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Lean and agile supply chain

Introduction

With the real-time access to the Internet and search engines like Google and with the increased global competition, customers have more power than ever before. They demand innovative product features, greater speed, more product variety, dependable performance and quality at a best in class and at a competitive price. Furthermore, today's discerning consumers expect fulfilment of demand almost instantly. The risk attached to traditional forecast driven lengthy supply line has become untenable for consumer products. In this chapter, we discuss how to take up this challenge through a lean and/or agile supply chain. As we discussed in Chapter 3 (see Figure 3.6), a distinction is often drawn between the philosophy of leanness and agility. Like the perennial business phrase 'quality' both 'leanness' and 'agility', there appears to be differing opinions as to what is meant or intended.

In their 'pure' form three models of supply chain can be identified being traditional, lean and agile.

- *Traditional* – Known for:
  - Protection of market, aims for leadership
  - Forecast driven
  - Higher emphasis on customer service than cost
  - Inventory held to buffer fluctuations in demand and lead times
- *Lean* – Characteristics are:
  - Integration upstream with suppliers
  - Integration downstream with customers
  - High emphasis on efficiency
  - Aims for minimum stock holding
- *Agile* – Noted for flexibility and speed in coping with innovative products and unpredictable demand.

Although many supply chains will be a hybrid of models, it is important to understand the differences and the application of each model and application whether pure or hybrid. The traditional supply chain model has been covered in various chapters of this book, this chapter will primarily cover lean and agile models.

The organization of this chapter is:

- The origin of lean
- The tools of a lean supply chain
- The characteristics of a lean supply chain
- The characteristics of an agile supply chain
- The strategy of a lean and agile supply chain

The origin of lean

As with all facets of the quality movement, the origin of Lean enterprises is in manufacturing. Lean enterprise philosophy, and make no mistake, Lean is more than a system it is a philosophy, began with Japanese automobile manufacturing in the 1960s, and was popularized by Womack et al. in *The Machine that Changed The World* (1990). *The Machine that Changed the World* is essentially the story of the Toyota way of manufacturing automobiles. Up until then the manufacturing of automobiles had changed very little since Henry Ford in 1913 adapted the conveyor belt for manufacturing cars. Prior to Henry Ford's assembly line the automobile had been a luxury item hand made by a group of workers in a stationary workplace. Ford's conveyor belt (the assembly line) approach was for production to take place on a moving belt with each worker doing a small specialized task. Ford believed that if each step of production was broken down to the smallest element that 'the stupidest man could become a specialist in two days'. With this moving conveyor belt approach Ford was able to produce 250,000 cars a year, which sold at $500 each. The car from being a luxury item that only the rich could afford now became in effect a consumer item within the reach of most families. The downside was the minute division of labour and the cyclical nature of the work, and the inexorable pace of the moving conveyor belt. Workers lost a sense of the purpose of what they were doing, they could not see that they were building cars, they saw a repetitive mindless task such as putting bolts on a component as it moved past them. 'The assembly line is no place to work, I can tell you. There is nothing more discouraging than having a barrel beside you with 10,000 bolts in it and using them all up. Then you get another 10,000 bolts and you know that everyone of those bolts has to be picked up and put in exactly the same place as the last 10,000 bolts.' Walker, and Guest (1952). Chrysler, and General Motors and other manufacturers soon adopted the assembly line approach, but whereas Ford only had one model (the model 'T') the others led by General Motors and Chrysler began offering several models in the 1920s. Ford had to follow suit and to do so had to cease production for 7 months while new models were rushed into production. The assembly line approach was still used and models were made in batches, changing a model required set-up time for change of dies, etc. Work at each stage of production was still broken down to the lowest level, workers were not expected to think and there was a heavy reliance on inspection and testing to maintain a standard of finished product. The next major change in car manufacturing is credited to Ohno Taiichi of Toyota. Ohno Taiichi, after visiting USA car manufacturers in the 1960s, returned to Japan and developed a new method of manufacturing, which became known as lean production.

The Lean Manufacturing, sometimes referred to as Toyotaism or Toyota Production System, is that materials flow 'like water' from the supplier through the production process onto the customer with little if any stock of raw materials or components in warehouses, no buffer stocks of materials and part-finished goods between stages of the manufacturing process, and no output stock of finished goods. This 'just-in-time' (JIT) approach requires that materials arrive from dedicated suppliers on the factory floor at the right stage of production just when required, and when the production process is completed it is shipped directly to the customer. With no spare or safety stock in the system there is no room for error. Scheduling of activities and resource has to be exact, communication with suppliers must be precise, suppliers have to be reliable and able to perform to exacting timetables, materials have to arrive on time and meet the specification, machines have to be maintained so that there is no down time, operators cannot make mistakes, there is no allowance for scrap or rework and finally the finished product has to be delivered on time to customers. This is often implemented by circulating cards or Kanban between a workstation and the downstream buffer. The workstation must have a card before it can start an operation. It can pick raw materials out of its upstream (or input) buffer, perform the operation, attach the card to the finished part, and put it into the downstream (or output) buffer. The card is circulated back to the upstream to signal the next upstream workstation to do next cycle. The number of cards circulating determines the total buffer size. Kanban control ensures that parts are made only in response to a demand.

This 'just-in-time' approach generally precludes large batch production; instead items are made in 'batches' of one. This means that operators have to be flexible, the system has to be flexible and 'single minute exchange of dies' (SMED) becomes the norm. A lean approach reduces the number of supervisors and quality inspectors. The operators are trained to know the production standards required and are authorized to take corrective action, in short they become their own inspectors/supervisors. The principles of TPM (Total Productive Maintenance) and Five Ss (Sort, Set in place, Shine, Standardize and Sustain) are followed and as a result the equipment becomes more reliable and the operator develops 'ownership' towards the equipment.

Another important aspect of the Toyota approach was to expand the work done at each stage of production. For example, a team of workers will be responsible for a stage of production or 'Work Cell' on the moving assembly line, such as installing the transmission, or installing the seats, etc. Each team is responsible for it is part of the assembly and might be able to make minor changes to procedures within the confines of a time limit (the time allowed on the moving line for production to move from one stage to the next) and within the limits of the specified standards (for example, the team can change the order of assembly at their workstation but would not have the authority to add extra nuts, etc.). Quality standards are assured the application of Zero Quality Control or Quality at Source before the actual production and Poka Yoke (mistake proofing) during a production process.

A visitor to a Lean manufacturer will be struck by the lack of materials; there is no warehouse, no stocks of materials between workstations, and no stocks of finished goods. At first glance this suggests that Lean is an inventory system. But Lean is not just an inventory system, Lean also means the elimination of 'muda'. Muda, is a Japanese word, which means waste, with waste being defined as any human activity that absorbs resource but creates no value. Thus, the philosophy of Lean is the elimination of non-value adding activities. The rough rule is the elimination of any activity that does not add value to the final product, and the taking of action so that the non-value activity never again occurs.

Before anything can be eliminated it first has to be identified. The Toyota approach to identifying areas of waste is to classify waste into seven 'mudas'.

The seven 'mudas' are:

- Excess production
- Waiting
- Movement or transportation
- Unnecessary motion
- Non-essential process
- Inventory
- Defects

The approach is to identify waste, find the cause, eliminate the cause, make improvements and standardize (until further improvements are found).

The tools of lean supply chain

The original Toyota model of Lean Manufacturing, from which various hybrids were developed, comprised eight tools and approaches:

1. TPM
2. Five Ss: These represent a set of Japanese words for excellent house keeping (Seiri – Sort, Seiton – Set in place, Seiso – Shine, Seiketso – Standardize and Shitsuke – Sustain).
3. JIT
4. SMED
5. Jidoka or Zero Quality Control
6. Production Work Cells
7. Kanban
8. Poka Yoke

The methodology of lean thinking and lean supply chain has moved on since Toyota's Lean Manufacturing model and embraced additional tools and approaches. We have therefore included two more:

9. Value stream and process mapping
10. Lean Sigma and FIT SIGMA

Glossary of lean tools

A brief description of frequently used tools and approaches in lean supply chain is given below. For further details please see:

- *Implementing Quality* (Basu, 2004)
- *Quality Beyond Six Sigma* (Basu and Wright, 2003)

TPM: In TPM, operators are enlisted in the design, selection, correction and maintenance of equipment so that every machine or process is always able to perform its required tasks without interrupting or slowing down defect-free production.

Five Ss: The five rules of good housekeeping – sort, set in place, shine, standardize and sustain.

JIT: It is an inventory strategy implemented to improve the return on investment of a business by reducing in-process inventory and its associated costs.

- *Single minute exchange of die (SMED)*: Operator techniques pioneered by Shigeo Shingo, a Japanese industrial engineer, that result in changeovers of production machinery in less than 10 minutes.
- *Zero Quality Control (Jidoka)*: The transfer of human intelligence to automated machinery so that machines are able to stop, start, load and unload automatically, detect when a defective part has been produced, stop themselves and signal for help. This means operators are freed up to do value adding work. (The practitioners of Japanese martial art Judo are called Judoka. Six Sigma also adopted terms like Black Belt and Green Belt from Japanese martial art.)
- *Production Work Cells*: At Toyota, the work done at each stage of production was expanded, so that a team of workers is responsible for a stage of production, and has the power to be able to make minor changes to procedures within the confines of a time limit and standards. The autonomy of operators is in direct contrast to Ford's production line drones. Lending power to the workers so they could take corrective action meant that there was less need for inspectors to stop mistakes.

- *Kanban*: Kanban cards ensures that parts are only made in response to demand – each workstation must have a card before it can start an operation.
- *Mistake proofing (Poka Yoke)*: A procedure that prevents defects or malfunction during manufacture by, for example, eliminating choices that lead to incorrect actions; stop a process if an error is made; prevent machine damage.

Value steam and process mapping: Process mapping is a tool to represent a process by a diagram containing a series of linked tasks or activities which produce an output. Value stream mapping is a high level process mapping to show the total operation or business and identify 'mudas'.

Takt Time is the pace of production needed to meet customer demand. It is the average rate at which customers buy products and hence the rate at which products should be manufactured. It is expressed in time units – one every so many minutes or so many minutes between completions:

$$\text{Takt Time} = \frac{\text{Available work time}}{\text{Customer demand}}$$

Lean Sigma and FIT SIGMA: Lean Sigma incorporates the principals of JIT and now relates to the supply chain from supplier and supplier's supplier, through the process to the customer and the customer's customer. FIT SIGMA incorporates all the advantages and tools of TQM (total quality management), Six Sigma and Lean Sigma. The aim is to get an organization healthy (fit) by using appropriate tools for the size and nature of the business (fitness for purpose) and to sustain a level of fitness.

The characteristics of lean supply chain

The characteristics and tenets of a lean supply chain are derived from the principles of Toyota Production Systems (TPS) and the methodology of Lean Sigma. Womack, Jones and Roos (1990) proposed five Lean principles based on TPS, viz. value, value stream, flow, pull and perfection. However, the application of Lean principles has moved with time and experience of organizations in both manufacturing and service sectors. Until recently supply chains were understood primarily in terms of planning the demand forecasts, upstream collaboration with suppliers and planning and scheduling the resources. Emphasis perhaps is shifted to provide what the customers want at a best in class cost. Cost reduction is often the key driver for lean, but it is also about speed of delivery and quality of products and services. The competition for gaining and retaining customers and market share is between supply chains rather than other functions of companies. A supply chain therefore has to be lean with four inter-related key characteristics or objectives:

1. Elimination of waste
2. Smooth operation flow
3. High level of efficiency
4. Quality assurance

Elimination of waste

The lean methodology as laid out by Womack, Jones and Roos (1990) is sharply focussed on the identification and elimination of 'mudas' or waste and their first two principles (i.e. value and value stream) are centred around the elimination of waste. Their motto has been, 'banish waste and create wealth in your organization'. It starts with value stream mapping to identify value and then identify waste with process mapping of valued processes and then systematically eliminate them. This emphasis on waste elimination has probably made lean synonymous to absence of waste. Waste reduction is often a good place to start in the overall effort to create a lean supply chain because it can often be done with little or no capital investment.

One popular area of waste in processes is excess inventory. Many organizations started to measure their 'leanness' only in terms of inventory performance. Inventory reduction attempts to reduce inventory through such practices as enterprise resource planning (ERP), JIT and modern approaches to supply chain management have led to lower inventory levels, but there is still plenty of room for improvement. In fact, most all manufacturers carry at least 25 per cent more inventory than they have to. The techniques of inventory management and reduction have been covered in Chapter 7. This inventory centred approach seems to be encouraged by *Leanness Studies* (Schonberger, 2003). In these annual study reports, Schonberger measured the trends in inventory turnover (annual cost of goods divided by value of inventory) and then graded and ranked the companies according to inventory performance. This approach although is a good indicator of inventory policy of a company, but it does not necessarily reflect the business performance of the company. For example, the inventory policy of a fast-moving consumer goods (FMCGs) company is different from that of a pharmaceutical company. Inventory is only one of the seven 'mudas'.

Cycle time or lead-time reduction is another target area of waste reduction. Cycle time is the time required to complete a given process. The cycle time required to process a customer order might start with the customer phone call and end with the order being shipped. The overall process is made up of many sub-processes such as order entry, assembly, inspection, packaging and shipping. Cycle time reduction is identifying and implementing more efficient ways of completing the operation. Reducing cycle time requires eliminating or reducing non-value-added activity. Examples of non-value-added activity in which cycle time can be reduced or eliminated include repair due to defects, machine set-up, inspection, waiting for approval, test and schedule delays.

There are a few formal and publicized methodologies for cycle time reduction including QRM (Quick Response Manufacturing; Suri, 1998) and SMED (Single Minute Exchange of Dies; Shingo, 1985). QRM is underpinned by two key principles. First, plan to operate at 80 per cent or even 70 per cent capacity of critical resources. Second, measure the reduction of lead times and make this the main performance measure. These principles are supported by material requirements planning (MRP) plans for production-oriented cells and continuous training. The SMED method involves the reduction of production changeover by extensive work study of the changeover process and identifying the 'in process' and 'out of process' activities and then systematically improving the planning, tooling and operations of the changeover process (see Figure 13.1). Shingo believes in looking for simple solutions rather than relying on technology. With due respect to the success of the SMED method, it is fair to point out that the basic principles are fundamentally the application of classical industrial engineering or work study.

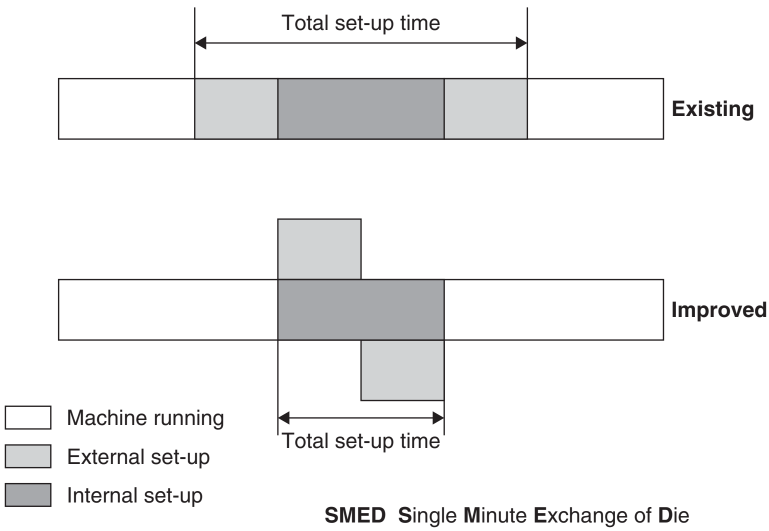

Figure 13.1 Set-up time reduction.
Source: Basu and Wright, Total Manufacturing Solutions (1997).

The reduction of cycle time has become an important feature of lean thinking beyond manufacturing industries where approaches other than QRM and SMED are applied. In service industries such as call centres there has extensive application of value analysis around process mapping charts. Even flow production technique (Ballard, 2001) is applied in reducing cycle time in the construction of repetitive residential homes. The technique comprises: (1) overlap activities within their phase of the work, (2) reduce activity durations through cycle time studies and (3) reduce work in process through the development of multi-skilled workers. Cycle time reduction is also an important area of Lean Sigma projects as illustrated by the following case example.

Case example: Cycle time reduction

Platinum catalyst is used for production of an active pharmaceutical ingredient (API) in an Eastern European Pharmaceutical Company (henceforth referred as 'company'). Used catalyst is sent back to supplier who recovers platinum and uses it for production of fresh catalysts. During that cycle certain quantity of catalyst evanesces and new quantity has to be purchased periodically to maintain required level of inventory. The catalyst is expensive because of platinum and the related cost of capital for required catalyst inventory is significant. A task team led by a Six Sigma Black Belt was formed to reduce the cycle time of procuring the platinum catalyst.

Catalyst inventory required for normal production of the API depends on catalyst consumption in production and catalyst regeneration cycle time. Time required for cycle of regeneration of catalyst (platinum recovery and new catalyst production) was about 3 months. During that period it was necessary to have enough catalyst in possession for normal production. Since significant improvements in the production of the API were already achieved in reducing catalyst consumption, the scope of the project included only activities related to the reduction of regeneration cycle time.

For the monitored period the mean regeneration times depending on the supplier varied between 77 and 69 days (year 2003) and during the year 2004 values were marginally better than the year before. During the year 2004 significantly better results were achieved also for the transport time and the average transport time was 5 ± 2 days what was acceptable.

Transport time had relatively less influence on overall cycle time. Still and it was important to minimize mistake opportunities during the transport. This was assured by proper planning (sales, production, purchasing and distribution), regular communication (all interested parties) and using only reliable and proved carrier and forwarder. Addition to that all transport details were carefully specified and agreed, transport of catalyst always had high priority (because of high value of shipment) and the company always had proper information about shipment status during the transport.

The biggest influence on overall cycle time was the regeneration of catalyst. This was clearly the supplier's responsibility and the company could not directly influence that process. The regeneration time specified in contract between the company and each supplier was 10 weeks for one mayor supplier and 11 weeks for another for year 2004.

After brainstorming the team identified only two possible solutions:

- To ask each approved supplier to prepare offer for year 2005 with maximum regeneration time of 8 weeks.
- To find and develop new supplier for catalyst who can fulfil our request.

Although the company developed four new suppliers for the platinum catalyst, only two of them were reliable and another two could not achieve required quality each time. Another problem was that the specification for catalyst was quite general and earlier analysis could not properly represent the regulated quality of the catalyst. Consequently, the development of approved new suppliers took a long time. Minimum regeneration time achieved in the past was 8 weeks and 6 days and because of all that the team decided to ask each of qualified suppliers to regenerate catalyst within 8 weeks and the team prepared negotiation strategy for that.

To test supplier's ability to fulfil new requirement, the company asked each of the supplier to deliver next shipments of regenerated catalyst till the end of the year 2004 within 9 weeks instead 11 (including transport). One of the approved suppliers answered positively but asked for some adjustment in packaging of spent catalyst which did not require additional cost, that allowed the company not to buy new quantity of 1.000 kilograms of fresh platinum catalyst and generated a saving in cost of capital of US $20,000 in last 3 months of the year 2004.

Negotiations with key suppliers for platinum catalyst finished successfully and resulted with new contracts where maximum regeneration time is 8 weeks. New contract with one of them was signed on February 2005, and with another one on March 2005.

New contract with supplier is a powerful tool for sustaining of new agreed platinum catalyst regeneration performance, and performance in the year 2005 is better than promised. All involved in platinum catalyst handling were educated against that standard operating procedure.

Both of these improvements cycle time was reduced by 30 per cent and the inventory of the catalyst reduced from 7.728 to 4.500 kilograms. The overall annual savings related to avoidance of cost of capital needed for buying of new quantity of catalyst was $408,615 per annum.

Smooth operational flow

The well publicized JIT approach is a key driver of Lean Supply Chain and, as we have indicated earlier, it requires materials and products flow 'like water' from the supplier through the production process onto the customer. The capacity bottlenecks are eliminated, the process times of workstations are balanced, and there is little buffer inventories between operations. Smooth operation flow requires the applications of appropriate approaches. Three of the most frequently applied approached are:

1. Cellular manufacturing
2. Kanban pull system
3. Theory of constraints (TOC)

In cellular manufacturing concept, traditional batch production area is transformed into flow line layouts so that ideally a single piece flows through the line at any time. In practice an optimum batch size is calculated starting with the most critical work centres and the largest inventory carrying costs. Action is taken for improvement at the work centres and methods that have greatest impact on the throughput, customer satisfaction, operating cost and inventory carrying charges. Good management consists of avoiding a wide variety of products. Cellular manufacturing concept is most appropriate when demand is predictable and products have low variety and high volume.

The Toyota Motor Company of Japan pioneered the Kanban technique in the 1980s. As part of Lean Manufacturing concepts Kanban was promoted as one of the primary tools of JIT concepts by both Taiichi Ohno (1988) and Shingo (1988). Inspired by this technique, American supermarkets in particular replenished shelves as they were emptied and thus reduced the number of storage spaces and inventory levels. With a varied degree of success outside Japan, Kanban has been applied to maintain an orderly flow of goods, materials and information throughout the entire operation.

Kanban literally means ‘card’. It is usually a printed card in a transparent plastic cover that contains specific information regarding part number and quantity. It is a means of pulling parts and products through the manufacturing or logistics sequence as needed. It is therefore sometimes referred to as the ‘pull system’. The variants of the Kanban system utilize other markers such as light, electronic signals, voice command or even hand signals.

Following the Japanese examples, Kanban is accepted as a way of maximising continuous flow and efficiency by reducing both cost and inventory.

The key components of a Kanban system are:

- Kanban cards
- Standard containers or bins
- Workstations, usually a machine or a worktable
- Input and output areas

The input and output areas exist side by side for each workstation on the shop floor. The Kanban cards are attached to standard containers. These cards are used to withdraw additional parts from the preceding workstation to replace the ones that are used. When a full container reaches the last downstream workstation, the card is switched to an empty container. This empty container and the card are then sent to the first workstation signalling that more parts are needed for its operation.

A Kanban system may use either a single card or a two cards (move and production) system. The dual card system works well in a high up-time process for simpler products with well-trained operators. A single card system is more appropriate in a batch process with a higher changeover time and has the advantage of being simpler to operate. The single card system is also known as 'Withdrawal Kanban' and the dual card system is sometimes called 'Production Kanban'.

The system has been modified in many applications and in some facilities although it is known as a Kanban system, the card itself does not exist. In some cases the empty position on the input or output areas is sufficient to indicate that the next container is needed.

Case example: Kanban pull system

The following example is based on the experience of Level Industrial, the Brazil subsidiary of Unilever in Sao Paulo.

Lever Industrial was engaged in the batch production of industrial detergents comprising nearly 300 stock keeping units (SKUs) which varied from a 500 kilograms draw to a 200 grams bottle. After carrying out a Pareto analysis the team selected three fast-moving products for a pilot Kanban system. These products in total accounted for 18 per cent of output.

The company adopted for each product, a simple single card Kanban system consisting of five stages as shown below (Figure 13.2).

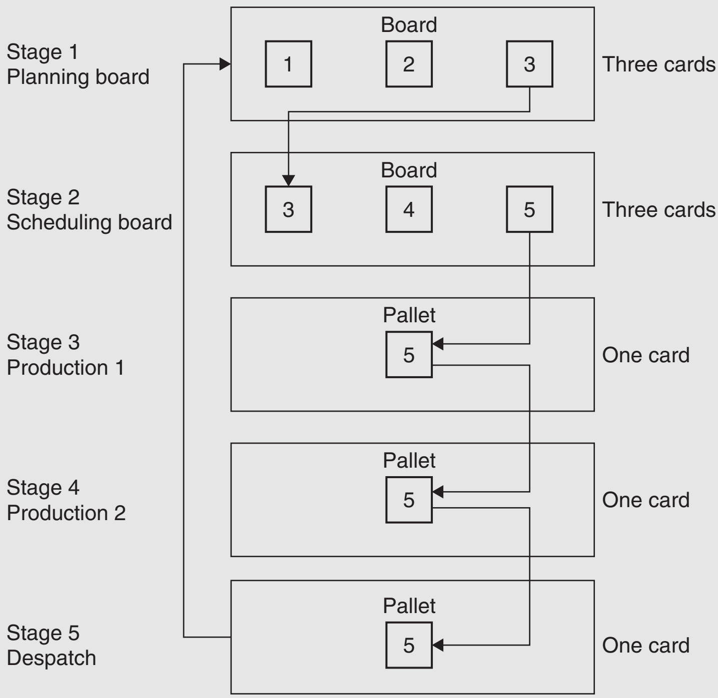

Figure 13.2 Kanban system.

Both the planning board and the scheduling board contain three cards each as a buffer between the variability of production cycle time and the availability of materials.

When the card arrives from the despatch (Stage 5) it is kept on the planning board and planning for the product starts. When the planning board is full with three cards, the third card is passed to the scheduling board and production scheduling is ensured. Similarly when the scheduling board is full, the third card is transferred to the pallet at the Production Station 1 and actual production begins.

When the pallet in Stage 3 (Production 1) is full, the card then moves to the next station (Production 2) in Stage 4, and then on to despatch in Stage 5. After the goods are despatched, the card returns to the planning board and the next cycle begins.

The pilot exercise was successful. It achieved an improvement in customer service which rose from 84 per cent to an excellent 98 per cent and inventory was also reduced. The Kanban system was extended to nine additional key products. The manual system was retained for the above five stages, although both the planning and stock adjustment processes were supported by MFG-Pro, the ERP system.

The Theory of Constraints (TOC) is a management philosophy developed by Goldratt (1992). It enables the managers of a system to achieve more of the goal that system is designed to produce. The concept or the objective is not new. However, in service operations where it is often difficult to quantify the capacity constraint TOC could be very useful. For companies that employ skilled workers and for many service organizations the constraint is often the time of one or a few key employees. The key steps in this process are:

1. *Identify*: The first step in applying TOC is to identify the constraining or bottleneck factor.
2. *Exploit*: Determine the throughput per unit of the constraining factor.
3. *Subordinate*: Prevent the resources needed from waiting in a queue at a non-constrained resource.
4. *Elevate*: If it still cannot produce enough products to produce demand, find ways to increase capacity.
5. Go back to step 1.

Implementation TOC, although simple in principle, is often difficult because it may require a complete change in the way a company operates. For example, TOC requires a shift from cost-based decision making to decision-making based on continuous improvement.

The smooth operation flow of materials and products are further enhanced by Lean Sigma methodology where the variances within processes and between workstations are minimized by the statistical techniques of Statistical Process Control (see Basu, 2004, pp. 151–157).

High level of efficiency

The more popular concepts of lean operations tend to be the concepts of muda, flow and pull system. A preliminary analysis of all these methods, as we have described earlier, however, highlights the fact that all assume sufficient machine availability exists as a prerequisite. In our experience for many companies attempting a lean transformation this assumption is not true. Machine availability depends on maximizing the machine up time by eliminating the root causes of down time. The ratio of up time and planned operation time is the efficiency of the operation. Therefore, in order to make lean concepts work it is vital that the pre-condition of running the operations at a high level of efficiency should be met. The old approach of measuring labour efficiency (e.g. the ratio of standard hours and hours worked) has now shifted to the efficiency of the control or bottleneck workstation.

There are many methodologies and tools of ensuring a high level of efficiency in a lean supply chain. We are going to describe one such methodology (viz. TPM) and two such tools (e.g. overall equipment effectiveness (OEE) and Five Ss).

Total Preventative Maintenance (TPM) is a proven Japanese approach to maximizing overall equipment effectiveness (OEE) and utilization, and relies on attention to detail in all aspects of manufacturing. TPM includes the operators looking after their own maintenance and thus encourages the empowerment. The use of the word 'maintenance' in the title is misleading. TPM includes more than maintenance, it addresses all aspects of manufacturing. The two primary goals of TPM are to develop optimum conditions for the factory through a self-help people/machine system culture and to improve the overall quality of the workplace. It involves every employee in the factory. Implementation requires several years, and success relies on sustained management commitment. TPM is promoted throughout the world by the Japan Institute of Plant Maintenance (JIPM).

TPM is the manufacturing arm of TQM and is based on five key principles:

1. The improvement of manufacturing efficiency by the elimination of six big losses.
2. The establishment of a system of autonomous maintenance by operators working in small groups.
3. An effective planned maintenance system by expert engineers.
4. A training system for increasing the skill and knowledge level of all permanent employees.
5. A system of maintenance prevention where engineers work closely with suppliers to specify and design equipment which requires less maintenance.

TPM requires the manufacturing team to improve asset utilization and manufacturing costs by the systematic study and the elimination of the major obstacles to efficiency. In TPM these are called the 'six big losses' and are attributed to (i) breakdown, (ii) set-up and adjustment, (iii) minor stoppages, (iv) reduced speed, (v) quality defects and (vi) start-up and shut-down.

The process of autonomous maintenance is to encourage operators to care for their equipment by performing daily checks, cleaning, lubrication, adjustments, size changes, simple repairs and the early detection of abnormalities. It is a step-by-step approach to bring the equipment at least to its original condition.

Some managers may hold the belief that in TPM 'you do not need experienced craftsmen or engineers and all maintenance is done by operators'. This is not true. The implementation of a maintenance policy with appropriate infrastructure is fundamental to planned maintenance. Planned maintenance is the foundation stone of TPM. However, if the skill and education levels of operators are high then a good proportion of planned maintenance activities should be executed by operators after proper training. Cleaning, lubrication and minor adjustments together with an ability to recognize when a machine is not functioning correctly should be the minimum which is required of operators.

For TPM to succeed a structural training programme must be undertaken in parallel with the stages of TPM implementation. In addition, 'one point lessons' can be used to fill in a specific knowledge gap. This uses a chart which is displayed at the workplace and describes a single piece of equipment and its setting or repair method.

Whilst great progress can be made in reducing breakdowns with autonomous maintenance and planned maintenance, 'zero breakdowns' can only be achieved by the specification of parts and equipment which are designed to give full functionality and not to fail. All engineers and designers of the user company should work concurrently with the suppliers of equipment to achieve a system of maintenance prevention.

Although there is a special emphasis of input by different employees to different aspects of TPM (e.g. 'six big losses' for middle management, 'autonomous maintenance' for operators, 'planned maintenance' for middle management, 'maintenance prevention' for senior management), TPM involves all employees and the total involvement is ensured by establishing TPM work groups or committees. Figure 13.3 illustrates an example of a TPM organization.

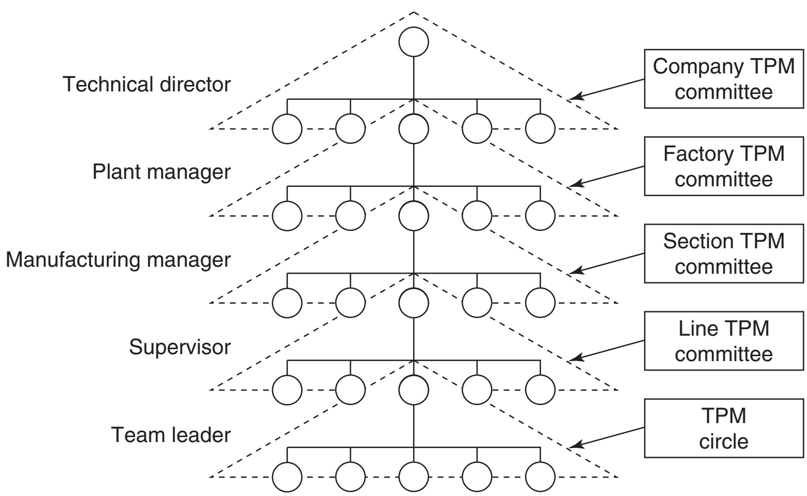

Figure 13.3 TPM organization.

To summarize, TPM is a factory-wide continuous improvement programme with particular emphasis on changing the culture of the shop floor through improved attitudes and skills. TPM progress is measured by the stages of autonomous maintenance completed, and visible progress is also seen in the higher reliability of equipment, reduction of waste and improvements in safety statistics.

Case example: TPM at Nippon Lever, Japan

Background

The Utsunomia plant in Japan was commissioned in 1991 on a greenfield site by Nippon Lever to manufacture household detergents products and plastic bottles for liquid detergents. The factory was experiencing ‘teething’ problems primarily due to the poor reliability and lack of local support of the imported equipment. Many of the employees were new to factory work.

To improve this situation the company used the help of the JIPM, an organization which is working on TPM with over 800 companies in Japan. TPM has been widely used in Japan, having been developed to support Lean/JIT and TQM. It was considered to be appropriate for the Utsunomiya plant TPM focuses on machine performance and concentrates on operator training and teamwork.

Approach

A TPM programme was launched at the Utsunomiya plant in July 1992 with the objective of zero losses:

- zero stoppages
- zero quality defects
- zero waste in materials and manpower

Strong organizational support was provided by the Nippon Lever management in terms of:

- a top management steering team to facilitate implementation by removing obstacles;
- a manager to work full time supporting the programme;
- one shift per week set aside for TPM work;
- training for managers, leaders and operators involving JIPM video training material.

The programme launch was initiated at a ‘kick-off’ ceremony in presence of the whole Nippon Lever Board and managers from other company and suppliers’ sites.

Implementation

The initial thrust of the programme was the implementation of 'autonomous maintenance' following the JIPM's seven steps:

1. Initial cleanup
2. Elimination of contamination
3. Standard setting for operators
4. Skill development for inspection
5. Autonomous inspection
6. Orderliness and tidiness
7. All-out autonomous working

To implement the seven steps, 'model machines' (those giving the biggest problems) were chosen. This approach helps to develop operators' knowledge of a machine and ensures that work on the model can be used as the standard for work on other machines. It also helps motivation. In that if the worst machine moves to the highest efficiency, this sets the tone for the rest of the process.

The improvements to the machines were made using Kaizen methodology (small incremental improvements), and were carried out by groups of operators under their own guidance. Two means of support were given to operators – a Kaizen budget per line so that small repairs and capital expenses could be agreed without delay and the external JIPM facilitator provided encouragement and experience to workgroups.

Results and learning points

By the end of 1993, substantial benefits were achieved within a year at the Utsunomiya plant including:

- £2.8 million reduction in operating costs;
- reduced need for expensive third-party bottles;
- production efficiency increased from 54 to 64 per cent for high speed soap lines and from 63 to 80 per cent for liquid filling lines;
- a team of trained, motivated and empowered operators capable of carrying out running maintenance.

The success of the programme at the Utsunomiya plant led to the introduction of TPM to other two factories of Nippon Liver (Shimizu and Sagamihara). Over the next few years the Corporate Groups of Unilever encouraged all sites outside Japan to implement TPM with remarkable successes achieved particularly in factories in Indonesia, Brazil, Chile, UK and Germany.

Tools and techniques used

OEE, Five S, Five Why, Kaizen, SMED

Source: Leading Manufacturing Practices, Unilever Research and Engineering Division (1994)

The Overall Equipment Effectiveness (OEE) is an index of measuring the delivered performance of a plant or equipment based on good output.

The method of monitoring OEE is devised in such a way that it would highlight the losses and deficiencies incurred during the operation of the plant and identify the opportunities for improvement.

There are many ways to calculate OEE (see Hartman, 1991; Shirose, 1992). In this section, we describe the methodology of OEE that was developed and applied by Ron Basu in both Unilever[1] and GlaxoWellcome.[2]

OEE is defined by the following formula:

$$\text{OEE \%} = \frac{\text{Actual good output}}{\text{Specified output}} \times 100$$

where specified output = specified speed × operation time

The application of OEE has been extensive, especially when driven by the TPM programmes, to critical plant and equipment. It can be applied to a single equipment, a packing line, a production plant or processes. In order to appreciate the usefulness of OEE it is important to understand equipment time analysis as shown in Figure 13.4 and described below.

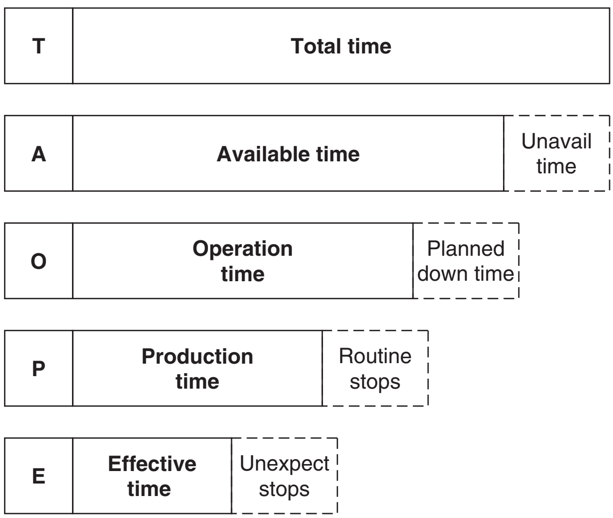

Figure 13.4 Equipment time analysis.

Total time defines the maximum time within a reporting period, such as 52 weeks a year, 24 hours a day, 8760 hours in a year.

Available time is the time during which the machine or equipment could be operated within the limits of national or local statutes, regulation or convention.

[1]In Unilever Plc, the methodology was known as PAMCO (Plant and Machine Control).

[2]In GlaxoWellcome it was called CAPRO (Capacity Analysis of Production).

Operation time is the time during which the machine or equipment is planned to run for production purposes. The operational time is normally the shift hours.

Production time is the maximum time during which the machine or equipment could be expected to be operated productively after adjusting the operation time for routine stoppages such as changeover and meal breaks.

Effective time is the time needed to produce a 'good output delivered' if the machine or equipment is working at its specified speed for a defined period. It includes no allowances for interruptions or any other time losses.

It is important to note that effective time is not recorded, it is calculated from the specified speed as:

$$\text{Effective time} = \frac{\text{Good output}}{\text{Specified speed}}$$

where specified speed is the optimum speed of a machine or equipment for a particular product without any allowances for loss of efficiency. It is expressed as quantity per unit such as tonnes per hour, bottles per minute, cases per hour or litres per minute.

In addition to OEE, two other indices are commonly used as shown below:

$$\text{Production efficiency (\%)} = \frac{\text{Effective time } (E)}{\text{Production time } (P)} \times 100$$

$$\text{Operational Utilisation (\%)} = \frac{\text{Operation time } (O)}{\text{Total time } (T)} \times 100$$

A properly designed and administered OEE scheme offers a broad range of benefits and a comprehensive manufacturing performance system. Some of its key benefits are:

- It provides information for shortening lead time and changeover time and a foundation for SMED.
- It provides essential and reliable data for capacity planning and scheduling.
- It identifies the 'six big losses' of TPM leading to a sustainable improvement of plant reliability.

Case example: OEE of ACMA soap wrapping machine

Consider the production data of a toilet soap packing line where the control station governing the specified speed is an ACMA 711 wrapping machine.

Week Number	31
Operation time	128 hours
Specified speed	150 tablets per minute

Good output	4232 cases
Routine stoppages	11 hours 30 minutes
Unexpected stoppages	27 hours 15 minutes

Given that each case contains 144 tablets,
Good output = 4232 × 144 = 609,408 tablets

$$\text{Effective time} = \frac{\text{Good output}}{\text{Specified speed}} = \frac{609,408}{150 \times 60} = 67.71 \text{ hours}$$

Production time = Operation time − Routine stoppages
= 128 − 11.5 = 116.5 hours
Total time = 7 × 24 = 168 hours

$$\text{OEE} = \frac{\text{Effective time}}{\text{Production time}} = \frac{67.71}{128} = 0.53 = 53\%$$

$$\text{Production efficiency} = \frac{\text{Effective time}}{\text{Production time}} = \frac{67.71}{116.5} = 58\%$$

$$\text{Operation utilization} = \frac{\text{Operation time}}{\text{Total time}} = \frac{128}{168} = 76\%$$

It is important to note that the effective time was calculated and not derived from the recorded stoppages. There will be an amount of unrecorded time (also known as time adjustment) as, in the example, given by
Unrecorded time = (Production time − Unexpected stoppages) − Effective time
= (116.5 − 27.25) − 67.71
= 21.54 hours

- It provides information for improving asset utilization and thus reduced capital and depreciation costs in the longer term.

Five S is a tool for improving the housekeeping of an operation, developed in Japan, where the Five Ss represent five Japanese words all beginning with ‘s’:

- *Seiri (organization)*: Separate what is essential from what is not.
- *Seiton (neatness)*: Sort and arrange the required items in an orderly manner and in a clearly marked space.
- *Seiso (cleaning)*: Keep the workstation and the surrounding area clean and tidy.
- *Seiketson (standardization)*: Clean the equipment according to laid down standards.
- *Shitsuke (discipline)*: Follow the established procedure.

In order to retain the name ‘Five S’, a number of English language versions have evolved. These include:

- *Seiri*: Sort
- *Seiton*: Set in order/Stabilize
- *Seiso*: Shine
- *Seiketsu*: Standardize
- *Shitsuke*: Sustain

The Five S method is a structured sequential programme to improve workplace organization and standardization. Five S improves the safety, efficiency and the orderliness of the process and establishes a sense of ownership within the team.

Five S is used in organizations engaged in Lean Sigma, JIT, TPM and TQM. This principle is widely applicable not just for the shop floor, but for the office too. As an additional bonus there are benefits to be found in environmental and safety factors due to the resulting reduced clutter. Quality is improved by better organization and productivity is increased due to the decreased time spent in searching for the right tool or material at the workstation. Consider the basic principle of a parent tidying a small child’s room which is overflowing with clutter and sorting together various types of toys. The end product should be a neater, warmer, brighter and more civilized play environment which will encourage the child to utilize all toys and equipment more productively because all relevant pieces are together, space is enhanced and mess is reduced.

It is useful to note that the quality gurus of Japan like numbered lists, for example the Seven Mudas, the Five Whys, and the Five Ss. However, the exact number of Ss is less important than observing the simple doctrine of achieving the elimination of wastes.

As the Five S programme focuses on attaining visual order and visual control, it is also a key component of Visual Factory Management. As Five S is primarily a visual process, a good example of promoting its message would be to display pictures of a workplace with photographs showing both ‘before’ and ‘after’ depictions of the implementation of Five S.

Case example: Five S at Northrop Grumman Inc., USA

Northrop Grumman Corporation is a global defence company headquartered in Los Angeles and provides technologically advanced products, services and solutions in systems integration, defence electronics, advanced aircraft and space technology.

Northtrop Grumman first deployed Five S on a part delivery process. The work area assembled a variety of components into a single product.

Before Five S, the area was not well organized, and the process was inefficient. With Five S implementations, the area saw a huge 93 per cent reduction in the space employees travel to complete tasks as well as a

42 per cent reduction in the overall floor space and 20 per cent improvement in operational efficiency.

The system has become a one-piece flow operation between assembly and mechanics, enabling everyone involved to know what the station has and what it needs.

Source: Skinner (2001)

Quality assurance

Womack Jones and Roos (1990) propose perfection as the fifth Lean principle and according to this a lean manufacturer sets his/her targets for perfection in an incremental (Kaizen) path. The idea of TQM also is to systematically and continuously remove the root causes of poor quality from the production processes so that the organization as a whole and its products are moving towards perfection. This relentless pursuit of the perfect is key attitude of an organization that is 'going for lean'.

The incremental path to TQM progressively moves from earlier stages of quality control and quality assurance. Quality assurance focuses on the prevention of failures or defects in a process by analysing the root causes and sustaining the improved process by documenting the standard operating procedure and continuous training. TQM is quality assurance of all processes across the organization involving everyone from the top manager to a trainee. Therefore, the central driver towards perfection is quality assurance.

This drive for quality assurance has now been extended beyond TQM to Six Sigma with additional rigour in training deployment (e.g. Black Belts and Green Belts), the methodology of DMAIC (e.g. Define, Measure, Analyse, Improve and Control), and measurement (both variances and savings). The principles of Six Sigma are embedded in the path towards perfection in a lean supply chain and Six Sigma has now moved to Lean Sigma and FIT SIGMA. Basu and Wright (2003) explain that the predictable Six Sigma precisions combined with the speed and agility of Lean produces definitive solutions for better, faster and cheaper business processes. Through the systematic identification and eradication of non-value added activities, optimum value flow is achieved, cycle times are reduced and defects eliminated. The dramatic bottom line results and extensive training deployment of Six Sigma and Lean Sigma must be sustained with additional features for securing the longer-term competitive advantage of a company.

Case example: Lean supply chain in Seagate, USA

Background

Seagate Technology is the world's largest manufacturer of disc drives and HDD recording media. With its headquarters at Scotts Valley, California, the company employs 62,000 people and its turnover in 2000 exceeded $7 billion. The business operates in a market environment of short product life cycle and quick ramp to high volume. The data storage market is growing 10–20 per cent per year and the technology content doubles every 12 months. Volume products remain in production for only 6–9 months.

Approach

In 1998, Seagate's senior executive team was concerned that business performance was not on par with expectations and capabilities. The quality group was charged with recommending a new model or system with which to run the business. The Six Sigma methodology was selected and launched in 1998 to bring common tools, processes, language and statistical methodologies to Seagate as a means to design and develop robust products and processes. Six Sigma helps Seagate to make data-based decisions that maximize customer and shareholder value thus improving quality and customer satisfaction while providing bottom line savings.

Six Sigma was one of the three key activities seen as essential for Seagate's continuing prosperity. The other two were:

1. *Supply chain*: How to respond to demand changes in a timely manner, execute to commitments and provide flexibility to customers.
2. *Core teams*: How to manage product development from research not sure what you are saying hereto volume manufacture.

Implementation

Seagate Springtown (which is part of Seagate Recording) started a supply chain project to improve materials management and develop a strategic vendor relationship. The fabrication plan at Springtown introduced the Lean Manufacturing philosophy that recognizes waste as the primary driver of cycle time and product cost. Very soon a change had taken place at Springtown and Lean Manufacturing was wholly integrated with the supply chain initiative.

The corporate office at Scotts Valley was rolling out a global Six Sigma deployment programme. The Springtown site followed the Six Sigma training programme and implemented a number of tools and techniques including the process map, sampling plan, cause and effect analysis and control plans, which identified a 'hidden factory'. The less visible defects of this 'hidden factory' included:

- Repeated measurements (in and out)
- Repeated chains (post and pre)
- Transits between manufacturing areas
- Process steps conducted in 'non-standard operating conditions'
- High rework on a process

Results and learning points
The Six Sigma methodology proved a key enabler for supply chain /Lean Manufacturing and the integrated programme achieved improved process capability and quality as shown by:

- Increased throughput by 31 per cent
- Significant impact on capital expenditure due to increased efficiency of existing equipment
- Lower work in progress
- 80 per cent pass rate on qualifications for vacuum tools (previously 40 per cent)

The main learning points from the Six Sigma programme at Seagate Technology include:

1. Companies using Six Sigma need to learn how to use the metrics to manage – to make appropriate decisions on a holistic basis, avoiding sub-optimization. This task of integration with the whole of the company's business process is the key.
2. Set aggressive goals – do not make them too easy.
3. Develop a system for tracking 'soft savings'.
4. Develop a common language and encourage its use on a widespread basis early in the program.
5. Embed the business process within the organization by training all functions – use green, black belt and customized programs as appropriate.

Source: Basu (2004, p. 257)

The Toyota Production System is frequently modelled as a house with two pillars. One pillar represents JIT, and the other pillar, the concept of jidoka. Jidoka is 'automation with a human touch'. This is usually illustrated by example of a machine that will detect a problem and stop production automatically rather than continue to run and produce bad output. Jidoka principle contributes to the achievement of both high efficiency and sustainable quality assurance.

The principle was first used by Sakichi Toyoda at the beginning of the 20th century when he invented a loom which stopped when the thread broke. Jidoka comprises a four-step process that engages when abnormalities occur:

1. Detect the abnormality
2. Stop
3. Fix or correct the immediate condition
4. Investigate the root cause and install a countermeasure

The first two steps can be mechanized or automated. Poka-yoke method also allows a process to detect a problem and stop. Ultimately, it is about transferring human intelligence to machines to eradicate the problem.

The characteristics of an agile supply chain

In Chapter 3, we highlighted the distinction between a lean supply chain and an agile supply chain in concurrence with both Fisher (1997) and Christopher (2000).

Christopher (2000) defines agility as achieving a rapid response on a global scale to constantly changing markets. The rapid response needs to cover changes in demand for both volume and variety. A third dimension is lead times and how long it takes to replenish the goods in order to satisfy demand.

Agility is achieved by flexibility and in order to achieve flexibility standard platforms are postponed and components and modules are final assembled when the demand for volume and variety are known. The standardized components and modules enable minimum stock keeping of finished products while at the same time the late assembly makes mass customization possible with short lead times. Buffer capacity is maintained in order to satisfy the fluctuation of demand. The above described agile set-up demand that the full global supply chain is involved. The subassembly of components into modules can be done in a low-cost environment, where as the final assembly will often be done close to demand in order to localize the product. Christopher suggests four characteristics of a truly agile supply chain as (1) market sensitive capable of reading and responding to real demand, (2) virtual which is information based rather than inventory based, (3) process integration ensuring collaborative working between buyers and suppliers and (4) network committed to closer and responsive relationships with customers.

Fisher (1997) offers a similar view on agile and responsive supply chain based on predictable demand versus unpredictable, but also with the product component of functional versus innovative products. Functional products are like staples that can be bought at groceries and petrol stations satisfy basic needs and have a predictable demand with a long lifecycle and low profit margin. Innovative products on the other hand are like state of the art MP4 players or fashion clothes having a short life cycle, with higher profit margins but with very unpredictable demand. These distinctions are exemplified as the product life cycle for functional products is typically more than 2 years, but for innovative products it can be from 3 months to 1 year. The margin of error for forecasting for functional products is in the 10 per cent range, but for the innovative products it varies from 40 to 100 per cent. Based on the short lifecycle and the unpredictable demand and forecasting, innovate products need an agile supply chain. The agile supply chain is achieved by buffer capacity and buffer stocks.

Fischer further argues that it is critical that the right supply chain strategy is chosen in order to match the demand and the product, so that innovative products with a high margin are channelled trough a responsive supply chain.

The cost of the buffers in capacity and inventory will be offset by a higher margin and the lower number of goods needed to be sold. The agile supply chain is achieved, according to Fischer, by adopting four rules, such as (1) accept that uncertainty is inherent in innovative products, (2) reduce uncertainty by finding data that can support better forecasting, (3) avoid uncertainty by cutting lead times, increasing flexibility in order to produce to order or move manufacturing closer to demand and (4) hedge against uncertainty with buffer inventory and excess capacity.

Yusuf et al. (2003) claim that there are four pivotal objectives of agile manufacturing as part of an agile supply chain. These objectives are (1) customer enrichment ahead of competitors, (2) achieving mass customization at the cost of mass production, mastering change, (3) mastering change and uncertainty through routinely adaptable structures and (4) leveraging the impact of people across enterprises through information technology. This list clearly shows that enhanced responsiveness is a major capability of an agile supply chain.

In congruence to our research and experience we summarize that in order to achieve the responsiveness required for innovative products, an agile supply chain should contain the following key characteristics:

1. Flexibility
2. Market sensitivity
3. A virtual network
4. Postponement
5. Selected lean supply chain principles

Flexibility is a key characteristic of an agile supply chain. Flexibility in manufacturing is the ability to respond quickly to the variations of manufacturing requirements in product volume, product variety and of the supply chain. The variability in volume is demonstrated by product launching, seasonal demand, substitution and promotional activities. The changes in variety relate to increased number of SKUs in new products, distributors' own brands (DOB), etc. The variations in the supply chain result from variability of lead times of both suppliers and customers, increased service level, change in order size, etc. There are instances of failures during the 1980s where companies invested in sophisticated flexible manufacturing systems (FMS) in pursuit of flexibility. At the other end of the scale all the attentions were given to organizational flexibility (e.g. cultural and skills integration between craftsmen and operators), producing limited success. Recognizing a closer link between agile processes there is a huge interest in the service sector, also how to optimize the benefits of agile processes for a faster response to customer demand. In order to improve flexibility in a supply chain, it is crucial to reduce complexity in product specifications to maximize mass customization, reduce complexity in processes by standardizing them and enhance organization flexibility by multi-skilling and seamless working practices.

Market sensitivity means that the supply chain is capable of responding to real demand. This requires demand planning not to be driven by periodically adjusted annual forecast, but by actual customer requirements. The scheduling of operations will be reverse scheduling based on customer orders rather than forward scheduling based on forecast. In addition to actual customer order, the use of information technology and efficient consumer response (ECR) and customer relationship management (CRM)systems should be utilized to capture data directly from point of sales and consumer buying habits. The growth in 'loyalty cards' and 'store cards' is also another source of consumer data to enhance the management of market sensitivity.

The use of Internet and information technology have enabled the real-time sharing of data between customers, buyers, suppliers, planners, manufacturers and distributors in a virtual network. The visibility of demand and collaborative planning forecasting and replenishment (CPFR) systems (see Chapter 12) in a virtual network are important tools to respond to the real needs of customers in a global market. The concept of competitive advantage through world class manufacturing in individual sites has now shifted to network excellence. The supply chain where a group of partners can be linked together in a virtual network and communicate on-line and on time is a vital characteristic of agility.

Postponement is based on the principle that semi-finished products and components are kept in generic form and the final assembly or customization does not take place until the final customer or market requirements are known. The principle of postponement is an essential characteristic of an agile supply chain. The rapid response tailored the customer needs is also helped by the buffer capacity of key workstations. The point in the supply chain where the semi-finished products are stocked is also known as 'de-coupling' point. This point should be as close to the market place as possible in the downstream of the supply chain. In addition to responding quickly to specific customer demand, the concept of postponement offers some operational, economic and marketing advantages. As the inventory is kept at a generic level there are fewer SKUs and this makes easier forecasting and less inventory in total. As the inventory is kept at an earlier, stage stock value is also likely to be less than the value of finished product inventory. A higher level of variety can be offered at a lower cost and marketing can promote apparent exclusivity to customers by 'mass customization'.

An agile supply chain also shares some lean supply chain principles or characteristics. The enhanced responsiveness of an agile supply chain is in addition to the high level of efficiency, quality assurance and smooth operation flow which are the key characteristics of a lean supply chain. An agile supply chain also focuses on the elimination of waste or mudas as in a lean process but with a different strategy for buffer capacity and inventory required for postponement. However, a pure lean strategy can be applied up to the de-coupling point and then an agile strategy can be applied beyond that point. It should be possible to achieve volume-oriented economies of scale up to the de-coupling point. This is similar to a service operation (e.g. a bank) where the repetitive activities are isolated or de-coupled and carried out in the back office with lean thinking while responsive customer service is provided at front end.

The strategy of a lean and agile supply chain

The above analysis and our experience strengthen the suitability of a pure agile supply chain for innovative products with unpredictable demand pattern with high profit margin and high variety requiring many changes and shorter lead time. A pure lean supply chain, on the other hand is suitable for high volume functional products with a lower margin and variety requiring a few changes. A lean supply chain may also compromise a longer lead time for a lower cost.

A survey by Yusuf et al. (2003), which was carried out by questionnaire to 600 manufacturing companies, showed that only a few companies adopted agile supply chain practices, but many companies embraced long-term collaboration with suppliers and customers, which was conceptualized as lean supply chain practices.

Christopher (2000) comments, ‘There will be occasions when a pure agile or a lean might be appropriate for a supply chain. However, there will often be situations where a combination of the two may be appropriate, that is a hybrid strategy’.

Naylor et al. (1997) agree that both agile and lean can be combined in the same supply chain calls it ‘Leagile’.

In the business world it is more likely that companies have a mixed portfolio of products and services. It is also likely many high volume manufacturers or service providers experience short-term or seasonal demand of novelty products (e.g. chocolate eggs at Easter and T-shirts for the Olympics). There will be some high volume products where demand is stable and more predictable and there will be products with sporadic demands seeking agile response. Therefore, it is not important to follow either lean or agile supply chain strategy. However, it is important to recognize that a supply chain can be lean for part of the time, agile for part of the time and both lean and agile (hybrid) for part of the time.

Case example: A lean and agile supply chain

Zara is a successful apparel company in Spain supplying fashionable clothing to an international target market of young customers between the age of 18 and 35. The market positioning of the company places it in competition with some of the leading operations in the business, including the Italian company Beneton, the US based Gap, and the UK based FCUK and Monsoon.

The process of supply planning starts with a cross-functional team comprising fashion, commercial and retail specialists working in Zara’s head office in La Curuna, Spain. The design reflects the international fashion trends of target customers with inspiration gained through visits to relevant fashion shows, stores, university campuses, cafes, clubs and events appropriate for the life style of young aspiring customers. The team’s understanding fashion trend and demand forecast is further guided by regular inflow of sales data from company's stores around the world.

Raw materials are procured from three buying offices in the UK, China and the Netherlands and most of the materials are supplied from India, China, Mauritius, Turkey, Morocco and also from New Zealand, Australia, Italy and Germany. Approximately 40 per cent of broadest but least transient garments are purchased as finished products from the low cost centres of the Far East. The remaining 60 per cent are produced by quick response in Zara's-automated factories in Spain and a network of small contractors. Materials or fabric are also held in semi-finished form (e.g. un-dyed and un-printed),

Zara's manufacturing systems are modelled upon ideas developed in conjunction with Toyota. The operations with a higher economy of scale (e.g. cutting, dying, labelling and packaging) are conducted in-house to enhance cost efficiency. Other manufacturing activities including the labour intensive finishing operations are accomplished by a network of 300 specialist subcontractors. These subcontractors work exclusively for Zara's parent company, Inditex SA. They receive necessary training and technological, financial and logistical support as if they are subsidiaries of Zara. The system is flexible to adjust total capacity depending on the fluctuation of demand and production is kept at level below expected sales to keep the stock moving.

Zara's rapid and sustainable growth in a competitive market is attributed to its ability to establish an agile supply chain which also incorporates many lean characteristics. There is a success story of a combined lean and agile supply chain strategy.

Adapted from Christopher (2000)

Summary

Changing customer and technological requirements, volatile markets and global sourcing have created fresh challenges to supply chain management and the traditional forecast driven longer and slower logistic pipelines are becoming non-competitive and therefore unsustainable. In this chapter, we have discussed how to respond to this challenge by a lean and agile supply chain. We have developed the key characteristics of a lean supply chain as elimination of waste, smooth operation flow, high level of efficiency and quality assurance. We have differentiated the characteristics of an agile supply chain as flexibility, market sensitivity, a virtual network, postponement and selected lean supply chain principles. We have also given guidelines to apply appropriate strategies of lean and agile supply chain. The supply chain objectives and characteristics of a lean and an agile supply chain are summarized in Figure 13.5.

	Lean	Agile
Objectives	• Low cost • High utilization • Minimum stock	• Fast response • Buffer capacity • Deployed stock
Process characteristics	• Elimination of waste • Smooth operation flow • High level of efficiency • Quality assurance	• Flexibility • Market sensitivity • A virtual network • Postponement • Selected lean supply chain principles
Product characteristics	• Functional products • Low variety • Low margin	• Innovative products • High variety • High margin

Figure 13.5 Lean and agile characteristics.