Transferring Lean Manufacturing to Small Manufacturers: The Role of NIST-MEP

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Abstract

This paper describes the emerging role of a new source of federal assistance for small manufacturers, the Manufacturing Extension Partnership. The MEP can help make SMEs more competitive by transferring the lean manufacturing management system through a network of centers, field agents and service providers that complement the programs of traditional SBDCs. A survey of MEP field agents suggests a need for technical and management systems training in the lean approach.

Introduction

Before 1900 manufacturing was a craft and all products were custom made. In the early 1900's, Henry Ford introduced mass production and changed manufacturing forever. The Ford System had three key elements: a conveyor to move work to the worker, a division of labor to separate the manufacturing process into simple, repetitive tasks and an integrated supply chain to bring parts and materials to the assembly line. In the late 1940's, the Toyota Production System evolved from the Ford manufacturing system. Managers and workers learned to question the need for every work sequence, every item of in-process-inventory, and every second that people, material and machines were idle (Shingo, 1989). As a result, manager and employees learned to identify and eliminate waste, increasing both production and quality. The terms “continuous process improvement” and “lean manufacturing” appeared in the late 1980's as the American label for the Toyota Production System.

Lean manufacturing is necessary in today's global markets where buyers, not sellers, control price and demand instant gratification with near perfect product and service. As a result, large OEM manufacturers now demand very small lot sizes, multiple models and quick response from suppliers. Companies survived the rapid shift to this new environment by driving down costs while increasing quality and responsiveness. The traditional financial model was: make a product at a given cost then add a profit to derive the selling price. The lean manufacturing financial model is driven by the price that the customer is willing to pay for the product. The lean manufacturer subtracts the cost to make the product from the market price to derive the profit and net revenues.

Small manufacturing enterprises (SMEs) have been targeted by the Manufacturing Extension Partnership (MEP) which is funded by the National Institute of Standards and Technology (NIST) for the Dept. of Commerce. This relatively new federal program provides technical assistance to help SMEs become more competitive. In some areas, the MEP supplements business assistance from the SBA’s Small Business Development Centers. Specifically, lean manufacturing training and implementation, one of the services offered by MEP centers, is becoming a major source of developmental assistance to SMEs.

The purposes of this paper are to: (1) discuss lean manufacturing and its tools, (2) report survey results of MEP field agent knowledge of lean manufacturing and the degree to which MEP field agents have been able to transfer "lean" to client firms, and (3) illustrate via success stories the pay-off of transferring lean manufacturing know-how and tools to manufacturers.

Lean Manufacturing

Lean manufacturing is more than a set of tools and techniques. Lean manufacturing is a culture in which all employees continuously look for ways to improve processes. It is a management philosophy and system of organizing to eliminate all non-value added activities, or waste, throughout an organization's complete system. The essential goal of lean manufacturing is to compress time from the receipt of an order all the way through receipt of payment. The results of time compression are greater productivity, shorter delivery times, lower cost, improved quality, and increased customer satisfaction.

Building Blocks of Lean Manufacturing

The driving factor in lean manufacturing is to satisfy the customer, including customers that are downstream employees. As a result, the goal is to produce what is needed, in the amount needed, at the time needed, with minimum materials, equipment, labor and space. The basic building blocks of lean manufacturing are shown in Figure 1. Each of these tools is briefly described in the following sections.

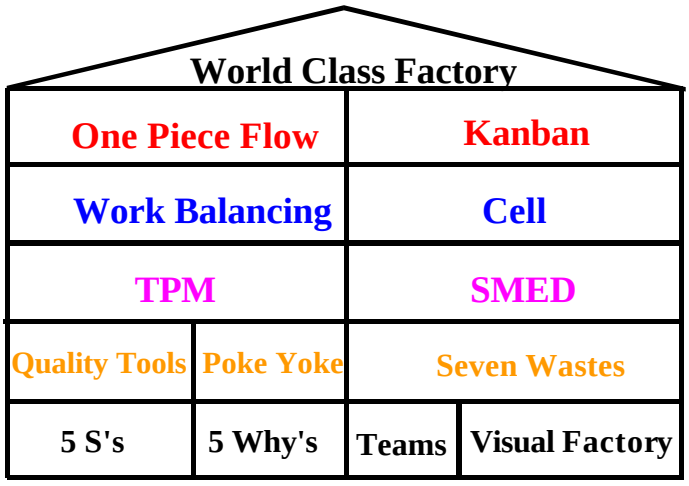

Figure 1. Lean manufacturing building blocks

3.1 The 5 S's - The 5 S's of good housekeeping are the first step of lean thinking (Hirano,):

- Sort - separate out all things that are unnecessary and eliminate them
- Straighten - arrange essential things in order for easy access

- Scrub - keep machines and work areas clean
- Stabilize -make cleaning and checking a routine practice
- Sustain - make the 5 S's a way of life

3.2 The 5 Why's - When a problem is found, ask "why" five times. Repeating "why?" five times gets to the real root cause of the problem rather than merely responding to symptoms.

3.3 Visual Factory - Visual factory is a shop floor concept for making basic task and process information available and understandable at a glance for each operator. The elements of the visual factory are visual documentation of processes, visual production controls, visual quality controls, and visual process indicators (Grief, 1991).

3.4 Teams – Continuous improvement depends on on-going diagnosis of problems, brainstorming countermeasures, and timely implementation. An empowered team approach is essential both within the normal operating group and in kaizen blitz events. The group's collective intelligence is often greater than any outside expert's opinion or a manager's plans.

3.5 Quality Tools - Lean manufacturing begins with process understanding and leads to process improvements. Typical quality tools are flow charts, frequency histograms, pareto diagrams, cause and effect diagrams, and control charts.

3.6 Poka Yoke (Mistake Proofing) - Poka Yoke are simple, low cost devices that prevent defective parts from being made or passed into the process. Poka Yoke eliminates defects by eliminating mistakes. Some typical Poka Yoke devices are different size guide pins, error detection and alarms, limit switches, counters and checklists (Shingo, 1986).

3.7 Seven Wastes - Waste is anything other than the absolute minimum resources of material, machines, and labor required to add value as defined by the customer. Waste is anything that the customer will not pay for or does not need. The seven wastes of manufacturing are (Ohno, 1988):

- Waste of overproduction - producing more than needed
- Waste of waiting - operator or machine idle time because the process is unbalanced
- Waste of transportation - any movement of material that does not directly support value added operations
- Waste of processing - any operation that does not add value to a product
- Waste of inventory - any inventory in excess of that required to produce product
- Waste of motion – any movement of people or machines which does not add value
- Waste of defects – all repairs to product to fulfill customer requirements

3.8 TPM - Total Productive Maintenance extends the practice of preventive maintenance with the concepts of total quality control and total employee involvement. TPM is a company-wide equipment maintenance program that covers the entire equipment life cycle and requires participation by every employee. A key element of TPM is autonomous maintenance where the operators are responsible for maintaining their own equipment (Nakajima 1988).

3.9 SMED - Single Minute Exchange of Dies is a system that allows the mixing of production as much as required without slowing output or creating higher costs associated with the waste of setup. Changeovers add no value and should be minimized. (Shingo, 1983)

3.10 Work Balancing - Work balancing maximizes operator efficiency by matching work content to TAKT time. "TAKT" is a German word for pace. TAKT time is the rate at which customers require the product. TAKT time defines the manufacturing line speed and the cycle times for all manufacturing operations. TAKT time is computed as:

$$\frac{\text{Available work time per day}}{\text{Daily required customer demand in parts per day}}$$

3.11 Cells - The proper placement of machines is essential in achieving an operational objective. Benefits of good cell layout are reduced inventory, a balanced cell, less walking time and an improved work area.

3.12 One Piece Flow - One-piece-flow is based on the concept of minimizing work-in-process by having operators throughout the process focus on making only one part at a time before starting the next part. That is, make-one, move-one. One-piece-flow dramatically reduces handling and transportation and provides immediate feedback to any overlooked defect (Sekine, 1992).

3.13 Kanban - The translation of kanban is card. A kanban system is an information system that controls (pulls) the production of the required parts in the required quantities and at the required time (Mondon, 1983).

Continuous Process Improvement

Continuous process improvement is a methodology to improve a process continuously and relentlessly. The Japanese word for continuous improvement is Kai for change and Zen for good or for the better. Hence the word Kaizen to describe an organized process improvement event. Table I outlines what continuos process improvement is and is not. Figure 2 outlines the steps in the continuous improvement process**.**

When combined with an effective champion and corporate culture focused on continuously improving customer value, these tools make lean manufacturing a much more powerful systemic approach. The lean philosophy and methods have been shown to work in a variety of settings including continuous, batch and job shop operations, union and non-union plants, small and large operations, for-profit and not-for-profit firms.

Table I. What continuous improvement is and is not

Continuous improvement is not	Continuous improvement is
Just a program	Company philosophy
Departmental	Total plant
Program of month	Long term and un-dramatic
Big splash	Small incremental continuous steps
Technology and equipment	Conventional knowledge
Major improvements	Many small improvements
Money investment	Simple low cost solutions (e.g., Walmart supplies)
Results oriented	Process oriented (results will follow)
Working harder	Working smarter
Time oriented	Task oriented
Complicated	Common sense
Eliminating jobs	Job security by being competitive
Sacrificing safety	Make safety a standard
Done to workers	Done with workers
Involving few employees	Involving everyone

Manufacturing Extension Partnership (MEP)

The MEP is a nationwide network of more than 100 not-for-profit Centers located in all 50 states and Puerto Rico. These centers provide small and medium-sized manufacturers with the help they need to succeed. The network lets even the smallest firms have access to more than 2,000 knowledgeable manufacturing and business specialists. Each Center can assess where a company stands today, provide technical and business solutions, help create successful partnerships and provide seminars and training programs. With local expertise and access to national resources, the Centers made quick impact. Since 1988, the MEP has assisted more than 62,000 firms in problem-solving, quality management, business systems, human resource development, market development, materials, engineering, plant layout, product development, energy/ environmental audits, financial planning, CAD/CAM/CAE, and EDI.

Driven by ISO-9000, global competitors, market demands, and OEM insistence, many small manufacturers in many industries (e.g., automotive, aerospace, appliances, HVAC, farm equipment) are being forced to adopt lean manufacturing or go out of business. MEP field agents include a high percentage of industrial engineers and former plant managers, many of whom are experienced in traditional problem-solving. This study assessed the MEP field agent's capability to help small manufacturers implement the lean approach.

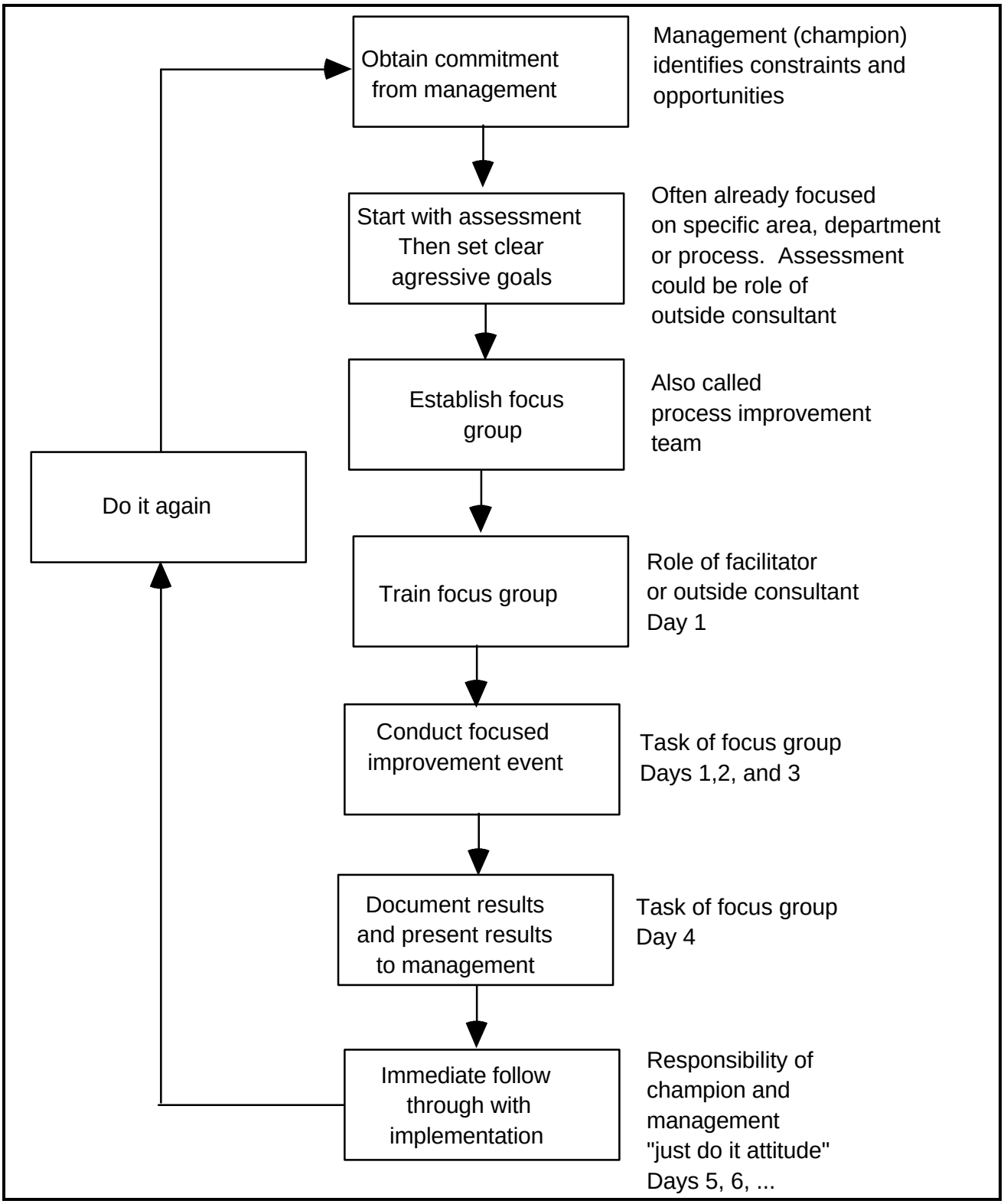

Figure 2. Continuous improvement proces

Survey of MEP Field Agents

Representatives of MEP Centers who attend the annual Modernization Forum served as the sample for this study. We focused on 255 attendees at the 1997 ModForum who were listed as MEP manufacturing specialists, field engineers, project engineers or field agents. Each was faxed a one-page survey of traditional and lean manufacturing methods and tools. The survey assessed current MEP agent capabilities in lean manufacturing, agent training needs, and clients' needs/requests. Fifty-two surveys were returned (response rate – 20%). . MEP agents from 18 different states returned surveys: New York (10), Alabama (6), Texas (5) and Oregon (4). Respondents held 41 undergraduate and 15 advanced degrees in science or engineering, and 5 bachelors and 6 advanced degrees in business. Respondents were an experienced group, averaging 20 years of industrial experience and 2.6 years as MEP agents.

MEP Field Agent Knowledge of Lean Manufacturing

The results (Table 2) indicate that MEP agents know and use traditional problem solving and industrial engineering much more than lean manufacturing tools and techniques (shown in **bold**). Forty to sixty percent of the respondents had no knowledge of eight key lean tools. Only 6 had participated in a kaizen event and 40% did not know how to lead a kaizen.

MEP Field Agent Self-Reported Training Needs

Although less than a third (20-30 percent) indicated a need for training in any manufacturing technique, all eight top training needs of MEP respondents were lean techniques (bold in Table 3). Interestingly, half of these top 8 needs focus on management of lean organizations: lean goals, organizing, reward systems and team building. MEP agents expressed greater need for training in areas where they have some knowledge, but don't use the technique. Agents expressed less need for training when they know enough to use the method/tool or where they have little knowledge. This confirms that individuals need to know something about a topic to recognize a need for that training. As to type of training in lean manufacturing assistance, almost half (25) respondents requested class training, 23 requested training materials, 22 simulations, 15 videos and 12 in-plant kaizens.

Table 2. MEP Agent Knowledge/Use of Lean Manufacturing

MEP Assistance Method or Tool	Don't know (1)	Know, don't use (2)	Use some (3)	I am an expert (4)	Mean
5 S's	66 %	13 %	15 %	6 %	1.62
Calculating & using TAKT time	60	19	16	5	1.65
Reward systems for lean mfg.	55	32	13	0	1.53
5 Whys	53	23	15	9	1.79
7 Wastes	51	20	22	16	1.80
Poka Yoke	48	25	23	4	1.84
Visual factory	44	26	23	5	1.82
One-piece flow	42	16	35	7	2.02
Leading kaizen events	39	39	16	5	1.18
Rapid prototyping	37	26	30	7	2.07
Total productive maintenance	36	36	24	5	1.98
SMED/quick changeovers	36	24	31	9	2.14
Organizing lean manufacturing	34	26	37	3	1.98
Computer modeling/simulation	34	22	37	7	2.17
Baldrige Award application	30	47	21	2	1.92
Setting lean goals/objectives	30	16	50	4	2.30
Managing organization change	26	22	46	6	2.30
7 Basic quality tools/SPC	25	16	36	23	2.57
ISO certification	23	16	34	27	2.60
Leadership development	21	17	51	11	2.51
Kanbans	19	30	47	5	2.37
Teams/cells	17	19	43	21	2.68
Strategic planning	16	22	51	10	2.47
Work balancing	15	18	53	13	2.64
Traditional industrial engineering	15	6	42	37	3.00
Measuring improvement results	14	16	56	14	2.70
TQM	11	23	51	15	2.70
Benchmarking	9	28	61	2	2.51
Process reengineering	9	26	50	15	2.72
Problem solving	2	2	53	43	3.37

Table 3. Top Training Needs of MEP Agents

MEP Assistance Method or Tool	Knowledge /Use Mean	% Needing Training
Total productive maintenance	2.0	30.8
Setting lean goals/objectives	2.3	25.0
Organizing lean manufacturing	2.0	23.1
Computer modeling/simulation	2.2	23.1
SMED/quick changeovers	2.1	21.6
Leading kaizen events	1.2	21.2
Reward systems for lean mfg.	1.5	19.6
Teams/cells	2.7	19.6

MEP Clients' Needs/Request

MEP agents reported that most clients need or request quality improvement, traditional engineering and problem solving (Table 4). According to these respondents, lean manufacturing tools ranked the lowest on client needs and requests.

Table 4. Client Needs and Requests

MEP Assistance Method or Tool	Knowledge/ Use Mean	% MEP agents reporting Clients Need/Request
ISO certification	2.6	55.8%
7 Basic quality tools/SPC	2.6	48.0
Problem solving	3.4	46.2
Traditional industrial engineering	3.0	44.2
Work balancing	2.6	40.4
Strategic planning	2.5	38.5
Teams/cells	2.7	36.5
TQM	2.7	34.6
Process reengineering	2.7	34.6

Survey Conclusions

Results of the survey suggest that MEP field agents have limited awareness, knowledge and use of lean manufacturing methods and tools, and that only about 10% of MEP agents are providing lean manufacturing assistance. With so little knowledge of lean manufacturing, MEP field agents fail to recognize the need of manufacturers for the lean approach or lean tools.

Since lean manufacturing is a key weapon in improving competitiveness of US manufacturers, MEP agents will likely need training to help clients develop a systematic, holistic approach to cutting costs and time. Because lean thinking is learned best by direct experience, training will likely require kaizen participation as well as more traditional methods of delivery.

Finally, MEP clients do not perceive clients needing or requesting lean manufacturing (which may be industry dependent). Yet, MEP agents do report clients request or need tools or techniques that are used in lean manufacturing, including TQM, strategic planning, process reengineering, work balancing, teams/cells, etc. The survey suggests that even if expert agents combine these techniques to meet client needs, the client will still not have implemented lean manufacturing. Thus, MEP agents may need in-depth training to assist MEP clients with the power of the lean approach.

Some MEP Success Stories

The Manufacturing Center at the University of Alabama in Huntsville (part of the Alabama Technology Network) has been assisting clients in lean manufacturing for about three years. Sometimes the Center recommends a third party service provider to provide lean manufacturing assistance. In other instances, engineers from the Center provided the assistance directly. In both cases, the improvements achieved by client firms who participated in kaizen events have been noteworthy as described below.

AS

AS was founded in 1948 in Decatur, Alabama. The firm now employs over 100 people and is a leading manufacturer of screw machine products. The management of AS realized a systematic, results-oriented approach was needed to increase operational efficiency. They decided the best way to achieve this goal was to develop a rapid improvement team. Two approaches were considered: employing customer recommended consultants and developing the program internally. UAH MEP staff had previously developed a working relationship with AS and, based on the company's needs, UAH recommended High Focused Improvements, Inc. (HFI), a North Alabama consulting group that specializes in implementing the Toyota Production System utilizing Kaizen blitz events.

HFI assessed the plant and focused first on the processing of a set of slotted aerospace fasteners. Order size averaged 5000 units and required 6 separate operations. Fasteners were moved to each operation in lots of 5,000 and would wait until all 5,000 were processed thus

resulting in excessive WIP and a 24 week lead-time. A 3-day Kaizen event was scheduled with aggressive goals: increasing productivity by 30%, decreasing WIP by 50%, and improving throughput by 50%. After initial training, the cross functional team spent the first day timing and analyzing the operations, balancing the line and developing a cellular layout. The second day the team rearranged equipment and built the cell. Finally, on the third day the team debugged the new cell and produced fasteners. In three days, product that had been taking 24 weeks to process now flowed through the cell in minutes. With the new cellular layout, 2 people could operate all 6 machines. Productivity improved by 25% and throughput by 90% with a 90% reduction in WIP.

LM

LM is a small Alabama firm that produces farm equipment such as cutters and landscape boxes. The firm has been in operation since 1967, and currently employs 50 workers. LM's manufacturing process performs several operations to metal bar stock and plates, such as bending, shearing, and drilling. Products are then welded, assembled, and painted before shipment to customers. LM planned to add eight new products to its line, and had five more in the design stage. The firm needed to use available floor space more efficiently, improve the flow of work through the plant, and reduce travel time.

Over a two day period, UAH MEP staff trained a cross functional team from LM on Kaizen concepts, including waste minimization techniques. After training, the team studied the processes on the plant floor and recommended ways to eliminate waste. Within two days, all non-production elements were removed from the floor, leaving only equipment and work-in-process materials. Equipment was rearranged to improve product flow. According to the Production Supervisor at LM, the Kaizen event reduced travel distance by 50% and required floor space by 70% and is expected to result in a 30% increase in productivity.

ST

ST is a rapidly growing, high-precision aerospace manufacturer, founded in Huntsville, AL in 1987. ST is a primary supplier of Gulfstream aircraft parts, Tomahawk missile bodies, and Al-Li panels for the Space Shuttle external tank. The company recently completed a new facility in Cullman, AL to manufacture PLS flat-racks for the US Army. With 1997 sales of more than $50 million, ST employed over 450 people in Alabama. Strategic planning facilitated by UAH MEP staff identified process improvement as a key to better on-time delivery, more capacity and profitability goals.

After an initial walk-through assessment with HFI, UAH helped ST management identify more than 10 candidates for kaizen events. The VP of Manufacturing and VP of Programs focused on critical activities just before final assembly: the deburr, inspection, cleaning, and painting steps. In its first three-day kaizen event at ST, a cross-functional team led by HFI flowcharted the process, estimated cycle time and actual value-added operations time, and determined that parts were being moved at least 13 times, a total of more than 1600 feet. In the remaining two days, the team relocated two of the four operations, co-located a new staging area and reduced the total travel distance to 160 feet.

TC

TC is the fastest source of high-quality, standard and custom industrial heating components for the U.S. plastics industry. The firm designs, produces and markets its own lines of band, strip and cartridge heaters, thermocouples and RTD probes. From 1992-95, using Total Quality Management (TQM), the firm changed its "five day delivery on standard products" strategy to same-day shipment.. As a result, over 50% of orders now ship the same day. In 1994 and 1995, TC won the Alabama Senate Productivity and Quality Award. With 1997 sales of about $4 million, TC employed over 40 people, with high customer satisfaction and an excellent reputation. In 1997, the company won the Huntsville/Madison County Chamber of Commerce Small Business of the Year Award in Manufacturing.

To meet expected demand from a new marketing initiative, manufacturing needed to increase output. A new addition would add required capacity, but the staff needed help increasing throughput. To take TQM to the next level, management focused on implementing lean manufacturing techniques learned in UAH MEP seminars. The challenge was to improve a process that had to be flexible enough to handle both the standard and custom engineered products in small batches while maintaining quick ship capability.

UAH MEP business staff provided financial ratio analysis, benchmarking, and market analysis that confirmed a need for improvement in both productivity and quality. UAH manufacturing specialists then led a three day Kaizen event with ten TC employees on process flow in the manufacturing of band heaters. The team learned basic Kaizen principles, viewed operations on the shop floor, listed more than 40 problem areas, identified countermeasures and set deadlines. About 80% of the problems were symptoms of inefficient process flow. After much frustration, the team designed a new layout that would improve the flow. The initial idea was directly attributable to the cross-fertilization among the functions represented. The new flow also made it possible to synchronize production scheduling with sales and shipping and receiving. The new layout required 15% less floor-space, reduced 325 feet of travel distance to 210 feet and compressed production time by an estimated 30%.

WM

WM, founded in Decatur, Alabama in 1945 as a structural steel fabricator, is now a leading equipment manufacturer and construction contractor for the detention industry. Employing approximately 100 people, WM provides a wide range of products, including metal furniture, bar doors, sliding doors, bullet-proof glass, and electronic controls. In late 1996, the president of WM considered bringing the production of hollow metal doors and frames in-house. He realized that to be competitive, WM must improve efficiency, possibly through the implementation of manufacturing cells. He researched the topic, spoke with consultants, and in early 1997 attended a UAH MEP "Lean Manufacturing" seminar. The presentation helped refine his understanding of lean manufacturing principles and solidified his decision to move WM to cellular manufacturing.

UAH MEP recommended HFI for continuous process improvement training and development of manufacturing cells. HFI conducted a three day Kaizen event at WM, with a one day follow up event. Since then, Willo has begun conducting another event every two weeks. The events are half or whole day efforts, and employees have been successful in greatly improving many processes in the plant. For example, a sub assembly process was reduced from approximately fifty minutes to only eighteen minutes. The time required for another sub-assembly was cut by nearly thirty percent. Overall efficiency in the plant has improved greatly, and additional gains continue to be realized as the events continue and additional data is collected.

Conclusions

Lean manufacturing provides a new management approach for many small and medium size manufacturers, especially older firms organized and managed under traditional push systems. Improvement results can be dramatic in terms of quality, cycle times, and customer responsiveness. If fully implemented through a complete organizational change, lean manufacturing can help SMEs achieve world-class performance. One difficulty with lean manufacturing is that the complexity of the new approach takes a long time to implement fully. If managers use a few of the basic lean tools only to "pick the low-hanging fruit" in a quick fix approach, the real potential for dramatic and continuous improvement is usually lost.

Since few small firms have the resources to implement the lean approach on their own, MEP field agents can play a key role in transferring the lean approach to SMEs at each stage of the implementation process. In the initial stage of cleanup and workplace reorganization, assistance usually focuses on guiding the client to good improvement targets and helping set and achieve ambitious goals. After the SME adopts basic lean techniques (e.g., the 5 S's or setup reductions), it often needs help continuing implementation beyond initial workplace reorganization. The second phase often involves significant changes in management behaviors as empowered teams learn how to use data to make decisions. Senior MEP change management specialists can help willing managers make the transition to lean champion and leader. In the final phase, MEP staff can often help the client more quickly synchronize the operation to market demand and institutionalize on-going improvement.

However, the results of this survey indicate that MEP field agents rely most on traditional industrial engineering, problem-solving and strategic planning rather than lean manufacturing. Among this sample, less than a majority was interested in learning lean techniques. Yet, respondents requested the most training in eight key lean tools and techniques. NIST MEP staff recognized this need and formed a Lean Working Group to develop a training program to certify MEP field agents as lean implementers. Staff from two MEP centers are now presenting the first of eight short-courses to other centers, in addition to many small and large manufacturing clients across the U.S. The combination of traditional business and technical assistance with the lean approach holds great promise for restoring the competitiveness of many small and medium-sized manufacturers.

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