

*Fab Management
Strategies*

5 Fab Management Strategies

Through the use of a variety of management strategies, the semiconductor facility is made more productive and more cost-effective, without requiring the purchase of new equipment. These strategies are the tools companies use to continuously improve the organization's responsiveness to customer needs, improve problem-solving capability and reduce manufacturing costs. Implementing company-wide management changes is especially challenging to many of the largest IC manufacturers, which have operated in very traditional manners in the past. Figure 5-1 summarizes different management strategies including total quality management (TQM), total productive maintenance (TPM), cycle time management (CTM), activity-based costing (ABC), and total employee involvement (TEI), along with some of the tools used to implement these strategies. Most semiconductor manufacturers have active total quality management programs that incorporate the tenets of some or all of these strategies.

There are numerous success stories about companies that are using key management strategies to achieve manufacturing excellence. As with any new management philosophy, the benefits lie not in the method used, but in the successful implementation of the program. Here we review the successful use of self-directed work teams (SDWTs), the theory of constraints and other strategies by

companies including Intel, Siemens and IBM. Benefits attained by these companies include (but are not limited to) higher efficiency, manufacturing cost reduction, improved yields, and improved employee morale. Important elements of each strategy include:

- Complete commitment to the program by senior management professionals,
- Education and training programs used to improve employee's skills and performance,
- A focus on critical success factors (i.e., cycle time, product quality, cost, etc.) with the ultimate goal of improved customer satisfaction,
- Setting of reasonable goals, methods for measuring performance, and feedback methods,
- Frequent meetings to determine/update performance goals,
- Continuous, unbiased feedback of team progress, and
- Rewards (i.e., bonuses, leave time, paid meals, etc.) for meeting or exceeding program goals.

The Self-Directed Work Team Approach

The self-directed work team (SDWT) strategy essentially converts a management-directed work force to a self-directed work force. The SDWTs each has a coach (formerly a manager)

and team members who are working toward a series of common goals. The SDWT approach shifts commitment, ownership, and responsibility from management to employees. Important elements in the successful execution of SDWTs are: management commitment to the new business structure; education; a focus on critical, measurable success factors (i.e., cycle time, product quality, cost, meeting production commitments); and a formalized program to reward team progress. Tools used to implement SDWTs include surveys, cross-training, team-developed guidelines and procedures, and team-developed awards. The teams ultimately:

- Have no direct supervision,
- Set their own missions, goals, and objectives in harmony with the organization's goals and objectives,
- Share and rotate various management and leadership functions,
- Plan and schedule their own work to meet delivery and cycle-time targets,
- Define and measure critical performance indices,

- Coordinate work with other teams,
- Order materials, keep inventories, etc.,
- Maintain and continuously improve overall equipment effectiveness and workplace environment,
- Prepare and monitor their own budgets,
- Cross-train members,
- Interview and hire team members, and
- Conduct peer performance evaluations.

As one might imagine, restructuring an organization with a top-down management structure into a self-directed team structure requires fairly dramatic changes in attitude throughout the organization. Many companies will use SDWTs to facilitate the various management philosophies of total quality management, cycle time management, etc., to achieve improvements in yield, lowering of product cost, reduction in cycle times, etc. Companies will often develop a SDWT pilot line to test the program, followed by proliferation into sections of the fab (i.e., photo cell or metalization cell), and finally throughout the entire factory.

Level of Complexity	Total Quality Management (TQM)	Total Productive Maintenance (TPM)	Cycle Time Management (CTM)	Activity Based Costing (ABC)	Total Employee Involvement (TEI)
Low	<ul style="list-style-type: none"> • Problem solving process • Seven quality tools 	<ul style="list-style-type: none"> • OEE improvement process • 5S industrial housekeeping 	<ul style="list-style-type: none"> • AdeltaT • Quick change over 	<ul style="list-style-type: none"> • Activity based accounting • Cost benefit analysis 	<ul style="list-style-type: none"> • Empowerment workshop • Team building • Valuing diversity
Medium	<ul style="list-style-type: none"> • Statistical process control • New seven quality tools • Benchmarking 	<ul style="list-style-type: none"> • Failure modes and effects analysis • Phenomena-mechanism analysis 	<ul style="list-style-type: none"> • The Pull system • Line balance techniques 	<ul style="list-style-type: none"> • Manufacturing cost variance • Cost of quality • Cost of ownership 	<ul style="list-style-type: none"> • Facilitation skills • Interviewing skills • Project management
High	<ul style="list-style-type: none"> • Design of experiments • Taguchi methodology 	<ul style="list-style-type: none"> • Predictive maintenance • Quality maintenance 	<ul style="list-style-type: none"> • IE techniques • Factory simulation 	<ul style="list-style-type: none"> • Cost of variability • Cost simulation tools 	<ul style="list-style-type: none"> • Management skills • Policy deployment

Source: Xerox/IEEE/SEMI

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Figure 5-1. Management Philosophies and Tools Used to Implement Them

Cross-training is typically performed to improve labor productivity, reduce tool downtime and improve operational flexibility. The benefits of cross-training include improvements in the management of WIP (work in process), increased throughput and finally, elevation of factory output. Cross-training is an inherent part of cooperative team structures, which offers individuals the opportunity to expand their skills outside their immediate area of responsibility, enabling the company to make better use of human resources. Cross-training can play an integral part in achieving a variety of quality goals including reduced scrap and rework, and reduced cost for spare parts.

Using Cross-Functional Teams to Accelerate Ramp-up by 4X

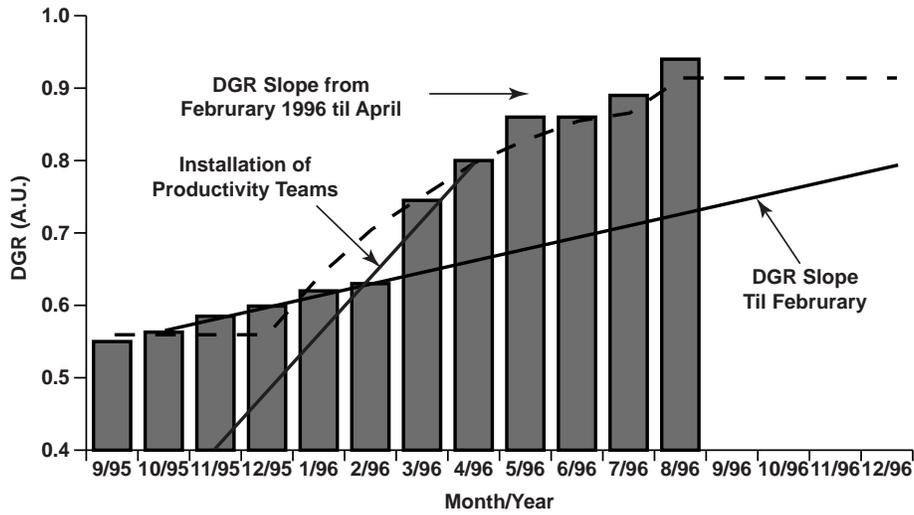
In 1995 and 1996, Siemens and IBM expanded their 200mm Advanced Semiconductor Line in Essonnes-Corbeil, France, ramping up the line capacity of 16M DRAMs by 70 percent between January and July of 1996. Cross-functional teams of operators, technicians and engineers were used to achieve this rapid ramp-up. The teams successfully synchronized the workforce, wafer flow, tool-set, and process/business components of the ramp-up. Two weeks after implementing the teams, the line ramp-up slope was increased by a factor of five and reached a peak value of daily going rate (DGR) ramp-up speeds corresponding with increases of 700 wafer starts per week each month^[1]. The ramp-up of the Corbeil, France expansion is shown in Figure 5-2. Emphasizing the importance of rapid ramp-up, the companies estimated that a 4-week delay in fab ramp-up can cost as much as \$20 million.

Ramp-up of a fab requires the ramping of yields (yield learning), the ramping of capacity (tool installation and qualification), and the

ramping of production throughput (DGR). DGR refers to the number of processed wafers per tool per day. When an existing fab is being expanded, as in this example, ramp-up of the DGR and associated synchronization routines influences overall ramp-up performance the most. While increases in manpower and capacity are relatively easy to manage, work in process (WIP) balancing is more difficult ^[1], especially due to the logistical complexity of semiconductor fabs. The success of a ramp-up is tied to the teams' ability to rapidly realize problems, analyze them, make decisions, execute actions, and repeat these cycles of learning effectively.

In the Siemens/IBM ramp-up, the teams tracked daily fab productivity using opportunity charts, charts used by both production and by management personnel to prevent ambiguities in the areas of data sampling, representation and interpretation of data. An example of an opportunity chart is shown in Figure 5-3. These charts include:

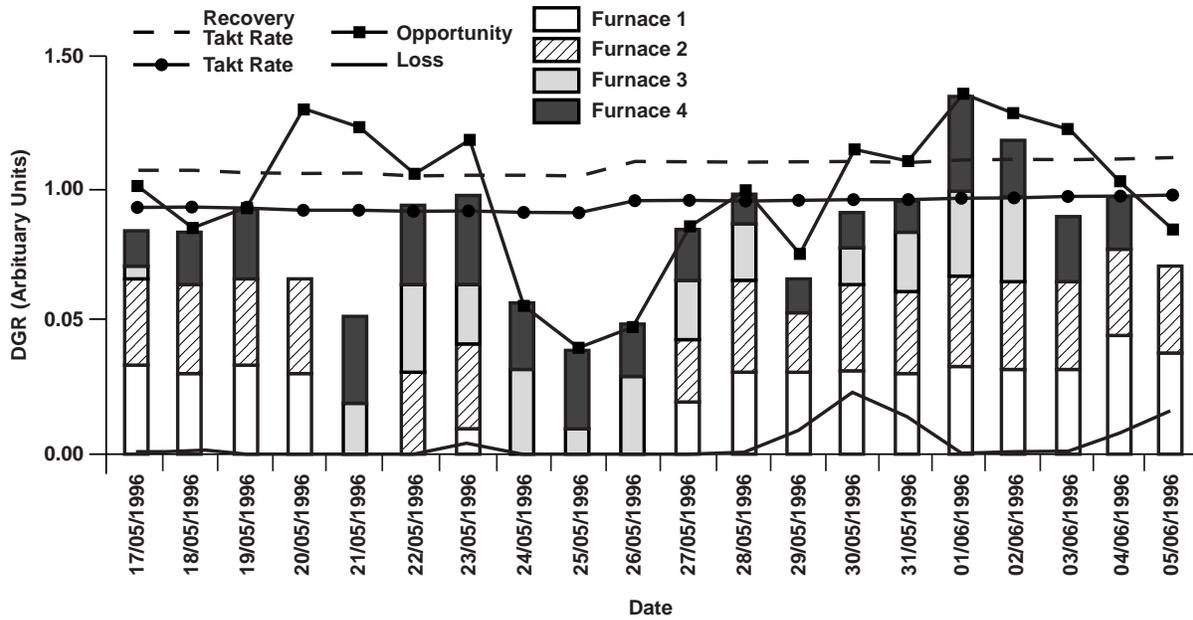
- Number of wafers processed per tool and per day (DGR)
- Total number of wafers produced per day
- Takt rate (long-term average rate of number of wafers that should be produced per day, based on average line capacity including downtime for equipment, problems with operator availability, etc.)
- Recovery takt rate (RTR) (takt rate + 15 percent, i.e., the target when no logistical problems exist for a given operation)
- The maximum possible number of wafers produced according to the daily tool availability (opportunity)
- The maximum possible number of wafers produced according to the WIP situation (potential)
- The difference between DGR and the opportunity or potential (whichever is smaller), so called loss



Source: IEEE/SEMI Advanced Semiconductor Manufacturing Conference

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Figure 5-2. Daily Going Rate (DGR) Ramp Up 1995-1996



Source: IEEE/SEMI Advanced Semiconductor Manufacturing Conference

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Figure 5-3. Node Nitride Opportunity Chart

The opportunity chart provides an immediate indication as to whether productivity targets are being met. As illustrated in Figure 5-3, the opportunity chart indicates tool problems when the opportunity is smaller than the RTR. A problem with wafer flow is indicated when the potential is smaller than RTR. A loss is caused by manpower problems since less wafers are produced than the tool situation (opportunity) and the WIP situation (potential) allow. Most importantly, opportunity charts allow rapid identification and separation of different types of problems, even if they occur at the same time. In other words, the team can identify whether the problem relates to the workforce, wafer flow, tool-set, process, or business components of the ramp-up.

Beyond daily performance tracking, Siemens and IBM use three tools to localize operational bottlenecks in the production line for long-term problem solving. The first employs Pareto charts showing which range has failed to deliver its minimum output during the last 7 days the most (to identify emerging bottlenecks) and during the last 24 days. The second also uses a Pareto chart, but this one tracks cycle time detractors per operation. The third utilizes operation curve analysis which, using cycle time and tool utilization data, separates and quantifies numerically the influence of different detractors (such as tool breakdown, set-ups, rework, etc.) on cycle time and DGR.

Siemens and IBM were able to increase the slope of DGR by a factor of 5. Through effective utilization of cross-functional teams, the fab reached the targeted DGR (corresponding roughly with installed bottleneck capacity). Enabling factors include the formation of a highly empowered, cross-functional

workforce with the tools needed to synchronize workforce, tooling, processing, and problem-solving in a focused manner.

Using Yield Risk Cards to Reduce Line Yield Losses

At Intel's D2 fab, the company visually highlighted at-risk production lots using special cards to effectively identify and reduce line yield losses^[2]. With line yields struggling to exceed 88 percent, the company decided to construct Pareto charts to identify the main causes of line yield losses. Causes included recovery from machine errors and interrupts (including preventive maintenance), issues with training, passdown losses (from one process to another), and communication issues. Due to the nature of the problems, a visual solution seemed appropriate.

Using the theory-of-constraints management concept of achieving ambitious targets, Intel addressed:

- What to change?
- What to change to?
- How to cause the change?

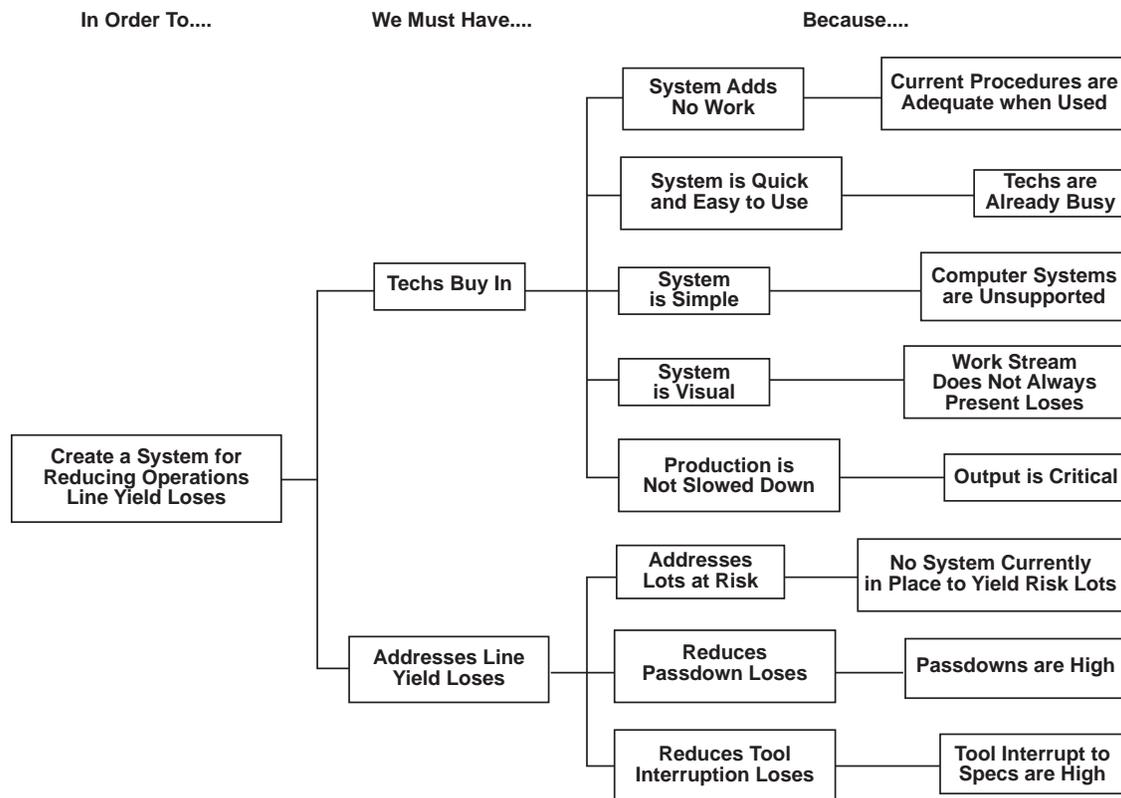
The company's Future Reality Tree (shown in Figure 5-4) shows a simple, visual system that addresses main types of losses as the key elements of the two branches, identifying a need for technician buy-in to address and prevent the losses. To obtain technician buy-in, the ambitious target was stated and each member of the team was asked to raise one obstacle, from which suggestions were solicited for obtaining an intermediate objective for the given obstacle. These steps are repeated until no identifiable obstacles remain. The team is also asked to raise reservations associated with achieving the

intermediate objectives. Importantly, the cards were introduced to the technicians as an optional tool for flagging lots at risk.

Intel implemented this plan on one production shift which, within four weeks, was using the yield risk cards on the entire shift. The cards are badges stating that the lot is at risk and cannot be processed until the technician in charge (with stated identification code or pager number) is contacted. Importantly, proliferation occurred by word-of-mouth from one technician to another. In this case, the cards were adopted across all

shifts first by personnel in the lithography cell. Yield improvements are illustrated in Figure 5-5.

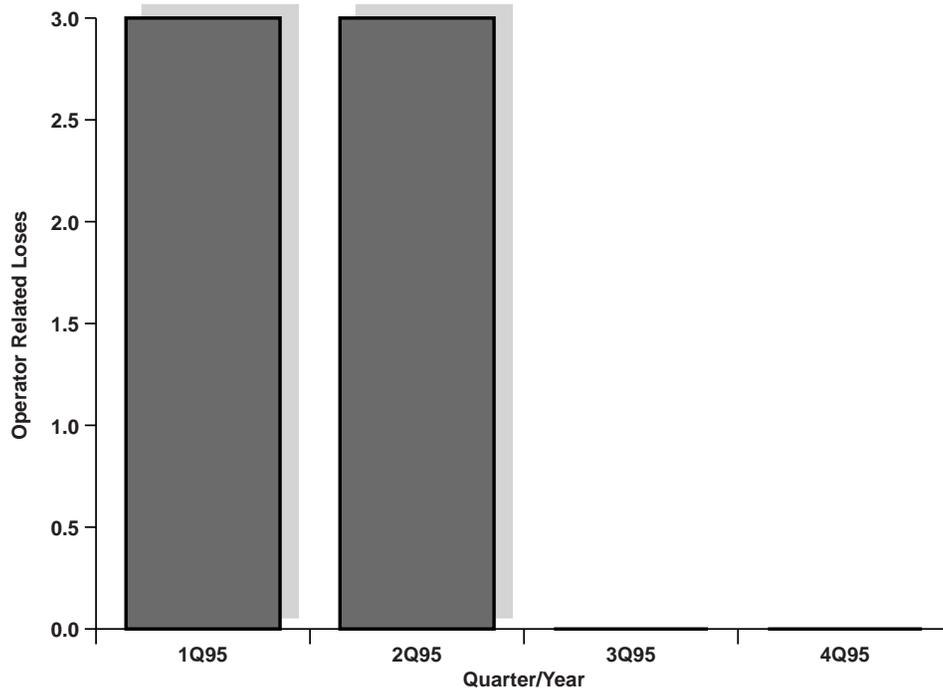
The success of the Yield risk card lies in the system's simplicity as well as the unique proliferation method. It represents an effective method for highlighting uncommon conditions that can be used in many different situations. The "obstacle and Intermediate Objective" approach allowed technician buy-in and empowerment.



Source: IEEE/SEMI Advanced Semiconductor Manufacturing Conference

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Figure 5-4. TOC Logic Tree



Litho total implementation results indicate no operator related losses after Q2 implementation.

Source: IEEE/SEMI Advanced Semiconductor Manufacturing Conference

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Figure 5-5. Litho Operator Loss Trends in 1995

Conclusions

By removing the barriers between management and manufacturing personnel, operational effectiveness can be dramatically improved. By making priorities — such as throughput, contamination-free manufacturing, process control, reliability, etc. — everyone's responsibility, continuous improvement and sustained profitability in the face of increasingly complex manufacturing requirements, are possible.

Using Supply Chain Assessment to Reduce Cycle Time and Costs

Customer linking, also known as Supply Chain Assessment, integrates and synchronizes the customer supply process of the vendor's business with the procurement and production planning processes of a key

customer such that cost and non-value-added time are removed from the extended supply chain and the customer's customers are better served^[3]. DuPont Photomasks and Motorola used Customer Linking to improve efficiencies by eliminating redundant steps or redesigning steps in the supply chain for masks and reticles. Using a Fab Pull methodology, the companies optimized capacity loading in the supply chain, thereby reducing costs and improving the utilization of working capital.

The chain begins with Motorola's High Performance Embedded Systems Division in Oak Hill, Texas, through DuPont Photomasks' mask facilities in Round Rock, Texas, to Motorola's MOS-8 wafer fab in Austin, Texas. People at all facilities were interviewed to determine the flow of information and data from marketing through

manufacturing. Interviews by DuPont's Continuous Business Improvement group identified areas where closer supply chain linking opportunities existed which could be changed to reduce cycle time and cost. Within Motorola, people in all sectors were interviewed including marketing, product engineering, CAD, photo manufacturing, photo engineering, device engineering, and fab process control. Disconnects and redundancies in the supply chain were identified. A significant finding was the lack of a feed-forward mechanism from DuPont Photomasks informing the fab when reticles were scheduled to be shipped. Mask schedule changes were not relayed to the fab personnel.

To alleviate this problem, DuPont began generating daily status reports that had been sent electronically to the mask prep designer, and was now relayed to include the wafer fabs facilitating the distribution of this information in a timely manner. In addition, a Fab Pull concept was introduced to tie the reticle deliveries with the real demand of the fab. Unlike Just in Time which allows a small buffer of inventory, Fab Pull attempts to allow a small buffer of time between reticle receipt and physical use. The time buffer needs to be managed to at or slightly above the average time required to expeditiously remanufacture and deliver a reticle. Eventually, the companies moved to an automated communication link between the fab's scheduling system and that of the mask shop. This process change reduces fab costs as reticles are not received several weeks prior to use, tying up in-process working capital which could be used in other areas of IC manufacturing.

Finally, a simple yet important change in the communication links between Dupont and Motorola's personnel allowed 24-hour coverage. Contact lists include key individuals, normal hours of work, phone number and pager number. The overall supply chain process allows better communication of changes in delivery or scheduling, better resource allocation based on real fab demand and fast response to questions through an improved communication route.

References

1. F.G. Boebel, "Quintuple Ramp Up Slope by Implementing Cross-functional, Self-directed Work Teams," *IEEE/SEMI Advanced Semiconductor Manufacturing Conference Proceedings*, 1996, p.436.
2. T.Agostino, et.al., "Yield Risk Cards at D2," *IEEE/SEMI Advanced Semiconductor Manufacturing Conference Proceedings*, 1996, p. 443.
3. D.A. Abercrombie, et.al, "Customer Linking: a Motorola/DuPont Photomasks Supply Chain Assessment," *IEEE/SEMI Advanced Semiconductor Manufacturing Conference Proceedings*, 1995, p.297.