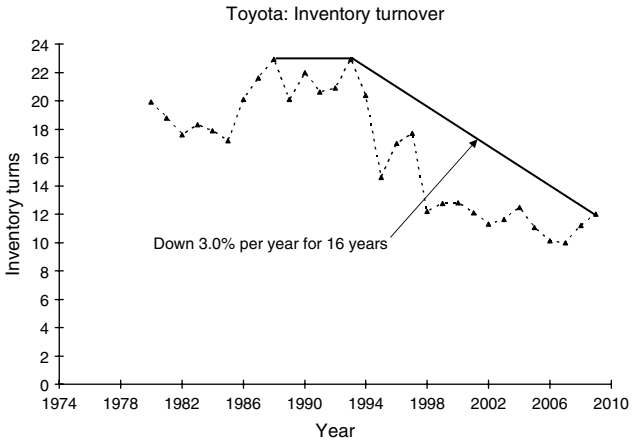

Figure 1: After reaching a peak in the late 1980s and early 1990s, Toyota's annual inventory turnover declined for 14 years before recovering somewhat in the last two years.

seen the inventory statistics worsening for years, as I have as a plotter of inventory trends for Toyota and many other companies in my longitudinal research.

A close reciprocal relationship exists between quality and inventory. Bad quality corrupts the processes with disruptive turbulence, extra inventory as scrap and rework, and the need for "just-in-case" buffer stock; good quality avoids that process corruption. Inventory reduction improves quality by exposing quality issues early, before they magnify and ripple, and while causes and evidence are still active and actionable; inventory growth has opposite, worsening effects.

Much of the speculation in the news as to what went wrong at Toyota centers on errors in product engineering. Thus, we are to conclude, this knowledge of what went wrong isolates what Toyota must do to fix its quality problems. However, it covers only the already-known quality problems (and does not get at the issue of Toyota's fixation on pell-mell growth, which may be the main underlying culprit). Defects buried in the enlarged inventories are not known yet, and the slowed reaction times residing in the inventories make finding the causes that much more uncertain.

Toyota's quality problems, known or unknown, cannot be isolated to a particular stage of the value chain. Figure 2, showing production days of inventory, illustrates the reasons, as described in the following list.

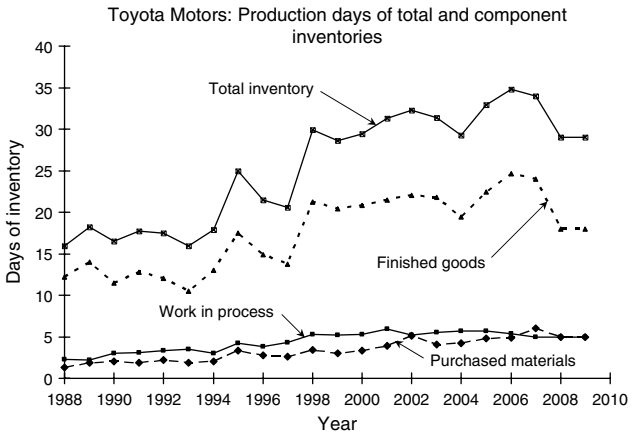

Figure 2: The four trend lines show, for Toyota, growing production days of purchased materials, work in process, finished goods, and total inventories.

• Toyota's finished goods (vehicles and service parts) have nearly doubled, from a low of 10 days in 1993 to a recent average of approximately 20 days. This growth represents erosion of customer connectivity, and an extra 10 days' worth of problems to discover and resolve.

• Work-in-process and purchased materials trends follow similar patterns. Each has grown from approximately 2.5 days in 1988–1989 to a mostly flat 5 days in recent years. That extra work in process plus raw materials adds up to 5 more days of delay in discovering and fixing quality problems.

I wondered if strong lean trends among Toyota's suppliers might be offsetting some of Toyota's own sinking inventory turnover. In checking my leanness database, I found 13 Japanese manufacturers whose main business is producing automotive parts. Six of them, suppliers Aisin Seiki, Koito, and Denso, and affiliates Toyota Industries, Daihatsu, and Hino Motors, are close members of the "Toyota family." Denso's inventory turnover trend has been flat. However, the turnover trend of the other five producers has been sharply down for 13, 15, 15, 22, and 21 years, respectively—trends that seem as bad as or worse than Toyota's 16-year decline. These unlean trends have injected still more slowed responsiveness into the value chain, thus elevating risks of late discovery of quality problems.

Caution: As I discussed in part I, using other company examples, inventory numbers at the company level can be skewed by shifts in the product line and other major company changes. However, Toyota does not appear to have changed its spots much; it is still a car company. Thus, the worsening trends strongly suggest that backsliding in lean has impaired cause-and-effect connectivity along the manufacturer's value chain.

Although Toyota serves as a good example, all companies with flat or growing long-term inventory—about 70 percent of the more than 1,300 companies in the lean database (Schonberger 2008)—should realize the following: Usually, as inventory grows, quality problems grow with it, and vice versa. And a flat trend in inventory tends to coincide with general malaise in overall process improvement, including attention to quality.

We turn now to still another, more subtle, concern about measuring lean effectiveness: the skewing effects of an erratic long-term inventory trend.

Federal Mogul's Long, Erratic Upward Trend

The merits of even output as applied to lean scheduling of factory operations are well understood. Manufacturers plan for it through the use of takt-time scheduling, because uneven production brings forth buffer inventory buildups and costly delays. The consequences of unevenness in long-term inventory turnover are not so readily recognized—but could be a good deal worse.

Consider Federal-Mogul. Its inventory turns have improved at a rate of 1.4 percent per year for 35 years (see Figure 3). Since 1990, however, Mogul's turns have exhibited extreme unevenness. Although a diversified company with an ever-changing product portfolio is likely to experience erratic inventory patterns, Federal-Mogul, which has mostly stuck to its knitting—automotive parts—is not such a company.

Figure 3 includes dashed lines representing (very inexactly) upper and lower control limits, as in statistical process control. Points above or near the upper limit signify abnormal highs in inventory turns. Because high turns come from low inventories, Mogul's marketing managers may have been wringing their hands over impending or actual stockouts and its purchasing and production managers about

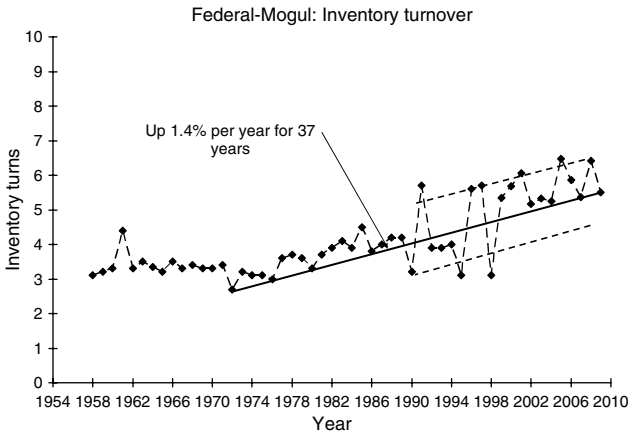

Figure 3: For Federal-Mogul, this graph shows an improving long-term inventory turnover trend but one that becomes highly erratic in more recent years. The dashed lines are rough approximations of upper and lower statistical process control limits.

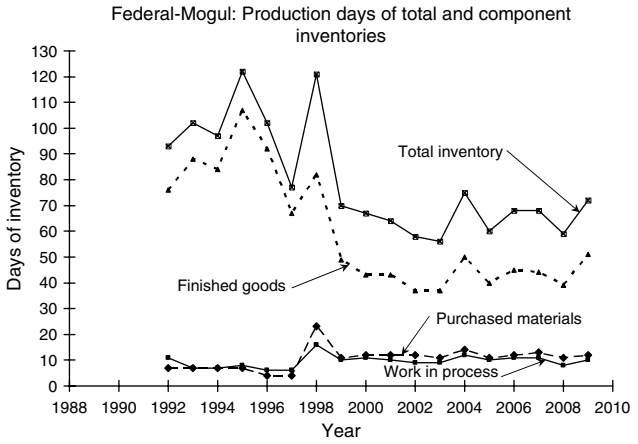

Figure 4: For Federal-Mogul, the four trend lines show sharp declines in production days of finished goods and total inventories, but not much change in purchased materials and work in process.

back orders and overuse of capacity, including costly overtime.

On the contrary, points below or near the lower limit point to gluts of inventory. The consequences could include (1) excess purchased materials gathering carrying charges in bulging stock rooms; (2) scheduling below productive capacity, perhaps to the point of shutting down lines and laying off employees; and (3) sales mounting promotions and cutting prices to move finished goods out of clogged distribution warehouses. At Mogul, it was all consequence (3), not (1) and (2). Figure 4 illustrates the evidence: purchased materials and work in process are low and steady; finished goods are high and highly variable—and responsible for nearly all of the company's erratic turns. In other words, purchasing and production were operating with impressive (in standard lean terms) evenness but were pumping out finished goods that appear to be poorly synchronized with what customers were buying. As to why, a spokesperson at Mogul told me that most of the inventory spikes relate to acquisitions and divestitures. Still, the unevenness is extreme. Mogul's finished inventories, high over the 17 years and very high in 1993, 1995, and 1998, were a costly burden.

In 2001, cash and earnings woes forced Federal-Mogul into reorganization under Chapter 11 bankruptcy. We may judge the especially erratic turns in the 1990s (see Figure 4) as a contributor to Mogul's financial crisis in the 2000s. The company, however, has survived; it emerged from Chapter 11 in 2007, reorganized as New Federal-Mogul. Partially offsetting the high costs of unevenness are the 37 years of rising inventory turns, generating (1) working capital usable perhaps for product development, better equipment, and employee training, and (2) tightened linkages with suppliers (although not with customers)—bankable assets to cushion some of the blow of Chapter 11 and keep Mogul viable as a survivor.

So far, all our examples of uses and misuses of cycle time and inventory as lean metrics have been in manufacturing. Most of the concerns disappear in retailing and wholesaling, which we consider next.

Lean Effectiveness in Retailing and Wholesaling

Retailing and wholesaling are much more inventory intensive than manufacturing, and their inventory represents a far larger component of cost. Inventory, in these sectors, therefore stands high among financial business metrics. Walmart—the platinum standard for lean retailing—seems to have built much of its business strategy around that business metric. Its inventory turns have improved at an average annual rate of 2.3 percent over the past 18 years (see Figure 5). Moreover, Walmart's upward trend line is not erratic; it is

Figure 5: Walmart's inventory turnover is shown rising modestly between 1978 and 1990, then rapidly for the next 19 years.

nearly arrow-straight, which is surprising inasmuch as the company has aggressively expanded globally, including making a few large acquisitions and in some countries false starts. The trend lines (not shown) for retailers Office Depot and Staples and distributor Avnet are nearly as good, although these companies have not had to face the challenges of moving massively into global markets as Walmart has. Retailers and wholesalers have only one category of inventory—purchased materials, which are not transformed into work in process and finished goods. Impressive trends, such as those of Walmart and Avnet, are therefore owed mainly to lean supply chain management (SCM). Manufacturers might do well by taking lessons from these SCM experts.

Inventory Reduction as a Goal: A Bad Idea

Did Walmart's heralded lean supply chains stem from setting tough inventory-reduction goals? I doubt it. Rather, I think, they represent Walmart's primary means of meeting the promise of its long-standing business model and marketing slogan, "everyday low prices." One does not have to be a retailer to understand that lower prices require lower costs, which in retailing requires lower inventories.

That logic also holds in manufacturing, although inventory is a lesser component of cost in this industry. Go to nearly any manufacturing plant with a lean initiative; you'll see performance charts showing two lines: one for actual performance (on inventory, quality, etc.) is erratic; the second, which is usually a straight line, represents the goal. It seems that goal-setting behaviors are so entrenched among managers and executives that setting inventory goals is hard for them to resist.

Here's the problem: setting an inventory goal is sure to reduce inventories, that is, purchasing to buy less, production to produce less, and distribution to keep less in stock. Likely perverse results will be stockout-induced production stoppages, reintroduction of costly expediting, shortages in order fulfillment, and customer defections, all of which adversely affect both top and bottom lines.

Lean effectiveness—measured by inventory numbers—must come from process improvements: acts that reduce queues and lot sizes, flow distances and space, defectives and breakdowns, and other causes of delay; that make the human and physical resources versatile, flexible, and responsive; and that develop suppliers and customers as process-improvement partners. "Goals are necessary for you and for me, but numerical goals set for other people, without a road map to reach the goal, have effects opposite to the effects sought" (Deming 1986, p. 82).

Although management goal setting has become almost universal in business, a contrarian body of knowledge has arisen (Ordóñez et al. 2009). What contrarians there are in the field seem to be mostly quiet, although I've found one who is worth quoting: Ed Grinde, Business Unit Controller at Watlow Electric, Hannibal, Missouri. (Watlow is a pioneer in lean accounting applications.) Grinde says, "There are too many variables that the value stream cannot control to make hard goals realistic"; he prescribes, instead, "making sure your value-stream metrics are trending in the right direction" (Cable 2009). Brosnahan (2008) includes more information on Watlow's lean accounting.

Summary: Parts I and II

In this paper, I have placed lean and its metrics on an examining table. Lean and quality, lean's close partner, warrant that attention because their main results are highly customer critical. All customers throughout the value chain want what lean aims for—quick, flexible response with high quality.

Lean is administratively fat if it requires a lot of managerial, professional, and technical hand-holding, and it becomes limited to discontinuous improvement—occasional projects—if its wait-time reduction activities are dominated by the same. Quality at the source—in which the first responsibility rests with those doing the job—is a bedrock concept in the more mature subfield of quality management. First responsibility for lean should be no different, because lean-based improvement and quality-focused improvement are close working partners in continuous process improvement.

Companies measure leanness, and do so frequently, partly because measuring it is so easy and so visual: just time the wait or count the units waiting. These measures of lean efficiency are useful for the same reasons a dieter might step on a scale almost every morning: to keep the quest freshly and constantly in mind, to glory in each improvement, and to motivate corrective action when indicators go negative.

Lean's benefits for a services provider can show up multiple times per day, in the form of customers or clients being processed with dispatch rather than annoying waits. For all that immediacy of lean delivery and response, lean effectiveness in services is not easily captured in aggregated form, simply because the time value of services is difficult to measure. An inventory-intensive organization, on the other hand, can readily provide its senior managers with a lean effectiveness indicator—an upward-tilting trend in inventory turnover—that accounts for both time delay and monetary value. For our dieter, the closest counterpart might be the doctor's charts, which move the doctor, after a few years of your dieting, to say that your risk of diabetes, hypertension, and so on are way down; keep doing what you've been doing. Both the company executive and the doctor, however, need to look carefully at various causalities that are not accounted for in the metrics.

This two-part paper, in considering lean metrics from several angles, implicitly answers the unstated question: Do we really even need measures of lean efficiency and lean effectiveness? A clearly yes answer applies to lean efficiency: without the simple, visual, high-validity measures of it—counts of units waiting—those in the best position to effect lean transformations have little in the way of a steering mechanism; lean becomes a rudderless boat. We've seen that lean effectiveness measures, which senior managers surely need, are imperfect, because the best metric available, long-term trend in inventory turnover, is sometimes less an indicator of lean and more of changes in basic company conditions.

My research reveals that there is more to the question. Most of the lore of lean centers on lean in operations, where any heaps of work-in-process inventory are obvious targets. The much larger issue, for most companies, is gluts of inventory and commensurate long lead times in supply and distribution channels. These inventories are, as they say, "out of sight, out of mind." Companies do have their own accounts for them: raw material and finished-goods numbers. What companies usually do not have are data on how much inventory suppliers are carrying for them plus how much are in transit. The same goes for finished goods in the distribution system. These inventories are not only out of sight, they are on the other parties' books. Financial metrics that encourage screening off and pushing off these external inventories act as a disincentive to collaborate with supply and distribution entities to correct the causes. If means are not developed to deal with these issues, lean will continue its tendencies to focus inwardly and neglect the typically huge unlean external inventories and compromised responsiveness.

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