THE THINKING PRODUCTION SYSTEM

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Toyota Motor Corporation no longer needs an introduction. The spectacular success of Toyota in the last few years, combined with the no less spectacular problems of western automakers, has propelled Toyota from an isolated curiosity within one industry to a model of world-class design, development and manufacturing. Much of its success is attributed to its now fabled Toyota Production System (TPS), dubbed *lean manufacturing* (or simply, "lean") in Womack, Jones and Roos' ground-breaking book, *The Machine that Changed the World*[1]. Since that time, TPS has been extensively studied with dozens of books and articles describing the system and its tools and techniques, and promising significant gains in efficiency, quality and on-time delivery. Numerous authors have described successful lean transformations[2]. Toyota itself has contributed significantly to the diffusion of its model, because they need their local suppliers to perform at the same high level if they want to reproduce their success outside of Japan. Indeed, lean is now being applied across broad sectors of the economy, from logistics to healthcare[3] to building construction[4] to services[5].

And yet, though many corporate players have endeavored to "go lean," few have succeeded beyond reaping the low-hanging fruits. Hajime Ohba, head of the Toyota Supplier Support Center, recently commented, "Many firms have doubled productivity in the short run, but few have been able to evolve by continuing to apply the principles of TPS."[6] Similarly, in the authors' experience, despite the increasing armies of internal and independent consultants en route to turning lean

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[1] J. Womack, D. Jones & D. Roos (1990) *The Machine That Changed the World*, Rawson Associates.
[2] J. Womack & D. Jones (1996) *Lean Thinking*, Simon & Schuster; J. K. Liker (ed.) (1998) *Becoming Lean*, Productivity Press.
[3] S. Spear (2005) "Fixing Healthcare from the Inside, Today", *Harvard Business Review*, September.
[4] L. Koskela, G. Howell, G. Ballard & I. Tommelein (2003) "The Foundations of Lean Construction", in: R. Best & G. de Valence (eds.) *Design and Construction: Building in Value*, Butterworth-Heinemann
[5] C. Swank (2003) "The Lean Service Machine", *Harvard Business Review*, October.
[6] H. Ohba (2002) Communication to the "Making Things 21C" Conference, Nagoya, March, 7th.

consultancy and training into an industry of its own, truly lean enterprises as defined by Womack and Jones[7] are rare.

In today's environment of global competition and intense cost pressures, the low rate of successful lean transformation is worth investigation. At first, explanations about the difficulties of implementing lean in western companies were about culture. But, as Toyota transplants have shown that TPS can perform equally well in the US or Europe as it does in Japan, the culturalist argument gave way to a "lack of leadership" thesis. But even that is not very satisfying as, clearly, companies in the automotive industry and elsewhere have taken lean very seriously. They've created lean-VPs, invested in lean offices staffed with lean officers, and driven their lean programs hard. Thus, the failure to realize the full promise of lean does not seem to be due to lack of initiative or effort – something else is at work.

We believe deep frames pervade TPS that fundamentally alter how the system is understood and therefore how to proceed with implementation. "Frames," or "frameworks" are the mental constructs through which we see, interpret and act on the world. Furthermore, we argue that if lean tools (such as kanban, SMED, 5S, TPM, poka-yoke, etc.) are applied without "frame control," the results will be disappointing beyond gathering the obvious low-hanging fruit. If managers and program leaders fail to understand the frameworks underlying TPS, they consequently miss the point of the tools and therefore fail to achieve the expected results. The fact is, TPS masters continually harp on issues of frame control (making sure the tools are applied in the right perspective), but few seem to pay much heed. The good news, though, is frame control can be taught, and thereby significantly improve the effectiveness of lean programs. Indeed, the implementation implications of better understanding the framing of TPS are significant, and open the way for another approach to lean implementation.

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[7] J. Womack & D. Jones (1994) "From Lean Production to the Lean Enterprise", *Harvard Business Review*, March-April.

Framing is a well-studied concept in social science. It can be described as implicitly selecting some aspects of perceived reality as more salient than others, thus orienting problem definition, causal interpretation, moral evaluation and eventually action recommendation. Framing, then, explains why the same events can be interpreted very differently depending on the observer's framework. Framing can be thought of as, literally, looking at as situation through a picture frame and focusing on some aspects, while completely missing others.

The lean movement has been responsible for changing some frames in the industrial world. For instance, large inventories, which were once viewed as healthy assets that could be tapped when needed, are now generally seen as sources or symptoms of waste. Large batches produced to fulfill "economic order quantities" are increasingly unacceptable as a result of a new framework for seeing inventory. Toyota's expertise in creating level flow of goods through a "pull" manufacturing system has changed the frame by demonstrating that the real issue was reduction of inventory, rather than the management of it. For instance, an expensive Texas Instrument (now Raytheon) automated warehouse was scrapped before reaching full production when it was realized that the real issue was to reduce inventories rather than build ever-more efficient warehouses[8] In this case, reframing led TI executives to focus on the causes of excessive stock and how it should reduce inventories rather than building ever-more efficient warehouses.

Today the true promise of lean can be realized through a shift in how executives frame this system. Most western efforts at implementing lean are about, in one way or another, *applying lean tools to every process* in the company. This would seem logical enough to most western thinkers. This approach eliminates waste, improves quality, and leads to greater profits over time. Who can argue with this? But Toyota's own

[8] NCMS Projet (2000) *Product Development Process, Performance Measures & Methodology*, Final Report of NCMS Project n°130120.

TPS masters have a different take. As TPS veteran Teruyuki Minoura[9] explains, the "T" in TPS stands for "Thinking." To him, TPS as about creating "an environment where people have to think [which] brings with it wisdom, and this wisdom brings with it kaizen (continuous improvement)." Nampachi Hayashi[10], a Toyota Executive Advisory Engineer and disciple of the legendary Taiichi Ohno, argued that the essence of TPS is developing within in each employee a "kaizen consciousness." TPS master Hajime Ohba, quoted earlier, attributes the difficulties of transferring lean to a failure to apply TPS as a "system of training." In other words, TPS masters view lean transformation from a different frame: *changing the thought processes of every employee*.

Going lean, then, is less about "leaning out" every business process or applying finely tuned tools to achieve a certain lean aesthetic, and more about improving organizational performance, seeing problems, solving them the "right" way, and in doing so continually increasing the intellectual capacity and skill of all members of the organization. Why is this important? As we explain in the following pages, the "apply lean tools to every process" frame is inherently limited. Such an approach can spark real gains—yet these improvements are often isolated, blind to the waste they cause elsewhere in the system, and invariably doomed to wane when the key players move on or another fad sweeps the workplace. On the other hand, tapping and evolving the creativity of every employee, if properly cultivated and directed, has unlimited potential. This enables the core principle of lean—kaizen—to take root at the genetic level so that learning becomes an organic process of operations. Realizing the full promise of this thinking production system requires a shift to this learning frame.

We expose this fundamental difference in perspectives by identifying four deep frames that pervade the TPS. It's important to learn how to recast one's understanding of commonly "understood" lean practices with the following frames:

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[9] T. Minoura (2003) Communication at the "2003 Automotive Parts System Solution Fair", Tokyo, June, 18th.

[10] N. Hayashi (2002) Communication to the "Making Things 21C" Conference, Nagoya, March, 7th.

performance mindset, *problem awareness*, *solving problems the "right" way*, and *developing people through problem-solving.*

IMPROVING PERFORMANCE: QUALITY, COST AND LEAD-TIME REDUCTION

Improving performance is the first goal of TPS, not implementing tools for the tools' sake. Improving performance is explicitly framed as:

- *Quality improvement* through building in quality 100% at the process rather than inspecting it in later.
- *Improving customer service by reducing response time:* how can I please my customers by delivering to them exactly what they want, exactly when they want it, in the right quantity at the highest quality and the lowest cost?
- *Cost reduction through waste elimination*: anything other than the minimum amount of equipment, materials, parts and working time absolutely essential to production are merely surpluses that only raise cost.

Missing the deep "performance improvement" frame can lead to self-defeating outcomes. For instance, one of the authors, who worked several years for Toyota in Japan and was trained in the plant where Taiichi Ohno initially tested many of the TPS tools, agreed to help a U.S. based company with the implementation of TPS principles in low volume, high mix machine intensive shop where others were having no real luck. After discussion and analysis it was decided with management that improving on-time delivery, reducing inventory, and improving productivity were key goals that mattered over the next year. Furthermore, from his observations and discussions, he determined that on-time delivery problems were due to an incorrect mix of components coming from the critical pacemaker machining processes. Over the following weeks and months, the author advised the plant personnel in improving set-up times, reducing batch sizes, and reducing lost production time on specific machines through cross-training among other improvements. As a result, plant employees discovered the main problems in each the key areas, devised countermeasures, and implemented them on a trial basis as

necessary. A year later, the most problematic plant in the division was now shipping almost 100% on-time with one third less inventory, and labor productivity was up 15% or more. As a result of the improved shipping performance, organic growth, and other key improvement activities, sales were increased and profits as measured by return on sales were up nearly six percentage points from a year earlier.

The division managers and plant staff expected to receive internal accolades for their improved performance. Sadly, however, they were in for a rude awakening. Despite its recent performance improvements, the plant scored among the lower performers in the entire company on a standard lean survey audit that measured adherence to tools. The reasons cited were that the value stream maps and tracking center did not follow the internal standard, all machines did not have standardized work charts, and the way visual control was implemented also was not the method the central function wanted, etc. In other words the corporate auditors had a very different frame than that of the plant and our author-consultant. Despite the tremendous improvement in performance and customer satisfaction, the corporate "apply lean tools to every process" frame lead them to view the plant's lean progress as not up to snuff and deserving of a dressing down - which it disappointingly received.

PROBLEM AWARENESS: DEVELOPING A KAIZEN CONSCIOUSNESS

The second deep frame of TPS is problem awareness, in which lean thinkers frame problems that arise as a chance to discover flaws in the process rather than anomalies that must be "fixed." In the words of Nampachi Hayashi: "the biggest problem is thinking you are okay." A general, and understandable, human tendency is to blame circumstances when we run into difficulties. The TPS frame looks to take responsibility, challenge assumptions and conduct the famed "5Why" exercise of asking "Why?" until the root cause of a problem is uncovered. Steven Spear and H. Kent Bowen describe[11] a harrowing session when a TPS master asked a group

[11] S. Spear & H. K. Bowen (1999) "Decoding the DNA of the Toyota Production System", *Harvard Business Review*, September-October.

working on tool change reduction why they had not achieved the five-minute goal they had originally established – although they had reduced the changeover time by 50%. The group offered explanations to do with machine complexity, technical difficulties and equipment upgrade cost. The TPS sensei responded to these replies with more questions, and pushed the group members to challenge their assumptions on the smallest details. Spear and Bowen assert that the sensei was not suggesting the team had failed, but that he was trying to get them to realize that they had not fully explored all their improvement opportunities because they had not questioned their assumptions deeply enough. They thought they were okay because they had achieved the "easy" 50% reduction.

Because confronting problems is a strongly embedded frame of TPS, managers learn to avoid their natural urge to "work-around" a problem with a quick fix, and instead sort out the fundamental issue. That's why TPS masters say "No problem is a problem." For example, one of the authors recently toured a 1,000-person Toyota engine plant in West Virginia that manufactures over a half million small engines and transmissions annually. The plant has won the prestigious Harbor award for four years running in North America as the most efficient engine plant in the U.S, which numbers for inventory, scrap, defects, downtime and safety problems that stand up to, and in some cases exceeds, the operating metrics of its sister plants in Japan. The overall layout as well as the minutest detail of the plant was well thought out. The workforce was bright, multi functional, and highly engaged.

Yet despite being perhaps the best Toyota engine plant in the world, management's mindset was focused solely on further improvement opportunities. On each production line, the respective team leader pointed out the precise details of the top five quality problems, the top ten downtime machines in terms of frequency and intensity, the most likely potential causes for accidents in their area, not to mention the two top reasons for some real or perceived minor decline in worker morale. Everyone was focused on exactly how to get another 10% productivity improvement in the upcoming year. This mindset was problem awareness to the fifth degree.

PROBLEM-SOLVING: GO AND SEE, QUICK EXPERIMENTS AND RIGOROUS RESULTS CHECKING

Thirdly, TPS also conveys a deep-frame for experiential problem-solving. As Ohno once said[12], "in a production plant operation, data are highly regarded – but I consider facts to be even more important." The difference is more than semantic: TPS considers facts to be events that you have yourself witnessed at the real place, with the real parts and the real people. Questions are not abstract exercises but real shop floor experiments that highlight the problem and uncover the flaws through many iterations. Indeed, many of the most famous TPS "tools" such as SMED, flow-and-layout, and others, are nothing but observation practices that permit a hands-on understanding of the issues, and therefore a concrete resolution. Masters seek clear explanations instead of quick "solutions."

One of us witnessed this frame early in his career as an engineering trainee at Toyota. A particular grinding process was producing between 2-3% scrap, which was ten times the current "acceptable" amount for that type of machine. After studying various data at his desk all morning without arriving at any insight as to the cause of the problem, he was asked by his supervisor to go stand in front of the machine for an hour and then report back. Upon doing so the trainee felt no closer to solving the problem than he had in the morning. The supervisor then suggested that the trainee draw out the grinding process in excruciating detail and then list all the potential things that could be affecting the quality of the part on a flip chart. After about 15 things were listed and accepted as potential causes, the trainee was told to devise a test for each of them, carry them out only one at a time, and report back his findings after each one. The tests involved grinding wheel speed changes, wheel in-feed changes, dressing wheel changes, clamping changes, cycle time changes, coolant amount, and other variables that each took a couple hours to ready and involved much begging of help from either the operator or maintenance.

[12] T. Ohno (1988) *Toyota Production System: Beyond Large-Scale Production*, Productivity Press

The first eight experiments took two days to complete and did not resolve the problem but did importantly clarify cause and effect of certain items in the trainee's mind. The ninth experiment on the morning of the third day finally yielded a breakthrough. The machine's coolant tank was badly contaminated with bacteria of some sort and fouling the concentricity of the solution. This minor issue was enough to cause the majority of the scrap problem on the machine. The question acquired a new focus: why hadn't the coolant been checked on a proper interval as specified, and how had this machine been missed? Furthermore, what had contaminated the coolant and how had this occurred?

After resolving the high scrap rate problem in the grinding problem above, the trainee asked his supervisor how quickly he would have isolated the cause of the problem. The supervisor's reply: about ten minutes. He had solved a similar problem years ago and could tell the contamination by smell. When asked why he did not share this insight up front and saved the trainee several days of work, he remarked, "This way you learned one thing for sure that worked and eight other things that did not work. If I had told you the answer up front you would have learned eight things less." The trainee's focus had been in fixing a quality problem. The Toyota manager's goal was to teach the Toyota way of thinking while solving an actual problem, reflecting one of the deeper, essential frames of TPS, that of developing people as the starting point for making things.

DEVELOPING PEOPLE BEFORE MAKING PARTS

Recalling his days as an Ohno disciple, Teruyuki Minoura muses, "I don't think he was interested in my answer at all. I think he was just putting me through some kind of training to get me to learn how to think." Hajime Ohba depicts TPS as fundamentally a system of training where everyone solves problems under the guidance of a mentor. Kenji Miura, head of Toyota's Operations Management Consulting Division, on recent visit to a European plant chided the plant

management, “Don’t have kaizen-men and observers.” This was a strong way of saying that developing a “kaizen consciousness” was the responsibility of the management, not of staff “experts.” In fact, the TPS frames every manager’s job very strongly as:

- Build the performance mindset
- Establish the standard method
- Track actual performance (make problems or abnormalities visible)
- Teach a basic way for analyzing work
- Develop employees through solving problems or improvement tasks

This difference in framing is extremely significant for lean implementation because the goal is not likely to be the same. The endgame of a traditional lean program is a plant that “looks lean,” where the tools in the manual are being used and obvious wastes cannot be seen. In contrast, the goal of the true TPS form is a shop floor where production processes perform at a very high level, but also where every production worker routinely identifies problems in their work routines and actively works on solving them; where supervisors and team leaders coach their direct reports in problem-solving, but are also aware of the most important problems plaguing their work area and are working hard at resolving problems of their own, again under the close guidance of a coach; where line stoppages and gaps between performance and goals are commonplace.

Certainly solving the problem at hand is important. But just as important, perhaps more so, is the learning and skill development that takes place. In this sense, problem resolution is the test or confirmation of the learning. Thus, TPS mentors ask structured questions that force the trainee to stay on track and reinforce the problem solving mindset:

- What is the exact problem in question?
- What is the specific goal of your activity?
- What is the root cause of the problem?

- What action items are necessary to solve the problem?
- How will you check the actual effect of the action items?
- What remains to be addressed to achieve your goal?

In TPS, a problem or any deviation from a standard requires immediate attention. For a supervisor or manager, however, it is not only a matter of solving the problem; it is a matter of training and development as well. A true measure of a manager is said to be when he hands over duties to a subordinate. If performance stays on track after the hand off, the manager has done his job correctly. If performance falls, the manager is viewed by everyone as having done a poor job in terms of employee development.

THE ROLE OF THE TOOLS

All of this talk of frames is not to say that the principles and tools of TPS are unimportant. They have a key role to play in frame-control. Lean principles function to orient the thinker in the right direction, such as the Just-in-time principle to reduce or eliminate the stagnation of material and information, or the Jidoka principle to build quality into the product by "stopping at the first defect." The lean principles tell us which performance metrics are important (*performance mindset* frame control), help us identify problems *(problem awareness* frame control), provide direction in the appropriate countermeasures to move the operation forward with a learning approach (*problem-solving* frame control), and indicate what concepts must be mastered and internalized as part of one's skill development (*developing people* frame control). Thus lean principles are important, but do not supplant the primary frame. Rather, they guide organizational behaviors and priorities in ways that deepen the basic frame.

The lean tools take on a whole new dimension from this new perspective. They become much more than just mechanisms to implement the lean ideals, as important as that is. They also become vehicles by which the deep frames are instilled. For

instance, from the typical frame, 5S is often seen as a straightforward housekeeping tool or practice ("everything has a place and everything in its place," etc.). However, with the new frame in mind, what was a tool or practice for cleaner working environments becomes a way to develop an operator's knowledge and responsibility about their work cell. 5S becomes an ongoing practice to help people think about how their workstation is laid out and arranged, and for them to act on all the small things that can make it better, safer, more ergonomic, and easier to work in. Companies that do not share this frame will hire external consultants or appoint a "5S manager" to make sure that the shop floor is clean all the time, not recognizing that the teams must take ownership for their cells, by applying the tool themselves! Management in these companies understands the part about cleaner environments, but they completely miss the "developing people" frame. Not surprisingly, like a fad diet without change in the fundamental behavior of the person, these "5S" drives fail time and time again. The tool is important, but must be applied with the proper frame in mind.

Value stream mapping is another useful tool for companies on the road to lean. From the typical frame, the VSM helps the plant (or value stream) manager envision what the overall material and information flow in the lean system should look like, identify the true value-adding activities, and determine the potential for production lead-time improvement. However, from the new frame, VSM highlights specific kinds of problems (i.e., those related to stagnation of material and information flow), and where to focus their people's problem-solving efforts to have the biggest impact on performance measures of significance to overall plant performance. From the traditional frame, VSM is useful; from the TPS frame, it is powerful.

Certainly, workshops (or "kaizen events") such as flow-and-layout manpower, Single Minute Exchange of Die for lowering tool change-over time, or Quick Response Quality Control are invaluable tools to kick-start the thinking process in any plant. But to gain sustained improvement over time, these efforts must be conducted with the right frame – to uncover problems, challenge assumptions,

resolve problems, and ultimately help shop floor staff learn how to best use their existing equipment to produce better parts for the customer. The act of improvement however in TPS can not be separated from that of people development. In TPS the Japanese phrase "*mono zukuri wa hito zukuri*" (making things by making people) is an required way of life.

MANAGEMENT IMPLICATIONS

The framing debate has considerable managerial implications, both at the levels of day-to-day management and for the deployment of "lean" programs. Firstly, frame control becomes essential, that is, the ability to keep the frame of reference focused on the right things: performance improvement, problem awareness, solving problems the right way, and developing people. This, in itself, is a major challenge for any manager, whose days are typically consumed by fighting one fire after another. Making sure that managers and supervisors surface problems rather than go around them, and then treat them as development opportunities for employees requires a deep commitment to continuous improvement, and rigor in day-to-day applications. Truly, many TPS tools properly applied will help, as their main purpose is to make problems appear at the right place, and the right time. Moreover, "frame control" also applies to the way programs for lean transformation are conceived and deployed, on four main points: focusing on performance in terms of customer delivery; using the tools to back track to problem areas and find out what is really limiting performance; identify problems one at a time, and develop individual by asking them to solve these problems rigorously; and establish a system of training in which every manager has a coach, works on problem solving and coaches his own people in turn[13]; similarly, every front line employee works on problem solving with the guidance of a coach.

The broader managerial challenge is to shift from using TPS principles to produce brilliant products and processes, to applying TPS frames as a means of developing people. In Toyota, implementing TPS is not just a staff issue but a line role, starting

[13] S. Spear (2004) "Learning to Lead at Toyota", *Harvard Business Review*, May.

with the plant manager. Indeed, within Toyota establishing work standards and fostering kaizen is a key supervisory role; and supervisors, not engineers, are accountable for both work instructions and line performance in terms of productivity and quality. Consequently, deploying TPS through a firm is not about how many areas have been "kaizened" but how many plant managers, and then supervisors and team leaders, have been trained by a sensei and can start training people on their own.

Consider the case of Isao Kato who is a now a retired manager from Toyota's training and development department in Japan. Internally for many years he was famous as Toyota's internal master of standardized work, among other topics. Toyota did not attempt to train every employee in the company in standardized work, as there are over 200,000 employees in the company. Instead, for each plant around the world, Mr. Kato would develop ten or so standardized work trainers who were acknowledged as good supervisors and potential competent instructors. The ten people selected attended a two week special course on how to teach standardized work. Upon successful completion of the course, they would return to their home plant and teach the ten hours (five days by two hours) course under the strict supervision of Mr. Kato. Once certified as competent instructors, they were responsible to teach all their fellow supervisors standardized work as the need arose in the future. Mr. Kato worked with production managers to make sure they followed up on the courses and made sure the lessons were applied. Beyond this level, however, standardized work was now a plant management responsibility – not a staff or training department issue. Virtually all off the job training is handled in this cascaded fashion[14] in Toyota. This is not an easy challenge and Toyota itself is suffering from a dearth of experienced masters like Mr. Kato (and many others on different topics) as it grows faster than its capacity to develop "masters." Still, compared to traditional companies where management continues to manage by the

[14] The origins of the cascading training model can be traced back to the "Training Within Industry" program in the US, as exported to Japan by McArthur's Occupation Authority. For further information, see: J. Huntzinger (2002) "The Roots of Lean", *Target* 18(1); and D. Dinero (2005) *Training Within Industry: the Foundation of Lean*, Productivity Press.

numbers and firefight, and a few staff people are given the impossible mission to "apply lean" in all processes, engaging the creative potential off every organizational asset seems a better recipe for sustained success.

How people frame problems has real consequences. Until this fundamental truth is acknowledged, and lean converts face up to the need of developing frame control in applying the tools and techniques developed by Toyota, lean transformation will continue to be slow, frustrating and ultimately unrewarding. If your frame is "apply lean tools and principles to every process," you will certainly gather the low hanging fruit, but the potential for your lean transformation will remain limited. On the other hand, if you frame lean transformation as "change the thought processes of every employee to develop kaizen consciousness," the potential is unbounded. In the present industrial context, the framing issue is not just of academic interest as a manner of explaining why paradigm shifts are so slow and painful. It is of critical importance for firms investing resources, time and efforts in a lean transformation and who need to radically improve their performance if they want to compete with low cost providers, who, incidentally, are also improving their own operations at an incredible pace. The TPS masters, the true lean experts and originators of lean, realize they're not in the same framework as the people they're trying to coach, but, conversely, the frame of their audience is so strong, their message is not heard!

In the end TPS is best viewed as a developed practice, not a theoretical philosophy or set of tools. Lean is not and probably never will be a codified body of knowledge. It's the cumulative behavior and experience of the people who practice the system. And although its practice is demanding and difficult because it does not come naturally to our organizations nor our mentalities, TPS, the Thinking Production System is also profoundly empowering. In the words of Michikazu Tanaka, a former managing director of Daihatsu Kogyo who was trained by Taiichi Ohno: "In terms of results, [TPS] involves reducing work-in-process, raising productivity and lowering costs.

But the real aim is to bring out the capabilities of each individual. The ultimate aim is to draw out people's motivation."[15]

[15] S. Hino, (2006) *Inside the Mind of Toyota*, Productivity Press