Integrative Total Productive Maintenance: Lean Practices

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Abstract:

A key aspect of lean manufacturing practices is the implementation of an integrative total productive maintenance (TPM) system. Manufacturers and others implementing lean practices need to understand the importance of employee involvement and support of an integrative TPM approach. The paper summarizes key aspects in the literature associated with team based and union environment that support and impede the implementation of integrated TPM as a part of lean practices.

Introduction

This paper forms the theoretical and conceptual foundation for the further development of an attitudinal questionnaire used to survey union represented employees in several component plants of a major original equipment manufacturer. The discussion revolves around the key aspects of total productive maintenance (TPM) as one of the critical components to successful lean manufacturing implementation.

The historical background, current, and future TPM practices are framed in the context of lean manufacturing. Finally the discussion will focus on how a major OEM has developed and applied their TPM approach as a part of their lean manufacturing practices.

Subsequent work has been completed to empirically test relationships and predictive measures but is not included in this discussion.

Historical Background of Total Productive Maintenance (TPM)

Preventive maintenance was introduced to Japan from America in the 1950s, when Japanese process industries were beginning to get back on their feet after the war. *Productive maintenance*, developed in the 1960's, incorporates such disciplines as maintenance prevention design, reliability and maintainability engineering, and economic engineering to enhance the economic efficiency of equipment investment for the entire life of equipment (Suzuki, 1994). The Japanese were the first to realize the importance on improved equipment maintenance on gaining the competitive market edge.

TPM links to many other initiatives, which include zero defects, lean manufacturing, total quality management (TQM), continuous process improvement, and productivity, to name a few.

Another key manufacturing initiative is the just-in-time (JIT) system. To enable a company to properly operate in a JIT environment, maintenance is a critical factor to meet customer requirements. The total integrated supply chain requires that all companies be able to meet each other's requirements.

JIT forces companies to go to TPM so as to develop this environment of process predictability. TPM, a term originally coined by General Electric in the early 1950's sadly has been largely neglected in the U.S. until recently. The philosophy behind TPM parallels that of total quality. While total quality moves from an emphasis on historical practices such as inspection, sorting and rework to an emphasis on prevention, TPM moves from an emphasis on simple repair to a primary focus of the prevention of machinery breakdown before it occurs (Robertson and Niehaus, 1992).

A complete definition of TPM includes the following five elements (Nakajima, 1988):

1. TPM aims to maximize equipment effectiveness (overall effectiveness).
2. TPM establishes a thorough system of PM for the equipment's entire life span.

3. TPM is implemented by various departments (engineering, operations, and maintenance).
4. TPM involves every single employee, from top management to workers on the floor.
5. TPM is based on the promotion of PM through motivation management: autonomous small group activities.

The major thrust of TPM is to maximize equipment effectiveness. With any process or program, to determine the success, there needs to be metrics to track the progress.

Maximizing equipment effectiveness is a key element of overall plant effectiveness. There are eight major losses to the plant that hinder a plant from achieving its maximum effectiveness. They include the following:

1. *Shutdown loss* is time lost when production stops for planned annual shutdown maintenance or periodic servicing.
2. *Production adjustment loss* is time lost when changes in supply and demand require adjustment in production plans.
3. *Equipment failure loss* is time lost when a plant stops because equipment suddenly loses its specified functions.
4. *Process failure loss* is time lost when a plant shuts down as a result of factors external to the equipment, such as operating errors or changes in the physical or chemical properties of the substances being processed.
5. *Normal production losses* are rate losses that occur during normal production at plant startup, shutdown, and changeover.
6. *Abnormal production losses* are rate losses that occur when a plant performs inadequately as a result of malfunctions and other abnormal conditions that interfere with performance.
7. *Quality defect losses* include time lost in producing rejectable product, physical loss in scrap, and financial losses due to product downgrading.
8. *Reprocessing losses* are recycling losses that occur when rejected material must be returned to a previous process to make it acceptable (Suzuki, 1994)

These losses can have a serious financial impact on the company. It is essential to minimize these losses and prevent their occurrence. These losses, if significant, could have a detrimental impact on the continuing existence of the company. Loss of customers is hard to quantify other than a reduction of sales and lost future sales.

Measuring the success of the TPM program is important. There are several key measures that can assist in tracking progress during implementation of TPM. These measures include measuring availability which takes into consideration operation time and loading time where operation time is defined as loading time less downtime (Nakajima, 1988). A metric can be established to compare actual performance. The key to successful performance measurement is accuracy. If the information is not accurate, the metric will be bogus and will not provide meaningful information.

Another measure identified by Nakajima is the performance efficiency. This compares theoretical cycle time with actual cycle time. Additionally, he defines a third measure referred to as rate of quality products. The three measures; availability, performance efficiency, and rate of quality products multiplied by each other gives the key metric of overall equipment effectiveness (Nakajima, 1988). This metric measures the success of TPM.

Preventive plant maintenance aims to control planned maintenance activities instead of allowing machine breakdowns, which result in unexpected expenses. Studies show the good preventive maintenance practice will reduce maintenance costs by 30% when compared to expenses incurred from reactive maintenance. In addition, good plant maintenance will result in improved production capacity, thus, boosting the plant's bottom line profit (Brautigam, 1993).

Because there are numerous constraints involved in implementing TPM, the use of linear programming models may be useful to properly consider all the constraints and limitations.

Another statistical technique that could aid in evaluating the constraints associated with TPM implementation is goal programming. Goal programming would take into consideration setup time, profit goals, cost savings, capacity constraints, production objectives, product mix, and inventory issues.

Since Ford Motor Company is quite large; the development of statistical models would be quite complex to ensure that all variables have been properly included in these models to calculate a meaningful result.

TPM Today

The TPM process needs to start with the requirements for the equipment to be purchased. Equipment Maintenance Council executive director Jack Mears (1996) says that equipment breakdowns can be prevented by adopting a PM program. PM, which stands for planned maintenance, programmed maintenance, and preventive maintenance involves the identification of mechanical problems before these affect production. Mears (1996) also says that function rather than price should be the main consideration in equipment selection. In the automotive industry where the lowest price gets the highest consideration, the lowest price does not always mean the lowest cost. As companies focus on cost reduction efforts, there is a need to properly evaluate the equipment purchases and this may require paying a price greater than the "lowest bid price" to achieve overall lowest life cycle cost.

Companies who continue to purchase equipment at the lowest price are living for the short-term and not properly planning for the future profitability. Short-run decisions such as these have focused on today's profit and not tomorrow's cost.

Once the equipment has been purchased, the key focus is on maximizing machine effectiveness. Maintaining productivity involves balancing many factors including operator training, equipment maintenance, quality control and production scheduling. Cross-training of operators helps maintain productivity even when a key operator is missing. Preventive maintenance is essential but should be flexibly scheduled. The quality of raw materials directly impacts productivity by contributing to machine downtime and production re-runs. Production should be scheduled based solely on what materials are currently available. Total Productive Maintenance affects the entire business. It affects human resources and requires that proper training and change management is addressed. It impacts productivity and output, which could have an impact on the customer. It affects the entire supply chain from supplier to customer.

As mentioned earlier, TPM is linked to many continuous improvement initiatives. A new approach is presented using theory of constraints (TOC). TOC focuses on the company's goal and how to achieve such a goal. It does not focus on cost reduction like many other improvement programs. Rather, it seeks to increase the level of manufacturing (Chakravorty and Atwater, 1994). The Ford Motor Company supports the Theory of Constraints (TOC) philosophy which focuses on increasing the level of production which ultimately will decrease cost and increase profitability.

Autonomous maintenance is also a significant element in TPM. Autonomous maintenance activities are one of the main features of TPM, and are a key point in its development. Changing the lack of interest in maintenance on the part of operators, who think that "I'm the operator, and you're the maintenance man", and developing autonomous maintenance-i.e. "autonomously maintaining the equipment one uses by oneself" – is not something that can be done overnight. It takes two to three years from when TPM begins to be introduced up until the introduction stage is fully implemented, and this is because it takes time to change the attitude of human beings (Nakajima, 1986). In a union environment it requires receiving a buy-in from the union to modify work rules and therefore move to flexible job classifications. This is a big barrier in the automotive industry. It also requires cross training of the employee to provide them with the technical tools necessary to allow for autonomous maintenance.

The main goal of an effective TPM effort is to bring critical maintenance skilled trades and production workers together (Labib, 1999). This effort is not always an easy one. Many issues arise as this foundational effort is undertaken. The role of the worker is changed from the traditional craft mentality to the removal of barriers that have been in place since auto production started (McAdam and Duffner, 1996). This effort requires an "Active Organization" (Yamashina, 2000). This requires competent leaders that are willing to invest in education and willing to empower the workers. As TPM is a common element to the lean drive, it requires not only flexible equipment but employees involved in the production process (Sahin, 2000).

Many issues arise when trying to implement TPM in a union environment. Workers fear that the only drive is to improve production efficiency, reduce labor, and increase employee work load (McAdam and Duffner, 1996). Many operators don't want additional responsibility and are happy with the situation the way it is. In addition the skilled trades enjoy their indispensable role and feel that the autonomous maintenance activity threatens their jobs (Patterson, et. al, 1995).

TPM and the Future

Moving forward, as there is movement to what is known as the knowledge-value society, knowledge workers will constitute a significant part. One aspect of this knowledge-value revolution is the emphasis on man-made resources as capital goods and other goods of heavy technological content. TPM is a critical part of the strong technology base for “man-made resources” (Banker, et al., 1996)

The value of TPM cannot be realized or maximized if the following does not occur: (1) cost savings from TPM can be predicted and measured, (2) cross-functional teams are integrated to enhance the value of TPM, and (3) the root cause of equipment problems is effectively identified (Leblanc, 1995). This goes back to the earlier discussion regarding the importance of identifying metrics to track progress. TPM goals and objectives need to be fully integrated into the strategic and business plans of the organization because TPM affects the entire company and is not limited to production.

Improvement in equipment striving for the optimal conditions leads to zero breakdowns, and zero breakdowns lead to zero defects. Striving for zero defects target leads to significant cost reduction, which in turn provides the needed cost and quality to protect investment and jobs in the future. This is the Total Productive Maintenance reaction (Banker, 1995). This supports the philosophy and methodology that the Japanese profess to when it comes to successful implementation of TPM.

As the TPM process is implemented, maintenance cost will be reduced as the quality of the product manufactured is improved (Koelsch, 1993).

Automation integration is important and is the way of the future for any manufacturing initiatives including TPM. Early warning is a key to total equipment failure.

Hazard studies, expert systems, failure mode and effects analysis (FMEA) or PFMEA (Process FMEA), root cause and fault tree analysis, and condition monitoring give early warning of impending failure. Equipment designs emphasizing reliability and maintainability (R & M) attack causes (Owen, 1994). These methods have been used for many years by industries outside of automotive and in the past few years, the automotive industry has realized the benefits of these methods.

R & M systems will only provide useful output if the input to these systems is timely and accurate; garbage in, garbage out. It is the responsibility of the operators not maintenance to keep the information up to date so that maintenance can respond before the problem becomes serious and causes long-term damage to the machinery.

More operators work with advanced diagnostics and help systems today. Help systems walk even a novice through an incident, asking questions and prompting action. The operator can go as far down in the system as needed to find the right corrective action, thanks to maintenance manuals that live not in a supervisor's drawer but on line (Owen, 1994).

The real future lies in maintenance-free. This is the vision of many companies but very few are even close to this point. This would enable equipment to be up and running all the time. A study was conducted to identify how this may occur.

The NRC study provides the last word: "The ideal manufacturing environment of the future has no maintenance organization. Every piece of equipment is expected to be available 100% of the time. Sensors monitor the conditions and performance of equipment throughout the manufacturing operation and feed relevant data to system controllers. Controllers interact with technically sophisticated human operators, who use the data to maximize throughput, do timely maintenance, and recover promptly from failures. Equipment is designed by concurrent engineering teams that draw on comprehensive data from the equipment and from an installed base of industrial users" (Owen and Sprow, 1994). Is this a reality in the near future? In the automotive industry with a strong union advocating strict job classifications, this will be a difficult change to implement. The use of operators in a maintenance role has been met with resistance. If companies can reach flexible work arrangements with their workforce, future initiatives can be successfully implemented.

TPM Benefits

Companies, which seek to improve competitiveness, must infuse quality and improvement measures in all aspects of their operations. This principle led to complete overhaul of maintenance practices in manufacturing plants. Maintenance managers now view the consistent production of quality goods as greatly dependent on the quality of operations rendered by the necessary machinery. The TPM approach helps increase uptime of equipment, reduces machinery set-up time, enhances quality, and lowers costs. Through this approach, maintenance becomes an integral part of the team (Avery, 1993). The ultimate benefits that can be obtained by implementing TPM are increased profitability and improved productivity. Financial quantification specifically calculating the savings is not directly shown on the income statement. Non-financial measures can be converted into financial savings and cost reductions realized by implementing TPM. The implementation of TPM is interwoven with other initiatives causing a confounding impact.

Several Japanese companies with more experience in the process have realized significant improvements from fully implementing TPM. These improvements include equipment availability up 50% and failures down 90%, process defects down 90%, customer complaints down 75%, maintenance costs down 30%, and maintenance inventory down 50% (Windle, 1993). Before progress can be identified, companies will first need to establish the current performance so as to properly monitor progress towards their goals. As can be seen from the above measures, the entire organization and customers are affected by successful implementation of TPM.

TPM Case Studies

Although TPM originated in the U.S., the Japanese have been the forerunners in the successful implementation of the process. At Kokura Steel Works, the entire Works, with special mention to the Equipment Maintenance Department, is aiming to establish an ‘Effective Equipment Maintenance System’. Therefore, we have continuously developed TPM activities with the participation of all the employees at the Works including members of affiliated companies and subsidiaries. As a result, there has been an improvement in factory operation, an increase in working efficiency of maintenance personnel, and a reduction in repair costs (Fujiwara, et al., 1993). In an earlier discussion the importance of involving all employees is required for TPM to be successful. At the Works, significant improvements and reductions in cost were realized as a result of a total organizational effort. If the maintenance department did not have support from all employees, it is doubtful that the implementation would have achieved the results that it realized.

Total Productive Maintenance methods and tools are being applied in a silicon wafer fabrication facility as part of continuous improvement efforts to achieve manufacturing competitiveness. The five-phase road map to implementation includes: (1) an awareness program to obtain management commitment and support; (2) a restructuring of the manufacturing organization to integrate maintenance in production modules; (3) planning maps to cover TPM activities related to equipment effectiveness, maintenance management system, workplace and workforce improvements; (4) an implementation process based on the work of cross-functional, multi-skilled, self-directed teams; and (5) an assessment process to “close loop” the implementation process and define directions for continuous improvements (Fujiwara, et al., 1993).

Another example of TPM is the implementation by Monsato. Monsato implemented an on-line predictive maintenance system. Monsanto Company’s Chemical Group is increasing its use of on-line predictive vibration monitoring to obtain early and reliable detection of problems with the equipment involved in its chemical processes. Failure in these pumps, compressors, gear drives, fans, agitators and centrifuges could result in fires or explosions. Safety concerns, lower maintenance costs and increased productivity as well as the prevention of catastrophic failures and related damaged equipment costs were prime considerations in the establishment of an on-line predictive maintenance system (Berggren, 1994)

In the Monsato case, in addition to productivity and efficiency, safety was a critical factor. Failure to properly monitor equipment maintenance could have resulted in serious injury, or worse yet, death.

Another aspect overlooked by companies is the human element of implementing TPM. One of TPM's major benefits is the production function, aligned with production goals and focusing on prevention and increased profitability, thus empowering operators and technicians to make decisions. The concept of empowerment has become the most powerful notion at GM Opel in Eisenach. TPM's success at the Eisenach plant stems from the formation of cross-functional teams involving operators, maintenance people, engineers, and managers who cooperate to improve equipment and people performance. It is this partnership – people systematically combining knowledge and skills to maximize equipment outputs with minimum inputs – that significantly lowers life cycle costs (Hamrick, 1994). Flat organizations are conducive to implementing TPM because authority and responsibility are shifted to the lowest levels within the organization. Another key element is the importance of cross-functional interaction. This is not just a production activity; it affects everyone within the supply chain.

TPM team activities also contribute intangible results, such as enhancing the quality of work life, improving participating, reducing stress and reducing absenteeism. Greater job satisfaction can translate into higher productivity and quality, and ultimately contributes to lower manufacturing cost (Hamrick, 1994). Companies need to consider the human aspect of TPM in combination with the technical and financial impacts.

Work Groups

One key strategy in effective implementation of workgroups is management and how they support the effort to drive continuous improvement in the team environment. Why is this important and how does it drive improvement? Building on trust through effective communication, worker participation in decisions, acceptance of ideas and frequent feedback are catalysts that drive improvement. How can you find out if this is working? Conducting a plant survey can be an effective tool to determine the direction required to tailor the approach to this change effort (Clifford and Sohal, 1998). What role does leadership play in effective workgroups? An effective workgroup does not mean the absence of leadership (Appelbaum, et, al, 1999). Leadership must provide a consistent message not conflicting ones. Team leadership should include encouraging, facilitating, maintaining order, and helping with decision-making. Leadership needs to provide feedback.

Feedback is an essential element required to operate a lean site. This feedback system is an essential tool that plant leadership must use to drive continuous improvement. To be successful in the lean environment, feedback from workers must be relied on heavily (Forza, 1996). Major transformations in leadership skills are required to drive new behaviors. The new management style required to drive from traditional mass production to lean must be change (Bennis, 1999). The top down management structure of the past promotes resentment in the workers. What does leadership need to do? New leadership must understand and practice appreciation. They must also build trust leading to allies in the work place. Similarly, Manzoni and Barsoux (1998) points out the authoritarian systems of the past hierarchical systems and how they result in the "set up to fail syndrome". Employee trust can only be established if the managers communicate truthfully. Argyris (1986) states that managers need to lose their skills of deception and learn to deal with problems directly and honestly. How can this be accomplished? By building management and employee relationships, natural outcomes of personal need self-fulfillment are possible (Cook and Wall, 1980).

What happens to organization structure? As companies continue to downsize, key middle management and supervision is being removed. As a result of this effort, more emphasis is being placed on the workers performance. What are the benefits of this changed organizational structure? In the high tech organization, Carroll (1999) indicates that elimination of boundaries and having effective cross-functional teams is an effective way to design and build utilizing minimal resources.

What effect does this transition to lean have on relationships? Skorstad (1994) points out that as inventories are eliminated the mind numbing stress of mass production is being replaced by "creative tension". This drive for waste elimination could promote resistance within the organization. With effective change management transition to lean and changes within the workgroups can be smooth and seamless (Groebner, 1994). Several methods are employed to break down the barriers between management and the work force. Berggren (1993) points out the removal of differences such as management casual dress, help to eliminate separation, promote trust and encourage communication.

What kind of relationship is needed between management and workers? The relationship that exists between management and workers is a key strategy in improving the effectiveness of workgroups. Relationships are very important in the launch of a lean production system. The workforce needs to be highly skilled and flexible (Forrester, 1995). Confidence is a key consideration in this process. In Babson (1995), Macduffie highlights the fact that lean production dismantles "job control" utilized by unions to protect against management abuses. In order to accomplish this management and workers must have relationships built on confidence, cooperation and openness Doucet, et, al, (1996). As pointed out by Carr (1994), changes required to transition to lean must come from the way workers and management interact. Both sides need to be flexible. If this effort is successful, data indicates that the transition from mass to lean will have a positive effect and outperform mass production plants (Macduffie, 1995). With studies conducted in England, Cook (1979) finds a good work environment can lead to total life satisfaction and happiness. Adams and Kydoniefs (2000) point out that you must be an active partner with unions. This is an essential ingredient to the success of the effective workgroup.

Effective work processes are necessary to fuel effective workgroups. Team problem solving is key to effective implementation of lean processes (Forza, 1996). Team problem solving is pivotal in effective and rapid identification of problems and implementation of corrective action. Empowering others to act on the vision is key in any transformation effort (Kotter, 1995). Setting work goals and giving the employee the authority to do the job are key work processes that lead to effective workgroups. Adequate training is key to any change effort. In a study conducted at two English factories implementing JIT, Oliver (1989) found that the one group conducting awareness training had much better results in the change effort. Training and support are keys to successful implementation of teams (Dumaine, 1994). Teams cannot be launched in a vacuum with no support and training. Even in the furniture industry, ongoing training is deemed necessary to obtain increases in productivity, quality, cost and higher employee moral (Thompson and Wallace, 1996).

Effective transfer of information further drives effective workgroups. Trusting the information that is available, data that is understood, data that is used and trusted by the employees, will result in more participation and effectiveness. The need for an effective communication system is required for team problem solving (Appelbaum, et, al, 1999). In the traditional mass production system, data is driven from the bottom to the top so that managers can tell employees what to do (Meyer, 1994). In the lean system teams implement improvement ideas using data they collect. This implies that management trusts data from employees. This trust that must exist between employees and management is more critical today as systems are available that provide powerful plant floor surveillance (Sewell and Wilkinson, 1992). Misuse of this information can quickly destroy any trust and relationships that have been built.

The conflict continues between both union and management over the team concept. Many unions favor the team concept and consider it a big step in the improvement of working conditions, improved moral, early control, ability to save jobs and for workers to gain respect and dignity. However on the flip side fears are also persist and consist of management distrust, fear of reelection, member loss and dissatisfaction with increased responsibility (Huszczo and Hoffman, 1999).

On the management side some consider this very beneficial in that the workers ideas are utilized, eliminates firefighting, works at competitors and is support by senior management. Conversely many are against, fearing loose of status and power, distrust for the union and the view that this is just another program of the month (Huszczo and Hoffman, 1999).

It is seen that this process of empowering the workforce is transformational and represents a radical change in the business practices of the past.

Current research is investigating the interactions of work groups and how they seem to be more effective and productive. It has been demonstrated that many groups are most effective when operating in an ad hoc fashion, reacting on emergent issues and problems as they arise. These process improvements are then integrated into work process where individual actions play an important role (Weldon, 1998). In addition several studies have been conducted which investigate the diverse background on the team members (Pelled, et al., 1999). This studies overwhelming indicate that the more diverse the background "Task conflict" the more favorable the performance consequences. This would indicate that well rounded small group activities consisting of both management, production workers, skilled trades and machine vendors would be the most successful and productive teams in a TPM environment.

Ford Total Productive Maintenance

At Ford Motor Company, FTPM, Ford Total Productive Maintenance, is designed to improve the overall effectiveness of the plant facilities, equipment, processes and tooling to the focused efforts of workgroups by the elimination of the "seven major losses" associated with manufacturing equipment (Nakajima, 1988).

TPM is the process utilized to improve equipment effectiveness through the efforts of workgroups, focused on continuous improvement of their equipment, processes, tooling and work area, by applying operational constraint identification processes, 5-S processes and the 7-steps of autonomous maintenance. The process to accomplish this task of improving equipment and eliminating these major losses involves a seven-step process described below.

The first step "Cleaning is Inspection" step is designed to discover hidden problems so that the equipment can be restored to its ideal state. The act of cleaning equipment not just for making the equipment superficially clean but to discover nonconformities in equipment operation utilizing the five senses (touch, sight, smell, hearing, taste) The initial cleaning is aimed at totally eliminating accumulated dirt and all nonconformities that may cause failures, defects or accidents. Tags are attached to the equipment, a problem summary list is developed and corrective actions are identified to provide permanent resolutions. During this cleaning process the equipment is cleaned and "all" dirt is removed from every corner of the equipment.

All abnormalities are identified using TPM tags. Abnormalities are recorded using a problem Summary List. Preliminary cleaning standards are developed along with procedures and schedules.

Step two is "Eliminate or Control the Sources of Contamination and Hard to Reach Areas". Workgroup members support activities identified in step one by performing activities that correct the problem summary list by modifying the equipment, processes, work areas or work practices to eliminate, contain or control contaminates. This can include the modification of work areas of work practices aimed at reducing the time to clean, lubricate or inspect.

Step three is "Cleaning, Lubrication, Inspection & Safety Procedures". Cleaning standards are established to include description, method, cleaning tools, cleaning time and frequency. Machine lubrication should include a lube diagram, lubrication standard, type and amount, method, tools, frequency and pictorials to assist in this step. Energy control and power lockout placards and lockout pictorials must be attached to machine in accordance with established standards. Equipment inspection checks to include daily startup and shutdown procedures must be considered. Maximum use of visual management is utilized in accordance with visual factory standards.

Step four "General Inspection Training" is designed to deliver overview technical training for workgroup members in the fundamentals of their equipment, this should include hydraulic and pneumatic devices and systems, fasteners, leak prevention and seals, fundamentals of power transmission (e.g. drives gears etc, fundamentals of spindles and bearings, electrical devices and lubrication). Maximum use of technical training, single point lessons, sectioned teaching aids and skilled trade subject mater experts is required.

Step five "Self Directed Workgroup Inspections and Procedures" drives work groups to become mature and self-directed. Based on knowledge gained through general inspection training, there is expanded use of checklist and check sheets. The maintenance organization has improved there standards in performing the required PM and utilization of predictive technologies.

Step six "Work Group Organization" the workgroup fully utilize the 5S process to insure that the work areas are clean, orderly and free of scrap materials etc. The 5s process is described as:

1) Organization - organizing the workplace by identifying unneeded items and removing them right away
2) Orderliness (Standard Labeling): Orderliness means laying out only the items needed so that they're easy to use, and labeling them so that everyone can see where to find them and put them away.
3) Cleanliness: Cleanliness means performing a through cleaning and inspection of everything in the workplace.
4) Standardized Cleanup: Maintaining the first three Ss
5) Discipline: Following standards and educating everyone so that the 5Ss become a habit people follow without being told.

Step seven "Work Group Equipment Management" results when workgroups have achieved a high level of autonomy for managing their equipment and manufacturing process, continuously improving their equipment and work area. Improvements in reliability and maintainability and quality have been achieved. Groups continually analyze production data looking for opportunities to improve overall equipment effectiveness. Workgroups consist and interface with suppliers, customers, support organizations, central maintenance, engineering etc.

Data collection, analysis and document control are required for effective equipment management based on current accurate data and is dependent on a process to collect, report, and analyze that data. Documented data collection and document control process, defined maintenance management system, and workgroup involvement in data collection and analysis.

Summary - Literature Gaps

Many gaps exist in the research conducted in US based facilities. These gaps are possible due to the resistance to change as we globalize.

Ingram (1996) suggests that a link be established between teamwork and performance measures utilizing a survey. Teamwork is measured in terms of indices such as information sharing, support, shared vision and orientation to task. The so-called soft indicators of the survey are linked nowhere to the hard indicators, or performance outcomes. An interesting point by Benders (1996) is that a substantial part of data is provided directly or indirectly by companies themselves and contains company rhetoric, a distinct lack of data and employees views.

Many of the studies as pointed out by Daniels and Burns (1997) measure the attitude performance of kaizen teams but have large gaps when looking at performance outcomes. Chrysler's studies associated with the implementation of a modern operating agreement (MOA) focus on team satisfaction but don't look at performance outcome linkages (MacDuffie, 1989).

In Italy, Forza (1996) links workgroup organizational practices to lean plant indices but fails to link to specific measures such as equipment improvements. Similarly, Kadipasdaglu, et al., (1999) attempts to relate improvement programs such as cellular, factory automation, JIT and TPM to performance outcomes concluding weaker than expected correlation and unexplained variation.

Liker (1998) in his book, "Becoming Lean" describes an empirical study by Steven Rasch where Rasch states, "where lean is implemented performance improves"; however, the performance outcomes are not evident in his research.

And lastly Jonnson and Lesshammar (1999) conclude in their research that it would be interesting to analyze the role of an OEE measurement system for achieving high performance work teams. Lean production systems have had greater opportunities to mature in European and Asian facilities, hence more available data. This Ford Total Productive Maintenance (FTPM) research will help fill that void and will provide an exceptional model and the required detail to explain components of effective team based efforts and there performance outcomes.

Future Research

From the extensive literature search, a survey was developed, piloted, and tabulated to gain a better understanding of how attitudes impact performance measurement. This empirical paper is close to completion and will extend this initial study to add to the body of knowledge.

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