The decision by EMS firms and OEMs to reduce lot sizes on the plant floor to respond to order changes comes at a hefty price. With margins already razor thin, increased changeover frequency fuels the fire, as planned downtime rises and asset utilization falls. The probability of quality issues also increases as the number of opportunities for error during setup occurs.

This growing negative OEE (Overall Equipment Effectiveness) trend can be seen throughout facilities in North America. Facilities once running world-class OEE rates (above 85%) now fall below 70%, even 50%. The shift of large-volume production overseas has created an adverse effect to OEE. Changes are made on the production floor to satisfy requests for smaller lot sizes, faster turn time and schedule flexibilities. Balancing these changes, manufacturers need to address the side of the OEE equation they can control: their process. Often, however, limited resources and funding allocations result in long-term damage to the manufacturer’s profitability.

Pretend, for a moment, you are plant manager for Company ABC and have instructed your engineers to improve cycle time by 10%. Will that alone improve OEE? Not likely, but let’s prove it. As everyone in the Lean world knows, OEE = Availability x performance x quality

Another way to look at it is:
OEE = Good pieces x ideal cycle time / Planned production time

Assume manufacturing requires a changeover (C/O) time of 20 min. from model A to B, and the current cycle time (CT) for both models is 1 min./panel. The current lot size is 200 boards, with about 10 min. of unplanned downtime (DT) during production during each run. The current OEE is around 87%. With a 10% cycle time improvement, OEE becomes 86%. That’s not much of a change, and probably worth the investment to increase throughput capacity. But what happens when the lot size is reduced to 100 boards after improving cycle time? OEE drops to 75% from 86% (Figures 1-2). What happened?

Now let’s say you made a dramatic improvement in cycle time and reduced it 50% (0.5 min/board). How did improving throughput by 50% result in a 77% OEE with a lot size of 200 and only 63% when lot size is reduced to 100 (Figure 3)? Answer: I changed half the equation and didn’t compensate for the other half.

What are the correct steps to improve OEE while decreasing lot sizes and cycle times, and understanding what process improvements are required to achieve the OEE goal? If you as the manager are going to require engineers and production to maintain an 85% OEE target with a 0.5 min. CT and 100-piece lot sizes, you also will need to support the resources and expenses associated to achieve a combination of reduced changeover time and unplanned DT. In Figure 4, assuming an improvement of 50% to unplanned downtime to 5 min. would require an improvement in C/O time of 75% (around 4 to 5 min.). Is this physically possible with your equipment, labor resources and current factory processes? The trend in lot sizes seems to be headed from 500 to 50, but Figures 1-3 show the severity to OEE as cycle time drops, assuming constant C/O and DT. Manufacturers with dense, complex boards, or who develop multi-up panels requiring longer CTs between machines, are able to maintain a higher OEE rate with lot sizes closer to 50 (Figure 5).

The first step toward improving OEE is to identify the root cause of the problem and prioritize the improvements. Table 1 shows the improvements in program cycle time, and Table 2 shows the current revenue analysis. Table 3 shows the proposed revenue opportunity.

### Table 1. Improvements in Program Cycle Time

<table>
<thead>
<tr>
<th>Product Family</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in changeover carts</td>
<td>50%</td>
<td>50%</td>
<td>25%</td>
</tr>
<tr>
<td>Reduction in changeover time</td>
<td>33%</td>
<td>33%</td>
<td>33%</td>
</tr>
<tr>
<td>Reduction in cycle time</td>
<td>10%</td>
<td>10%</td>
<td>9%</td>
</tr>
<tr>
<td>Increase in line capacity</td>
<td>10%</td>
<td>18%</td>
<td>15%</td>
</tr>
</tbody>
</table>

### Table 2. Current Revenue

<table>
<thead>
<tr>
<th>Product</th>
<th>Current Run Hr./Mo.</th>
<th>Average $ value/board</th>
<th>Average cycle time (min.)</th>
<th>Total revenue $/mo.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMT 2</td>
<td>200</td>
<td>$75</td>
<td>1</td>
<td>$2,605,500</td>
</tr>
<tr>
<td>SMT 3</td>
<td>200</td>
<td>$75</td>
<td>1</td>
<td>$2,605,500</td>
</tr>
<tr>
<td>SMT 4</td>
<td>179</td>
<td>$75</td>
<td>1</td>
<td>$2,025,500</td>
</tr>
</tbody>
</table>

### Table 3. Proposed Revenue Opportunity

<table>
<thead>
<tr>
<th>Product</th>
<th>Proposed Run Hr./Mo.</th>
<th>Total new hr. available</th>
<th>Average $ value/board</th>
<th>Added potential revenue/mo.</th>
<th>Added annual potential revenue</th>
<th>Potential revenue % increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMT 2</td>
<td>180</td>
<td>119</td>
<td>$75</td>
<td>$35,000</td>
<td>$4,266,000</td>
<td>20.60%</td>
</tr>
<tr>
<td>SMT 3</td>
<td>145</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMT 4</td>
<td>135</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
profitability is determining whether judging a facility by OEE alone is truly a Key Performance Indicator (KPI). If reducing cycle time resulted in an extra 10% in sales that month, was it really wrong that OEE fell? If I were an operator on the production floor and my performance based on OEE, I’d slow all my machines to half speed and have a longer run-time to make my OEE look great. After all, that’s what the manager is judging, not profitability. OEE is just one KPI, but the true KPI should be net profitability. Increases in profitability mandate improvements in the processes performed to manufacture goods. Focus needs to be on the reduction of non-value-added times, from staging, kitting, changeover, unplanned downtime, material handling, labor resources and quality.

A recent episode shows how OEMs can reduce operational costs through proper evaluation of the entire operation, not just the SMT lines. A leading commercial alarm system manufacturer was producing PCBs for its finished products. It recently had reduced lot sizes to meet customer schedule needs, but did not improve internal processes to reduce changeover and downtime. The OEM’s primary concern was improving a shrinking on-time delivery rate, which slipped to 80% from an original target above 95%. The solution: a four-line facility, two-shift operation with each production line containing approximately 25 different models to build. Lot sizes ranged from 10 to 600, with an average of about 60, a changeover time averaging 20 min., and 15 min. of additional unplanned downtime with an average cycle time around 1.1 min. The high percentages of changeover and additional unplanned downtime were due to waiting for the next work order to be ready from kitting, incorrect parts loaded onto feeders, and process steps performed during a changeover. **Figure 6** represents the current OEE state of about 60%.

After an in-depth, weeklong onsite analysis consisting of observing current factory processes, a new model was developed, approved by management and implemented. The model included development of a combination of fixed feeder and exchange feeder setups on each line, which reduced kitting activities along with changeover activities. Program cycle times were improved through better optimization tools, as well as integration of fixed nozzle changer and board support setups. **Tables 1-3** show the solution proposal results.

The solution proposal included:

• Using customer-provided data of production schedules, volumes and observations during onsite visits, the proposal focused on reduced kitting efforts.
• Each line was carefully evaluated to determine part commonality.
• **Figure 7** shows the feeder tables determined to be most effective to be fixed with specific high use parts across each of the three production lines.
• **Figure 8** shows benefits gained by assigning specific parts to fixed locations with tape splicing over kitting exact processes.

Product family A (SMT2) details:

• 50% reduction in exchange carts 8 carts → 4 carts.
• 33% reduction in changeover time 15min → 10 min.
• Estimated 40% reduction loading parts into feeders.
• Estimated 10% reduction in overall product cycle times.
• Estimated 10% increase in line capacity.
Product family B (SMT3) details:
• 50% reduction in exchange carts 8 carts ➔ 4 carts.
• 33% reduction in changeover time 15 min ➔ 10 min.
• 40% reduction loading parts into feeders ➔ 239 kitting/setup man-hours.
• 21% reduction in overall product cycle times.
• 18% increase in line capacity: Current 200 hr. to produce ➔ Proposed 145 hr. to produce.
• Increase possibility to produce within one shift, with occasional OT or 2d shift based on demand spikes.

Product family C (SMT4) details:
• 25% reduction in exchange carts 8 carts ➔ 6 carts.
• 33% reduction in changeover time 15 min ➔ 10 min.
• 35% reduction loading parts into feeders ➔ 132 kitting/setup man-hours.
• 12% reduction in overall product cycle times.
• 15% increase in line capacity: Current 179 hr. to produce ➔ Proposed 135 hr. to produce.
• Increase possibility to produce within one shift, with occasional OT or 2d shift based on demand spikes.

To improve OEE, improvements had to be made in the changeover processes, as well as the other unplanned downtime activities because, as mentioned, the improvement in cycle time alone would have resulted in a negative impact to OEE. The new average cycle time reduced to 0.78 minutes from 1.1 minutes. To offset this impact, improvements were made in the changeover processes to reduce the time from 20 to 10 minutes, and unplanned downtime from 25 to 5 minutes, by improving kitting activities. Larger minimum lot sizes of 60 or more also were considered to achieve above the new 76% OEE rate. Further steps are in place to further reduce changeover time and increase lot sizes to around 105, which would help achieve an 85% OEE (Figure 9).

The result provided a well-balanced flow between kitting/prepping and the production lines. Consolidating non-value processes and improving OEE permitted the potential to generate an additional $6 million/year in revenue and improved net profitability. Small lot sizes then could be used while still maintaining higher OEE levels. A combination of reduced unplanned downtime and changeover time with better cycle time optimization provided an increase in plant capacity and the reduction of one production line. Not only were three lines now able to produce what four lines were producing, they also were able to consider the possibility to operate on only one shift, if necessary. The main objective was achieved; to improve on-time delivery while having the flexibility to run small lot sizes to meet customer daily demand changes while maintaining a higher OEE level.

In summary, a combination of improvement initiatives (Lean, Six Sigma, etc.) is necessary for EMS and OEM SMT manufacturers to be profitable. Taking the time to calculate the true net benefit of the improvements is a must. All departments within the facility must work as a team to guarantee the savings captured is real. Allowing purchasing to buy a cheaper component because it saves 5 cents/board doesn’t make sense if it results in a 15-cent increase in scrap, rework or labor time required to use the cheaper component. Processes need to be in place to ensure scrap, rework and labor times improve or remain constant, so any cost reductions truly can be captured and contribute to the bottom dollar. Inviting a third-party consultant to review your operations is an inexpensive option to gain insight and higher confidence that an alternative hasn’t been overlooked. These types of engagements generally result in a 10:1 ROI benefit.

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