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Dr. Manocher Djassemi

ABSTRACT

This study presents a practical framework for introducing lean principles in small manufacturing shops. These shops are characterized by low volume, large variety and one-of-a kind products, accounting for a significant portion of the U.S. manufacturing industry. The potential challenges for adopting a lean system in small manufacturing shops are reviewed. An implementation strategy encompassing the formation of diverse teams of employees, training by external consultants, and the exploration of process improvement opportunities are discussed. While the author's observations point to the success of lean implementation in a local small manufacturing shop, they also reveal several potential barriers as impediments to introducing lean culture in these types of shops.

INTRODUCTION

Lean manufacturing principles are aimed at eliminating all forms of waste or non-value added activities, and improving production cost, quality, and delivery. While the principles of lean are relatively constant, there are many different practices that have been implemented in the quest for value creation in the manufacture of products, such as pull production, cellular flow, employee involvement, total productive maintenance, standardized work, and quality management (Doolen & Hacker, 2005). The successful application of various lean practices have been documented in many large manufacturing plants within various industries, such as electronics, aerospace, computer manufacturing, and automotive assembly (Doolen & Hacker, 2005; Waurzyniak, 2005; MacDuffie, Sethuraman & Fisher 1996). These plants are typically characterized by substantial capital investment, mass production and a repetitive manufacturing environment. In spite of various data sources pointing to the significance of small manufacturing shops to the overall economy (Baker & McInturff, 2007; National Association of Manufacturers, 2001), still relatively little is known about lean practices in these kinds of shops, which are characterized by low volume, small to medium batch sizes, and one-of-a kind products. In a study conducted by James-Moore and Gibbons (1997), the authors have pointed out the lack of published work to explicitly address the issue of whether lean methods are suitable and applicable in low-volume, low repetitive production environments. Shah and Ward (2003) conducted a survey of nearly 1800 plants in the US to investigate the effect of shop size on the likelihood of implementing 22 manufacturing practices including several lean practices. The findings of the study support the notion that large companies are more likely to possess the resources to implement lean practices than are smaller companies.

The objectives of this study are to investigate how small and large manufacturing shops differ in introducing lean practices in their operations, and to offer an implementation plan suited for small manufacturing shops. First, the potential challenges and barriers of adopting lean practices in SMSs are discussed and compared with similar efforts in conventional large manufacturing facilities. Next, a three-phase implementation strategy comprising of the training of diverse teams of employees; the identification of improvement opportunities; and implementation of lean practices is outlined. Finally, based on six pilot projects, the author presents several observations, and managerial aspects of introducing lean process improvements in an SMS.

BACKGROUND AND RELATED WORKS

The characteristic of small manufacturing shops has been discussed in a few studies. In one such study, Baker and McIntuff (2007) presented their observations when visiting a number of industrial parks throughout the southern California region and randomly interviewing shop owners in these industrial parks. They found that among the shop owners, the perception of the number of employees in a small shop is generally somewhere under 50 employees. The authors also pointed out that, small shops appeared to have weathered global competition better than larger firms. However, small shops continue to confront competition, tax burden, environmental regulations, downward pressure on prices, and narrow margins. Under such circumstances, lean manufacturing can competitively position a small shop by lowering cost and increasing productivity. Golhar, Stamm & Smith (1990) stated that lack of power in negotiations restricts small firms from achieving equitable contract positions on price, quantity, and timing issues. Small companies have limited financial leverage but typically adopt and benefit from lean much quicker than larger companies (Yamashita, 2004). As Manoochehri (1988) pointed out, fortunately for the small firms, multi-functional workers are the norm, possibly facilitating the implementation of lean principles.

Before the small versus large differences and challenges are even explored, there is a need for acknowledgement that small, low-volume enterprises need to undergo lean process improvement. Small companies often start out as very small organizations, either with a sole entrepreneur or a small closely knit group of people (Conner, 2009). In these early formation stages, by default, the operation closely follows lean operation principles because there is little other choice. Resources and time are sparse; the highest possible production level with the lowest inventory and number of processes is the obvious choice in most cases. With the growth of small and lean operations there are new employees, customers, equipment and organizational procedures. These changes often come rapidly, and companies often treat the implementation speed as the most significant criterion for decision making due to their limited resources. The result is often a patchwork of employees, tasks, equipment and production flows that become unwieldy to manage. What was once a lean organization, that responded directly to customer demand and grew quickly and profitably, may now find it hard to meet production goals and maintain its profit level. When this underlying situation eventually becomes obvious and undeniable, the organization often turns to "firefighter" mode, deploying all resources in putting out the "fires" of production problems and customer issues. When operations reach this status, the implementation of lean principles may not be the best remedy. As Rother & Womack (1999) pointed out, revamping production lines, retraining employees, and implementing new systems can all be seen as ill afforded costly concepts when a company is struggling with deadlines, and slipping away from profitability.

CHALLENGES AND BENEFITS

Many of the traditional lean manufacturing principles that are used to improve a large, high-volume environment may be an awkward fit in a small, low-volume operation. When an organization has fewer than 50 employees it is difficult to have full time employees focused on lean strategies. A low-volume, high-mix product family may have different performance metrics than a high-volume, low-mix production. The job descriptions and operating unit responsibilities in a small organization may be much broader and have much more cross-over between disciplines than in a large, tightly-structured organization. The available resources and the cost of implementing new solutions can be drastically different between small and large volume operations (Lee 1997). Table (1) depicts some of the differences between these two types of organizations.

A LEAN ADOPTION STRATEGY

As Lee (1997) pointed out, firms with less than 50 workers probably suffer from certain restrictions that impede implementing lean practices. There may be several reasons explaining the differences between small and large firms some of which are alluded to in this study (Tables 1 & 3). As indicated in the previous section, it is very likely that in an SMS, the available resources and budget will be more restricted than in a large shop. Therefore, any attempt to introduce lean manufacturing principles in an SMS should be planned accordingly. To this end, a three-phase implementation strategy is presented in Figure 1, and discussed as follows.

Phase 1: Training

The introduction of lean concepts into an SMS starts by conducting a training program led by an outside consultant, or team of consultants. This involves brief classroom training of employees followed by specific lean implementation projects that are designed to show the staff and management tangible levels of improvement. These lean training

TABLE 1. COMPARISON OF CHARACTERISTICS OF SMALL AND LARGE SHOPS

Characteristics	High Volume (mass) Production	Low Volume (SMS)
Typical annual volume*	From 100,000 to 1,000,000+ units	From 5000-20,000 units
Typical # of employees	Over 500	Below 100
Product variety and complexity	Medium variety, simple to medium designs	High variety, medium to complex designs, one-of-a kind products
Management layers	Multiple layers	Flatter organizational structure
Manufacturing planning system	Make to stock	Make to order
Lean manager position	Generally a dedicated position, justified by sufficient workload	Typically cannot justify the cost of a full time manager

* From Jina, J, 1997

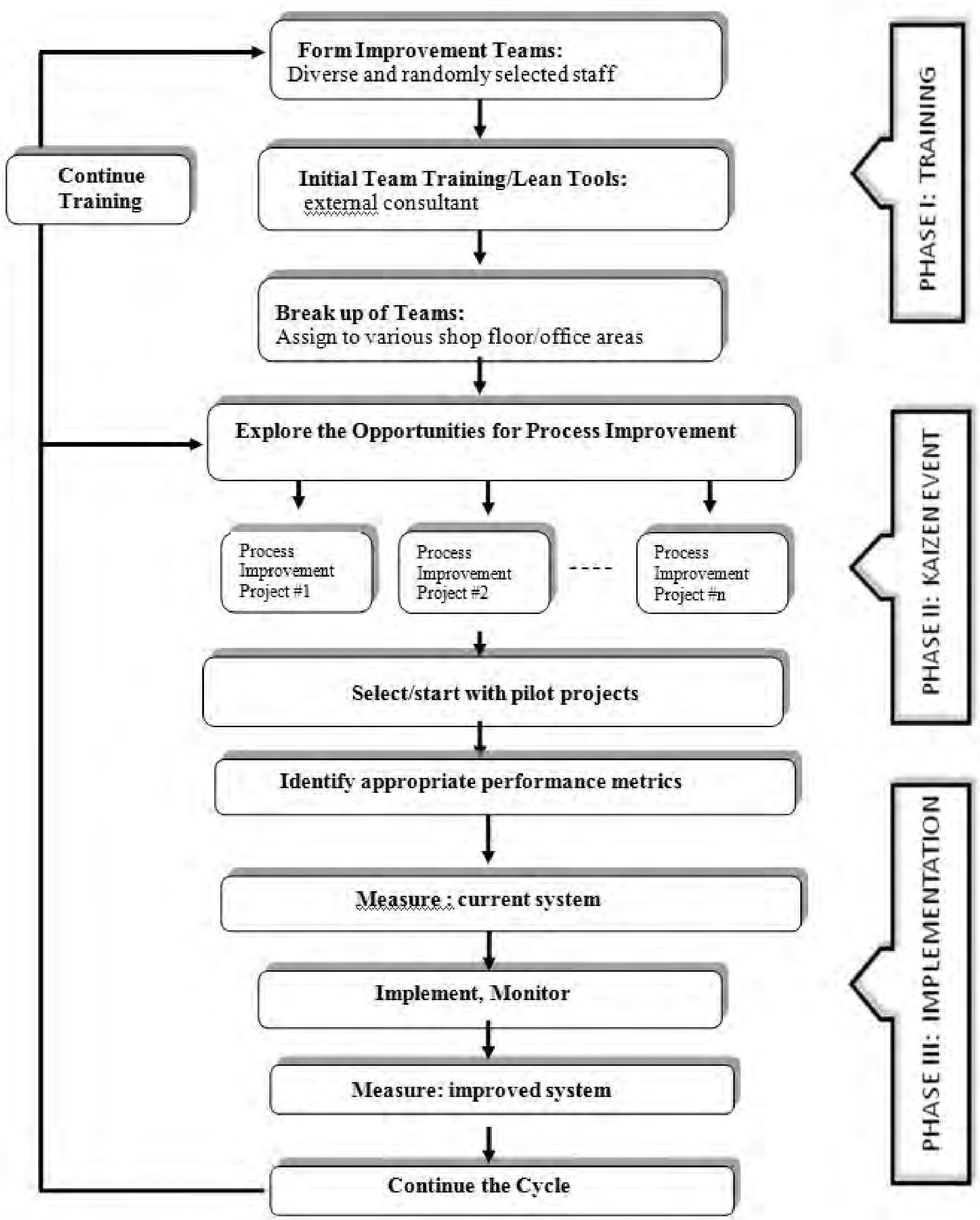
courses may be repeated occasionally with the return of the external consultants in order to focus on new concepts, or retrain employees over time. Next, the employees are divided up into teams and assigned to various areas of the shop.

Improvement Teams

The team composition is a key instrument in creating a foundation for a cultural shift within an organization. Even though most employees interact with almost every other employee in a small company, there can be some pre-constructed divisions with employee groups that may impede the efficient development and implementation of new ideas (Shani, Lau, Brownlee & Coget 2004). In order to counteract this potential bias, an established principle for maximizing diversity within each team is applied. The method of achieving this diversity can be strictly constructed through a decomposition/re-composition matrix in which an equal representation from each traditional division of the company is represented in each team, or through a random draw process; which will randomize the team composition and ensure no selection bias has occurred.

The improvement teams can be determined by

FIGURE 1. A STRATEGY FOR ADOPTING LEAN PRINCIPLES IN A SMALL MANUFACTURING SHOP



an alphabetic algorithm that selects teams based on the last name of each employee. This approximates a randomized composition of the teams. The composition of the teams can be changed early on in the training program if a team seems to be overly skewed towards one department or there is an inner-team conflict that threatens to damage progress. Changes in team composition should be kept to a minimum but should be done quickly and without excessive disruption. To maintain the team cohesiveness, every member of the company must be assigned to a team and every member must attend all training sessions with the fewest possible exceptions (Bertain, 2005).

Lean Tools

The training class should be designed in such a way that it does not overload the employees with charts or maps; the purpose is to see the bigger picture. During the initial training sessions the goal of the class is to define lean manufacturing terms, and the basic tools that help teams seek out the obvious waste around them and determine the processes that would make the greatest improvement based on the lowest cost and effort.

The most important element of training in the first week is to understand the difference between value added and non-value added activities, and properly identify and quantify waste. The tools introduced within the first few weeks of training are intended to be utilized by all employees in their everyday work. These tools may include the prioritization matrix, value stream mapping, cause and effect diagramming, and the 5-Why analysis.

Phase 2: Kaizen Events

Under the guidance of the consultant, teams will identify specific improvement opportunities (Kaizen) that demonstrate tangible levels of improvement to the staff and management. The emphasis will be on finding improvement projects with the potential to recoup the project cost quickly after completion. This is a crucial step for initiating a lean program in an SMS in the sense that it encourages future projects and affects the likelihood of acceptance of a project by the shop owner and/or manager.

Phase 3: Implementation

Once the teams have identified the improvement projects that they are going to undertake, a plan for project execution is prepared and presented to management for approval. The format for a team's plan is a predefined framework in which the team will define the problem, identify the root cause of the problem, identify countermeasures, and suggest a specific implementation strategy for the countermeasures.

In order to generate measurable results, appropriate performance metrics are first defined. This is followed by an initial measurement of the current system. After the project implementation, a final measurement will be conducted on the improved system and compared with initial measurements. The assessment results will be disseminated in a visible way to the company.

APPLICATION

A small manufacturing shop on the Central Coast of California was studied to exemplify the application of the forgoing 3-phase lean implementation approach. This shop is a specialty machine shop that serves large customers in the aerospace and semi-conductor industries with prototypes and low-to-mid volume parts. The company employs approximately 40 people and is owned by its founder who started the company in 2002. The company's customer base is large, but the majority of its routine jobs come from approximately 14 main customers. The company's facility is a 10,000 sq. ft. stand-alone building that is 80% manufacturing space, and 20% office space.

This particular company is an ideal facility for studying lean introduction process because its size is well within the range of small manufacturing shops. The product mix and customer base are also large enough and diverse enough for the company to represent small shops across a wide range of industries. The owner/manager has a better than average appreciation for the value of developing a lean implementation program and realizes that his company needs a comprehensive approach to bring his entire staff to a higher level of lean understanding.

Phase 1: Training, Team Formation

The training program began by an initial external training course, studying an implementation program, and planning an internal implementation program to be conducted by the staff. This training sequence is designed to most closely match the resources and needs of a small, low-volume/high-mix production company.

Following the guidance of the consultant, a cultural shift was initiated by undergoing a 5-week comprehensive staff training program. This training program involved two hours of training, four days per week for every employee in the company. To facilitate this, the staff was divided into six teams for the training. During the training stage several potential process improvement projects were identified. After 10 weeks of data collection and process observations, a series of refined process improvement projects was recommended to management as pilot lean projects.

Phase 2: Exploring the lean opportunities (Kaizen event)

With exposure to the core lean principles, the teams were sent to put the concepts into practice through the defined pilot improvement projects. Since the teams comprised a diverse array of employees from different departments, the initial exploration efforts served as a lesson for the team members and provided an opportunity for employees who may not interact on a regular basis to share their experiences with each other. For instance, one group was comprised of a machinist, a project manager, and two technicians. In this group, there was an opportunity for the technicians to take time to show the project manager and the machinist details of process issues that impede their ability to work effectively.

Phase 3: Implementation

The six teams each made presentations about their identified projects to reduce waste along with their proposed countermeasures and implementation programs. While there is no particular mechanism in the training program to prevent teams from approaching the same issue, it often occurs that the teams naturally develop into unique projects with small initial overlap. As the teams explored their projects, there were some areas of overlap between projects because different manifestations of waste may have the same root cause. At the end of the project presentations there was a coherent theme to all of the projects, no matter how dissimilar they were at the start in their principle subject matter. Although consultant service continued throughout the pilot projects, the actual implementation was conducted by the team members.

In the next section an overview of the first five pilot projects is presented followed by details of the sixth one.

Pilot Projects

Parts Surface Finish Quality – The problem identified by the team was that an excessive amount of non-value added time was being spent in part surface finishing, including cleaning and deburring. The main cause of this waste was identified as a lack of staff knowledge in status and priority of part orders.

External Setup –The problem identified by the team was that an excessive amount of non-value added internal setup time was being spent on clamping parts on machine tools, resulting in an increase in machine idle time. A proposed solution was defined as additional training on conducting machine setup externally and the addition of setup carts and fixed tool holders that would allow for such external setup tasks to be completed without interrupting workcell operations.

Manufacturing Engineering Review – The manufacturing engineering process is started for each project by a customer contract. These contracts establish the payment terms and total price of a contract based on the customer requirements. The problem identified was that, on average, 40% more labor time was actually being spent on a given contract than what it was allocated in the contract. The countermeasure was an adjustment to the contract development workflow to improve the accounting of contract requirements and benchmarking based on previous contracts.

Cutting Tool Maintenance – In a machine shop the cutting tools are the front line of manufacturing. Part production can often require more than 10 different cutting tools to complete a machining operation. The operator of the machine must find, measure, and load the tools at the beginning of an operation and must ensure tool quality during an operation. While there was evidence of some 5S activities in place (sort, straighten, shine, standardize, and sustain), the problem was that there was no continued effort to maintain these activities or place responsibility accordingly. This led to an increase of non-value added search time for finding cutting tools that were being improperly stored or not returned to storage.

Fixture Organization – Complex machining operations often require special fixtures to hold the parts during an operation. The problem was identified as an extraneous amount of time required to find fixtures due to excessive number of fixtures being held in storage. The proposed countermeasure was a new fixture storage system with a visual management system for identifying fixtures by company or job type.

Quality assurance project– In this shop, one of the required operational tasks is certification of the products before they can be shipped to the customer. In many operations, quality assurance is not a value-added process because the customer only assigns value to parts that comply with required specifications; therefore quality assurance labor and costs often have the same attributes as scrap or other non-deliverable goods. In this shop, quality assurance does not fall exclusively into the non-value added category because part of the customer requirement is a package of product certifications stating that parts have been certified to meet a predetermined quality level. The problem was identified as an excessive workload in the Quality Assurance (QA) department which caused a bottleneck in production flow. For this project, the appropriate metrics for measuring improvement were defined as total overtime spent on QA tasks, and on-time delivery rate.

The excessive workload was quantified by a total of $23,000 in overtime, $15,000 in measured non-value added activity by the QA department and, a 76% on-time delivery rate. The last element of delivery rate indicates that 24% of all contracts are in jeopardy of losing repeat business due to inadequate performance. The financial loss of a single customer is estimated to be between $75,000-100,000/year.

The primary cause of the quality assurance problem was identified as a lack of communication and scheduling between the QA and other departments. This problem led to the QA department being unable to effectively schedule its workforce to match the work levels, which led to bottleneck in part processing. This in turn led to an extraneous amount of time elapsing before job orders were released to shipping or to subsequent processing departments.

The countermeasures proposed included: cross-training other departments to complete some quality assurance procedures during their operations to eliminate part movement; reducing QA department workload; and developing scheduling queues in other processing departments to help QA plan scheduled tasks with higher accuracy. The implementation strategy was created to standardize work instructions for QA inspection procedures; consolidate QA documentation to reduce paperwork flow, and provide a visual indicator for machining work stations to indicate when inspections would be required.

Table (2) shows the performance data for the current and improved QA department.

Training

As one can expect from a small manufacturer, the shop under observation could not afford the cost of a dedicated position for lean continuous improvement. Instead, the manager decided to temporarily hire an external consultant for staff training, hoping this would bring a continuous improvement of lean culture. The manager was also expecting the training program to embed continuous improvement responsibility within the shop floor staff and line managers.

One challenging aspect of lean training in small shops is the drastic interruption in production during training due to the limited number of personnel. In comparison, in large shops, staff training is more feasible without significant interruption in daily operations.

Dissemination

Introducing lean thinking in a large organization requires training and commitment of multiple layers of management as well as a larger number of shop floor workers. In an SMS, even with a small number of employees, dissemination of a continuous improvement culture is achievable with an owner or manager committed to lean thinking.

Tracking the waste

As one can expect, small manufacturing shops are typically less complex, therefore tracking the source of defects is much easier than in larger shops. However, the author noticed the lack of information

TABLE 2. PERFORMANCE DATA FOR QA DEPARTMENT

Metrics	Current System	Improved System	Net Improvement
On-Time Delivery	76%	87%	11%
Overtime	$15,000	$9,500	37%

MANAGERIAL ASPECTS

At the end of this study, the shop completed the implementation of pilot projects and proceeded with their continuous improvement journey. The tools used to identify and analyze the waste in the pilot projects were simple and predicated on significant but easy to implement improvements procedures while gaining buy-in from employees and management to the lean manufacturing principles. The next step in the ongoing lean adoption process for an organization is to refine and expand the use of lean tools and identify more hidden sources of waste as well as more complex, yet powerful countermeasures. Table 3 depicts a comparison of small and large shops in terms of lean implementation issues. In the following section several managerial aspects and observations made during lean introduction in the shop under study are presented.

sharing and competition in a few areas that could potentially prevent the dispersion of knowledge of quality problems. This can be attributed to tight work space and close personnel interaction.

Cost

Considering the training and implementation costs of a lean project, it is essential to have an estimate of the amount of savings that can result from such a project. The cost of training employees has a direct impact on the net revenues of a firm. In a large manufacturing environment where there may be more than 100 operators in a given production area, cycling 10-employee groups into a training program will only reduce productivity by approximately 10%. If the company has only five employees in a production area, cycling any number of employees into a training program is going to have a 20%-100% reduction in production capacity.

Supply chain/job contract issues

On the customer side, the uncertainty of customer demand can affect the ability of the small shop to smooth its production flow. With respect to the supplier side, supplier constraints may preclude timely deliveries in small quantities. Small shops such as the one studied here have a high level of outsourced parts; therefore, they may find themselves dependent on priorities set by their suppliers and not on their own production requirements. Hence, small shops may face longer lead times as their orders wait to fit into the supplier's production schedule.

Lean level scheduling

One common lean manufacturing principle is the pull system, the goal of which is to create a part mix sequence to match the customer demand, while producing a quantity of parts that minimizes work-in-process (WIP) inventory. In small shops, due to smaller job orders and batch sizes, lean level scheduling of material flow is more manageable, and successful in reducing WIP inventory. However, since the typical SMSs have a limited number of production units and high production mix parts, there are often long setup time requirements to switch between job orders as part variety increases. Without a formal lean level scheduling and job order prioritization system, workers will often pick and choose jobs to minimize setup times, a tendency that can increase WIP inventory if left unchecked.

Cellular/one-piece material flow

One-piece material flow concept involves the transferring of parts in a batch size of one between machines, which are closely laid out in a production cell. Distances and batch sizes in large shops are typically high, and may require the use of capital material handling equipment. A small shop lends itself better to one-piece flow due to lesser distances between machines and other shop areas.

TABLE 3. LEAN IMPLEMENTATION ISSUES IN SMALL AND LARGE SHOPS

Characteristics of Lean Manufacturing	High Volume (mass) Production	Low Volume (small shop)
Training: effect on daily operations	Interruption: less significant	Can be tangible due to smaller workforce Limited resources for internal training
Dissemination to employees	Required at multiple layers of management and staff	Typically one or two layer: shop manager and staff
Employee involvement	Lower, considering total # of employees	Higher, considering total # of employees
Waste reduction: tracking waste	May not be easy due to size of facility	High visibility, easier to track
Implementation costs	Easier to justify: a drop in the overall budget bucket	More tangible especially in personnel cost
Pilot project magnitude	Focus on solving larger problem first	Start with smaller problems
Culture of continuous improvement	Direct coercion by higher level executive	Requires direct involvement of owner
Management Support	Needs support of top management	Needs direct involvement of ownership
Supply chain: job contracts	Less sensitive to supplier's priorities	More sensitive to supplier's constraints
Lean level scheduling	May require significant planning due to high product volume/ variety	More manageable
Cellular layout (one-piece flow)	May require substantial cost for relocating equipment into a cell	More practical due to proximity of resources

CONCLUSION

While data sources point to small manufacturing shops as a major contributor to the national economy, still relatively little is published regarding lean practices and successes in these types of shops. In this study, the attributes of small and large manufacturing shops were compared with an emphasis on challenges for adopting lean thinking in small shops. In this regard, anecdotal evidence suggests that resource limitations place an SMS at a particular disadvantage when it comes to adopting lean principles. Considering these limitations, a strategy for lean implementation by small manufacturers was outlined, encompassing the formation of diverse teams of employees, training by external consultants, and the exploration of process improvement opportunities. While tentative, this strategy seems to have a great upside in gaining buy-in from employees and management as it starts with projects that have low implementation costs and potentially quick turnaround times. The proposed strategy was applied in a small shop with a series of pilot projects. While the author's observations point to feasibility of the strategy, they also reveal some barriers to adopting lean principles; including potential interruption in daily operations, and the disadvantageous position of the shop with respect to suppliers' delivery priorities.

Given the rarity of publications demonstrating lean practices in this significant sector of industry, further studies are needed to disseminate the results of the lean practices and challenges of introducing lean culture in SMSs. For instance, the studies related to use of value stream mapping can visually highlight the benefits of a lean system by exposing the wastes in the value stream, and identifying improvement opportunities. All pilot projects mentioned in this study could have been developed with the help of value stream map. This should function as a vision of a waste-free future state of processes that can be communicated to employees. Case studies in lean implementation that involve the use of relatively low cost lean tools such as 5S, visual management, standardization, and statistical process control are also appropriate extensions of this study.

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