LEAN THINKING

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Introduction

Muda means "waste," specifically any human activity which absorbs resources but creates no value:

- mistakes which require rectification,
- production of items no one wants,
- processing steps which aren't actually needed,
- movement of employees and transport of goods from one place to another without any purpose,
- groups of people remaining idle because an upstream activity has not delivered on time,
- goods and services which don't meet the needs of the customer.

Lean thinking is the antidote to muda. It provides a way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively. Lean thinking means doing more and more with less and less human effort, less equipment, less time, and less space – while coming closer and closer to providing customers with exactly what they want.

Lean thinking also makes work more satisfying by providing immediate feedback on efforts to covert muda into value. Unlike process reengineering, it provides a way to create new work rather than simply destroying jobs in the name of efficiency.

Understanding Value

Value must be created by producers for customers. Yet for various reasons, value is very hard for producers to accurately define. For example, in Germany, since the end of the cold war, complex, customized designs and sophisticated processing technologies favoured by German engineers have become too expensive for customers to afford and are often irrelevant to their real needs. This has landed segments of the German industry in a crisis.

Lean thinking starts with a conscious attempt to precisely define value in terms of specific products with specific capabilities offered at specific prices through a dialogue with specific customers. The way to do this is to ignore existing assets and technologies and to rethink firms on a product-line basis with strong, dedicated product teams.

The value stream is the set of all the specific actions required to bring a specific product through the three critical management tasks of any business: the problem-solving task running from concept through detailed design and engineering to production launch, the information management task running from order-taking through detailed scheduling to delivery, and the physical transformation task proceeding from raw materials to a finished product in the hands of the customer.

Value stream analysis will usually show that:

- Many steps are unambiguously creating value,
- Many other steps are creating no value but are unavoidable with current technology and equipment,
- Many additional steps are found to be creating no value and can be immediately eliminated.

Once value has been precisely specified, the value stream for a specific product fully mapped by the enterprise, and obviously wasteful steps eliminated, it's time for the next step in lean thinking – a truly breathtaking one. Make the remaining, value creating steps flow.

Lean thinking must look at the entire set of activities entailed in creating and producing a specific product, from concept through detailed design to actual availability, from the initial sale through order entry and production scheduling to delivery, and from raw materials produced right to the finished goods in the hands of the customer. The organizational mechanism for doing this is the lean enterprise.

Getting value to flow

We are all born into a mental world of "functions" and 'departments" a commonsense conviction that activities ought to be grouped by type so they can be performed more effectively and managed more easily. In addition, to get tasks done efficiently with departments, it seems like further common sense to perform similar activities within batches.

Batches, always mean long waits as the product sits patiently awaiting the department's changeover to the type of activity the product needs next. This approach keeps the department busy, all the equipment running hard, and justifies dedicated, high-speed equipment. But it is not efficient. Tasks can be accomplished much more efficiently and accurately when the product is worked on continuously from raw materials to finished goods. In short, things work better when the focus is on the product and its needs, rather than on the organization or the equipment, so that all the activities needed to design, order, and provide a product occur in continuous flow.

Henry Ford was probably the first person to realise fully the potential of flow. He lined up all the machines needed to produce the parts for the Model T in the correct sequence and tried to achieve flow all the way from raw materials to shipment of the finished car. But his method only worked when production volumes were high enough to justify high-speed assembly lines, when every product used exactly the same parts.

After World War II, Taiichi Ohno of Toyota concluded that the real challenge was to create continuous flow in small-lot production when dozens or hundreds of copies of a product were needed, not millions.

Flow thinking is counterintuitive. It seems obvious to most people that work should be organized by departments in batches. Then, once departments and specialized equipment for making batches at high speeds are put in place, both the career aspirations of employees within departments and the calculations of the corporate accountant who wants to keep expensive assets fully utilized work powerfully against switching over to flow.

Lean systems can make any product currently in production in any combination, so that shifting demand can be accommodated immediately. It has the ability to design, schedule, and make exactly what the customer wants, just when needed. This means we can throw away the sales forecast and simply make what customers actually need. So customers can pull the product instead of the manufacturer pushing products, on them.

As organizations begin to accurately specify value, identify the entire value stream, make the value-creating steps for specific products flow continuously, and let customers pull value from the enterprise, the strive for perfection becomes very strong.

Getting value to flow faster always exposes hidden muda in the value stream. And the harder one pulls, the more the impediments to flow are revealed so they can be removed. Dedicated product teams in direct dialogue with customers always find ways to specify value more accurately and often learn of ways to enhance flow and pull as well.

A lean system is transparent. Subcontractors, first-tier suppliers, system integrators, distributors, customers, employees – can see everything, and so it's easy to discover better ways to create value. What's more, there is nearly instant and highly positive feedback for employees making improvements, a key feature of lean work and a powerful spur to continuing efforts to improve.

Based on years of benchmarking and observation in organizations around the world, the authors provide simple rules of thumb: Converting a classic batch-and-queue production system to continuous flow with effective pull by the customer will double labour productivity all the way through the system while cutting production throughput times by 90 percent and reducing inventories in the system by 90 percent as well. Errors reaching the customer and scrap within the production process are typically cut in half, as are job-related injuries. Time-to-market for new products will be halved and a wider variety of products, within product families, can be offered at very modest additional cost. The capital investments required will be very modest, even negative, if facilities and equipment can be freed up and sold.

Benchmarking is a waste of time for managers that understand lean thinking. The authors' earnest advice to lean firms today is simple. Forget competitors; compete against perfection by identifying all activities that are muda and eliminate them.

Defining Value

Why is it so hard to correctly define value? Partly because most producers want to make what they are already making and partly because many customers only know how to ask for some variant of what they are already getting. They simply start in the wrong place and end up at the wrong destination. Then, when providers or customers do decide to rethink value, they often fall back on simple formulas – lower cost, increased product variety through customization, instant delivery – rather than jointly analyzing value and challenging old definitions to see what's really needed.

Another reason firms find it hard to get value right is that value creation often flows through many firms. Each firm tends to define value in a different way to suit its own needs. These differing definitions often do not add up in a meaningful way.

The most important task in specifying value, once the product is defined, is to determine a target cost based on the amount of resources and effort required to make a product of given specification and capabilities if all the currently visible muda were removed from the process. Doing this is the key to squeezing out the waste.

Just as activities that can't be measured can't be properly managed, the activities necessary to create, order, and produce a specific product which can't be precisely identified, analyzed, and linked together cannot be challenged, improved and, eventually, perfected. The great majority of management attention has historically gone to managing aggregates – processes, departments, firms – overseeing many products at once. Yet what's really needed is to manage whole value streams for specific goods and services.

The amount of time when value is actually being created is infinitesimal in relation to the total time. Bulk of the time the value stream is not flowing at all. This gives rise to the muda of waiting.

Designing a flow system

The first step, in making value flow is to focus on the actual object – the specific design, the specific order, and the product itself and never let it out of sight from beginning to completion. The second step, is to ignore the traditional boundaries of jobs, careers, functions and firms to form a lean enterprise removing all impediments to the continuous flow of the specific product or product family. The third step is to rethink specific work practices and tools to eliminate backflows, scrap, and stoppages of all sorts so that the design, order, and production of the specific product can proceed continuously.

A lean approach believes in truly dedicated product teams with all the skills needed to conduct value specification, general design, detailed engineering, purchasing, tooling, and production planning in one room in a short period of time using a proven team decision-making methodology commonly called Quality Function Deployment (QFD). This method permits development teams to standardize work so that a team follows the same approach every time. Because every team in a firm also follows this approach, it's possible to accurately measure throughput time and to continually improve the design methodology itself.

In the lean enterprise, Sales and Production Scheduling are core members of the product team, in a position to plan the sales campaign as the product design is being developed and to sell with a clear eye to the capabilities of the production system so that both orders and the product can flow smoothly from sale to delivery. There are no stoppages in the production system and products are built to order. Only a few hours elapse between the first operation on raw materials and shipment of the finished item. Orders can be accepted with a clear and precise knowledge of the system's capabilities. There is no expediting.

Rising awareness of the tight connection between sales and production also helps guard against one of the great evils of traditional selling and order-taking systems, namely the use of bonuses to motivate a sales force working with no real knowledge of or concern about the capabilities of the production system. These methods produce periodic surges in orders at the end of each bonus period and an occasional "order of the century" drummed up by a bonus hungry sales staff, which the production system can't handle. Both lead to late deliveries and customer dissatisfaction.

JIT can only work effectively if machine changeovers are dramatically slashed so that upstream manufacturing operations produce tiny amounts of each part and then produce another tiny amount as soon as the amount already produced is summoned by the next process downstream. JIT is helpless unless downstream production steps practice level scheduling to smooth out fluctuations in day-to-day order flows. Otherwise, bottlenecks will quickly emerge upstream and buffers will be introduced everywhere to prevent them.

The lean enterprise puts products into continuous flow wherever possible. In a continuous flow layout, the production steps are arranged in a sequence. The product moves from one step to the next, with no buffer of work-in-process in between. To achieve single-piece flow in the normal situation when each product family includes many product variants it is essential that each machine can be converted almost instantly from one product specification to the next. It's also essential that many traditionally massive machines be "right-sized" to fit directly into the production process. This, in turn, often means using machines which are simpler, less automated, and slower than traditional designs.

To get continuous-flow systems to flow for more than a minute or two at a time, every machine and every worker must be completely "capable." They must always be in a proper condition to turn precisely when needed. Every part made must be exactly right. By design, flow systems have an everything-works-or-nothing-works quality which must be respected and anticipated. The machinery must be available all the time. Work must be rigorously standardized. Employees and machines must be taught to monitor their own work. It must be impossible for even one defective part to be sent ahead to the next step.

Some tools will be unsuited for continuous-flow production and won't to be easy to modify quickly. It will be necessary to operate them for an extended period in a batch mode, with intermediate buffers of parts between the previous and the next production step. The key technique here is to think through tool changes necessary to reduce changeover times and batch sizes to the absolute minimum that existing machinery will permit.

Some manufacturers have opted for massive centralized facilities for product families while outsourcing more and more of the actual component part making to other centralized facilities serving many final assemblers. To make matters worse, these are often located on the wrong side of the world from both their engineering operations and their customers to reduce the labour cost.

The production process in these remotely located, high-scale facilities may even be in some form of flow, but launching products and improving the process machinery is much harder because the core engineering skills are on the other side of the world.

The result is high logistics costs and massive finished unit inventories in transit and at retailer warehouses. Another consequence is obsolete goods, eventually sold at large discounts, created by the need to place orders based on forecasts months, ahead of actual demand. Often it makes sense to locate smaller flow facilities incorporating more of the total production steps much closer to the customer.

The types of activities which people all over the world consistently report as most rewarding involve a clear objective, a need for concentration so intense that no attention is left over, a lack of interruption and distraction, clear and immediate feedback on progress toward the objective. They also involve a sense of challenge, the perception that one's skills are adequate, but just adequate, to cope with the task at hand.

When people find themselves in these conditions they lose their self-consciousness and sense of time. They report that the task itself becomes the end rather than a means to something more satisfying, like money or prestige. People experiencing this condition are in the highly satisfying psychological state of flow.

Classic batch-and-queue work conditions are hardly conducive to psychological flow. The worker can see only a small part of the task. There is often no feedback. The task requires only a small portion of one's concentration and skills. There are constant interruptions to deal with other tasks in one's area of responsibility.

By contrast, work in an organization where value is made to flow continuously also creates the conditions for psychological flow. Every employee has immediate knowledge of whether the job has been done right and can see the status of the entire system. Keeping the system flowing smoothly with no interruptions is a constant challenge. But the product team has the skills and a way of thinking which is equal to the challenge. And because of the quest for perfection, there is maintained in a permanent creative tension, which demands concentration.

Putting in place a pull system

Introducing flow in any activity does not happen by chance. The systems must be made to pull. This means that no one upstream should produce a good or service until someone downstream asks for it. The best way to understand the logic and challenge of pull thinking is to start with a real customer expressing a demand for a real product and to work backwards through all the steps required to bring the desired product to the customer. The operating doctrine is simply "Don't make anything until it is needed; then make it very quickly."

Toyota realised it could dramatically shrink the sizes of the storage bins, and reduce the lot size for reorders. Instead of ordering from suppliers on a weekly or monthly basis, it could order daily and order just the amount shipped to the dealer that day. Also, instead of asking dealers to order large batches weekly and then make special requests each night for missing parts, dealers could order daily just the amount sold to customers that day.

The ability to get parts resupplied very quickly from the next level of the system, and therefore the ability to reorder in small amounts, is always the secret to reducing total inventories in a complex supply chain.

Sales promotions are not consistent with lean thinking. They require the production of large amounts in advance, but it is never possible to predict how much would actually be sold. When not all the parts made are actually needed, dealers ship them back until the excess inventory is consumed. The net result is a temporary increase in orders to suppliers to a level far above long-term average demand followed by a dramatic drop in orders to far below long-term average demand. This is costly. It requires overtime in parts plants during the upswing and causes excess capacity during the downswing. It also creates costs in the distribution channel to ship excess parts back from the dealers and for the excess stocking and picking costs of running the same parts through the warehouse system twice.

According to Womack and Jones, the most striking feature of this decade is the relative stagnation and predictability of most product markets. In activities ranging from motor vehicles to aircraft to industrial machinery to personal computers to home building, the trajectory of product technology is quite predictable. What's more, the end-use demand of customers is inherently quite stable and largely for replacement. The authors emphasise that the volatility in these industrial activities is in fact self-induced, due to large inventories cause by batch-and-queue system and by sales promotion.

The quest for perfection

At every step there is the need for managers to learn to see value being pulled by the customer. The final form of seeing is to bring perfection into clear view so the objective of improvement is visible and real to the whole enterprise.

One of the most important things to envision is the type of product designs and operating technologies needed to take the next steps along the path. One of the greatest impediments to rapid progress is the inappropriateness of the most exciting processing technology and many product designs to the needs of the lean enterprise. A clear sense of direction that products must be manufactured more flexibly in smaller volumes in continuous flow – provides critical guidance to technologies in the functions developing generic designs and tools.

In addition to forming a picture of perfection with the appropriate technologies, managers need to set a stringent timetable for steps along the path. The high achievers set specific timetables to accomplish seemingly impossible tasks and then routinely meet or exceed them. The low achievers, by contrast set reasonable objectives and become happy with satisfactory underperformance.

Lancaster

The authors have explained the process of switching to lean manufacturing through the example of Lantech a manufacturer of stretch-wrapping machines. In order to gain scale economies, Lantech decided from the beginning that each department should do its work in batches: ten frames welded for the E model, then twenty frames welded for the T, then twenty-five welded for the V. This minimized idle time during the changeover to a new part. In addition, running long batches was thought to improve quality by minimizing opportunities to misset machines and by keeping operators focus on the operation itself rather than changeovers.

To move in the direction of a lean enterprise, Lantech had to line up the essential activities required to design, order, and manufacture a stretch-wrapping machine and perform them in sequence, one machine, one design, one order at a time. The value stream had to flow smoothly, continuously, and rapidly.

The company immediately went to work with a simple plan: Disaggregate the four basic types of machine flowing through Lantech's departmentalized, batch-and-queue production system; eliminate all of the production departments; create a production cell – four in total – for each type of machine; and then line up all the activities required to make each machine within a cell and perform them in a continuous flow. This was the kaikaku phase, the time to completely tear things apart and recombine them in a totally different way.

Lantech had to right-size many of its tools and devise a number of new tools so that smaller saws and machining tools could be fitted in the work cells. The excess workers freed up by rethinking production flow were able to make most of the tools needed. Finally, Lantech had to learn how to perform quick changeovers on all of its tools so that it could make all of the parts for each machine and a variety of product options for successive machines with very little downtime.

By the fall of 1992, the whole Lantech production system had been converted from batches to single-piece flow.

The consequences for performance were truly staggering. Although Lantech's headcount stayed constant at three hundred, the number of machines shipped doubled between 1991 and 1995. The sales growth was due to a general recovery in the market, aggressive pricing by Lantech to capture share, and a host of new products. The plant, where inventory had been piling up now had 30 percent excess space despite the doubling of output. The number of defects reported by customers fell from 8 per machine in 1991 to .8 per machine in 1995. Production throughout time, fell from sixteen weeks to fourteen hours. The percentage of machines shipped on the date agreed with the customer went from 20 to 90.

The rethinking of work in accord with lean principles produced the potential for greatly expanded experiences of psychological "flow." Workers in the Lantech manufacturing cells could now see the entire work flow from raw materials to completed machine. Takt time, standard work, and visual control gave an immediate sense of how the work is proceeding. Multiskilling and job rotation made full use of each worker's skills and the frequent repetition of kaizen events gave an opportunity to participate actively in work design. The constant elimination of muda and the movement of workers out of work cells as more efficient methods were discovered mean that the work is a constant challenge. Finally, there were few interruptions in the form of line stoppages or sudden demands to shift to a completely different task to deal with a crisis.

Firms which never start down the path because of a lack of vision obviously fail. Other firms set off full of vision, energy, and high hopes, but make very little progress because they go after perfection in many directions and spread their resources thin. What's needed instead is to form a vision, select the two or three most important steps to get there, and defer the other steps until later.

Top management must agree on a few simple goals for transition from mass to lean. It must select a few projects to achieve these goals. It must designate the people and resources for getting the projects done. It must establish numerical improvement targets to be achieved by a given point in time.

Wiremold

Wiremold was manufacturing wire management systems. These systems routed complex combinations of power, voice, and data wiring through buildings and power protection devices such as surge protectors and line conditioners, which protected sensitive electronic equipment from voltage fluctuations. These were "low-tech" products made with "low-tech" tools by a unionized, immigrant, aging workforce with limited skills, working in an ancient facility.

In September 1991, Wiremold had a classic batch-and-queue system. Products took four to six weeks to go from raw materials to finished goods. Orders took up to a week to process. New products, even when they were minor improvements over existing ones, required two and a half to three years to progress from concept to launch. As a result, only two or three products were being launched each year. Thick departmental and functional walls were everywhere damming up the flow of value and creating an opaque system.

As the move towards lean manufacturing got under way, hundreds of week long kaizen activities were under way involving practically every employee, as every value stream in Wiremold was repeatedly evaluated for ways to make it flow better and pull more smoothly. Wiremold's assumption was that every stream could always be improved in pursuit of perfection. Equally important, it was presumed that results could be achieved very quickly. Once this was mentally reinforced by results and employees began to believe management's guarantee that no job would ever be lost due to improvement activities, improvement became self-sustaining.

Wiremold removed peripheral jobs and frills that could no longer be afforded. It also smashed the departmental barriers to focus everyone's effort on the value stream by creating dedicated production teams for each of Wremold's six product families. The purchasing, manufacturing, and scheduling (MRP) groups within the Operations Department, the Engineering Department, and the "process villages" in the plants were eliminated. Personnel were reassigned to product teams and provided with all of the resources needed to produce a specific product family.

To get the production teams to work in accordance with lean principles, Wiremold revamped its traditional system of standard cost "absorption" accounting, which allocated costs by labor and machine. This system had given an overwhelming incentive to keep every worker and every machine busy to "make the number" by providing inventory, even if the inventory consisted of items no one would ever want.

As in most batch production organizations, Wiremold's order entry and shipping was disconnected from physical production. A master schedule in the MRP system, based on market forecasts, was supposed to ensure that adequate stocks of finished goods were always on hand in a massive centralized warehouse, so that when an order was received, it could be processed and then shipped from inventory.

Parts which had been produced in one-month batches were soon being produced every day. This required many machines to be changed over twenty to thirty times per day against the former three to four times per week.

Kaizen teams moved quickly to dramatically reduce the number of suppliers, from more than 320 in 1991 to 73 by the end of 1995. Wiremold realised the need for closer and deeper relationships with its customers.

In April 1992, a Wiremold kaizen team paid a visit to Ryerson, a giant steel fabricator much larger than Wiremold, with fabrication facilities spread all across North America. Ryerson supplied Wiremold with large rolls of steel just begun to deliver to Wiremold every day, "just-in-time." However, at the back of Ryerson's plant, the Wiremold JIT team found just what they had expected: a neat row of steel coils, each a day's supply for Wiremold, fifty days in a row produced by Ryerson in one enormous batch. Just-in-time had been nothing more than an inventory shuffling exercise. Ryerson just didn't know how to produce in small lots.

The first two years of comprehensive kaizen activities produced $11 million in cash. Wiremold decided to use this cash to buy up small firms with allied product lines (and who use batch-and-queue methods) in order to increase the scope of operations. The result was five firms with complementary product lines generating $24 million in sales volume.

Wiremold was able to convert $11 million of muda (in the form of inventory), which would have cost about $1.1 million in carrying costs (assuming 10 percent as the cost of money and storage), into $24 million in new sales volume, which at a 10 percent operating margin generated $2.4 million in income. The $3.5 million income swing was highly significant for a company the size of Wiremold (with about $250 million in annual sales). Because the product lines of the five firms were complementary to existing lines, Wiremold's sales force suddenly had a much more complete range to offer customers. This helped increase the overall growth rate.

Product development and time-to-market reduced from 24-30 months to six-nine months. Sixteen to eighteen new products began to be introduced each year (compared with two or three in the period through 1991), but the engineering/design headcount stayed the same.

The rethinking of order-taking, scheduling, and shipping also produced impressive results. The old batch system, which needed more than a week to receive, process, and ship a typical order, now needed less than a day. Past-due orders were now less than one tenth of their 1991 level and continued to fall as Wiremold refined its pull system through all six product teams. Order entry errors were practically eliminated. Misrouted or unanswered queries in the much small Customer Service Department fell from 10 percent to less than 1 percent.

In physical production, the results were exactly as one would expect. The amount of plant space needed to produce a given volume of product was cut by 50 percent. Productivity began to increase at a rate of 20 percent per year. The time for raw materials and components to travel from the receiving dock to the shipping dock in Wiremold's plants shrank from four to six weeks to one to two days. Inventory turns increased from 3.4 in 1990 to 15.0 in 1995.

Porsche and the German tradition

A snapshot of the Porsche company in the years up to the late 1980s shows a classic German model of successful mid-sized engineering firms, traditionally the great strength of the German economy. There was an intense focus on the product itself, its superior performance being the firm's most important concern. Perhaps the most striking feature of Porsche in the late 1980s was its craft culture. From the early days, Porsche had stressed its craftsmanship. Many workers with craft skills migrated to Porsche from the larger firms in response to the introduction of deskilled high-speed, mass-production operations with short work cycles. As a result, the skill level on the floor was high. But Porsche's organization chart was entirely departmental and steeply hierarchical. Each major activity was conducted inside its own organizational unit. Every important decision was referred upward though layers of management.

Pratt & Whitney

When it was established in 1860, The Pratt & Whitney Company believed that best practice called for the creation of special-purpose machines able to perform specific operations on specific parts, if possible at high speeds in high volumes. They further believed that machines performing similar types of tasks should be grouped together in departments. They built the precision machinery needed for the familiar world of batch-and-queue.

Over the next sixty-five years, Pratt & Whitney grew from a small workshop under the direct management of the two founders into a massive and highly successful organization. Its many departments focused on specific processes – casting, drilling, tapping, heat treating – Pratt produced the parts needed for latches, grinders, millers, cutters, and borers for metalworking industries. The firm also pioneered extremely precise gauges to check the accuracy of parts and sold these along with their tools. Over the years, Pratt's machines became more complex and capable of more delicate and sophisticated tasks. In addition, advances in metallurgy made it possible to work prehardened metals so parts could be made to net shape without fear that subsequent hardening steps would interfere with interchangeability. However, the basic production philosophy did not change.

When the flow of orders increased significantly in World War II, Pratt made the final leap to mass production in the factory. A shortage of skilled workers meant that the new machine tools for the war effort were designed for very specialized tasks with only modest skill requirements by the operator. The volume of orders meant it was often feasible to dedicate a given machine to a given part, perhaps for years at a time, so the need to do frequent setups was reduced. Work-in-process, travel within the production system, rework in the test department at the end of production, and managerial complexity all increased but engine output increased even more. High level of production was the only important consideration during the war.

Pratt had much more space, tools, and people than it would ever need again, even if it did not improve its productivity. The company therefore announced in December 1991 that 2.8 million of its 11 million square feet of manufacturing space would be closed. Every product, would be made in continuous flow with the aid of lean techniques, in order to reduce costs by 35 percent over the next four years and the lead time for physical production from eighteen months down to four.

Pratt's supplier base was reduced to facilitate working with a small number of suppliers in long-term relationships. Process improvement teams were dispatched to facilitate this task.

Lean thinkers call a "monument" any machine which is too big to be moved and whose scale requires operating in a batch mode. The monument in Pratt & Whitney was the massive, $80 million complex of twelve blade grinding centers, custom-made in Germany and installed in 1988. The idea had been to automate the grinding of the blade roots for turbine blades using the world's fastest and most sophisticated equipment.

By mid-1995, Pratt had totally revamped its entire physical production system. The mass-production, batch-and-queue, philosophy built up over nearly 140 years was gone and the company was completely converted to a flow organization stressing first-time quality with no backflows.

The Porsche supply base was yet another typical feature of German industry. By the late 1980s, the firm had 950 suppliers even though Porsche made many of its parts itself. This meant one supplier for every nine employees and a vast purchasing department to manage them. But unlike in the US, relationships were typically very long term and very cooperative. Porsche would even bail out some small suppliers on the edge of bankruptcy.

Porsche was primarily interested in the contribution of purchased parts of the performance of the car, not in their cost, the frequency and reliability of deliveries, or the percentage of defective parts. Porsche would perform 100 percent inspection on incoming goods and maintain a vast warehouse to guard against supply disruptions.

Much of the craftwork at Porsche was muda. The factory was not closely involved in designing the product. So Porsche designs were high on performance but very low on manufacturability. Far from protesting, the skilled workers resolutely shouldered the burden of making unmakable designs, often by means of lengthy adjustments and fitting of parts. Similarly, it was accepted that many parts from suppliers would be defective, and would arrive late. And sometimes, wrong parts arrived.

Porsche offered truly superlative performance and filled a special niche in the market for true sports cars with production reaching only 33,000 units in the peak year for the highest-volume model, the 944, and never exceeding 21,000 for the upmarket 911. As a result, it was difficult for giant car companies to compete with Porsche. On the other hand, smaller specialist firms who might have copied Porsche's product philosophy and worked cost-effectively at low volumes lacked the necessary product technologies built up over many years by Porsche's consultant engineers.

However, the firm's special situation also created vulnerabilities. Any model change was truly a "bet-the-company" proposition. So over time the management erred on the side of caution. A majority of those with the money and desire to buy a Porsche in the 1980s lived in North America, while practically 100 percent of Porsche's value was created in or near Stuttgart. The boom year of 1986, when Porsche sold a record 50,000 cars (62 percent of them in North America) gave way to serious problems from 1987 onwards as the mark strengthened against the dollar and sales steadily tumbled. By 1992, Porsche was selling only 14,000 cars worldwide and only 4,000 in North America.

In May 1992, Porsche launched a four-pronged offensive to overcome the crisis. It restructured operations from six layers of managers to four and created four cost centers and three support functions to make responsibilities much clearer. The number of managers was reduced by 38 percent – from 362 in July 1991 to 328 in July 1992 to 226 by August 1993. In the new system, the support functions concentrated on developing the supply base, devising quality systems, and planning improvements while day-to-day operating tasks were assigned to the cost centers.

Porsche negotiated with its Works Council for a new team structure on the plant floor. Production departments of twenty-five to fifty employees reporting through several layers were broken down into two to three teams of eight to ten workers with each group of teams reporting directly to a single meister.

A "quality offensive" was launched to show the workforce the true costs of Porsche's quality practices. The most effective tool was to estimate the cost of catching a defect at the moment it occurred, compared with the cost at the end of the line, in the vehicle rectification area at the end of the plant, and in the hands of the customer. A problem costing 1 mark to fix at the spot it happened on the assembly line was estimated to cost 10 marks to fix at the end of the line, 100 marks in the vehicle rectification area at the end of the plant, and 1,000 marks at the dealer under warranty! This came as a revelation to the Porsche workforce, which had simply never looked downstream from their own work area to see the consequences of their mistakes.

Porsche also introduced a policy development and visual management system called the Porsche Improvement (Verbesserungs) Process, or PCVP for short. This set measurable targets, monthly and annual, for each cost center and for each work team along four dimensions – cost, quality, logistics, motivation.

The first objective of the lean initiative was to get rid of the mountains of inventory and eliminate the “treasure hunting” for parts. Then made the parts flow from receiving to engine assembly to the final assembly plant very rapidly with no stopping, no scrap, and no backflows to fix defects.

The amount of space for inventories was reduced from 40 percent of the assembly area to zero, the amount of parts on hand was reduced from twenty-eight days to essentially zero. Parts were in the assembly area for only about twenty minutes before the completed engine was sent to the final assembly area.

A kanban system was installed with major suppliers so that the needed parts were delivered directly to the assembly area at frequent intervals. The massive automated central warehouse Porsche previously used for received parts was partly emptied and the space made available to the service parts organization.

However, growth looked unlikely to return to the level of the 1980s, until the introduction of new models. In addition, it was apparent that Porsche was engineering and making a wide range of parts and components in-house at absurdly low volumes and high costs. It made more sense to buy from the firms supplying similar parts to the big car companies.

A onetime adjustment in the workforce of 2500 employees was carried out over a three-year period beginning in mid-1992 to bring the headcount to a level consistent with long-term needs. Some workers took a special retirement offer. Others were given a large severance. Because natural attrition was about three percent a year, given the age distribution of Porsche’s workforce, an additional 30 percent reduction in the workforce could be achieved in the next decade without resort to layoffs if no additional sources of production volume could be found.

While this reduction in headcount was taking place, the management made a commitment to the works council that no one would ever lose their job due to the introduction of lean thinking. But the company added that the nature of everyone’s job would constantly change. A collapse in sales might necessitate another round of departures to save the company. This guarantee was originally given for the three-year period 1991-1993, and later extended for another three years till 1996.

Porsche had 950 suppliers. The first step was to reduce the supply base. About 60 suppliers were designated as critical systems suppliers. It was often possible for the former direct suppliers to become second tiers suppliers to these firms.

German industry possesses many unique strengths. German firms still benefit from a stable system of industrial finance which emphasizes the long term. Senior management believes in the product itself as the most important factor in competition. Relations with suppliers are both long-term and supportive. Both the factory workforce and technical specialists in manufacturing firms have the highest skill levels in the world. But cross functional coordination has been a key German weakness. The emphasis is on deep but narrow skills for technical operations rather than horizontal systems needed to pull all operations together.

Meanwhile, on the factory floor, the Meister system of a large group of twenty-five workers reporting directly to the shop head, who refers problems up the hierarchy for solution, is contrary to small-scale work teams. These workers should be focused horizontally on a linked set of activities along the value stream and perform many of the indirect tasks associated with managing their work, including quality assurance, machine maintenance, tool changes, development of standard work, and continuous improvement.

A second German weakness has been a fondness for large machines which produce in huge quantities. A third German weakness has been the tendency to substitute the voice of the product engineer for the voice of the customer in making trade-offs between product refinement and variety on the one hand and cost as reflected in product price on the other. Variety and refinement almost always entail costs, particularly when products are designed without much attention to manufacturability.

Nevertheless, the German system was highly competitive until recently because each weakness was offset by the tremendous skill levels on the plant floor. It was possible to fix each problem as it arose. Skilled product development engineers could modify designs coming from upstream rather than talk to upstream specialists about the problems their designs were creating. Because of the technical depth of a firm's functions, it was often possible to add performance features to products which offset their inherently high development and production costs. Thanks to the sophisticated German machine tool industry, the high German wages could be offset by Computer Integrated Manufacturing breakthroughs which coupled highly flexible production operations with automated materials handling.

In the 1990s, these offsetting strengths have been overwhelmed by world conditions. Wages have risen behind a soaring mark, East Asian firms have attacked traditional German market niches. The current generation of factory automation has become too expensive for Germans to afford. Lean manufacturing will have to become a way of life for the Germans.

Showa, Toyota and the Japanese way

In 1983, Showa Manufacturing, a maker of radiators and boilers, celebrated its one hundredth anniversary. The firm had been steadily successful in the Japanese market and in the 1960s. However, Showa started to struggle after the second oil shock in 1979. Demand for its industrial products slumped as Japanese firms cut back expansion plans and considered more modern concepts in heating. The cost structure at Showa, with its traditional Japanese commitment to its 750 core employees, seemed difficult to alter.

Showa's initial response was typical of Japanese firms in these circumstances. To raise the cash to avoid layoffs it sold the valuable real estate under its center-city offices and main plant and began relocating its production facilities to cheaper but more modern sites nearby. It also diversified into ornamental castings for bridge railings and began to implement a plan for exporting its cat-iron boilers to America to take advantage of the weak yen.

When Showa's original office and manufacturing complex in crowded Fukuoka City was fully relocated in 1983 to new plants in suburban Umi and Koga, the management expected its fortunes to change. Instead, the decline continued. Process villages for casting, cleaning, stamping, welding, painting, and assembly running in batch mode created mountains of parts which were then taken to central stores before reshipment to the next processing step. Orders took months to work their way through the system. The cost of starting exports was high. The diversification into ornamental castings pitted Showa against larger firms with established reputations in the building trades.

It was at this point that Showa decided to contact Taiichi Ohno and ask for help. Ohno immediately asserted that by moving to small-lot production and producing only what was requested by the next production step, it would be possible to reduce the three months of inventory of a typical part to a few days. He felt that it would also be possible to double labor productivity and halve the amount of plant space needed for current output. He felt this could be done very quickly with practically zero capital investment.

The Showa workforce, however, was completely skeptical and resistant. And the line management felt little different.

Despite the skepticism of the workforce, and pointed disagreements with them at almost every step, in less than a week it was possible to eliminate half the plant space, 95 percent of the in-process inventory, half of the human effort, and 95 percent of the throughput time needed to make a coil. The capital investment and time needed for the transition were trivial in comparison with the benefits.

As a result, Showa clawed its way up from deep losses to modest profits. Still, selling prices for Showa's products continued to decline in a stagnant market. It was clear that cost cutting alone would not be sufficient to generate adequate profit.

In 1987, Showa broke up 104 years of centralized corporate structure by creating new, horizontal product teams, one each for a range of new product lines. Each product team had its own marketing, product design/engineering, and production system, renting space in Showa offices and plants as appropriate. Within a brief period the centralized, “batch” operations of the old Showa were eliminated and replaced with dedicated, continuous-flow teams for each product family. These employed a very high fraction of Showa’s total headcount. Only a few workers were left in the tiny, centralized functions consisting of production scheduling, finance, supplier development and logistics, human resources, quality assurance (to deal with complaints for customers), and, of course, “production research” to continually improve every activity.

In the new system, a high fraction of costs was directly assigned to individual products. Only a small fraction was allocated from general overhead. So it was possible to know whether product families were producing an adequate profit. The team leaders were told to renew their product ranges continuously and to be prepared to exit product lines where they could not make money.

In this new system, orders with incorrect information would never be passed forward by the designers, and engineers. Meanwhile, the customer had to be educated to understand that Showa needed only four days of lead time before the product was ready to ship. So there was little point in specifying exactly what was wanted (and then changing the order repeatedly) until it was time to build it. The customer also had to be convinced that Showa could now ship exactly on schedule.

The Showa ordering and scheduling system became completely open for everyone along the value stream to see – the customer, the distributor, the Showa product team, and the component and materials suppliers. Only the product team could change the information on the electronic schedule board, but everyone with an interest in the outcome could electronically check on the status of orders at any time.

Showa also began to develop a new strategy for serving markets beyond Japan. The first step (in 1995) was to establish a subsidiary in China, but one with a very different purpose from those of many other Japanese, European, and American firms. The new Showa subsidiary customized designs and then manufactured Showa products for the Chinese domestic market. Most of the manufacturing was done at one site in China using lean techniques, for rapid delivery to Chinese customers. The objective was to take full advantage of the strengths of a lean firm by customizing and manufacturing in the market of sale and developing strong relations with local customers. There is no intention to export Showa products from Japan to China or from China back to Japan or to other markets. In the future, any major market with promise for Showa will get its own design and production system to serve that market. But Showa will share globally a set of technological capabilities and the vital lean know-how for managing production, product development, and order-taking.

The evolution of lean production in Toyota

Taichi Ohno, the architect of Toyota’s lean production system noted that workers spent most of their time simply watching machines do their work. Many bad parts were produced before they were discovered by inspectors from the Quality Control Department.

Ohno quickly devised a set of simple limit switches and go/no-go gauges so that machines, once loaded, could do their work to completion without human intervention and stop working immediately if they detected an error in their efforts. With these simple devices added to conventional machines tools, it was quickly possible for one worker to superintend many machines and perform quality checking as well. The worker intervened only to load machines and to deal with malfunctions.

Ohno also realised that "when you have lots of inventory you are always one part short." He decided that the problems could only be solved only if the previous processing step picked up exactly the number of parts needed for the next step of production.

Ohno decided that the machines should be moved from process villages into "cells." There, they would be placed in the exact sequence required by the part being made. By focusing on the needs of the object undergoing manufacture, rather than the maintenance needs of the machines, the traditional skill sets and work methods of the workforce, or conventional thinking about scale economies, he focused the value stream and eventually perfected the concept of "single-piece flow."

By the mid-1960s Ohno had finally pushed his ideas all the way through Toyota's own production facilities. The logical next step was to help suppliers. Toyota discovered that its suppliers were relying on finished goods warehouses filled with small piles of parts assembled far in advance for their hourly or several-times-a-day shipments. The piles were created from large production batches. Suppliers had no idea how to produce in small lots to replenish the amounts withdrawn from stocks several times a day by Toyota.

In 1969, Ohno directed a new group of direct reports he had trained personally, the Production Research Office (now called the Operations Management Consulting Division [OMCD]), to set up mutual-help groups among Toyota's forty-two largest and most important suppliers.

Finally, the initial shusa system Toyota put in place with the Crown in the early 1950s worked less and less well as the number of products began to proliferate. (Even as late as 1966, when the Corolla was launched, Toyota had only three automotive products, the Crown , the Corona, and its ill-starred "people's car," the Publica.) By 1991, Toyota was offering thirty-nine models of cars and trucks, based on nineteen separate "platforms."

In 1992, Toyota reorganized its products into three platform groups overseen by truly heavyweight program managers with a much higher level of dedicated engineering resources. The objective was to focus on product families which shared components rather than on stand-alone products, to dedicate engineering resources to the platform groups, and to streamline the flow of designs all the way into production so that new vehicles could be carried from concept to launch in 27 months.

Toyota's first and second-tier suppliers learnt to operate their production facilities in accord with the Toyota Production System. But according to the authors, the performance of the third-tier makers of small parts is still inconsistent. Most raw materials suppliers are still stuck in the world of batch production. These firms, accounting for more than two-fifths of the total manufacturing cost of a vehicle, are outside the Toyota Group's reach and most have been resistant to Toyota's requests to streamline their thinking.

In the West, raw materials probably account for no more than 25 percent of manufacturing costs. But because Toyota has been so effective in cutting costs in its supply base through four tiers of suppliers, the real cost saving for Toyota today lies in changing the thinking and behavior of materials suppliers.

It seems fair to say that by the mid-1990s most major Japanese manufacturing firms and many of their first-tier suppliers were fully aware of lean concepts and most had at least some examples of implementation. However, implementation has been uneven. Many big companies still place their bets on high-tech mass production. But high-tech mass production optimizes one tiny portion of the value stream while ignoring the costs and inconvenience to customers created elsewhere.

The Japanese also have to reexamine how they are globalising. To achieve the scale needed to justify the degree of automation it will often be necessary to serve the entire world from a single facility. But customers want to get exactly the product they want exactly when they want it. In almost every case, locating smaller and less-automated production systems close to the market, will yield lower total costs and higher customer satisfaction.

The authors feel that the right way for Japanese car makers is to find new things to do at home while aggressively replicating lean systems for product development, order-taking, and physical production in every major region.

The importance of change management

The most difficult step in the transition to lean manufacturing is to overcome the inertia present in any brownfield organization. A change agent will be needed along with the core of lean knowledge. Some type of crisis must exist to serve as a lever for change.

The change agent and all of the senior managers must master it themselves to a point where lean thinking becomes second nature. What's more, they should do this as soon as possible. If the change agent doesn't fully understand lean thinking, the campaign will bog down at the first setback. So he or she must truly understand the techniques of flow, pull, and perfection. The only way to gain this understanding is by participating in improvement activities, hands-on, to a point where lean techniques can be taught confidently to others. While doing this, the change agent needs to involve the other senior executives of the firm as well. Everyone's knowledge must be brought up to a minimum level to grasp the power of lean thinking.

An organization must be facing a crisis to take the necessary steps to adopt lean thinking across the board in a short period of time. So if a firm is in a crisis already, it must seize the invaluable opportunity. One approach is to take some subunit of the organization which is in crisis and focus all the energies on applying lean remedies to it.

Where no crisis exists, opportunity gaps must be identified to wake the company out of its slumber. There may be an opportunity for dramatic change if one can find a lean competitor. Yet another approach is to find a lean customer or a lean supplier.

According to the authors, many firms in a crisis respond mainly by blaming the industry rather than the firm. If a firm quickly eliminates muda in product development, sales and scheduling, and operations, it will soon discover that as it fundamentally changes, the cost production lead times and time-to-market for new products reduces. Even if it turns out that some businesses have severe structural problems, the firm wont be worse off for making them lean because very little capital investment will be needed. The cost base will fall. So operating results will improve even if sales volume and prices don't. The firm will also have bought time to think even if it turns out that a very lean business is not sufficiently profitable to continue.

There is a big difference between reengineering and lean thinking. Reengineering concentrates on information flow rather than operations or product development. Reengineering rarely looks beyond the firm to delve into the operations of suppliers and distributors, even when these account for a great proportion of costs. And the focus is usually on streamlining aggregated activities rather than on addressing the needs of individual product families.

One of the critical features of lean techniques is immediate feedback. The improvement team and the whole workforce should be able to see things changing before their eyes. This is essential to creating the psychological sense of flow in the workforce and the momentum for change within the organization.

No time must be wasted on benchmarking if there is any way to get the firm moving without it. For companies that are completely asleep, benchmarking may be an essential first step. However, if one already understands lean thinking and lean techniques, one should simply identify the muda around through value stream mapping and get started immediately on removing it. Benchmarking as a way to avoid the need for immediate action is itself muda.

It's important to produce some dramatic results quickly everyone can see by focusing on a particular troubled activity, usually in physical production. However, as soon as the first round of improvements are in hand, it's time to start linking the different parts of the value stream for the product family.

People who don't understand lean thinking become complacent after the exhilarating success of the initial "breakthrough" exercise. This is only the beginning. The next leap is to create an organization which can channel the flow of value and keep the stream from silting up again. The firm will also need to devise a strategy to fully utilize all of the resources being freed up. The firm must also have the courage to remove those managers who will never accept the lean thinking philosophy.

The firm will have too many people if sales remain constant. So excess people must be removed from activities where they are no longer needed. It will be impossible to make and sustain superior performance if one doesn't take this step. The correct thing to do is to face it up front, by estimating the number of people needed to do the job the right way, and moving immediately to this level. Then the firm must guarantee that no one will lose their job in the future due to the introduction of lean techniques. And the company must keep its promise.

According to the authors, "What you can't do is conduct drip torture in which you move through your organization activity by activity, asking your employees to help you eliminate their jobs with no end in sight. As we've tried to explain, in a lean world there is no end to improvement: Jobs are always being eliminated in specific activities. Employees will react as they should to the introduction of what they will call "mean" production with subtle but effective sabotage. Improvements will be impossible to sustain."

Lean techniques must not be seen as a clever way to quickly raise margins by eliminating as many people as possible. One can save some money at the outset but one will never sustain leanness. A far more promising approach is to devise a growth strategy which absorbs resources at the rate they are being freed up.

At the end of the first improvement initiative on an activity, the line management and the work team must be told that in three months it will be time to fix it again. It's critical to get employees to understand at the outset that no level of performance is ever good enough, and that there is always room for improvement. This will usually mean moving every machine and changing every job.

An even more important task for the annual policy deployment exercise will be to identify the tasks one can't hope to succeed at just yet but which some parts of the organization will badly want to tackle right now. One will need to publicly acknowledge that these are important but they will need to be postponed till the resources are available.

The primary workforce and frontline managers probably know the most about the hard technical aspects of getting isolated jobs done. But typically they don't understand how to think horizontally about the total flow of value and how to pull it. Nor do they fully appreciate the methods of root cause analysis to eliminate the need for fire fighting. Therefore, if one asks these people to implement lean techniques, one is likely to get a rush of suggestions followed by general disillusionment when they fail to work properly. To gain the critical lean skills, the workforce needs training, but of a special type. Faculty must be line managers who teach workers those skills precisely needed immediately for the next phase in the lean transition.

The firm will need to counter the ancient bias of managers that large, fast, elaborate, dedicated, and centralized tools are more efficient. For every activity the company should ask them to work backwards by asking, What kind of tools would permit products in a given family to flow smoothly through the system with no delays and no back loops? And, what types of tools would facilitate switch over instantly between products so there would be no need to make batches?

Internal activities account only for a third of the total cost and lead time needed to get its product to market. So, firms must work with their suppliers closely to fix their production, product development, and order-taking systems. The firm’s suppliers and downstream customers after improving their in-house performance, must assist their own suppliers.

Initially, the process improvement group will work top-down because the pressing need is to change the mindset of employees by directly demonstrating a better way. Over time, however, a more broad based effort will result.

In lean thinking the ideas themselves are extraordinarily antihierarchical and pro-democratic. Every worker inspects his or her own work, becomes multiskilled, and participates in periodic job redesign through kaizen activities. Layers of management are permanently stripped away. Transparency makes every aspect of the business open for everyone to see. Yet getting the critical mass of employees to change their traditional way of thinking requires stern direction as employees are asked to try things which seem completely crazy.

Review of key points

The objectives of the lean enterprise are very simple: Correctly specify value for the customer, avoiding the normal tendency for each firm along the stream to define value differently to favor its own role in providing it. Then identify all the actions required to bring a product from concept to launch, from order to delivery, and from raw material into the hands of the customer. Next, remove any actions which do not create value and make those actions which do create value proceed in continuous flow as pulled by the customer. Finally, analyze the results and start the evaluation process over again. Continue this cycle for the life of the product.

The lean enterprise seems so simple and obvious that many readers will think this type of analysis must surely occur routinely in practice, even if not in name. But this is not so. Most managers lack an understanding of the potential of flow and pull to remove waste when applied to the entire value stream. Moreover, a lean enterprise changes the status quo. Jointly analyzing every action needed to develop, order, and produce a good or service makes every firm’s costs transparent. There is no privacy. Thus the question of how much money (profit) each firm along the value stream is going to make on a specific product is unavoidable.

Value stream participants often behave in a very similar way, cooperating at the minimum level necessary to get a product made at all, but hoping that the other parties' ignorance of just what they are up to will permit them to grab a financial jackpot.

In the context of a lean enterprise, these principles might be something as follows:

- Value must be defined in terms of what the customer wants. It must be specified jointly for each product family along with a target cost.
- All firms along the value stream must make an adequate return on their investments related to the value stream.
- The firms must work together to identify and eliminate muda to the point where the overall target cost and return-on-investment targets of each firm are met.
- When cost targets are met, the firms along the stream will immediately conduct new analysis to identify remaining muda and set new targets.
- Every participating firm has the right to examine every activity in every firm relevant to the value stream as part of the joint search for waste.

As lean enterprises are created to channel the flow of value, more and more employees become directly involved in value-creating tasks. Much of the indirect effort formerly required simply disappears, along with most of the head count of the departments organizing this effort.

If, for the most part, employees are assigned to a particular product team to apply their skills to the value stream, they may begin to wonder if they are "going anywhere" and get confused about "who I am." While the actual work is likely to be much more rewarding than in the previously disconnected world of departmentalized batches and queues, the lack of perceived progression and specialization may be dispiriting.

This suggests that a new form of career must be devised, an "alternating career" in which employees go back and forth between applying what they know in a team context and taking time out to strengthen their functional skills.

Concluding notes

The great challenge for Americans is to overcome their individualism. Each organization along the value stream optimizes its own stretch while suboptimizing the whole. This tendency is exacerbated by the industrial finance system, which asks each firm to optimize its short-term performance but ignores the performance of the whole. Shares of individual entities and not the whole value stream are traded in the stock market.

The German challenge is in many ways the reverse of the American one. The idea of cooperation between assembler and supplier firms along value streams is well established in Germany. The industrial finance system understands and encourages this need as well. But this system has been under stress in recent years, primarily because of poor fundamental productivity. Also, workers in German firms show a clear discomfort with the type of cross-functional coordination needed to operate lean enterprises.

German firms therefore face a particular adjustment challenge. Each employee's loyalty and sense of possessing special skills must be encouraged while reducing the reluctance of the shop floor worker, meister, and engineer to participate in corss-skill problem solving. If this can be done, the superlative operations skills of most employees and their strong identification with the product, can be really leveraged.

In Japan, collective analysis of costs along the value stream is clearly accepted and practiced. Employees are ready to be moved around without much regard to functional career paths. What's more problematic is the role of vertical functions – which accumulate knowledge, teach it, and push it ahead in a society based on horizontal work. What's also problematic is the tendency to locate bulk of production at home. Even in a rapidly globalising market, local customization cannot be ignored.