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ABSTRACT	Lean manufacturing today is one of the most important industrial changes that have been undertaken by suppliers of goods and services in the modern world. This process is equivalent to changes that occurred when manufacturing transitioned from craft to mass production. Foundational to this process is the implementation of an effective total productive maintenance (TPM) process, which provides equipment that is reliable, effective, and provides the smooth flow of product to the end customer. Critical to this process is the utilization of work groups providing the link between man and manufacturing equipment and processes. Traditional mass production only utilizes the physical capabilities of the work force. In contrast, lean manufacturing uses both the physical and team based problem solving ability of the labor force. This study looked at the relationship between work group satisfaction as measured by a standard survey tool and relates this to the performance outcomes measured by annual audits

	conducted in automotive manufacturing facilities. Principal components analysis and robust regression were utilized to develop a predictive model and identify key elements and relationships between work group satisfaction and the effective implementation of TPM.
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WORK GROUP SATISFACTION AS A PREDICTOR OF
TOTAL PRODUCTIVE MAINTENANCE (TPM) PERFORMANCE OUTCOMES

by

MARK ALBERT JOHNSON

DISSERTATION

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DEDICATION

If it were not for my parents and the encouragement that they gave me in my early years to continue school I would have never succeeded. Despite the hardships that I faced in my early adult life their support helped provide a means to an end. They continued to support my goals to obtain higher education. In addition my love of aviation drove me to complete my undergraduate education so that I could fly aircraft in the US military. This single goal helped boost me over the bumps and allowed me to complete my education and successfully soar with the eagles.

Finally I own gratitude to my most wonderful wife, Dana Johnson, who has supported me during the countless hours that have gone into this work. She has been my sounding board during both the triumphs and the tribulations associated with this learning experience. Without her assistance, advice and understanding I could have never completed this work.

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In addition, I would like to thank the helpful advice of Dr. Lee Sanborn and Rob Shurell at Ford for working with me in developing and narrowing the scope of this project. Without their guidance and efforts this project could have easily exceeded available time to complete.

There are many people that I would like to thank as this step will allow me to pursue my interest in gaining entrance to tenure track world of academics. I would first like to thank my co-chairs Dr. Leslie Monplaisir and Dr. Antoinette Somers. Dr. Monplaisir supported me at times when I was ready to throw in the towel by supplying me with positive reinforcement and encouragement. In addition the help that Dr. Somers provided in setting up the logistics for meetings and providing a critical eye so vital to a quality product is appreciated. Secondary the support and many hours spent by all members including Dr. K.S. Krishnan, Dr. Ariel Levi, and Dr. Darin Ellis. I would like to thank all of my committee for helping see this project to the end. Finally, I would like to thank Marsherry Jarrett for helping with meeting schedules and obtaining signatures on all the paperwork required. Your assistance was appreciated.

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CHAPTER 1

INTRODUCTION

Background

Lean Production System is defined as a production system focused on the elimination of waste. Waste is any resource that is expended in the system that does not add value to the process. Wasted motion, excessive inventories, and ineffective problem solving are a few examples of waste in the typical mass production process. Looking at the value stream and eliminating any waste not required to produce product or service drives the lean production system. People serve as the foundation of a lean production system, a major change effort. In the implementation of change, the structure and technology often focuses on the systems and processes but fail to recognize the importance of people as the first step to design a program of change. The team structure based on workgroups focus on several dimensions including management support, employee relationships, work processes, and information sharing. Each of these dimensions has several characteristics or constructs, which form the foundation for an effective workgroup methodology to support the implementation of a lean production system.

A foundational element critical to any lean production system is an effective maintenance management system (MMS). This system provides the necessary tending of production equipment maintenance to allow the company to produce to customer demand rate without interruption. Critical to this process is the application of maintenance preventive measures along with a utilization of what is known as Total Productive Maintenance (TPM) methods (Nakajiema, 1988). TPM involves autonomous maintenance by unskilled machine operators focusing on the elimination of major downtime through interaction and utilizing small group activities referred to as work groups. These continuous improvement teams focus on those production processes that are considered bottleneck operations or constraints eliminating the source of concern and thus increasing process throughput. This process is aimed at improving the equipment effectiveness beyond initial levels thereby allowing the production facility to enable continuous improvement.

Past mass production practices overlooked issues with equipment, regularly dealt with crisis and built up production inventories to mask downtime issues. In a lean environment producing such excess inventories limit a company's ability to provide minimum order to delivery times, which, in turn, hampers the company's ability to deliver quality products and satisfy the customer.

Overview

In October 1993, Alex Trotman was named Chairman and CEO of Ford Motor Company. Ever increasing competitive pressures clearly indicated the need for change. The requirement for a globalized approach to product development and manufacturing strategies became the new management's first priority.

In 1994, the Ford 2000 initiative began with the consolidation of North American and European organizations into functional components that would transcend geographic boundaries. Asian and South American operations were to be integrated later. Full global integration was to be completed by the year 2000. The focus of the single, global management team would be to: (1) eliminate duplication, (2) initiate best practices, (3) use common components and designs for the advantage of scale, and (4) allocate resources to wherever they are needed to best serve market needs (Ford Motor Company).

Ford 2000 is linked to a key, strategic initiative known as the Ford Production System (FPS). TPM or Ford Total Productive Maintenance (FTPM) is embedded in FPS and is considered a foundational process that is required if FPS is to be successful. The FTPM process was initiated in 1990 company wide and is considered the foundation of FPS. Implementation of the Ford Production System represents a major transformational change in which leadership strives to improve overall efficiency and reduce costs. The Ford Production System is embedded within the Ford 2000 model as shown in Figure 1.

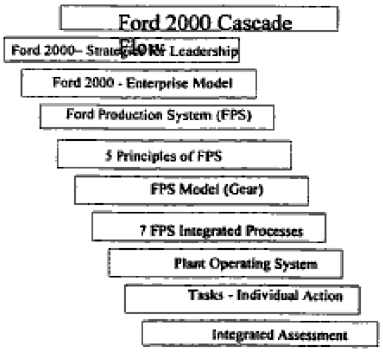

Figure 1 – Ford 2000 Cascade Flow (Ford Motor Company, FPS, 1997)

As one of Seven FPS Integrated Processes, FTPM is often referred to as the cornerstone of the FPS initiative.

Although FPS is still in its infancy, gains have already been realized. The 1999 Ford Motor Company Annual Report shows record profitability, which is an indicator of this success. The company has realized significant reductions in inventory and elimination of waste as a result of implementing FPS. Although FPS contributed to the successful cost reductions, there were other initiatives to support the cost reductions as well.

The timeline for Ford 2000 implementation (Figure 2) shows FPS taking the longest to implement. This is in line with Kotter's (1996) estimate that planned transformational change process takes several years (five to seven) to complete.

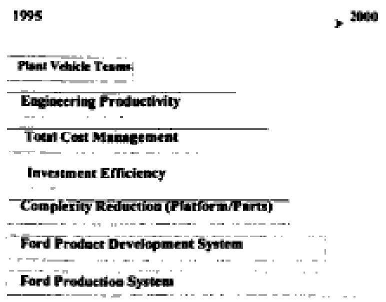

Figure 2 Ford 2000 Timeline

Traditional management practices present barriers to implementation of any major programs. Due to global competition, excessive waste and variation, poor productivity and inefficiency, less profitable operations, and slow market growth, it is necessary for organizations to make drastic changes in their operating strategies to be able to survive into the 21st century. Ford is not concerned as much with US based companies as it is with overseas firms, principally Toyota who has been the benchmark in the industry for product development and production processes for many years.

FPS appeared in early 1994 with the inception of Alex Trotman's Ford 2000. Hank Lenox, Director of the Ford Production System and 1998 winner of the Shingo Prize for Excellence in Manufacturing, oversees Ford's fledging internal blueprint for building cars and trucks more efficiently (Phillips, 1998).

As a result of FPS, Ford has changed its hiring standard for recruiting factory workers to include "soft skills", the ability to work in teams and identify and solve plant floor problems, all integral elements for successful implementation of transformational change (Phillips, 1998). Other companies have also implemented this hiring practice. For instance, Drake Products Corporation, based in Grand Rapids, Michigan, has experienced rapid growth since Drake's team implemented improved problem solving abilities (Chowdhury, 1996). This is only one example but there have been no empirical studies to properly analyze how many companies have experienced success in utilizing the "soft skills" of their factory workforce. An important point is that "soft skills" of factory workers can aid in the implementation of organizational change whether they are voluntary or mandated.

Another aspect of the organizational change processes for FPS relates corporate culture. For Ford 2000, in which FPS is a key strategy, the company is trying to change its bureaucratic and insular corporate culture by embracing teamwork, new technology, a global outlook, and internal cost control (Yung, 1997). This has been a difficult and painful experience. Most organizations today are under severe pressure to proceed with needed organizational transformation in order to cope with increasing rates of environmental change and turbulence (Devitsiotis, 1998).

When introducing previous initiatives such as QS-9000 into an organization, the culture of an organization often results in dissatisfied or distressed employees who may not buy-in (McNabb, 1995). McNabb & Sepic (1995) further state that if the organization's culture refuses to accept change, such initiatives as quality management system implementation will fail regardless of how well management has planned the change.

Culture is an important ingredient for successful implementation of FPS. Kotter (1996) states that most transformational processes that began with a cultural change effort fell flat. The automotive industry experienced a rich and long history of labor disputes and change as the workforce was unionized. This heritage resulted in a culture based on mistrust in any changes management proposes. A joint UAW and management Continuous Improvement Committee was formed as a result of the 1996 UAW contract, and this concept has become a key to the successful implementation of the FPS.

Ford is now in the process of rolling out FPS to its internal suppliers and will soon begin to roll out the process to the remainder of the supply chain. Without the support of the supply chain, the FPS process will not be successful.

The Toyota Production System relies heavily on the cooperation of its suppliers in the successful implementation of their production system (Monden, 1998).

Overview - Ford Production System

The Ford Production System is a unified system that integrates Ford's worldwide manufacturing, design and development, order and delivery, supply, and management functions. The part of FPS that encompasses what plants do is called the Plant Operating System (POS), which consists of seven components:

1. Human Resources
2. Industrial Materials (IM)
3. Material Flow
4. In Station Process Control (ISPC)
5. Ford Total Productive Maintenance (FTPM)
6. Manufacturing Engineering
7. Quality Operating System (QOS)

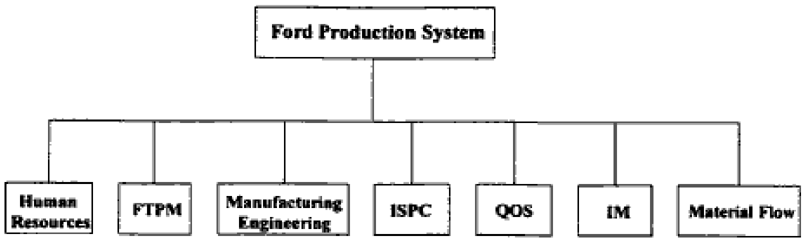

Figure3 Seven Components of FPS

Pivotal in this process is the Human Resource function heavily involved in the training and change management so necessary for this major transformational effort. In addition to the change issues, the HR function deals with changes required with both factions of leadership in a union environment, UAW and Management.

To deliver product at the customer demand rate, or takt time, detailed work instructions must be developed to reduce the likelihood of variance and mistake. In Station Process Control (ISPC), provides that guidance and acts as a standard for workstation management including standardized work, links to safety requirements, and detailed operator instruction or standardized work.

Manufacturing Engineering is another key element required in the lean process. As the manufacturing facility transitions from the past practice of mass production and building inventory, in-depth knowledge of process rearrange is required to smooth the flow of product. Application of techniques such as value stream mapping (Liker, 1998) is useful to determine areas of waste and eliminate them.

So essential to any lean effort is the application of a Quality Operating System (QOS). This system sets up the facility quality procedures that focus the manufacturing efforts on delivering a quality product to meet today's demanding customer requirements. This element ties in with ISO 9000 standards and quality requirements.

The Material Flow element acts as guidance to regulate the smooth flow of both raw materials and completed goods. Special focus on small lot size and continuous flow regulated by customer demand rate are considered. The Industrial Material (IM) guides non production material and assures that replacement parts and tooling are provided as needed.

One of the most important elements to a successful production system is a comprehensive system that manages the maintenance process. This system is responsible for the routine service required on complex production equipment but also the improvement actions required to obtain the uptime required to support a lean system. This MMS or Maintenance Management System is comprised of two major items. The first is considered as the facility Preventive Maintenance activities, which are designed to maintain the equipment, based on machine builders recommendations. Because much of the automotive manufacturing equipment is specialized continuous improvement activities are required to optimize and improve production capability. The second element of the maintenance process is the application of TPM activities designed to improve overall equipment effectiveness (OEE). At Ford this process is refered to as FTPM.

Overview - Ford Total Productive Maintenance (FTPM)

An essential element of FPS is Ford Total Productive Maintenance (FTPM). Without FTPM, FPS would be very difficult to implement. In fact, FTPM is more critical to the success of FPS than any other manufacturing initiative or strategy.

FTPM can be defined as a company focused, self-directed, cross-functional work group, working together to improve the overall effectiveness of the equipment and manufacturing process within its work area. This activity involves small cross-functional teams comprised of production workers, maintenance skilled trades engineering, and equipment vendors.

The improvement of overall equipment effectiveness is essential to drive a lean production system and is the product of three variables: performance efficiency, machine availability, and quality rate. The performance measures how well the machine runs when it is available, and it can be affected by minor stoppages such as blocked and starved conditions. Machine availability simply refers to the amount of time the equipment is able to run. Quality rate basically pertains to first run capability or first run quality. These three factors comprise the Overall Equipment Effectiveness (OEE) affect how closely the equipment and process perform to their ideal design levels.

The FTPM process aimed at improving the effectiveness of equipment consists of seven steps performed by work groups (Nakajima, 1988):

1. Cleaning is inspection
2. Cleaning, Lubrication and Safety procedures
3. Eliminating Sources of Contamination
4. General Inspection Training
5. Self directed small group activity (SGA) inspections and Procedures
6. Work Place Organization and housekeeping
7. Small Group Equipment Management.

The seven steps involve cleaning the equipment to identify safety problems, general problems and housekeeping problems. The cleaning and lubrication procedure documents the process required to perform the cleaning and lubrication of the equipment more effectively and with less waste. Eliminating sources of contamination can be as simple as redirecting coolant lines or repairing a leak in a hydraulic line. At Ford general inspection training involves workgroup member training in the basics of leak prevention, hydraulic devices, electrical components and spindles to name just a few. Self directed SGA inspections and procedures rely on small group activities to find hidden defects and correct them. Workplace organization and housekeeping is key in lean manufacturing; simply put, the team decides what needs to be organized and is responsible for keeping the area clean. The last step, small group management comprises the collection and tracking of data on equipment. The more accurate the data collection process the greater the improvement in equipment effectiveness and early equipment management activities.

Statement of Purpose

To remain competitive a manufacturing company must eliminate waste to lower cost. Failure to pursue this initiative could result in loss of sales and, ultimately in company. The timely pursuit of lean manufacturing is essential to maintain market share and grow business. The foundation of this lean process is stability of equipment and tooling to produce a continuous flow of goods to customers at their demand rate. The equipment stability and predictability can only be achieved by total effort of the workforce involved in equipment management and improvement.

The purpose of this study is to analyze the interaction between workgroup-measured satisfaction and the outcomes of the FTPM process as measured by the outcome of the audit process known as the FPS Integrated Assessment Tool.

with FPS and the element of interest, FTPM. Ultimately improved production effectiveness is the aim of both the company and the processes employed.

Key Variables and Operational Definitions

Ford Production System – A lean, flexible and disciplined common production system defined by a set of principles and processes that employs groups of capable and empowered people learning and working together in the production and delivery of products that consistently exceed customers' expectations in quality, cost, and time.

Work Group – Cross-functional problem solving teams consisting of production people, skilled trades workers, as well as engineers and supervisory personnel. Together they are charged with solving production problems, collecting and analyzing data, and providing the means to drive continuous improvement. These groups are limited to less than 12 people.

Integrated Assessment – This Ford developed tool is designed to assess the progress of worldwide manufacturing plants toward lean manufacturing. This process consists of ten elements administered annually by ten trained and qualified subject matter experts. This is also known as the ISR (Integrated System Review)

Quality Process System – A method of allowing the workgroups to document a standard for performing their tasks in a manner that will provide continuous improvement through the elimination of waste.

Quality Process Sheets – Operator instruction sheets developed by workgroup