Lean Kitting: A Case Study

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Abstract
Kitting is the first step in printed circuit board assembly. It is initiated well in advance of the actual production start to be able to prepare and deliver the kit on time. Kitting involves the gathering of all the parts needed for a particular assembly from the stockroom and issuing the kit to the manufacturing line at the right time and in the right quantity. This paper discusses kitting, describes ways to eliminate waste in different phases of kitting, and illustrates lean kitting using a case study conducted in a major contract manufacturer site.

Introduction
Traditionally, kitting is initiated by the production control department based on the shop floor order as generated by the plant's ERP/MRP system. Production control will first verify that adequate quantity is available for each part number. If there are parts shortages, parts are ordered. In general, the kit is not released to the stockroom until parts arrive, but in some special cases a shop order with a part shortage can be processed. Production control then releases the kit to the stockroom for picking. The kit is typically sent to the off line setup area within 48 hours. The time it takes to pick all parts depends on kit size and number and skill of employees.

When executed properly, benefits of kitting include:
- Maximize value add time of operators
- Easier operator training resulting in reduced training cost
- Maximized machine utilization – no line stoppage due to part shortages or searching for parts
- Reduced WIP
- Reduced lead times
- Reduced part damage due to excess handling

ERP/MRP systems are inherently inaccurate at maintaining on-hand inventory quantities as material is moved to and from the shop floor during kitting and restocking processes. Worse, ERP systems typically only know the total quantity of a part type and not how that material is delivered (i.e.- 20,000 total components vs. 4 reels of 5,000 components). This inaccuracy and lack of granularity, combined with stockroom personnel mistakes, lead to kitting problems that include:

- Insufficient quantity of components
- Excessive quantity of components
- Wrong components
- Incomplete kits
- Insufficient quantity of component packages (for example, insufficient quantity of reels for split parts)

These kitting problems will lead to increased machine downtime, lead times, and manpower.

Various shop floor supply schemes that vary the location of component storage units with or without kitting are used by electronic assembly plants. The following cases are the most typical:

- <u>ERP driven kitting from central stockroom</u>. Production Control releases kits generated by the ERP system to the central stockroom. Production Control relies on the ERP system to ensure enough quantity is available in the stockroom. Inaccuracy of on-hand inventory counts in the ERP system is a major issue in this approach. In case part shortages occur during shop floor order runs, the operator must walk to the stockroom, fill out paperwork for additional parts, wait for parts, and then walk back to the assembly line to do changeover and continue production. This can take 15-45 minutes and represents waste and lost production. This approach is still very much in use, especially in large contract manufacturing sites.

- ERP driven point of use kitting. This process is similar to central stockroom kitting, except inventories are located in storage units located on the shop floor close to the assembly lines. Storage units can be dedicated to a customer, to all SMT lines, to a set of assembly lines (for example lines that place components on one side only), or to the entire shop floor. The advantage of this approach is reduced machine downtime and reduced stockroom manpower. The disadvantage is increased floor space requirement and an increased level of control required to ensure operator discipline in picking components. The issue of inaccurate on-hand inventory counts still remains. This approach is more likely to be found in OEM assembly plants.
- In-house controlled supermarket-based kitting. Components are received and stored into the central stockroom. Supermarkets are placed throughout the shop-floor. The daily demand of parts and supplier lead times are used to determine the optimal inventory levels. Kanban cards are used to replenish supermarkets. Dedicated personnel are responsible for collecting and converting kanban cards into replenishment orders which are sent to the central stockroom. Kitting is performed directly from supermarkets by line operators. The advantage of this approach is reduced manpower. The disadvantages are operator training, lost inventories (if a reel is misplaced, a new one is ordered without locating lost one), and complex replenishment logic that requires advanced inventory control software. The issue of inaccurate on-hand inventory counts still remains because counts are still maintained by the ERP system. A variation of this approach is where only the most frequently used parts are stored in supermarkets and kitting is a combination of central stockroom kitting and supermarket kitting.
- Supplier controlled supermarket based kitting. A central stockroom is not used. The ERP system-based component procurement is abolished. A contractor who can supply all types of components is used. On-hand quantity requirement for each component is established based on the ERP forecasts (weekly consumption), or even better, actual sales. Part consumption and attrition is maintained using an MES system. The component supplier gets (daily) data from the MES system on part consumption. The supplier restocks parts once a week based on MES supplied data. The advantages of this approach are reduced inventory cost, more accurate inventory counts, reduced manpower, reduced paperwork and purchase order cost. The disadvantage of this approach is initial implementation cost. Also, tying all inventory needs to one or a few suppliers may be risky.
- Outsourced kitting. Component storage and kitting are pushed to the suppliers, as done by Toyota in the San Antonio Tundra plant. This is a way of reducing manpower and pushing waste to the suppliers. In the Toyota plant, suppliers deliver parts just-in-time and perform kitting for assembly lines. Toyota operators just assembly parts, which maximizes operator value added time and reduces manpower for Toyota. The same approach of outsourcing component storage and kitting is available to electronics assembly companies. Outsourcing kitting will result in a reduction of purchase orders, reduced administration costs, cash flow benefits from reduced inventory, reduced manpower, and reduced plant space requirement. Again, the disadvantage is the risk of loss of control of the materials management process.

Is Kitting a Waste and Should it be Eliminated?

In a lean world, kitting is considered a waste. Following Toyota's lean thoughts of the past, we should provide component storage racks, replenished using kanban signals, alongside assembly lines and have operators pick parts to set up the job when needed. In addition to that value added work, operators will also be responsible for locating parts, performing part verification, setting parts on feeders and setting feeders on machine. This approach, although eliminating kitting as a waste, may create waste in the area that does much more damage to the company's bottom line – assembly line throughput and process quality. An attempt to eliminate kitting should not be undertaken without much consideration of how it may affect the overall process and assembly line efficiency.

Furthermore, it has been recently reported that Toyota has started using kitting in some of their plants for high volume assembly operations **[**Lean Enterprise Institute, 1997**].** Toyota has implemented a new kitting process, called Set Pallet System (SPS), in their new production facility in San Antonio that makes Tundra full-size pickup trucks. Previously, line-side storage racks were used by operators to pick parts. Operators would walk from their assembly station to each rack and pick parts to install. SPS introduces kitting personnel that receive a signal with a list of parts to be kitted, pick parts from storage racks, and then deliver pallets of parts to the assembly stations. Assembly operators are not involved in the part picking process any longer. The advantage of this approach is more value added time by the operators, cleaner work areas with visual control, fewer part selection errors, and easier training of assembly operators. The disadvantage is increased manpower by adding kitting personnel.

This approach is equivalent to the supplier-driven supermarket kitting for PCB assembly, as explained in the previous section.

Lean Kitting

The approach taken in the kitting process improvement project described in this paper can be summarized as follows:

- Eliminate waste related to machine downtime caused by invalid kitting
- Kitting done right the first time
- Eliminate waste in kitting

The priority is to eliminate waste on the assembly line by making sure machine downtime due to kitting problems does not happen. Next is to eliminate waste and make the kitting process as lean as possible.

This Lean Kitting project was implemented at a large electronics contract manufacturer's site. The project involved an assembly line that included a new Fuji NXT pick-and-place line. The NXT machine is based on a new concept of modular, scalable, and reconfigurable pick and place machines. This NXT machine had 10 modules. Thus, the same part number may occur on different modules as a result of placement sequence optimization and load balancing.

In consulation with the plant management, the following goals were set:

- Reduce kitting cycle time
- Reduce manpower
- Reduce number of partial material packages returned to stockroom
- Eliminate the issue of insufficient quantity of material packages (reels) for parts split between different modules on NXT machine.
- Eliminate the possibility of wrong components being kitted by implementing electrical component test and component verification

Kit quantities per part number calculated by the ERP system do not take into account that a part could be split between a number of modules during machine optimization. For example, if the kit requirement for a part that is split between two modules on a machine is 4500, the stockroom may find a reel with 5000 parts and kit it for that part, which will cover the BOM quantity plus estimated attrition. The single reel will be sent to off-line setup and it will need to be split, or another reel ordered, which delays off line and adds manpower related costs. Another case is when the stockroom does kit two reels, with quantities of 4000 and 1000. Let us assume that the quantity placed from the first module is 2800 and from second module is 1700. The off line setup personnel will have two reels to prepare for the run and production can be started, but there is not enough quantity on the second reel and the machine will stop until a new reel is provided, adding to the machine downtime.

In this project, all activities that lead to delivering the kit to the assembly line, were considered to be part of kitting, including:

- Pulling enough quantity to place each part (including attrition)
- Determining which reel will be used first
- Verification of component electrical characteristics
- Verification of component feeder type, feeder rotation, and height verification
- Lead free compliancy
- Setup verification

Even though kitting can also include delivering the tooling kit to the line, it was considered out of the scope of this project.

Pre Improvement State
The line kit was prepared by stockroom personnel based on the kit released by production control. In case the kit was short, the stockroom would hold it until missing parts were provided. The line kit contained parts for all machines in the line. The parts needed to be separated by machine and by first and backup reels. For the NXT lines, the kit was separated by module by the operator visually checking license plates (also sometimes referred to as ReelIDs; a unique barcode identifier applied to each piece of material) and comparing them and their part numbers with the setup sheets. Separation of the NXT kit across modules took on average of 2.5 hours for the bottom side and 1.5 hours for the top side. For the NXT line with 10 modules, the kit was separated into 3 bins with 3 separations per module each, and the license plates for the 10^{th} module were put into the last bin and marked as the 10^{th} module.

The NXT kit was then moved across the plant to the NXT off line setup area. First, an operator was dispatched to start the electrical component verification, using an LCR meter (Inductance, Capacitance, Resistance). A second operator was sent after the first operator was given some time to test a certain amount of license plates. The second operator scanned license plates that were already LCR-verified and married them to feeders (via bar-coded feeder IDs) to complete offline setup verification. Component verification using an LCR meter was performed for the first license plates only and not for the backup license plates. Verification took on average of 55 seconds per component. Each license plate was tested, even if it had been previously tested. After the test, a "pass" sticker was put on the license plate. For components that could not be measured, license plates were put aside and another operator would verify those license plates visually, using component markings or manufacturing part numbers.

After the first license plate was verified on the feeder, it was placed on the feeder cart. After the entire setup was verified, feeder carts – one for each NXT module – were moved to the "NXT Supermarket/Kanban" area to wait for the online machine setup.

It took 3 people an average of 6.8 hours to process the kit that had been received from the central stockroom and deliver it to the NXT line. For components that had more than one component package kitted, it was important to maintain the order the packages were mounted on the machine, to minimize the number of partial packages that needed to be returned to the stockroom after the job was completed.

In the remainder of this paper, the term "license plate" will indicate a label attached to each piece of material that has a material ID and part number bar-coded on it.

After analyzing the process, the following types of waste were identified:
Extra Processing Steps
- Manually separating materials among NXT modules
- Re-ordering of part numbers that go into multiple NXT modules
- Redundant reel component testing which was separate from setup verification
- A "pass" sticker placed on the license plate when component has passed electrical test
- Splitting license plates if that is chosen as the solution for the ERP system not supplying enough quantity of license plates for split part numbers
- Difficulty locating components that are separated from license plates for electrical test since the company used black static-free mats for placing components

Defects
- License plates that fail electrical test were placed into "pass" bin and later used in assembly

Motion
- When scanning feeder, scanner label was on the opposite side of the feeder compared to the operator, forcing the operator to reach over and twist arm and hand to scan bar-coded feeder ID

Waiting
- If ERP system did not supply enough quantity of license plates for split part numbers they were ordered from the central stockroom

Transportation
- Material preparation and off line setup areas were separated and far from each other

Inventory
- Too many partial license plates returned to stock
- Too many setup carts with a single license plate on it in the kanban area.

Value stream mapping of the Pre Improvement state is shown in Figure 1.

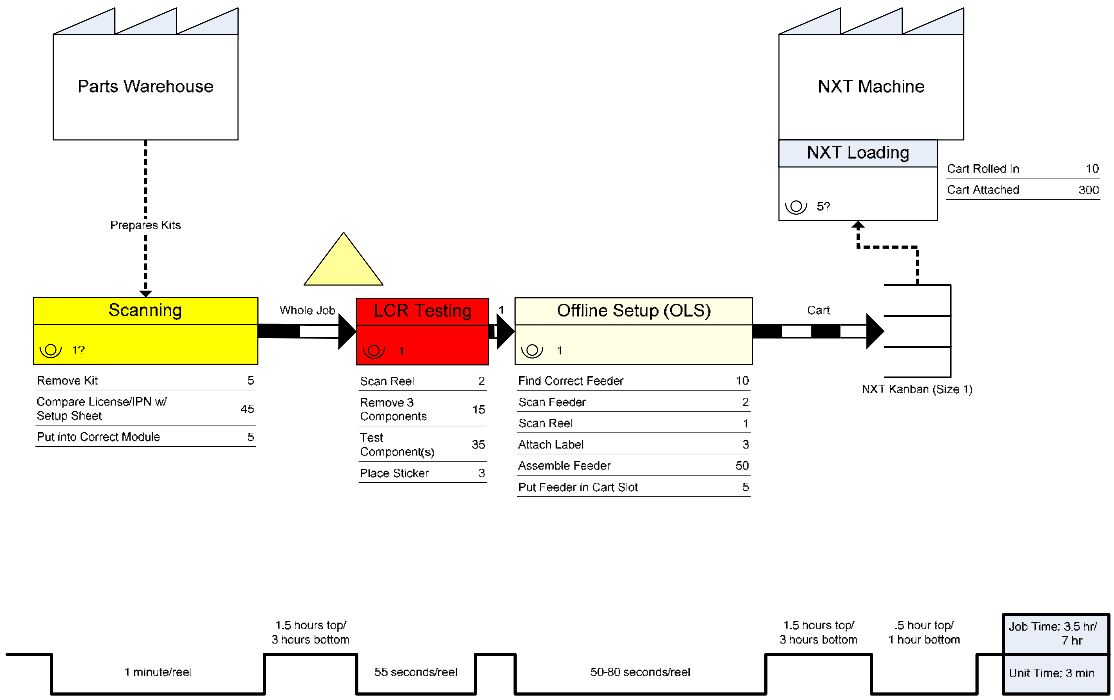

Figure 1. Value Stream Map – Pre Improvement State

Process Improvements

After a detailed analysis of the process, the following waste elimination goals were set:

- Install a computer application to automate the entire process, perform it on one station with one operator (instead of 3), and cut lead time by 50%.
- Provide bins with more than 3 modules/separators to avoid marking materials for the 10th module.
- Move NXT offline setup area to the same area material is received from stockroom.
- Integrate LCR measurement into setup verification to prevent the license plate from being verified on the feeder if it does not pass electrical test. This eliminates problems with wrong component placements and redundant LCR checks
- Provide white background on the desk surface where operators place components for the LCR measurement.
- Ensure that a unique license plate does not change for a particular piece of material to avoid repeated measurements of the same license plate and eliminate the need for placing a "pass" sticker on the license plate.
- Place another feeder bar code label on the opposite side of the feeder for easy and faster off line setup verification.
- To solve the issue with kitting enough license plates for part numbers of multiple feeders, identify 13 part numbers across 27 assemblies that are split. Based on historical work order run data, estimations of the number of license plates and quantity levels that need to be maintained in the small supermarket were made so that material could be placed alongside the line. Kitting is now a combination of central stockroom kitting plus kitting materials for these 13 parts at the supermarket.
- The supermarket is caged with a single entry point. The line lead operator will have control over the supermarket, picking parts and putting away parts.

Figure 2 describes process implemented in the computer application that performs component verification.

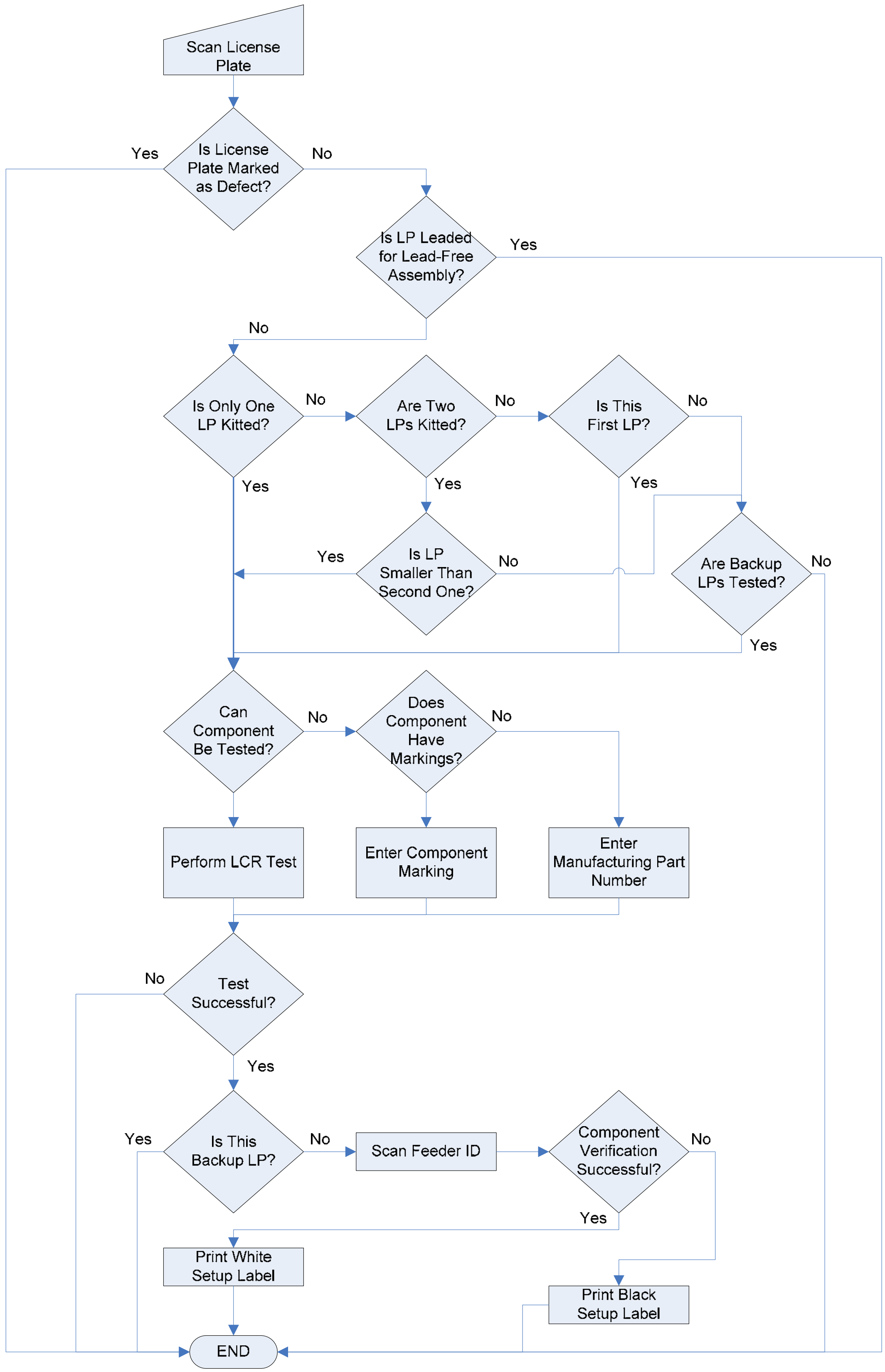

Figure 2. Component Verification Process Chart

The application performs the following component verification activities:

- Checks whether license plate is marked as defective due to recent customer feedback
- Checks whether the license plate is lead-free if the job is for a lead free assembly
- Determines which license plate is first to be set up on the machine
- Performs component test: electrical (LCR) test if data is available, or if it isn't, a markings test if markings are available on the component, or manufacturing part number (MPN) verification if markings are not available either.
- Verifies that component belongs to the setup
- Performs MPN data verification, i.e. checks whether feeder type matches required feeder type by MPN, whether feeder rotation matches MPN feeder rotation, and whether height matches MPN height. If MPN validation fails, which may affect machine program, black setup label is printed to warn process engineers that machine program change could be required.

Value stream mapping of the future state is shown in Figure 3.

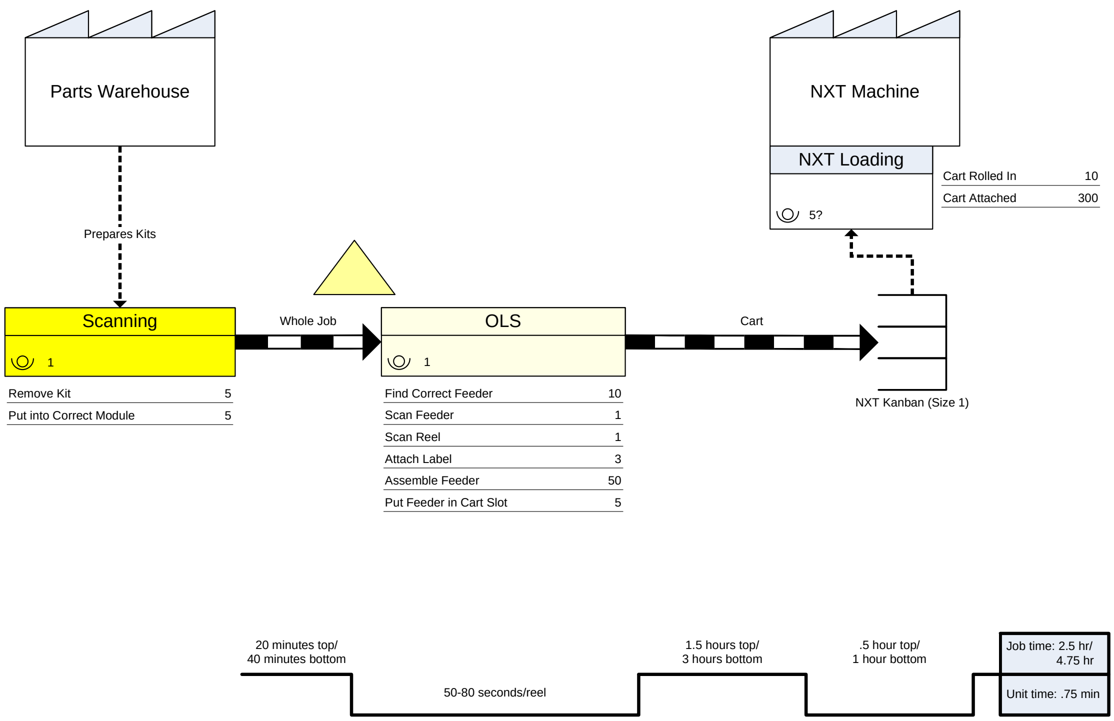

Figure 3. Value Stream Map – Future State

To validate the process improvement solutions, the future state process was modeled in a simulation model using an Arena Simulation package. The simulation model, shown in Figure 4 validated the goals, as shown in Table 1.

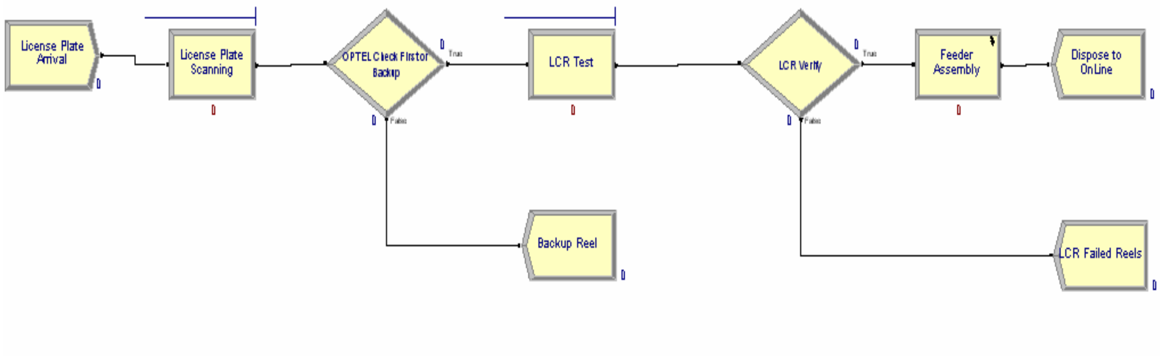

Figure 4. Simulation Model of the Future State

Table 1. Simulation Results

	Pre Improvement State	Proposed Solution 1	Proposed Solution 2
Total Cycle Time	6.803 hours	4.33 hours	2.22 hours
Processing Time/ License Plate	2.046 minutes	2.0803 minutes	2.080 minutes
Manpower	3 operators	1 operator	2 operators

The new process has been tested in production and these simulation results proved valid.

Conclusion

We discussed the role of kitting in electronics assembly and whether it should be eliminated as waste. We described a lean project aimed at eliminating waste in a kitting process for a major contract manufacturing site. Our recommendation is not to eliminate kitting and offline setup, but instead eliminate waste from kitting and make sure it is right the first time so that there is no machine downtime caused by invalid kits.

In general, this is the process recommended for electronics assembly plants:

- Dismantle central stockroom if currently in use
- Abolish ERP system based component procurement
- Sign a contract with a single contractor who will supply all types of components used in the plant
- Establish on-hand quantity for each component based on actual sales
- Use an MES system with real-time machine communication to monitor component consumption and attrition
- Ensure component supplier receives (daily) component consumption data from the MES system and restocks components once a week
- Establish several component supermarkets on the shop floor – using automated vertical carousels if possible
- Set up an offline setup area in each supermarket for kitting ,component verification , and setup verification that uses the MES system
- Determine which reels should stay on feeders at all times and maintained them in appropriate supermarkets. Use the MES system to maintain the quantity of reels that stay on feeder per part number
- Plan a Kanban setup area where setup carts are delivered for each supermarket (offline setup area)
- Provide a maximum of three setups at a time for each assembly line – one online, one in Kanban area waiting for production, and one currently being kitted
- Ensure the MES system provides a kit monitoring tool that allows everyone in the plant to view the status of each kit and KANBAN content
- After setup is completed, all parts (except reels that stay on feeders) are taken off the feeders and returned to the supermarket
- Establish a duty-cycle based feeder maintenance approach using the MES system

References

Lean Enterprise Institute, 1997, "Toyota's New Material-Handling System Shows TPS's Flexibility"