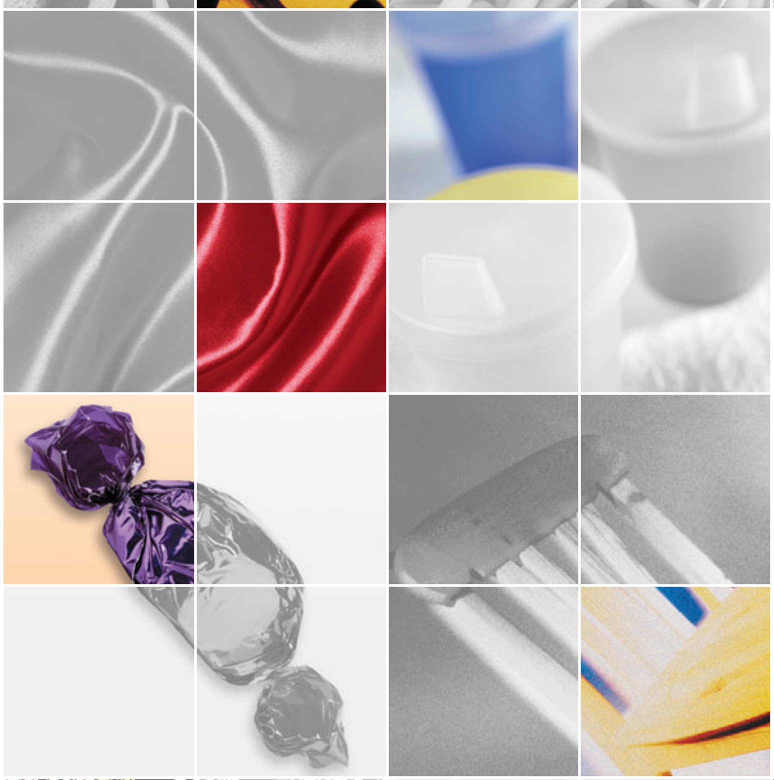


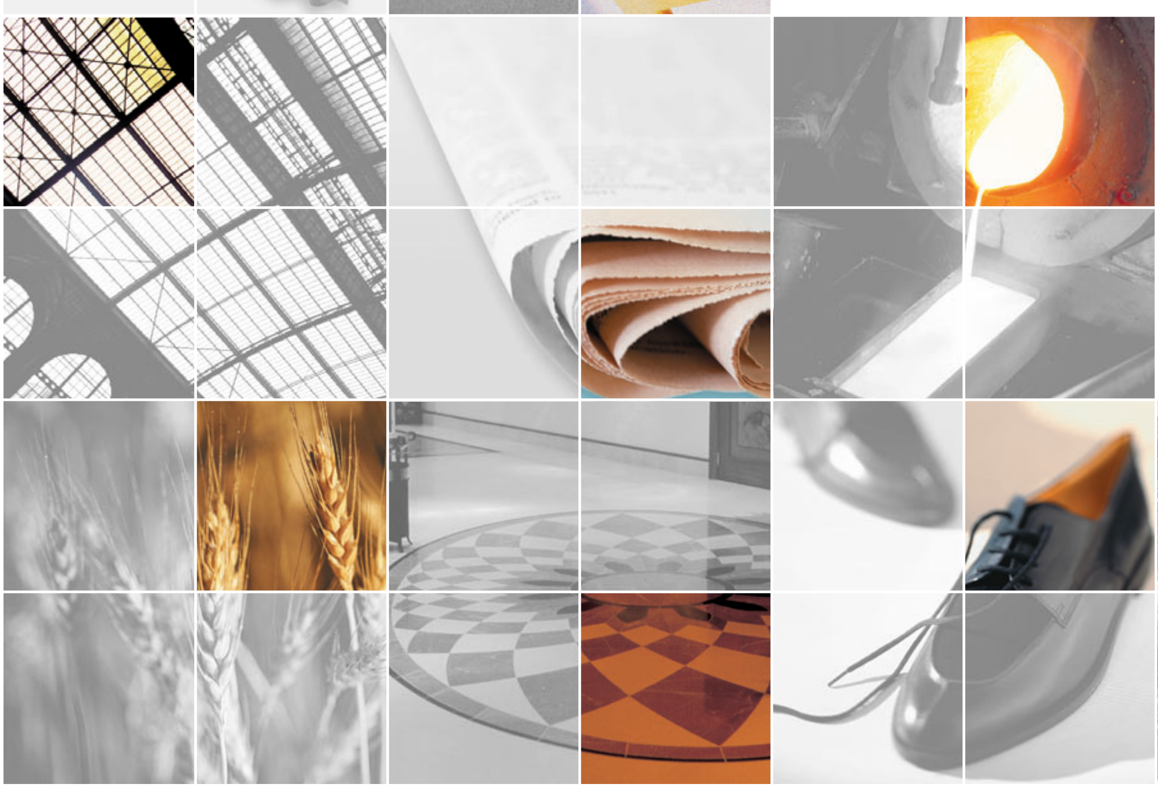
Capacity Optimization

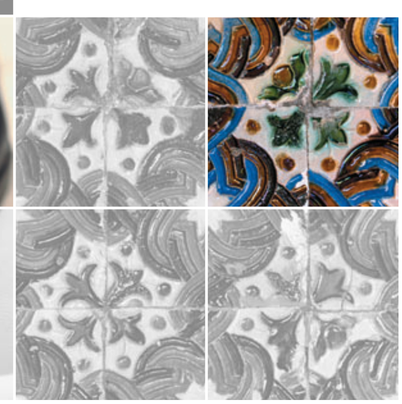
A manufacturer's guide for getting the most out of equipment, people, and processes

By John R. Brandt

and

George Taninecz



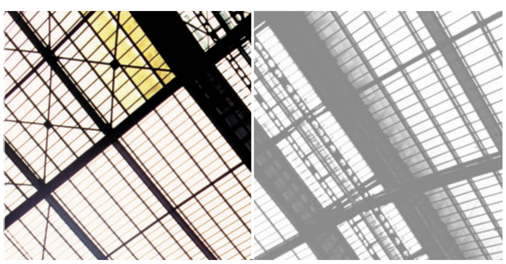


Capacity Optimization

A manufacturer's guide for getting the most out of equipment, people, and processes

The ability to squeeze every ounce of productivity from existing operations can mean thousands of dollars in savings. Yet many companies still confuse productivity with increased output – forgetting that *profitable* productivity not only increases margins but prevents costly overproduction. Savvy manufacturers focus instead on capacity optimization – the ability to efficiently produce exactly what's needed, when it's needed, without costly buildups of unwanted inventories.

Output vs. Optimization



Widespread adoption of manufacturing strategies that link production to customer demand – such as Lean Manufacturing, Toyota Production System, and Agile Manufacturing – has created a managerial revolution. Manufacturing executives now understand that producing more items faster isn't necessarily better. Old-fashioned "equipment utilization," in which traditional plants would run product simply to keep equipment active without concern for customer demand, has become regarded as a flawed strategy that generates excess inventory and cripples profitability.

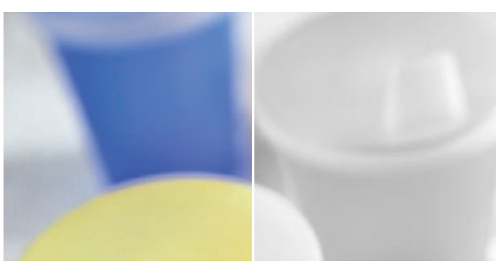
Savvy manufacturers now place greater value on their use of material (as raw materials, work-in-process, and finished goods inventories), labor forces, and plant equipment and capacity, trying to synchronize these inputs with actual customer orders. This is easier said than done. Unanticipated spikes in demand and supply-chain interruptions can cause missed deliveries and damaged customer relationships. To help manage this process and establish safe levels of inventories, executives often rely on complex formulas and information technologies; yet the metrics underlying this process are often disarmingly simple. Identifying and understanding these common building blocks of success are a critical step in optimizing capacity *and* profitability.

Production Capability

Production volume as a percentage of designed plant capacity is a measure that helps to indicate when a plant is outgrowing its facility and when new capacity (i.e., new plants or expansions) may be required for volume increases. If, for example, a plant designed to produce 10,000 units per year has reached its limit, more capacity can only come from this location through process improvements, expansion, or added labor shifts. *(Note: Designed capacity may take into account maximum hours of operation in a given period, with anything more jeopardizing reliable operation.)* This metric also helps COOs to evaluate the relative productivity and health of an entire portfolio of plants: i.e., if production volume as a percentage of designed capacity is consistently low and/or falling, that's a pretty good indication that tough decisions loom (e.g., plant closures or consolidations).

Production volume as a percent of designed capacity *(capacity usage)* is also useful at the individual plant level in determining whether a facility is poorly managed or scheduled. For example, if significant amounts of capacity go unused for long periods yet the plant requires consistent use of overtime and expediting, either production needs to be improved to eliminate the overtime and last-minute shipments, or possibly it's time to schedule more shifts or establish new lines/cells in unused portions of the plant.

Capacity usage also is a manufacturing barometer that shows the broad health of an industry; many executives consider the "healthy" threshold to be around 80%. The *IndustryWeek*/Manufacturing Performance Institute 2003 Census of Manufacturers revealed that production-unit volume as a percentage of designed plant capacity was a median 66% for all Census plants (average of 64%), and that nearly one-fifth of plants surveyed report capacity utilization of less than 50%. Conversely, one in four plants report capacity utilization at 80% or higher.[1] Individual manufacturers should assess how capacity utilization stacks up against other plants in a given region and within a specific industry (see chart "Capacity Usage by Industry"). If capacity usage is low compared to industry data, why? If it's high compared to regional data, is there an opportunity to lease additional capacity nearby, rather than to expand or build?



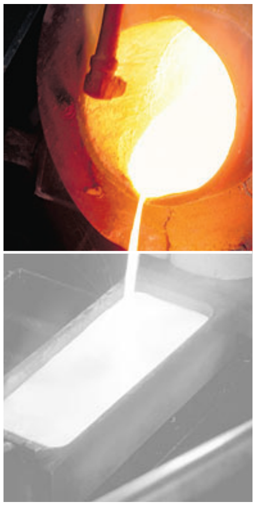
Capacity Usage by Industry
(production volume as a % of designed plant capacity)[2]

Industry	Mean	Median
Nonmetallic mineral products	73.8%	80.0%
Textile mills	74.4%	77.5%
Food manufacturing	71.5%	75.0%
Wood products	69.3%	71.0%
Furniture	70.0%	71.0%
Chemical	65.2%	70.0%
Miscellaneous	65.7%	70.0%
Plastics and rubber	67.2%	70.0%
Paper	66.1%	70.0%
Fabricated metal	61.9%	65.0%
Primary metals	64.7%	65.0%
Printing	67.8%	65.0%
Transportation equipment	66.4%	65.0%
Computer and electronic products	57.7%	60.0%
Electrical equipment, appliances, and components	60.0%	60.0%
Machinery	61.1%	60.0%

[1] *IndustryWeek/Manufacturing Performance Institute 2003 Census of Manufacturers, IndustryWeek* magazine and the Manufacturing Performance Institute, 2003.

[2] *IndustryWeek/Manufacturing Performance Institute 2003 Census of Manufacturers, Industry Week* magazine and the Manufacturing Performance Institute, 2003; industries for which 10 or more plants responded to the question pertaining to capacity usage.

Availability and Reliability



Even when the capacity in a plant has reached its limit, the ability to efficiently produce the right amount of product *as needed* can be severely undermined by any number of human and machine factors.

Many measures help manufacturers assess equipment reliability; one of the most common is *machine availability*. That is, when the plant needs a piece of equipment to operate and help produce product, how often (typically as a percentage of scheduled uptime) is it available? And while 100% machine availability is ideal, it's not realistic. Equipment breaks down, and some industries and manufacturing environments are exceptionally hard on equipment. For instance, although the median machine availability among Census of Manufacturers plants is 90% (average of 78%), each organization should compare itself to plants in similar industries to benchmark how machine availability can be increased *(see chart "Machine Availability by Industry").*

Machine Availability by Industry
(as a % of scheduled uptime)[3]

Industry	Mean	Median
Textile mills	78.5%	91.0%
Chemical	85.2%	90.0%
Computer and electronic products	83.0%	90.0%
Food products	84.9%	90.0%
Furniture	83.5%	90.0%
Nonmetallic mineral products	83.2%	90.0%
Transportation equipment	83.0%	90.0%
Miscellaneous	75.0%	87.5%
Fabricated metal	75.7%	86.6%
Primary metals	77.7%	86.0%
Paper	76.8%	85.0%
Plastics and rubber	74.5%	85.0%
Printing and support activities	69.8%	85.0%
Machinery	71.1%	82.5%
Wood products	78.2%	82.5%
Electrical equipment, appliances, components	75.2%	80.0%

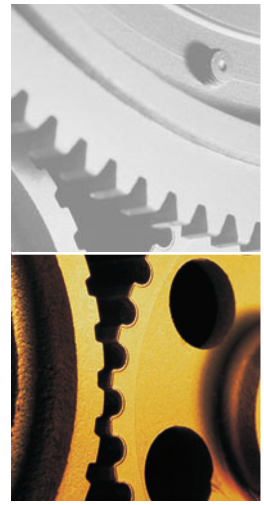
Basic as this seems – machines must be available in order to produce – it turns out that countless plants fail to track this measure, even those aware that they have problematic equipment. Many plant managers, even in equipment-intensive production environments, simply state, "our equipment is reliable. When it's not, we know it." Yet if machine availability isn't measured, it can't be improved. *(Note: To understand plantwide machine availability, the measure must be tracked by individual machine; a line dependent upon 10 machines only needs one breakdown to stop production entirely.)*

Machine availability can also be tracked to deduct for setup times and changeovers, potential indicators that capacity is being hamstrung by excessive setup and changeovers times (i.e., process improvements are needed). Remember, though, that improving machine availability by reducing the number of changeovers won't solve the changeover problem. Why? Because effort is better spent on increasing changeover speed, which then allows a plant to conduct *more* changeovers, permitting greater mix of product to move through the factory more efficiently. This added flexibility will minimize the inventory required to satisfy customer demand.

Other measures that highlight machine availability are figures such as *average time between equipment failures* (indicating that machines with more frequent breakdowns should be priorities for maintenance staff) and *reactive maintenance*, tracked by hours or as a percentage of all maintenance work (indicating a need for more preventive or predictive maintenance practices to stop unexpected equipment failures). Reactive work usually involves a production stoppage – needed capacity going unused – and may occur when replacement parts or maintenance staffs are not available to resolve the breakdown.

Attacking maintenance issues that prevent high machine availability or cause frequent machine failures directly leads to improved production capabilities. Take the case of the Baxter Healthcare facility in North Cove, North Carolina, a large-volume manufacturer of intravenous solutions and related products and winner of the *IndustryWeek*'s Best Plants award in 1994 and the Shingo Prize for Excellence in Manufacturing in 2000. In the early 1990s the Baxter manufacturing plant trained all 2,000-plus employees

[3] *IndustryWeek/Manufacturing Performance Institute 2003 Census of Manufacturers, IndustryWeek* magazine and The Manufacturing Performance Institute, 2003; industries for which 10 or more plants responded to the question pertaining to machine availability.



in total productive maintenance (TPM), a strategy that includes predictive and preventive equipment maintenance techniques, as well as production operator involvement with routine maintenance. TPM at Baxter allowed maintenance teams to focus on major assignments and resulted in longer equipment life, reductions in repair costs and times, and longer times between equipment failures (40 months in one case).[4]

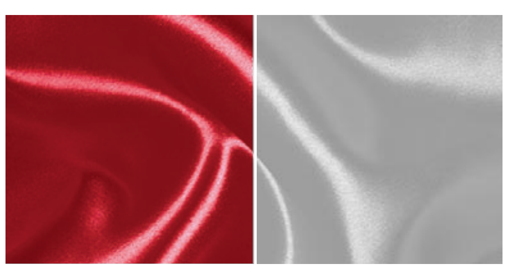
Even so, superb equipment performance means little without superb people to operate it. Availability also reflects measures within the labor force, such as *absenteeism rates* (missing workers can severely affect a cell's or line's productivity), *labor turnover rates* (new employees will take longer to get up to speed than plant-floor veterans), and injury and illness rates (high rates often coincide with high absenteeism and turnover rates, indicating dangerous working conditions). Root causes of low measures often point to a dissatisfied workforce, unsafe working conditions, noncompetitive wages, or lack of empowerment or potential for employee involvement – all factors that eat at productivity. The U.S. Department of Labor, Bureau of Labor Statistics, reports that the absenteeism rate across manufacturing was 3.8%, a figure that annually costs businesses millions of dollars in lost productivity.[5]

Just as important as equipment reliability is the reliability of personnel, processes, and machines to manufacture quality product. Every product that is reworked, scrapped, or returned by the customer is a product's worth of output gone to waste. There's no limit to the quality measures available to assess the performance of a plant, line, cell, or product family:

- *Scrap and rework rates* or ratios, either as percentages of hours worked, units produced, sales volumes, or some other measure of total production;
- *Finished-product yields* (percentage of products at the completion of production that pass inspection);
- *In-process yields*, particularly at critical process points upon which overall product quality may hinge;
- *Warranty costs* as raw figures or ratios; and
- *Customer reject rates.*

Customer rejects are clear indications of customers' perceptions of value, often leading to interesting discoveries. For example, one auto supplier had difficulties with a high rework rate for products coming out of a chrome paint process. After months of lost productivity as numerous parts were repainted, the plant staff realized that the majority of rejects were flawed only on the B side of the product; side A was nearly always perfect. Analysis of the problem revealed that side B was difficult to paint because design engineers never intended it to be flawlessly painted - it would eventually be attached directly to the auto body at the OEM and never seen again. Moreover, the customer didn't care how side B was painted and would *not* have rejected the parts the supplier was scrapping. So while it's critical to prevent poor quality from ever reaching your customer, it's also necessary to clearly understand what the customer expects.

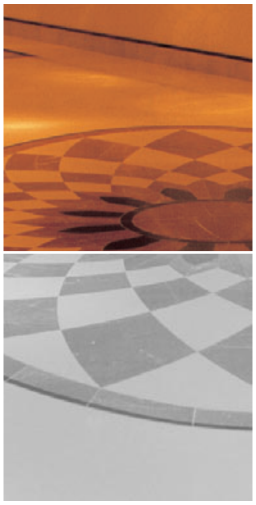
Quality measures such as *in-process yield rates* should be tracked as close to real-time as possible; this allows plants to stop production when the measures indicate that quality processes are out of control. Savvy manufacturers understand that it's better to have a line or cell down for 10 minutes, conduct quick problem-solving, and get to a root cause and a sound solution rather than to track quality only at the end of the line – after producing an hour's (or day's) worth of bad product.



[4] Kinni, Theodore, B., *America's Best*, John Wiley & Sons Inc., 1996.

[5] "Household data annual averages: Absences from work of employed full-time wage and salary workers by occupation and industry," U.S. Department of Labor, Bureau of Labor Statistics, 1998.

Speed and Efficiency



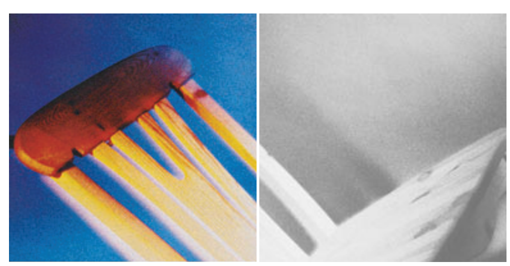
Speed, too, is important in helping to optimize capacity, but only in the sense that speed is used efficiently. Just as driving 90 miles per hour to get to a red light and wait is foolish, the speed of production must align with customers' demands for products. Few manufacturers ever have been more adept at aligning production with customer demand than Toyota Motor Corp. The company, which revolutionized manufacturing in recent decades and whose Toyota Production System spawned the lean-manufacturing movement, frequently posts stellar financial performances on the back of its operations efficiencies and high customer demand. For example, in the fiscal year ended March 31, 2004, Toyota posted a 55% increase in net income to 1.16 trillion yen (approximately $10.2 billion), a record high. Fujio Cho, TMC president, said, "In fiscal year 2004, Toyota's consolidated vehicles sales increased in all regions to 6.71 million units. As a result, our production reached full capacity, leading to improved profitability at our subsidiaries. Overall, operating profits of our subsidiaries have increased almost 300% over the past five years."[6]

Toyota establishes production speed by calculating *takt time*, which is the time available to manufacture product divided by customer demand for the product.[7] For example, if takt is one minute, then a product is moving off final assembly every minute. While understanding takt time is necessary to schedule a plant, the ability to produce accurately to takt indicates efficiency in meeting customer demand. An inability to produce up to takt time means that customer demand cannot be directly satisfied (i.e., not enough product coming off the line); root causes could be equipment and processes unable to operate at the required speeds when needed (e.g., an ailing machine or an understaffed work cell). Conversely, exceeding takt time means that the plant is producing more product than customers demand, which could turn into excess inventory or wasted output.

Most organizations also track the times that it takes to produce goods, either from start to finish (referred to as *manufacturing cycle time* by some and manufacturing lead time by others) or from the time an order is received until it is shipped *(order-to-ship lead time)*. The efficiency of these production times can also be tracked based on the percentage of time that operators or equipment are actually adding value to a given product rather than merely moving it along or having product sit in storage (*value-add time* as a percentage of the total time). Value-add time is an excellent internal benchmark to gauge production efficiency, but the ratio is accurately tracked by only a handful of organizations, mostly those dedicated to lean manufacturing. Cycle time and lead times are generally available, but quite specific to industries *(see chart "Manufacturing Cycle Time by Industry").*

Manufacturing Cycle Time by Industry
(hours for finished product)[8]

Industry*	Mean	Median
Food manufacturing	176	16
Plastics and rubber	191	36
Chemical	117	42
Textile mills	132	60
Nonmetallic mineral products	230	66
Paper	260	72
Wood products	489	84
Printing and support activities	153	96
Electrical equipment, appliances, components	151	96
Miscellaneous	259	96
Furniture	202	120
Fabricated metal	273	120
Primary metals	194	120
Machinery	514	168
Computer and electronic products	331	168
Transportation equipment	902	168



[6] "Toyota reports record year-end results," Toyota Motor Corp., May 11, 2004.

[7] *Lean Lexicon*, Lean Enterprise Institute, 2003.

[8] *IndustryWeek/Manufacturing Performance Institute 2003 Census of Manufacturers, Industry Week* magazine and The Manufacturing Performance Institute, 2003; industries for which 10 or more plants responded to the question pertaining to manufacturing cycle time

Collective Measures – OEE, LOE, and OPE

The internal plant characteristics of availability, reliability, and speed come together to provide an image of the plant's overall ability to optimize capacity. One traditional measure that pulls together the physical aspects of a facility's performance is *operating equipment efficiency* (OEE, also referred to as overall equipment effectiveness), which gauges how well a piece of equipment or line is at efficiently producing quality goods. OEE is based on a formula that multiplies the quality rate of the equipment *(yield percentage)* by the availability of the equipment when needed (*machine availability* as a percentage of scheduled uptime) by the equipment's run rate as a percentage of designed rate. *(Note: Many companies use variations of the above. While OEE is commonly captured around a piece of equipment, it can be rolled up to measure the performance of a line or work cell, or even broadly applied to assess a full plant – often as averages of individual lines or pieces of equipment.)* OEE has become viewed by many as a sort of silver bullet in that it can quickly capture a number of problems in the plant – from equipment breakdowns to sloppy quality practices.

On the softer side of the plant, the Manufacturing Performance Institute (MPI) has developed a measure called *labor operating efficiency* (LOE), which pulls together the availability of workforce (non-absenteeism rate), the accumulated knowledge-depth of the workforce (annual labor retention rate, which is the percentage still in place after voluntary and involuntary exits), and the quality of the workforce as defined by management's ability to empower the workforce to supervise itself and autonomously improve production (this measure can be expressed either as a percentage of workforce in empowered teams or a general level of empowerment within the facility). The multiple of these factors leads to LOE.

To bring the hard and soft side together, MPI factors OEE, LOE, and capacity usage to get a measure of *overall plant efficiency* (OPE). Based on these three components of efficiency – equipment, people, and space – executives can assess the overall efficiency of a plant network as well as individual sites; decisions can then be made on how to allocate production, to improve a facility, or to augment a network of facilities. OPE helps to identify and evaluate where "real" capacity might exist in a corporate network of plants and which facilities are making the most of their resources *(see formula "MPI's Measuring Overall Plant Efficiency (OPE)")*. OPE also indicates how much more capacity can be squeezed out of a plant if operational improvements are made.

For example, the 25 finalists facilities as identified by *IndustryWeek* magazine in its Best Plants competition in 2003 achieved an average OPE of approximately 48%: OEE 84%, LOE 72% (approximately 82% of workers in empowered or self-directed teams, turnover rates of 10%, and absenteeism rates of 2%), and capacity usage of 79%.[9] As a comparison to manufacturers in general, for all plants responding to the IW/MPI 2003 Census of Manufacturers, the average OPE was approximately 12%: OEE 73%, LOE 26%, and capacity usage of 64%.[10]

How can executives use OPE? If, for instance, a COO is trying to find a modest amount of manufacturing capacity for a new product and is evaluating between two plants, he or she might look at available capacity and see that Plant A has 40% available capacity and Plant B has just 30% available capacity. The quick decision might be to move production into Plant A. But an OPE review of Plant A – which takes into account a shaky OEE of 70%, and a troublesome labor environment (LOE of 27% based on 8% labor turnover, 10% absenteeism, and 33% empowerment, of which most is management) – would find that this facility has a poor OPE of 11%. Meanwhile, Plant B – with a solid OEE of 85% and a satisfied and involved workforce (LOE of 85% based on 90% empowerment, 5% turnover, and 1% absenteeism) – maintains an OPE of 51%. Clearly, Plant B has been doing a far better job of optimizing the equipment and people it has, and though it doesn't have as much unused space as Plant A, it should be rewarded the new production. Similarly, the OPE analysis indicates that there is far more than just 40% capacity available at Plant A, provided improvements are made to solve the problems that led to its poor OEE and disgruntled workforce.

In a time when many manufacturers chase low-cost manufacturing options overseas, it's worth analyzing how efficient – and low-cost – manufacturing could be right at home, whether that's in North American, Europe, or elsewhere. OPE is a useful new way to assess those possibilities, especially when measured alongside labor rates, to get a true measure of cost.

MPI's Measuring Overall Plant Efficiency (OPE)

Operating Equipment Efficiency (OEE)					X	Labor Operating Efficiency (LOE)					X	Capacity Usage
Machine availability %	X	Quality yield %	X	Run rate %	X	Empowered %	X	Annual labor retention %	X	Non-absenteeism %	X	Capacity usage %

[9] *IndustryWeek's Best Plants 2003 Statistical Profile, IndustryWeek* magazine, 2003.

[10] *IndustryWeek/Manufacturing Performance Institute 2003 Census of Manufacturers, Industry Week* magazine and the Manufacturing Performance Institute, 2003; averages. The Census did not assess absenteeism rates, so the U.S. national average absence rate for manufacturers (3.8%), as identified by U.S. Bureau of Labor Statistics, was applied. Additionally, empowerment averages were calculated based on number of respondents to groups of responses (e.g., 1%-25%, 26%-50%).

Conclusion

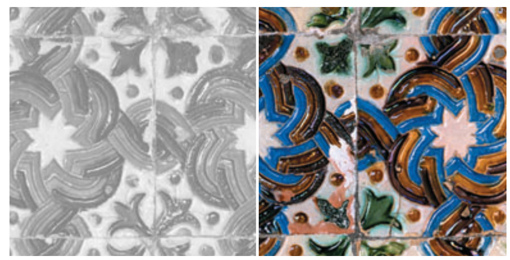
Not all the problems that can throttle efforts to optimize capacity occur within a plant's four walls; manufacturers also need to consider activities both upstream and downstream of the plant. Upstream issues that can be measured include *supplier delivery, reliability,* and *quality*; downstream issues can be monitored by metrics that address *customer order changes by volume and/or mix*, as well as other nonproduction factors that directly influence customer demand and production's ability to meet demand. For example, corporate marketing or promotional campaigns that create a surge in demand without alerting manufacturing are sure to create havoc with the best-laid plans to optimize capacity.

There are dozens more measures available to manufacturers and many resources to find metrics specific to any type of operations environment. Savvy manufacturers will invest the time and effort to adopt the right measures for their firm – those that help them to solve production problems, optimize capacity, boost margins, and increase profitability. Smart manufacturers measure it, improve it, and then measure it again.

How will you measure (and improve) your success this year? More importantly, how will you measure up next year?

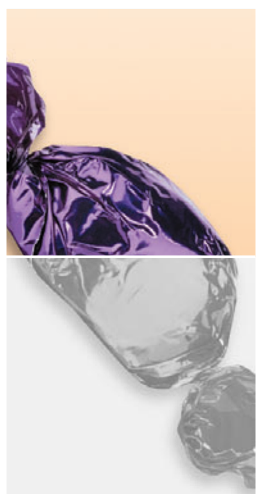
If your company would like to increase productivity and improve yields while being cost-efficient at the same time, then Italian machinery and technology should be a consideration in your upcoming capital purchases.

Contact Machines Italia c/o the Italian Trade Commission at **1-888-ITALTRADE**, or visit us at **www.machinesitalia.org** for more information on how Italian companies and technologies are providing North American companies with the means to increase margins while preventing costly overproduction every day.



John R. Brandt is CEO of the Manufacturing Performance Institute and the former editor of both *Chief Executive* and *IndustryWeek*.

George Taninecz is Vice President, Research, of the Manufacturing Performance Institute and the former managing editor of *IndustryWeek.*

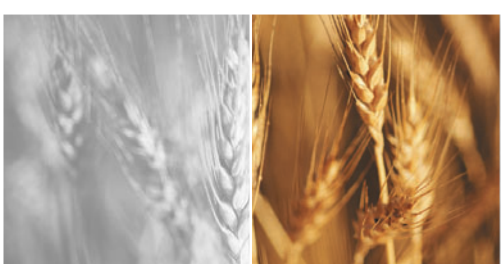


MACHINES ITALIA C/O ITALIAN TRADE COMMISSION

1-888-ITALTRADE

www.machinesitalia.org

NEW UPDATES AND INFORMATION ADDED PERIODICALLY!



"Capacity Optimization: A manufacturer's guide for getting the most out of equipment, people, and processes" is brought to you by the Italian Institute for Foreign Trade (I.C.E.) and its U.S.-based Italian Trade Commission as part of their Machines Italia promotional program. This program is designed to promote capital goods trade between Italian machinery manufacturers and U.S. companies. Participating Italian machinery manufacturers' associations include Agriculture/Farm Machinery; Ceramics; Earthmoving Machinery; Food Technology; Footwear, Leathergoods and Tanning; Foundry and Metallurgical Machinery; Glass; Marble and Stone; Metalworking; Packaging; Plastics and Rubber; Printing, Graphics and Converting; Textile Machinery; and Wood.