# Case A: Japanese Lean Volume Supply Systems

## Introduction

The Japanese industrial phenomenon started with World War II. At the end of the war, Japan was a defeated nation, with the remnants of a high-capacity vehicle manufacturing industry, but with limited markets for any manufactured vehicles, since postwar arrangements dictated by the US did not allow export. Meanwhile, the US dominated global markets with mass production, after the style of Henry Ford. Faced with only domestic markets for their vehicles, Japanese manufacturers faced a bleak choice: amalgamate; go out of business; or, find some way of keeping going with a greatly diminished market.

The Toyota Motor Company was one such organization. After the war, Taiichi Ohno and Eiji Toyoda pioneered the concept of lean production (Womack, *et al*., 1990). Ohno obtained some second-hand body presses from the US and experimented with them. The body presses were fitted with male and female dies, the shape of the required body part: these had to be accurately set up, else both the sheet metal and the die could be damaged in the process. In the US, changing dies to make a different body part would take 1–2 days, using highly skilled labor. Ohno's experiments cut die-change times down to three minutes (!), and moreover deskilled the task, using the same staff that worked the press to change the dies.

This one change afforded great opportunity: whereas with mass production it was essential to have long runs of identical items to amortize the cost of the machinery, with Ohno's approach it was feasible to have short runs, and to change dies frequently and easily. This, in turn, opened more doors. Instead of lengthy and expensive marketing assessments to assess likely sales potential for some proposed product, it now became simpler, quicker and much cheaper to make a spread of new items, present them to the market, and see which sold best. Toyota could now make a range of vehicles, cars, lorries, pickups, etc., for the domestic market, with economical short production runs on each.

Such a small market was soon satisfied, however. Repeat order sales would come only if the owners of vehicles had to replace them for some reason: if the vehicles wore out, or were unreliable,

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or rusted . . . . A regime was introduced where vehicles were allotted a life of, typically, six years, after which they had to be scrapped; this gave the motor industry a guaranteed turnover, but at a cost to the motorist. Initially, Japanese goods, including cars, were viewed as of poor quality: to use the contemporary expression, they had 'built-in obsolescence;' simply, they were designed to wear out quickly. This did, indeed, mean that the purchaser of a Japanese car would soon need a new one, but the buyer was very likely to choose a vehicle from a different manufacturer in the hope of getting a better deal.

Quality was an issue. Poor quality deterred buyers. Good quality meant the vehicles did not wear out, leading to vehicle retention and delayed repeat business. How to improve the quality and increase the business turnover at the same time . . . .

The answer was innovation: if people who had already bought a good-quality, reliable vehicle/computer/hi-fi/washing machine/etc., could be persuaded that there was a newer model or version now available that did more things, had more capability, went faster, or whatever, then they would buy the new one, regardless of the fact that their existing version was still perfectly good. So, the solution was a combination of high quality and continual innovation: together, these powered market demand ('market pull'), which lean volume supply systems depend upon for continued existence.

None of the above explains the leanness aspect of lean volume supply, however. Leanness derives from many different, interacting factors, including:

- Market pull (see above), as opposed to the production push of mass production: leads to . . .
- . . . making and assembling only that which had effectively been sold already,
- thereby eradicating stocks of unsold produce.
- Minimizing work in progress (WIP) within factories, in goods outwards, goods inwards, traveling between factories, between processes within factories, etc., etc. WIP costs money to buy, and makes no profit — in essence, it becomes a recurring cost, or an overhead.
- Just-in-time (JIT), part of minimizing WIP; parts to be machined, assembled, etc., are not stocked, are not held in batches awaiting processing, etc., but arrive just as they are to be processed.
- JIT and minimizing WIP dictate that parts being moved between factories are moved individually, rather than in lorries which wait to accumulate a full load before traveling. Motorcycle couriers may transport parts instead, as this may prove more economical overall, when the cost of the WIP-parts is considered.
- Small batches in innovative manufacture show up defects quickly, allowing errors to be corrected: also eliminate need for large inventories.
- Highly skilled and motivated workforce, multi-skilled, able and willing to tackle any job, resulting in high productivity per worker, and consequent low labor costs.
- Value engineering to establish the essential function of various parts/subsystems and their costs. Operates hand in glove with . . .
- . . . 'market price minus:' establishing an attractive market price early in the design process and working back from the overall price to the value, function and price of the various parts.
- Outsourcing complete subassemblies such as bumpers, dashboards and instruments, interior furnishings and furniture, etc. This is as opposed to the mass production practice where a bumper might be sourced as, say fifteen different parts, each of which could be separately designed by the mass producer, and separately sourced, with the attendant risk to the assembler that the various parts were, in some way, incompatible.
- Multi-sourcing, to guarantee supplies, and to shorten supplier reaction times

Culture played a large part in the Japanese success story, too; culture is often underrated in Western evaluations. The effects of culture are not always evident. For instance, it has been estimated that there may be as many as thirty times the number of personnel employed in counting stock of various kinds in a western factory as in an equivalent Japanese factory. Why? In the West, anything that is not secured is likely to 'walk;' i.e., be pilfered (stolen) by employees. Tires, engines, wipers, windows, seats, etc: every part, and even the machinery, will be stolen if not safeguarded. In a traditional Japanese company, all of the employees are 'family:' one does not steal from family, so, no pilfering. Hence, costs in a Japanese company will be significantly less, both because there is no need to replace pilfered stock and there is no need to employ small armies of stocktakers and security guards.

The culture allows different practices. In a western car manufacturer, tires might be supplied in bulk to some goods inwards store, and paid for as a load. In a Japanese company, the tires are supplied just in time (to be fitted to wheels and assembled), but the supplier is not paid until a vehicle rolls out of the door — at which point he is paid for five tires. This has several effects: first, the supplier is motivated to supply only what is needed, when it is needed, else he is funding WIP without return; second, the supplier becomes part of the team since he becomes actively interested if there are holdups on the assembly line, and will contribute to resolving holdup problems, which would delay his receipt of payment.

All of which presupposes a highly motivated Japanese workforce. Workers are given 'jobs for life:' they are paid by seniority for doing any given job, rather than by the nature of the job; were they to move to another company, they would then start at the bottom of the seniority ladder, and would take time, perhaps many years, to match their previous earnings. Workers become short-term fixed cost, like machinery, but cannot be depreciated. Instead, it was seen as good to continuously enhance workers' skills, and to *use* their knowledge and experience: in top Japanese companies, every worker actively contributes ways of improving processes and products, and is rewarded for so doing. The rate at which each worker contributes 'ideas and inventions' may be an order higher per worker than in western companies.

Symptomatic of the East–West dichotomy is the Japanese approach where workers report on the performance of their team leaders, while in the West, managers report on the performance of their workers. Japanese workers tend to work in teams, with a leader. Successful leaders attract the best workers to their teams, enabling such teams to compete successfully with other teams. Successful teams may be paid bonuses, which are for the whole team, not for the individual; generally, each individual in a team might receive identical shares of the team bonus. This has a cohesive effect within the team.

Suppose, for example, that one of the team were to be temporarily ill, off color, or perhaps suffering from personal problems. The prospect of a team bonus, rather than an individual bonus, motivates the other members of the team to pitch in and help the lagging individual, so that the whole team continues to perform. This is in stark contrast to 'performance-related pay (PRP),' popular in some control-centric western management circles, where individuals are earmarked for higher pay based on their manager's assessment of their performance. (PRP can be divisive, unfair, and is wide open to abuse, favoritism and bias. While the intent of PRP may seem obvious and rational, it is essentially an individual control mechanism that may demotivate, inhibit and fragment the team, rather than achieve its intended goal.)

Cultural differences are to be seen in contracting arrangements, too. Mass production sees the end supplier, the lead company, designing all the parts of some future product, and then putting the parts out to competitive tender so that each part can be procured at the lowest price. In this way, it is hoped to manufacture the end product for the lowest overall cost. It does not work well. Bidders, eager to get the business, offer to make parts at a price that is less than they can really afford, i.e., one that affords insufficient profit margin; if they do not, they may be unlikely to get the business. Once they have got the business, and the customer is supposedly committed, then the supplier will attempt either to make the part for less, perhaps by reducing quality, using different materials, finish, etc., or will try to raise the price per part, or both. This results in aggravation, confrontation, strikes, etc., and a general tendency for quality to go down and price to rise throughout a long production run.

Japanese lean production arrangements can be quite different. The design of some new product, or a new version of an existing product, may be a joint affair, with suppliers of various subsystems/subassemblies taking part. Once an overall design is generated, together with a selling price that will guarantee sales, then reverse engineering sees the design and specification of the various subsystems. The price of each subsystem is also agreed with the main contractor, and is set by agreement so that the respective supplier/subcontractor may anticipate a reasonable profit. This may involve a revised design of the subsystem, perhaps using different materials, with the active assistance of the main contractor, so that it may be manufactured to the right quality for the previously agreed price.

During a production 'run,' should a supplier find a way of making the part for less, then that supplier stands to make a greater profit. Alternatively, this could mean that the selling price for the whole product could be reduced, thereby enhancing sales prospects. One approach, then, is for the supplier to reduce his price to the main contractor, for the main contractor to reduce the overall price, for increased profit to accrue from increased sales, and for the supplier who lowered his price to benefit from the increased profit on sales. With this approach, it is in the suppliers' best interest to drive manufacturing costs down, and quality up, so that the supplier as well as the end contractor may increase profit. This arrangement may be included in the contract arrangements, with the result that the price of products may reduce throughout a production 'run.'

So, contracting arrangements for lean supply encourage cooperation and coordination between suppliers and end contractors — quite different from mass production, with its history of confrontation, discontent, strikes and rising prices. Culture in the West seems to be set into a pattern of confrontation and aggravation: lack of trust is endemic in both directions between governments and defense contractors, subcontractors and main contractors, and so on. Such a cultures will not promote and sustain lean production, at least not Japanese style.

Attempts in the US and in UK during the 1990s to introduce lean acquisition practices into national defense procurement were scuppered by the extant bureaucracies in both countries, each of which seem much more comfortable with the atmosphere of mutual antagonism and distrust that exists between government and the defense industry. Besides, the two bureaucracies would have been seriously undermined, to the extent that neither would have really been required at all — which would have saved each nation untold billions of dollars/pounds, and made thousands upon thousands of civil servants unnecessary and unemployed. Just as turkeys do not vote for Thanksgiving/Christmas, of course, bureaucracies exist chiefly to defend themselves . . . which, in this case, they did *par excellence*.

# Investigation

It is not the intent of this case study to explore the whole of the Japanese lean volume supply system; others have done that very well, and have written excellent volumes on the subject. Notable among these is 'the machine that changed the world' (Womack *et al*., 1990), which is based in a 5-year, 5-million dollar MIT study on the future of the automobile. Nor is it the intent to suggest that all Japanese industrial companies are as good as the best; they are not.

Instead, it is the intent to look into some of the phenomena that are at the heart of lean production, to see if the detail matches the hype, and to find rational — perhaps even scientific — support for the Japanese approach to systems engineering at enterprise, industry and socio-economic levels.

## The open system viewpoint

Figure A.1 shows an individual business entity, part of some notional lean volume supply system, presented in the form of a GRM. The enterprise is shown shaded, in the center, with the standard GRM aspects, which include culture within Behavior management. Parts from various suppliers, shown as Resource environment are passed through the enterprise, leaving at right as integrated products into an Operational environment, generally a market of some kind. A link from the Operational environment back to the parts supply at left suggests that flow of resources through the system is in response to demand for parts, and that such demand is accompanied by revenue from sales; in simple English, sales pay for more parts to make more products. For each enterprise in a chain, the next enterprise may be seen as its market.

The figure shows that there are two quite distinct categories of resource. Center bottom of the figure is a second resource pool, coupled to Viability management; these are resources that establish and maintain enterprise viability: synergy, maintenance, evolution, survivability, and homeostasis (S-MESH). Of these five, synergy and homeostasis are, perhaps, the most significant. Inflows and outflows will include men, machines, materials and money; with recruiting, retirement, training, research, development, planning, administration, security, internal communications, supply chain communications, outsourcing, goods inwards, goods outwards, sales, etc., etc. Maintaining

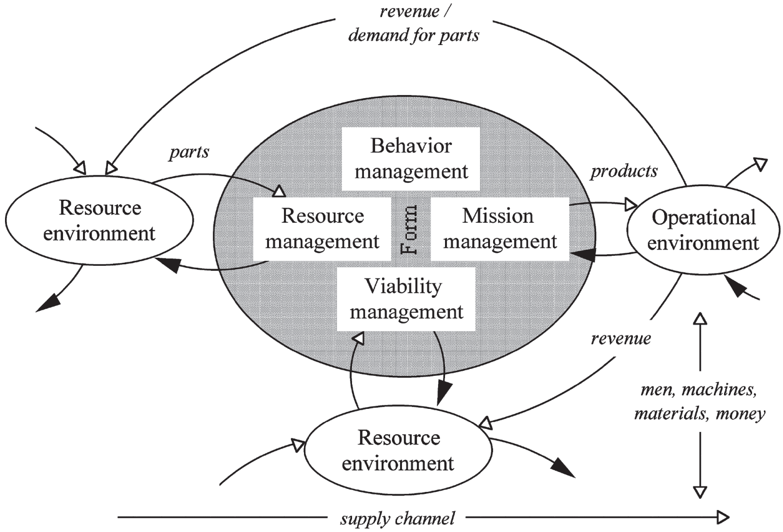



**Figure A.1** An enterprise, represented by a GRM, in context as one link in a lean volume supply system.

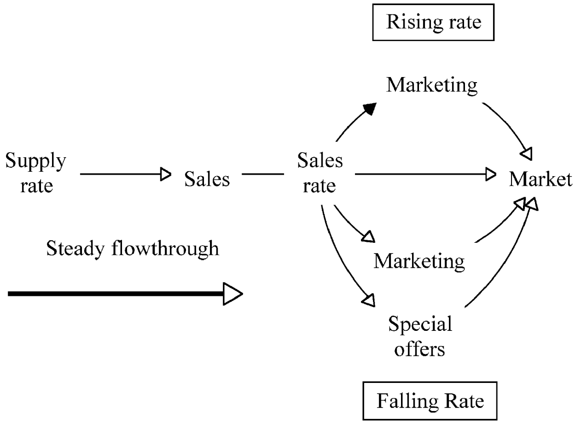



**Figure A.2** Heijunka. Flow smoothing by varying marketing and sales efforts to manipulate demand, leading to a steady flowthrough and consequent minimized unit production costs . . . ; solid arrowhead indicates *reduced* marketing effort.

homeostasis implies inflow/outflow balance between a wide range of many different features, some tangible (e.g., numbers of employees) and some less tangible (e.g., skill levels).

Figure A.2 shows a more pragmatic view of a notional enterprise, this time at the head of a supply chain, i.e., interfacing with the market and the consumer. The figure shows the bare bones of an end supplier or main contractor, with the manufacturer making a range of products, and being fed with parts by a range of suppliers for these various products. Each of the various products will experience peaks and troughs in demand; part of the manufacturer's plan will be to try to maintain the sales rate of each product in the range at a steady level: it can be shown that increased WIP, and hence potentially increasing costs, accompanies both a rise in manufacturing rate, and a fall in manufacturing rate; the lowest WIP is associated with steady manufacturing rates. Smoothing the flow rate into the sales channel is *Heijunka*.

Advertising tends to increase sales, demand and flow rate. Conversely, reducing advertising reduces demand, sales and flow rate. It is possible, therefore to use advertising as a 'control valve,' turning it on to anticipate dips in production flow, and similarly turning it off to anticipate rising demand. If these rises and dips can be effectively counteracted, then the revenue stream from the combined flows of all the products in the supply channel can, in principle, be maximized.

Of course, a time will come when a product within the product range is losing its consumer appeal to such an extent that neither increased advertising, nor 'special deals' can maintain sales flow: this product will have to be replaced in the product range, either by a totally new product or, perhaps, by introducing a new version of the previous product, one with enhanced 'bells and whistles,' perhaps even one that was pre-planned to deal with just this eventuality.

When the sales rate for a current product falls below a threshold, despite best efforts at advertising, etc., then the top loop in the figure will kick in, to conceive, create, test, prove and insert a new product or new version of a product into the production flow stream. In an ideal world, the transfer from the old to the new would be seamless; there would be no cessation of manufacture, no dip in sales, etc. For this to happen, the new product/version will have been advertised in advance to build up demand, so that it immediately has a sales flow upon introduction.

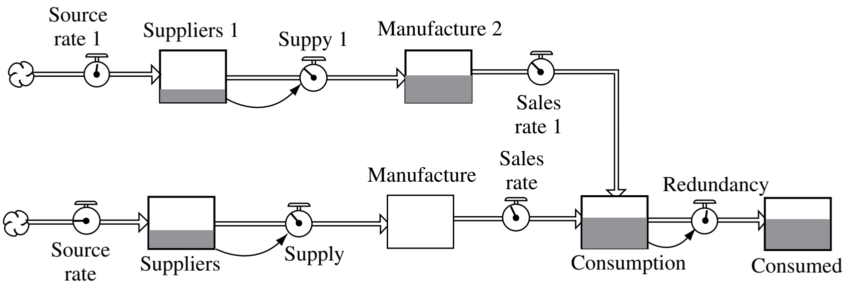
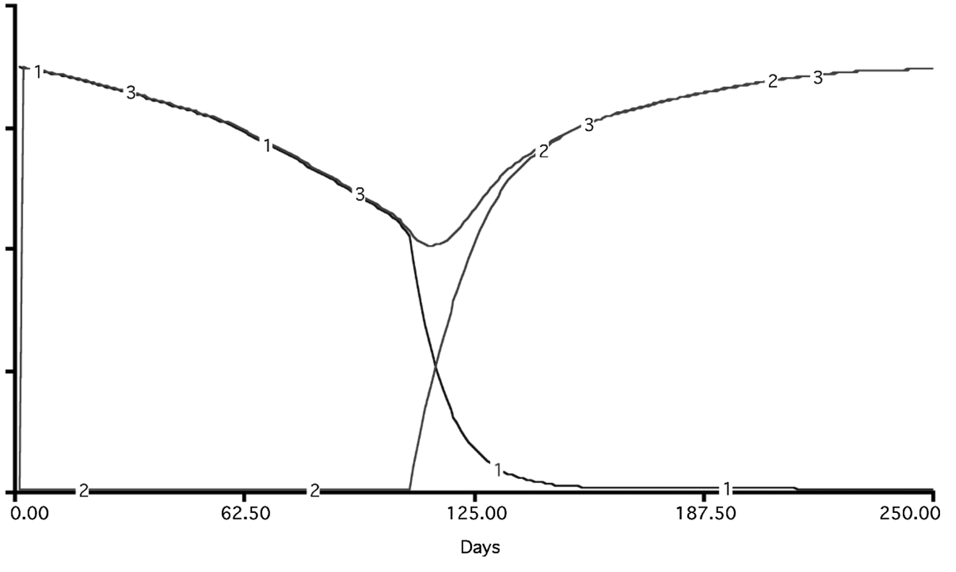



**Figure A.3** STELLA™ simulation model of Heijunka, or production flow smoothing.

The switchover situation is simulated, as in Figure A.3, which shows the original product in the supply chain at the bottom, and its replacement product at the top. As demand for the first product wanes despite sales promotions and marketing, a point will be reached at which manufacture of the first product falls away and manufacture of replacement product takes over.

Simulation results are shown in Graph A.1, where line 3 — the 'sum production rate' — is evidently not perfectly flat, indicating a dip in the sum of the production rates for the two products. It is difficult to bring about the ideal flat curve, even in a simulation: in the real world, there will be many imponderables. How much advertising, and of what kind, is needed to create demand for the new product, such that the rising curve of demand matches the falling curve of demand for




**Graph A.1** Heijunka — product switchover: STELLA™ simulation. (*X*-axis is elapsed days). Line 1 is the production rate for the product being replaced. Line 2 is the production rate for the replacement product. Line 3 shows the sum of their production rates. In an ideal world, line 3 would be flat and horizontal, showing a constant production rate with no 'hiccups.'

the old product? How much anticipation is needed, such that the replacement product is ready for manufacture in time, without being either too early or too late.

Accurately achieving the ideal switchover would require great skill, and not a little luck. On the other hand, the general approach could (and does) offer a reasonably smooth transition, and may be acceptable in the context of there being many other products in the product range that were continuing to be sold through the supply channel, unaffected by the switchover.

There are many mechanisms for maintaining homeostasis. Heijunka is one: supply assurance is another, in which forward planning determines the needs for future parts, including those associated with a new product or variant, and the new process that its manufacture will necessitate. New parts will have been designed jointly with the supplier, who may also provide assembly jigs, bandoliers for automated assembly of electronic devices, test harnesses, etc., etc., as well as the new parts to be assembled. Inserting the new product or variant seamlessly into the supply channel requires careful planning, testing and coordination. Given that, the overall result is another aspect of homeostasis, in that the overall inflow outflow balance is maintained — an essential for any open system to endure.

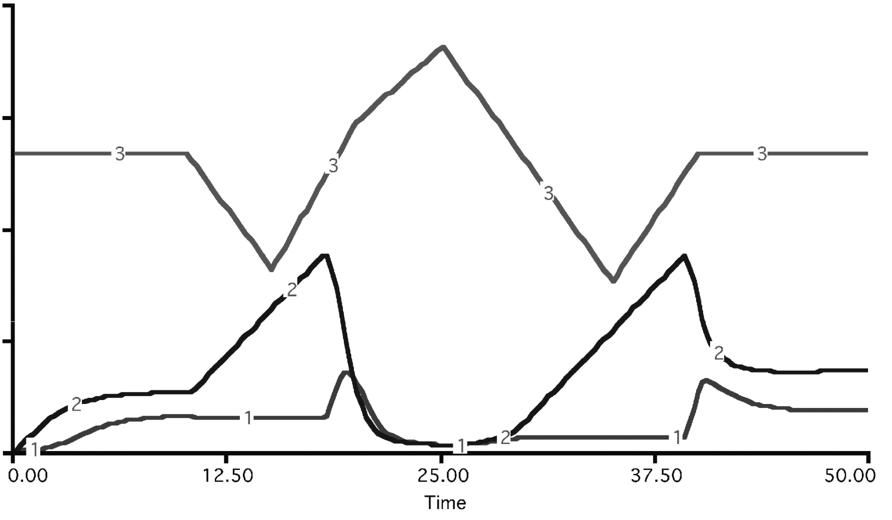
## Market pull vs production push

The lean volume supply chain operates in a ‘market pull’ regime as opposed to a ‘production push’ regime usually associated with mass production. In production push, production rates are maximized and held constant in order to amortize the cost of machinery and manpower across a large number of products, so keeping the unit production cost (UPC) to a minimum. This works well, provided there is a ready market for the product. When there is not, finished products accumulate in storage, at great expense to the manufacturer who has paid for the materials, the production and now the storage, all without any return. We are all familiar with the sight of large storage areas filled with brand-new, parked cars awaiting shipment and sale.

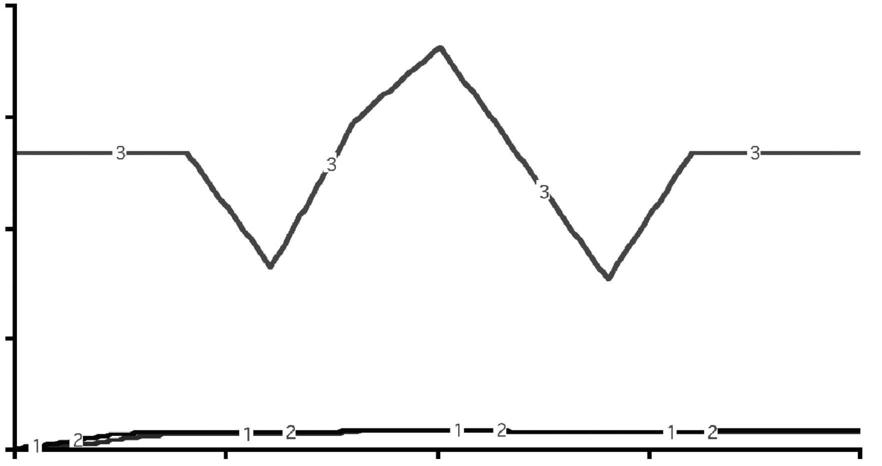
Market pull operates quite differently, by first creating demand for a product, and then meeting that demand. Demand is created by continual innovation, with new products, or new variants of existing products, being advertised and brought to the market with sufficient frequency to fill the production capacity. It has its problems: creating too many variants too quickly — ‘product churning’ — can cause customer disenchantment, as their bright, shiny new ‘toy’ is superseded by an even newer, even shinier model before they have had time to show theirs off! There is also the potential issue of delay: if the manufacturer is genuinely responding to demand, and only starts to make a product after it has been sold, then the customer will have to wait for the production time to elapse before receiving the product. For car production on mainland Japan, this delay may be a few weeks; for global enterprises, the delay would be biased by the time taken for parts to travel between various factories in the supply chain. Production push starts with a production target, which sees parts made in, say, the third tier being sold to second tier enterprises, which process and sell their products to first tier, the lead company, which then sells into the market.

In contrast, market pull starts market demand, creating a market discrepancy, which demands products to sell from the first tier. This creates a first tier discrepancy, which demands product parts from the second tier suppliers, and so on, from lead company back up the supply line.

Graph A.2 shows results from running a supply chain simulation in the production push mode. Line 3 shows market demand for the product going up and down vigorously, before leveling out. What happens within the supply chain? Lines 1 and 2 show typical first and second tier accumulation of parts and products, works in progress, which are ‘caught’ in the system by the downturn in demand. The second tier in particular sees a dramatic rise in ‘unsold’ product




**Graph A.2** Production push. Line 1: first tier WIP. Line 2: second tier WIP. Line 3: variable market demand for product. Variation in demand sees significant increase in WIP, increasing overheads and product costs.




**Graph A.3** Market pull. Line 1: first tier WIP. Line 2: second tier WIP. Line 3: variable market demand for product. Variation in demand has little effect on WIP within the supply chain.

parts, since (in the simple model) the rates of production have continued unabated. Even when market demand returns to its previous level, lines 2 and 3 do not return to their original, lower, levels.

Graph A.3 shows the same supply chain simulation, but this time run in market pull mode: the results are significantly different, with negligible amounts of WIP being captured, despite the same major changes in demand occurring.

The simulation is very simple, of course, but it does illustrate one aspect of lean production. While in mass production, dips in demand can leave the manufacturer with very large inventories of unsold stock — all of which has to be paid for — there is no such problem with market pull.

That is not the whole story, however. By changing the nature of demand such that it always outstrips production capacity (i.e., no dip), the simulation suggests that production push is at least as effective as market pull, and perhaps even more so, since there can be less delay in the production push system. It is reasonable to conclude, then, that market pull affords leaner production in variable markets, but not necessarily in markets where demand is continuously rising to outstrip supply.

## Kaizen and the assembly line

Taiichi Ohno's approach to assembling vehicles on an assembly line was unlike that of his mass production contemporaries. It was their general practice to keep the production/assembly line moving, that is to avoid any holdups. Their objective was to make as many of the product in the shortest time and to amortize the cost of the expensive manufacturing facilities by keeping them in continuous operation. So, the intent was to get the assembly line working at full speed from the beginning, and to keep it going.

Potential problems would arise when mass production assemblers tried to fit a part that either would not fit properly, or would not work correctly when fitted. To correct this *in situ* would hold up the line at that point, creating a queue behind, and rendering the assemblers ahead of the problem idle. This was unacceptable, so the offending part was 'tagged,' i.e., marked with a label to say what was wrong, and the assembly process continued unabated. Subsequent to completing the assembly process, tagged assemblies were taken to an area where work was done to repair the defect or deficiency. The repaired assembly could then pass quality control/inspection.

This did not work well. In practice, some tagged parts were buried under other assembled parts, and could not be accessed without significant disassembly; in consequence, defects that did not materially affect operation might be left *in situ* and 'forgotten.' As a result, mass produced cars, for example, could be less reliable than expected and hoped for. Moreover, post-assembly repair was not a rare event: on some assembly lines, the floor area set aside for post-assembly repair could be as much as 40% of the overall floor space.

Taiichi Ohno installed an alarm over every assembly station in the line. When any of the parts to be assembled/installed did not fit, or was in any way unacceptable, the assembler at that point raised the alarm, and the complete line stopped, while the defect was investigated. With all the other assemblers now unoccupied, there were plenty of people available to undertake the investigation. If the problem lay with the supplier of the part, then a team would visit the supplier to investigate the problem, help the supplier put things right, and then return to the assembly plant, to restart the assembly line.

With a significant number of parts to be assembled, the prospects for delay were manifold. If the line were not stopped at the first assembly station, then it would be at the second, or the third, and so on. Taiichi Ohno's contemporaries suspected that he would never assemble a single car in this way, since none would ever make it to the end of the line. However, he persisted, and each time that problems were sorted out, the assembly process went further along the line until, finally, it reached the end without any holdups. In the process, most, if not all, of the issues of supplied part quality had been resolved with the various suppliers, who were now welded into a composite team.

So successful was Ohno's approach that post-assembly quality control proved unnecessary. There were no tagged parts, no 'buried problems,' so the end vehicle was of good quality and reliable throughout. It also became characteristic of lean production assembly plants that they take time to reach their maximum assembly rate. Whereas mass production sought to sustain maximum assembly rate from the start – and failed — lean production assembly followed a rising curve as problems were eliminated, leveling at a maximum rate that could be sustained. And there was no need for a large, post-assembly repair area.

Ohno's approach is consistent with *Kaizen* — the philosophy of continuous improvement. Kaizen is to be observed in many areas of lean production, and may be seen as recognition that it is not possible to get everything absolutely right first time. Instead, it may be better, while trying to get things right, to continuously improve aspects of process, of design, of practices. If Kaizen is adopted in every aspect, then the end product must, eventually, be superlative. Moreover, if the nature of the demand changes, then Kaizen will oblige the product to follow the change. Kaizen is to be seen in successive models of Toyota cars, for instance, where each successive model overcomes deficiencies that may have emerged during the operation of the previous model. Kaizen has been criticized by those who say that Japanese car designs lack the flair of, say, a Ferrari, with more attention to detail than to the whole. On the other hand, Japanese car designs are continually improving and moreover Toyota's cars are likely to spend relatively little time in repair and servicing. The proof of that pudding is in the sales figures. . . .

The dynamics of the Toyota-style assembly process, its behavior if you will, are not difficult to simulate; creating such simulations helps to understand how queues and delays can occur, how they can be ameliorated, and so on. Figure A.4 shows a STELLA™ simulation of two stages in a notional multi-stage assembly process.

The partly assembled composite is seen entering Sector 2 at top left, marked exit GP server (where GP is Good Parts, as opposed to BP: Bad Parts.) These Good Parts pass through the Coupler into Queue 2, as directed by Operations Control, which coordinates activities; injected into the flow from Sector 1 are Good Parts 2, from the supplier of parts to be assembled in Sector 2. Also entering Queue 2 are Bad Parts, again from the Stage2 supplier, although these are not yet known to be bad.

On attempting to fit the flow of mixed good and bad parts, the good parts enter GP server 2 into Good Parts Assembly 2, while the bad parts are detected as unfit and are diverted into Bad Parts Diverter 2. As soon as this diversion occurs, Operations Control 2 stops the flow of both good and bad parts into Sector 2, and — not shown on this small part of the overall simulation — also stops all the other stages. Mean Bad Parts 2, bottom, is a reservoir of bad parts that is then reduced, simulating the process of eradicating the defect at source, through Rate Decrease 2. When the defect has been eradicated, the line starts up again — all stages in synchronism. Note that Mean Bad Parts 2, bottom, is fed with Degrading 2, which reintroduces defects — Bad Parts — over time, to represent lapses in quality against which no suppliers may completely protect themselves.

Figure A.4 represents only two stages in an assembly line: there could be many more, and the whole may be simulated by stringing together a sequence of such stages in series and, in some case, in parallel too; this would be facilitated by introducing more Couplers.

Graph A.4 shows the result from simulating just three stages. The $y$-axis shows the number of products emerging from the end of a three-stage assembly process over time. To start with, nothing emerges, as the initial defects are sorted out, stage by stage. Then, when early production starts, there are continual interruptions, as less obvious defects are discovered and, possibly, some new ones have crept in. The interruptions become less frequent, finally petering out to leave the assembly line operating at a set assembly/production rate. With more than three stages, there is

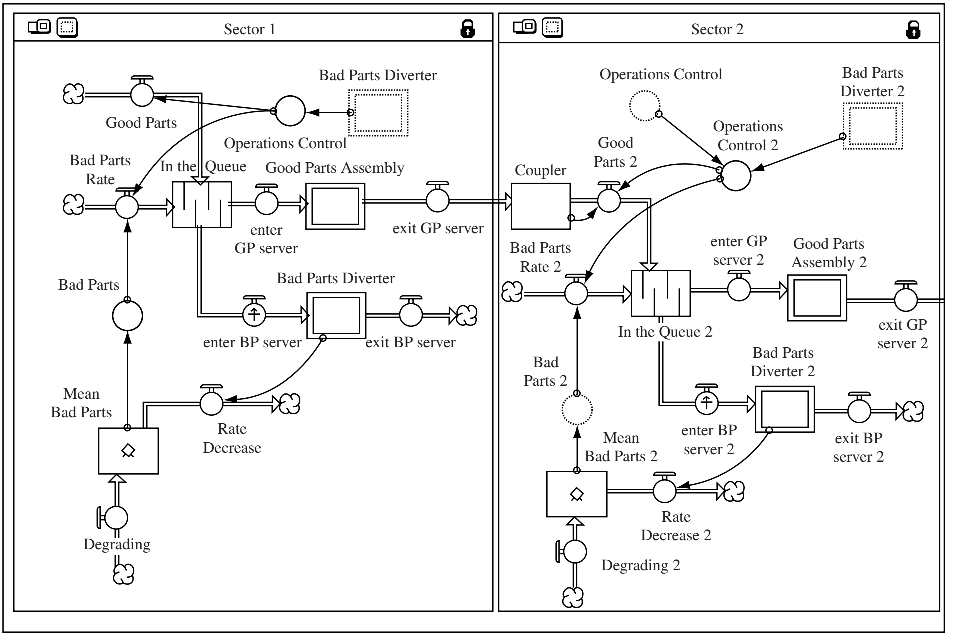
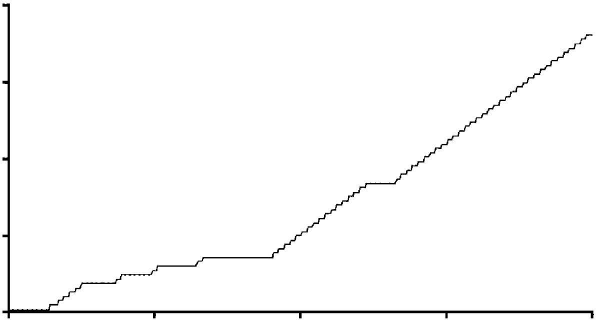



**Figure A.4** Two stages in a multi-stage lean production assembly line. Both stages are identical, as are subsequent stages in the simulation. A mixture of 'good' and 'bad' parts is received from suppliers. Bad parts, ones that will not fit or work correctly, are detected and diverted. The line is stopped (Operations Control), while diverted bad parts are investigated at source, where the deficiency is corrected, so reducing the incidence of further bad parts. Part of a STELLA™ simulation



**Graph A.4** Increasing production rate profile, lean production simulation.

potential for more initial delays; these lead to the characteristic slow start-up dynamic of many lean production exercises.

Processes are continually made leaner though kaizen: finding ways to do a particular job more quickly, or with less effort; identifying more suitable, less expensive materials, perhaps; simplifying

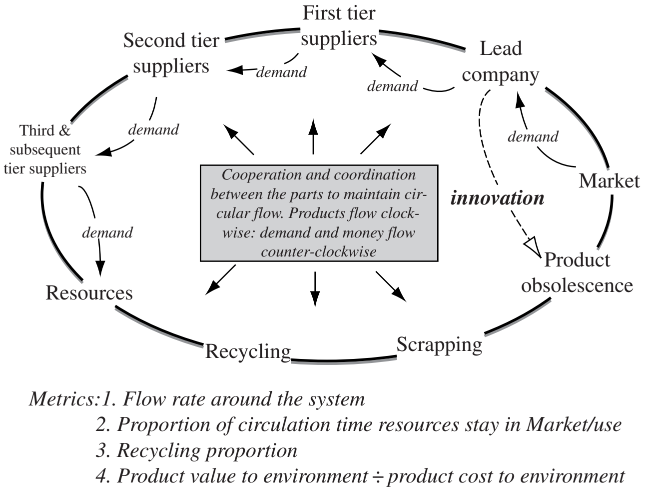



**Figure A.5** A lean volume supply system formed into a circle, in which obsolescent products are recycled to minimize the need for raw materials. Flow rate of materials around the system corresponds to flow rate of money in the opposite direction around the system. Coordination around the circle may be augmented by a dedicated IT system, triggering synchronized parts manufacture in response to demand. Cooperation is endemic in the culture, the supplier contracting arrangements, and in the Keiretsu — see text. Note the idealized metrics.

the assembly process into straighter lines, perhaps; and so on. As a result, there is a noticeable 'learning curve' effect, in which suppliers' costs fall through production — in stark contrast to mass production experiences.

## Keiretsu

Japanese lean volume supply organizations (LVSOs) operate within a financial and commercial environment that is significantly different from that of the West. Figure A.8 shows a notional LVSO, which has been formed into a loop by recycling obsolescent products, to reduce product costs and to reduce dependence on raw supplies. The lead company supplies to the market in response to market demand: products and materials flow clockwise around the circle. Revenue from sales goes with demand, anticlockwise around the circle. Products are made obsolescent by the advertising of innovative new products currently, or imminently, available from the company/manufacturer. It is the company/manufacturer that creates the demand to which it must then respond.

A LVSO may consist of a number of companies linked into a fan-in, or loop structure. A *keiretsu*, an association of commercial entities operating a system of circular equity holding, may support the industry. The entities would include suppliers, the lead company, banks, trading companies, insurance companies, even competitors: some twenty in all. The entities are arranged in a conceptual circle, in which each entity holds equity in the next around the circle. So, each member of the keiretsu is financially dependent on the others in the circle, and it is of course in everyone's interests to support all of the others. Western organizations, hoping to mount a stock exchange 'dawn raid' on a Japanese company might find, to their disappointment, very few shares available to buy, since other Japanese companies, in whose view the circle is considered to be defensively strong, already own them. Should one of the companies in a keiretsu feel inclined to dispose of their shares, then they would be likely to find shares in their own company being disposed of by others in the same keiretsu. Hence, shares move very little in and out of the keiretsu, to and from non-keiretsu organizations.

Unlike their predecessors, the zaibatsu, which were essentially holding companies, keiretsu are not legal entities. The member companies are not legally united, but are held together by a sense of reciprocal obligation. Zaibatsu were dismantled by the US after World War II. Keiretsu have vast financial resources, which underpin the integrity of member companies. This arrangement might well be deemed socio-economic systems engineering, Japanese style.

## Summary

The contrast between the traditional approach to mass production, as exemplified by the US manufacturing industry, and the lean volume supply, as exemplified by Toyota, Sony, etc., is best seen in tabular form:

| Traditional USA | *Comparison* | Japan |
|---|---|---|
| Profit | *Objective* | Survival |
| Free | *Competition* | Between chains/circles |
| Free market | *Regulation* | Indigenization |
| Production push | *Assembly* | Market pull |
| Cost plus | *Pricing* | Market minus |
| Adversarial | *Contract* | Synergistic |
| Specialist | *Defense* | Homogeneous |
| Hire and fire | *Labor* | Jobs for life |
| Specializations | *Skills* | Multi-skilled |
| Lowest bid wins | *Suppliers* | Vital source — protect |
| Supplier stocks | *Inventory* | Nobody stocks |

This stark comparison has been somewhat blurred in recent years, as some Japanese companies have been influenced by US practices, and as some US companies have adopted traditional Japanese practices. In any event, not all Japanese companies are as good as their leading companies. Today there are car manufacturers in the West who can match the performance of the best Japanese suppliers; to do so, however, they have had to instill a different culture throughout their organizations, one much more akin to that of the best Japanese industrial giants.

Attempts in the West to transfer the benefits of Japanese-style lean volume supply to acquisition and procurement in the defense sector have not been successful, however: in both the US and the UK, attempts have been frustrated by government bureaucracies. The culture of secrecy, mutual distrust and antagonism that pervades government defense acquisition and defense suppliers is alien to, and seems unable to accept, any sensible degree of cooperation and trust. Governments take their responsibility for safeguarding public monies to include tight control over defense research and development, and even tighter control over the costs of manufacture, test, integration, etc. The result is the opposite of what is required — rising costs, extending timescales, and concealed performance shortfalls, reminiscent of the problems experienced with classic mass production. Governments seem unable, or unwilling, to recognize that tight control of human activity invariably results in counterintuitive behavior, as control creates its own reaction.

The Japanese approach to lean volume supply throws a different light on systems engineering. The leading Japanese industries, rather than conduct systems engineering at artifact and project levels as in the West, operate instead at business, industry and socio-economic levels. Of course, artifact and project systems engineering are to be found, but the real focus is on the lean volume supply system as a system, i.e., as a whole. See Layer 4: Industrial Systems Engineering on page 12.

- The lean volume supply system is designed to be homeostatic; to maintain a steady flow, to balance inflows and outflows, to self-maintain, and to auto-reconfigure as needed to maintain homeostasis.
- Synergy is promoted throughout the chain or circle by creating an information system to coordinate activities, such that market demand for a product is signaled back through the tiers/anticlockwise around the loop, triggering the appropriate suppliers to make parts and assemblies for onward delivery at the right times such that JIT is achieved without queues, holdups or any unnecessary WIP.
- Lean volume suppliers, operating globally, accumulate wealth sufficient to undertake their own R& D, and enabling them to conceive, design and create innovative new products, and to spread the applications of new technology — in this manner, the lean volume supply system is able to evolve, to switch between markets with agility, even to create new markets and to satisfy them
- The ultimate business objective of lean volume supply systems is survival. To survive includes making a profit, of course, but short-term profit is not the goal — instead, it is survival in the long term. The leading organizations accumulate wealth, researching, innovating, adapting and evolving their product ranges, driving costs and process of products ever downwards, and responding with agility to changes in market tastes and climates.

The leading lean volume supply organizations 'press all the viability buttons.' If there is an Achilles' heel, it has to be in their ability to promote and maintain the culture on which their performance and success fundamentally rests. For more traditional western industrial organizations, the good news is that the culture can be created, and can take hold, within their organizations. Conversely, attempts to import many of the Japanese ideas, without first establishing the supporting and enabling culture, are unlikely to succeed.