LEAN FLOW ON THE SMT FACTORY FLOOR

Michael Ford
Mentor Graphics
Wilsonville, OR, USA
Michael_Ford@mentor.com

ABSTRACT

Today's SMT factories need to be flexible and agile, making continuously variable quantities of larger ranges of products, meeting volatile customer demand changes, without having to resort to the creation and storage of dormant stock. Creating a lean manufacturing flow in this environment is a major challenge for SMT, where experience shows that productivity is inversely proportional to the amount of changes that are needed. Applying Lean separately to the production processes, and then also to production flow, has often resulted in conflicts so that neither approach has really become mainstream in the SMT area to the extent that might have been expected. A new approach is required, where we explore how a Lean, yet agile SMT operation can be created and sustained by turning existing engineering programming and planning functions "upside down" and using this as a basis to apply the ultimate in Lean thinking for manufacturing.

DIFFERENT APPROACHES TO LEAN

The traditional headline approach to factory efficiency has been to ensure that all processes run at their maximum capability, that there are resources always available, so that the best productivity metrics can be achieved. However, benefits from such optimized, Lean processes are realized only when production throughput is stable and predictable. This approach to Lean in manufacturing, focusing on the wastes associated with running a single or narrow set of processes is, therefore, fundamentally limited.

Another typical application of Lean is to consider the factory operation from the product and production flow point of view. A product may take many days to be produced, from the start as an initial bare PCB to the finish as a shippable product, and much longer if the time spent in the finished goods warehouse at the factory is included. The Lean approach from the product flow perspective would be to consider what proportion of that time was spent adding value to the product manufacture and what part was effectively idle, and therefore a waste.

This approach is analogous to a typical tourist on vacation going through an airport. On arrival, there is the check-in process, waiting in line only to then spend about two minutes to check the luggage and get a boarding pass. Next is security, again, a long time spent in line for less than a minute for the scan of hand-carry items and a walk through the metal detector. There may also be a passport check stage with the same pattern. Then, of course, the long wait in the departures area, which certainly seems like hours of wasted time. Finally, the call to depart, another line, another passport check, and the long wait in the seat on the aircraft until the plane actually gets clearance, taxis out, and eventually takes off. Looking back at the typical two-hour airport experience, perhaps 10 minutes of it was actually spent doing necessary things as preparation for travel, with probably another 10 minutes or so for necessary logistics to walk from one area of the airport to another.

Most of the time spent at the airport, from the tourist's point of view, has been a waste. From a process perspective, however, the check-in desk, security, and passport control were always kept busy, appearing to waste little of their time, and claiming that they are overworked after seeing the long lines of impatient people waiting. However, the lines ensure that there is 100% use of key staff, effectively ignoring the cost of waste to the tourist. The fact is, however, that looking back over a day's airport throughput, each stage completed the processing of everyone who turned up, eventually. The amount of work done met the amount of work required. Is it possible then to complete the same amount of processing while eliminating the lines?

ADDED-VALUE TIME

Going back to the factory, the analogy is the ratio of actual processing time of each product, including any necessary logistics, compared to the total time that the product spends in the manufacturing process. A three-day product build of a single product unit will likely consume just a few minutes of assembly time, another few minutes of test, and a few seconds packing. If it added up to a total of 10 minutes added value with another perhaps 10 minutes of needed logistics, just 0.5% of the time the product spent in the factory was added value, implying a 99.5% waste. This is extraordinarily different from the picture as presented by today's typical production metrics based on processes, but is an equally important measure for production, however, because it is a measure of the effectiveness of the flow of the operation that consumes significant investment, as well as the flexibility to meet changing customer demand.

Imagine arriving at an airport just 10 minutes before boarding and being able to comfortably arrive at the gate in time to board the plane. These days it is a rare case, usually reserved for celebrities and those who pay extra for the privilege. For the rest of us who work, for example, in factories, let's try to recreate that scenario, by imagining that there are no "stock options," that is, the factory will be required to make products in a linear fashion, without storage or accumulation of semi-finished or finished goods. A single product would enter the first production process, starting as a bare PCB, going through the screen printer, an AOI, some SMT machines, perhaps more AOI, and then it is turned over, with the same process applied to the other side. Straight out then into PCB manual assembly, then onto the in-circuit test. In parallel, other sub-assemblies would have been made so that they are all ready for the final assembly, functional test, packing, and shipping. To put this one unit of a product through the factory in this way is no issue, the whole process could be completed in 10 to 20 minutes assuming all of the processes were set up.

The problem with this approach is that during this time, most processes in the factory were idle, meaning that the issue of waste has simply been moved from one area to another. As the number of products to be made concurrently increases, the utilization of machines and processes improves, but inevitably it also leads to increased waiting time until key processes become available, especially where the different products are mixed that require processes such as SMT machines to change-over to different programs and material setups. The application of Lean in a pure sense to the production flow as with a Kanban control creates this environment especially for processes such as SMT, where there is an absolute need for consideration of process optimization.

DOING THE UNTHINKABLE WITH LEAN

Higher mix production has to provide increased delivery flexibility, so the scope of what is considered productive, efficient, and therefore Lean, including both perspectives of process efficiency and production flow, needs to broaden. The engineering task that is related to both of these areas is the planning tool because it is responsible for mapping products and associated work-orders to production processes efficiently way to achieve the required completion targets. However, planning tools are largely overlooked when considering Lean. We are told that a flow cannot be Lean if fixed in advance as a schedule would be and would not respond to a live "pull signal." We have seen with our airport analogy that the application of pure Lean, whether applied to processes or to the flow of production, is not the answer. At least for SMT production, one simply trades off the other. Let's instead take the "forbidden step" to look at what a Lean planning tool would look like, applying the principles of Lean thinking through the planning mechanism to optimize both the process efficiency as well as to optimize the factory flow so that waste is eliminated across both.

The logic of generic planning is not so complex when applied in most production scenarios. It is just a matter of arranging a sequence of jobs across a range of resources in a particular order that yields the best result against a defined criteria which reflects planning policy and priorities. Looking specifically into SMT production, with many complex automated processes, you would expect a prevalence of such systems in use already, but this is far from reality. Instead, what is commonly found is a rough site-based, high level requirement coming most likely from ERP, which has then been taken to create an Excel spreadsheet in which some attempt has been made to map the high-level requirements onto actual process operations. How can it be that this area of SMT production engineering has been neglected for so long? Our application of Lean thinking can quickly reveal some significant reasons:

1) Product Assignment Limitations

The effectiveness of planning is dependent on the number of options and choices that planning logic is given. In most cases currently, however, the decision as to which product will run on which SMT line configuration is made in advance of the planning process by the SMT programming engineers. Not only will SMT programming define what amounts to effectively dedicated production lines, they will also define groups of similar products that then have to be made together on the same line because they share a common material setup. This is seen as reducing the significant overhead needed to change materials on the SMT machines between products. These grouping decisions are made based on products that have similar materials and PCB layout so that the degradation in efficiency of machine programs, caused by non-optimum per-product material layout across the range of products, will not be too significant.

Such is the difficulty to perform the complete engineering setup of a new product, it rarely leaves the SMT engineering time for the creation of support for alternate configurations or material setups. The designated programs and groups can often remain in use for quite a considerable time, with performance reducing as new models are introduced and old ones become obsolete. Very little, if any, consideration is made for the efficiency of the dedication of a product or group actually meeting the required completion demand. The effect of this is to "strangle" the planning system by not allowing choices that might enable lines to be utilized that better meet completion demands, and the ability to change those decisions as required. This kind of loss is only very rarely measured or reported, as most metrics report against the scheduled target, whereas this loss is already a part of that target.

1) Physical Materials on the Shop Floor

The traditional approach to SMT material logistics is to create kits of materials for work orders, often hours in advance, following the sequence of work orders on the Excel spreadsheet. The reason for doing this follows a history of material inventory inaccuracies that often lead to unexpected shortages, which if found at the time of setting the materials at the machine, would stop the line from working. The various kits of materials created in advance ensure that the machines have everything they need to run in the near-term, giving time for material issues to be resolved. Unfortunately, this creates the scenario where a significant quantity of materials are allocated to production and are physically out on the shop floor. As well as the sheer cost of investment of such materials, this creates a physical barrier to making planning changes because the huge quantities of prepared materials would have to be collected and either re-allocated or returned to the warehouse whenever a change to the schedule is made. The result is a moratorium in which the immediate schedules planned, having materials assigned, cannot be changed. This moratorium can extend many days, thereby reducing the opportunity of any planning changes.

3) Process Modeling: It takes a long time in production terms to set up and verify materials on SMT machines between products. Some materials should be torn down, others can stay in place, and others can remain at the machine, perhaps moved to another location, whether they continue to be in use or not. Using groups of products that share common setups of materials can reduce this time, but the SMT machine program optimization itself is dependent on the material setup matching the layout of components on the PCB. So when grouping products together, the program efficiency can reduce drastically. Planning with Excel can easily use program times for existing SMT programs that have been made in advance and use the calculated program times for each product on their designated line. If a generic planning system was allowed to move a product from one SMT line configuration to another as part of the planning optimization process, the planning system would not have an accurate model of what the resultant cycle time would be, nor the specific changeover time required at the start and end of any work order. Therefore, such decisions, without the provision of huge amounts of reference data from SMT programming, are near impossible.

These are some of the main reasons then why scheduling and planning in SMT production has remained a “dark art” over the years. These issues have to be addressed to create a Lean planning system.

TURNING THE PROCESS UPSIDE-DOWN

Applying the principles of Lean to the product assignment limitation issue simply shows that the engineering flow needs to be turned upside down. Instead of SMT programming being first to make decisions about product assignment to production lines or to create common material setup groups, this should be done as part of the planning optimization. The product model needs to be processed by the programming tool, such as design data import, the merge of the bill of materials (BOM) and management of a central material shape library, but no assignment to machines or lines should be made. Then the planning optimization engine must be able to model material assignments to machines, program times, line balances, and changeover times in a reasonably accurate way. The planning system will not be able to do this to the depth of actually creating optimized SMT programs because each iteration could take hours. However, with a good model of the machine capability and timing, with the ability to create groups of products that have common material setups based on actual completion requirements, it can be done in a reasonably short time per iteration.

The next issue then is materials, where we need to replace the advance preparation of kits “push” approach with a Lean material “pull” flow. With direct connections to the SMT machines through real-time communication interfaces, information can be gathered continuously that counts the consumption of materials and completion of products. Knowing the quantity of materials originally on each reel, together with the sequence of production, computerization can be applied where a “pull” signal is generated based on the expected need for replenishment of each material or the provision of materials for changeover. Instructions for material logistics from and back to the warehouse can then be made just-in-time (JIT). With the unique barcoding of material units and location management within the warehouse, the integrity of material inventory on a physical basis is maintained on a high level, meaning that the risk of unexpected material starvation at the machine is avoided. The accuracy of material inventory and the ability to find them when needed means that no additional buffer of materials is required between the warehouse and the shop floor, eliminating almost all unused materials, which represents a significant investment saving. For our Lean process, however, there must be no over-commitment of material, that is, the production plan is able to change to anything at any time without the need for extensive material reallocation. The moratorium for schedule change is now hugely reduced, basically to whatever is already running. The result is a moratorium in which the immediate schedules planned, with materials assigned, cannot be changed. The physical barrier for making short-term planning changes has been removed.

The final part of the Lean planning operation is how it integrates into the production flow. Let’s look at an example of a Lean factory working with a daily Lean planning cycle, two-days ahead. Let’s say today is Tuesday, and the delivery requirement for Thursday is received. The factory is already making products that will be shipped today and tomorrow. Rather than fixed production lines, the final assembly operation will likely consist of Lean production cells, where any cell can be configured to assemble or test a range of products, the assignment of which can be changed or reconfigured at short notice. Each product can require many operations, one or more of which can be performed in parallel by a pool of cells. The Lean production plan tool will start with the shipping requirement and work backward, so that each prior pool of cells takes as its completion requirement the next set of cells in the process in terms of initial product requirement time and then flow rate. The number of cells assigned to each stage of each product at any time will be calculated together with resource constraints. So far, a fairly standard Lean production flow procedure.

As we work back to the SMT area, however, things become more complex. The new requirements for Thursday production are derived from the plan of the first assembly cells for each product, again in terms of start time and rates. The production plan tool knows the existing schedule for all processes in the SMT area, including the lines of SMT machines and related processes such as screen printing, reflow, AOI, ICT, and hand assembly. The Lean production plan tool also has access to the real-time status of the machines and processes, using the same data from the direct machine interfaces as used by the Lean JIT materials logistics system. The availability of materials is also known because the production plan software can take a snapshot of the current materials situation from the JIT materials system. The on-going consumption of materials is then calculated using the information about the product models coming from the SMT programming software. Using a sophisticated simulation model of each machine, the production plan software can then optimize both the sequence of work orders as well as create the common feeder setups that enable the SMT machines to make a range of products without the need for material setup changes between products. This unique new addition to the planning software provides the elimination of waste by way of optimization, from an equipment perspective as well as from the product flow perspective. The final piece of optimization is to create the final SMT programs for the machines, which can be done with a third-party multi-vendor process preparation tool, or by using the software as supplied from the machine vendor. This is now happening after the planning optimization rather than before. The daily cycle may not fit all customer needs. It can be more often, perhaps every shift, or less often, such as weekly or even monthly. The principle, however, remains the same.

LEAN PLANNING – IT IS A THING

This method of reinventing the planning operation to support the optimization of process flow as well as asset utilization creates not only a Lean environment where more waste is removed than by the consideration of the two parts separately, but also creates a flexible environment that can respond to sudden changes in short-term demand without the penalty of significantly reduced productivity. The same factory output capability can be realized with a greatly reduced cost of operation. Storage of materials and semi-finished goods on the shop floor has all but been eliminated. True asset utilization has been improved. Responsiveness to changing demands means that the stock of finished goods at the factory and in the distribution chain can be reduced without risk of supply starvation, reducing depreciation risk and storage costs.

The Lean shop floor then is perhaps not quite what might have been expected. Lean production with cells and dedicated Lean processes are one thing, but it is the application of Lean to the whole operation that is the key, as governed by the Lean production plan. This Lean planning software as we have described here, is also perhaps the critical piece that provides the opportunity in SMT for computerization of multiple automated processes as defined by the European initiative, Industry 4.0. This approach also enables factories to make only what is needed, when it is needed, automating both processes and inter-process communication and control.