IMPROVING PRODUCTION PERFORMANCE THROUGH LEAN MANUFACTURING TECHNIQUES & EDUCATION IN LEAN CONCEPTS

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Introduction

Manufacturing productivity can be improved by reducing waste in production processes. Since the introduction of continuous flow and the concept of assembly line processing by Henry Ford, the industrial world has experienced a tremendous number of changes and modifications due to ever-increasing customer demands and expectations. These changes and growth have not always followed a systematic approach and have not always been without the accompanying growing pains. As a result, several significant problems have arisen. Companies have spent millions of human activity hours, have required a lot of resources and have created products with no value at all. Managers have made a countless number of costly mistakes which may have required rectification. Factories have had a great deal of products that were neither needed nor appreciated by the customer and this situation has resulted in overstock of inventories. All these problems can be summarized in one word: Waste, what the Japanese manufacturers refer to as "muda."

For many years, there were several attempts to decrease this "muda." The most significant among these techniques are "lean thinking."

With lean thinking, demand is anticipated and it is the engine that moves the entire system. A factory works as one big synchronized machine in which each step of the production process pulls the next. Lean thinking is reduced to three elements: flow, pull, and striving for excellence (Womack & Jones, 1998).

The implementation of lean thinking is complex, slow, incremental, and unpredictable. The process varies from case to case (Liker, 1998). For this article, two basic questions are proposed: In what ways are the current practices of lean manufacturing eliminating waste with less human effort, and in what ways are they leading to an increase in production efficiency? A second question can be asked: By observing the Japanese example, how could this technique be transferred to other companies? These questions will be answered in this article with the objective of demonstrating that lean manufacturing is in fact a technique that improves production performance.

The Importance of Educating Industrial Technology Students in Lean Manufacturing

"Today's manufacturing engineer requires a solid background in engineering principles, as well as business acumen and personal presence. He or she must be a good communicator, and a good listener." (Langenfeld, 1998, p.120)[11]

The manufacturing world has transformed the production and operational fields in recent times. The use of new fabrication and assembly methods based on technology has created the need to reorganize management and engineering policies in order to keep high quality standards and minimum possible cost. Lean Manufacturing definitely takes the lead for such changes in the industrial world. To train the workforce and to educate students interested in this area becomes imperative in order to face the new industrial challenge. We would not exaggerate if we state that today's business world is experiencing a new industrial revolution. Only through thorough education, it is possible to achieve the most ambitious goals in manufacturing.

The authors have developed courses and modified some others to focus on expanding students understanding and skills in "Lean Manufacturing." Major educational emphasis are placed on:

1. - Understanding the theory, concepts, policies, procedures and steps of Lean Manufacturing.

2. - Determining the major causes that create "waste" in factories and how to implement these modern techniques.

3. - Determining how Lean Manufacturing can be the answer to several problems in modern factories as a way to improve efficiency and reduce time and cost.

How Lean Manufacturing is Eliminating Waste and Leading to Efficiency

Lean manufacturing has changed the way factories have operated in the past. Managers of different companies such as Toyota, IBM Credit, and Kodak among others have demonstrated with their own experiences that lean manufacturing is a tool that has helped them eliminate waste and achieve efficiency in production.

In using this tool several issues, such as the role of the workforce, the level of inventory, and production times, have to be considered. Many operation managers have successfully been able to combine the principles of lean manufacturing with a manufacturing strategy developed by Toyota in Japan: the just in time techniques.

The Just in Time Techniques

"Just in Time (J.I.T.) is an integrated set of activities designed to achieve high volume production using minimal inventories of raw materials, work in process and finished goods. There are seven elements that address elimination of waste:

1. Focused factory networks
2. Group technology
3. Quality at the source
4. JIT production
5. Uniform plant loading
6. Kanban production control system
7. Minimized setup times"

(Chase, 2003, p.426, 428).[3]

Focused Factory Networks

It is a proven fact that small specialized factories provide better results than large vertically integrated plants. An example that supports this statement can be found in the case of the Toyota production system. Chase (2003) affirms that Toyota has 12 factories which are located around Toyota City and other parts of Aichi Prefecture, in Japan. Japanese executives have considered that it is easier to manage small organized workshops rather than large factories. The objective of this practice is to achieve economies of scale by saving costs and making better use of assets. In addition, with a smaller number of employees (30 to 1000, as Toyota has in each plant), it is also easier for managers to motivate the workforce.

Group Technology

This policy, which has been successful in several companies, ignores the division of production among departments. It treats production as a global task with the integration of machines and human skills.

"Group technology is a philosophy in which similar parts are grouped into families, and the processes required to make the parts are arranged in a specialized work cell." (Chase, Jacobs & Aquilano, 2003, p.428).[4]

According to Hammer & Champy (1994), IBM Credit applied this policy to their service operations. Their process started when a vendor requested a loan for a client. The whole procedure needed to grant the loan was long and painful. IBM Credit successfully integrated human skills by creating a control office that coordinated all the steps required for a loan grant. Their operation process was reduced from seven days to ninety minutes and increased productivity by five times.

Quality at the Source

The goal of this technique is to make every possible effort in order to achieve outstanding quality at every stage of production. At each step of the process, product quality is assured. Should a mistake be detected, the routine is stopped and the mistake is corrected instantaneously. This is a system in which workers become more careful and supervise their own job. Maintenance and control is observed at every step of a process to reduce the level of error.

J.I.T. Production

It is very important to have enough inventories to meet the production needs but be vigilant not to exceed this minimum requirement by a single unit. Inventory is analogous to an ocean that "hides" everything but the top of the iceberg. When we decrease inventory, (we lower the water level) we can detect many of the multiple problems (the rest of the iceberg) that a factory might have (Figure 1).

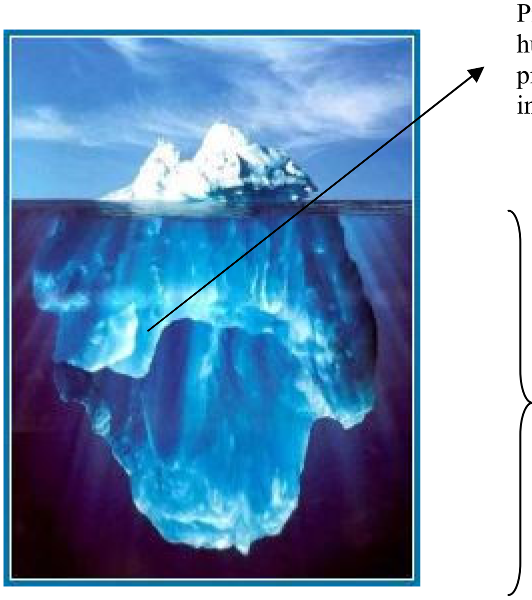

Figure 1 Analogy of the iceberg (Athropolis Guide to Arctic Sunrise & Sunset, 2004)[3]

Uniform Plant Loading

A wise decision is to build the same combination of products on a daily basis in small magnitudes so defects can be detected and efficiency improved. The Toyota plant in Japan has applied this principle. Monthly production schedules are reconfigured on a daily basis. For instance, a production of 6,000 sedans in a particular month corresponds to a daily production of

240 units, considering 25 working days in each month. Then the cycle time is calculated. According to Chase (2003) this is the fabrication time, expressed in minutes, of two identical units. These calculations are used at Toyota to correct errors and modify production in order to manufacture a defined and exact quantity.

Kanban Production Control Systems

"Kanban" is a Japanese word that means "signal card." The Just in Time (J.I.T.) production is based on the Kanban strategy. The Kanban consists of the use of cards and containers or squares drawn on the floor, which work as a signal or indication that it is time to order new inventory. An empty container, an empty square, or a specific mark on a card are the signals to replace inventory.

With the use of Kanban cards, managers know the appropriate number of containers of material that moves between provider and the user. Jacobs (2003) presents a formula to calculate the number of Kanban card sets:

> Each container represents the minimum production lot size to be manufactured. Hence, the number of containers controls the amount of work-in-process inventory in the system. The number of kanban card sets is determined by the formula:
>
> $$k = \frac{\text{expected demand during lead time + safety stock}}{\text{size of the container}}$$
>
> $$k = \frac{DL\,(1+S)\,.}{C}$$
>
> (p. 432).

Minimized Setup Times

The setup time is the time needed to calibrate and start the machinery. In many companies machine setup accounts for a significant loss of production time.

It is imperative to be able to set up the machines to produce the desired number of units. Large inventory levels mean extra maintenance cost plus depreciation expenses. In order to perform production more efficiently it is more advantageous to create small lot sizes.

The use of Just in Time techniques has been the key to success in several industrial settings. These techniques are a very important part of lean thinking.

Lean thinking

Just in Time techniques are an invaluable tool for production processes. When combined with other techniques, they can become a powerful antidote to "muda."

"Lean thinking" is a strategic procedure oriented to achieve constant process efficiency. Lean thinking is an effective solution to "muda." This strategy identifies value and determines the appropriate ways to make the value-creating steps run continuously through the manufacturing process. With lean thinking, the goal is to achieve "pull production;" that is, a factory creates only what the customer requires. Therefore, it is the customer who "pulls" the entire production from the raw material treatment to the final good delivery. Under the lean thinking philosophy, all activities are performed seeking for perfection. Operational excellence can be achieved by observing the following steps:

1. Encourage and train workers

Motivation is a key factor to achieve excellence in production processes. A small number of motivated employees can accomplish more synergy than a large number of workers under pressure. Many factories are investing a considerable amount of resources not only to train the workforce, but also to educate it. Training is any endeavor oriented to increase worker skills. Education, on the other hand, represents the teaching of a new knowledge, philosophy, technique, or strategy to pursue a particular goal. The concept of education involves a deeper and more extensive effort than the concept of training. Both, training and education increase the value of human resources. For example, Hill's Pets Products, a branch of Colgate-Palmolive, has applied this criterion in their Richmond, Indiana plant. Among the candidates who received job offers were former school teachers and former policemen. In other words, selected candidates were not the ones who had the most experience, but rather the ones who had a disposition to learn. Hill's Pets Products could train the new workers without major difficulties. Besides, this new workforce, with the inclination to learn, could easily be prepared to assume new responsibilities and to obtain promotions (Hammer & Champy, 1994).

An educational experience in lean manufacturing is the first step to improve productivity. The opportunity for students to be educated in lean concepts will offer them the unique skill to perform in a technical and scientific way. Educating students and teaching them lean concepts would offer a critical practical thinking and a skill to make fast business decisions in production, flexibility in manufacturing, inventory management, facilities layouts and workforce policies.

2. <u>Clearly specify the roles that each individual will have in order to accomplish all required modifications</u>**.**

People, not companies, are the ones who redesign processes in order to transform them in lean productive activities. Each individual in a company will assume a particular role in a renovation process that will make lean thinking a reality for that company.

3. <u>Define the methodologies needed to implement lean systems</u>

The implementation of lean thinking cannot be completed in one single action. It is necessary to divide the lean execution into smaller parts to be accomplished one step at a time.

4. <u>Define the environment that should be created to put into effect the new techniques</u>

The new techniques to be employed in order to achieve a lean corporation will lead inevitably to a change in the entire business environment. In this new corporative structure, the work units change from operating departments to process teams. The example of Bell Atlantic demonstrates the importance of teams. According to Hammer & Champy (1994), when a customer of Bell Atlantic demanded a telephone connection, usually the process moved through several departments. Only when Bell Atlantic organized process teams that focused directly on all and each one of the cases, the delivery time was reduced to days or even hours, instead of weeks.

When managers define the environment for the new techniques, they change values. Managers assume the role of leaders, rather than just bosses. Employees strongly consider that they work for the customer, not for the boss. This practice is not easy to achieve in reality.

Nevertheless, Hammer & Champy (1994) present the case of Xerox Corporation to illustrate that this goal can be achieved. At Xerox, the environment was changed. As a new policy, bonuses were granted based on customer satisfaction, not on each department's performance.

Lean thinking eliminates waste and increases efficiency.

The completion of the four steps detailed above leads to lean production. As a result, a series of benefits ensue. Each outcome becomes the source of another important consequence. The first effect is the reduction of lead times. And diminished lead times are the key for less costs and minimized inventory levels.

Lead time can be defined as "the gap between when an order is placed and when it is received" (Chopra & Meindl, 2001, p.182)[6]. Traditional manufacturing processes deal with batches, and these batches, as it turns out, always mean long waits as the product sits patiently awaiting the department's changeover to the type of activity the product needs next (Womack & Jones, 2001). Longer lead times affect the quality of the product by diminishing efficiency and accuracy.

Under lean thinking, several responsibilities are consolidated in order to eliminate unnecessary steps and focus on the final outcome. Lean procedures, while new for conventional factories, produce an impact on current production processes. In order to appraise the results of such practices and to assess their influence on lean thinking, Rash (1998) recommends the following measures:

- ***Shopfloor efficiency.*** This is an evaluation of the number of units produced per worker, and the manufacturing lead time for an order.
- ***Product Quality***. This is a measure of the percentage of raw materials scrapped in defective products, the percentage of workers' time spent on preshipment rework and the percentage of units re-worked due to quality problems.
- ***Employee complaints and Machine Uptime.*** At a lean company, cooperation among workers is crucial and to achieve this goal employee motivation is a very important factor.

We could express lean manufacturing with the following formula:

Lean manufacturing = production time + inventory level +

percentage of defects + percentage of units

reworked.

LM = PT + IL + PD + PUR

Consequently, a manufacturing company which has the smallest index (LM) will be the best follower of lean thinking. As stated by Womack & Jones (1998) excess production time, excess of inventory levels, defective products and re-worked units are all sources of waste or muda. According to the same authors, lean manufacturing is the most effective antidote for muda, so the less of these waste sources, the more lean a company is.

A few of the main components that affect this survival equation are efficiency, quality, and cost reduction in order to achieve competitive advantage. The implementation of lean manufacturing has been a reality in many companies such as Toyota, IBM Credit, Kodak, Hill's

Pets Products, Bell Atlantic and Xerox Corporation. Despite the fact that each company might present a completely different environment, there are some basic steps to be followed in order to transfer lean thinking, a roadmap for successful implementation.

Steps for a change: the Roadmap for Successful Implementation

Womack (2003) identifies some basic steps in order to achieve lean manufacturing:

- Specify Value
- Identify the Value Stream
- Flow
- Pull
- Perfection

Specify Value

When applying lean techniques, the starting point is to specify the value of the product. A very important issue in such a task is to always keep in mind that it is the customer who specifies the value of a product. The company must produce what the customer needs or wants, not what its full capacity determines. One should remember that offering the wrong product or service is also the first step to create "waste."

Identify the Value Stream

The value stream is identified as "the set of all the specific actions required to bring a specific product through the problem solving task, the information management task and the transformation task." (Womack, 2003, p.19)[19] By identifying the value stream, many worthless activities can and will be eliminated. Lean thinking requires seeing absolutely all activities as a whole.

Flow

The next step is to make all the value creating activities flow. With the batch system, products in each part of the assembly line had to wait until the machinery was calibrated and set ready to run. With a non-stop permanent flow, the whole factory works as one big machine that does not interrupt the process.

Departmentalized batch production requires lots of resources to create outcomes that often have no value at all. The idea of "flow" is to redesign processes eliminating a strict sequential order in manufacturing. Hammer & Champy (1994) have found in Kodak an example of good flow achievement. Lean thinking was successfully transferred to this company where several tasks are performed simultaneously. Additionally, by reducing the time between production steps, the need for changes in designs is also minimized. With a continuous flow, Kodak solves the problem of parts being useless or obsolete because every requirement is taken care of almost immediately and methodologies for tasks are constantly updated.

Pull

When the processes flow in a continuous and efficient way, production time is reduced. Changes in demand can be handled efficiently and solutions obtained effectively because the company has more time to react and correct errors. The pull system eliminates the need for sales forecasts. The customer is the one who finally decides the amount to be produced. It is the customer who "pulls" the whole production system. This is the modern tendency in business. No longer are inventories "pushed" to the customer.

Perfection

In order to achieve lean thinking it is necessary to allow every member of the production chain, and the business as a whole, to be familiar with all changes, strategies and processes. This is the key for having transparency. With knowledge and appropriate training, all business processes are understood in a better way, therefore, mistakes are avoided and solutions are provided. Additionally, management can obtain fast feedback with the possibility of applying quick adjustment measures.

Can Lean Strategies be Transferred Successfully?

> Lean Thinking can be applied to any organization in any sector; although its origins are firmly in an automotive production environment, the principles and techniques are transferable, often with little adaptation - and we have a wealth of case study evidence that backs up this assertion. Lean Thinking (Womack and Jones, 1996) showed how firms in several industries in North America, Europe and Japan followed this path and have doubled their performance while reducing inventories, throughput times and errors reaching the customer by 90%. These results are found in all kinds of activities, including order processing, product development, manufacturing, warehousing, distribution and retailing. (About the Lean Process, 2005)[1]

Lean strategies can be transferred successfully. By observing the Japanese example at Toyota, several companies have already applied lean principles to their particular processes. Kodak successfully utilized the lean principle of flow and minimized process time. IBM Credit improved coordination and control with the use of Just in Time techniques and lean thinking. Hill's Pets Products added the training principle to their current activities and enhanced human skills significantly. And when Bell Atlantic organized focused process teams, delivery times were reduced drastically. Finally, Xerox Corporation really took advantage of the lean objective of customer satisfaction. At Xerox, managers created the appropriate environment to put into effect lean principles. All these are just a few examples of several that could be found in the real business world. These cases demonstrate that lean manufacturing principles are transferable.

The challenges

After many observations of successful lean companies, authors such as Liker (1998) have concluded that not only a strong management leadership is imperative for a change, but also external consulting is beneficial. Unless the company counts with a well-built quality and delivery team (most enterprises do not), the external consulting services are the perfect match for a well organized operations management.

> The coaches need to take an aggressive role by driving the process more than passively offering suggestions and by making specific technical suggestions. This is a more hands-on and in some cases more directive role than most consultants I know take when working on organizational change projects. As Bill Constantino puts it: "Very simply, when people are in the process of dramatic change, they need a continuous resource

whom they can trust to guide them through the change. Without this resource, there is a high likelihood that the process will either be abandoned or modified to the point that it no longer meets its original purpose" (Liker, 1998, p. 508)[13].

From the technical point of view, in order to achieve successful lean transfers, it is crucial to count on a qualified specialized team in addition to external consulting services. In this case, the company will accomplish good technical support, which is the base for creation in the manufacturing world.

How to transform

The key for transformation is to do it step by step. To begin with, it is necessary to create a model line. In such a task, one model to follow is the one developed by the Toyota Production System. At this plant, management studied the model line closely to determine the basic characteristics of the production flow and its relation with the information and communication channels. The next step was to organize a plan of what the ideal production flow should become. The Toyota example demonstrates that management must always consider appropriate measurements and feedback links at every part of production. The goal is to transform the process into a continuous flow based on a pull strategy and to balance production based on anticipated demand. The first noticeable result of continuous flow is the reduction in set-up times.

The appropriate atmosphere for a change

While the biggest threat to start a lean administrated company is worker-resistance, the "friendliest" environment to transfer lean thinking is the one in which trust is achieved. It is necessary to convince employees about the imperative need for change. Actions and useful training is the first step to build a rapport.

Can Lean Strategies be taught in an Educational Setting Successfully?

"A good reliability management and education system is a key factor for total quality management." (Park, 1999, p.291)[15]

The possibility to educate student and train employees in the concepts explained above is a very important goal of the authors. Upon completion of a lean manufacturing course each student will have the chance to demonstrate his/her knowledge in one of the most important and contemporary techniques in the operations world. The educational methodology includes lecturing, analysis of cases and results and the study of real business situations that have lead factories to either success or failure depending on the appropriate implementation of lean thinking. Educating in lean strategies concerns several challenging and interesting educational tasks such as:

1. – The clear understanding of terms, definitions, concepts and policies of Lean Manufacturing.
2. - The formulation of recommendations in order to achieve operations improvement.
3. - Techniques used to analyze and redesign many of the most important processes in production processes in order to reach competitive advantage.

4. –The comparison and matching of lean manufacturing with several other manufacturing strategies.

Suggested Structure of a Lean Manufacturing Educational Program

The concepts presented in this paper would be the "raw material" for courses or conferences oriented to educate in lean manufacturing. Starting from ground, and designing a pedagogical strategy for optimal results among students, a structure for a program would be as follows:

1. Basic definitions
2. The advantages of a lean system over the mass production system
3. An ideal process: efficiency and synchronization
   - Waste and its sources
   - Synchronized Networks
4. Improving flows in a supply chain
   - The "Bullwhip" Effect
   - The improvement process
     - Reengineering techniques applied to production processes
     - Benchmarking
5. The Toyota Production System
6. Just in time and lean systems
   - Introduction

- JIT Implementation Requirements. – (JIT layouts and design flows, JIT applications for line flows, JIT for job shops, Stable schedules and Suppliers)
- JIT in services

7. Jidoka & Heijunka Systems

8. Kaizen

- Basic concepts
- Examples

9. Lean Production for “Pull Systems”

- Human organization
- Quality system
- Material handling system

10. How to achieve a “Lean Transportation Network”

- Transportation in a Supply Chain
    - Direct Shipping with “Milk Runs”
- Network design
- Information Technology in a Supply Chain

11. Using total quality to achieve lean manufacturing

- The Process Management
- The Quality Assurance System
- Quality Circles, Quality and Project Team Activity

12. How to achieve lean manufacturing techniques in service operations

Conclusions

The current practices of lean manufacturing are indeed eliminating waste with less human effort. In order to achieve efficient production and to eliminate waste it is necessary to understand and completely apply the policies presented in this study. All these procedures must be followed not only by management, but also by the workforce.

- Focused factory networks
- Group technology
- Quality at the source
- JIT production
- Uniform plant loading
- Kanban production control system
- Minimized setup times

Additionally, as explained in this study, lean thinking is leading to an increase in production efficiency by identifying and concentrating in activities that represent a value for the customer. Those value added activities must be connected in a whole process and must flow through the entire production route. Also it is important to keep in mind that lean thinking applies the pull system in which everything is produced according to the customer needs. The customer pulls production and every workstation pulls requirements from the previous one based on the customer.

In conclusion, it is important to remember that lean manufacturing is transferable. The keys for a successful lean manufacturing transfer include training the workforce, educating the students who will become the operations managers in the future, maintain focused process teams in order to reduce product delivery time and last but certainly not least, create, produce and manage according to customer satisfaction. Any activity that is not oriented to customer satisfaction is a non-value activity.

As presented through extensive literature review, several companies that try to transfer lean thinking end up with no achievement at all. The secret to success is knowledge, ability, appropriate feedback, and quick reactions to solve problems. While there is a lot of literature about how to create lean companies, the authors would like to conclude by analyzing several ways to fail. Many mistakes can be avoided in order to achieve lean thinking as stated by Hammer & Champy (1994).

Trying to correct production processes instead of changing them is a big administrative mistake. In many cases, the production line must be re-designed completely. Most enterprises still refuse to see that it is the customer who pulls the entire system.

Sometimes, when operation problems arise, there is a tendency of finding "who to blame." Corrections should be applied to the processes, not the people. People should be educated and trained, and processes should be redesigned to satisfy demand in the shortest time possible.

Any improvement has to be achieved with people. No matter how good a new strategy might seem, the employee is the one who will finally create the lean factory. Several failures have happened because of the difference of commitment inside the company. In order to succeed, managers are not just bosses, but true leaders that guide the workforce. They must have the leadership power to start changes. From the same point of view, workers are not followers anymore; rather, they become part of a team that contribute and bring solutions. The goal for workers is not to satisfy the boss, it is to satisfy the customer.

Management should focus on one step at a time, without spending too much time in planning new designs. While designs are important, the execution phase must not be delayed. Big changes require commitment. It is time to act and react, there is no step back. In several cases, lean manufacturing is the only way to go.

Suggestions for additional education in operations and manufacturing

Other topics worthy of consideration and inclusion in a curriculum in lean manufacturing may include:

- Set-up reduction
- Process flow
- Variation reduction
- Design of experiments
- Failure models
- Effects analysis
- Measurement systems
- Evaluation
- Mistake proofing

- Statistical Process Control
- Total productive maintenance and maintenance excellence
- Benchmarking

References

1. About the Lean Process, Lean Thinking. (n.d.). *Applying Lean Thinking in Different Sectors.* Retrieved February 6, 2005, from www.leanaust.com/about.htm.

2. Anupindi, R., Chopra, S., Deshmukh, S.D., Van Mieghen, J.A. & Zemel, E., (1999). *Managing Business Process Flows,* New Jersey: Prentice Hall.

3. Athropolis Guide to Arctic Sunrise & Sunset. (n.d.). *Is This Real?A Beautiful… but Impossible Photograph*. Retrieved December 21st 2004, from www.athropolis.com/news/berg-pic.htm

4. Chase, R.B., Jacobs, R. & Aquilano, N.J. (2003). *Operations Management for Competitive Advantage* (10th ed.). New York: Mc. Graw-Hill.

5. Choi, T.Y. (Eds.) (1998). *The Successes and Failures of Implementing Continuous Improvement Programs: Cases of Seven Automotive Parts Suppliers*. Portland: Productivity Press.

6. Chopra, S. & Meindl, P., (2001). *Supply Chain Management, Strategy, Planning and Operation,* New Jersey: Prentice Hall

7. Fukida, R. (1998). *Building Organizational Methodology for Transformation and Strategic Advantage.* New York: Mc: Graw-Hill.

8. Hammer, M. & Champy J., (1994) *Reengineering the Corporation: A Manifesto for Business Revolution.* New York: Harper Collins Publishers Inc.

9. Hayes, R.H., Pisano, G.P. & Upton, D.M. (1996). *Strategic Operations.* New York: Harvard Business School, Free Press

10. Jordan, J.A. & Michel, F.J. (2001), *The Lean Company, Making the Right Choices.* Portland: Society of Manufacturing Engineers.

11. Langenfeld, G., "Fixing Manufacturing Education," *Manufacturing Engineering,* Volume 24, Issue 1 (1998), p. 120.

12. Lee, D., "The Manufacturing Professional's Changing World," *Manufacturing Engineering,* Volume 131, Issue 6, (2003), p. 20.

13. Liker, J.K. (1998). *Becoming Lean.* Portland: Productivity Press

14. Miller, R., "What's up in Factories?" *Educational Leadership,* Volume 53, Issue 8 (1996), p.30-33.

15. Park S.H., "Reliability Management and Education in Manufacturing Industries," *European Journal of Engineering Education,* Volume 24, Issue 3, (1999), p. 291-298

16. Peterson, D., "Bringing history into classrooms: Reconstructing a colonial supply chain," *Logistics Spectrum,* Volume 33, Issue 2 (1999), p. 12-16.

17. Rasch, S.F. (Eds.) (1998). *Lean Manufacturing Practices at Small and Medium-Sized U.S. Parts Suppliers*. Portland: Productivity Press.

18. Shook, J.Y. (Eds.) (1998). *Bringing the Toyota Production System to the United States: A Personal Perspective.* Portland: Productivity Press

19. Womack, J.P. & Jones D.T. (2nd ed.) (2003). *Lean Thinking: Banish Waste and Create Wealth in your Corporation.* New York: Simon & Schuster.

20. Womack, J.P., Jones D.T. & Roos D. (2001). *The Machine that Changed the World, The Story of Lean Production.* New York: Harper Collins.

21. Wright M., "What Should Students Learn about Manufacturing?" *Technology and Children,* Volume 5, Issue 3 (2001), p. 2-3.

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