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A Comparison of the Level of Maturity of Manufacturers in the Lake Land College School District in Lean Manufacturing Techniques as Compared to Goodson's Survey Data

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Eastern Illinois University

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**A Comparison of the Level of Maturity of Manufacturers in
the Lake Land College School District in Lean Manufacturing
Techniques as Compared to Goodson's Survey Data.**

(Title)

BY

Mark Henderson

Thesis

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science in Technology

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

2001
YEAR

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Running head: A COMPARISON OF LEAN MANUFACTURING MATURITY

A Comparison of the Level of Maturity of Manufacturers in the
Lake Land College School District in Lean Manufacturing
Techniques as Compared to Goodson's Survey Data.

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ABSTRACT

The purpose of this study was to determine if manufacturers in the Lake Land College School District have implemented Lean Manufacturing techniques and score as high as the manufacturers in Goodson's Michigan study. Lean Manufacturing techniques have revolutionized the auto industry, with the Toyota Production system the benchmark in Lean Manufacturing techniques. A survey using Goodson's Rapid Plant Assessment compares the level of maturity in the utilization of the Lean Manufacturing techniques with the manufacturers in the Lake Land College School District and Goodson's survey of manufacturers in Michigan. The mean score of 57.67 for the manufacturers in the Lake Land College School District was slightly higher than Goodson's mean score of 55, but not a statistically significant difference.

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The committee gave unselfishly of their time, talents, wisdom and patience both in the thesis preparation and review, and in the classroom. As a fellow educator, I am honored by their dedication to their profession.

TABLE OF CONTENTS

TITLE PAGE	1
SIGNATURES.....	2
ABSTRACT.....	3
ACKNOWLEDGEMENTS	4
TABLE OF CONTENTS.....	5
LIST OF TABLES	8
CHAPTER 1	
INTRODUCTION	9
1.1 Statement of purpose	10
1.2 Statement of the problem	11
1.3 Significance of the problem	11
1.4 Definitions of terms	12
1.5 Assumptions	16
1.6 Participants.....	16
1.7 Limitations	17
1.8 Delimitations	17
CHAPTER 2	
RELATED LITERATURE	18
2.1 Major elements of Lean Manufacturing.....	19
2.2 Benefits of Lean Manufacturing	36
2.3 Implementation of Lean Manufacturing Techniques	38
2.4 Will Lean Manufacturing work in the United States?	39

2.4.1 Lean Manufacturing implementation problems	40
CHAPTER 3	
METHOD	43
3.1 Research question	43
3.2 Research approach	43
3.3 Subjects for research	43
3.4 Procedure for gathering data	44
3.5 Analysis of data.....	45
CHAPTER 4	
SURVEY RESULTS	46
RAPID PLANT ASSESSMENT COMPOSITE RESULTS	47
4.1 Data analysis and findings	48
4.2 Individual company survey results.....	48
CHAPTER 5	
SUMMARY, DISCUSSION, RECOMMENDATIONS and CONCLUSIONS	51
5.1 Summary	51
5.2 Discussion	51
5.3 Recommendations for companies with little knowledge of Lean Manufacturing ..	52
5.4 Recommendations for companies with some knowledge of Lean Manufacturing .	53
5.5 Recommendations for companies with high scores on the RPA	54
5.6 Recommendations for participating companies.....	55
5.7 Recommendations for companies providing training in Lean Manufacturing	55
5.8 Recommendations for further study.....	55

5.9 Conclusions..... 56

REFERENCES 57

APPENDIX A: Survey Instrument The Rapid Plant Assessment Questionnaire 59

APPENDIX B: The Rapid Plant Assessment Rating Sheet..... 61

APPENDIX C: Lean Production Implementation Roadmap 62

LIST OF TABLES

TABLE I.....27
TABLE II.....47

A Comparison of the Level of Maturity of Manufacturers
in the Lake Land College School District in Lean Manufacturing Techniques.

This study sought to determine if the survey scores of manufacturers in the Lake Land College School District were equivalent to the mean score of the manufacturers in Goodson's Michigan study (Goodson 2002). R. Eugene Goodson is an adjunct professor of operations management at the University of Michigan. Goodson developed the Rapid Plant Assessment (RPA) to quickly assess a plants strengths and weaknesses in lean manufacturing techniques (see Appendix A and B). The variables studied include:

1. Customer satisfaction
2. Safety, environment, cleanliness and order
3. Visual management system
4. Scheduling system
5. Use of space, movement of material, and product line flow
6. Levels of inventory and work in progress
7. Teamwork and motivation
8. Condition and maintenance of equipment and tools
9. Management of complexity and variability
10. Supply chain integration
11. Commitment to quality.

Since 1998 Goodson has used the assessment in more than 400 tours of over 150 operations. The mean score of Goodson's surveys is 55, with potential scores ranging from a low of 11 to a high of 121.

Womack, Jones and Roos (1990) chronicled the advancement of manufacturing from craft production, to mass production, to lean manufacturing. Lean manufacturing techniques have contributed significantly to the competitive advantage of some Japanese automobile manufacturers. With heavy foreign competition, U.S. manufacturers are struggling to unburden themselves from the old mass production techniques and to adopt the lean manufacturing techniques, which have proven to produce tremendous competitive advantages.

Strozniak (2001, p. 2) reports improvements in lean manufacturing techniques are becoming more prevalent.

The 2001 census shows, for example, that 32% of manufacturers use predictive or preventive maintenance, up significantly from 28% in 2000 and 20% in 1999.

The survey indicates that 23% of manufacturers are widely using continuous-flow production, up from 21% in 2000 and 18% in 1999, and 19% of manufacturing firms have adopted cellular manufacturing, a slight increase from 17% in 2000. Still, less than 20% of manufacturers say they have widely adopted other lean practices such as lot-size reductions, bottleneck/constraint removal, quick-changeover techniques, and focused-factory production systems.

1.1 Statement of the Purpose

The purpose of this study was to determine if manufacturers in the Lake Land College School District have reached a maturity level in the use of lean manufacturing techniques similar to the subjects in Goodson's study.

1.2 Statement of the Problem

Manufacturers in the Lake Land College School District use a variety of production models. Without a high degree of skill in lean manufacturing techniques, manufactures will have difficulty competing. Company profits and employee jobs are jeopardized when manufacturers are at a competitive disadvantage.

1.3 Significance of the problem

The findings of this research will be of interest to the organizations participating in the survey and to organizations contemplating adopting Lean Manufacturing techniques. With significant plant closings in the Lake Land College School District and global competition, the need to gain a competitive advantage becomes an urgent requirement for industry. The lean manufacturing techniques were developed to gain competitive advantage by using less inventory, fewer people, less floor space and reduced cycle time.

A review of the Dislocation Event Tracking System database (2002) through the Illinois Department of Employment Securities (IDES) reported plant closing and layoffs in the Lake Land College School District between May of 1998 and May of 2002. The IDES reported 6 plant closings with a total of 2,234 lost jobs. During the two-year period, 2 plants layoffs affecting 150 employees occurred (Illinois Department of Employment Securities Dislocation Event Tracking System).

The results of the research may also be of interest to educators in the region interested in providing classes for organizations interested in Lean Manufacturing Techniques. The survey results may be of interest to organizations like the National Association of Industrial Technology.

Lean Manufacturing is designed to eliminate 7 categories of waste. These waste (Japanese Management Association, 1986, p. 16) include:

1. Waste arising from overproducing
2. Waste arising from time on hand (waiting)
3. Waste arising from transporting
4. Waste arising from processing itself
5. Waste arising from unnecessary stock on hand
6. Waste arising from unnecessary motion
7. Waste arising from producing defective goods

The study will determine if the manufacturers in the Lake Land College School District have reached a level of maturity equal to the manufacturers in Goodson's survey in Michigan (Goodson, 2002) by comparing the mean score of the two surveys.

1.4 Definition of Terms

Five S - Hirano (1995) defines the Five S's and the English equivalents as:

Seiri - Clearing Up

Seiton- Organizing

Seiso - Cleaning

Seiketsu - Standardizing

Shitsuke - Training and Discipline.

The benefits of Five S include: reduced changeover time, reduced defects, less waste, lower production costs, more reliable deliveries, reduced injuries, better maintenance, greater confidence and trust among employees, and higher profitability. The concepts of Five S are very simple. The Five S techniques are frequently met with

resistance from employees who feel they don't have time to implement the techniques. The components of 5 S maintain and promote a "healthy" organization.

Quick Changeover - Shingo (1985) developed extensive SMED (Single Minute Exchange of Dies) techniques to reduce the downtime required to change from producing one product to the next. Quick Changeover is a major element of Lean Manufacturing. Mass production builds large inventories, which increase the costs to warehouse and move product in and out of storage. The cost of interest on large inventories is substantial. Shingo created a systematic method to analyze setup operations and separate the internal and external setup steps. Performing the external setup steps while a machine is producing product eliminates downtime and maximizes production.

Total Preventive Maintenance - a disciplined approach to scheduled and preventive maintenance. When manufacturers turn to lean manufacturing techniques such as Just-In-Time (JIT) and Kanban systems, it is imperative that the workflow is not delayed by equipment failures. Equipment failures jeopardize productivity and quality and turn JIT and Kanban systems from incredible business strategies, to monumental constraints in productivity.

Mistake Proofing - The Japanese words Poka-Yoke translate into mistake proofing. "A poka-yoke is a device or practice that guarantees that an error, once its cause is known, will never recur" (Robinson, 1990, p. 6).

One-Piece Flow - Sekine (1992) describes One-Piece Flow as creating the most efficient flow of materials and work to move from start to finish. Henry Ford popularized one-piece flow in his motor driven assembly line. Taiichi Ohno, an executive of Toyota Motor Company advanced the one-piece-flow process. Ohno observed while visiting

American supermarkets a wide variety of consumer needs were efficiently met with a highly effective supply system. Ohno's observation triggered the Just-In-Time concept, which required a more efficient production system. The four rules of One-Piece Flow are: (1) Base the cycle time on market requirements, (2) Base equipment capacity utilization on cycle time, (3) Center production on assembly processes, and (4) Factory layout must be conducive to one-piece flow production.

Visual Controls - visual controls aid the worker in communication, increasing productivity and problem solving activities. With job rotation and multi-skilled workforces, permanent, visual instructions and controls enhance communication. Visual controls eliminate the need for memorizing and recalling detailed instructions, and reduce the production of defects and errors.

Kanban - the Japanese word for sign. Liker (1998) reveals the Kanban system signals suppliers to produce the appropriate product in the proper quantities. Kanban systems are one of the critical communication tools that enables Just-In-Time and One-Piece-Flow to work effectively. Kanban is used to signal both internal and external suppliers. If used properly, "the Kanban is a foolproof method of producing the right part, at the right time, in the right amount" (Liker, 1998, p. 54). An unusual benefit of the Kanban system is that it is a tool for Kaizen. Liker (1998) reveals "By making the entire material and information flow transparent to everyone, problems surface and improvements are easy to find, on both the micro and macro levels" (p. 54).

Supplier Kanbans - just as Kanbans are essential for the success of JIT systems, the manufacturers using internal Kanbans must require effective Kanban systems with each supplier in order to maintain uninterrupted work flow. Manufacturers may be

highly efficient in internal Kanban systems, however, if their external supplier is not effectively using Kanban, they may have work flow interruptions that jeopardize on time delivery.

Jidoka - means building in quality and designing operations and equipment so people are not tied to machines but are free to perform value-added work that is appropriate for humans (Liker, 1998).

Takt Time - a German word for musical meter, takt time is used to describe the process to link production to the pace of actual sales (Liker, 1998).

SPC – “Statistical process control involves the implementation of statistical tools (including control charts) that monitor processes in order to identify improvement opportunities. Process faults are identified, a root cause of the fault is isolated, and corrective actions are taken to improve the process” (Goodson, 2002, p. 17).

Supply Chain – “The supply chain denotes the process by which components are moved and produced from raw material to the ultimate consumer. It also includes the details of that process such as cost, time, transportation, packaging, etc. It may involve two or three levels of suppliers, one or more OEM plants, a distribution system, spare parts, replacement parts flow, and the disposal and recycling process” (Goodson, 2002, p. 18).

Inventory - Goods or parts held by a company for later assembly, or purchase by a customer.

Leveled Production – The even flow of production throughout the organization to maximize resources and capabilities, and reduce waiting time.

Andon - A light or signal that alerts workers to problems in an operation. If a process is stopped for quality issues, employees in the immediate area can be alerted to the problem and react appropriately. The Andon facilitates quick responses for problem solving.

Lean Manufacturing - a system of producing goods and services that reduces the costs of labor, inventory, floor space, tools and engineering time lower than traditional mass production techniques. The system of lean manufacturing includes techniques such as: Just-in-Time, Kanban, Poka-Yoke, Single-Minute-Exchange of Dies, One Piece Flow, Cellular Manufacturing, Kaizen, Five S, Preventive Maintenance, and Problem Solving.

1.5 Assumptions

For the purpose of this study, it is assumed that:

1. The companies responding to the survey are representative of the entire population of manufacturers in the Lake Land College School District.
2. The participating manufacturers divulge accurate and complete information.
3. The surveys were administered in a consistent manner.
4. The surveyor was not biased towards any of the manufacturers.

1.6 Participants

A letter was mailed to 43 manufacturers in the Lake Land College School District soliciting participation for the survey. Seven companies responded to the mailing. Students and the instructor from TEC 5123 Industrial Productivity Analysis at Eastern Illinois University arranged participation from two manufacturers in the Lake Land College School District. Manufacturers were surveyed only once.

Nine manufacturers, over 20% of the survey population, participated in the survey. The participating companies ranged in size from a workforce of 52 to over 1200 employees.

1.7 Limitations

1. Surveys were completed with those companies that responded to the request to participate.
2. Manufacturers Cooperation: the study was limited to the manufacturers willing to participate in the survey. Those companies willing to invest the time to administer the survey and divulge the information required may have limited participation.
3. Participation may have been limited if some companies were not aware of Lean Manufacturing and felt no benefit in participating.
4. Companies confident they had developed a high level of maturity in Lean Manufacturing techniques may not have seen a benefit in participating.

1.8 Delimitations

1. Geographic: The study is limited to counties, or portions of counties that make up the Lake Land College School District including: Coles, Douglas, Edgar, Clay, Jasper, Cumberland, Effingham, Fayette, Shelby, Montgomery, Macon and Moultrie. The school district covers approximately 4,000 square miles with a population of approximately 201,000.

Related Literature

Manufacturing has evolved over the years into a highly sophisticated process of meeting customer needs through various production models. As early as the late 1800s, automobiles were still manufactured primarily by hand. Skilled craftsman produced the individual parts and hand fit the parts to produce an automobile. Each part was unique and required a skilled craftsman to make the individual parts fit. This fitting of parts had required significant time and costs to produce a finished automobile. Henry Ford revolutionized manufacturing in the early 1900s.

The key to mass production wasn't-as many people then and now believe-the moving, or continuous, assembly line. Rather, it was the complete and consistent interchangeability of the parts and the simplicity of attaching them to each other. These were the manufacturing innovations that made the assembly line possible. (Womack, Jones, and Roos, 1990, p. 26)

Ford's introduction of the assembly line and interchangeable parts eventually cut the consumer cost of an automobile by two-thirds. Ford developed efficiency in manufacturing with the production line and specialized simple tasks for relatively unskilled labor. "As cars and trucks became ever more complicated, this minute division of labor within engineering would result in massive dysfunctions" (Womack, Jones, and Roos, 1990, p 33). The lean manufacturing techniques developed over the years were the solution to the massive dysfunctions created by a large manufacturing systems.

As a result of an exhaustive five year, five million-dollar research project, Womack, Jones, and Roos (1990) published the book "*The Machine That Changed The World*" which chronicles the development and benefits of Lean Manufacturing. Lean

production is a superior way for humans to make things. It provides better products in wider variety at lower cost. Equally important, it provides more challenging and fulfilling work for employees at every level, from the factory to headquarters. It follows that the whole world should adopt lean production, and as quickly as possible (p. 225).

2.1 Major Elements of Lean Manufacturing

The complexity of lean manufacturing may be a major contributor to the reluctance or resistance for organizations to implement lean manufacturing techniques. The complexity of lean manufacturing is highlighted by the extensive list of major elements in Appendix C which include: Quick Changeover, or SMED, Total Preventive Maintenance, Excellent Scheduling and Communication Systems, Mistake Proofing or Poka-Yoke, Statistical Process Control, One-Piece Flow, Visual Controls, Five S, Kanban, Supplier Kanbans, Supplier Quality, Excellent Training Prior to Production, Low Employee Turnover, Discipline, Support from Senior Management, Team Work, Takt Time, Problem Solving Fluency, Accurate Measurement Systems, A Motivated Workforce, Skilled Workforce and Just-in-Time supply and production systems. Many companies struggle implementing individual elements of lean manufacturing.

Following is a description of the major elements of Lean Manufacturing.

Form Teams. Undertaking the process of implementing the various disciplines and skills of Lean Manufacturing techniques is best accomplished with teams of workers. Teams will need to be established for a variety of tasks included in the Lean Production Implementation Roadmap in Appendix C. Scholtes, Joiner and Streibel (2001) suggested organizations can solve the many faceted problems they face by bringing a wide range of

people together to make good decisions and solve problems. Teams require well-defined goals and parameters tied to key business initiatives.

Zenger, Musselwhite, Hurson, and Perrin (1994) identify 4 types of teams.

Intrafunctional Teams - leaders and employees working together to improve capabilities of the department or business units.

Problem-Solving Teams - temporary groups established to focus problem-solving skills on business issues. Problem-solving teams may study current processes, analyze causes and recommend solutions.

Cross-Functional Teams - includes team members from all of the areas affected by and involved in the initiative. A team of members from the order entry, inventory control, shipping, and invoicing department, for example may address delays in distribution.

Self-Directed Team - Decisions on how to accomplish tasks and daily work are made by the team members, rather than by management.

Train Teams. Team training is crucial for the success of teams and the movement to full utilization of Lean Manufacturing Techniques. Team training can be an extensive undertaking. In the Team Handbook, Scholtes, Joiner and Streibel (2001) develop a comprehensive list of skill sets for success in teamwork. The scientific approach skill sets include: collecting data, mapping processes, exploring data relationships, and a structured problem solving approach. These skill sets are essential for successful problem solving in teams. How teams function during these problem-solving activities is described as doing work in teams. Team activities include: conducting meetings, facilitating effective discussions, making effective decisions, keeping records, and planning successful projects.

Five S. A series of Japanese words that translate into Clearing Up, Organizing, Cleaning, Standardizing and Training and Discipline. The activities in Five S work to enable a Factory to move towards lean manufacturing. Without the Five S activities, many of the elements of lean manufacturing will not reach maturity and yield the positive results. Eight benefits of Five S are identified by Hirano (1995).

1. Zero Changeovers Bring Product Diversification. By reducing the time required to changeover to produce a different product, customer demands can be met as needed, rather than when it is convenient to produce. Companies in a mass production mode frequently batch similar production runs to “save” money by not incurring setup, changeover costs and downtime. Mass production tends to build up larger inventories and incur the costs of carrying the inventory over a long period of time. Efficient changeover procedures require having all necessary tools close by, organized and identified so workers do not waste time looking for tools or dies. An organized workplace also allows new employees to implement changeovers more efficiently.

2. Zero Defects Bring Higher Quality. An organized, clean work place allows defects to more readily detected. Eliminating defects reduces costs. Maintaining and storing quality measurement tools and instruments allow workers to detect and eliminate defects easier. Reducing defects reduces the time required to fulfill orders, the cost of the raw materials needed to complete an order, and the storage space needed for inventory.

3. Zero Waste Brings Lower Costs. Eliminating non-valued-added steps and processes helps to lower production costs. Eliminating waiting time, unneeded storage, and wasteful motion can reduce production costs.

4. **Zero Delays Bring Reliable Deliveries.** Zero delays allow One-Piece Flow to work. Eliminating the causes of production delays allows companies to deliver on time. Reducing cycle time from order to delivery can create a competitive advantage that translates into more orders and market share.

5. **Zero Injuries Promote Safety.** In an orderly, clean environment, injuries can be avoided. Oil on shop floors creates slip hazards. Cluttered walkways create trip hazards. Dirty equipment is more difficult to operate and maintain safely. Extremely high insurance costs and workman compensation claims caused by unsafe conditions negatively impact the profits of an organization.

6. **Zero Breakdowns Bring Better Maintenance.** Dirt and dust frequently lead to shorter equipment life. Equipment kept in top working order breaks down less frequently and frees time for maintenance crews to work on maintaining the equipment, rather than fixing the equipment.

7. **Zero Complaints Bring Greater Confidence and Trust.** “Factories that practice the 5S’s are virtually free of defects and delays. This means they are also free of customer complaints about product quality” (Hirano, 1995, p. 23).

8. **Zero Red Ink Brings Corporate Growth.** Factories with reduced waste, lower inventory costs, fewer defects, fewer accidents and reduced cycle time reduce financial losses. Eliminating red ink allows an organization to grow.

With all of the benefits of implementing Five S, the application is frequently met with resistance. Hirano (1995, p. 13) list the twelve types of resistance an organization is likely to meet.

1. What’s So Great about Organization and Orderliness?

2. Why Should I, the President, Be Five S Chairman?
3. Why Clean When It Just Gets Dirty Again?
4. Implementing Organization and Orderliness Will Not Boost Output.
5. Why Concern Ourselves with Triviality?
6. We Already Implemented Organization and Orderliness.
7. My Filing System Is a Mess-but I know My Way Around It.
8. We Did the Five S's Years Ago.
9. Five S's and Related Improvements Are Just for the Factory.
10. We're Too Busy to Spend Time on Organization and Orderliness.
11. Who Are They to Tell Me What to Do?
12. We Don't Need the Five S's- We're Making Money, So Just Let Us Do Our Work.

A resistance to Five S's Hirono does not bring up in this section is the frequently espoused, "That's not my job." Especially in union shops, a machinist may not be permitted to perform duties perceived as those of a janitor. A much different mentality must be adopted. Without top management support, cultural change is difficult to develop and sustain. Five S must be in place for Just-In-Time and Total Productive Maintenance to work.

Mistake Proofing or Poka-Yoke. Eliminating mistakes and defects is a critical enabling process for the lean manufacturing system. If inventories and buffers are reduced to minimum levels, defective parts may shut an operation down, impact delivery schedules, and cause costs to skyrocket. Hinckley (2001) reports a study of corporations considered to be quality leaders in the United States "rarely achieved defect rates below

1,000 parts per million” (p. 2). These quality control costs for scrap, rework and warranty costs accounted for 6 to 24 percent of their total production costs. Toyota, in comparison, spends less than 3 percent of their production budget on the same quality costs. By eliminating errors through mistake proofing techniques, Toyota holds their defect rate below 50 parts per million.

Statistical Process Control has been used to detect the causes of defects and control processes, however proponents of Mistake Proofing prefer to eliminate the causes of the defects rather than detect them after they are made. Hinckley quotes Shiegeo Shingo, Toyota’s Quality guru.

We should recognize that people are, after all only human and as such, they will, on rare occasions, inadvertently forget things. It is more effective to incorporate a checklist-i.e., a poka-yoke- into the operation so that if a worker forgets something, the device will signal that fact, thereby preventing defects from occurring. This, I think, is the quickest road leading to attainment of zero defects (Hinckley, 2001, p. 15).

The following classification of mistakes highlights the many areas contributing to errors (Hinkley, 2001, p. 63).

- Causal factors (fatigue, noise, poor lighting, urgency, interruption)
- Project phase (design, fabrication, assembly)
- Ergonomic factors (perception decision, action, skill, training)
- Human error probability (error frequency, human performance)
- Mistake consequences (injury, loss, damage)
- Function or task (welding, milling, detailing, inspecting)

- Behavioral factors (communication, motor processes, perception)
- Corrective action (rework, repair, scrap)

The ten most frequent mistakes include: (Hinkley, 2001, p. 68)

1. Omitted operations
2. Omitted parts
3. Select wrong orientation
4. Misaligned parts
5. Select wrong location
6. Select wrong parts
7. Misadjustments
8. Commit prohibited actions
9. Added material or parts
10. Misread or mismeasure

Creating solutions to prevent mistakes or defects from occurring eliminates the problems created by defective parts. Mistake proofing focuses on preventing the defect, rather than inspecting to find the defect after it is made.

In order to create an environment conducive to mistake proofing, Hinkley (2001, p. 97) recommends the following key actions.

- Stop punishing or rewarding unintentional mistakes
- Provide small rewards for mistake-proofing suggestions
- Implement mistake-proofing.
- Reward successful mistake-proofing.
- Put pressure on management to teach and apply mistake-proofing

Standardize work and inventory buffers. Without standardization of work procedures and operations, variation and waste will reduce efficiencies. When different operators run the same piece of equipment using different techniques, product quality and productivity vary. Without consistent production volume and quality throughput, scheduling is more difficult.

When work is standardized, there is only one place for job instructions, tools, parts, equipment, and supplies. Standardization creates efficiency by eliminating the time it takes to locate where the last operator put something.

Inventory buffers need to be standardized to minimize the cost of inventory, and provide the buffer necessary to eliminate downtime. Too much inventory providing a large cushion increases costs unnecessarily. Too little buffer exposes the manufacturer to the risk of not being able to produce when problems occur and an upstream operation cannot deliver parts on time. Standardization of the inventory buffers allow the organization to determine in the buffers are indeed properly established.

Just-in-Time. Jacobs (p. 1) describes Just-in Time (JIT) as “a management philosophy that strives to eliminate sources of manufacturing waste by producing the right part in the right place at the right time.” Without delays and buffer times, significant savings can be accomplished along with quicker cycle time. In Table I, Hay (1988, p. 23) lists the range of improvements realized both in dollar savings and in improved service to customers.

Table I

JIT Opportunities

<i>Opportunities</i>	<i>Range of improvement %</i>
Lead-time reduction	83-92
Productivity increase	
Direct labor	5-50
Indirect/salary	21-60
Cost of quality reduction	26-63
Purchased material price reduction	6-45
Inventory reduction	
Purchased material	35-73
Work in process	70-89
Finished goods	0-90
Setup reduction	75-94
Space reduction	39-80

Three major misconceptions of JIT are highlighted by Lubben (1988). JIT is not an inventory control system. Developing a manufacturing system implementing JIT techniques will help to control the level of inventory. The second misconception is JIT is used to force a manufacturer's inventory buffer from the factory floor back to the supplier's floor. Although inventory shifting sometimes occurs, that is not the intent of JIT. When inventory of parts is shifted from the manufacturer to the supplier, it is typically an incomplete understanding of JIT and how to integrate the system into both

the manufacturer and the supplier. If a company allows the supplier to stockpile inventory, they may believe they have shifted the burden and cost of the inventory to the supplier. What the manufacturer does not realize is the supplier incurs the extra costs by stockpiling inventory. If the supplier properly used JIT, they wouldn't have to absorb the additional cost of the inventory and could pass part of the savings to the manufacturer in the form of lower costs. These additional costs include borrowing money for raw material purchase and production costs, warehousing raw material and finished goods, and additional handling.

A third misconception is JIT is a quality control program. JIT is not designed to improve quality, however, without an excellent quality program, JIT will not work. The reduced buffer time and lack of excess inventory in JIT systems can create problems. If defects are detected during the production runs, inadequate supplies of parts to replace defective parts may shut down production and create missed shipments.

One-piece flow. Originated by Henry Ford, one-piece flow was developed to minimize excess movement by the worker in the production of the automobile. Originally, the car would stay in one location and the different workers would move from one station to the next putting on the appropriate parts. Ford recognized the waste of movement and thought the workers could produce more if the car moved to them. Ford developed the assembly line with the cars pulled in a line in front of the workers, eliminating the unnecessary movement of the workers. The assembly time per vehicle was reduced from 13 hours to under 6 hours (Sekine, 1992). Sekine (1992, p. 6) lists the rules and conditions of one-piece production.

Rule 1: Base the cycle time on the market requirements.

Rule 2: Base equipment capacity utilization on cycle time.

Rule 3: Center production on assembly processes.

Rule 4: Factory layout must be conducive to one-piece production.

Rule 5: Goods must be conducive to one-piece production.

With the efficiencies gained through one-piece flow come certain disadvantages.

One-piece flow requires a high level of quality. Sekine contends that zero defects is the only quality system that will work in one-piece flow systems. Mistake proofing is essential to eliminating the problems defects produce in the production process.

Quick Changeover and Single Minute Exchange of Dies. The waste created by excessive changeover time and excess inventories created by large batch sizes are reduced using Quick Changeover and SMED techniques. Efficiencies were once thought to be gained by lengthy production runs. Longer production runs reduced the downtime created by frequent changeovers and setups. The long runs contributed to the inflexibility of manufacturing in meeting the needs of consumers by extending the cycle time from order to delivered goods. Shigeo Shingo developed revolutionary concepts in changeover and setup procedures in his concept of SMED. "Four hour setup times were reduced to three minutes" (Shingo, 1985, p. 18). These incredible breakthroughs created many benefits. The cost of the time to changeover was significantly reduced. The wasted time of additional line employees waiting for the changeover to take place was reduced. With insignificant changeover times and costs, small batch size is a viable option. Small batch size is a requirement for One-Piece Flow. Small batch size and quick changeovers allow an organization to respond quickly to changes in demand and to problems in the manufacturing system.

Two key components of SMED are Internal setup and External setup. Internal setups are activities such as removing dies that can only be accomplished when a machine or line is stopped and not producing product.

External setups are activities that can be accomplished while the press or production lines are in operation. External setup activities include transporting dies to and from the press or production line, and preparing connection devices. After the internal and external setups are identified and separated, work needs to take place to move as many of the internal setup activities to external setup. An example of converting internal setup to external setup would be pre-heating a press die prior to insertion into the press. The hours required to heat the mold can be accomplished prior to the press shutting down to exchange the die.

Focused equipment improvement and total productive maintenance. A variety of titles cover the area of maintenance in Lean Manufacturing. Total Productive Maintenance, Total Preventive Maintenance, and Focused Equipment Improvement all focus on maintaining equipment to ensure productivity. With Just-In-Time deliveries of raw materials, parts and production scheduling, downtime on equipment can create massive losses in the lean organization. There are six big losses that lower equipment efficiency (Japan Institute of Plant Maintenance, 1996, p. 23).

1. Breakdowns
2. Setup and adjustment loss
3. Idling and minor stoppages
4. Reduced speed
5. Defects and rework

6. Startup and yield loss

Achieving Total Productive Maintenance requires activities in eight key areas:

(Japan Institute of Plant Maintenance, 1996, p. 15).

1. Focused improvement (kaizen) to make equipment more efficient.
2. Autonomous maintenance activities.
3. Planned maintenance for the maintenance department.
4. Technical training in equipment maintenance and operation.
5. An early equipment management program.
6. Quality maintenance activities.
7. A system for increasing the efficiency of administrative and support functions (office TPM).
8. A system for management of safety and environmental issues.

Visual Controls. Communicating critical production information, product defects, location of tools and parts assist the workforce in performing tasks and making decisions efficiently. Hirano (1995, p. 151) states, “once the red-tag strategy and signboard strategy are implemented, a factory’s problems, waste, and abnormalities become clear as day.” Without visual controls, the workers struggle to find tools, materials, and information critical to the success of their operation.

Reapply Five S. After the initial implementation of Five S, many changes to the organization take place. During the application of standardizing work and inventory buffers, one-piece flow, quick changeover, focused equipment improvement, mistake proofing, and applying visual controls, the processes and instructions will change. A

reapplication of Five S is needed to insure the new methods and practices adhere to the principles of Five S.

Implement automation, or Jidoka. Womack and Jones (1996) describe Jidoka as (p. 305) “Transferring human intelligence to automated machinery so machines are able to detect the production of a single defective part and immediately stop themselves while asking for help.” Automation allows one operator to operate several machines simultaneously. With automation, the operator does not have to spend considerable amounts of time inspecting parts.

Implement production smoothing. Smoothing the production flow helps to even the workers workflow and reduce the backlog of inventory and parts. The workflow is paced off of customer orders with each area producing only what is needed for the next operation. The entire operation and the production capacity are reviewed to make certain that production is run smoothly and at a consistent level, rather than high levels of overtime production followed by downtime.

Apply Kanban system. Kanban means “card” or “signboard” and is used to visually signal the flow of production materials. The Productivity Development team (1998, p. 20) describes Kanban as “a mechanism for managing a pull production system.” In the classical pull production system, a part is only produced when a downstream customer or system needs the part. The Kanban system is the communication device that identifies the parts and signals that the parts are needed to be produced. The three types of Kanbans are: move Kanban, production Kanban and supplier Kanban.

The seven basic rules of Kanban listed by The Productivity Development team (1998, p. 24) are as follows:

1. The later process goes to the previous process to withdraw only what it needs.
2. The previous process makes only the quantity needed to replace what was removed by the later process (or the handler).
3. Defects are never sent to the next process.
4. A kanban must always accompany products on the line.
5. Production quantities must be leveled to avoid fluctuation and eliminate waste.
6. Use kanban to fine-tune the schedule.
7. Stabilize, rationalize, and simplify the process.

An advantage of a Kanban system is only the parts needed are produced. In the traditional “push” system, where parts are manufactured in large production lots, excess costs are incurred in excess inventory of raw materials, parts and finished goods.

Interface with Materials Resource Planning II. Materials Resource Planning (MRPII) is utilized to coordinate the purchase of materials and parts with the needs of the production system. The system is designed to identify each of the resources required to produce a product to meet customer orders and schedule the purchase and delivery in time for production. If an MRPII system is to be used, the Lean Manufacturing techniques must be interfaced with the different elements of the manufacturing process to acquire and schedule materials flow.

Robinson makes an insightful observation about the roll of materials planning and the difference between American and Japanese applications (1990, p. 9):

This American mentality has also kept us from exploring the impact of changing the basic structure of problems. If one is confronted with a highly complex factory environment-lots of production stages, lots of products, lots of flow patterns, lots of inventory locations, and so forth- one can deal with it in one of two ways. One can either attempt to develop a highly sophisticated (and usually computerized) information and control system to manage all this complexity, or one can set about reducing the complexity....We have spent over a decade and millions of dollars developing elegant Materials Requirements Planning systems, while the Japanese were spending their time simplifying their factories to the point where materials control can be managed manually with a handful of kanban cards.

Deploy lean enterprise in value chain. Lean Manufacturing techniques must be strategically applied to the appropriate components of the value chain. The value chain consists of each step in the manufacturing process that adds value to the end product or service.

Educate and involve all employees. Education and involvement of all employees is one of the enabling activities crucial to the success of Lean Manufacturing techniques. Without a highly educated workforce, implementation of the Lean Manufacturing techniques will only serve to confuse and complicate the manufacturing process.

Low turnover. One of the benefits of an organization that fully implements Five S is “Absenteeism is lower at Five S workshops” (Hirano, 1995, p. 23). High turnover in organizations reduces quality and productivity.

Apply concurrent engineering. Anderson (1997, p. 1) states, “concurrent engineering of product families and flexible processing can eliminate setup by designing versatile tooling and fixturing that can accept entire groups of parts without setup.” The engineer must look at both what is to be manufactured and how it is to be manufactured. By looking at the entire product mix, machines and processes can be designed to handle a wide variety of parts and products with little or no set up time. Concurrent engineering creates efficiencies and flexibility in the manufacturing process, and allows quick reaction to changing market conditions.

Initiate supplier development program. Supplier development programs may be one of the more critical enabling activities in the adoption of Lean Manufacturing techniques. Manufacturers cannot make high quality, low-priced products with poor-quality high-cost raw materials. Lean Manufacturers search for suppliers who fit the needs of high quality and low-cost, however, these needs may not be available in the open market. If some of the requirements of supplied parts or services are not readily available, manufacturers may choose to initiate supplier development programs to help the supplier learn new techniques to reduce defects and delays. By helping the supplier, the manufacturer benefits with higher quality and lower costs for raw material and parts. The supplier development program is driving the adoption of ISO 9000 and QS 9000 quality systems in the automobile industry.

Apply Quality Function Deployment. Quality Function Deployment (QFD) incorporates visual decision-making procedures to aid project teams in making decisions involving engineering designs that meet customer needs. QFD integrates the perspectives of multi-skilled project teams to focus on key customer requirements and make certain that areas

are not overlooked or are counter productive with other areas. Womack and Jones (1996) contend that QFD reduces expensive project reworks as projects near completion.

Lean Manufacturing evolved over many years with various people and organizations contributing components. The manufacturer that most embodies the essence of lean manufacturing is the Toyota Motor Company in Japan. Eiji Toyoda and Taiichi Ohno at Toyota borrowed several manufacturing techniques from The Ford Motor Company and other manufacturers and developed the concept of lean production. John Krafcik, a researcher at International Motor Vehicle Program, coined the term “Lean production” in “The Machine That Changed The World”

because it uses half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also, it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever growing variety of products (p. 13).

2.2 Benefits of Lean Manufacturing

The benefits of Lean Manufacturing are substantial. One example of the impact of lean manufacturing is in reducing the inventories American automakers carry. In 2000, the finished goods inventory levels of General Motors was approximately \$20 billion, Ford was \$15 billion, and Daimler Chrysler \$10 billion. These figures represent an average of 60 days of inventory. In contrast, Honda and BMW operate on about 30 days supply (McElroy, 2000). The interest on excessive inventories represents hundreds of millions of dollars lost. McElroy indicates that in the future, a customer will be able to receive a special order car in as little as ten days.

Day (1995) reports that Fredenberg-NOK cut production lead times in half, increased productivity by 52 %, work in progress inventories were cut by 85%, floor space required reduced by 28%, reduced new product development time by 20%, and sales grew 17% annually.

Sheridan (2000) reports that at Lantech, the first three years of adopting lean manufacturing techniques reduced start-up defects from eight defects per machine to less than half a defect per machine. Cycle time on custom built machines went from five weeks to 11 hours.

With the higher quality levels achieved by lean manufacturing techniques, the expenses of warranty costs are reduced. The Big Three U.S. automakers spend about \$6 billion dollars on warranty costs in North America alone. American manufacturers warranty costs average \$500 per vehicle, while their Japanese counterparts may be less than \$75 per car (Allen, 2001). Lower warranty costs are a tremendous financial advantage created by lean. Brand loyalty created by cars not requiring repairs helps to create lifelong customers.

Womack, Jones and Roos (1990) developed a comparison between General Motors and Toyota to illustrate the impact of Lean Manufacturing. The comparison between GM Framingham and Toyota Taksoka reveals a significant advantage for Toyota and their lean techniques. In comparing GM's results to Toyota, Toyota required only half the assembly time, averaged 85 fewer defects per car, and needed only half the assembly space. The average inventory of parts is a staggering comparison of 2 weeks for the GM plant to 2 hours for the Toyota plant.

A study on the effects of Lean Manufacturing practices was published in 1992 by the Midwest Manufacturing Technology Center in Ann Arbor Michigan.

The results show conclusively that by implementing a lean supplier system, a high involvement organization, a built-in quality system, and a JIT system, both manufacturing performance and company wide performance increase significantly. In addition, the results indicated that giving workers decision-making power and authority coupled with implementing JIT techniques will increase productivity by increasing machine uptime. In other words, U.S. manufacturers need lean manufacturing strategies as well as employee involvement to achieve world class results (Liker, 1998, p. 118).

Besides the financial benefits of lean, there are many significant additional benefits. Womack, Jones, and Roos (1990) shared that the mass-production techniques common in many manufacturers is mind numbing and unbearable for the workforce. Lean manufacturing requires the worker to multi-task and problem solve which adds more variety and job satisfaction to their work. With the benefits of lean manufacturing so high, more manufacturers should be adopting lean techniques to gain a competitive advantage in their market place.

2.3 Implementation of Lean Manufacturing Techniques

In order to implement Lean Manufacturing, a roadmap helps to guide the organization through the complex process in a logical sequence. The Productivity Group Lean Production Management Implementation Roadmap (Appendix C) illustrates the complexity required. The roadmap illustrates over thirty steps suggested to implement

Lean. The complexity of the implementation, and difficulty of the steps may explain why more companies are not implementing Lean Manufacturing.

2.4 Will Lean manufacturing work in the United States?

Organizations reluctant to change may not believe that Lean Manufacturing will work in the United States. Robinson (1990) details the transformation of a General Motors manufacturing plant in Fremont California that was closed in 1982. Prior to closing, the plant had one of the worst quality and labor records in all of G.M.. Toyota partnered with G.M. in creating the New United Motor Manufacturing Incorporated (NUMMI). Many of the workers were hired from the original workforce and a miraculous turnaround developed. Absenteeism and quality were major problems at the Fremont plant before the partnership. After implementation of the Toyota Production system, the plant became a model for employee involvement. Quality at the Fremont facility topped the G.M. standards and competed with the top Toyota plants.

There are a variety of lessons and pitfalls that Liker (1998) observes in "*Becoming Lean*" (p. 176).

- Evolutionary change is the key - batting singles
- Revolutionary change is less frequent - don't wait for home runs
- Commitment by top management is vital
- Continuous improvement team projects - quality not quantity
- It's a continuous process - not "program of the month"
- Toyota "Five Whys" is great discipline
- The kanban system works best with level schedules
- Local ownership on the shop floor is critical to success

- Fear of layoffs is a serious obstacle to progress and must be realistically addressed
- Productivity improvements do not necessarily require capital expenditures

With the extensive number of new activities and processes to learn, and with a significant number of pitfalls and difficulties to address, it is not difficult to understand why many companies struggle with lean manufacturing implementation. The lure of substantial savings captures the interest of many organizations, however, the road towards lean manufacturing is long and difficult. Few companies have the vision and discipline to chart the course, take the necessary steps, and weather the storm of change that will test even the most patient management teams. The incessant American drive for instant profits steers many organizations toward the quick illusive profits, and away from the meticulous, slow developing rewards of lean manufacturing techniques.

2.4.1 Lean Manufacturing implementation problems

The problems inherent in implementing Lean Manufacturing techniques are many. Hancock (1998), identifies several problems inherent in the implementation process applicable to existing or “brownfield” sites. Convincing top management, union representatives, staff personnel and workers of the benefits of lean is a major undertaking. The education required for the management and workforce is massive. Hancock (1998, p. 2) reports the extensive training “is in itself a problem not only because of the number of people that need to be trained, but also because the instructors must become the leaders of the implementation efforts after the instruction is finished.”

In order to meet the demanding schedules of JIT, poor equipment reliability can be a problem. The ability of the maintenance department to respond quickly to

breakdowns can have a major impact on the on-time delivery and productivity of the organization.

In many Lean Manufacturers, the operators perform their own maintenance and troubleshooting. Operators performing maintenance and troubleshooting may become a hurdle in the existing company if a union contract prohibits this type of cross-functional behavior. During the negotiations for the NUMMI joint venture between General Motors and Toyota, the job classifications under the old UAW contract were reduced from 64 to 4. This flexibility is necessary for Lean Manufacturing to work, however, this flexibility is a difficult sell to an existing union workforce.

Poor setup discipline can create high levels of work in process and negate the Lean initiative. Without inventory buffers the lean organization needs quick solutions to production problems. Hancock cautions about the responsiveness typically received from engineering, maintenance, quality control and management. "Usually these groups are not used to devoting the level of time and expertise to root cause problems" (Hancock, 1998, p. 4).

Initially, the production staff may not believe they will be able to produce the level of output targeted for the Lean operation. Trust must be developed through education and time.

The many fads, or flavor of the month have laid a history of failures that the workforce is well aware of. The organization implementing Lean must prove the value of the conversion consistently throughout the transformation.

A survey instrument used to evaluate the maturity of an organization's maturity in Lean Manufacturing techniques is the RPA questionnaire (Appendix A) developed by R.

Eugene Goodson. Goodson is an adjunct professor of operations management at the University of Michigan Business School in Ann Arbor, Michigan. The survey was used with the permission of the author, R. Eugene Goodson.

Goodson's survey was developed after his experience with a Japanese competitor. The Japanese competitor requested a brief plant tour in exchange for a brief tour of their facility. Goodson's team learned virtually nothing from touring the competitor's facility. Goodson was astonished when he read a report of the Japanese tour of his facility. The Japanese visitors tour lasted about an hour. Goodson was shocked that the Japanese described his plant in detail with accurate estimates of his cost of sales.

After Goodson's experience with the Japanese tour, he set out to develop the RPA. The RPA can be administered in as little as thirty minutes. The survey searches for visual evidence of lean manufacturing practices in use. One of the benefits of the visual evidence is a tour guide cannot just talk about their adoption of Lean techniques, the visual evidence must be in place. Goodson teaches a class at the University of Michigan with his students using the RPA to survey companies.

Hancock indicates a time should be set aside for the training and transformation to take place. After a specified time frame, those employees that have failed to make the transition may need to be reassigned. Hancock (1998, p. 6) states, "Lean production is so dependent on everyone doing what is expected that there is no room for employees who cannot or will not perform."

Method

3.1 Research Question

Have manufacturers in the Lake Land College School District reached a level of maturity of Lean Manufacturing techniques equal to those companies of Goodson's Michigan study when comparing the mean scores of the surveys?

3.2 Research Approach

The approach taken to research the subject was to administer the RPA questionnaire (see Appendix A) to each of the companies willing to participate. The surveys were conducted during plant tours of the participating companies. The mean score of the surveys from the Lake Land College School District was compared to the mean score of the Michigan survey conducted by Goodson.

3.3 Subjects for Research

The study was conducted during the fall of 2002. There were two sources of participants in the survey. The first source were the respondents to a mass mailing to the manufacturers in the Lake Land College School District. Portions of thirteen counties in east central Illinois make up the college district. The counties include: Coles, Douglas, Edgar, Clay, Jasper, Cumberland, Effingham, Clark, Fayette, Shelby, Montgomery, Macon and Moultrie.

Mr. Glenn Gee arranged the second source of participants. Mr. Gee teaches the TEC 5123 Industrial Productivity class at Eastern Illinois University. This class studied the effects Lean Manufacturing had on industrial productivity and used the Goodson RPA for class projects.

The subjects of the survey were manufacturing companies in east central Illinois willing to participate in the survey. The RPA have been administered over 400 times to more than 150 individual companies. A survey is conducted using the RPA with the survey team compiling the results. Companies are rated from 1 (*poor*) to 11 (*best in class*) in eleven categories on the RPA. The results are totaled to indicate the level of “Leanness” in the organization. The typical scores on the RPA rating sheet for the 11 categories range between 30 to 90. The mean score was 55. Goodson confirmed the validity of the RPA survey by surveying the same company with different teams, which produced similar scores.

3.4 Procedure for Gathering Data

Data was gathered using the RPA during plant tours of the participating manufacturers. Goodson’s RPA questionnaire is made up of 20 yes/no questions. The questions ask for visual evidence that the Lean Manufacturing techniques are being actively used in the facility.

For the purpose of this study, a mean score of 55 from Goodson’s Michigan study was used to determine if the manufacturers in the Lake Land College School District had obtained a mature level in the use of Lean Manufacturing techniques. The survey was designed by Goodson to be administered in as little as thirty minutes. The surveys take slightly longer than a normal plant tour of the facilities. Observations made during the tour on the RPA questionnaire were used to complete the RPA rating sheet (see Appendix B). The RPA rating sheet consists of 11 categories of Lean Manufacturing techniques each with a 6-point Likert scale. The appropriate questions are analyzed and combined into a category rating on the Likert scale. The Likert scale used is illustrated below:

1	3	5	7	9	11
poor	below avg.	avg.	above avg.	excellent	best in class

3.5 Analysis of Data

The ratings were tallied in the eleven categories of the RPA rating sheet. Each of the eleven categories was rated on a scale of: 1 (*poor*), 3 (*below average*), 5 (*average*), 7 (*above average*), 9 (*excellent*), and 11 (*best in class*). The potential scores range from a possible low of 11 to a high of 121.

The Goodson survey scores range from a low of 30 to a high of 90 with the average score of 55. Only four companies scored below 30, and only three companies scored higher than 90. For the purpose of this study, the mean score of 55 from Goodson's study was used in this study to determine if a manufacturer has attained a mature level in the use of Lean Manufacturing techniques.

Survey Results

Nine manufacturers responded to the request to participate in the survey. The manufactures ranged in size from 52 employees to over 1200. The size of the manufacturing facilities ranged in size from approximately 50,000 square feet to 1.1 million square feet under roof. Manufacturing techniques included fairly labor-intensive operations with 40-year-old technology to highly sophisticated CNC machines and robotics.

The participating companies experience in implementing lean manufacturing techniques ranged from three participants indicating they had no prior knowledge of Lean Manufacturing, to companies that had made substantial investments in training and adoption of Lean Manufacturing techniques.

The results of the Lake Land College School District survey are compiled in Table II. Each company score for the appropriate category is listed below the letter designating the company.

Table II

Rapid Plant Assessment Composite Results

Categories	Company Scores									Mean
	A	B	C	D	E	F	G	H	I	
1. Customer Satisfaction	5	7	9	9	5	5	9	7	9	7.22
2. Safety, environment, cleanliness and order	3	7	5	5	3	3	9	9	9	5.89
3. Visual management system	5	1	7	5	1	3	7	5	7	4.56
4. Scheduling system	3	3	5	5	5	5	7	5	9	5.22
5. Use of space, movement of materials, and product line flow	3	5	3	5	3	5	7	7	5	4.77
6. Level of inventory and work in progress	3	5	3	7	3	3	7	7	7	5.00
7. Teamwork and motivation	3	3	5	7	3	1	9	7	5	4.77
8. Condition and maintenance of equipment and tools	5	3	5	5	3	3	5	7	7	4.77
9. Management of complexity and variability	3	3	3	5	5	5	5	9	9	5.22
10. Supply chain integration	3	3	3	9	3	3	3	7	5	4.33
11. Commitment to quality	5	5	5	9	3	3	5	9	5	5.44
Company Total Score	43	45	53	71	39	39	73	79	77	57.67

Note. Rapid Plant Assessment survey from "Read a Plant Fast" by R. Eugene Goodson, 2002, May, p. 108. Harvard Business Review. Used with permission.

4.1 Data Analysis and findings

The company scores in the Lake Land College School District survey range from a low of 39 with a high of 79. The mean score of 57.67 is 2.67 points higher than Goodson's Michigan survey.

The scores of Goodson's survey ranged from a low of 30 to a high of 90, with a range of 60. The scores of the companies in the Lake Land College School District ranged from a low of 39 to a high of 79, yielding a range of 40.

The standard deviation of the mean scores in the Lake Land College School District was 17.008. The standard deviation for Goodson's study was not included in the results.

4.2 Individual Company Survey Results

Company A – score 43. A small manufacturing company with approximately 200 employees. This company is in the transition stage in the adoption of lean manufacturing techniques. Techniques evident during the survey included partial adoption of Kanbans, Poka-Yoke, and Kaizen events with employee involvement. The Lean Manufacturing techniques had not yet been developed in all of the areas. The lower scores may have resulted partially due to Goodson's survey techniques, which state that each question should be answered yes, or no. If the answer is not a total yes, then the response is no. Some areas of the plant were very clean, however, leaking oil from some machines, and grime build up on some floors, ceilings, and equipment did not fully display adoption of Five S techniques of cleanliness. One area of the plant was laid out in continuous flow; however, some of the production was still in a shop format.

Company B - score 45. A small family owned manufacturer of just over 50 people. The president indicated he had not heard of Lean Manufacturing. Lower scores due to: High inventory, lack of visual management, little display of customer satisfaction, no supplier certification, high inventory, and inventory not stored next to line. Strengths included: Good one-piece flow, cleanliness, and organization.

Company C - score 53. A large manufacturer and assembly plant. This organization had substantial progress in adopting Lean Manufacturing techniques. Lower scores were attributable to: High inventories of parts, little visible problem solving among team members, evident clutter, and shop set up, rather than one-piece flow. Strengths include: One of the best Kanban systems in the survey and high customer satisfaction.

Company D - score 71. A small manufacturer of approximately 200 employees producing fairly sophisticated parts for supply to customers for assembly. This organization is ISO-9000 certified. Weaknesses included: A poor labeling system. Some parts and materials did not appear to be organized or stored properly. Strengths: Documentation, Poka-Yoke devices, quality standards and instructions.

Company E - score 39. A medium sized manufacturer with two different product lines and processes. Weaknesses included: Poor cleanliness and visual controls, and high inventory. One-piece flow inhibited by evolutionary building expansions.

Company F - score 39. A small manufacturer employing 55 people not exposed to Lean Manufacturing techniques. Weaknesses: Poor set up in job shops, visual controls, cleanliness, and clutter.

Company G - score 73. A medium sized company producing finished metal goods. Strengths: Extremely low inventory, problem solving activities on display, one-piece

flow, visual management, cleanliness, lack of clutter, safety, and teamwork. Weakness: Poor air quality in one area of the plant.

Company H - score 79. Strengths: Excellent visual management. Customer satisfaction, quality, defects, and on-time delivery were all well displayed. Cleanliness, organization, instructions and quality standards posted. Mistake proofing systems were evident.

Weakness: Inventory levels could have been lower, however, manufacturer was building up inventory to meet upcoming customer peak demand and level workload. Parts and assembly have been uncoupled. Manufacturer stated tying parts and manufacturing together had created bottlenecks for them in the past.

Company I - score 77. Large manufacturer of over 1200 employees with highly complex processes. Strengths: Visual management system and Five S highly developed.

Cleanliness and lack of clutter was evident. Problem solving and teamwork were evident, however, teamwork may need to be pushed lower into the organization on the line. Weakness: Inventory not stored next to line.

Summary, Discussion Recommendations and Conclusions

5.1 Summary

The purpose of the study was to determine if manufacturers in the Lake Land College School District had achieved a maturity level in Lean Manufacturing techniques by comparing the mean score of the survey to the mean score of Goodson's Michigan study.

The results of the survey show that the manufacturers in the Lake Land College School District have a mean score on the Rapid Plant Assessment of 57.67 compared to Goodson's Michigan Study mean score of 55. The survey results indicate Lean Manufacturing techniques of the manufacturers in the Lake Land College District are similar to the manufactures in Goodson's Michigan study.

5.2 Discussion

The wide range of scores in the composite results of Table II indicates there is opportunity for improvement in the Lake Land College School District. Improvement in scores for the individual RPA categories should increase the manufacturer's ability to compete in the market place. The lowest scores in the composite results were category number 10 and category number 3. Category number 10, supply chain integration, had a mean score of 4.33. Category number 3, visual management system, had a mean score of 4.56. Of the low scoring areas, the easiest to remedy would be the visual management system. Upgrading the visual management system can be accomplished with a higher degree of labeling of tools and equipment, and a well developed reporting and display system of the business metrics. Visual labeling of tool and parts locations aids in plant operation by eliminating the need to search for tools and parts. The upgraded visual

management system allows employees to focus on attainment of goals, and important production details.

Supply chain integration, which scored very low in this survey, is one of the more complex areas to improve. Integrating the supply chain requires several disciplines for both the customer and the suppliers. Customers must effectively communicate critical quality requirements, delivery and production schedules. Suppliers must accurately represent their capabilities for quality requirements, delivery and production schedules. For example, if a customer were to implement a JIT system without supply chain integration, the benefits of the JIT systems may not be realized, and increased delivery problems of supplied parts may develop. An organization with fully implemented Lean Manufacturing techniques can readily communicate the production requirement to a supplier.

The manufacturers participating in the study should gain significant insight from the individual results of the survey. An increased awareness of the deficiencies they have in Lean Manufacturing techniques can help them focus on the areas in which improvement will be most beneficial.

5.3 Recommendations for companies with little knowledge of Lean Manufacturing

Three managers of companies, thirty-three percent of the companies surveyed, indicated they had not heard of Lean Manufacturing. These three companies scored 39, 39 and 45 on the RPA. For these low scoring companies, their managers may benefit from understanding the principles of Lean Manufacturing techniques. In two of these companies, high inventory levels of raw materials were maintained. Reducing these high inventory levels would free up capital and reduce the costs to store the inventory.

Employees in the two lowest scoring companies did not maintain clean work environments. Cluttered work areas can cause delays in locating necessary parts and tools, and reduce production efficiencies.

In all three companies, there was no evidence of a visual management system. These companies could benefit from the advantages of a well-implemented visual management system. In a visual management system, employees have written instructions at each work station. Written instructions help the employee to complete tasks with fewer errors, avoid improper use of parts, and adhere to proper quality standards. Visual displays of commitment to quality was also lacking in all three lower level companies. Displaying positive feedback from customers about excellent quality motivates employees to continue to produce high quality parts and services.

5.4 Recommendations for companies with some knowledge of Lean Manufacturing

Company A scored a 43, and company C scored 53 on the RPA. Company A had begun implementing Lean Manufacturing techniques in several departments within the plant. The RPA score would have been higher, if all departments in the plant had fully implemented appropriate Lean Manufacturing techniques. During the plant tour, the manager conveyed a thorough knowledge of Lean Manufacturing techniques. The manager expressed frustration with the lack of support for the Lean initiative from top leaders in the organization. Top leaders continued to ask the manager to perform his regular duties, and act as the sole resource in Lean training and implementation. Company A may benefit by hiring outside trainers to assist in training the workforce, or by freeing up the in-house expert to train the employees.

Company C had invested significantly in implementing Lean Manufacturing techniques. Inventory of some parts and materials was quite high. The company could benefit with more visual evidence of teamwork, state of the operation, preventive maintenance schedules, customer satisfaction, and supplier quality.

5.5 Recommendations for companies with high scores on the RPA

The RPA scores from companies G, D, H and I ranged from 71 to 79. These companies displayed a thorough understanding of Lean Manufacturing techniques. Each of the tour leaders in the companies with high RPA scores were knowledgeable or spoke fluently of the Lean Manufacturing techniques and the benefits of each technique.

Even among companies that scored high in Lean Manufacturing techniques, the RPA survey category that consistently scored low was supply chain management. The benefits of improving supply chain management include: higher quality of supplied parts, better flow of materials to the manufacturers, reduced inventory, and less downtime due to late shipments. One reason supply chain management may be less evident is manufacturers do not have control or authority over their suppliers. As Toyota evolved into Lean, it discovered that it had to teach Lean Manufacturing principles and techniques to their suppliers to avoid production shutdowns and defective supplied parts. If an organization struggles to learn and implement Lean Manufacturing techniques, it may be difficult to convince a supplier of the benefits from implementing new processes and procedures.

5.6 Recommendations for participating companies

1. The results of the survey may be used by managers in the participating companies to present an unbiased appraisal of the strengths and weaknesses of their organization.

2. Participants could benchmark their strengths and weaknesses by comparing their RPA score to other RPA scores and decide which areas should be targeted for further development.

3. For the organizations that scored above 55 on the RPA, the results can confirm their maturity in Lean Manufacturing techniques and give the organization a benchmark to measure progress in the future. Goodson uses multiple assessments over time to measure the progress of companies in Michigan.

5.7 Recommendations for companies providing training in Lean Manufacturing

Companies providing training to organizations on Lean Manufacturing techniques may realize there is still a market for training services. Training programs could be developed and promoted to companies for those Lean Manufacturing techniques showing consistently low scores on the RPA.

5.8 Recommendations for further study

1. What are the barriers to implementing Lean Manufacturing techniques?
2. Is there resistance from employees when attempting to implement Lean Manufacturing techniques?
3. Is there resistance from management when an organization attempts to implement Lean Manufacturing techniques?
4. Will manufacturers participating in the survey more fully develop Lean

Manufacturing techniques in the future and score higher on future surveys?

5.9 Conclusions

The survey results indicate the manufacturers in the Lake Land College School District have achieved a level of maturity in Lean Manufacturing techniques comparable to Goodson's Michigan study.

The lower scores in certain categories indicate various areas of opportunity for improvement. Improving low scoring areas such as supply chain integration, visual management system, use of space, movement of materials, product line flow, condition, and maintenance of equipment and tools could raise the RPA scores of the companies.

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Appendix A:

Survey Instrument: The Rapid Plant Assessment Questionnaire

The total number of yes responses on this questionnaire is an indicator of a plant's leanness. The more yes responses, the leaner the plant. Each question should be answered yes only if the plant obviously adheres to the principle implied by the question. In case of doubt, answer no.

circle the correct response

1. Are visitors welcomed and given information about plant layout, workforce, customers, and products? Yes No
2. Are ratings for customer satisfaction and product quality displayed? Yes No
3. Is the facility safe, clean, orderly, and well lit? Is the air quality good, and are noise levels low? Yes No
4. Does a visual labeling system identify and locate inventory, tools, processes, and flow? Yes No
5. Does everything have its own place, and is everything stored in its place? Yes No
6. Are up-to-date- operational goals and performance measures for those goals prominently posted? Yes No
7. Are production materials brought to and stored at line side rather than in separate inventory storage areas? Yes No
8. Are work instructions and product quality specifications visible at all work areas? Yes No
9. Are updated charts on productivity, quality, safety, and problem solving visible for all teams? Yes No

10. Can the current state of the operation be viewed from a central control room, on a status board, or on a computer display? Yes No
11. Are production lines scheduled off a single pacing process, with appropriate inventory levels at each stage? Yes No
12. Is material moved only once and as short a distance as possible? Is material moved efficiently in appropriate containers? Yes No
13. Is the plant laid out in continuous product line flows rather than in “shops “? Yes No
14. Are work teams trained, empowered, and involved in problem solving and ongoing improvements? Yes No
15. Do employees appear committed to continuous improvement? Yes No
16. Is a timetable posted for equipment preventive maintenance and ongoing improvement of tools and processes? Yes No
17. Is there an effective project-management process, with cost and timing goals, for new product start-ups? Yes No
18. Is a supplier certification process-with measures for quality delivery, and cost performance-displayed? Yes No
19. Have key product characteristics been identified, and are fail-safe methods used to forestall propagation of defects? Yes No
20. Would you buy the products this operation produces? Yes No

Appendix B:

Rapid Plant Assessment

Ratings

	poor (1)	below avg. (3)	avg. (5)	above avg. (7)	excellent (9)	best in class (11)	category score
Categories / (related question in the RPA questionnaire)							
1. Customer Satisfaction (1, 2, 20)							
2. Safety, environment, cleanliness, & order (3-5, 20)							
3. Visual mgt. System (2, 4, 6-12, 20)							
4. Scheduling system (11, 20)							
5. Use of space, movement of materials, and product line flow (7, 12, 13, 20)							
6. Levels of inventory and work in process (7, 11, 20)							
7. Teamwork & motivation (6, 9, 14, 15, 20)							
8. Condition and maintenance of equipment & tools (16, 20)							
9. Management of complexity and variability (8, 17, 20)							
10. Supply chain integration (18, 20)							
11. Commitment to quality (15, 17, 19, 20)							

Appendix C:

Lean Production Implementation Roadmap as prescribed by Productivity Inc. of Portland
Oregon

Phase I Plan 1-6 months

Perform assessment

Define goals, objectives, measures, and milestones

Establish a lean organization

Lean learning

Research current conditions

Deploy policy and master plan

Communicate policy

Phase II: Pilot 3-6 months

(Initial Application Area Teams Form)

Value stream management

Apply 5S

Standardize work and inventory buffers

One-piece flow

Apply quick changeover

Focused equipment improvement

Apply visual controls

Apply mistake proofing

Analyze results

Reapply 5S

Phase III: Deploy 6-12 months

(Additional Teams Form and Norm)

- Improve implementation plan
- Repeat application in other areas
- Apply advanced one-piece flow
- Implement autonomation (jidoka)
- Implement production smoothing
- Analyze results
- Apply a kanban system
- Analyze results
- Interface with MRPII
- Analyze results

Phase IV: Integrate 2-6 months

(Teams Perform)

- Deploy lean enterprise in value chain
- Educate and involve all employees
- Analyze results
- Apply concurrent engineering
- Analyze results
- Initiate supplier development program
- Analyze results
- Apply Quality function deployment
- Analyze results

Study results and revise strategy

Phase V: Excel Forever and always

(Teams Transform)

Break your paradigms