White Paper

Lean Manufacturing

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Executive Summary

The pressure on manufacturing organizations has increased dramatically over the last 15 years. This has been driven by globalization in the aftermath of the Cold War, the liberalization of markets, and the emergence and growth of economies such as Brazil, Russia, India and China. Organizations that continue to manufacture in high-cost countries must eliminate any "fat" from their manufacturing if they are to remain competitive.

Lean manufacturing is now a widely adopted philosophy for focusing on customer value-adding activities through eliminating waste and striving towards continuous improvement. An ARC Group's strategy report authored by Simon Bragg (2004) suggests that today 36 percent of U.S. manufacturers and 70 percent of U.K. manufacturers "are using lean as their primary improvement methodology." There is nothing radically new in lean manufacturing. It has evolved over the last 50 years from its roots in the Toyota Production System and today embodies a variety of concepts and techniques.

In today's complex, dynamic and global manufacturing supply chains, software solutions play an increasingly important role in supporting lean manufacturing. Lawson provides business software solutions in what we call the "make, move and maintain" (M3) market. Within "make," Lawson supports three key manufacturing philosophies: lean manufacturing; world-class MRPII manufacturing and advanced manufacturing.

Lawson has a wide range of solutions and components available to support lean manufacturing, and has been developing and delivering lean manufacturing solutions for over 15 years. Lawson lean manufacturing solutions support the five main elements of lean thinking and enable organizations to quickly achieve 20 to 30 percent of the benefits of a lean manufacturing approach. The rest of the benefits will come over time through focusing on the fifth element—the search for perfection through continuous improvement.

In addition to the customary lean manufacturing software components, Lawson offers a Theory of Constraints (TOC)-based production planning solution that conforms to the TOC specifications laid down by Goldratt (1986) and provides a unique competitive advantage.

While lean concepts and tools are best suited to certain environments, a "lean" philosophy can be applied in almost any manufacturing environment. Just-in-Time kanban-based systems are best suited to manufacturing assembly operations. Theory of Constraints is a lean approach that is appropriate for manufacturing environments with volatile demand and a changing order mix. A simple orderless production and material backflushing approach is often appropriate for high volumes, demand volatility and short lead-time environments such as food manufacturing.

Material requirements planning (MRP) can coexist with pull-based lean concepts to achieve lean manufacturing in environments where there is a wide variety of products, variable or infrequent demand for products, and long purchasing and/or throughput lead times such as in the fashion, service spare parts and asset-intensive industries. The strength of pull-based Just-in-Time techniques is in control and execution, while MRP's strength is in planning.

Introduction

Lawson provides business software solutions in what we call the "make, move and maintain" (M3) market. Within "make," Lawson supports three key manufacturing philosophies: lean manufacturing; world-class MRPII manufacturing and advanced manufacturing. This white paper focuses on planning and control within lean manufacturing.

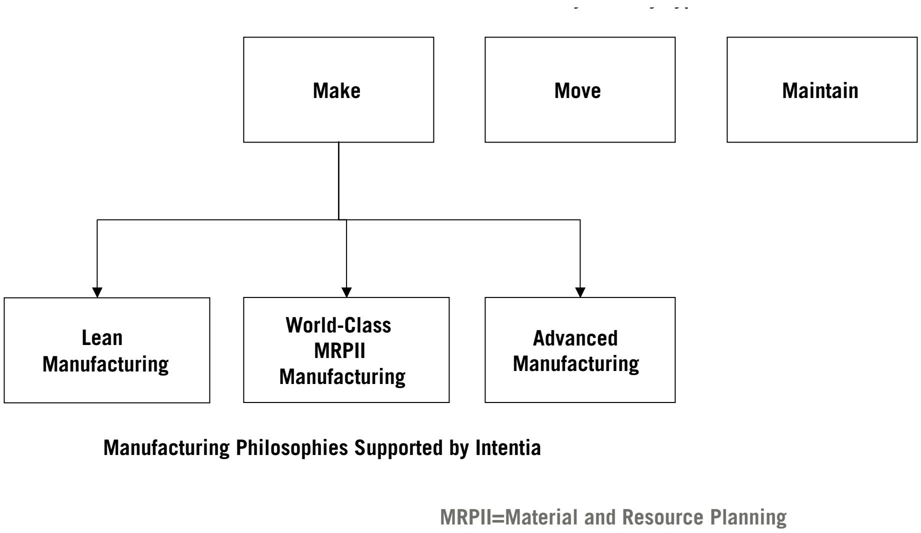

Fig. 1. Manufacturing philosophies supported by Lawson.

An ARC Group strategy report authored by Simon Bragg (2004) suggests that today 36 percent of U.S. manufacturers and 70 percent of U.K. manufacturers "are using lean as their primary improvement methodology."

Lean Manufacturing—So What?

Lean manufacturing concepts have been around for years. The roots of lean manufacturing are in the Toyota Production System developed by Taiichi Ohno (Brown et al. 2000) after the Second World War. By the 1980s, some Western manufacturers were adopting Japanese lean production methodologies in an effort to become more efficient and competitive. Early implementations were primarily Just-in-Time pull systems supported by card-based kanbans or supplier call-offs, and the establishment of quality circles or kaizen teams for continuous improvement. Kaizen teams involve groups of workers identifying and resolving issues in performing their daily work tasks to reduce waste and improve efficiency.

During the 1980s, the use of lean techniques mushroomed, especially in the automotive industry. Examples of this include the General Motors NUMMI project with Toyota (Brown et al. 2000). Since then, the lean manufacturing bandwagon has grown to encompass most industries, and a myriad of software vendors claim to support "lean manufacturing" with new applications being launched every week and old ones being rebranded as "lean manufacturing."

So what does this much-used "lean manufacturing" term actually mean? By definition lean manufacturing is essentially a focus on customer value-adding activities and the systematic identification and elimination of waste, and continuous improvement in flow manufacturing environments to achieve this.

Lean manufacturing encompasses a number of other manufacturing philosophies and concepts including: Toyota Production System (TPS), Just-in-Time (JIT), Theory of Constraints (Goldratt et al. 1986), Six Sigma (developed by Motorola), Lean Production (Womack et al. 1990) and Agile Manufacturing (Kidd 1994). (See the timeline in figure 2.) Lean manufacturing is supported by a wide range of methodologies and techniques including Just-in-Time, kanban, kaizen and continuous improvement, Theory of Constraints, orderless production, and takt or repetitive scheduling, to name a few.

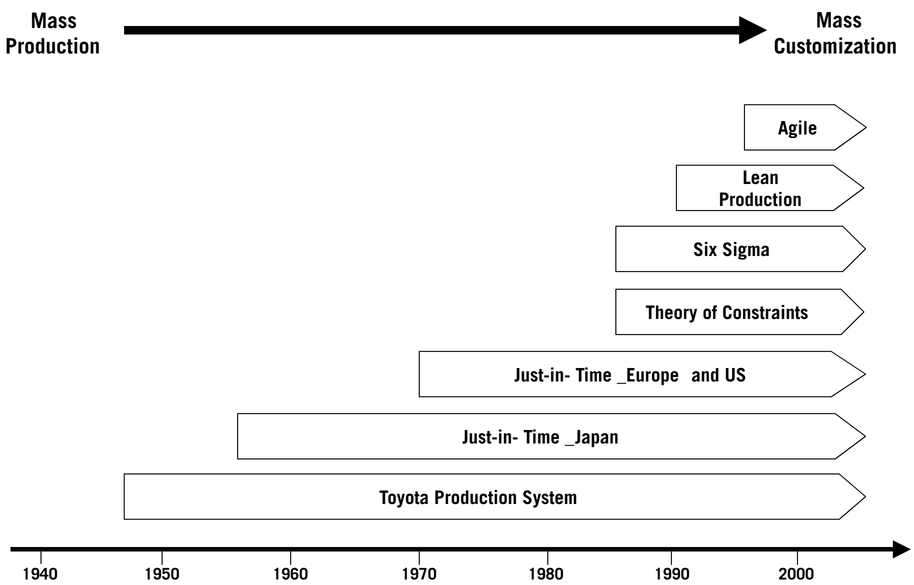

Fig. 2. The evolution of lean manufacturing.

Lawson has been supporting lean initiatives and methodologies for many years, and has treated these simply as methods for delivering business performance improvements and value to our clients. With the massive interest in lean manufacturing, the time has come for Lawson to communicate our views and experience in lean manufacturing and the range of solutions and tools that we offer to support organizations with a lean manufacturing philosophy. In addition to supporting the customary areas such as enterprise performance measurement, business process mapping and design tools, lean material planning, leveled scheduling, Just-in-Time and kanban, Lawson offers a Theory of Constraints-based production planning solution that conforms to the specifications laid down by Goldratt and provides a unique competitive advantage.

Objectives

The key objectives of this white paper are to determine:

1. What does lean manufacturing mean in terms of planning and control, and what tools and approaches are best in different environments?
2. How does software support planning and control in a lean manufacturing factory?
3. What planning and control tools does Lawson offer to support lean manufacturing?

This white paper does not aim to cover how to configure the components in Lawson solutions to support lean manufacturing. That is covered in a separate document.

Chapter 2 describes some of the challenges facing manufacturing organization in the 21st century. Chapter 3 investigates lean manufacturing, some key issues, and the characteristics, advantages and disadvantages of lean manufacturing. Chapter 4 analyzes some techniques that support lean manufacturing and how material requirements planning and Just-in-Time can coexist and compliment each other. Chapter 5 presents how and where Lawson solutions support lean manufacturing. Finally, chapter 6 draws some conclusions.

The Manufacturing Challenge

Over the last 15 years, pressure has been continually increasing on manufacturing organizations as customers become increasingly demanding. The competition to supply the category of products each manufacturer produces has amplified in the marketplace. This is the case in almost all industries. This chapter explores the challenges that manufacturers are facing.

Globalization and Competitive Pressure

Competitive pressure has accelerated even faster over the past 15 years with the advent of modern globalization in the aftermath of the Cold War, liberalization of markets and emergence of the likes of Brazil, Russia India and China in the global marketplace. Globalization has led to changes and created ramifications that are continuing to alter relationships between customers and suppliers as global supply chains develop and evolve. Manufacturing organizations must look for new ways to maximize customer value-adding activities and to respond to customer demand with greater agility.

Mass Production to Mass Customization

Henry Ford introduced the production line in 1916 and christened this system "mass production" in 1926 (Brown et al. 2000). In the last 30 years, the world has changed dramatically. There has been a move away from mass production, where customers purchase uniform products that differ from what they really want, to mass customization that satisfies the demand for user-configured products. While organizations that are market-led please the individual customer, it complicates manufacturing, which must learn and adapt to cope with the complexity of planning and controlling production of an ever-expanding product range.

Shortening Product Life Cycles

Not only are customer demands driving organizations to deliver products that are configured to the customer's requirements, but at the same time product life cycles are shrinking. To maintain or grow market share, manufacturers must introduce more new products and revamp existing ones at a quicker pace than ever before. Shortening product life cycles impact across the entire manufacturing operations of an organization and affect everything from process design, through training and quality, to planning and control.

Smaller Batch Sizes and Shortening Lead Times

If the need for a wider range of products and increasingly frequent new product introductions is not enough, customers are demanding shorter delivery lead times. The need for mass customization is driving batch sizes towards "one." At the same time, manufacturers are under continual pressure to reduce working capital by cutting inventory and work-in-process levels. Manufacturing organizations need to embrace new manufacturing philosophies and techniques that will enable them to shorten lead times and free up working capital.

Outsourcing and Specialization

Large low-cost emerging economies such as Brazil, Russia, India and China are rapidly ramping up their manufacturing capabilities. Western organizations are being forced into making decisions on whether to outsource manufacturing to these or other low-cost countries, or to specialize and compete on knowledge- and technology-based differentiation. While there may be benefits in proximity to major markets, those organizations that continue to manufacture in Western countries must eliminate any "fat" from manufacturing if they are to remain competitive.

Summary

To compete in the future, organizations need to become lean and to make continual improvements in order to:

- Maximize customer value delivered;
- Reduce wasted effort and costs by removing "fat" and non-value-adding activities;
- Quickly react to customer needs and changes in demand.

Lean Manufacturing

"Lean thinking" can be applied in almost any environment. This chapter explores some of the thinking behind lean manufacturing. This includes the key concepts and principles for lean manufacturing, the characteristics of where lean concepts are most effective, and the advantages and disadvantages of a lean manufacturing approach. Finally, it assesses whether there is a role for software solutions in supporting lean manufacturing.

Elements of Lean

Womack and Jones (1996) defined the five main elements of "lean thinking," which are now widely accepted. These five main elements that enable a lean approach are:

1. Value—Identify value since it is lean manufacturing's role to deliver value to the customer.
2. Value stream—To create customer value, managers need to identify which activities add value and which do not.
3. Flow—Managers must focus on the flow through the value chain in the factory and eliminate non-value-adding activities. This usually involves a "single piece" flow concept.
4. Pull—The value chain is based on a pull approach; that is, customer demand drives manufacturing activity and material flow.
5. Perfection—Continuous improvement in pursuit of perfection.

Customer Value Is a Strategic Issue

Muda is a Japanese word relating to waste. This is a key word in lean manufacturing. Waste is evil. The aim is to remove waste by focusing on customer value-adding activities while removing unnecessary cost. The seven main types of waste defined by Toyota and at the core of their Just-in-Time (JIT) philosophy are: overproduction, waiting time/delays, transport, process/poor work practices, inventory, motion/unnecessary movement, and defects (Slack et al. 2001; AT Kearney 2003).

Overproduction involves build-up of finished goods stock and work-in-process between operations. Waiting time or delays involve machines idling or producing the wrong thing because the critical materials are not available. Transport refers to the movement of materials and work-in-process around the factory that does not add value. Process concerns the poor design of parts or procedures and a lack of maintenance, incurring waste. Inventory is a key issue and must be removed wherever possible (see section 3.3 'Inventory as a Strategic Issue'). Motion focuses on simplifying procedures to reduce non-value-adding work performed by operators. Defects cover the elimination of product defects and quality problems.

Maximizing customer value is a strategic issue for lean manufacturing organizations.

Inventory as a Strategic Issue

Traditional Western thinking saw inventory as an asset. More recently it has been recognized that inventory ties up capital and is a risk. Push-based material planning and control approaches, such as material requirements planning (MRP), have sometimes been blamed for high inventory levels. This has inspired the adoption of Japanese JIT or pull-based techniques in an effort to reduce inventory. JIT has often been seen as a direct challenge to MRP.

Wherever supply exceeds demand, inventory will be incurred (Slack et al. 2001, p. 377). It can be argued that inventory provides a safety buffer against, for example, market fluctuations, production stoppages and supplier delays. Too-low inventories endanger customer service and supply costs. High inventories tie up working capital and incur additional storage and handling costs. Wherever there is a lack of trust between two parties in a value chain, there will be inventory. The receiver holds stock to protect against delivery failures while the supplier keeps a stock buffer to handle surprise demands.

In today's dynamic and competitive environment, customers are demanding faster service, shorter product life cycles, higher quality and greater variety (mass customization). Inventory quickly becomes obsolete or its value falls below its cost. Inventory is a risk that must be managed. Organizations must remove inventory to remain competitive. Automotive assembly is a good example of where this has happened. Lean manufacturing philosophies and techniques have been central to achieving this goal by focusing on a Just-in-Time demand-based pull that only replenishes inventory when required. Minimizing inventory is a strategic issue for lean manufacturing organizations.

Characteristics for Successful Lean Manufacturing

Some of the business and manufacturing scenarios that make a Just-in-Time lean manufacturing philosophy easier to implement are where there is:

- Flow manufacturing and a one-part/single-piece flow;
- A steady demand pattern to ensure a level schedule and avoid capacity bottlenecks;
- A limited product mix, preferably with a significant degree of parts commonality; that is, where products are configurable and componentized;
- Short lead times to ensure responsiveness to customer demands;
- High process and product quality to minimize rework and variations in material requirements. Six Sigma plays a major role in achieving high quality;
- An ABC costing approach.

However, it is still possible to take a lean approach where these conditions do not exist. While a lean manufacturing approach using kanban is best suited to environments where there is stable demand, limited product mix and short lead times, a Theory of Constraints approach can be employed to support lean manufacturing in more complex production environments.

Advantages of Lean Manufacturing

There are many inherent advantages in a lean manufacturing philosophy that have led to its extensive adoption. Four main advantages are:

- An overriding focus on customer value-adding activities;
- The elimination of all categories of waste, effectively reducing the working capital employed in delivering products to customers;
- Reduced lead times and agility to respond to changes in demand due to a faster material flow through the factory;
- A focus on continuous improvement.

As part of eliminating waste, inventories are reduced throughout the production process from raw material supplies, through work-in-process, to finished goods. This is achieved by the demand-based pull and replenishment of inventory only when there is demand for it. In contrast, when implementing MRPII, if the business processes and working practices are not reviewed, there is a risk of simply automating the waste. Lean manufacturing is not something that is implemented and left to run; it is a long-term journey in pursuit of perfection.

There is much to be said for the greater worker independence in the execution of plans under a lean philosophy. This leads to higher employee motivation and productivity as workers are asked to come up with solutions to problems as opposed to having to work with flawed procedures. Total quality and Six Sigma also play a major role in achieving lean manufacturing, since quality improvements play a key role in the battle to eliminate waste. However, these are outside the scope of this paper.

Disadvantages of Lean Manufacturing

While lean manufacturing yields many benefits, there are also drawbacks and situations where it is not always the best approach. Recording and accurately tracking inventory and material usage in an orderless environment is a challenge, especially where material usage varies due to errors or the nature of the process, or there are very long lead times. The counter argument from the "lean gurus" is that recording variations is a waste since it does not add any value for the customer. Also, for how much of the lead time is work actually being performed on the item?

Capacity utilization is often sacrificed in conventional JIT environments (Slack et al. 2001, p. 485) in favor of removing inventory. One solution to this is to create an annual hours contract with staff so that capacity can be flexed.

When kanban cards start piling up at a work cell due to the cell taking longer than the takt time to complete a task, it is clear there is a bottleneck. However, capacity planning is difficult in a Just-in-Time pull-based or orderless environment, especially if there is a product mix where operation times vary. Simulation tools are of value here.

The concept of lean manufacturing is to make problems immediately visible. However, due to the nature of many lean manufacturing techniques, there are limited historical records for analysis of processes and continuous improvement, which is a key concept within lean manufacturing.

Furthermore, techniques such as kanban are difficult to use once outside the line of sight within the factory. Simply put, using visual signals and kanban conveyers becomes totally inadequate to communicate with suppliers, customers, subcontractors and other partners in a global supply chain.

Finally, if anything breaks down in the production process in a lean environment, there is no safety buffer and the entire material flow quickly stops. To avoid this, lean manufacturing focuses on total productive maintenance.

In summary, lean manufacturing is more difficult to implement when there are significant demand variations, major changes in the product mix or complex global supply chains.

Manufacturing Philosophies

MRP and Push-Based Systems

Material Requirements Planning

MRP is a push system that starts production based on expected demand, while JIT, for example, is a pull system where production starts based on actual demand (Karmarkar 1989). MRP provides raw material and parts planning for dependent demand (Brown et al. 2001). MRP performs a netting of requirements, bill-of-material explosion, lot sizing, and order generation and release with offsetting of inventory against lead times. Some of the strengths of MRP are its ability to handle (Slack et al. 2001, p. 504–6):

- Variety (which is continually increasing in this era of mass customization);
- Infrequent demand for parts (that is, slow movers and sporadic demand for service spare parts);
- Long purchasing and throughput lead times.

The benefits of MRP can include reduced inventory, higher inventory turns, fewer material shortages and customer delays, and more accurate delivery time quotes. This often leads to better utilization and less time expediting. However, MRP uses fixed lead times based on the worst-case scenario, sometimes resulting in the early releasing of orders (Karmarkar 1989, p125) and surplus stock. MRP is weak on production control.

MRP is particularly successful in assemble-to-stock, assemble-to-order and manufacture-to-order industries, such as tools, appliances, trucks and heavy machine tools (Chase et al. 1998). These strengths also fit well with the characteristics of the fashion industry and spare parts and equipment manufacture for the service parts and asset-intensive industries. However, many of these industries are nevertheless moving towards lean manufacturing.

To apply a pull-based JIT approach where there is significant variety, the solution is to design the production process for customization as late as possible. This means moving the decoupling point between component or subassembly production and final assembly to customer order as late as possible. Where lead times for components are longer, these components or materials are stocked and the end products made to order. This is the case in, for example, the fashion industry where there is a basic style and the final stockkeeping unit (SKU) will depend on the trimmings and accessories used.

The Truth about Material Requirements Planning

In many cases, material requirements planning (MRP) has been blamed for high work-in-process and surplus stocks of raw materials and finished goods. In some cases it is probably true, but in the majority of cases it is due to poor configuration settings and the planning process. Old habits, low forecast accuracy, bad data accuracy, too-long lead times and complex pricing structures from both suppliers and within organizations all create problems. Stock buffers are then deployed as a simple but costly solution. In an attempt to create workarounds to these problems, a number of inventions such as lot sizing and safety stocks have been introduced into the original MRP theory and can cause surplus stocks.

Contrary to popular belief, MRP was actually a first step towards facilitating lean material planning in environments other than pure line manufacturing combined with a limited mix of products. Prior to MRP, most companies used a manual reorder point system with no reflection of future demands. The introduction of MRP drastically changed the possibilities to enhance the material planning.

From an MRP perspective, there are two main dimensions of the planning that will affect the leanness of the result. These are:

- Item and quantity—The principle being to forecast and source the correct item and quantity to minimize any excess and only source the required materials and finished goods.
- Time—Forecast and source at the correct time. The main reason for high work-in-process levels in MRP environments is poor settings and bad timing of order release to the shop floor.

Forecasting and sourcing the wrong item and quantity will cause shortages as well as high stocks. Sourcing at the wrong time will cause shortages and high work-in-process and stock levels. If the settings are correct, MRP is a very powerful tool that will greatly improve planning. MRP supports lean manufacturing by offering longer-term forecasting, capacity requirements planning and the development of supplier purchase agreements.

Orderless Production and Backflushing

In a move towards lean manufacturing, some organizations that operate in fast-moving environments--where lead times are too short for production to start based on the customer order pull--use orderless manufacturing. These manufacturers, such as certain food manufacturers, start from the forecast and then explode the bill of material to determine the packaging and ingredient requirements and generate purchase orders for suppliers. Due to the short lead times and often high order volumes, they do not want to report completion and material quantities used against specific manufacturing orders and operations. Instead, they prefer to simply work to a master production schedule and register finished product as inventory that is available to meet customer orders. Backflushing is then used to report operations and record material usage based on standard bills of material. This approach saves time and simplifies execution. However, it requires high quality data and an error-free, predictable production process.

Just-in-Time and Pull-Based Systems

JIT emerged in the Japanese shipbuilding industry in the late 1950s and early 1960s (Slack et al. 2001). JIT is often achieved through a kanban or similar approach. According to Hill, "The idea is for all materials to be active in the process at all times, thereby avoiding situations of cost without appropriate benefit." (Hill 1993, p. 207) Some of the desirable characteristics for successful JIT production are:

- Simple product structures with high parts commonality (Slack et al. 2001, p. 504);
- High repeatability;
- Stable levels of demand;
- Short throughput times relative to demand lead times (Slack et al. 2001, p. 504).

The benefits of JIT are improved quality, productivity, customer service, standardization, transport systems and flexibility. At the same time, inventory, batch sizes, lead times, unit costs, design time, space, energy and confusion are reduced. JIT is particularly successful in mass production and mass customization environments; that is, where there is variety based on a product platform. According to Hill, "Toyota can point to an inventory turnover of 70 times on purchased parts and work-in-process and 16 times if finished goods inventory is included." (Hill 1993, p. 207) While JIT offers simple, paperless control, there are limitations (Slack et al. 2001, p. 504). JIT is weak on planning.

Total quality management plays an important role in JIT as errors slow down production and reduce dependability on the previous operation's ability to supply materials on demand. Speed of production is also important for reacting to customer demand without holding finished goods inventories. In addition, flexibility is important to be able to quickly deliver a wide product mix.

Leveled Scheduling

In a JIT environment it is common to "level the production schedule so that mix and volume are even over time." (Slack et al. 2001) The leveling of production schedules is known as Heijunka, takt planning or production rate planning. A leveled schedule means that you will typically complete a smaller batch of each product every day as opposed to producing one large batch once per week or once per month.

Level scheduling is beneficial in industries such as automotive and potentially fashion manufacturing. Manufacturers level their master production schedule over a number of weeks to determine the production rate per product per day and takt time. Leveling of the schedule works best where:

- There is a single piece flow right through the various stages of production;
- There are relatively few different products produced per line;
- There is relatively stable and predictable demand; otherwise an inventory buffer becomes necessary to meet peaks in demand.

Not only is finished inventory reduced, but work-in-process falls as smaller batches are moving between each stage in the process. An even greater benefit is the simplification of planning and control, since every day in the plan within the leveled period is the same (Slack et al. 2001, p. 498). This gives production operators a far better understanding of what they have to do each day and how they how they are performing. In addition, as Slack et al. (2001, p. 498) point out, "regular daily schedules can be passed upstream to suppliers."

Kanban

Kanban comes from the Japanese words "kan" which means "card" and "ban" which means "signal". A kanban signal triggers movement, production or supply of materials or components (see figure 3). These materials or components are usually held in bins of a fixed size. The signal can be a card, empty squares on the floor for bins, lights or a computer software generated signal. The aim is to improve inventory control and shorten production cycle times. The level of inventory and work is controlled by the number of kanbans in the system. Over time and with process improvements, the quantity of components in the kanban bin can be reduced.

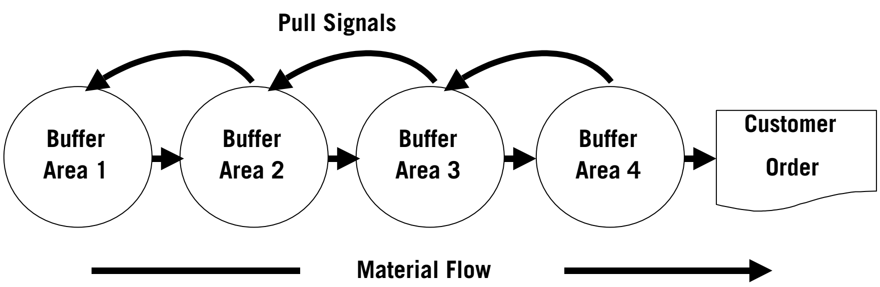

Fig. 3. Customer order initiates kanban pull signals that trigger material flow through production.

The challenge in kanban is often in the setting of the number of kanban cards in the system and the size of the kanban. This can become complex if the demand for each product varies significantly and the production layout is not line- or cell-based. Where the order mix changes and/or not all resources are dedicated to lean flow manufacturing, then kanban sizes must continuously be reevaluated. In these situations, a Theory of Constraints approach is often more appropriate.

Supplier Call-Offs

Some simple JIT systems rely on electronic data interchange (EDI) or AS2 messages to call off inventory from suppliers. This enables manufacturers to minimize their inventory. However, this is sometimes achieved at the expense of tending to push inventory onto suppliers.

Theory of Constraints

Lean planning focuses on the flow and the takt of the flow through the factory. The Theory of Constraints (TOC) optimizes the flow through the factory by focusing on planning the takt of the flow through the bottleneck. This objective of continually improving flow and planning the takt is consistent with lean manufacturing.

TOC aims to systematically identify and resolve constraints to improve throughput. Goldratt et al. (1986) define throughput as production that can be invoiced. The TOC philosophy and the drum-buffer-rope concept focus on planning the bottleneck and only providing an indication of the priority of tasks on other non-bottleneck resources. The bottleneck determines the maximum throughput rate and inventory. Utilization of non-bottlenecks is determined by the critical bottleneck. An hour lost on the bottleneck is lost forever and an hour saved on a non-bottleneck is a mirage (Goldratt et al. 1986). Hence, as with JIT, the thinking is that there is no point in producing if there is no customer demand.

The drum-buffer-rope concept is that the bottleneck is the drum or beat of the system. The rope represents the fact that new material is pulled into and up to the bottleneck as material is processed through the bottleneck. Since time lost on the bottleneck is time lost forever, an inventory buffer is kept in front of the bottleneck to ensure that it is never idle.

Execution on non-bottleneck resources is by priority. This is typically indicated by the use of green, yellow and red flags where red is the highest priority and the tasks that should be focused on. Operators then execute according to priority level rather than against a defined order sequence and specific times as in MRPII. Since inventory is only held in front of the critical bottleneck, it is normal to end up with significantly less inventory in a TOC system than the cumulative inventory if using MRP or JIT.

TOC is often more suitable than a JIT philosophy supported by a kanban system for discrete job shop manufacturing where there are deep bills of materials, complex routings, variations in lead times and a product mix that often results in different resources becoming the critical bottleneck at different times. These are typically less line-oriented, make-to-order environments such as sub-suppliers to the automotive, machine building, and heating ventilation and air conditioning industries, or the complex equipment manufacturers themselves.

Evaluation of MRP Push versus JIT Pull

A pull system such as JIT works well for line flows where order releases do not vary from week to week. JIT is not suitable where there are large, unpredictable demand variations (Karmarkar 1989, p. 124) and material flows are complex (Krajewski and Ritzman 1993). Sometimes categorizing products into runners, repeaters and strangers is appropriate where there is highly variable demand and an order mix. However, where product structures and routings are more complex, MRP is often required for planning (see figure 4).

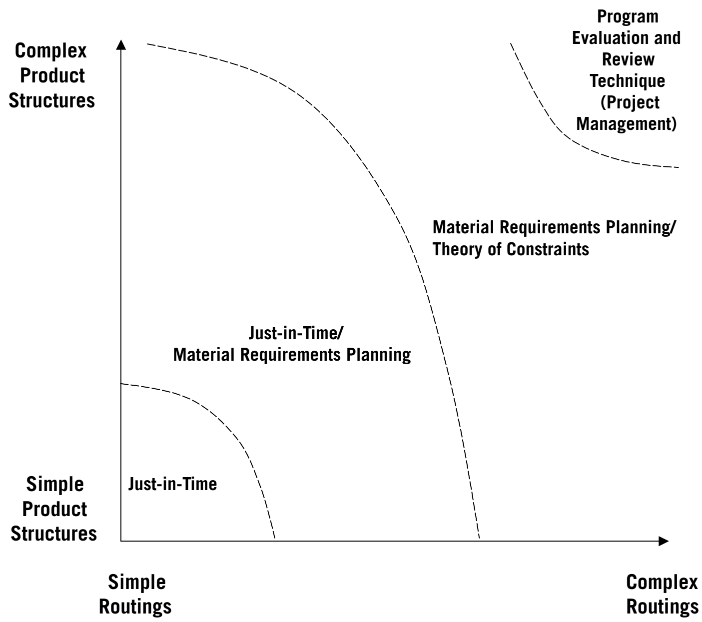

Fig. 4. Complexity as a determinant of an appropriate planning and control system. Source: Adapted from Slack et al. (2001), Operations Management, third edition, p. 507.

MRP is most effective where there are varying order quantities, a product mix and a need for high-level coordination of material flow (Slack et al. 2001) (see figure 5). As discussed earlier, there is a need to forecast to identify capacity requirements and determine long-term purchase contracts with suppliers against which to call off. However, MRP does not offer a method for internal quality or a mutually beneficial strategic vision for working with suppliers (Brown et al. 2000). A pull-based (JIT) approach is most suitable for shop-floor control. Thus, there is often value in MRP and JIT coexisting.

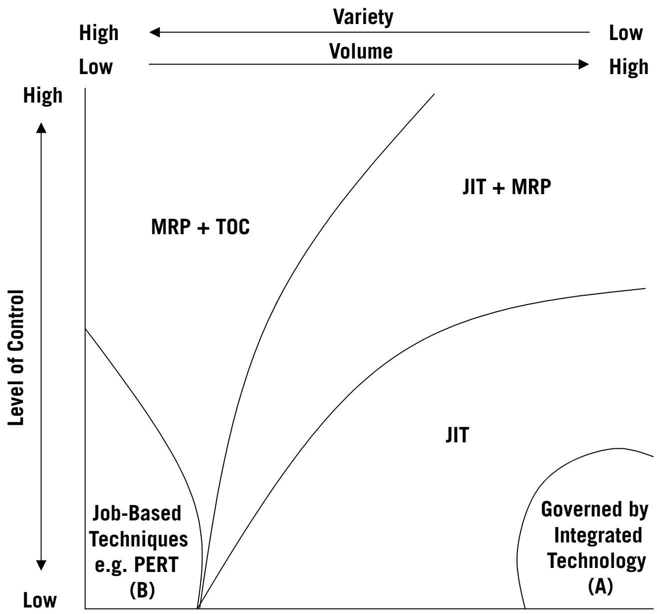

Fig. 5. Volume-variety and the level of material control required. Source: Adapted from Slack et al. (2001), Operations Management, third edition, p. 507.

How MRP, JIT and TOC Can Coexist in Plants

Combining MRP and JIT

Karmarkar (1989) proposes that in continuous flow and repetitive manufacturing environments, it is possible to combine MRP and JIT methods (Karmarkar 1989, p.127–129). MRP performs the material planning, coordination and purchasing while the shop floor operates on JIT. Figure 6 shows how MRP and JIT can coexist. A master production schedule exists, but material is actually pulled through production using a JIT approach. Figure 7 shows a more detailed example, where planning is MRP-based and execution is JIT-based.

For example, automotive suppliers, such as Thule, level their master production schedule over a number of weeks to plan and determine the production rate or takt in manufacturing. MRP is used for purchase order generation, while a kanban system is used for controlling the supply of components and final assembly.

Major automotive manufacturers such as Nissan use JIT principles for supplying components to assembly lines. A leveled master production schedule for cars and components exists from which material requirements information is fed to suppliers. Car seat sets, for example, are then delivered to a factory a few hours before they are required and pulled to the side of the line using kanban.

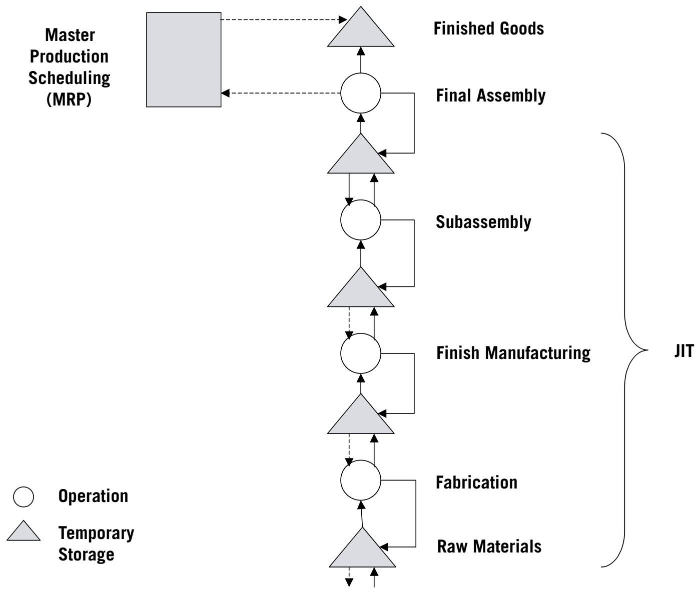

Fig. 6. Combined MRP and JIT approach to production. Source: Adapted from Chase et al. (1998), Production and Operations Management: Manufacturing and Services, eighth edition, McGraw Hill, p. 648.

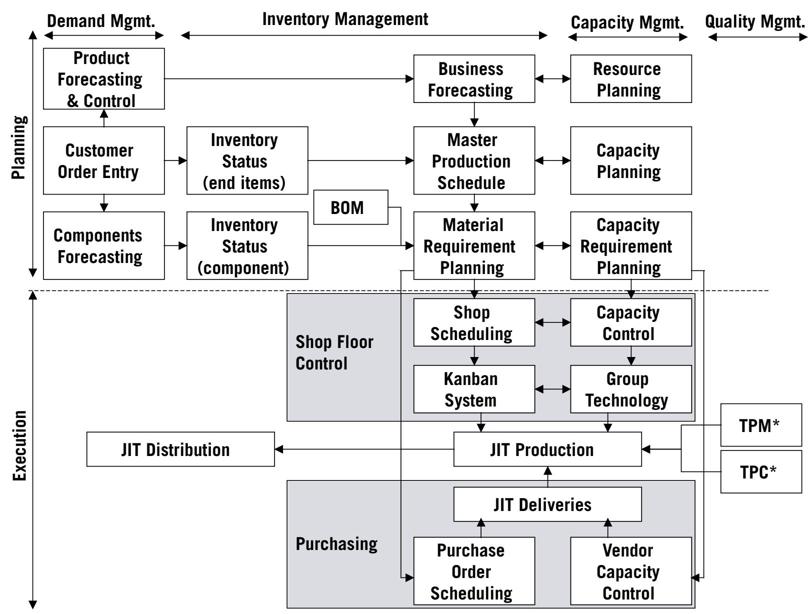

Fig. 7. A hybrid of MRP and JIT. Source: Based on Chase et al. (1998) Production and Operations Management: Manufacturing and Services, eighth edition, McGraw Hill, p. 648, and Chong Y. Lee, "A Recent Development of the Integrated Manufacturing System: A Hybrid of MRP and JIT", International Journal of Operations and Production Management 13, no. 4 (1993), p. 9.

MRP or JIT Depending on the Product

As an alternative to the above hybrid model, it is possible to use JIT for planning and control of highly repetitive products (that is, the runners) and MRP for infrequently made parts (that is, the strangers).

Slack et al. (2001, p. 504–505) site an example of a forklift manufacturer who used JIT for common part numbers used by all product family members and time-phased MRP scheduling for less frequently made parts (see figure 8).

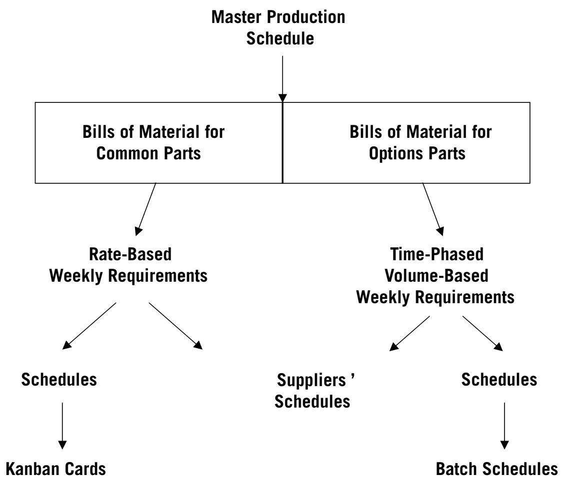

Fig. 8. Use of kanbans for high-volume parts and MRP for lower volume batches of parts. Source: Based on Chase et al. (1998), Production and Operations Management: Manufacturing and Services, eighth edition, McGraw Hill, p. 648.

Combining JIT and TOC

Where demand is variable, a runner/repeater/stranger analysis will identify which products are stable and where a JIT-based kanban approach can be used and the other products can be planned and executed using TOC. This is a good approach for, for example, the fashion industry where there are continuity garments (runners), seasonal garments (repeaters) and high-fashion one-season-only garments (strangers).

With configure-to-order type products in discrete manufacturing where demand is variable on the end product but the demand for sub-assemblies or components is stable, again a good approach is to use a JIT-based kanban approach for sub-assembly or component production. Final assembly is then performed on a make-to-order basis using TOC.

Does a Lean Manufacturing Philosophy Require Software?

Lean manufacturing is a broad and deep subject. For many people, it simply conjures the image of manual pull-based kanban systems that rely on cards or traffic lights, and there does not appear to be a place for software solutions. In reality, this is wrong on three counts.

- Firstly, kanban is only one method that can be used as part of achieving a pull-based lean manufacturing environment.
- Secondly, physical kanban cards were used first because software was not widely available at the time the concept was originally developed. However, today computerized kanbans are widely used. The advantage of electronic kanbans is that they overcome the problems of paper or physical token kanbans getting lost either through carelessness or sabotage. It is also difficult to introduce and phase in new products when using paper-based kanbans since it is important to collect and remove all the old kanbans from the system.
- Thirdly, supply chains/networks have become more complex with globalization, specialization and outsourcing. Today there is less vertical integration and each player is more dependent on its partners in the chain/network. Minimizing inventory not only needs good internal material planning and control, but also good supplier and customer relationships. As Burt (1989) states, "It is futile for big businesses to try to reform their manufacturing operations without the strong support of suppliers." Software is an excellent tool for supporting planning and execution across supply chains.

In today's world of complex global supply chains, an ever-increasing product mix and greater demand volatility, software is an essential part of achieving lean manufacturing.

Lawson Lean Manufacturing Solutions

Figure 9 shows a high-level overview of some of the solutions and tools that Lawson delivers to support lean manufacturing. These solutions and tools are briefly described in this chapter.

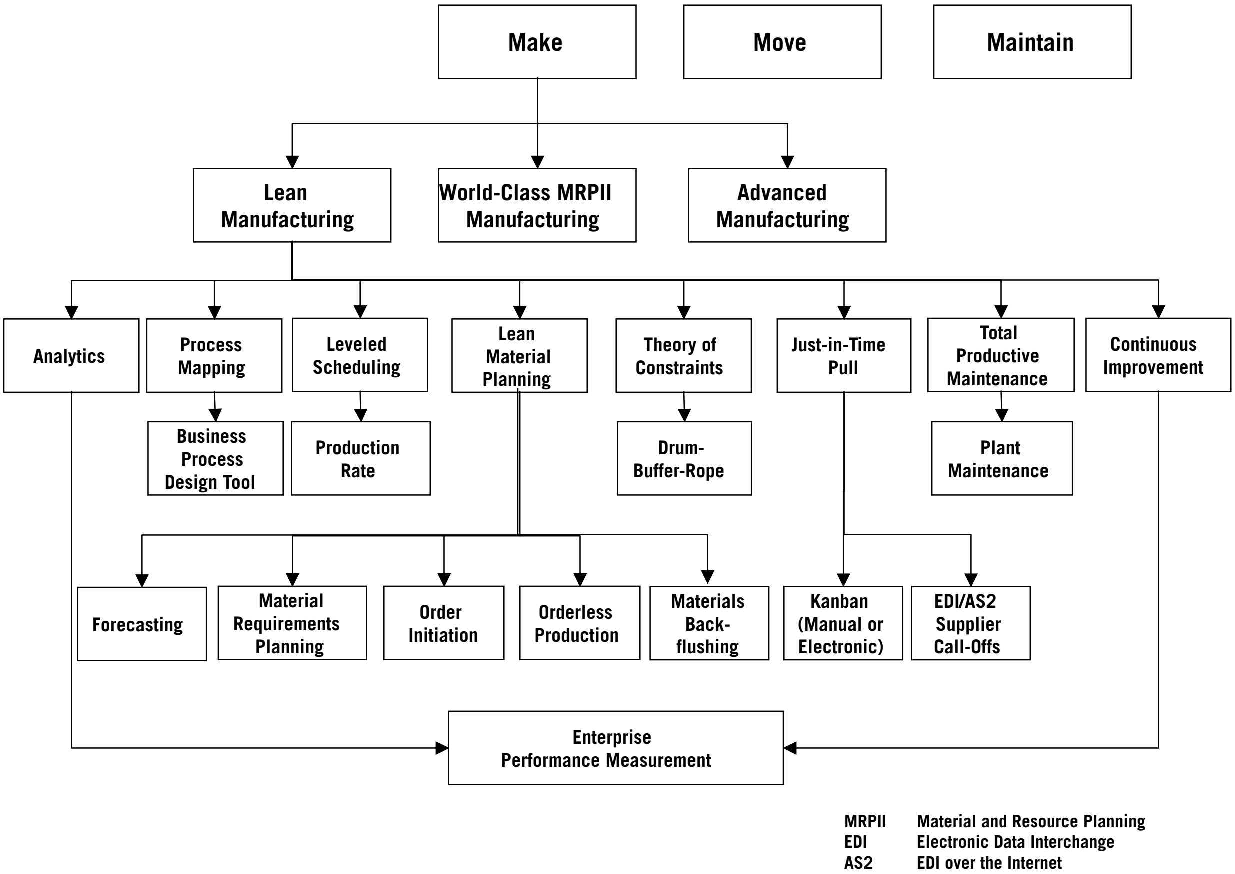

Fig. 9. Main solutions and components delivered by Lawson to support planning and control in a lean manufacturing environment.

Lawson provides solutions to support all of the five main elements of lean thinking. Figure 10 lists the five main lean elements and highlights some of the components and tools available in the Lawson M3 Enterprise Application System to support each of these elements.

Element	Lawson M3 Enterprise Application System	Comment
Value	Enterprise Performance Management	Identification of customer value
Value Stream	Business Process Design Tool	Process mapping to identify the value in the value chain
Flow	Business Process Design Tool Forecasting and Demand Planning Supply Chain Planning and Material Requirements Planning Production Rate (leveled scheduling) Global Capable-to-Promise Plant Maintenance	Process mapping to design the flow of value through manufacture Estimate demand Level demand and determine long-term capacity requirements and purchase agreements Set the takt for production Quoting of delivery date Total productive maintenance to keep material flowing
Pull	Order Initiation Kanban (manual or electronic) EDI/AS2 Supplier Call-Offs Theory of Constraints Safety Stock Planning	Initiate the pull Pull-driven JIT material movement, production or supply Pull components or materials from suppliers Maximize flow through bottlenecks resources Reorder point policies to trigger deliveries from suppliers
Perfection	Enterprise Performance Management	Measurement and analysis to support continuous improvement

Fig. 10. How some of the components in the Lawson M3 Enterprise Application System support the five main elements of lean manufacturing.

Achieving Value and Perfection

The Lawson enterprise performance management (EPM) solution enables organizations to identify where there is customer value and where they should focus their efforts. The EPM solution also supports the ongoing pursuit of perfection through continuous improvement.

The EPM solution consists of a data warehouse and around 600 predefined measurement models for tracking key performance indicators (KPIs) and trends. Others can be defined, as required. A range of popular analytical software tools can be used for analyzing the cubes extracted from the data warehouse.

Defining the Value Stream

The Lawson M3 Business Process Design Tool supports organizations in mapping out their processes to identify the value stream. This enables organizations to identify value-adding and non-value-adding activities.

Making Value Flow

Lawson has been developing its material planning knowledge over the past 20 years and offers one of the most powerful systems on the market. Lawson supports lean material planning through forecasting and purchase agreements, material requirements planning (MRP), safety stock planning, orderless production and backflushing. Leveled scheduling enables the setting of takt times, while total productive maintenance ensures the availability of equipment and avoids unplanned stoppages.

Designing the Flow

Lawson M3 Business Process Design Tool supports organizations in designing the material flow. The normal aim is to design a process that supports a single-piece flow.

Lean Material Planning

Long-Term Forecasting and Purchase Agreements Powerful forecasting tools enable long-term forecasts to be generated and used for capacity requirements planning and to design and implement supplier purchase agreements. This is a starting point in making value flow.

Material Requirements Planning

As was highlighted in the previous chapter, MRP can support a lean manufacturing approach, and MRP and JIT can coexist effectively in a lean manufacturing environment. MRP performs the forecasting, material planning, coordination and purchasing while shop floor operations use JIT control.

Orderless Production and Backflushing

Lawson M3 Enterprise Application System supports orderless production. As the name suggests, in orderless production, execution is not performed against manufacturing orders as in MRPII and advanced manufacturing. Execution is orderless with only a master schedule to work against. There is no recording of operation statuses and actual materials used until the final product is complete. Material backflushing is then used to record material usage based on standard bills of material. This significantly reduces paperwork and administration time, which is highly beneficial in fast-moving environments such as food and beverage manufacture.

While the Lawson solution never creates actual manufacturing orders in an order-less environment, it can create order proposals to simulate future kanban orders and enable planners to obtain projected capacity requirements and a schedule of projected material usage.

Leveled Scheduling

To level the master production schedule, Lawson offers a production rate solution to determine the takt. Lawson M3 Enterprise Application System looks at the total quantity that has to be planned in a planning period and breaks this down to an average daily quantity based on a set of rules. Production rate is useful where demand is relatively steady over time and there is a limited product mix. As discussed earlier, this gives production operators a far better understanding of what they have to do each day and how they are performing.

Global Capable-to-Promise

Global capable-to-promise functionality supports sales order entry in quoting delivery dates for products.

Total Productive Maintenance

The Lawson integrated plant maintenance solution supports total preventive maintenance to maximize the efficiency and availability of critical tools and equipment and avoid unplanned stoppages. When operating a lean manufacturing philosophy, it is very important to ensure that manufacturing equipment does not break down, otherwise everything quickly comes to a standstill since there is no stock buffering in the production system. Hence, effective maintenance becomes critical.

Pull-Based Production

Lawson M3 Enterprise Application System supports a JIT pull-through production via order initiation, kanban, supplier call-offs and safety stock planning for control and execution. MRP is normally still used for the planning. Lawson offers a Theory of Constraints solution where demand is volatile or there is a wide order mix with deep bills of materials, complex routings and variations in lead times.

Order Initiation

Order initiation functionality generates the demand for a product and the material flow through production is pull-based.

Kanban

When selecting an ERP system, it is important to ensure that all forms of kanban are supported in order to create the most efficient business practices possible. Lawson supports the four different kinds of kanban:

- External kanban requirements from customers;
- Internal production kanban;
- Internal transport (movement of material) kanban;
- External kanban requirements for call-offs to suppliers.

Lawson M3 Enterprise Application System supports simple, visual internal and external kanban signals. These can, for example, be an empty container, a card or a message at a workstation in a computerized system, or an EDI message from a customer or to a supplier.

Repetitive Scheduling and Supplier Call-Offs

A long-term delivery schedule provides information for material planning where kanban requirements from customers and to suppliers are performed via electronic data interchange (EDI) or AS2 messages. Incoming kanban requirements consume the long-term delivery schedule demands.

Safety Stock Planning

Lawson M3 Enterprise Application System supports manual and automatic reorder point policies for maintaining safety stock levels. These can be used with a kanban system to trigger deliveries from suppliers. The safety stock levels can be defined.

Theory of Constraints

Lawson offers a Theory of Constraints (TOC) planning and scheduling solution that supports lean manufacturing by focusing on identifying and planning the bottleneck. This solution has been continuously developed over the past 15 years to apply Goldratt's principles, and focuses on planning the bottleneck resources while flexibility is left for local decision making during execution on non-bottlenecks. The solution conforms to specifications laid down by Goldratt and provides manufacturers with a significant competitive advantage.

A TOC solution is a more appropriate lean manufacturing approach where there are complex product structures, demand variability, and/or a changing product mix in a job shop environment. In this environment, the bottleneck resource is likely to change over time. The potential benefits are impressive. For example, a global manufacturer's Danish operation achieved a 16 percent improvement in throughput within a few weeks of going live with a Lawson TOC solution.

From an implementation perspective, TOC is a much simpler project than world-class MRPII or an advanced manufacturing system. A TOC solution can be implemented in less than 50 percent of the implementation time of an advanced planning system. This is due to the lower data requirements, the fact that data quality levels are not an issue to start using the system, and that less training is required for the production planners and shop floor operators. Execution is also far simpler in TOC with shop floor staff empowered to make decisions.

Other Areas Supported

Lawson also supports removing significant levels of waste in administration by streamlining processes and reducing the volumes of data entry.

Implementing Lean Manufacturing

The majority of Lawson's manufacturing consultants have many years of industry experience and have implemented a wide variety of manufacturing solutions spanning from lean to advanced manufacturing. Lawson has many customers who use a wide variety of lean manufacturing concepts in their manufacturing environments.

Lawson believes that one solution does not always fit all (see figure 11). In pure make-to-stock environments, MRP is often the best solution. In make-to-order where demand is very volatile, routings are complex and resources are shared by different product value streams, TOC is often the best solution. Research has proven that TOC can realize significant benefits, such as inventory reductions of 50 percent, reductions in production cycle times of 66 percent and substantial increases in throughput (Balderstone and Mabin, 1998). These benefits are often realized over a short space of time. However, quick wins are only a small part of the overall benefits gained by adopting lean manufacturing. In between these extremes, a kanban solution is often most appropriate and can remove large amounts of WIP, raw material and finished goods inventories to free up working capital and dramatically shorten production cycle times. Kanban also reduces space requirements and empowers workers.

We recognize that many organizations have a range of products with different demand characteristics ranging from stable to highly volatile, and that these products might be produced on a make-to-stock, assemble-to-order or make-to-order basis. To maximize the achievable business performance improvement, it is often necessary to apply different approaches to different areas of an organization's business. Lawson calls this flexible approach "hybrid solutions."

While the journey to lean manufacturing is a continuous one with only 20–30 percent of the ultimate benefits achievable over the short term, Lawson can deliver technology to support some quick wins.

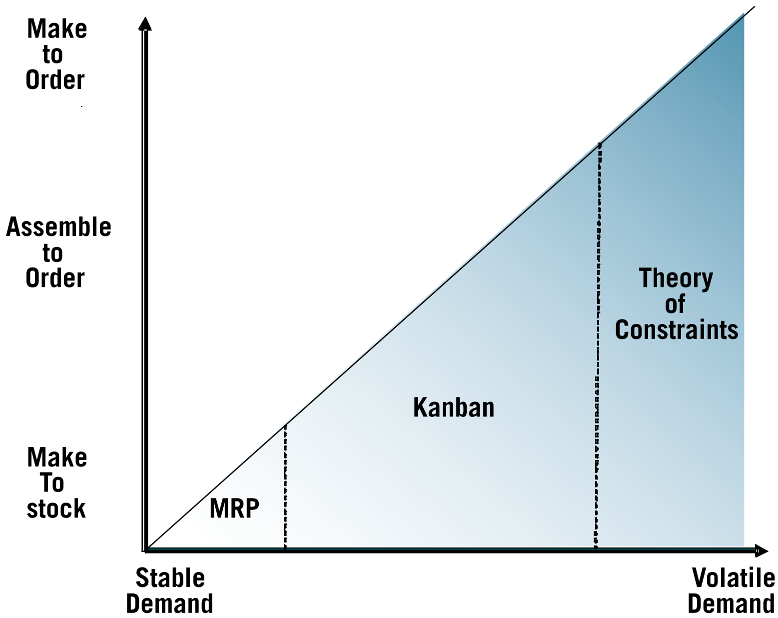

Fig. 11. Appropriateness of different planning and control systems for different manufacturing methods and demand characteristics.

Conclusions

So what can we conclude about lean manufacturing? There is nothing radically new in lean manufacturing. It has evolved over 50 years starting with the Toyota Production System and it today embodies a variety of concepts and techniques. The main aims are the focus on customer value, the planned elimination of all waste, and continuous improvement in pursuit of perfection.

These different concepts and techniques are suited to different environments. In fast-moving environments such as some manufacturing in the food industry, orderless production and material backflushing support a first step towards a lean approach. Just-in-Time kanban-based systems are best suited to discrete manufacturing and assembly environments where there are simple product structures with high parts commonality, high repeatability in the process, stable levels of demand and short production throughput times.

A Theory of Constraints-based approach is more appropriate in discrete job shop manufacturing where there is demand volatility, deep bills of materials, complex routings, variations in lead times, and a product mix that causes the bottleneck resource to change over time.

MRP still has a major role to play regarding long-term forecasting and capacity requirements planning and in defining supplier purchase agreements. This is especially true where there is significant product variety, infrequent demand for parts, and long purchasing and throughput lead times such as in the fashion, service spare parts and asset-intensive industries.

Pull-based JIT techniques are highly effective for control and execution. However, they are weak on planning. MRP is strong on planning and weak on control. Thus, there is a place for both, and these can successfully coexist when appropriate, such as where there are complex product structures and JIT alone is not enough because there is a need to MRP plan and coordinate material flow at a high level, or where there is a mix of runners, repeaters and strangers and a hybrid solution is most appropriate.

Software solutions play an important role in supporting a lean manufacturing philosophy. Lawson has been delivering lean manufacturing solutions for over 15 years. The range of components and tools supplied in Lawson M3 Enterprise Application System provide support for the five main elements of lean manufacturing.

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