当考虑到各种内容的所有因素时，不实行自动化的实际成本在很多情况下可能明显高于很多制造商所意识到的，包括劳动力、场地面积、产品处理、重新测试、以及材料成本。劳动力是一个很大的问题：雇用成本不是没有后果的。招募、培训、保留、质量、生产率以及基础设施都有相关费用，同制造的劳动力因素直接相关。所谓生产线后终端自动化正取代出现在定制和特殊机器人生产单元工作室。新设备可抓起、感知、测试和贴安装特殊尺寸的元件，而无需定制或特定软件。

Can Odd-Form Automation Increase Returns?

Allen W. Duck and Patty Chonis

Still placing odd-form parts by hand? How to determine ROI of end-of-line automation.

Like so many phrases, return on investment is overused, yet engineers accustomed to dealing with SMT, VOC, PTH and ICT now utter ROI as part of their everyday language. But do we know what ROI really measures in the manufacturing arena? Do we understand how it can be used to justify *and* quantify investments in capital equipment? And is ROI even an appropriate datum, given the available manufacturing information flows?

As a simple equation, ROI can be described as

$$\frac{\text{(Profit/loss before extraordinary items + interest expenses)}}{\text{(Total assets – non interest-bearing liabilities)}} \times 100$$

ROI is a historic reference point. It cannot be determined as fact that any investment has made or lost money until after a period of time has passed. Companies use ROI more as a target, a corporate goal and a measurement of management effectiveness. For those buying and selling machinery, the term is often misplaced. Other metrics that could be more relevant to capital justification are positive cash flow, payback period, tangible quality improvements, floor space savings and reductions in cost-of-goods (COG).

Within electronics assembly, the avenues of competitive performance have been explored to the extent that very few tangible increases in efficiency can be attained. Finance options have brought cash flow and improved results, new SMT machinery has reduced overall footprint and AOI systems permit QA to be validated at multiple points on the assembly line. In addition, the cost of equipment has significantly declined due to economic and supplier pressures.

Faced with a less than 3% (in many cases) reduction in margins and increased capacity, are capital expenditures a reasonable agenda item for the next management meeting? Without a doubt. To curtail technology investments will quickly result in technological obsolescence, impacting any potential competitive advantages.

The past 12 months have taught us many lessons, not the least of which is the impact of labor on the efficiency of a company and the COG of its products. When demand peaks, manufacturers need to make their profits. This often leads to large capital outlays for new plants and machinery. Furthermore, increases for labor are sought to support the machinery and fulfill the manual elements of assembly – impacting variable costs.

Much of the capital outlay is kept off the balance sheet through the use of lease companies and cash outflow is minimized via the same financing mechanisms. In essence, machinery is justified and supported through cash flow. Machinery is disposed of, moved to other facilities, sold at auction or returned to the financers. The original cost is seldom realized if a machine was purchased, although some degree of return is ascertained. In effect, there is a cash inflow or cessation of cash outflow when cash is most important.

Labor is the greater issue in that the costs of hiring are not inconsequential. Recruitment, training, retention, quality, productivity, infrastructure: all have associated costs directly linked to the labor element of manufacturing.

Labor that has cost so much in recruitment, training and retention may become redundant with production fluctuations. The cost of redundancy does not come without penalty. Most companies exercise severance programs that cover employees for periods of time employed and fund benefits even after the employee has left the company. And people take up space. That space quickly becomes vacant in a reorganized facility and the general overhead rate increases as a percentage of outbound products when factoring in cost of property.

We come full circle: letting staff go is also a financially, emotionally and organizationally expensive exercise.

Here is the critical question: What could be done differently and where should investments be made that permit a company to grow efficiently while also protecting itself against variable costs of fluctuating labor requirements?

For some corporations, the answer is to move offshore to regions offering low-labor rates. Such a move makes sense for multinational companies, but is simply not realistic for others – local markets need to be served locally and not everyone can afford the time and monies associated with offshore manufacturing. The dynamic between large-scale manufacturers and smaller ones is changing and greater proportions of finished product and subassembly parts are coming into the U.S. from China, but it is simply not possible for this trend to continue unabated. It does, however, provide yet another opportunity for U.S. manufacturers to make gains in efficiency and competitiveness. The U.S. market for electronics is massive, and in the consumer arena the costs associated with offshore manufacturing and importation are not inconsiderable, providing an advantage for those that are U.S.-based and capable.

Where do the investment opportunities lie in automation that could possibly make a difference? Looking back, the advent of volume SMT was the downfall of the leaded through-hole component. No package type or electrical performance requirement would be left untouched by the newer, smaller, on-the-top phenomenon. Yet almost every board has some type of odd-form content, and through-hole components linger for certain mechanical or electrical performance needs.

As automation levels rise and SMT becomes faster and cheaper, the few components left with leaded terminations have been managed by most companies through the application of manual labor – which is highly variable. Most eschew the idea of automating the final stages of component assembly in favor of flexible manual operations, even at the critical point when the added value of the SMT assembly is at its highest and the risk of misinsertion, misorientation or wrong part insertion will most affect product cost (and operating profits).

The reasons to avoid automation are well-founded: Odd-form insertion systems historically have lacked flexibility, are large relative to the number of components being handled and are expensive. Plus, the unspoken belief remains that the few leaded components may be designed out at the next iteration.

However, when all the elements of variable content are accumulated, the costs of not automating may in many cases be significantly higher than many manufacturers realize, including

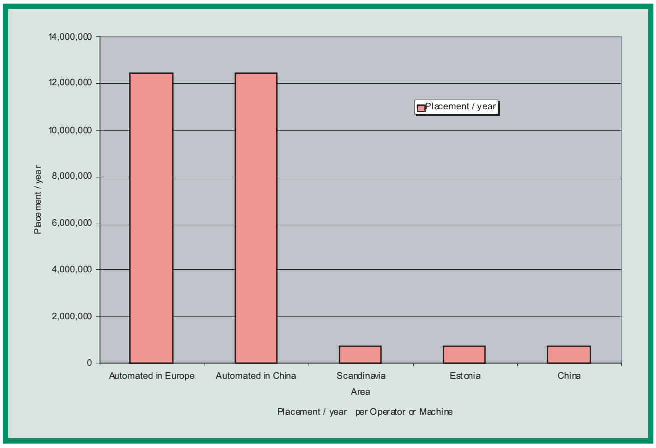

FIGURE 1: Operators place a fraction of the parts of an automated system.

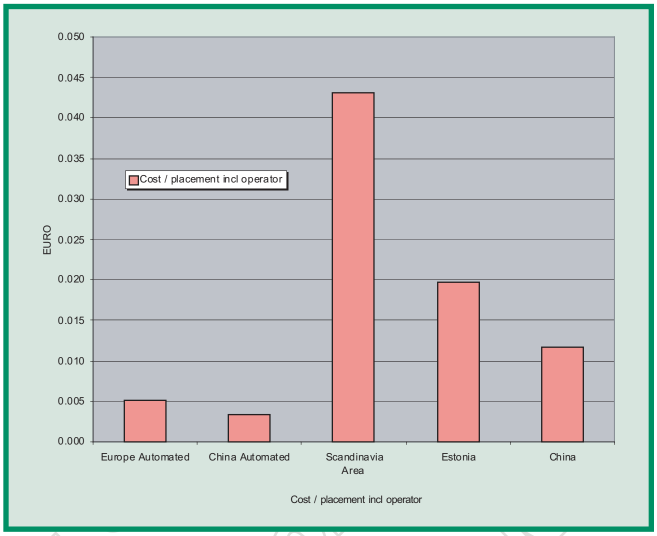

FIGURE 2: Actual cost per part placed is an extreme unit cost expense compared with automated alternatives.

labor, floor space, rework, product handling, re-test and cost of materials in circulation (**Figures 1 and 2**).

With diminishing margins and the drive to squeeze the process in terms of repeatability, reliability and consistency, automation may be the difference. The one area of machine technology that has been subtly improving over the past four years and provides an avenue for further exploration is automated odd-form equipment. (Authors' note: "Odd form" conjures an inaccurate image. A more accurate term would be end-of-line automation, which recognizes the traditional break point where automation gives way to other operations from test to manual assembly, rework and finally to box-build.)

The humble odd-form machine has come a long way. In the way that the MPS 525 and MS90 gave way to Fuji and Siplace, EOL automation has transcended the highly custom and specialized robotics cells of yesterday and is now closer in specification to highly flexible placement machines. Differences exist in the array of picking, sensing, testing and placing options available, and EOL automation does not need customization or specific software development.

"Flexibility leads to complexity leads to redundancy" is the most usual response to a suggestion that what was primarily accomplished manually be automated. While certainly true in the case of a robotic cell being configured to meet a given product's demands, today's EOL machines no longer center their technologies on robotics systems. Instead, they favor Windows OS and the generic motion control, vision systems and feeders used by many other SMT machines.

A typical automation cell today is 1 m in length; productivity can be enhanced through the use of multiple cells in a line. One cell typically will cover the output of three operators per shift in 1/6th of the area required by a manual workforce. We return to our discussion of justification (**Table 1**).

The tangible and intangible factors are subject to interpretation and investigation, but experience indicates that many companies fail to recognize the benefits of EOL automation and the opportunity for efficiency gains.

What payback does automation offer?

Tangible
Materials
Labor
Plant overhead
Intangible
Rework
Quality impacts
Rework inventory (cash flow)
Customer satisfaction

TABLE 1: Tangible and intangible factors affecting COG.

- Predictability (no vacations or sick time).
- Greater productivity per unit of space.
- Process repeatability.
- Multi-shift ramp with a minimal incremental cost.
- Better floor space utilization.
- Reduced manual operatives with their associated high degrees of variability.

Consequentially:

- Quality improvements are expected.
- Rework requirements are diminished.
- Inventory management is improved.
- Actual costs are reduced.
- Increases in productivity can be realized instantly.

Of course, some obstacles to EOL automation need to be recognized and addressed prior to implementation. For instance:

- Few standards exist for component packaging.
- Product design must account for the methodology of automated assembly. It is not realistic to take a product that presents difficulties to an operator and expect machinery to overcome those issues.
- Incoming materials inspection must be able to pick up variances in batches of materials. Simply accepting variability in the supply of materials frustrates an otherwise straightforward process.

Cost per placement and actual increases in quality, reduction in labor and floor space are all measurable, and can be quantified with some degree of accuracy to help determine whether an EOL investment makes sense. ■

Allen W. Duck *is CEO and president of PMJ USA and* ***Patty Chonis*** *is sales and marketing manager; patty.chonis@pmjusa.com.*