Tools & Methods for Lean Production Management in EA

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Abstract
Lean manufacturing is far from a new concept, and many within the Electronics Assembly (EA) industry are already familiar with the principles and concepts behind it. However, in spite of widespread understanding, the percentage that actually "Live Lean" within EA tends to be far less.

If "Lean" offers such a compelling business advantage, one must critically ask why it has not yet been adopted widely and successfully to date in the "Leading Edge" EA industry? Fortunately today, several technologies and tools available to the EA industry offer new possibilities to realize a major impact as never before.

The intention of this conference paper is to examine some of the new developments in Lean Production Management in EA. Included is a brief look into Lean Production Management concepts such as the coordinating the "Value Stream" supplying products according to customer demand. Lean Production Management can be viewed as "real-time execution-based scheduling" and can keep the factory activity in perfect synchronization with minimum effort.

For high-mix EA operations this paper will also introduce "capacity-driven" beside the "inventory-driven" methods whereby supplying processes are triggered to produce the next item needed when capacity becomes available in downstream processes.

An important consideration of Lean Production Management is effective control of material levels and WIP (Work In Process). Using various methods for tracking and control provides the ability to highlight "Hidden" problems, and with visibility – further enables one in continuous improvement of the production system.

This paper considers tools and technologies available to assist in institutionalizing Lean Production Management. A discussion of a case study is included.

The Typical State of Today's Electronics Assembly (EA) Industry

Lean manufacturing is far from new, and many within the Electronics Assembly (EA) industry are already familiar with the principles and concepts behind it. Several of the elements within the Toyota Production System (TPS) such as JIT (Just In Time) and ***KANBAN*** are well known and have been in use for some years.

The difficulties with implementing only a few of the elements of TPS, is that only partial benefits may be realized, and are often not sustainable. It is important to understand the underlying principles as well as the complete Toyota Production System.

One could suggest that while individual elements of TPS existed before, it was not until they were combined with a specific focus that they had such a huge impact.

"Yes, we know Lean" is not an unusual response from the EA industry. Many electronics manufacturing operations may already have a "Lean" program in place inspired by the TPS principles. Automotive Electronics operations are more often amongst the leaders in actual practice of Lean Production Management. As suppliers to Toyota, stable and predictable supply chains, including from vendors, is in the best interest of the business. Many Contract Manufacturers (CM) also have "Lean Initiatives" in place due to the highly competitive and margin sensitive nature of this business.

While many profess to "Know Lean", the percentage that actually "Live Lean" within EA tends to be less.

If "Lean" offers such a compelling business advantage, one must critically ask why it has not yet been adopted widely and successfully to date in the "Leading Edge" EA industry?

Fortunately today, several technologies and tools now available to the EA industry offer new possibilities to realize a major impact as never before, coupled with the foundation of TPS methodology.

This paper examines some of the challenges affecting acceptance and success of Lean Production Management within EA. Also considered are recent developments in IT technologies coupled with Lean Production Management principles that now offer the possibility to institutionalize major benefits of lean manufacturing within the EA industry.

“Common Myths Surrounding Lean Manufacturing”

Myth No. 1: Lean systems don’t require IT

While some Lean “Purists” may reject Manufacturing IT as unnecessary and overly complex systems, one only needs to look at Toyota. IT systems are as much a part of the corporate DNA at Toyota, as is the culture of the TPS. Significant investments in IT at Toyota bring strategic and possibly unattainable advantages that would not be possible with any other approach.

As an example one only need look at – the Toyota ALCS (Assembly Line Control System) that is responsible to coordinate that resources and materials required arrive successfully sequenced to the proper location and time during **execution** of the assembly process.

Imagine yearly production of approximately 9 million automobiles, without a method to accurately transmit demand throughout the supply chain. With manual *KANBAN* errors and costs simply due to lost and missing cards alone would be staggering. Production line downtime due to missing materials could be crippling. **Scalability** is the key.

Real Time Monitoring, Process Control **(***Jidoka***)** and Visual Controls **(***Andons***)** have always been central principles of TPS. With takt times often under a minute in the production facilities, **timely notification**, and **correct resolution** are a key to maintaining dependable production processes. **Coordination** of various departments **across a complex organization** to ensure performance of the necessary tasks at the right time is the key.

IT technologies are used effectively to remove the walls between the departments.
Furthermore– Toyota has made huge investments into tools that allow its dealer network to make certain readily accommodated “In-Process” changes to automobiles already in the production pipeline.

Clearly IT in manufacturing is here to stay, and brings distinct capabilities not possible before.

Myth No. 2: Lean Systems are not suited for Build to Order or low volume/high mix environment

Traditional thinking suggests production well suited to the principles of TPS should be Low-Mix, with similar characteristics, be of a repetitive nature, and with a predictable demand. Changeover often may not be required at all, or can be accomplished very rapidly, with the use of such practices as family setups.

In these operations flow production fits easily, and dedicated resources are relatively simple to justify. The product families and corresponding “Value Streams” tend to be very similar. Lean Production Management is readily applied to such environments, and the benefits are usually easy to visualize. *KANBAN* systems work very well in this environment where a minimum of inventory of each part must be maintained at each workstation. Consumption by a downstream workstation, this immediately signals the upstream workstation to begin work to replenish the part. In a pure *KANBAN* system, there is a *KANBAN* loop for every part, with one or more *KANBAN* cards.

However in today’s demand-driven markets, ‘low mix’ is becoming the exception rather than the norm at many EA operations. As a result the EA sector is facing several critical challenges:

- High mix / low volume environment
- Cost of inventory obsolescence due to shorter product life cycles
- Demand volatility over the planning horizon including seasonality demand swings
- Supplier delivery schedule stability
- Customer rush jobs
- High capital equipment investment
- Cost of line changeovers (reduced production effectiveness)

Some manufacturers may be required to produce hundreds of different item types including SMT and other assemblies. These models often compete for shared resources and assembly lines. Work content and customer demand may also vary considerably from product to product.

Traditionally, shared resources like SMT assembly equipment are often run "Flat Out" to achieve a high utilization. This tends to drive the manufacturer to batch type production, often with larger batches resulting. Larger batches in turn mostly cause larger amounts of WIP and an increased lead time to replenish, typically followed by adding additional inventory to protect against variability and cover increased lead time. The risks associated with excess or worse, wrong inventory, well known.

The central concept of Lean is to provide the customer exactly what they want, when and where they want it, with a minimum of waste.

Developing the capability and flexibility manufacturing and supply systems to adapt to changing business needs is in fact very closely aligned to the central objectives of the Toyota Production System.

In fact one of the first challenges Shigeo Shingo was asked to solve by Taichii Ohno (Founders of the Toyota Production System) was to reduce system changeover times to enable small batches! It was recognized early on that the "Ford Production System" – which was the basis for TPS, while having many strengths was not particularly well suited to multiple or new products.

Rapid changeover between models is a critical foundation element of the Toyota Production System [1].

Myth No. 3: Lean Manufacturing is synonymous with *KANBAN*

In environments with repetitive products and stable demand, using current inventory consumption as a proxy for future demand is a reasonable approach.

Appropriate utilization of a *KANBAN* system is an effective and proven method to provide a good level of customer service with short lead times. Stocking appropriate levels of inventory is a tool to shorten reaction times as well as deal with inherent variability of the process itself, and changing customer demands. Inventory has always played a central role within TPS. The key is having the right inventory!

KANBAN are designed to produce standardized products where manufacturing activities are repetitive, work instructions can be standardized, and scheduling can be managed through a pull system. When it's a Make-to-Order, Design-to-Order, or Engineer-to-Order environment then *KANBAN* may not provide the flexibility to produce or schedule these types of products quickly. Even with more standardized products, shortened product life cycles and the rate of change of technology may demand a manufacturing environment that can adapt quickly. In such environments with custom products, changing product mix, infrequent orders, or highly variable demand, maintaining an inventory stock of items in *KANBAN* based on anticipated demand is not a reasonable assumption. That is impractical when there are thousands of possible parts, many of which may not be needed for weeks or months at a time.

A "Job Shop" has different operational considerations. How does Lean Production Management fit to an operation – perhaps even where you may never build the same model more than once?

Clearly *KANBAN* is not a "One Size Fits All" solution.

EA manufacturers of High-Mix and custom engineered products can also fully realize the benefits of lean manufacturing by using a **hybrid** approach that leverages the principles of Lean Production Management while providing the flexibility required when dedicated flow lines are not practical or possible, and simple visual control methods are not sufficient.

Additional techniques must be developed that support this environment, but that still adhere to the foundation principle of TPS – Material Pull - where upstream processes are only allowed to produce, when the downstream process authorizes upstream production activity.

With these other techniques the "trigger" to authorize production at the supplying process is a signal other than a *KANBAN* card, signaling downstream capability, but more on this later.

These techniques have been developed by lean experts over the past few years. These techniques have been proven to work well in high mix environments – the only limitation is that they are more complex than *KANBAN* and therefore require a certain level of system support.

Therefore the term "SIGNALING" is becoming a key lean concept within the communities.

Lean Production Management Concepts

But before considering the new techniques in EA, a brief look into Lean Production Management concepts is in order.

Coordination of the "Value Stream" or activities undertaken to supply a product according to customer demand is based on two fundamental pillars:

- **Pacemaker** process – is where production activities for the value stream are scheduled in a method synchronized to meet customer demand. Customer demand is expressed in terms of takt.

  *"**Takt time** can be defined as the maximum time allowed for producing a product in order to meet demand. It is derived from the German word taktzeit which translates to clock cycle. The pace of production flow would then be set based on this takt time." – Wikipedia*

  One objective of scheduling the pacemaker is to prevent overproduction. Careful management of the pacemaker scheduling is implemented to ensure capacity utilization of the production system as uniformly as possible. This is known as Volume Leveling or smoothing,

  Additionally where more than one model is being produced, the runs of products are mixed as much as possible to allow the smallest possible batch sizes within the constraints of capacity. This is known as Mix Leveling.

  "Heijunka" is the Japanese term that is often used to refer to leveled scheduling. When leveling is applied at the Pacemaker – the result is a smooth material flow throughout the supply chain.

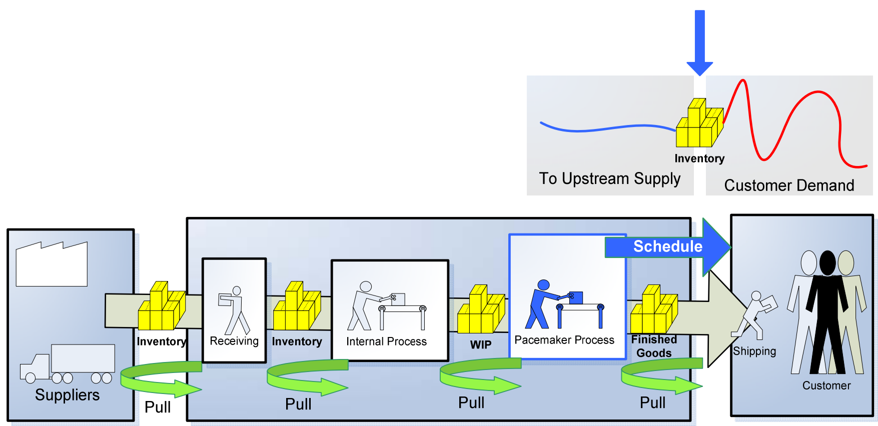

Figure 1 – The role of leveling and signaling in production

- **Signaling** is where downstream and upstream processes are linked to the pacemaker by simple rules: First, every upstream process produces only when provided a replenishment requirement or an authorization signal from the next downstream process (Pull signals such as *KANBAN*). Second, processing downstream from the pacemaker must occur in continuous flow (with the exception of the finished goods supermarket, if needed.) The result of this control system is that the pacemaker gets a schedule and every other internal and external supplier in the factory and supply chain is synchronized with the pacemaker.

  Signaling can be accomplished in a variety of methods. Traditional methods such as cards or empty totes can of course be utilized, but fortunately leveraging technologies such as **RFID** or **MES** (Manufacturing Execution Systems) adds benefits of timeliness (Real Time) labour savings and accuracy. An integrated approach is vital to enterprise level Lean Production Management

Signaling keeps production of all other processes in synchronization with the pacemaker based on actual execution throughout the shop floor. Ideally, signals provide work centers with:

- A list of jobs to execute
- A sense of urgency or priority for every job
- Grouping/sequencing of jobs with similar attributes – minimizing setup and changeover.
- A feeling for lateness and queue size
- Progress Status of orders and WIP levels.

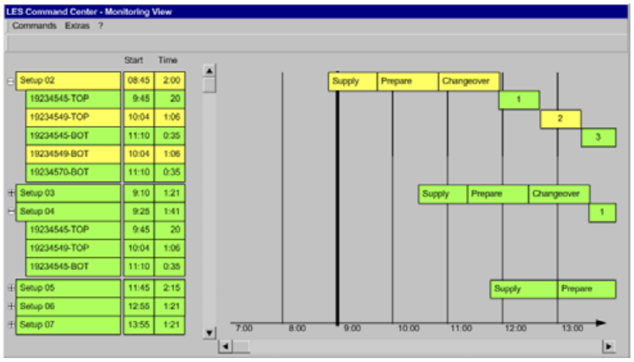

Figure 2 – Example of a Signaling Screen for coordinating SMT production

Using these elements, Lean Production Management can also be viewed as "real-time execution-based scheduling" that keeps the factory activity in perfect synchronization with minimum effort.

For High Mix EA Operations, "The Devil is in the Details"

For factories that produce high variety or custom engineered products, the calculations for pacemaker scheduling must also take additional factors into consideration; such as: the mix of build-to-order (BTO) and build-to-replenishment (BTR) items on the same resource, as well as considering frequent new product introductions (NPI) and end-of-life (EOL) planning.

In certain facilities NPI activities may be conducted on a dedicated line prior to ramping to production volume, and BTO types of production may also be handled in a similar way. But this is dependant on the size and nature of the operation, and this may not always be possible. Shared resources and lines are a reality in production that must be considered in providing an effective solution

Considering signaling, the difference between High-Mix and High-Volume manufacturing is even greater. As mentioned previously inventory buffers and signaling methods for all parts such as *KANBAN* /supermarkets cannot be universally applied. Clearly other methods to address High-Mix are required.

Instead of being **'inventory-driven',** where supplying processes are triggered to produce parts to replenish an inventory buffer, new signaling methods utilized in Hi-Mix environments are '**capacity-driven'.** With this new method, supplying processes are triggered to produce the ***next item needed*** **when** ***capacity becomes available in downstream processes.***

Wherever it is possible, strategic planning for spare capacity on critical resources enables even greater system responsiveness. This may seem somewhat counter to "Running Flat Out" In the big picture – but the ability to satisfy the customer order is the critical point, not the100% utilization of a particular capital resource.

When a process approaches full utilization – cycle times will explode, and the ability to successfully react to variation becomes severely limited. This principal is known as "***Little's Law***" [2] or "**Queuing Theory**".

A real life example would be the difference in time for a commute during the peak time of rush hour, or a commute during off-hours. The distance and the result is the same, but the time spent commuting increases "explosively" once the utilization of the roadway increases past a certain point. This effect is no different in manufacturing. Material, like traffic, also tends to flow better when there is less of it.

This brings to the forefront an important consideration of Lean Production Management, Controlling the level of material and WIP in the process in an effective way. Whether the signal technique is *KANBAN* or another technique – the objective is the "WIP Cap" –that is to try to drive the process to the right level of material. Reduction of WIP also highlights "Hidden" problems, and once visible – enables one to continuously improve the production system.

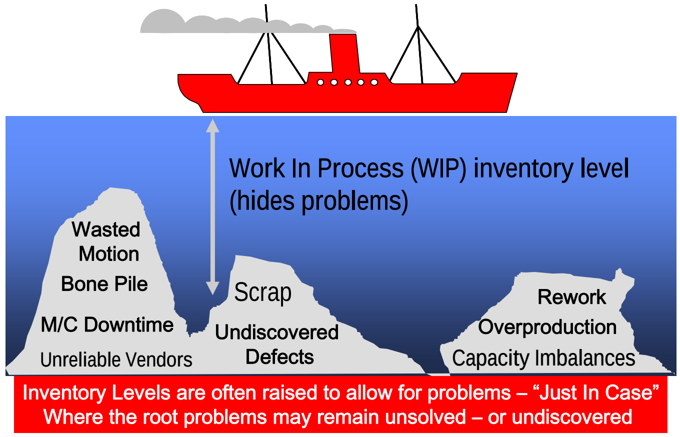

Figure 3 – The classic "WIP Ship"

The benefits of reducing the inventory are clear. How then does one implement a production management system in an environment where *KANBAN* is not appropriate?

"WIP-CAP" is the true motivation and reason for preferred methods of production control like *KANBAN* or **CONWIP** [3] (**CON**stant **W**ork **I**n **P**rocess) – where once a specific level of WIP is reached, no new jobs are authorized for the production system until work is completed and leaves the production system. Demand is accumulated on a backlog list, if the system is "Full" and is released to the system when capacity is available. If the system is not full – work is released to the system – according to the demand signals received. Like *KANBAN*, WIP can be controlled by the number of "cards", but in the case of CONWIP, this card is not part number specific.

Work on an item in the production system does not begin unless both conditions of available capacity signal and a demand for the specific item are met. If both are not present and available – production activity will not start.

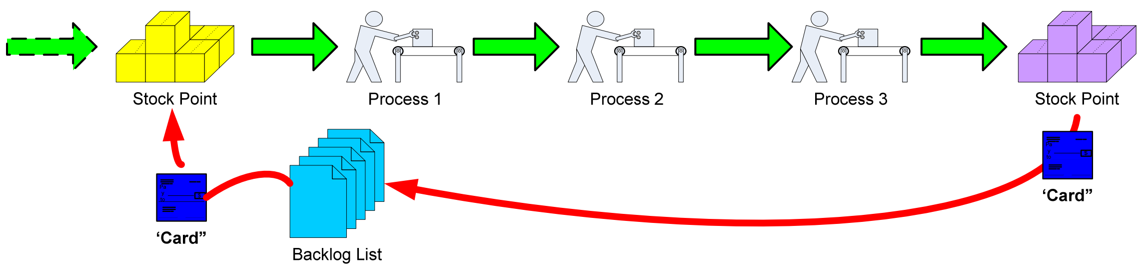

Figure 4 – CONWIP Principle

Another hybrid control system is known as **POLCA**[4] (Paired Overlapping Loops of Cards with Authorizations) POLCA has some similar characteristics to CONWIP with "Cards" as capacity signals and the "Authorization" or "Backlog" list. Again production activity will not start unless both items have been satisfied. Additionally POLCA is very well suited to controlling the movement of products that must take variable routes through a production system with multiple shared work centers. Essentially, the use of POLCA cards assures that each cell only works on jobs that are destined for downstream cells that will also be able to work on these jobs in the near future. If a downstream cell is congested, it will not release the POLCA card to the upstream partners. The upstream partner's capacity is ideally better utilized, if possible to work on an item needed by one of the other available downstream work centers.

All of these methods discussed share the characteristic that if a work center goes down (for whatever reason), upstream processes will stop their activity when the capacity or replenishment signals have been "Consumed". Further WIP accumulation will stop.

Demand will "flush out" downstream WIP, if the failed process remains down long enough, stock outs will occur and customer service levels will be affected.

In the case of decreasing demands – *KANBAN* systems, if unaltered will rebuild inventory to specified levels, while CONWIP and POLCA will purge the production system. Additionally in the case of *KANBAN*, if demand changes (upwards) with no adjustments, the production system is again at risk of a stock out.

Practical implementation of these production control methods and the tools used on the shop-floor (like recalculation of signaling levels (such as *KANBAN* loop sizes) in reaction to demand changes – are often still spreadsheets that have been developed in house by production planners. Some of the difficulties associated with these "home brewed" tools is that they may be specific to a production line, or a product family. These tools may be difficult to maintain, and scale across the enterprise. Additionally maintenance of these tools may be complex, should the "Spreadsheet Guru" move on to other tasks.

The complexity of schedule leveling and modeling of the production processes is also not an easy task. Using multiple production control techniques simultaneously can also add to the complexity. The good news is there are available SW tools today addressing exactly the needs (and beyond). \

Supporting Practices for Successful Implementation:

Ensuring high availability and quality output of the production system is critical. System or machine failures and production defective items can adversely affect the success of implementing Lean Production. It is important that other important foundation elements, such as "Built in Quality at the Source" or ***"Jidoka"*** "Total Productive Maintenance" (TPM) to ensure reliable equipment, and Quick Changeover Processes are in place.

Coordinating activities across the organization including material supply activities, offline setup execution, in order to support the production line also plays an important role in enabling smaller lot sizes. The various departments can perform their task ensuring minimal production impact. Providing the "Heads Up" awareness of task status, expected start, task duration and current anticipated finish can also quickly alert the manufacturing team to developing issues, enabling a timely resolution.

Ideally the production order sequence assigned to the floor already minimizes the changeover requirements and efforts by grouping models with higher commonality, or with a logical sequence. Ideally such a tool can be provided to the planner, where rapid feedback can assist the planner in making sound decisions. While the planner may not understand all nuances of the SMT process, tools now exist to support this need.

With respect to changeover activities – ideally they are conducted in an external fashion, performed while the production process is running. In the case of SMT equipment hardware such as additional feeders, Offline verification software and trolleys (Change-Over Tables) can be utilized to "Externalize" change-over effort. Additionally well thought out "Family Setups" and "Floating Changeover" to reuse setup elements can further minimize change over time.

With reduced or eliminated online changeover times – the system enables the user to realize the benefits associated with smaller batch production, with minimal availability penalty.

"Pull" and "Push" Signals & Capacity Consideration

In order to be fully effective in most EA environments, a lean production system needs to utilize a combination of signaling techniques appropriate to a given factory's products and manufacturing process. These include:

- Inventory-driven (Pull) signals
  - ***KANBAN*/Supermarkets** for high volume
- Capacity-driven (Pull) signals
  - For items that are needed less frequently
  - For make-to-order job shop environments where flexible routings use cells as needed.
- Material availability signals
  - **"Push"** signals - where the pacemaker is not the last process, but establishes the sequence of downstream processes (e.g. FIFO).

These material control strategies based on SIGNALS all respond to the real-time situation on the shop floor without the need to 'schedule' any work centers in advance, other than the pacemaker process. They can all be implemented using either manual cards for relatively simple environments, or electronic 'job boards' for more complex environments.

The different signals represent a spectrum of strategies that enable a company to take advantage of lean production principles in any environment – including those where many different products are made; where demand is volatile; and where full flow/dedicated lines are not practical.

But – one main challenge remains: "despite the best planning, sometimes capacity issues do occur. How does one deal with this?"

The Implementation of the new signaling methods AND the consideration of CAPACITY issues is more complex than a Change Management Project based on LEAN principles described above. These subjects will be discussed in a future in-depth case study and report.

An EA Case Study

While all the theory sounds very compelling, how does it fit to an actual operation? The following case study is intended to briefly show the reader how these techniques can be applied to an actual EA production environment.

So where does one start?

To understand the complexities of a modern electronics factory, especially with multiple production areas, and product families, one must have a way to understand and visualize the material, product and information flow in an objective way. Fortunately such a tool exists – Value Stream Mapping.

To be able to improve any system, no matter what it is, you must first have the ability to measure it.

Additionally – once one "Has the Big Picture" one can consider the application of appropriate technologies and operational practices in the future. Required improvement activities are highlighted. Some of the improvement activities would not be evident without considering the complete operation.

All too often in EA – our attention may be fixed on the optimization of one particular process in isolation. Often we have been conditioned to think this way. This leads to driving practices in production such as "Achieve 100% Utilization on SMT Placement" as a KPI measurement may make the individual department look very favourable, often achieved by running larger batches, but in the larger picture can result in unnecessary WIP or a loss of flexibility for the overall operation.

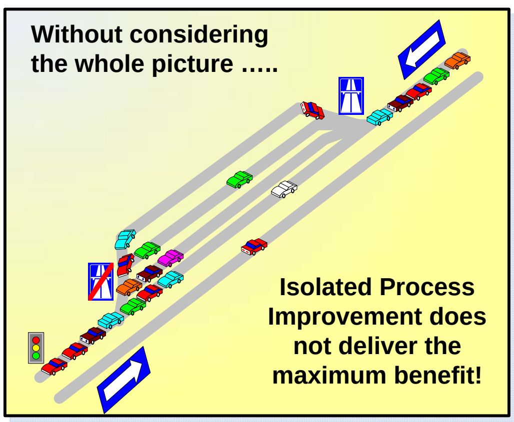

Figure 5 – Isolated Improvements

Additionally – the organizational structure of an operation can encourage certain behaviours. One cannot fault the individual departments, as they are trying to run their "area" using their best abilities, the way the organization expects of them. Communication between the different "areas" is an ongoing daily challenge. Add additional in process inventory (for Just In Case… "We don't want to be the reason the downstream department can't hit their numbers") and a higher mix of products to the picture and it becomes even more complex. Additionally many conventional ERP systems notify "Job Complete", and push the job to the next operation, further reinforcing this behaviour.

No one starts out with this intention – but we need a clear and objective picture of the current state.

Conducting the Value Stream Mapping Exercise

The preparation for the VSM exercise was very important. The first step was to find an internal project sponsor to act as champion, and in some cases assist with some of the organizational issues – or more commonly known as "Politics". In the selection of the team members for Value Stream Mapping exercise it was important that make up of the team included various disciplines from the factory, including Production, Engineering, Planning, Quality, Material Control, Stores and Management. The attempt was to involve a representative from each stakeholder department. Without the team participation and commitment, "Silo Thinking" may otherwise kick in, and there would have been no way to reach a consensus on the results.

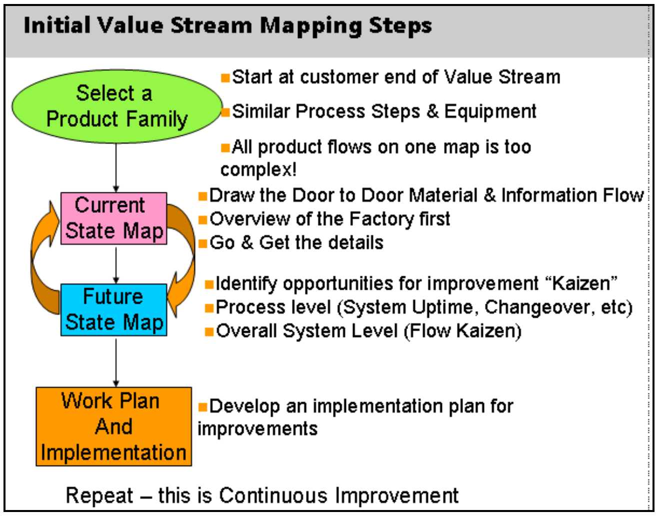

Figure 6 – Value Stream Mapping Steps

The objectives of the exercise were explained. A brief training session was conducted to enable the team in the VSM techniques. After this session - the team was able to put the technique in practice, documenting the material and information flows for the complete facility by walking "Dock to Dock" over the course of several days. The objective of the exercise was to gain an understanding of the overall operations of the factory and express it in an objective way, quickly understood (and agreed) by all involved.

Additionally key business data was captured including process times, product routings through work centers, inventory and materials information, as well as customer demand (order) history. After much discussion – the team assembled a representation of the "Current State" of the production process.

<u>The Current State</u>

To understand the operation of any EA facility, one must understand its purpose first, which very clearly is to assemble products according to customer demand. Understanding production demands is just the first step in any Value Stream Mapping exercise. "Just what is it you do here anyway?"

From analyzing production order history for this operation, which happened to be a contract manufacturing (CM) operation – it was found that there were 500+ active assemblies (SKU) just within the brief period of time that was examined. Clearly this was a "High Mix": facility. The facility also had to service multiple customers. The customer delivery frequency ranged from every few hours in some cases (A sister facility on campus) to several weeks (more geographically distant customers).

Production demands ranged from tens of thousands of units to single units for the active SKU's within the study interval.

The overall organization of the factory included several SMT production lines supported by offline SMT setup operations. Needless to say, with the large number of SKU's, the effort for setup and changeover activity was found to be significant for supporting the production operations.

Other process areas and departments within the facility included:

- Device preparation
- (THT)Through Hole Technology (manual & automated)
- Wave soldering
- In Circuit Testing (ICT)
- Mechanical Assembly
- Unit Functional Testing
- Final Quality Control
- Packaging.
- Multiple "Semi-finished inventory locations:

In other words a typical EA manufacturing facility

Other findings included:

- Not all areas and departments worked the same shifts or production hours
- Jobs were scheduled to each area by ERP, and at completion of batch, transacted to next area.
- Downstream work center started activities based on available Jobs (Completed batches from the previous area)
- Supervisors could reprioritize the activity of each area based on the needs for "Hot Jobs". Often the supervisor would override the ERP system to select the jobs for their area.
- Long changeover considerations of some key assets, in some cases caused larger batches.
- Not all products (SKU's) went through all work centers. Entry into the process was not always at "The Front" (e.g. some products did not include SMT)
- Routings tended to vary from work center to work center for differing models
- To accommodate "Just In Time", and sometimes "Just In Case", and variable demands several "In Process" warehouses were incorporated into the process between work centers. This was in addition to inventory that was normally found on the floor.

The results found during the VSM exercise were far from unusual, and certainly nobody's fault. With everyone focused on "making the numbers", and the variation within day to day manufacturing – "stuff just happens over the course of time".

A further analysis of the inventory –revealed the following:

- A large percentage of the stock in the central warehouse was sufficient to support more than a year or more of some production item demands. The concern of course here being occupied capital, or worse still potential obsolescence of the stock
- In some cases a relatively large percentage of inventory had no stock whatsoever.
- The "In Process" Inventory detected varied anywhere from 6 months to less than a week, depending on item. Stock found on the floor was typically in the range of days.

These findings were far from unusual. The key point is that inventory had somehow accumulated and much like water "found its natural level" as it typically does with any system. The question is of course – was it the right inventory?

Implementing Lean Production Management

During the VSM exercise and measuring the current state, process steps that required improvement, as well other improvement opportunities were clearly recognized.

This identification process can lead to a ***"Kaizen"*** or continuous improvement opportunity.
Kaizen opportunities identified can be specific to a process -"Point *Kaizen*" or can relate to the entire production process – "System or Flow *Kaizen*"

The benefit of the VSM approach is that System *Kaizen* becomes somehow much more evident. Point *Kaizen* is typically somehow more obvious – such as a process that may generate excessive scrap, have high downtime, or long changeover times.

With the Value Stream Mapping exercise more than 75 kaizen opportunities were detected (addressing "basics" such as system reliability, uptime, and defects) even with the limited time spent on this exercise. Definitely this is a testament to the "Go and See" philosophy with TPS and the VSM approach.

The other critical point here is that improvement could begin right away on many of these opportunities that were identified – with little or no capital investment. Realization plans were worked out and many of the improvements were put in place in a relatively short time frame.

Moderate term improvements in some cases were realized with software upgrades with improved functionality and performance. These were made without major changes to the current business process. Redundancy of effort was eliminated in several cases. Where data was being collected manually – automatic web based data collection and reporting was implemented – with labour saving and reporting timeliness. With performance information available – this was also a basis for further continual improvements. "How can you improve what you can't measure?" Keypunching of data that could be transferred automatically after upgrade was also eliminated. This task was error prone, and admittedly, dull, and did not add value.

However one of the major benefits delivered from this exercise that may not have resulted otherwise was seeing the opportunity for "System Kaizen" based on the big picture. The important point again – is that an isolated point optimization may not always deliver the maximum benefit.

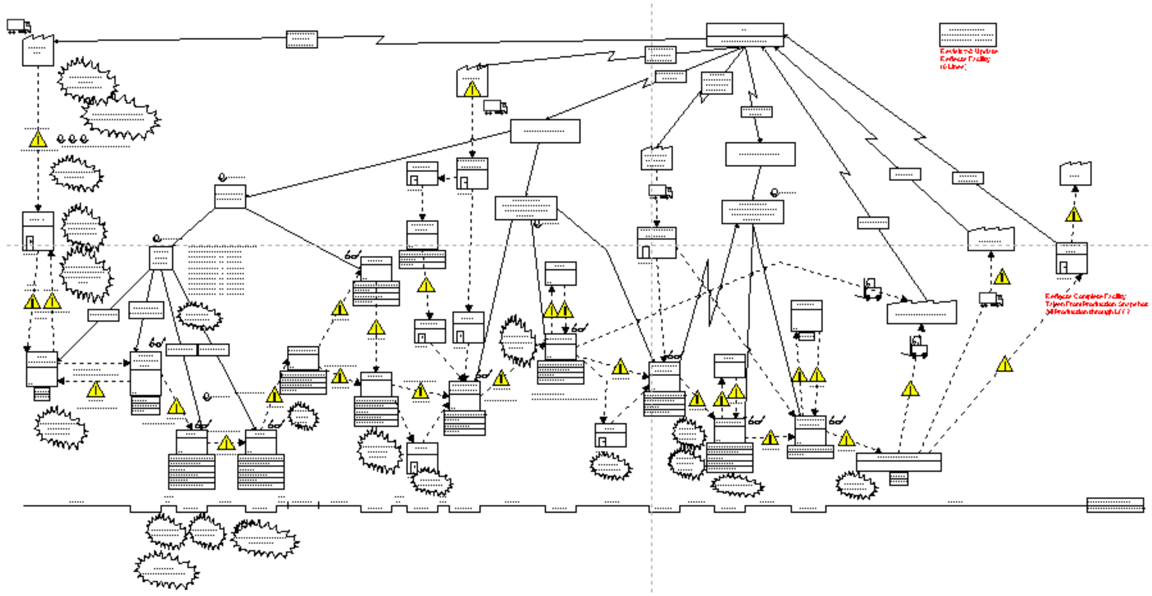

Figure 7 - Resulting Current State Map

One of the other results was to identify opportunities for improving operational and business practices that could benefit from advances in production methods, equipment and IT technologies.

Fortunately for today's EA operation there are several technologies that are now available that can help in the realization of Lean Production Management, as never before. While not all technologies were well suited to this particular operation – the VSM exercise did a good job to highlight some of the appropriate candidates from these technologies for potential implementation:

<u>Technologies such as:</u>

- Rapid and error free transfer of CAD & BOM data to Product & Recipe definition on the production floor. Systematic control to ensure the latest and most correct information.
- Empowering the production planner to create "Effort Aware" production schedules and sequences to reduce effort on the floor, while meeting deadlines.
- Use of group technologies – to eliminate or minimize changeover – including intelligent family setups clustering.
- Coordination across departments to synchronize material supply and preparation activities with the production line needs.
- Use of additional hardware and software to support external setup activities to enable rapid changeovers and smaller production batches.
- Use of Online "Floating Changeover" techniques to minimize material handling and maximize production line availability by reducing or eliminating changeover times.
- Enhanced visibility of resources and locations, including material and tooling – including movements, completions and consumption.
- High production equipment availability through Totally Productive Maintenance practice (TPM) and Usage based Maintenance Management software
- Web based real time alerts and process KPI reporting to support timely actions and support Visual Manufacturing, including Andon Displays
- Error proofing –machine tooling/material setup validation and automatic process interlocking
- Comprehensive planning solutions to support BTR and BTO production strategies.
- Real time signaling on the production floor to coordinate production job execution.
- Leveraging technologies such as MES, RFID, and Internet based technologies to gain visibility and integration into the supply chain and the manufacturing floor.

As a part of the VSM exercise – The current state was critiqued. Details of the findings were checked to ensure they were realistic. Then, the Ideal Future State was constructed in a brainstorming session.

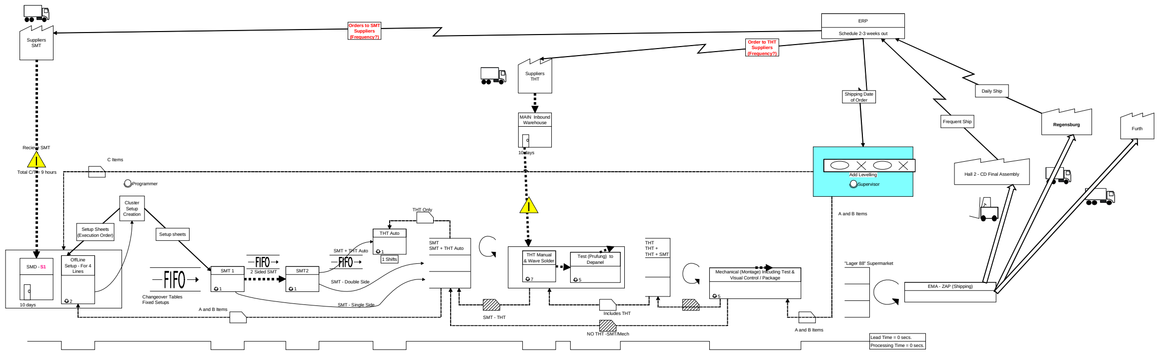

Figure 8 - Future State Map

Detailed analysis of the 500+ SKU's produced during the production interval revealed that 37 SKU's comprised more than 85% of the production volume. Of these assemblies – once the process steps were related – 6 product families emerged.

Planning and Implementation of System Level Improvements

Perhaps notable were some of the findings of the exercise towards the "System Kaizen" level. Implementation of improvements in this area was more involved and required additional efforts in understanding and planning. However to come to this realization may not have happened as quickly without the VSM exercise.

As is the case with many operations, even though this was a High-Mix operation, a significant portion of the production activity was well suited to flow production, utilizing techniques such as *KANBAN*. The other SKU's were perhaps better suited to other production management methods.

Given the size of the facility - a logical (and fortunate) conclusion was to locate these higher volume items, onto the same SMT Lines. One effect of this approach – is that setup time would be reduced significantly, and in some cases practically eliminated. This reduction of setup would also provide additional available capacity.

Key personnel at the production facility were trained in Lean Manufacturing methodologies, followed by the implementation of *KANBAN* and flow where the product demand was well suited. BTR handling of these products, with leveled scheduling resulted in several benefits, including reduced WIP/inventory, reduced lead time, and far less "Fire Fighting". Management of 85% of the production now required far less effort, as it practically managed itself. The team was now able to focus more attention on the 15% of the production that was more complex.

Additionally it was important to demonstrate "This Lean thing may actually work" to keep up the momentum with the team, and show positive results. By tackling the "Low Hanging Fruit" the team succeeded in this objective.

The remaining challenge was the management of the other SKU's in the facility not so well suited to Flow/*KANBAN* handling. One could not simply afford to ignore the remaining 15% of production, nor attempt to apply a tool that did not address the need.

"If the only tool you have is a hammer, then every problem looks like a nail"

Given the shared resources, and the fact that several product families did not use all work centers, had low volumes or highly variable demands, consideration was given to other techniques to address the production management. It was decided the remaining production was to be handled as BTO (Build To Order). CONWIP was selected as the production control method for the remaining products as a technique to control the WIP level on the production floor as it was not SKU Specific.

For each of the product families determined by the shared process steps and equipment – a Pull Target value was set for each of the Value Streams or "Flow Paths". System support was beneficial here to deal with the more complex control technique, the variability associated with differing models and work content, as well dealing with the influence of the shared resources.

Fortunately the system also provided the production planner with tools to assist in determining if it was appropriate to transition the products to/from BTO/BTR finished goods handling based on the individual end item demands. Additionally if the current production plan and inventory strategy would not meet the customer needs – an alert would be issued calling for planner intervention.

Pull Signals for BTO end items were then provided to guide the production activities, based on demand, and system capacity, according to the CONWIP principles.

In the case of SMT assemblies, another tool was implemented to handle the signaled order list, and assist the planner to make informed decisions for production orders sequencing and execution. Immediate feedback to the planner improved the use of setup/material commonality reducing the efforts on the floor, both in material handling and setup effort reduction. Additionally as the planner was reviewing the resulting production sequence, they now had the ability to understand the impact of completion times, and needed due dates of orders, and if necessary rearrange the orders, or update the completion dates accordingly.

With the tool that was implemented - upon completion of the sequence planning session, all areas were immediately updated with the tasks required by the plan. Coordination of the material supply and setup preparation activities to support the production line allowed the various groups to see at a glance what activities were required, when they were required, and understand the status of the tasks within the factory.\

With the implemented system it was now possible to coordinate resources and materials required, to arrive successfully sequenced to the proper location and time during **execution** of the assembly process.

Benefits and Value Realized

Continuous improvement has become firmly established as part of the daily culture. This has resulted in the large numbers of improvements and waste reduction. Additionally new Production Management practices were implemented, enabled by the adoption of several new software tools.
The intention here is to summarize some of the key benefits that were realized as a part of these efforts:

Changeover Time Reductions:

- Implementation of family setups sets and flow production for higher demand products
- Improved feedback to the planner in order planning process – resulting in better sequences
- Sequencing and Use of Flying Changeover Capability – 80 % reduction

Productivity

- Greater than 12% Improvement in overall availability for Production purposes

Material Handling

- Greater than 10% reduction in Material Handling Efforts
- Fewer stock outs, expediting and line down situations
- Reduction in raw material requirements
- Reduction in Work In Process Inventory
- Reduced Line downtime – due to kit availability on time

Flexibility and Responsiveness

- Improved ability to insert Hot Jobs with detailed schedule visibility and line status
- Reduction in New Product Introduction efforts – with setup commonality
- Smaller batches enabled with dramatically reduced setup times

Variability

- Unplanned Downtime Reduction due to TPM Implementation
- Reduction due to visibility of Tasks across departments (Warehouse, Setup, Production)
- Improved Customer Service level of On Time Order delivery
- Improved Quality – Right parts, right place

Resources

- Reduced requirements for feeders and changeover tables due to smarter setups

Working Environment

- Less hectic, reduction of the "Pit Stop" factor due to improved coordination

In Conclusion

The deployment of TPS and Lean Manufacturing is not a destination but a journey. With an integrated approach – there are proven benefits with pursuit of the path of continuous improvement. Fortunately today - within EA – there are also tools and technologies to assist in the success of institutionalizing Lean Production Management within the operation today.

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Tools & Methods for Lean Production Management in EA

(Electronics Assembly)

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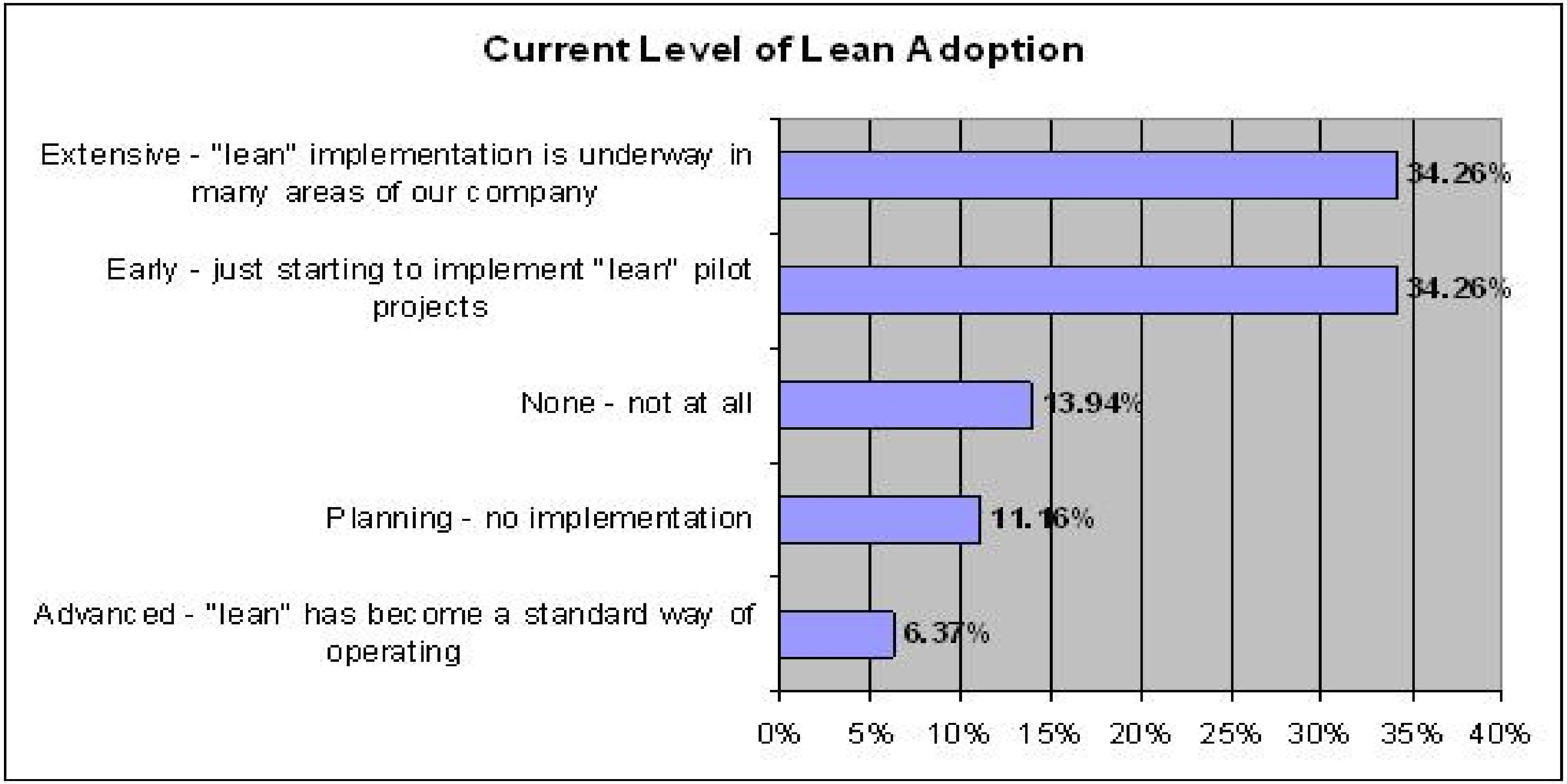
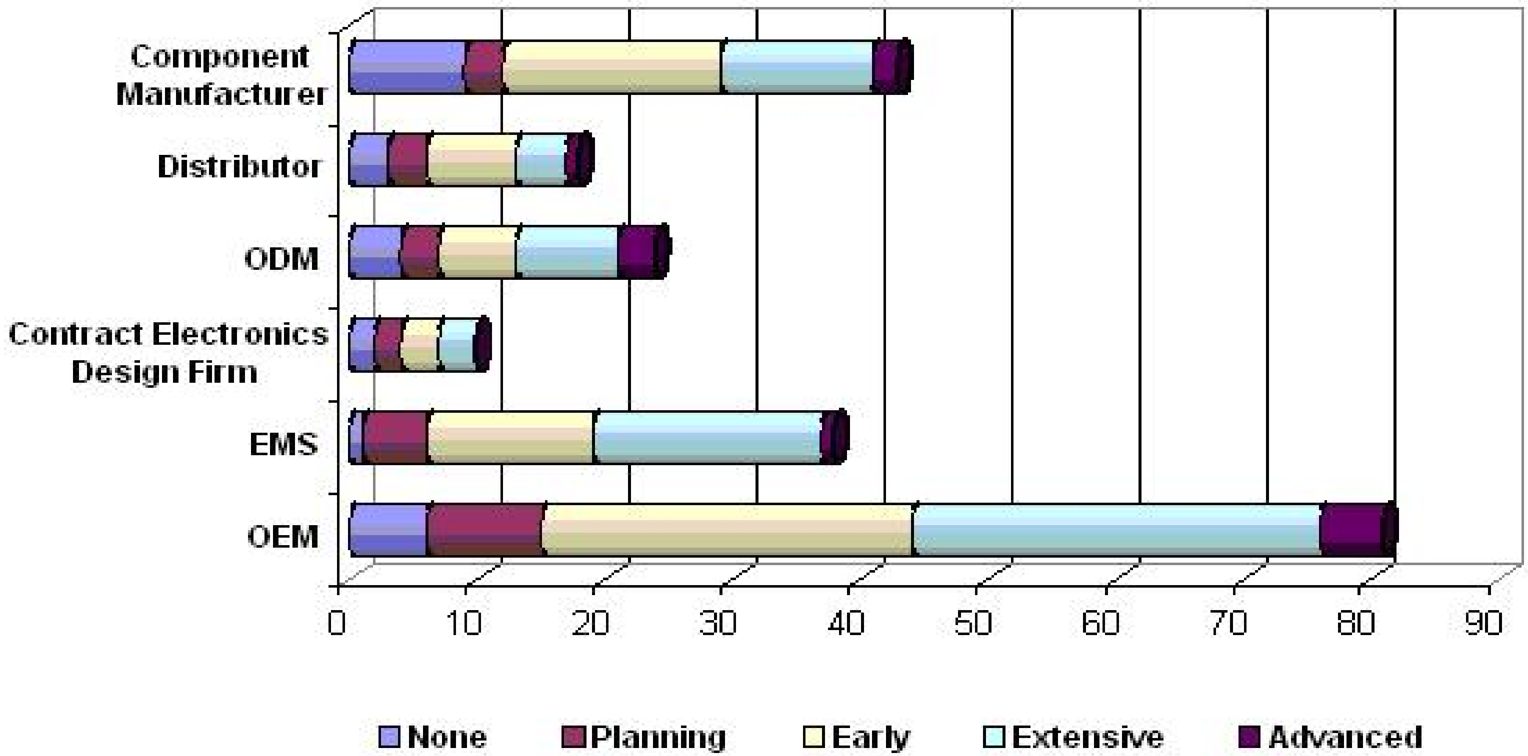
Industry Sector

Lean Adoption Varies in the EA Industry



Current Level of Lean Adoption (Source: Technology Forecasters Inc.)

Lean Adoption by EA Company Type



Company Type and Level of Lean Adoption (Source: Technology Forecasters Inc.)

Common Myths Surrounding Lean Manufacturing

Myth # 1

- **Lean Systems don't require IT**
  - Toyota has extensive investments in IT
  - 9 Million Automobiles / Year - Complex!
  - Lost KANBAN cards would be crippling
  - ALCS (Assembly Line Control System) coordinates resource and material sequencing during execution.
  - Real Time Monitoring and Signaling across complex organization is a key to timeliness

Common Myths Surrounding Lean Manufacturing

Myth # 2

- **Lean Systems don't suite Build To Order (BTO) and Low Volume/High Mix Environments**
  - Lean is easier to apply in repetitive Low Mix operations
  - KANBAN works well in this Flow Production
- **But EA operations today are tending increasingly toward Higher Mix**
  - **Shorter Product Life Cycles/Inventory Obsolescence**
  - **Volatile Demands / Supplier Stability**
  - **High Capital Investment & Costly Line Changeover**

Common Myths Surrounding Lean Manufacturing

- The Ford Production System was the basis for Toyota Production System, with many strengths but was not well suited to multiple/new products.
- One of the first challenges Shigeo Shingo had to solve was to reduce changeover to enable small batches.
- Central to Lean is the ability to provide the customer exactly what they want, when and where they want it with a minimum of waste
- **Rapid Changeover** between Models is a critical foundation element!

Common Myths Surrounding Lean Manufacturing

Myth # 3

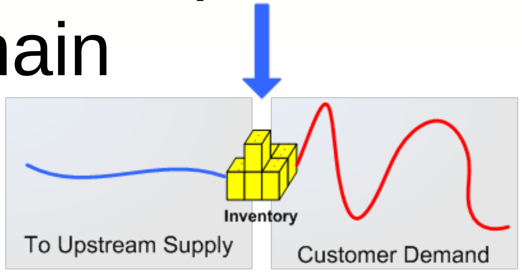
- **Lean Manufacturing is synonymous with KANBAN**
  - KANBAN works well in repetitive environments
  - One KANBAN per part number is impractical in High Mix/ Build to Order shops – even prohibitive!
  - Clearly KANBAN is not a "One Size Fits All" Solution
  - For High Mix - Hybrid Approaches have been developed adhering to the principles of TPS (Material Pull) – More complex – but with IT system support …
  - Downstream processes authorize Upstream Activity by "Triggering" or "**Signaling**"

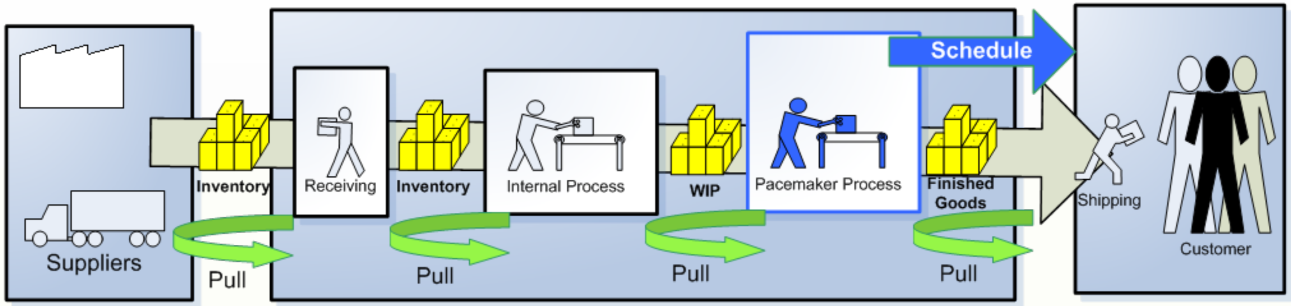
Lean Production Management Concepts

- Coordinating Value Stream Activities
  - Pacemaker: All production activities are synchronized with customer demand
  - Customer demand is expressed in terms of *takt*. Maximum time allowed to produce an individual product to meet a customer demand
  - Pacemaker scheduling is a way to meet customer demand, as well as prevent overproduction of non-required items. (Waste)

Lean Production Management Concepts

- Leveled scheduling or “ Heijunka” includes Volume Leveling and Mix Leveling (Model) to smooth material flow in the supply chain.
- Leveling has a “Calming” influence on upstream tasks and the rest of the supply chain





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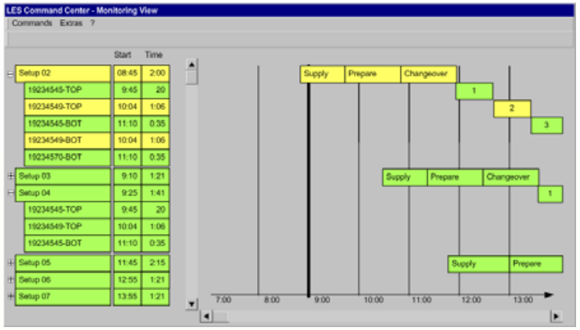
Lean Production Management Concepts

- **<u>Signaling</u>**: A method to keep upstream and downstream production resources in synchronization with the Pacemaker
- A method to authorize Production activity in any environment including High Mix
- Technologies such as RFID and MES can also be leveraged.
- IT also fulfills a Role



Example Signaling Screen

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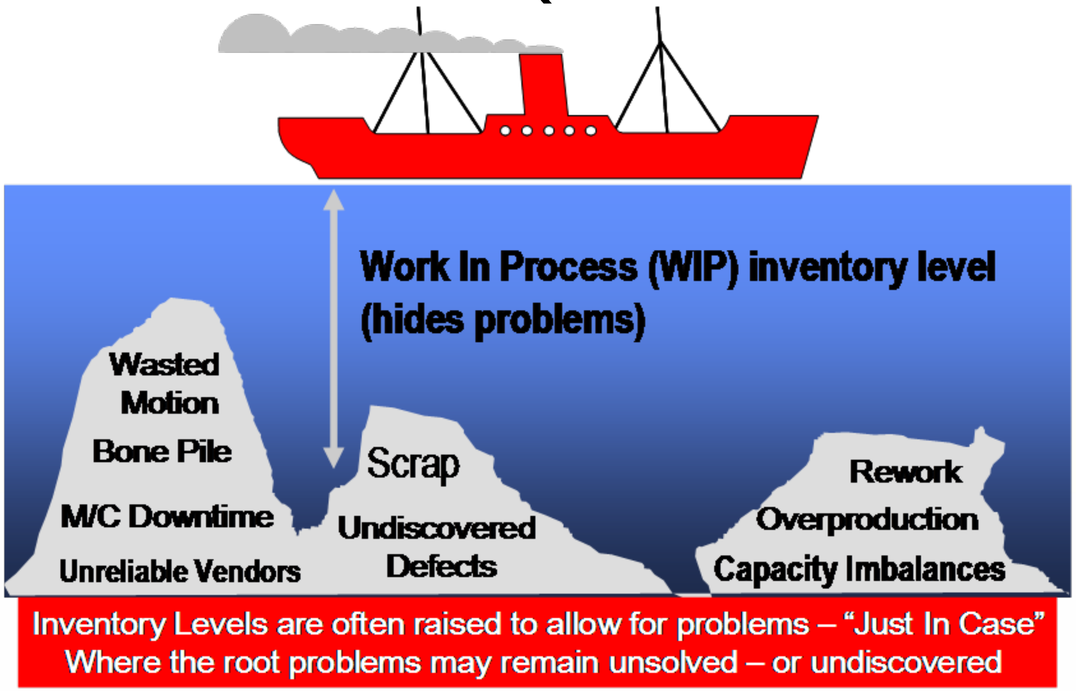
High Mix Compared to High Volume

- High Volume processes are triggered in Lean to replenish "Inventory Driven" (KANBAN)
- High Mix environments should be triggered on "Production Capability" as opposed to Inventory signals
- Signaling of available production capacity and controlling utilization is possible with hybrid techniques (More on this later)

High System Utilization

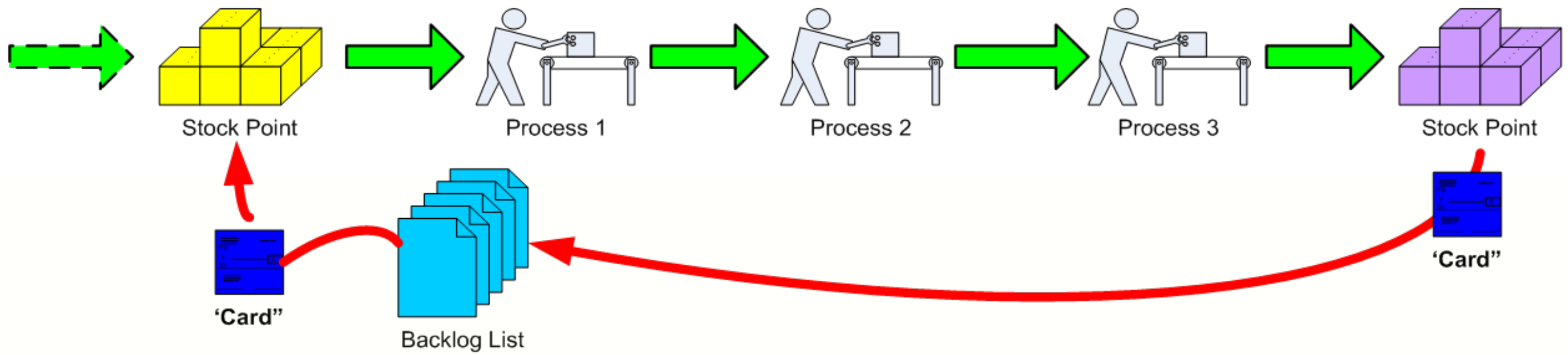
- When a process approaches full utilization – cycle times explode
- Think of the difference in commuting time on a busy freeway
- Well known as “Little’s Law” or “Queuing Theory”
- Material and WIP, like traffic flows better when there is less of it

Excessive WIP (Work In Process)



- The problem of Excess WIP is well known – hence the classic "WIP Ship"
- The Key is to control the WIP – with a "WIP Cap"

“WIP Cap” in High Mix Environments

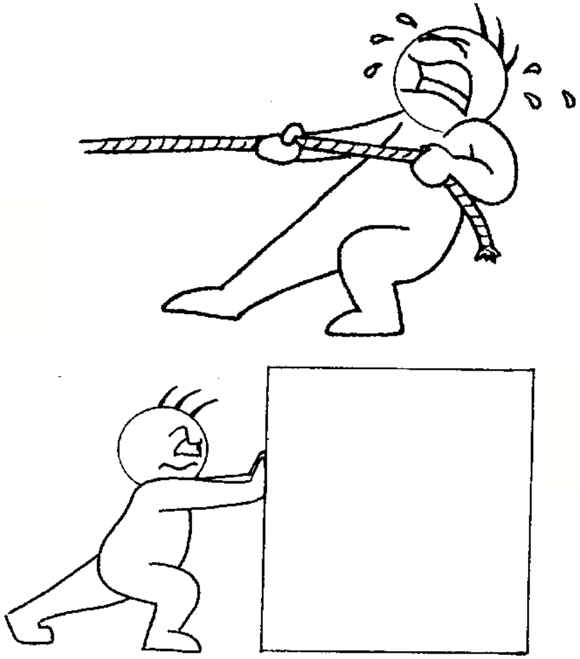


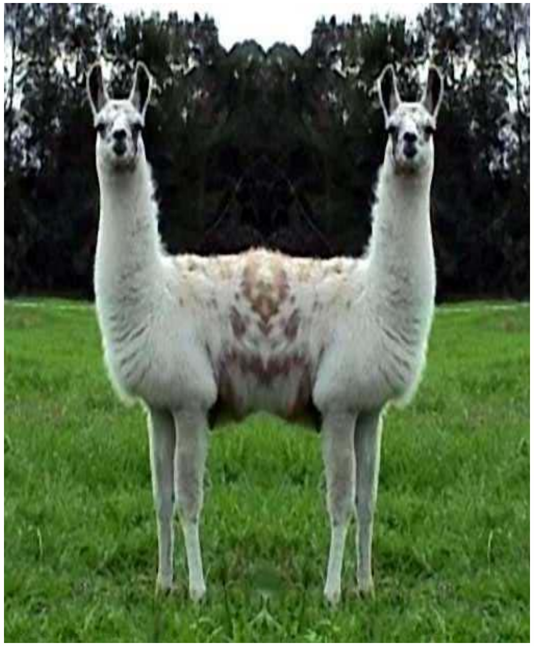
- CONWIP (**CON**stant **W**ork **I**N **P**rocess)
- Also Known as “Generic KANBAN”
- After a defined level of WIP is released into the process is reached, no further items are releases until available capacity is signaled
- POLCA (**P**aired **O**verlapping **L**oops of **C**ards with **A**uthorization) is similar to CONWIP – but useful for variable routing – it is a capacity signal

Other Supporting Elements

- Additional Inventory is often used to "Cover" for system problems – **"Just In Case"**
- The Production Process must be reliable.
- Reliable Equipment – ensured with TPM (Totally Productive Maintenance)
- Quality must be assured at the source (Jidoka)
- Quick Changeover Practices are in place (SMED)
- Activities are Coordinated across departments (Signaling and Visual Manufacturing)

A Hybrid Approach

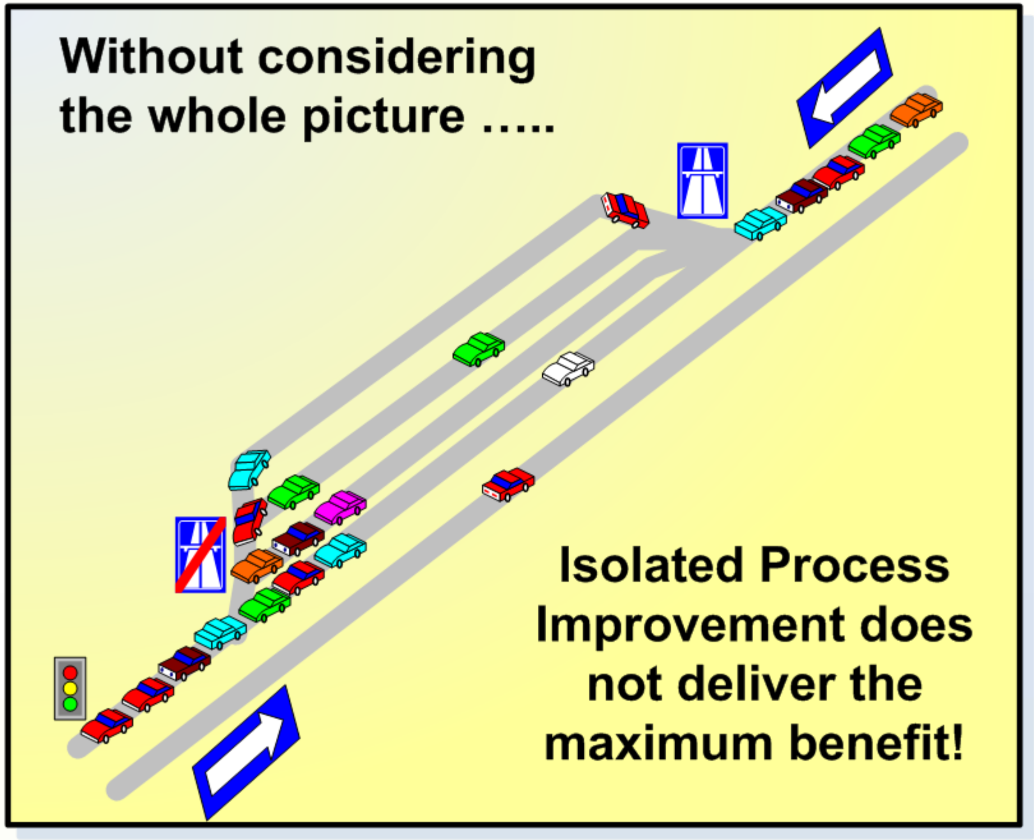




- It may take a “Little Push and Pull”
- A combination of these techniques is appropriate in High Mix EA
- A key is Signaling to coordinate production processes, and may involve elements of system support, including IT

An EA Case Study

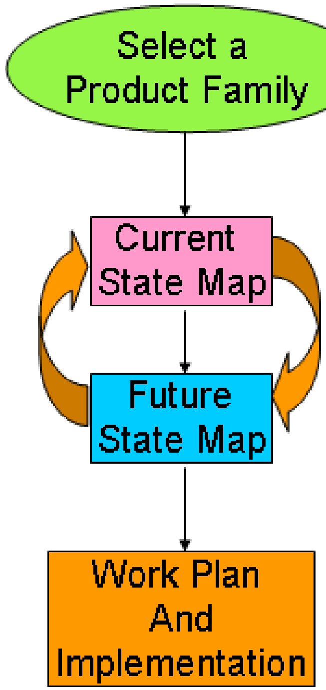
- One Must consider the complete picture



Value Stream Mapping

- An Objective way to “See the Whole”

Initial Value Stream Mapping Steps



- Start at customer end of Value Stream
- Similar Process Steps & Equipment
- All product flows on one map is too complex!
- Draw the Door to Door Material & Information Flow
- Overview of the Factory first
- Go & Get the details
- Identify opportunities for improvement “Kaizen”
- Process level (System Uptime, Changeover, etc)
- Overall System Level (Flow Kaizen)
- Develop an implementation plan for improvements

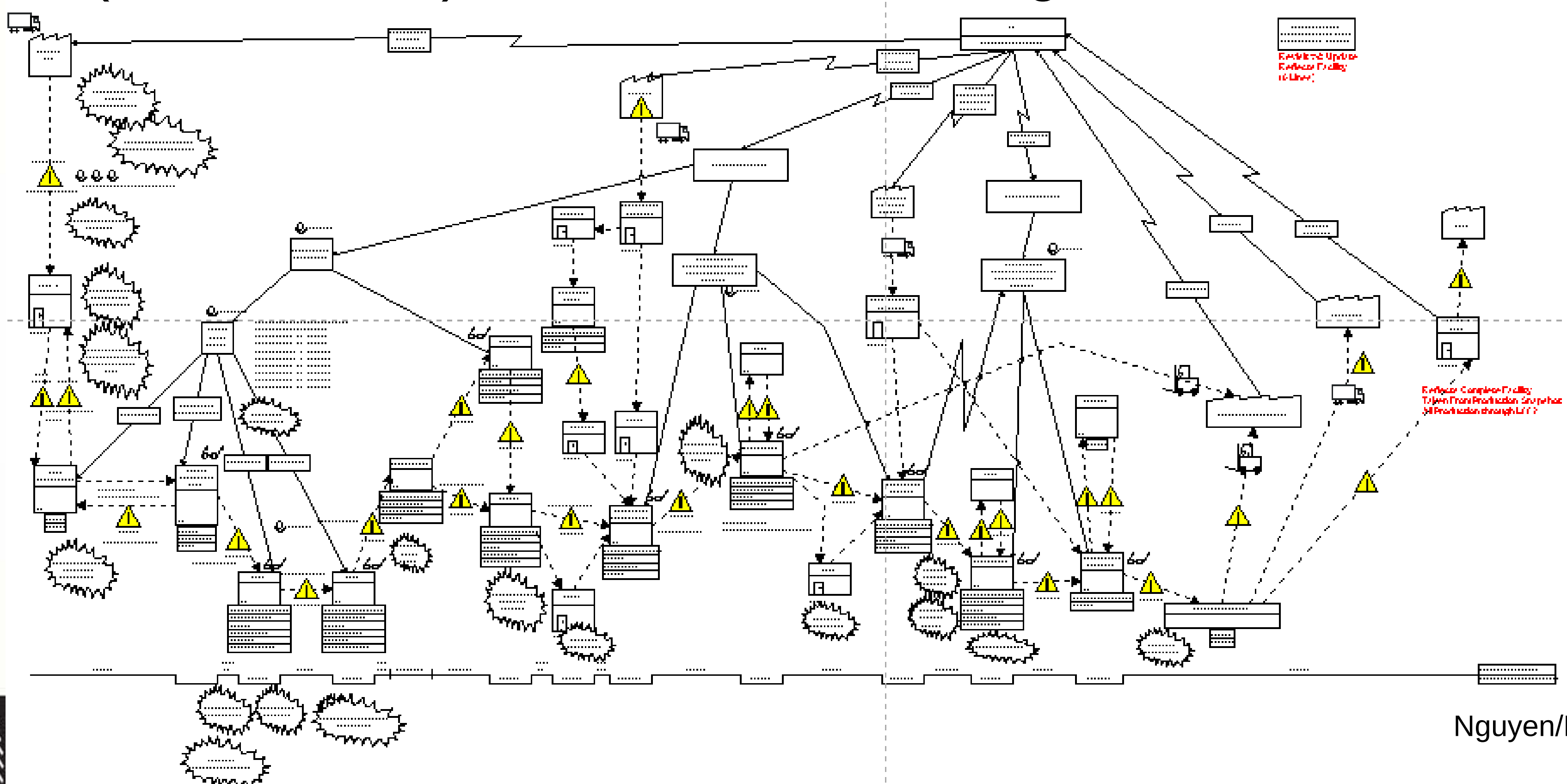
Repeat – this is Continuous Improvement

Understand the “Current State”

- Involvement of the actual people that “Do actual the work” is absolutely key
- Selected findings include:
  - Disparate Shift Schedules amongst departments
  - Jobs are pushed to the workcenter at completion of prior order by ERP
  - Supervisors typically reprioritize task for Workcenters – based on “Hot Jobs List” overriding ERP
  - Long Changeovers tend to drive the system to plan for larger batches
- Far from unusual findings in today's EA domain

Today's Current State Result

- Some Detected Improvements can be implemented immediately without significant investment or justification (Point Kaizen) detected from "Seeing the Whole"



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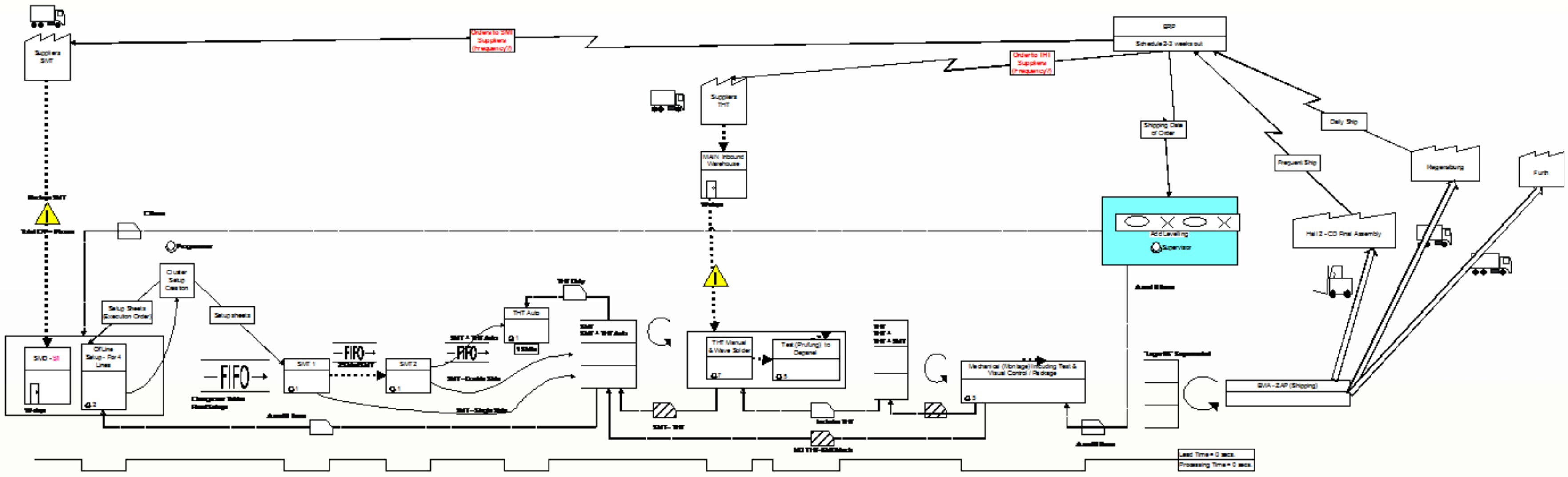
Considering Appropriate Technology Available Today – For EA

- Before constructing the Future "Ideal" State – consider available technologies
  - Utilizing Rapid and Error Free NPI Processes (New Product Introduction)
  - Empowering Production Planner with "Detail Awareness & Effort" for Assigning Production Sequences
  - Use of Group Technologies to eliminate or minimize changeover
  - Well thought out Hardware and Software system solutions to reduce or eliminate changeover time
  - Real Time Coordination and Visibility of activities across departments to synchronize Production Operations
  - Reliable Equipment and Processes
  - Leveraging Other Technologies such as RFID, MES

The Future State

- After “Brainstorming” and Extensive Critique of the “Current State”
- A Future State and Implementation Plan is Developed
- Implementation is broken into stages in the plan and monitored



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Implementation

- Product Families and ABC Analysis suggested different product assignment to lines than the traditional approach (Multi-Line Facility)
- KANBAN was appropriate for certain products, CONWIP for others
- Important to show success quickly to build momentum – “Hey there may be something to this Lean Thing after all”
- Linking the Planner to the Production Process in an “Intuitive Way” to reduce chaos was critical
- Better Planning – with Better Execution a Key

Benefits and Value Realized

- Changeover Time Reduction – better planning
- Improved Productivity – Less Line Downtime
- Reduced Material Handling
- Smaller Batches
- Reduced WIP
- Improved "Hot Job" Handling
- Unplanned Downtime Reduction
- Improved Visibility Across Departments
- Resource Reduction
- Improved Working Environment – Less Hectic

Tools & Methods for Lean Production Management in EA

(Electronics Assembly)

Thank You For Your Attention!

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