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Dr. Knuf has left the University of Kentucky and is now Principal, Organizational Learning Systems, Inc., and can be reached at joachim.knuf@leansystemsdesign.com or (859) 559-5345.

NORMAL EXCELLENCE:
LEAN HUMAN PERFORMANCE TECHNOLOGY AND THE TOYOTA PRODUCTION SYSTEM

Joachim Knuf
University of Kentucky

Mark Lauer
Indiana University

An ethic of value

The field of Human Performance Technology (HPT) is establishing itself rapidly at the intersection of a number of disciplines that are all invested, in their various ways, in investigating, and then promulgating, methodologies that make human effort in the workplace more effective. What distinguishes HPT from prior organizational practice, originally associated with the Taylorist (‘scientific’) management practices of the Fordist or mass-manufacturing era (Taylor, 1911; Tsutsui, 1998), is not simply a reaffirmation of the essential unity of physical and intellectual effort that had been severed by the counterproductive segregation of work and its management but a foundational commitment to an ethic of value that guides the design of work systems. The definition of such value is ultimately relational and collaborative within the value chain and, in any case, permanently emerging as system dynamics change in response to physical, organizational, economic, social and intellectual factors. It is thus not simply effectiveness that is sought by HP technologists but the delivery of work that is relevant and meaningful to all its constituents. The central role of value in the work system shields the constituents against abuse and thus ensures that HPT serves as an enabler of value generation benefiting society rather than as an instrument of raw performance extraction at the hands of the owners of the means of production. Ultimately, of course, only equitable systems are sustainable and likely to produce both a satisfactory return on capital *and* a high quality of life for those at work and those who depend on them.

In this chapter, we focus in particular on some HP technologies embedded in the Toyota Production System (TPS), which has given rise to a family of manufacturing, or perhaps better, business systems that are generally described today as 'lean.' The quality of leanness, elusive in both concept and practice, is usually described negatively, as the absence of waste; here, however, we want to demonstrate its ultimate grounding in the ethic of value already introduced. For the purposes of this chapter, then, a (business) system is considered lean if all its constituents and relationships fully satisfy the value definition of the recipient of its output, expending only the minimum of effort necessary towards that end while yielding a rent sufficient to the long-term competitive viability of the system and respecting and empowering, at all times, the people in it, as well as protecting the environment. It is important to understand that leanness is hence not a teleological property of a system, and thereby an absolute; there is, in other words, no lean end-state. Instead, lean systems, in their respective ways, react to the pressures of their competitive markets by continuously developing new intellectual, organizational, behavioral and physical resources that reduce that required effort in a manner that maintains the integrity of both system and value proposition; the reduction and elimination of waste plays an obvious contributing role in this. Lean systems are therefore autopoietic; they evolve in a process of self-determination that demands, on the one hand, continuous reflection on all current activities, especially communication and learning exchanges, on the other, close monitoring of the characteristics of the system environment. Self-determination is partly strategic and centralized, partly decentralized and local, consigning necessary decisions and resources to their appropriate place in the organization by balancing the requirements of reactive speed and of strategic alignment, all with a view to value optimization.

The relativity of leanness to the requirement of a customer and to the principle of respect protects human performers as well as nature against exploitative practices in pursuit of the ultimate rent. Mature lean systems therefore seek to achieve pace before speed, build to order rather than to capacity, restrict their output to actual consumption, are adaptive instead of rapacious, flexible rather than dogmatic, always seek simplicity, show minimal social and functional segmentation of processes, prefer horizontal to vertical organization, emphasize communication and transparency internally and externally, regard empowered people as their main asset, and execute their processes preferably in teams, which produce both material and intellectual outcomes. Indeed, lean systems are epigenetic systems, in which the state of the work system here and now has resulted in an evolutionary manner from previous ones that have proven to be useful there and then. Note that epigenesis is not a linear process in which new ideas accumulate over time, "but rather (…) a system of concepts and experiences recursively connected and in continual evolution" (Bertrando, 2000, p. 85). One of the signature practices of lean systems, continuous improvement or *kaizen,* is thus immanent system epigenesis providing, if a simpler metaphor might serve, 'the little engine that could.'

The literature on TPS and lean systems (in Europe, 'lean production') has grown rapidly, especially after the establishment of Toyota's first wholly owned manufacturing plant in Georgetown, Kentucky, in the mid-1980s (Abo, 1994, 1998; Besser, 1996; Bremner & Dawson, 2003; Cooper, 1995; Cusumano, 1985; Imai, 1986; Kenney & Florida, 1993; Liker, 2004; Liker (Ed.), 1997; Monden, 1993a, 1993b; Ohno, 1988a, 1988b; Schonberger, 1982, 1986; Schreffler, 1986; Shingo, 1988, 1989; Spear & Bowen, 1999; Taylor, 1990; Womack & Jones, 1996; Womack, Jones, & Roos, 1990; Yasuda, 1991). However, technological discussions form the main thrust of these publications, whereas human and system perspectives have not fared equally well (Besser, 1996; Knuf, 1995, 1996, 1998; Kochan, Lansbury, & MacDuffie, 1997; Parker, 2003; Springer, 1997, 1999; Wood, 1993). Moreover, not everything that has been written is enlightening, nor is it ultimately consistent; studies purporting to represent the reality of lean work life have been conducted too often in environments that do not really deserve that name, even though some lean shop-floor tools may be have been in use (Delbridge, 2000). Indeed, labor relations and human resource management topics have shown particular polarization (Babson (Ed.), 1995; Fucini & Fucini, 1990; Green & Yanarella, 1996; Hampson, 1999; Harrison, 1994; MacDuffie, 1995; Moody, 1997; Rinehart, Huxley, & Robertson, 1997; Springer 1999). In general, there is a distinctive lack of actual research on lean human performance. This is due in part to the small number of companies that have mature lean systems, in part to the reluctance of these companies to allow access to what they perceive to be the source of their competitive advantage, in part probably also to a general failure in the research and professional communities to understand the substantive distinctions between mass-manufacturing and lean systems.

It seems appropriate, then, to attempt to remedy this situation and unravel the lean system with a view to what it can teach us about human value generation or "worthy performance" (Gilbert, 1996). Below, we will attempt to tie the features of this work system back to themes of interest to students and practitioners of HPT. Along the way we hope to add to the more common focus on performance outcomes, in particular on performance gaps, problems and interventions (Carr, 1995; Dick & Wagner, 1995; Foshay & Moller, 1992; Harless, 1995; Rosenberg, 1990), a process dimension stressing the opportunities dormant in regular work system design and thereby bundle the 'what' in HPT a little more closely with the 'why' and 'how.' Ultimately, of course, the technologies of human performance must be returned to the performers themselves, so that they can create and then improve work systems in which possible behaviors always default to correct behaviors—and where excellence is normal!

Genesis and epigenesis of the lean system

It is said that necessity is the mother of invention, and this is true of the principles and practices that make up the lean work and management system. Originating in Japan at the end of World War II, the lean philosophy and the tools and practices derived from it were a direct response to the severe financial and material limitations under which Toyota and other Japanese auto manufacturers struggled (Fujimoto, 1999; Ohno, 1988a, 1988b; Reingold, 1999; Toyoda, 1987). The system crystallized in an environment of social crisis, economic need and material poverty, energized by an entrepreneurial mandate to match the highest existing production standards within a short period of time (Ohno, 1988a, p. 9) and then fueled by the serendipitous surge of demand following the outbreak of the Korean War. At that time the avant-garde of Japanese industry had already experimented with Western management approaches for fifty years or so (Tsutsui, 1998) and was about to receive further assistance from US quality gurus like Deming and Juran (Aguayo, 1990; Deming, 1986; Gabor, 1990, Tsutsui, 1996). However, many of the solutions to the post-war economic challenges were home-grown originally or greatly reinterpreted and modified Western imports. In how far characteristics of national culture played a role in all this remains a matter of opinion; the successful establishment of Toyota transplant organizations in many countries around the world would argue against a culture-determinist view (Besser, 1996; Knuf, 1995).

The Toyota Production System (TPS) did not develop from a carefully designed master plan. It emerged a little at a time and then proceeded to evolve from the steady stream of ideas and experiments of the dedicated members of a company that was fighting for a way to survive (Yasuda, 1991). In this respect, nothing has changed at Toyota; *kaizen* continues the epigenesis of TPS today. In addition, TPS originated as a growing accumulation of more or less discrete elements and could not be considered an integrated system suffusing all aspects of business until about two decades from its inception. Today, while TPS is writing its own future, other companies are adding to the lean system, contributing the unique extensions required by its many derivative applications in industries characterized by products of high variety, of low volume, with unique design and engineering requirements, as well as in those not using discrete but constantly flowing materials, such as chemical, pharmaceutical or food processing. Furthermore, we observe highly interesting efforts to leverage lean systems into transactional environments, for example, accounting (Cunningham & Fiume, 2003; Maskell & Baggaley, 2003) or engineering and product development (Itazaki, 1999; Sobek, Liker, & Ward, 1998; Ward et al., 1995), as well as into service industries (George, 2003), health care (Lewis, 2001; Panchak, 2003), government and education.

Several attempts have been undertaken to unravel the building blocks of the lean system (Liker, 2004; Schonberger, 1982, 1986; Spear & Bowen, 1999). Below we advocate a different view, one that is serious about an assertion often heard but never cogently explained, and will treat the lean system as a business *philosophy*. We propose that, like all philosophies, the lean philosophy is grounded in a plausible, parsimonious, discrete (or independent), and consistent (or non-contradictory) set of foundational assumptions (or axioms), that these assumptions give rise to a small number of derivative principles, and that these principles in turn guide actions, behaviors, practices, or the use of lean tools, in other words, define the visible face or the technology of the system in performance. This whole lean philosophy ultimately attaches to a specific business model, which we will characterize first, before discussing three foundational assumptions and four principles of the lean philosophy. Some of the important actual performance technologies are described subsequently.

The lean business model acknowledges the reality that at least in industrialized societies the days of unlimited demand for mass-produced goods are waning. Lean systems are conceived around the construct of a relational customer, not that of an anonymous commodity market that may or may not absorb product, with any absorption uncontrollable by the manufacturer, hence necessitating substantial, and expensive, inventories of finished goods to meet high absorption, respectively costly campaigns and ultimately obsoletion of products under low absorption. Commodity markets do not allow a sufficiently targeted value definition as customers and their demands are unknown. Conversely, customer anonymity makes it impossible for the manufacturer to compete on grounds other than price, whereas lean companies can tune combined product and service offerings to other, known, customer value propositions, for example, convenience, availability, after-sales services, life-cycle support, innovation, ecological concerns, esthetics, and so on. Many companies find that it is this very ability to offer additional services that enables them to retain and eventually grow their customer base. The relativity of all elements of the lean system to a specific customer value proposition is its central feature; in the terms of systems theory, value functions as the 'strange attractor' that reveals the order ultimately inherent in a chaotic system (Gleick, 1987; Wheatley, 1999).

Lean foundational assumptions

The lean system, then, provides a unique business and work environment. It is built around a small number of fundamental assumptions, or axioms, that distinguish it from the Fordist world of mass manufacturing. Most importantly, as we have already discussed, lean systems are about *value generation and growth*. It is a satisfactory value definition that ultimately authorizes all production and support activities throughout the value chain—the partnership of suppliers, manufacturers and distributors. Only superior value, compared to competitors in the (increasingly global) market, can ensure that customers return and provide future income opportunities to all the members of that value chain. Mass-production economics looks upon the price of goods and services as the sum of material and production cost plus desired profit. The ability of a company to show a profit is hence a function of the price it can command for its product. Such thinking was reasonable at a time when market demand was unlimited, quality driven by proprietary technologies or privileged knowledge, and producers had high control over consumer behavior. Cost control, certainly of concern in conventional business thinking, was, however, a primarily tactical pursuit, that is, occasional and opportunistic. From the lean economic perspective, the price of a product or service is assumed as already fixed by the market, where innovations typically manage to assert themselves only briefly against imitation products of comparable functionality and quality. Given a fixed price, profit is then a direct function of cost control. In other words, the lean enterprise identifies the production process as the major source of sustainable income—luckily one that is under its exclusive control, aided by its partners in the value stream. At the end of the day, of course, total value chains compete in the marketplace, not so much companies by themselves (Christopher, 1998).

The second foundational element of the lean system is its relational nature: *relationships* between the members of the organization itself, between different functions and departments, and, externally, among the various partners in the value chain secure customer value. Lean organizational structures and processes of manufacturing, as well as support functions, rely fundamentally on strong relationships of individuals and groups, of business units and partners. Evidence can be found in the basic team organization, which is characterized by the smooth and synergetic collaboration of a small number of operators in a well-defined work area, supported by a team leader who also spends a significant amount of time on the line. Similarly, larger units collaborate, such as functional domains in concurrent design and engineering, both in-house and involving suppliers as partners. Continuous improvement of the production system is largely in the hands of *kaizen* teams and quality circles, whose membership is voluntary. The salaried staff typically rotates through different areas of responsibility on a scheduled basis, thereby supporting the lateral integration of all elements of the system. Furthermore, the assembly of products depends on the just-in-time delivery of parts and components manufactured by a closely integrated network of internal and external suppliers.

Given the importance of relationships, lean companies typically offer extensive training programs to enhance their members' knowledge and abilities in this area, among them courses in communication, listening, presentation skills, effective meetings, small-group interaction and, of course, the basics of the lean system and behavior (Knuf, Haney, & Lauer, 2003; Knuf & Lauer, 2004). For the same reason, they send out people to visit partner plants and suppliers for internal or external benchmarking (Knuf, 2000). This aspect of the lean system by itself accounts for an important proportion of knowledge transfer and provides opportunities for organizational learning for both partners. Finally, relationships work best if power is distributed and shared. In view of this, lean companies provide for the broad delegation of decision-making and problem-solving authority to the operational interface and encourage the involvement of team members in all work management issues. Serendipitously, this also builds trust and commitment, two exceedingly valuable assets when facing rapidly changing environments.

Both relationships and value are mediated by the final foundational element of the lean system, its *people*. Lean companies could not function without the constant attention of people at all levels of the organization to the system of work. The full commitment and support of operators is as essential as that of the leadership or the functional groups. In the lean system, people are the ultimate source of authority. Operators are empowered to make important decisions about the work they do. As we shall see below, they routinely stop production, hundreds of times each shift if necessary, to address problems and quality issues the moment they are recognized. Moreover, they determine the rate of workplace and process improvements by contributing ideas that result in safer, more ergonomic, simpler and less costly work—evidence that they take ownership of every aspect of the business, from the shop floor to the offices. Last but by no means least, only people are capable of learning, and so the continuous evolution of the lean system depends on their efforts. In this truly ubiquitous task senior leaders, middle managers, and operators all collaborate. The teaching cascades through the organization and is strategically supported by strong communication pathways and the use of dialogue, narratives, and other means (Knuf, 1999). As senior people work with junior ones, not only do they impart their knowledge, but they also acquire a firm understanding of the work their reports do. This shared knowledge strengthens the vertical integration of the company and, in turn, supports relationships.

Lean principles

Given the foundational value definition originating with a relational customer, the importance of relationships and ultimately of people in actually delivering that value, we can now identify a small number of derivative principles that guide the resulting daily activities of the lean system. Prominent among them is that of doing everything *just in time*. Value to the customer is maximized if all direct production and associated transactional activities necessary to produce what the customer has ordered are arranged along a unidirectional time line characterized by a regular, sustainable pace and minimal activity interruptions from internal (e.g., equipment breakdowns, mistakes) or external sources, such as shortages of materials supplied by a vendor. Transactional support functions interface with production seamlessly and directly, migrating pertinent decisions as close as possible to the respective activity, thereby allowing maximum participation from local members of the organization under conditions of ideal visibility of the elements of the situation. Production and transactional activities are typically tightly coupled (Glassman, 1973; Weick, 1976) with a minimum of strategic buffers, which is a powerful technique to force exposure of problematic areas. All activities are triggered and then paced by an actual customer demand, not by a forecast. This creates a type of tight coupling that is particularly attractive to any business, that of its expenditures on production with the revenue flow from the customer. In other words, in the lean world tight coupling applies to cash-to-cash cycles also.

Lean systems continuously strive for stability. The principle of *stability* is balanced dynamically by that of *continuous learning and improvement,* or *kaizen*. In a lean environment, stability comes in many forms. Below we discuss in some detail various relevant performance technologies; let us mention briefly some other sources of stability:

- Sophisticated employee selection and assessment processes, followed by extensive and ongoing education and training (Knuf, Haney, & Lauer, 2003; Knuf & Lauer, 2004), comprehensive use of personal development plans, proactive evaluation methods and organizational development efforts help standardize work behavior at all levels of the organization. Education broadens and deepens knowledge and understanding, training reduces the variability in human performance.
- Such investments in people make sense as long-term employment is protected to the greatest extent possible (including, as a first preference, managerial self-sacrifices) while compensation systems ensure high satisfaction with working conditions and careful work design maximizes the sense of personal accomplishment that is conveyed so motivationally by a job well done.
- Lean supply-chain management creates stability in the flow of purchased components through the process. Negotiated long-term relationships with a major (and often a back-up, minor) supplier ensure that mutual investments in the close

coordination of production efforts among all members of the value chain pay off in reduced fluctuation and reliable availability while keeping inventories low.

- Production control tools clearly signal daily requirements to the workforce and update everyone on the shop floor in real time about their performance against the plan. This provides full visibility of production obstacles and also warns workers of any overtime that will be required to close the production gap at the end of the shift.
- Maintenance personnel keep all equipment in excellent working order and address any emerging problems at the earliest point of manifestation. Plants are scheduled to run two shifts only, with overtime buffers between them, leaving several hours for plant and equipment maintenance during shut-down every night. Production workers participate in the maintenance effort by continuously monitoring settings on tools and equipment and confirming the quality of the parts they are producing.
- Coupled to this, an *andon* or stop line enables workers to signal any deficiency at the very moment when it is discovered. The *andon* board then alerts support staff to the area and the deficiency is rectified with full participation of the workers. If that is impossible within the given production time interval, the *takt* time, production will come to a full stop until temporary, and in due course permanent, countermeasures are in place.
- This particular lean tool is an important element in assuring quality at the source, that is, within the manufacturing process itself, where the optimum configuration of materials, skills and expertise, and functional support is available to fix such problems just in time; quality cost increases proportional to the distance between the point of origin of a problem and its point of discovery and rectification.

Other examples of the stability principle could be mentioned, but the present list should suffice to indicate the central importance of stability to the lean system. Stability, of course, then becomes the platform for continuous improvement, for which another set of techniques is available, as we shall see below. These two principles describe, in short, the crucial lean dialectic that couples the non-standard to the standard, forming out of this inherent contradiction a higher synthesis that in time becomes the foundation for the next generation of value-adding activity—pregnant with its own contradictions. Thus system epigenesis can be seen to have infinite points of origin, yet it also has but one target: superior customer value.

A final principle underlying the lean system we want to mention here is *respect for people*. The activities we are describing in this chapter clearly require considerable degrees of personal dedication, discipline and physical, paired with intellectual, effort. This effort can only be voluntary, so it has to be elicited as a response. Respect is an appropriate trigger. It derives from an appreciation of noticeable accomplishments of another person (or of a team), is therefore a feedback mechanism that acknowledges those accomplishments. A consequence of the principle of respect is the protection of a worker's employment against the consequences of continuous improvement efforts. Here reassignments are needed, and generally there are many opportunities for someone with advanced *kaizen* skills to benefit other areas of work. Understandably, people will not consciously improve themselves out of a job, so members of lean organizations typically are assured by senior management that only dramatic downturns in the company's business will force personnel reductions. During good times, in turn, these companies will also take on new employees only very slowly and deliberately as they understand the force of this mutual commitment.

Elements of lean human performance technology

In the following paragraphs we attempt to describe some of the ways in which the lean work system is designed to maximize *normal* human performance. In this respect what we propose here may differ in emphasis from the more typical assignments of HP technologists. For their lean colleague, the goal is not so much to provide specific interventions or an intervention capability within an existing organizational process, to close gaps between given and optimal performance; from a lean perspective, systems should produce very high levels of performance as a norm—and preferably by default rather than choice—and only exceptions should be managed, in numbers steadily decreasing over time as systems mature. In fact, such systems and all their subsystems should be designed to learn and self-correct where the minimum effort is required, that is, *at the level of their operations*, including, of course, those in the transactional realm. As a result, HP technologies for performance assurance and then its continuous improvement must be provided to the workers themselves, in preference to external experts, as workforces mature. Gaps are addressed within this normal process, immediately as they emerge. Since HPT is rational and scientific, the lean system has to provide broad capabilities at data collection and the use of analytical tools to its members to support this effort; commensurate authorization, for example, through a carefully designed system of interlinking team charters overlaying the work flow, is a must.

The description of lean human performance technologies below remains at a sufficiently general level and avoids descending into the world of specific industries or work functions. We are seeking to capture the essential elements of a number of central process features that have to be in place to call a work system or enterprise 'lean.' The grounding of the various technologies in the foundational assumptions and principles described above will be apparent with a closer reading. It is this grounding in the lean philosophy, and then the everyday, living engagement of all members of the organization with that philosophy, that ultimately secures reliable responses at the behavioral level that are consistent and sustainable across the total process and allow the leveraging of intellectual resources to its continuous improvement. The overall integration of the technologies speaks to the strongly syntagmatic nature of the lean system: it excels at creating smooth interfaces in a highly complex horizontal process array concatenating dissimilar elements (machines, people, functions, organizations), supported by strong communication, relying on the competent and timely performance of work as the product progresses stage after stage towards the customer.

Pull and flow

As we noted, all production commences only in response to a specific customer order. The objective is then to concatenate all required activities effectively to flow the order toward the customer. This typically entails the close physical collocation of the different workstations through which the product will flow, often in dedicated work cells; this approach applies to the physical side of production as much as to transactional activities. In the ideal case, then, when the order arrives, the product is removed for shipment not from a warehouse where it has been stored (at potentially considerable cost) but directly from the final station in the production chain. This station then no longer has work. It therefore removes product from the previous station and executes its own finishing operations. At the same time, the previous station removes product from the next one upstream to work on. This process reaches back to the beginning of the production chain and initiates the first production step, in all likelihood pulling materials and components from external vendors in successive moves all the way through the tiers of suppliers to the origins of the value chain. All such movements of product (and associated services) are synchronized by technical and logistic means in a minutely calibrated pace or *takt*. As the product advances through the chain, information about what is required to complete an order travels backwards and outwards—upstream from station to station in the plant and outwards to partners in the supply chain.

As a good example of the just-in-time principle at work, the lean system is also known as a *pull system*, because it does not rely, as does the (mass-manufacturing) push system, on starting as much product as possible on the basis of a forecast and then running all work stations at maximum capacity to achieve high asset utilization and absorption rates. Such conventional mass-production practices quickly build costly in-process inventories in front of slower operations and cause idling behind them. A system such as this is almost designed to be wasteful! In contrast, pulling product, preferably piece by piece, from the back of the process allows manufacturing to proceed with minimal inventory—just enough to do the job on hand. Only what actually has been sold to the customer will be produced. Pulling product on demand reduces cost and leads to the discovery of many kinds of waste, not only in the form of costly inventories of finished products that might go out of fashion or become obsolete through innovation. Even minor changes in customers' engineering specifications tend to result in expensive rework or scrap. Where large batches of product built to inventory are defective, such masked defects will only become apparent when the first units from that batch are shipped and rejected by the customer. In-process corrective action becomes practically impossible.

More than customer value is realized in pull and flow systems, however. In a just-in-time environment, relationships are crucially important and define the ultimate productivity of the value chain. The best relationships are reciprocal—a form of dynamic stability we find in the lean world. All operations are concatenated effectively and democratically. No work process is more or less important than any other, all have to connect equally and equitably, on shop floors as much as in offices. Furthermore, this performance principle extends to the network of mutual customers and suppliers both inside and outside the plant. Since every supplier is also a customer, accountability and authority are balanced. Of course, the ultimate determination of value remains in the hands of the customer.

Superior flow also leads to an increase in quality. This occurs in two basic ways. First, quality problems are discovered quickly because the parts flowing through the manufacturing process are not coming from built-up inventory. Instead they are pulled from the station immediately preceding it. If there is a quality problem, it is quickly detected. And this leads to the second benefit to quality. If there is good flow there is little need to build up inventory. Thus the risk of a quality problem going undetected because it is masked by inventory is greatly reduced. Good flow therefore serves to increase quality without special effort. It allows for flexibility in meeting changing customer need. Since inventory is not being built up, any changes a customer desires may be more readily accommodated. Finally, flow leads to shorter delivery lead times. A plant floor with good flow delivers products on the customer's schedule more easily because there are reduced levels of work-in-progress and smaller batch sizes, ideally of one single piece only.

Single-piece flow

By incorporating the principles of just-in-time production and stability, the technique of single-piece flow fulfills all three lean foundational assumptions. Single-piece flow is relational in that it links all operators, suppliers and production steps, it produces value by reducing inventory cost, and it is enabled and sustained by the continuous attention of people. As a technology, it reduces lot sizes to the essential minimum. Product is moved from station to station, determined in quantity and kind by customer demand, and the needed materials flow individually and evenly to those stations. This is advantageous because it allows the fastest turn-around of products in response to changing customer demands. Where customers require products in specific mixes, single-piece flow makes such production schedules possible. This is a complete reversal of mass-market, large-batch production thinking, where economies of scale are relied on to control cost and enhance competitiveness.

In the mass-market manufacturing process, economies of scale are determined externally by discounted purchases, internally by the cost of set-up time: A machine that is being set up cannot produce value. However, direct and indirect set-up costs are not often calculated correctly. These costs include long lead times to the customer, since the current batch has to be built—and all materials consumed or removed—before another product can be manufactured; wait times in subsequent processes in cases of delays and errors; damage to parts; inventory costs and additional handling times as large amounts of materials are stored, processed and stored again at work stations; and the inability to detect quality problems through timely receiving inspection at the next station, requiring sorting of the whole batch once a defect in even a single product has been found.

Still, some technological aspects of production are not as flexible as others. For example, in changing the dies in large presses more time is consumed than the system-wide *takt* time makes available for work on the current unit. Changeover times will therefore have to be distributed across several production *takt* time units, and hence batches of some kind will be scheduled, leading to the undesirable build-up of in-process inventory. However, these batches can be much smaller than those calculated by traditional mass manufacturers, as long as operators are skilled in adjusting the tooling quickly. Obviously, hourly set-ups provide much better flexibility—and avoid more inventory and other cost—than daily schedules. Set-up reduction is a continuous learning process that can yield astounding results. In the case of a 1000-ton press used by Toyota, set-up times were reduced, step by step, from a high of four hours to three minutes (Suzaki, 1987, p. 43); note that this learning process spread out over 25 years of sustained effort! Some authors claim that quick die changes are the heart of just-in-time production (Shingo, 1985), although effective lean supply chain management is of obvious importance also.

Set-up reduction or quick changeover

Performance technologies supporting quick changeovers and set-ups of equipment, sometimes referred to as SMED (single-minute exchange of dies), support the ability of the lean system to react with minimal delays to the requirements of the customer and to flow product toward the consumer. Several forms of waste, such as excessive inventory and waiting, are eliminated in this process, and customer value increases proportionally. Mastering quick changeover involves a number of connected elements. First, the process must be closely studied and documented; then, the workers responsible for changeovers must be carefully trained on the standard procedure to be used. This is supported by detailed and strongly visual standardized instructions. Finally, all necessary tools, attachments and other needed equipment must be available. It is essential that any speed gain never come at the cost of safety!

At the heart of quick changeover there is then a system of standardized procedures that reduce the amount of effort it takes to prepare a piece of equipment to run a different part. A good way to measure this effort is by examining the time it takes from running the last good part of the previous production to running the first good part of the new production. From this description it is also clear that quick changeover is actually a continuous improvement technique that helps to reduce waste in the production process. Advantages include the increased availability of equipment, with which comes reduced downtime and the ability to make more products without further investments in capital goods; increased operator efficiency, as more parts can be run in the same time; reduced overtime as a related benefit; better flexibility in accommodating changing needs of customers without requiring significant levels of safety inventory; and, in general, support of single-piece flow, with the advantages already described.

The changeover process is unique for each piece of equipment. However, analyzing a changeover for redesign follows a general process. The first step in quick changeover is to *make a record* exactly how a changeover is currently done. This requires operators and set-up specialists to perform an actual changeover, which may be videotaped and observed in every detail. All steps performed in the changeover must be documented, numbering them in the correct sequence. Descriptions must be detailed and the amount of time taken by each step must be recorded carefully. It is important that this record reflect the differences between internal components of the changeover (activities that can only take place when the machine is shut down, such as removing and replacing the die) and external components (things that can be prepared or done while the machine is still producing parts, such as preparing the necessary tools). Also noted are all of the problems that become apparent during the changeover, such as excessive walking time, adjustments, availability of all tools and components, waiting, and other forms of waste. Next, it is beneficial to keep the shut-down for changeover as brief as possible. Downtime can be reduced by making many of the internal changeover process steps external, so they can be performed while the equipment is still producing parts. Some of the ways in which this can be done is to bring out dies early, before the production run is finished, locate all of the tools and materials that will be needed next to the machine, and ensure that the people required for the changeover are available. Finally, many machines use bolts to secure changeable parts such as dies. In a lean system, this fastening method is often supplanted by simpler clamping devices. It is also important to maintain all tools to tight tolerances and use gauges to determine the exact location of dies or other critical machine parts. Both practices contribute to the elimination of adjustments. Add to these lots of practice and continuous team support, changeover times can be cut dramatically, contributing to customer value.

Total productive maintenance

While we are on the topic of the role of equipment in the lean work system, we should mention another technology common in the lean environment, total productive maintenance (TPM). Traditionally, maintenance has been the responsibility of a specific group of employees. In the lean system, through the TPM process, maintenance also becomes the responsibility of all workers. This serves three basic purposes. First, it improves equipment reliability. If individual equipment reliability improves, then the entire production process becomes more reliable. Second, it helps maintain good flow. If the production process is reliable, *takt* time is more readily maintained and flow improves. And finally, TPM increases safety. If equipment is well maintained, the risk to employees who must work around it is reduced.

In most lean systems, TPM has five elements, the first of which is *cleaning*. Operators clean and inspect their equipment in accordance with the principles of 5s, which are discussed below. Clean equipment makes it much easier to identify potential maintenance areas. This is followed by *inspection*. Operators inspect their equipment on an ongoing basis. When dirt and debris are removed from equipment, a person can easily start to find specific problems that need to be corrected. The earlier a problem is identified, the less likely flow will be degraded. Next, *check sheets* must be created. When cleaning and inspecting, workers keep track of the time it takes and the steps that need to be followed to properly clean and inspect the equipment. From this, a check sheet is created that will be used as a historical record to understand and determine how much time it takes to clean and inspect each vital point of the equipment. This check sheet is a tool that can be used to direct the thinking of workers and work teams and possibly lead to improving the cleaning and inspecting process. As in all aspects of lean work, *skill development* is another important element. Team members increase their maintenance skill levels in order to be able to take on more complex maintenance procedures with their equipment. Indeed, operators often receive more *advanced maintenance training*. This advanced training will allow operators to increase their ability to predict machine failures and take corrective action before the machine goes down.

In addition, TPM typically involves several other elements, of which we want to mention two. *Single point lessons* are training aids that show a particular maintenance point on a piece of equipment that needs to be cleaned and inspected. These are used with a check sheet that lists all of the single point lessons that the team goes through when conducting TPM on a particular machine. Furthermore, three-part tags help communicate that there is a problem with a piece of equipment that cannot be fixed during the scheduled TPM period. The three-part tag system visually identifies problematic equipment. The tagging process is straightforward: first, a worker places one tag on the equipment in the approximate location of the problem. This tag describes the problem the equipment is experiencing. Then, a second copy of the tag is given to the production schedulers. A third copy of the tag resides with the supervisor of that area. This tag is used for the planning of the repair.

The benefit of using a three-part maintenance tag system is that it makes all associated maintenance activities concurrent. Schedulers can reschedule production onto other machines or time slots, maintenance can spring into action directly, and internal customers can be alerted about production conditions. If TPM is done correctly, it has the potential to reduce unexpected downtime to negligible levels.

Kanban

As product is pulled and flows step by step towards the customer, raw materials and components will be needed in the workstations. For the close coordination of supplies to their points of use, a specific lean technology is available. The *kanban* technology was inspired by the experience one of the founding figures of TPS, Taiichi Ohno, gained in visiting American supermarkets (Ohno, 1988a). He noticed that shelves were continuously restocked as product was removed and applied this insight to the shop floor. Much as customers leave behind money so the supermarket can order new product, so operators who remove materials leave behind a *kanban,* or order card, which authorizes material handlers to restock the location. Similarly, *kanban* cards can enhance the flow of a product from station to station. The number of *kanban* cards is determined by the amount of material in the system, the speed of its consumption, and lag factors deriving from the resupply turn-around time and the various administrative processes to move cards and send out orders. The use of *kanban* takes a lot of the guesswork out of production. Supervisors do not have to determine what is to be made as the actual and precise requirements are communicated via one of the *kanban* signals. This also helps eliminate waste in the production process. Ultimately, *kanban* is a supply-chain communication tool; it controls inventory visually, makes scheduling easy and supports the reduction of waste, such as excessive stocks of raw materials and work-in-process, as well as material movements and overproduction. Notice how this supply-chain technology also accomplishes prompt first-in-first-out stock rotation, which reduces spoilage cost—another form of waste.

Kanban cards contain information about the nature of the product, the place where it is used, and the location where it is kept. Some *kanbans* circulate between stations in a plant and are therefore referred to as ‘in-house’ or ‘move’ *kanbans*. Other *kanbans* connect the plant with a supplier's plant, to signal that more parts are needed. These *kanbans* are also called 'interplant' or 'replenishment' *kanbans*. There are five basic *kanban* signals.

- *Cards* can authorize employees to move or make an item. Here the *kanban* is a returnable order form. It comes attached to a container of materials and often is a never-ending ticket that keeps circulating. As a worker begins to use material from the container, the card is sent back to the station that produced the parts, which authorizes that station to make the same quantity of the same parts. All *kanban* cards together regulate the flow of materials through workstations, promoting single-piece flow. The system will not function if cards are not returned promptly or if they are mislaid or lost. Good discipline is essential to the success of card use as a *kanban*.
- *Containers* can authorize an employee to make an item. Sometimes a container is used without a special card attached to it. In this case, the container itself becomes the *kanban*. As a workstation consumes parts produced by another station, the empty container is sent back to that station. When it arrives, that station is now authorized to make just enough parts to fill the containers and then send them back to the station that needs them. The size of the container determines the number of parts produced. When there is no empty container to fill, parts are not produced.
- *Flags* can signal the need to start making an item. Flags or similar signals mark the level at which parts inventory will have to be replenished so that the consuming workstation does not run out. They are found typically in lot production and not where there is a container-for-container replenishment system.
- *Squares* or other shapes can be considered reserved parking spaces for containers or carts with materials; as a location is vacated by the removal of materials in a workstation, the empty space signals the need to produce more parts to keep the space filled. No parts can be produced until space is available where to put them, thereby keeping inventory levels low.
- Computer screens can authorize production and can display production directions. In this case the consumption and replenishment of materials and parts is regulated electronically, usually by operators scanning bar codes as they consume materials, telling the workstation that produced them to make another small quantity.

Kanban is one of the performance technologies by which employees manage their own work, here inventory control and material flow. Shingo (1988) claims that managing this information flow will eventually allow producers to adopt a non-stock production system that will eliminate all waste from this aspect of manufacturing. *Kanban* is an instantiation of the just-in-time principle; as a system, it also stabilizes the manufacturing process by keeping it supplied with all required parts in the right quantities. It removes the waste of waiting and inventory and thereby reflects the value axiom. Furthermore, *kanban* regulates the exchange of products in the supply chain, underscoring the relational nature of the lean system.

Takt time

Takt time (from the German *Takt*, or musical meter) has been referred to several times already. As a lean technology that steers the flow of product through the manufacturing process it exemplifies the principles of just-in-time and stability and promotes value and relationships. The *takt* or pace of production is determined by the number of products that have been sold and need to be manufactured. *Takt* time therefore is a technology that allows the matching of production pace to the pace of customer sales. By taking the total available operating time (that is, regular overall work time minus breaks, maintenance, clean-up, etc.) and dividing it by the daily total demand for product, a figure is derived which forms the basis of all steps to produce a component or product. The *takt* time prescribes the total sojourn of the product in any workstation. All workstations have to be synchronized through careful workload leveling. Use of the *takt* time technique sets demanding standards for production. Any deficiency in the process will surface promptly and lead to learning and improvement. Other lean technologies integrate with *takt* time: *andon*, *kaizen*, *kanban*, *heijunka*, standardized work, and single-piece flow.

Here is an example to illustrate the concept, assuming a standard eight-hour work shift (allowing 30 minutes for breaks and cleanup), with a required quantity of 1000 units per day. Daily operating time is:

> *7.5 hrs (8 hrs – 30 minutes) x 60 (minutes) x 60 (seconds) = 27,000 available seconds in a workday. The resulting takt time is 27,000 ÷ 1000 = 27 seconds.*

In its purest form, *takt* time is determined by the customer. If customer demand increases to 2000 units in a given shift, *takt* time drops to 13.5 seconds in the above example. Likewise, if customer demand drops, *takt* time increases. Incidentally, *takt* time can be difficult for workers to embrace initially; the technology goes against what most workers have had drilled into them since the day they stepped on the mass-manufacturing line: make it fast, and make as much as possible. *Takt* time does not follow that philosophy. In fact, some stations that have been racehorses in previous production schedules may actually have to reduce their production rates to maintain *takt* time. What matters in the lean system is not the capability of the equipment or the skill and knowledge of the worker: it is solely what the customer needs and when he needs it that determines the synchronization of production.

Takt times vary considerably in manufacturing industry; whereas the automobile sector figures its *takt* in seconds, production progress on airplanes or ships may be measured in days or weeks. In any case, however, *takt* provides a numerical basis for procedural discipline and adherence to the system and is hence a driver for quality and productivity. Without a strong *takt* image, it is difficult to create a sense of timeliness and urgency in the production environment; adherence to the production plan then becomes a matter of personal discipline and therefore more difficult to sustain.

Leveled production (heijunka)

Just-in-time production and adherence to *takt* time benefit if some leveling techniques or *heijunka* can be introduced to mediate between demand *peaks* and the work process. In the absence of such mediation, people, equipment and material capacities would all have to equal the historically highest customer demand lest business and revenue be lost. This is obviously very expensive and hence wasteful.

Creating technologies for leveled production is a complex task that is influenced by market characteristics, the nature of the relationships with customers, the technological capabilities of the manufacturing system, the product mix and order cycle, and other factors. Accordingly, solutions differ. Toyota effectively uses a three-step order buffer to level its own production both in terms of demand levels and sales proportions of its models. (Toyota Motor Corporation, 1996). Their leveling effort hence relies on strong relationships in the value chain. Toyota dealers inform the company about their anticipated sales for the following month, providing an overall framework for resource planning at all points in the supply chain. Dealers base their figures on their own yearly and monthly experience, but they also add flexibility to the distribution network as a whole: they can affect production leveling by increasing sales through both internal and external promotions or decrease sales by not having enough cars in stock. In the second step, Toyota dealers transmit actual sales every ten days, and these figures provide the basis for detailed production plans in the plant itself and among all suppliers. Finally, some adjustments in specifications, such as vehicle color, can be made with as little as three days' lead time.

Other companies have developed production scheduling techniques suitable to their own environments. Among them we find the use of multiskilled workers who can be assigned to different product families as needed; modular production lines that can be set up quickly to satisfy temporary demands; variable *takt* times that speed or slow production; a flexible, temporary workforce that can be added to the core workforce as needed; partnerships with other manufacturers to handle overflow at demand peaks; promotional packages or price adjustments (in both directions) to influence order volume directly; use of time not needed for production to hold continuous learning or improvement activities; and many others. Leveled production is made possible by the application of the four principles of just-in-time, respect for people, standardization, and continuous learning. In turn, leveled production improves relationships among all people in the organization, and of all partners in the supply chain, as cyclical stress build-up is avoided, and it creates value by averting the inefficiencies of inventory, equipment, and overtime or staffing demand peaks.

Andon

But what happens when in this elegantly ordered flow of production steps something goes wrong? The *andon* technology is part of a visual control system that empowers operators to stop production the moment a defect or other problem is detected. Thus it is related to the error-preventing *pokayoke* technology described below, which is also applicable to human processes. Team members are trained especially to use a defect signaling system, the famous *andon* cord (or its equivalent, for example, a stop button), which summons immediate team leader support to a local problem situation and also notifies everybody in the work environment by the use of prominently displayed signal boards that communicate current production conditions publicly. If attempts at correction are ineffective within the time period the work piece spends in the affected area, production in the next segment of the process, and then successively wider adjacent areas, comes to a halt until a remedy is found, involving progressively larger and more diverse support groups. Applied conscientiously, this process averts the production of defective parts or assemblies, whose subsequent rework or, ultimately, repair in dealerships would entail substantial cost for the manufacturer and dissatisfaction for the customer.

From the Fordist perspective of mass-manufacturing, the *andon* technology gives rise to much concern. After all, it empowers team members to stop production, and that has the potential to make it impossible to predictably achieve business goals. Instead, it is much more common that team members need to be continuously encouraged to use the system as they dislike disruption of their work. At the same time, this disruption is essential to reaching the high quality goals as well as effective cost control, as the cost of repairs increases as soon as a defect has escaped from its point of origin. *Andon* lines are typically connected to a computer, which takes note of the process that has occasioned their use. Data can then be aggregated at higher levels to initiate proactive reengineering efforts aimed at eradicating the root causes of recurring problems.

As a performance technology, *andon* demonstrates all four TPS principles. It is applied just-in-time and improves just-in-time product flow step by step; allows corrective intervention in machine-based processes, demonstrating the priority of operators over machines and thereby gives respect to people; and adds stability to the process by promoting continuous learning about sources of defects. The people axiom is hence strongly evident in *andon*, as is that of value. Relationships are validated by the focused collaboration of team members and team leaders on problems of common concern.

Pokayoke

To minimize the need for disruption, to reduce mistakes and errors and the resulting scrap and rework, the technology of *pokayoke* is designed to create a work environment that is replete with fail-safe devices. It is immediately obvious that *pokayoke* instantiates the principle of respect for people by giving them control over machines. But the use of *pokayoke* also creates stability in the production process, supports just-in-time product flow, and both results from and leads to continuous learning and improvement based on organizational routines and events (Knuf, 1996).

The fail-safe devices of *pokayoke* ensure that operations are mistake-proofed by the widest application of sensors, go/no-go fixtures and other technical means, or stopped before defects would be built into products. Product design supports these efforts by removing sources of error from the product, for example, symmetry in attachment points. *Pokayoke* technologies help control waste by supporting quality at the source, and they bring to bear the intelligence and experience of empowered operators who notice and address abnormalities in the process. *Pokayoke* is similarly applicable in production support environments. Sales representatives can be given spreadsheets that force the collection of certain kinds of information from the customer by not allowing data entry to progress until required fields have been filled. This addresses a common problem in production scheduling, the lack of detail in sales documentation, which leads to multiple subsequent contacts and interactions with the customer, creating inconveniences that reduce satisfaction.

According to Ohno (1988a), the technique of *pokayoke* derived directly from Toyota founder Sakichi Toyoda's auto-activated looms, which were designed to stop upon recognizing a break in a thread. Similarly in TPS, an infrared beam or a mechanical feeler might be employed to measure a critical dimension of a product, so that interruption of the beam by an odd-sized piece would alert an operator to this abnormal condition and countermeasures could be instituted, either automatically or manually. Stopping production the moment a defect is detected has the added advantage of exactly preserving the state of the production environment that has caused it, facilitating problem solving and learning. Incorporating error detection capability into equipment also allows the use of human labor for value adding work—not for watching machines cycle. The axioms of people and value are strongly evident.

5S

Two related technologies address the overall preparation of the physical plant to accommodate lean work processes. The first one of these, 5S, has been described as the housekeeping routine of TPS; the name derives from the original Japanese terms *seiri* (sifting), *seiton* (sorting), *seiso* (sweeping), *seiketsu* (spick and span), and *shitsuke* (worksite discipline). By reducing a great deal of immediately obvious waste from the shop floor, this technology prepares the organizational environment for other aspects of the lean transformation. It is a great step toward the simplification of existing operations, which results in added effectiveness, reduced frustration, and hence savings in monetary and social cost. Fundamentally, however, 5S is much more than a housekeeping exercise—it is the source of much learning about the organization of work and hence a major resource for *kaizen*.

In its international instantiation, the first S denotes *sorting* and *scrapping*. Everything on the shop floor—and, for that matter, in the office—is examined for its purpose, and unnecessary items are removed. The second S instructs workers to *straighten* the materials and tools that have survived the initial sort. All items are stored in easily accessible locations, and these locations are clearly marked. For example, shadow boards that show their outline are set up to store tools. Any tool not in its place is thereby known to be in the hands of an operator. The third S is the actual cleaning operation. Now that clutter has been removed and things are in their places, work surfaces, floors, equipment and everything else is *scrubbed*. This S is also a reminder to fix up the facility, paint floors, walls and ceilings, and install good lighting. The fourth S stands for *standardization*. Practices and rules for workplace maintenance are formulated for all areas of the plant and workers are trained to follow them without further supervision; this is the fifth S, *systematization* (Knuf & Lauer, 2004). Upon closer view, 5S enables the application of the principles of just-in-time and standardization to all processes. By empowering all members of the organization to eliminate multiple sources of waste, it answers to the people and value axioms.

Visual management

Related to the technology of 5S is that of visual management. Visual tools and controls encode crucial information about production processes, outcomes and environments. They allow people to provide stability by making available information just in time when it is needed, enhance continuous learning and improvement, and thereby create value. Visual techniques support all others in TPS and contribute to the overall simplicity of operations (Hirano, 1995).

In TPS, a visual message is essentially public. It is not restricted to a group of precisely identified individuals or specialists, or to a particular level of hierarchy. Since visual messages can be observed by everyone working in a given area or passing through it, current operational conditions become evident and can be addressed or enjoyed. It is good to keep manufacturing and office operations in a visual relationship: at the Mercedes-Benz plant in Vance, Alabama, for example, the central office extends like a second-floor island into production space. A band of interior windows provides an uninterrupted panorama of all shop floor activities, and support staff can literally keep an eye on crucial production conditions from their desks.

Visual techniques must focus on providing quick and accurate access to information. The meaning of this information may not be evident immediately, however. Hence visual factories must strive constantly to enlarge the community of people who understand the meaning of visual cues to extend their value (Greif, 1991, p. 8). In this sense, visual management promotes continuous learning; supports the acquisition of multiple skills; breaks down functional barriers, including communication barriers; and also contributes to the democratization of the workplace.

Standardized work

The technologies described above relate in the first instance to aspects of the lean production system itself. Members of the organization certainly play a major role in their design, use, and continuous improvement. However, with the focus in this chapter on normal excellence in human performance, the preeminent technology undergirding the lean system is standardized work. Standardized work applies the principles of just-in-time, respect for people, stability and continuous learning. It strongly represents the influence of all three axioms. It is the most efficient way known to manufacture a product, combining human work with that of machines. Standardized work must be established where the actual work is done, and it must be documented; its procedures have been analyzed microscopically for the value they add.

Standardized work means that operators execute all steps of the process in the same manner, time after time in the prescribed sequence, with the prescribed tools and equipment, within the prescribed pace or *takt* time, and safely. They draw on reliably available stocks of materials as they do so; timely material flow is regulated by the use of *kanbans*, as we discussed. Standardized work brings stability and thereby quality to the manufacturing process and, in turn, provides the basis of continuous learning and improvement.

The value of standardization in the lean work system is not necessarily obvious; indeed, this value can be overshadowed by the more visible practice of *kaizen*—the energetic pursuit of newness. But as Ohno (1988a) writes:

> We have eliminated waste by examining available resources, rearranging machines, improving machining processes, installing autonomous systems, improving tools, analyzing transportation methods, and optimizing the amount of materials at hand for machining. High production efficiency has also been maintained by preventing the recurrence of defective products, operational mistakes, and accidents, and by incorporating workers' ideas. All of this is possible because of the inconspicuous standard work sheet. (p. 21)

TPS employs training and many visual management tools to support standardized work. Textual instructions, schematics and pictures demonstrate the proper work process; here simplicity appears to translate into effectiveness. Displays close to workstations offer salient comparisons between good and defective parts, and tools and materials are kept in specially marked locations for instant retrieval.

If there is a pivotal technique in TPS it must be standardized work. All principles and axioms apply here. The relentless pursuit of perfection, driven through *kaizen* techniques, dissipates the effect of innovations if they are not supported by a stable base to which production can return if the trial-and-error process of learning has fallen short of its objective (Knuf, 1996). Standardized work holds not only the promise for future, better work, but is an effective insurance policy against the loss of productivity in the here and now.

Kaizen

The human performance technologies described in this section so far create and guarantee the current capability of the lean work system. The future capability of that system, however, is assured by another technology, that of continuous improvement or *kaizen*. *Kaizen* is without doubt the most popular and widely acclaimed technology in the TPS arsenal (Imai, 1986; Japan Human Relations Association, 1989, 1990; Suzaki, 1987). Indeed, there are many companies that use *kaizen* as a stand-alone intervention and erroneously claim to have implemented lean manufacturing. Analogously, if the Internet is any indication, there are more consulting efforts focusing on *kaizen* than on any other aspect of the TPS.

Grounded in all three axioms, *kaizen* combines and balances the principles of stability and of continuous learning. *Kaizen* uses multiple analytical and synthetic tools to advance to a higher level of effectiveness in the organizational process, which then, in turn, defines the next work standard. Analytical tools include statistical control methods, flow charting, conventional measurements of time, effort and cost, problem-solving protocols like fishbone or Ishikawa diagrams and the routine of 5Y (or ‘five why?’, the five-fold examination of causes). Synthetic tools include brainstorming, nominal groups, various forms of modeling, and the eventual hands-on reorganization of the manufacturing process itself, which invariably includes a trial-and-error component. It is important to note that in TPS, *kaizen* is a work-team-level activity that is supported by outsiders only in case of functional need; expert-driven *kaizens* undermine the team ownership of process and results and abort crucial learning curves.

Of considerable popularity at the time of writing is the so-called ‘*kaizen* event’ (or ‘*kaizen* blitz’), a program lasting several days, up to a week, during which operators and external experts and consultants take on a medium- to large-scale redesign of their work process. In general, *kaizen* events aim for a big, breakthrough effect, and in this manner they differ from the gradual and incremental *kaizen* of the TPS; Womack and Jones (1996) refer to this form of activity as *kaikaku* (‘upheaval’); its valence is obviously ambiguous and the ability to sustain gains once the external support staff leave is low due to the lack of local ownership and expertise.

There are then both advantages and disadvantages that attach to large-scale *kaizens*. On the positive side, they allow the immediate harvest of many ripe opportunities. They also issue radical challenges to the accepted wisdom of the operation and can hence push through conventional thinking with considerable force. On the negative side, they are more difficult to sustain as a learning and improvement mode since they consume considerable energies, and they can disrupt the alignment of dependent processes. It is our opinion that a policy of continuous smaller steps, supported by extensive conceptual and practical training and undertaken by team members themselves, is the preferable approach (Knuf, Haney, & Lauer, 2003). Indeed, small steps invariably also lead to major improvement opportunities, but in doing so they preserve a better sense of both ownership and strategic direction.

To sum up, *kaizen* is a team function. In order to reach new levels of performance, the joint commitment of team members is necessary and cannot be replaced by the intervention of external experts (Brooks, 1994). The team needs far-reaching authority in its approach to *kaizen* but also multifunctional support from the organization, as appropriate. The key to continuous *kaizen* successes lies in the improvements in the workplace itself: as they facilitate the daily work of people, the self-rewarding nature of this technique quickly becomes evident and sustains the practice.

Conclusion

At the beginning of a new millennium we are getting ready to leave behind a mode of industrial work dominated by mass markets and the easy availability of resources and energy. The new workforce has grown up in a period of considerable affluence and security and demands a democratic workplace that provides meaningful work through empowerment, participation and self-development. Work has to satisfy complex economic, social, and psychological needs—and not necessarily in this order. More and more, job security is sought not in large systems but in the qualifications individuals gain through continuous learning and improvement, through a demonstration of their own ability to perform.

The Toyota Production System and the various lean systems derived from it provide an important milestone in this development. Lean axioms reflect, on the one hand, deep human needs, on the other they satisfy the demands of society for products of highest quality and value. We believe that the lean philosophy contains the seeds for a post-industrial model of work whose outlines we are just beginning to discern.

The new work will again be people work, much of it done in teams. Many teams will be self-organizing and multi-skilled. By rotating leadership, they will seek out and complete tasks in appropriate social, organizational, informational, and material arrangements, matching their own complexity and performance ability to the requirements of the task. This will be enabled by high levels of task and process competence, innovative organizational support structures that facilitate access to knowledge resources; provide work environmental and reward flexibility; observe both competence, learning needs, and fairness in fast-changing project assignments; and promote very high levels of trust. Teams will not only be self-directed, but eventually semi-autonomous, in that they may take over more and more business functions of the organization as well. The organization that leverages the collective potential of its employees to the highest degree will prevail in a fiercely competitive global market; and since the initial advantage of the team is its ability to turn around a task expediently, even small organizations will, over time (and in the absence of accidents) outperform larger, less capable ones in their own economic niche.

As a milestone, however, TPS is but one instantiation of this new model of work. While we have much to learn from it, we have to add to it the experience of other organizations, other industries, and other experiences and also draw increasingly on the research in the social sciences and humanities. This, then, is truly a millennial project. It demands our support but also our critical awareness: we are moving beyond clear transactional systems into organizational forms of considerable fuzziness in which the relationships between people and organizations will become more and more ambiguous and potentially chaotic. Ownership of the means of production, intellectual assets, and complex value definitions in ever-changing markets will ultimately require a positioning of human performance technologies at all levels of the organization for the promise of normal excellence to be fulfilled.

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