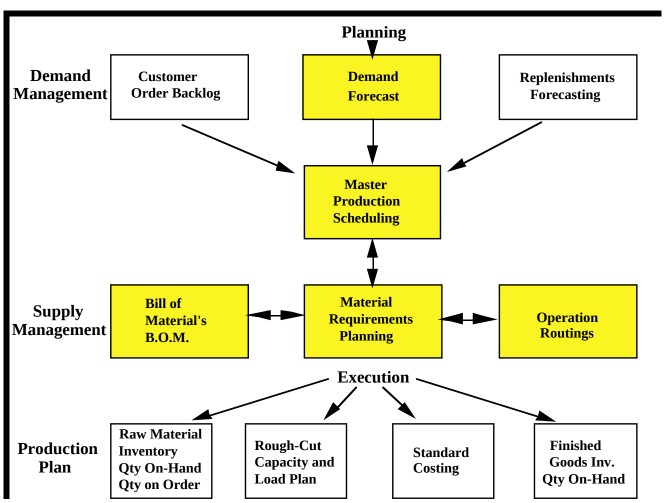
The objective of this white paper is to provide a basic road map for companies wishing to merge MRP and Lean Manufacturing methods.

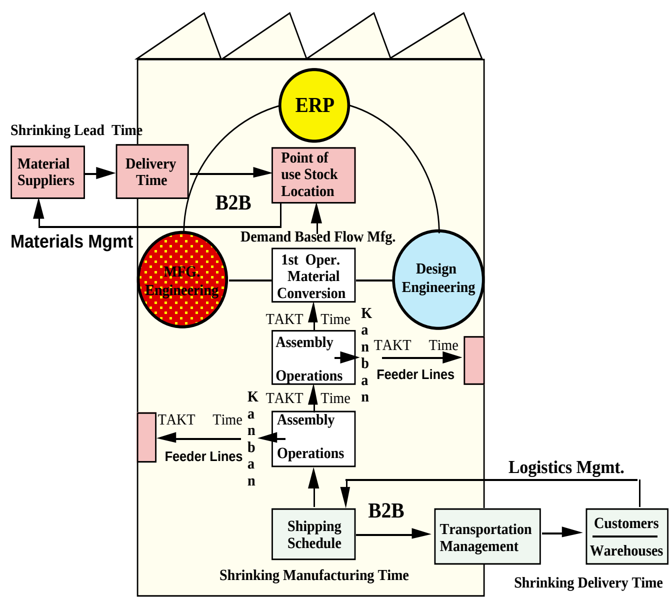
Illustration 1 ERP Planning and Control



ERP emphasizes organization, discipline, and control.

Lean emphasizes process simplification, elimination of waste, synchronization, uniform plant load, and continuous improvement.

Illustration 2 LEAN MANUFACTURING VALUE CHAIN



" In time, real competition in the global economy will boil down to which companies have the morecost-effective, flattened, and responsive Value Chains."

Introduction

For the purpose of this paper, the term ERP represents the many integrated applications found within current day Enterprise Resource Planning systems: Integrated financials, manufacturing planning, inventory management, purchasing, materials receiving, accounts payable, order processing, shipping, and accounts receivable. The term MRP represents ERP applications: master production scheduling, materials requirements planning, capacity requirements planning, and costing. We will first begin with a review of the basic functions of ERP and Lean Manufacturing, then discuss major differences in four areas: material flow, production planning, material planning, and cost accounting. Concluding with a brief overview of the new manufacturing measurements driving supply chain performance.

American manufacturing is at a crossroads. Advanced technologies, automation, philosophies such as Lean Manufacturing (Lean) and quality management (Six Sigma), along with computer integrated manufacturing (CIM) technologies have redefined the factory. A large number of American manufacturers have initiated major projects designed to re-engineer their manufacturing processes to make use of these new methods and practices. The terms used to identify this new environment are “LEAN” and “Continuous Improvement”.

Over the last 35 years, US industry has been developing technology in four “independent” areas: Enterprise Resource Planning (ERP), Computer-Aided-Design (CAD/CAM/CAE), Plant Automation (MFG. ENG), and Warehouse Automation (Logistics).

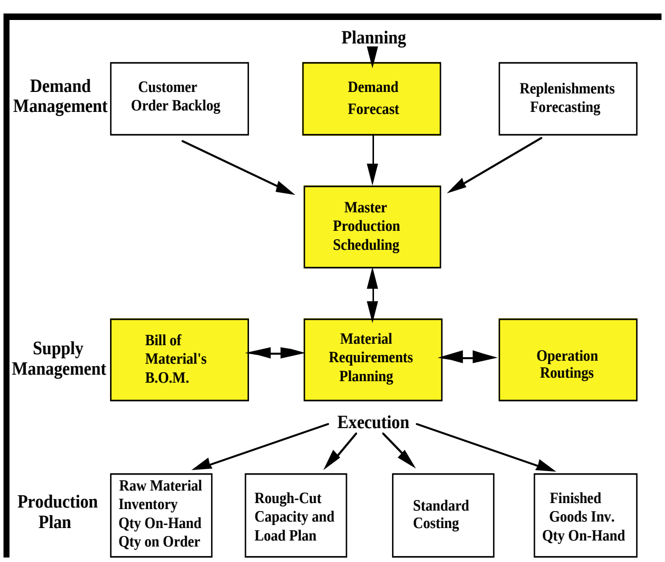
Starting later and building on many U.S. ideas, Japan, using a more “integrated” approach, developed a methodology encompassing all of these areas into a manufacturing methodology called Lean Manufacturing. Lean Manufacturing is adaptation of the highly successful, and significantly copied Toyota Production System (TPS), detailed in the national best seller “*The Machine That Changed The World*”, an MIT study of world wide production methods.

Although Lean Manufacturing is not an inventory control technique; its dramatic effect in reducing manufacturing lead times has caught the attention of many innovative people in the production engineering area. Unfortunately, the planning and scheduling techniques of traditional ERP, specifically the Material Requirements Planning Module (MRP), appeared to be in competition with the demand flow concepts of Lean production methods. ERP people, especially the technicians and promoters of this long-standing technique feel a bit threatened by Lean methods. The ERP community has failed to grasp the fact that Lean represents a manufacturing methodology within which techniques such as ERP can be enhanced.

Rethinking the way we manufacture is key to understanding Lean. This includes process simplification, elimination of waste, synchronization, uniform plant load, and continuous improvement. ERP, on the other hand emphasizes organization, discipline and control: something that should occur before, during, and after we simplify the process. If we totally focus on the control aspects of ERP alone, we can become trapped by the ERP culture, where storeroom controls and lot sizing is often emphasized over process management. ERP advocates support the elements of Lean that stress minimizing setups, quality defects, lead times, and inventory. The conflict between ERP and Lean advocates appears to center around process flow, scheduling, and reducing lead times. Lean Manufacturing methods utilize a radically different approach than traditional ERP. In Lean, lead times are dramatically reduced because of manufacturing with lot sizes approaching one, meaning we start producing products as needed, using KANBANS of pull signals received from the next higher operation. In ERP, large production "batches" are pre-planned and scheduled, using forecasts of "anticipated" demand to optimized capacity and achieve efficiency. It bears repeating that the key to understanding Lean is that it begins by rethinking the way we manufacture.

ERP functions can be shown as a matrix. We first divide the matrix horizontally into planning and execution activities; we further divide these functions vertically into demand, supply, and capacity elements. The planning elements of ERP are vital to the success of any manufacturing strategy. In fact, US efforts, dating to the late 1950's to provide computer based information support, have developed sophisticated ERP Planning functions such as: Forecasting, Order Entry, Product Configuration, Production Planning, Capacity Planning, Master Scheduling, and Standard Costing.

Illustration 1 **ERP Planning and Control** Dan Reed

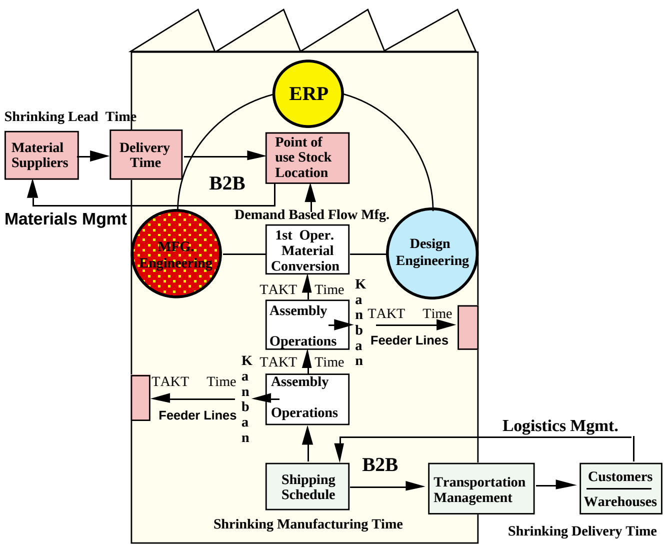


Toyota developed Lean over a fifteen-year period starting in the early 1960's. At the time, Toyota was not involved in MRP. Toyota developed its methodology virtually bypassing MRP, because they worked toward a philosophy of extending the assembly line back through all the feeder operations including the supplier network. Their goal was to put raw material in at one end, one piece at a time, and produce a car at the other end, one car at a time, with no interruption along the way. This concept was pioneered by Henry Ford in the early 1900's. The emphasis of many years of effort was to eliminate all forms of waste that would not add value to the product. As part of this program to eliminate waste, quality improvements and programs to reduce defects were instituted to ensure that parts were made right the first time. One of the essential points to get from Lean methods is that inventory itself is considered a waste of money and space, since resources have to be expended to store the material, then to retrieve it, move it, etc. Finally, response to real demand necessitated an aggressive attack on product design, tooling, and process flow, so that the lot size corresponded to actual demand, and lead times could be reduced.

In Toyota's drive to reduce waste, other aspects came along such as the need to schedule final assembly lines to avoid surging of components. This meant that instead of making trucks at the beginning of the month and sedans at the end, there was a mixed model assembly of both vehicles every day. This meant that the manufacturer of truck axles would be continuously busy as opposed to either working hard at the beginning of the month without work at the end of the month or building inventory.

As a part of Toyota's simplification process, they developed Kanban, a method that works on the principle that each feeding operation replaces what is consumed by the next succeeding operation, no more, no less. Traditional MRP need not be eliminated by this approach; it performs a capacity and commodity-planning function, but is no longer required for daily production planning, or priority scheduling. It may be an over simplification, but MRP deals with planning, while Kanban deals with operations and execution. The portion of illustration 1 showing the execution phase is drastically simplified and quite different under Lean. For a company "evolving" to Lean, the key connecting link is material requirements planning and scheduling; that is until Kanban is sufficiently advanced to allow the "pull system" concept to take over.

Illustration 2 **LEAN MANUFACTURING VALUE CHAIN** Dan Reed



" In time, real competition in the global economy will boil down to which companies have the morecost-effective, flattened, and responsive Value Chains."

Integration of MRP with Lean Methods

With the dramatic reductions in lead times, and lot sizes that a Lean manufacturing environment creates, the operation of MRP should be significantly altered as a planning tool. In practice an eventual goal would be to have the combined manufacturing lead times shorter than the customer delivery lead times. With short manufacturing lead times, it's practical to manufacture to real demand. This expands to improved "Forecasting" with suppliers, for their loads will be more accurate as the total internal manufacturing lead times are in hours and days, as opposed to weeks. As part of the evolution to Lean methods, significant modifications to MRP should be undertaken. This evolution can be viewed from four different but overlapped perspectives: material flow and tracking, production planning, material planning and control and cost accounting:

Illustration 3 **ERP TO LEAN MIGRATION STEPS** Dan Reed

- **Departmental Flow to Demand Flow.**
- **Forecast driven Master Schedule to Demand Pull.**
- **Capacity Calculations to Rate Based Schedules.**
- **Work Order Material Release to Floor on hand storage with automatic Backflush.**
- **"Planned Orders" to Pull signals.**
- **Multi-level Bills of Material to Single level Bills of Material.**
- **Routing operations to Operational Method Sheets.**

1. Material flow and tracking deals with re-engineering and layout of the factory to reduce the footage traveled, and process changes that impact on inventory staging, and transaction processing.

2. Production planning and control portion includes the Production Planning, Master Production Scheduling, Customer Order Entry and Final Assembly Scheduling.

3. Material planning and control deals with the features needed in MRP to plan Kanban controlled parts, as well as MRP controlled parts, and MIN-MAX controlled parts.

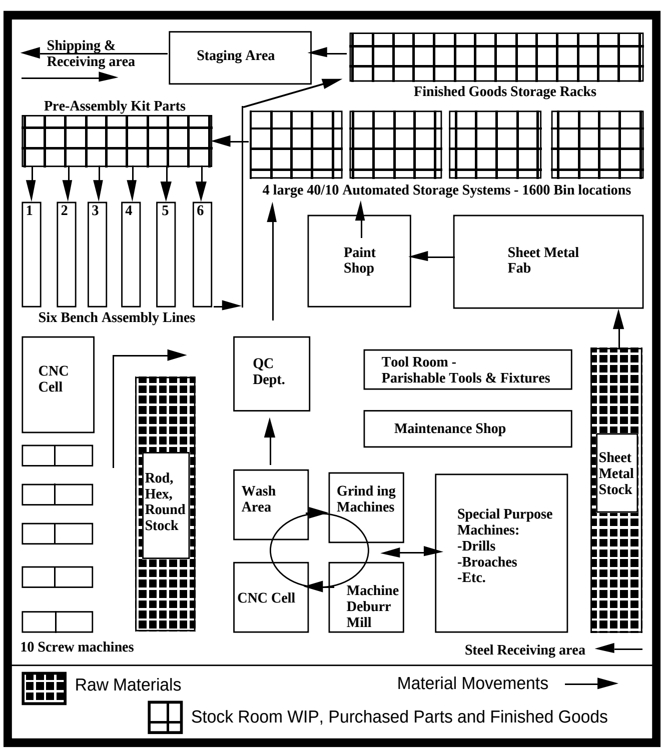
4. Cost accounting deals with management measurement versus inventory valuation.

Material Flow and Tracking

One of the fundamentals of Lean production is the concept that the flow of material through the manufacturing process is always moving, and the amount at any point in time is so small that elaborate tracking systems are both impractical and unnecessary. The reason is that with operations linked closely together in space and timing, the product is visible and factory control is simplified. Unfortunately, Lean is not implemented all at once. Thus, our first step is to highlight the migration of the material flow process.

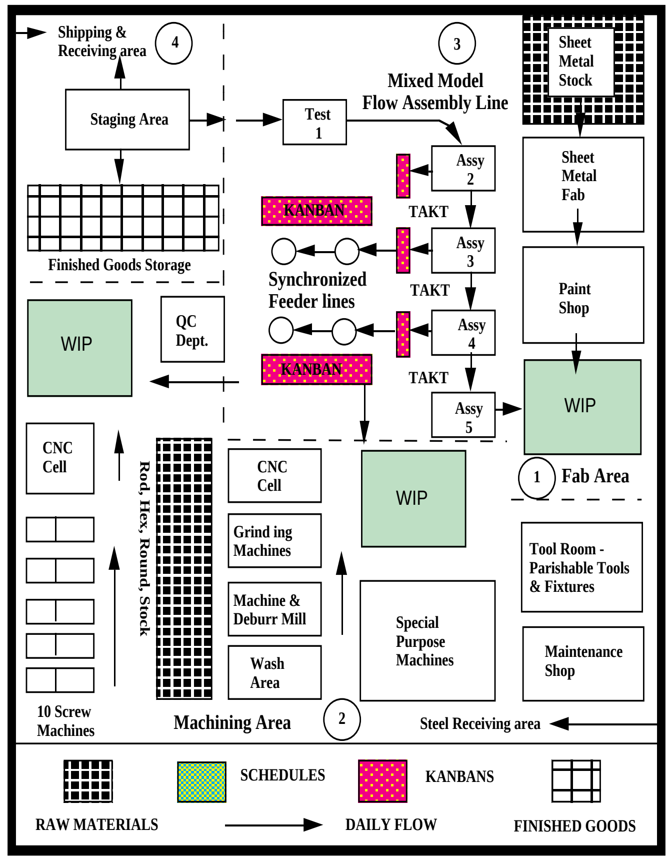
One of the most significant differences between Traditional ERP and Lean is the flow of material. In order to gain an overview of the manufacturing process flow, the first step is to develop a diagram that accurately reflects the current manufacturing flow through existing stocking locations and manufacturing areas. This diagramming is known as "Value Stream Mapping."

Illustration 4 **Plant layout - ERP Batch Material Flow** Dan Reed



The next step is to develop a concept design of how material eventually would flow, integrating both fabrication and subassembly operations into final assembly. The material flow may look like illustration 6.

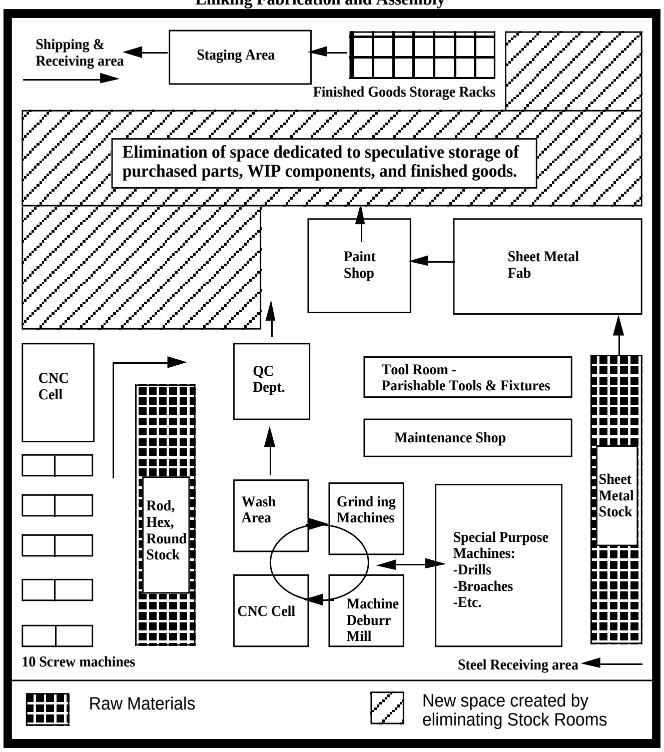
Illustration 6 **Plant Layout - Lean / Demand Flow** Dan Reed



Once the conceptual design or goal has been established, we need to recognize that Lean implementation is an evolution. Therefore, interim flows that reflect temporary stockrooms should be identified.

The first major milestone in a typical Lean implementation sequence is the linking of subassembly manufacture directly to assembly, thus eliminating the subassembly stockroom.

Illustration 5 — Plant layout - Lean Migration Path Linking Fabrication and Assembly — Dan Reed



ERP not only must be able to adapt to these process improvements; it must be able to intelligently track material within these modified material flows while the lean evolution develops.

In the ERP environment, material tracking includes the timing of when a work order is opened and material is allocated, how and when material is issued, when material is "Converted" and committed to the next level, and finally, when a work order is closed. This is called a "push" environment where detailed schedules and pick lists "Push" material into the manufacturing process. Using work orders to batch material is very complicated, requiring an elaborate material tracking approach and many transactions to record quantity needed, when needed, and where needed in the process. In order to reduce complexity and transaction volume, the process of transacting individual material issues to a work order has been replaced by "backflushing." Backflushing is the process where component material is consumed upon completion of a job. However, with manufacturing throughput times lasting weeks or more, inventory records do not reflect material consumed until the job completes. Without highly accurate work-in-process tracking, MRP can loose visibility of Work In Process, resulting in lost time to purchase replenishment materials.

A more preferable approach to material tracking is to use floor-on-hand inventory located at each operation, and backflushing consumed material at "intermediate operation" count points. These floor-on-Hand balances represent the quantity of a component on the floor regardless of whether this component is now part of a subassembly. This means that job orders and/or schedules are not recognized in the MRP netting process, only the floor on hand balances of components and assemblies. This technique is a valuable interim step in evolving to Lean. While still using MRP, this method establishes the foundation for introducing Kanban and "Rate Based Scheduling."

In a Lean environment material is "pulled" using a process called Kanban. Theoretically, material tracking in Kanban is not required, as the "Pull" card, or container is the only authorization for material to be moved. However, in order to evolve to Kanban, a plan must be developed to migrate from a work order environment to a rate flow environment. However, material tracking is a valuable "audit assist" in highlighting potential imbalances and bill of material problems. In either case, the quantity of transactions is significantly reduced.

The MRP system must also recognize whether the particular process is in a "work order" environment or a "rate based" environment, as different "MRP netting logic" may be used. Changes have to be made in the netting logic. A work-order system determines the net requirements by subtracting quantities on hand and on order from the gross requirements. The Kanban net requirements would be computed by subtracting the on hand and the in process quantities from gross requirements. Logic changes include minor changes to the netting logic, handling lead times of zero, and using multiples of fixed lot size rule.

As the manufacturing process evolves to Kanban, where operations are synchronized, a shift to a "pull" environment occurs where the "using" operation "pulls" material from a feeding operation to make more items. This simpler "pull" environment does not require work orders, schedules, priority lists, or pick lists, as the authority to make parts is generated from the "consumer" of those parts with its "pull" card!

The key difference between ERP and Lean is in the delivery of material to the next higher operation. In ERP, pick or kit lists are the usual method of getting and delivering material to the floor. Quite often this material is "pushed" to a staging area whether or not material is required since the schedule instructs that the items be picked. In Kanban, material is not "delivered." In practice, the using operation goes and gets material from the supplying operation. This "pull" then becomes the authorization for the supplying cell to make a predefined quantity of the same item just pulled. It should be noted that in a job shop environment where the same item is rarely repeated the pull signal becomes the authorization to commence manufacture of the next predetermined block of work (usually 2-4 standard hour's worth)

Production Planning and Control

Effective "front end" planning is key to the success of either an ERP or Lean environment. The production plan determines what is to be purchased and what is to be manufactured. While front end planning is necessary in both ERP and Lean, it is important to discuss the major differences between the two approaches. In this section we will discuss production planning using traditional ERP: Master Production Schedule, MRP, and Lean production planning using: Kanban, and Final Assembly Schedule.

Both MRP and Kanban have the same starting point in the manufacturing planning process, a workable Production Plan. In an MRP environment, a production planning process balances the market forecast along with the customer order backlog, and/or the finished goods inventory replenishments, to achieve a production plan. In a Kanban environment, the production planning process is synchronized to actual customer demand and daily shipping schedules.

The production plan in ERP is the output from Customer Orders, Forecasts, and Replenishments" loaded into the Master Production Schedule and MRP as shown in illustration 1. The role of the Master Production Schedule in ERP serves two functions: first to check for availability of materials, and second, to check for load. The execution functions: plant scheduling, production capacity, purchase order scheduling, and vendor management are secondary, as MRP is primarily concerned with Demand and Supply. Two major characteristics of MRP planning are forecasting requirements, and planning at the finished good " End Item level." Forecasting is the business function that attempts to estimate future demand, so products can be manufactured in appropriate quantities in advance. Production planning in traditional MRP requires three separate but linked applications (MPS, MRP, and CRP).

The master production schedule (MPS) is not a sales forecast that represents a statement of demand. The master production schedule represents what the company plans to produce, expressed in specific configurations, quantities, and dates. The material requirements planning module (MRP) contains all logic rules needed to match configurations, quantities, and dates to specific materials availability, and project potential shortages. The capacity requirements planning contains all logic rules needed to match process routings, theoretic machine loads, and dates to determine available resources, and capacity. The master production schedule must take into account the forecast, the production plan, and other important considerations such as backlog, availability of material, availability of capacity, etc.

The goal of a master production schedule is to balance the Demand and Supply side of production. The Master Production Schedule in ERP serves two functions: On the Supply side, to check for the availability of materials and products. On the Capacity side, to check for the availability of resources and capacity.

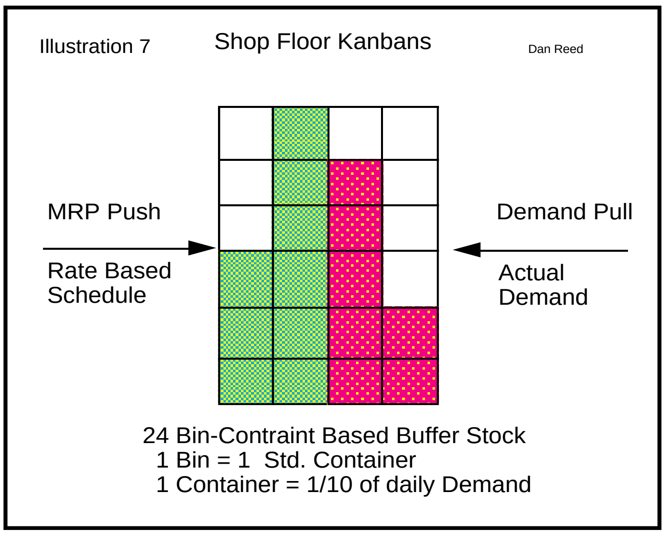
In LEAN, which utilizes JIT, the production plan becomes the input to both the detailed Kanban planning functions, as well as the limits for Final Assembly Scheduling (FAS) as shown in illustration 6. The purpose of the Production Plan is to develop the Uniform Plant Load or "focused factory", using a combined Bill of Resource and Bill of Material (BOR/BOM). The calculations are nothing more than determining the frequency in time that the production comes off a given operation, cell, or line. At the operation and cell levels this is expressed as "Takt time." At the line and process level this is expressed as "Cycle time." Cycle time along with demand rate and lead-time becomes the basis for the required Kanban calculations such as cell manning, supplier demand rates, or capacity required.

The final assembly schedule (FAS) portion in Lean effectively replaces the master production scheduling process in ERP. In a Lean environment, the final assembly schedule is primarily to check for load by ensuring that customer orders or finished goods replenishment orders meet but not exceed the production plan from the "planning" perspective as well as to sequence the final assembly schedule. The "availability" issue which balances supply schedules and on-hand balances against demand is secondary, for the Lean goal is to manufacture all products to the customer order as needed. The emphasis then is on planning and execution as opposed to demand and supply, since we plan components in families for capacity purposes and execute with end product numbers. This effectively eliminates the need to develop "planned" supply orders as in ERP environments. Also, if purchase lead times are short enough, then suppliers can deliver material to "pull" signals without the use of "planned purchase orders." In a pure Lean environment, we only need a production plan at the component level (level-1), if we call the end product (level-0) and final assembly schedule of customer orders (Level-0).

ERP and Lean Interface

A dual environment occurs when manufacturing processes are partially managed by ERP and partially converted to Lean. This frequently occurs when the plant floor is organized around flow methods, while operations, Information systems, etc. are using ERP software. Therefore, before we achieve our Lean environment, we most likely will operate a mixed environment, using two methods of tracking material, MRP, and Kanban.

First it is important to recognize that material flow will be mixed. Some portions of the operations will be on a "push" environment while others will be on a pull environment. Illustration 5, discussed earlier in material tracking, is an example of how this might operate. With this mixed environment, the MRP planning mode must be synchronized with the Kanban execution mode. Illustration 7 highlights



the merging of the key elements of MRP Planning with Kanban execution. The key point is that the MRP part master record must be able to identify weather a part is Kanban controlled or MRP controlled. For MRP parts, a second breakdown then determines which are Master Schedule controlled and which are MRP controlled. Because all Kanban parts are effectively an extension of the assembly line, Kanban parts are identified in the bill of material as phantoms for planning purposes. Independent demand parts, such as spares, can end up as either MRP parts or Kanban parts, if set up in their own focused lines.

In a mixed ERP and Lean environment, many different front-end planning and control approaches may be utilized. Illustration 8 summarizes some of these additional alternatives.

Illustration 8	FRONT END PLANNING AND CONTROL	
JIT- Focused Final Assembly lines	• Production Plan • Final Asembly Schedule • No Master Schedule	Level 1 (Family Level) Level-0 (End Products)
Flow - Feeder Assembly Lines	• Production Plan • Family Master Schedule • Final Assembly	Level 1 (Family Level) Level 1 (Major Sub-Assemblies) Level 0 (End Product)

In order to get better perspective on the planning process; it is first necessary to discuss what is necessary for pure lean planning and control and then progress to a mixed environment where both MRP and Kanban are involved.

Material Planning and Control

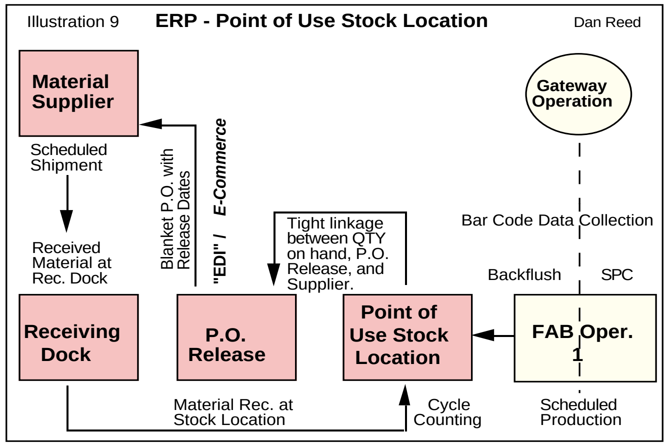
The third major area affecting ERP in a Lean environment is material planning. In a pure sense, material planning in Lean is done from the pull signals as actual lead times are reduced. The only planning needed is for resources and commodity availability. In MRP material planning is done with planned orders so that dependent demand on components can be developed through the bill of material explosion process. The critical issue becomes the process of moving from planned orders to pull signals while still satisfying the existing materials systems function.

The traditional ERP work order approach described in Illustration 1, using requirements to force shortages, is well understood. However, for clarity it makes use of the following logic: customer orders "independent demand" along with planned orders "dependent demand" are the primary inputs to the planning process, sometimes called "order release." Released orders combine to make up the Master Production Schedule (MPS). MPS data is then loaded into material requirements planning (MRP). The MRP logic performs an explosion process to force visibility into shortages of material and capacity. This explosion process consists of: exploding released orders at the finished product "end item level" against each end item bill of material and operation routing to generate gross requirements. Gross requirements are then "netted" against MRP logic rules (on-hand, on-order, Pegged, scrap allowances, lead times, lot sizing rules, etc.) to determine "net requirements." The resulting net requirements produce an exception report "to do list"! The last step involves human interpretation and reaction to exceptions. Theoretically this process is repeated until a "workable production plan" is achieved.

Material planning in Lean is based on "Actual Demand" driven by "uniform scheduling." Uniform scheduling separates the planning function from the authorization to execute the plan. Traditionally, a schedule has been an authorization to initiate action. However, uniform scheduling concentrates only on assembling the necessary resources to meet production. The act of production is delayed until the last possible moment to allow for last minute changes. The final assembly schedule and the "Pull System" initiate execution authorization.

For many ERP purchasing systems, planned purchase orders and released open orders are tracked on an order-by-order basis. Lean purchasing has the need to plan on a "commodity basis" for capacity and rate purposes only. The execution again will be handled by the pull system. Additionally, Lean-purchasing systems must have the capability of planning "commodity demand" for capacity purposes.

Illustration 9 summarizes this ERP to Lean material planning and purchasing, using point of use stocking locations.



When an ERP system plans for a weekly schedule the corresponding requirements may be a week's worth of material. In Lean, material is fed to the line in daily or more frequent intervals. In the mixed world of ERP and Lean, pegged dependent requirement records in MRP need to recognize a "short interval release" for delivery, along with the normal "required" and "issued" quantities that already exist in a "push" approach. In this small lot MRP approach, it is necessary on the released parent assembly schedule, to show the expected daily rate along with the lot size or schedule quantity planned for longer running times over one day. Experience has shown, a less complex approach is to position materials on the floor as close to the using operation as possible.

ERP Planning and Lean Execution.

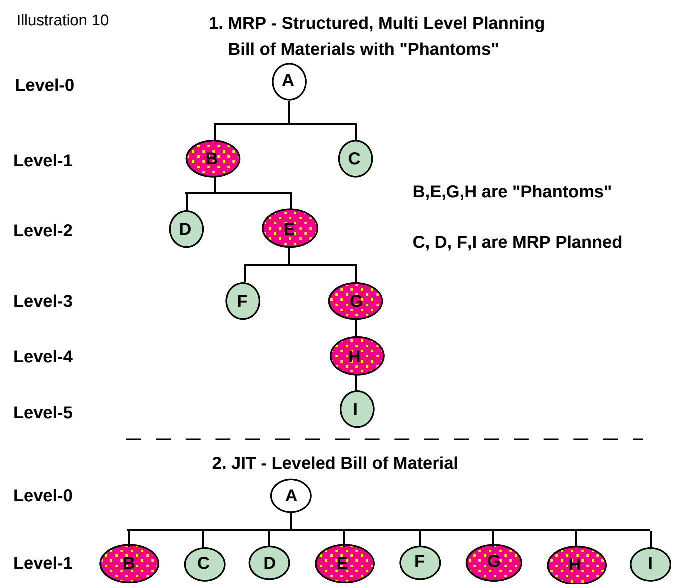
In order to migrate from traditional ERP to Lean, a method must exist that eliminates the need for planned orders. The first step is to enhance the MRP system to recognize schedules instead of using work orders. This approach mirrors the Repetitive MRP method, while beginning the process of rate based scheduling. Migrating from MRP work order planning methods to using schedules dramatically simplifies material planning by eliminating "Planned Orders." However, migrating from work orders to schedules is an evolution requiring significant modifications to work order based MRP. Material Planning without planned orders requires enhancements to the following ERP data files: item master, bill of material, material requirements planning, and purchasing.

The ERP item master file needs to be enhanced in two ways. The first enhancement needs to recognize and account for materials and components that are manufactured and stored on the factory floor. This requires item master records be maintained on the in-process inventories, as well as raw materials and stores. The second enhancement requires the item master file to identify, and account for, MRP, and Kanban controlled parts. This requires a change from storing and issuing materials and parts from stock rooms, to Materials and parts being stored and consumed at appropriate production "inbound stock points".

The bill of material (BOM) system is similar in both ERP and Lean. However, the two systems differ significantly in how they utilize the bill of material. In traditional ERP the BOM tends to have a multi level structure. This structure is excellent for developing and maintaining accurate bills of material and standard costs. Using this structured approach, the master scheduler plans at the finished good "end item level," utilizing planned orders. Under Lean, the bill of material tends to have a flattened structure. When using this approach the master scheduler plans at the "component level" without planned orders. To achieve this, the MRP system must provide for planning bills of material, phantoms, and backflushing from mid point operations.

Lean manufacturing requires a less complicated bill of material because Lean cells eliminate several levels of subassembly. When manufacturing in discrete lot sizes, the items are produced to work orders and stocked. If Item A in illustration 10 is produced in a Lean cell, then parts D, F, I and C would be supplied to appropriate production points of the cell. Since parts B, E, G, and H are not stocked in a stock room, but on the Lean line itself, they need not be utilized in the MRP explosion process. This requires a Planning BOM where items B, E, G and H are defined as "Phantoms". This application of Phantoms allows the MRP explosion to "blow through" parts B, E, G and H. As a result, the multi level MRP bill can be flattened to a single level bill.

Illustration 10



The material requirements planning (MRP) system in Lean is similar to MRP in batch manufacturing, except that requirements are generated for purchase parts only. With the demand flow system implemented on the production floor, work orders are no longer required. The primary function of the MRP system in Lean is to provide the purchasing department with visibility of the purchased parts required to support replenishments of raw materials. For the MRP module to plan requirements, three functions have to be modified: Order Release, Netting logic and pegging.

Order Release. Unlike the work center in an ERP environment, a Lean cell is triggered by pull signals generated by the production Line or other cells it feeds. This requires disabling the ERP order release function.

Netting logic. Changes also have to be made in the MRP netting logic. A work order based system determines net requirements by subtracting quantities on hand, and on order, from the gross requirements. Net requirements for a Kanban item would be computed by subtracting the actual on hand "available" quantities from the gross requirements. Also, Kanban items are generally moved in small lot quantities, typically in standard-size containers. Therefore, the planned flow quantity should be a multiple of the standard container quantity. This requires modifying MRP lot sizing to use a "multiple" of lot sizing rules.

Pegging. In a traditional MRP system, a pegging function is available that allows the planner to evaluate competing finished good items and allocate based on the highest priority item. In Lean, end item planning is not required because actual demand determines the required parts using pull signals. In Lean, a part is required when the pull signal appears. This requires modifying MRP by eliminating material allocations "pegging."

Purchasing. The traditional ERP approach to purchasing is based on three concepts: Planning of on-hand material stocks is driven by a need to eliminate material shortages. Stocking enough on hand materials to meet production requirements. Buying in large lot quantities in order to reduce material costs. Under Lean, the purchasing function changes significantly. As a manufacturer migrates toward Just in Time (JIT) supply, JIT-capable suppliers have to be identified by purchasing. This requires a major change in the traditional relationships between buyers and suppliers. There are different measurements for JIT and MRP systems; for example, in a traditional MRP system, an early delivery of materials may be considered on time, but in JIT, on-time delivery occurs only if delivery is exactly on time. Quality measurements are also different using ERP systems, where a defect rate of 4% may be acceptable. Under JIT, defect rates are measured in defects per million. Once vendors are qualified as JIT suppliers, their materials will seldom be stocked in a receiving area or a raw material stock room. Orders for each delivery are generated by pull signals similar to the Kanban's on the shop floor. Much of this supplier activity is currently being done using EDI, and is rapidly evolving to Internet business to business e-commerce.

MRP Migration to Lean.

For MRP migration toward Lean, a means must be developed that eliminates the need for planned orders. The first step is to enhance the MRP system to recognize schedules instead of using job orders. When a schedule approach is used, the MRP planning process nets against floor-on hand balances at specific gateway operations. When an item "crosses" a gateway operation, it adds to the on-hand work in process quantity at the higher level, and reduces the on-hand material quantity of the lower level. This allows for planning without using planned orders, yet still retains the MRP planning environment with a net requirements explosion.

Next, the material planning portion of MRP needs to be altered to highlight capacity or resource issues for

Kanban-Controlled parts. The reason is that intermediate levels are not stocked, and material planning under Kanban is done at execution time with pull signals. Since Capacity Requirements Planning (CRP) is not required for Lean, the other need for planned orders is eliminated.

Move from " End Item" Part numbers to Commodity groups. The MRP system in Lean can be used to plan for cell manning, pull card volumes, and standard cost calculations. This requires a gross explosion capability not only by part number but also by supplier commodity group or manufacturing cell. For those parts not managed by Lean, this gross explosion can be used as a side benefit for estimating usage on Min-Max, reorder point parts to compare with historical usage.

As discussed previously, material planning by part number through the use of planned orders does not occur in Lean. The order release function of MRP is eliminated as an execution function. In Lean, work is both authorized and prioritized by use of the "pull System." In those situations where the manufacture of a product is not repetitive, then the "pull" signal is an authorization "when" to manufacture product, and the gross explosion of the final assembly schedule determines "what" is to be manufactured or delivered by a supplier in sequence to the final assembly schedule.

Cost Accounting

In ERP systems, material, labor, and overhead cost data is collected and calculated using work orders. This data is then used to set standard costs, value inventories, and calculate labor and material variances. Traditional ERP systems generally apply overhead as a percentage of direct labor. These traditional cost calculation methods are not capable of, are not focused on, and do not monitor actual production costs. In fact, the cost measures we find in ERP systems conflict with Lean manufacturing in the following ways: Machine utilization that encourages keeping machines busy to absorb more overhead, building excess inventory. Purchase policies that encourage excess inventory, increased carrying costs, and a loss of focus on quality, delivery, and service. Earned hours, where supervisors depart from planned schedules to maximize production output.

Lean cost accounting is significantly different from ERP standard cost calculations. Lean costing is closer to process accounting. In Lean, there are no work orders, and direct labor is not tracked discretely. This is because the percentage of total product cost that can be attributed to direct labor is relatively small; so labor variance reports have little meaning. In Lean there is no job costing, only a period costing of material, and all variable costs of labor and overhead. These period costs are then divided by units produced, yielding a cost per unit. The term most associated with this costing method is activity based costing (ABC).

Activity-Based Costing

The underlying principle of activity-based costing is that activities consume resources, and products consume activities. As Illustration 11 describes, the labor costs of supporting departments can be traced to activities by assessing the portion of each person's time spent on each activity, which can allow for restatement of departmental cost in terms of customer activities, and their associated costs.

Illustration 11

Activity-based accounting unbundles the traditional cost view by responsibility center, and restates costs according to the way resources are consumed.

Standard Cost View	Activity-Based View
Material Handling	Material Handling
Materials @ Std. $ 50,000. Labor @ Std. 15,000. Overhead @ 2.3 * Labor 35,000. ----------	Materials @ Std. $ 50,000. Labor: Direct 10,000. Handling 5,000. Overhead: Actual Overhead 20,000. Handling 15,000. -----------
Total $ 100,000.	Total $ 100,000.
WHAT IS SPENT	HOW IT'S SPENT

Activity costs then are traced to specific products based on the amount of volume each product consumes. The overall impact is to produce more accurate product costs. Rather than a tool for cost reduction, activity-based accounting provides a tool for more effective product costing and profitability analysis. ABC costing includes the following:

• Use of a Frozen Standard Cost. This standard cost is calculated at the beginning of each year, frozen, and used for inventory valuation purposes throughout the year.

• Use of Current Standard Cost Calculations - Period Costs. Actual materials, labor, and variable overhead costs are based on consumed materials and direct labor. Variable overhead is based on criteria other than direct labor, e.g. cost drivers. Therefore the "actual standard" calculated at the beginning of the month would be determined from the standard material cost plus all variable costs of direct labor and overhead. Variable costs would include material handling, inspection, maintenance and most any other labor related activity.

• Fixed Overhead. The remaining fixed costs would most likely be charged based upon the expected monthly production plan. Even depreciation, which should convert from a period approach to depreciation per piece produced, can be variable. The intent is to have rent and other related items as the only fixed costs. Fixed costs would be Applied Based on Execution of the Production Plan.

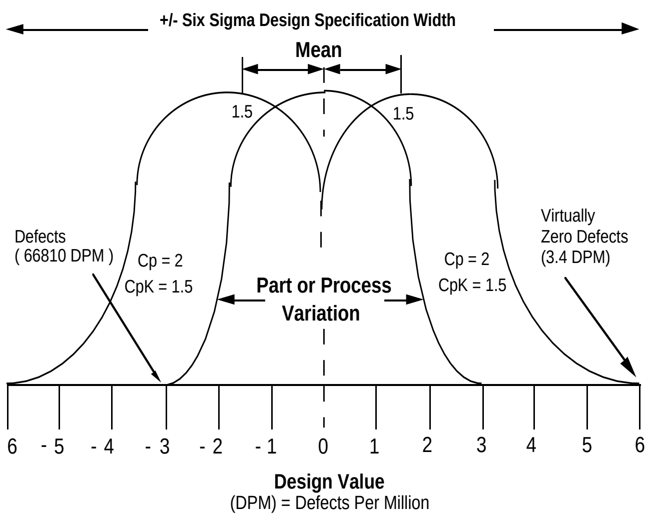
The Bill of Material, Routing, and Resource File can be expected to include these cost factors. The Production Plan and Resource requirements are already part of the ERP system. Thus, all the necessary data required to develop variable standard costs are resident in the modified ERP database.

Performance Measurements

Under Lean, many existing ERP measures become inappropriate. This is primarily due to ERP over reliance on financial measures. New manufacturing measurements have evolved that are more aligned to implementing and achieving "World Class Manufacturing Status." These new manufacturing measurements can be grouped into the following best in class practices: quality, supplier lead-time, cycle time, and schedule attainment.

Quality is the most important because it measures three major elements: Product, Process, and management. "If you can't produce consistent quality, your entire operation is suspect". Quality is measured using statistical process control (SPC) methods, which utilize control charts to observe abnormal values, investigate probable cause, and initiate alarms for corrective action. Building on data captured in SPC, Process Capability (Cp), plots the range of normal process variation, measured to plus or minus "*Six Sigma"* for a given part characteristic. It is generally used to track variable data such as length, height, temperature, etc. A process is targeted to operate at a value called nominal value, which may be the mid-point of the specification or design tolerance. The objective of using SPC, process capability, and six sigma, is to radically reduce defects to less than 5 defective parts per million .

Illustration 12 **Process Capability at Six Sigma**



Outstanding process control and manufacturing results will come from these three steps: 1) applying SPC to measure and adhere pre-defined parts characteristics. 2.) Utilizing 100% monitoring where process drift occurs. 3.) Utilizing 100% monitoring at each critical process conversion point. While this method of achieving "World Class Quality" is still being debated, the object of reducing defective parts per million is a major element to achieving World Class Status.

Supplier lead-time improvement is a major step in evolving to Lean. Performance measures that need to be implemented include lead times from supplier to your production facility, and lead times of delivering materials to the point of production. The objective of these measurements would be balancing the rate of consumption with the rate of replenishment. This balancing process is not achieved overnight. To achieve the goal requires measuring each step within the material delivery to production process.

Cycle time can be expressed in two different measurements: Takt time and Cycle time. Takt is the German word for the baton that an orchestra conductor waves at musicians, to regulate the speed at which they play. Takt time is a calculated value. Takt time is the speed at which parts must be manufactured to satisfy demand. The second time measurement is "cycle time." Cycle time is a measured value. In other words, you must go out to the plant floor, and measure the time it actually takes to manufacture the product.

Schedule attainment is the measure of how many units were produced as a percentage of the plan is a traditional measurement. However, Linearity to a schedule measures how well we perform to each day's schedule completion on an absolute basis. This applies to model mix not just the total schedule. For example, a schedule of 100 units per day could yield the following results:
Even though the actual production met the schedule, the linearity was only 80% as there was an average of a 20%

Illustration 13 **SCHEDULE ATTAINMENT - LINEARITY**

DAY	PROD MIX	SCHEDULE	ACTUAL	VARIANCE
1	A	100	80	- 20
2	B	100	90	- 10
3	C	100	130	+ 30
		-----	-----	----
TOTAL		300	300	
DAILY AVERAGE		100%	100%	

DAILY PRODUCT MIX VARIANCE = 20%

swing each day. In a Lean environment, the 130 production on day three could not be produced unless the feeder operations were on a push environment and the extra 30 parts were in the pipeline.

The ability to respond quickly to customer demand, while maintaining a minimum of inventory, is key to remaining competitive in today's customer responsive manufacturing environment. In order to achieve excellent customer service with quick response, while maintaining low inventories, each step through out the entire supply chain must be synchronized and balanced to actual customer demand. In order to accomplish this goal we need to make use of all the tools available. To succeed, we need a mixture of modified ERP, and state of the art Lean Manufacturing.

ABOUT THE AUTHOR:

Dan Reed is a manufacturing technology specialist with over twenty years of manufacturing software experience. Dan has worked for a number of major technology suppliers: XEROX, GE, SDRC, ROCKWELL-ALLEN BRADLEY, AMERICAN SOFTWARE, as an MRP II consultant, a Computer-Aided Engineering Specialist, and Area Manager for Industrial Computer and Cell Control products. Dan's experience involves application of Computers, Computer Software, and Process Controls to improve Product Design, Production Management, and Process Capability. Experiences include assisting manufacturing managers with solving productivity problems using software technology.

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