Nurturing Lean Manufacturing Concepts in the Industrial Engineering Subject at the Undergraduate Level

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Abstract

Lean is about doing more with less: less time, inventory, space, labor, and money. Lean Manufacturing System (also known as the Toyota Production System) is, in its most basic form, the systematic elimination of waste - overproduction, waiting, transportation, inventory, motion, over-processing, defective units - and the implementation of the concepts of continuous flow and customer pull. There are five areas that drive lean manufacturing: cost, quality, delivery, safety, and morale. Just as mass production is recognized as the production system of the 20th century, lean manufacturing is viewed as the production system of the 21st century. Lean manufacturing is an assembly-line manufacturing methodology developed originally for Toyota and the automotive manufacturing industry. The goal of lean manufacturing is described as "to get the right things to the right place at the right time, the first time, while minimizing waste and being open to change". Engineer Ohno, who is credited with developing the principles of lean manufacturing, discovered that in addition to eliminating waste, his methodology led to improved product flow and better quality.

The authors believe that the good concepts in lean manufacturing system are worth looking into and nurture in the Industrial Engineering subject in the effort to elevate the quality of the university students and graduates. Thus, the paper discusses about the current subject syllabus as to where and how to nurture the lean manufacturing concepts.

Keywords: Lean Manufacturing; Toyota Production System; Engineering Education

1. Introduction

1.1 What is lean manufacturing?

Operations and industrial engineering practice have been transformed over the past 20 years by the principles of lean thinking. Womack and Jones [1] described lean thinking as an antidote to *muda*, meaning waste. Lean thinking helps to create a value stream throughout the supply chain by eliminating waste.

Lean is about doing more with less time, less inventory, less space, less labour, and money. It is also known as the Toyota Production System (TPS). In its most basic form, Lean Manufacturing system is the systematic elimination of waste - overproduction, waiting, transportation, inventory, motion, over-processing, defective units - and the implementation of the concepts of continuous one piece workflow and customer pull. Contrasting with the mass production that was recognised as the production system of the 20th century, lean manufacturing is viewed as the production system of the 21st century.

The lean manufacturing concept was to a large extent inspired by Kaizen - the Japanese strategy for continuous improvement. Employee empowerment and promotion among them of a way of thinking oriented at improving processes, imitation of customer relationships, fast product development and manufacturing, and collaboration with suppliers are the key strategies of leading lean companies.

Lean manufacturing aims to achieve the following:

1. the best quality,
2. the lowest cost,
3. the shortest lead time,
4. the best safety, and
5. high morale.

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1.2 Why Lean Manufacturing?

The Lean Manufacturing or the Toyota Production System is a unique approach to manufacturing. From literature [2], Taiichi Ohno, founder of the TPS says that:

All we are doing is looking at the time line from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that time line by removing the non-value-added wastes. (Ohno, 1998)

Toyota developed the production system after World War II, at which time the economic crisis in Japan was in chaos. While Ford and GM in the United States used mass production, economies of scale, and big equipment to produce as many as possible, and as cheaply as possible, Toyota's market was small. Toyota needs flexibility to produce a variety of vehicles on the same production lines to satisfy its customers. Thus Toyota make a critical discovery by making the lead time short and focusing on keeping production lines flexible, and getting higher quality, better customer responsiveness, better productivity and better utilization of equipment and space.

In March 2003, Toyota earns USD 8.13 billion – larger than the combined earnings of the Big 3 (GM, Chrysler, and Ford). Its net profit margin is 8.3 times higher than the industry average. While the Big 3 stock prices were falling in 2003, Toyota shares had increased 24% over 2002. In August 2003, for the first time Toyota sold more vehicles in North America than one of the Big 3 automakers (Chrysler). With the TPS, Toyota has the fastest product development process in the world. New cars and trucks take 12 months or less to design, while competitors take two or three years. Toyota peers and competitors throughout the world make Toyota as their benchmark for high quality, high productivity, manufacturing speed, and flexibility. [2]

Toyota also has astounding quality reputation. Customers know that they can count on their Toyota vehicles to work right the first time and keep on working, while most US and European automotive companies produce vehicles that may work when new but almost certainly will spend time in the shop in a year or so. In 2003, Toyota recalled 79% fewer vehicles in the U.S. than Ford and 92% fewer than Chrysler. [2]

Figure 1 shows the lean manufacturing system or also known as the TPS house diagram, it has become one of the most recognizable symbols in modern manufacturing. As stated earlier, the goals of lean manufacturing as achieving the best quality, lowest cost, and shortest lead time, is indicated as the roof in Figure 1. There are two outer pillars; just-in-time and *jidoka*, which in essence mean never letting a defect pass into the next station and freeing people from machines. The centre of the system is people. Various fundamental elements in lean manufacturing include the need for standardised, stable, reliable processes and also, *heijunka*, which means levelling out the production schedule in both volume and variety. *Heijunka* is important to keep the system stable and to allow minimum inventory.

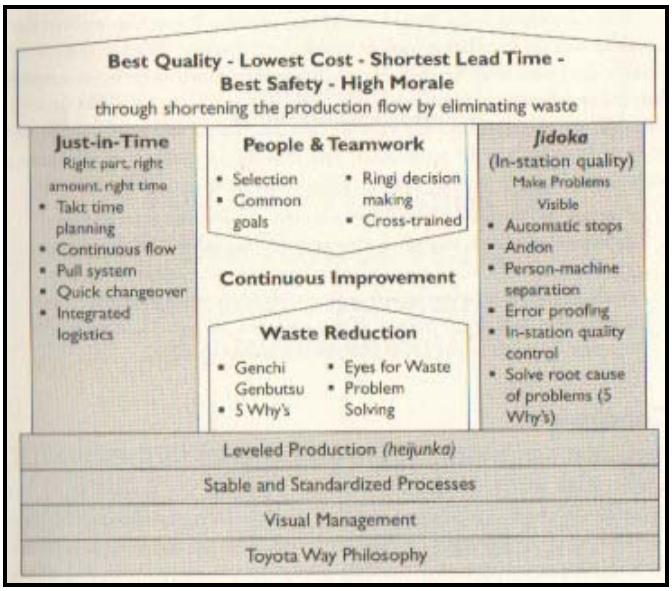

Figure 1. The Lean Manufacturing (Toyota Production System (TPS)). Source: Ref. [2] page 33.

Each element of the house is important, but the way how it is reinforced is more important. Just-in-time (JIT) is about removing as much as possible the inventory used to buffer operations against problems that may occur in production. This reinforces *jidoka* which halts the production process. This indicate that workers must fix the problems immediately and urgently to resume production.

In lean manufacturing, people must be trained and educated to see waste and solve problems at the root cause by repeatedly asking why the problems really occurs. Problem solving is at the actual place to see what is really going on (*genchi genbutsu*). [2]

The lean manufacturing goals as shown in Figure 1 are the positive values that lead to the development of excellent and successful people. Lean thinking will not come on its own. The authors feel that, lean thinking needs to be developed and nurtured especially in engineering graduates. Industrial Engineering subject has

been identified as a platform where lean thinking and lean philosophy can be nurtured in the students. The authors have identified several benefits to the students which include the acquiring of problem solving skills, multi tasking, work smart attitude, continuous improvement thinking, ready to take challenge spirit, team working skills, cost consciousness and learning by doing. These benefits are inline with the attributes of University Technology Malaysia graduates.

Genchi genbutsu (go and see for yourself to thoroughly understand the situation) will develop student's mentality to solve problems to the root cause rather than theorising on the basis of what other people or the computer screen tells. At the same time, students are also encouraged to make decision slowly by consensus, thoroughly considering all options; implement decision rapidly. That lean philosophy is called *nemawashi*, a process of discussing problems and potential solutions with all those affected, to collect ideas and get agreement on a path forward. The consensus process, though time consuming, helps broaden the search for solutions, and once the decision is made, the implementation is done quickly. Lean manufacturing also values ideas. This method of problem solving is one of the lateral thinking techniques and also encourages good team working as every body are able to express their voice in solving problems. The one-piece flow manufacturing principle also drives to a problem solving technique. Teruyuki Minoura, former President of Toyota Manufacturing, North America said that "*If some problem occurs in one-piece flow manufacturing then the whole production line stops. In this sense it is a very bad system of manufacturing. But when production stops everyone is forced to solve the problem immediately. So the team members have to think, and through thinking team members grow and become better team members and people.* [2]

Toyota leaders truly believe that if they create the right process the result will follow. This whole production line stops when there is a problem, and it resume until the team members fix the problem, is called *jidoka.* This develops quality consciousness and will help to find the root cause of the problems and able to bring problems to the surface. This also tells the students that to be excellent and success professionals they have to be multitasked, not only too specialised in specific areas. Fast action to solve problems is needed.

The lean manufacturing philosophies lead to produce smart young professionals. The continuous improvement (*Kaizen*) that incorporated with the people and team working improvement as well as the waste reduction lead to educate the young professionals to always think on improvement, getting the works done with minimal cost and effort in their every day life. *Kaizen* will also nurture spirits to take challenge to the young professionals. The authors believed *Kaizen* can produce problem hunter professionals instead. A problem hunter professional is a professional who always hunting for problems rather than just sitting behind the desk.

Mr Kiichiro's father, Mr Sakichi Toyoda who is the architect of the lean manufacturing, gave challenge to his son just after graduating in Mechanical Engineering from the prestigious Tokyo Imperial University; he gave his son a major project in his life. He asked his son to take the project as a challenge and told him that "*Everyone should tackle some great project at least once in their life. I devoted most of my life to inventing new kinds of looms. Now it is your turn. You should make an effort to complete something that will benefit society.* [3] Then finally Kiichiro becomes the founder of Toyota Automotive Company. The company was grown on his father's philosophy.

Despite the formal education he obtained from the University, he followed his father footsteps of learning by doing. This is another lean manufacturing philosophy. Shoichiro Toyoda, his son described his father, Kiichiro Toyoda as a genuine engineer who: "*…gave genuine thought to an issue rather than rely on intuition. He always liked to accumulate facts. Before he made the decision to make an automobile engine he made a small engine. The cylinder block was the most difficult thing to cast, so he gained a lot of experience in that area and, based on the confidence he then had, he went ahead".* [3] This encouraged the problem based learning for the Industrial Engineering subject. Students learn the subject by solving the problems. From problems, they are able to derive the concept and theories of the subject.

The 5 S activity in the lean manufacturing; sort, stabilise, shine, standardise and sustain will also produce good working habits thus lead to the quality people. Students who take this subject are also nurtured with this culture.

All those positive elements should mate together and house as a system. The system is expected to help students to be a charismatic future leader in industries. The current President of the Toyota Motor Corporation, Fujio Cho said that "*Many good American companies have respect for individuals, and practice kaizen and other TPS tools. But what is important is having all the elements together as a system. It must be practiced every day in a very consistent manner-not in spurts-in a concrete way on the shop floor.*

2. The IE syllabus – now and future

Table 1 shows the topics currently being covered in the Industrial Engineering (IE) subject. The subject itself is about productivity and quality. Productivity is about doing the right things and doing them right, or in other words, doing work effectively and efficiently. So, it is all about doing more with less time, less inventory, less space, less labour, less rework and less financial burden. Or in other words, productivity is about having more output out of lower inputs or using fewer resources.

Quality is about getting it right the first time, every time. It is about supplying or providing goods and services that meet the specifications. Basically it is about making the 'customers' satisfied, or in other words providing products or services that can be stamped as 'satisfaction guaranteed'. The customers on the other hand can be the external ones or the internal customers such as the downstream processes in a manufacturing plant.

Having these definitions of productivity and quality, the IE subject aims to provide to the students the techniques available in running a productive organization. Therefore, each topic in the syllabus includes tools and techniques to improve the productivity, applicable to both the manufacturing and service industries.

Table 1. Industrial Engineering syllabus

Topic	Content
1.	**Introduction To Industrial Engineering** • The Development of Engineering Field • Industrial Engineering • Organization Structure
2.	**Manufacturing** • Introduction • Manufacturing System • Manufacturing Engineering • Manufacturing Processes
3.	**Facilities Planning & Design** • Introduction • Location • Facilities Layout • Materials Handling
4.	**Work Study** • Introduction • Method Study • Time Study/Work Measurement
5.	**Ergonomic** • Introduction • Anthropometrics Data • Ergonomic Study
6.	**Production Planning And Control** • Introduction • Forecasting • Planning And Scheduling • Inventory Management • Just In Time Philosophy (JIT)
7.	**Project Management** • Introduction • Project Scheduling • Project Management Technique
8.	**Quality Control** • Introduction • Statistical Quality Control • Total Quality Management
9.	**Productivity** • Introduction • Productivity Measurement • Productivity Improvement

Table 2 below compares several concepts of lean manufacturing (LM) with the current Industrial Engineering syllabus. Each concept is briefly defined in the 'LM Concept' column, and the topics in IE which nurture the particular LM concept are discussed in the 'IE Topics' column. The IE topics are described based on the current syllabus and also the intended future focus and addition to the syllabus.

Table 2. Lean Manufacturing (LM) concept versus Industrial Engineering (IE) syllabus

LM Concept	IE Topics
jidoka, which involves immediately responding to abnormalities in a process, driving to the root cause of the problem and preventing recurrence - all of which ensures quality is built into each process step.	***Topic 9: Quality Control*** which includes sub-topics such as quality inspection and statistical process control tools, such as *Ishikawa* / fish bone diagram, check list, Pareto analysis, and quality control charts. Currently, the students are taught to build and do analyses on quality control charts (refer to Figure-2) to check on the process capabilities - whether or not a process is in or out of control, stable or otherwise. What action to take if the data shows a process is out of control or has a tendency to go out of control? The students are also taught to check the causes of variations that occur in a process, and to use the statistical process control tools to aid with the investigation. Proposal for future syllabus: include a topic on metrology and measurement equipment with build-in quality

	inspection capabilities.
JIT is a management philosophy of continuous and forced problem solving. Supplies and components are 'pulled' through system to arrive where they are needed and when they are needed. The focus is on the value that is created for the customer, and the elimination of all aspects of waste reduction and ultimate elimination of inventory, over-processing and excessive transportation/material handling.	***Topic 6: JIT***. Currently, only the basic concept and philosophies of JIT are taught in class. The concept such as JIT is a pull system, and examples of *kanban* system application in production are provided. The idea about JIT inventory to eliminate/minimize inventory by exposing actual problems and issues are also discussed in class (refer to Figures 3a and 3b). In future, specific tools that can be used to determine the production schedule and inventory system will be elaborated further. An IE lab that includes works on JIT should also be planned for. This is to simulate the benefits of JIT.
kaizen, continuous improvement and *heijunka*, which means leveling of the production volume and variety	Currently, these concepts are covered in ***Topic 4: Work Study, Topic 6: Production Planning and Control, Topic 7: Project Management and Topic 9: Productivity.*** Work Study comprises of Method Study and Work Measurement. Method Study deals with standardizing method of doing a job. It involves activities from identifying critical works to study until to continuously maintaining and monitoring new and improved work standard that has been implemented. Meanwhile, Work Measurement is about setting time standards. The standard time is for evaluating workers' or machines' efficiency, scheduling operations, training purposes, continuous improvement, and calculating costs of resources. Production Planning and Control includes forecasting and production scheduling. Several basic techniques are taught to enable students to make based decisions on cost effective and productive running of a manufacturing organization. Some of the techniques learnt can be used in service industry, as well as day to day life requirement. Proposal for future IE syllabus: to emphasize on JIT production system (for example: production lot size of 1), and to introduce other manufacturing systems, such as the Flexible Manufacturing Systems (FMS). In Project Management, students are taught to build network diagrams and carry out critical path analysis. For future syllabus enhancement, the topic should include the important relationship between critical path analysis and resource requirements and scheduling. The topic on Productivity covers

Use reliable technology that serves workers and processes	***Topics 8 & 9: Quality and Productivity***. To increase productivity means to do work more effectively and efficiently. Reliable technology is one way of achieving productivity and ensuring product quality, although both productivity and quality are achievable without major investment on technology. Currently students are taught that good quality and high productivity can be achieved through the basic principles of human factors. Technology is used to support people and unless the people are effective and efficient, technology will be unreliable and ineffective.
newamashi, slow decision but fast action, and *genchi genbutsu*, where problem solving is done by going to the actual place to see what is really going on	***Group project and assignments,*** where team work is a must. The project requires the team to go to industry or any organization to observe the industry/organization current practices, identify problems and suggest solutions using methods learnt in the subject. Discussions and group meetings are part of the project requirement. The final report must include minutes of group meetings. The purpose is for the lecturer to assess the group progress, member's participation in decision making (*syura*), and each member's contribution in the project.

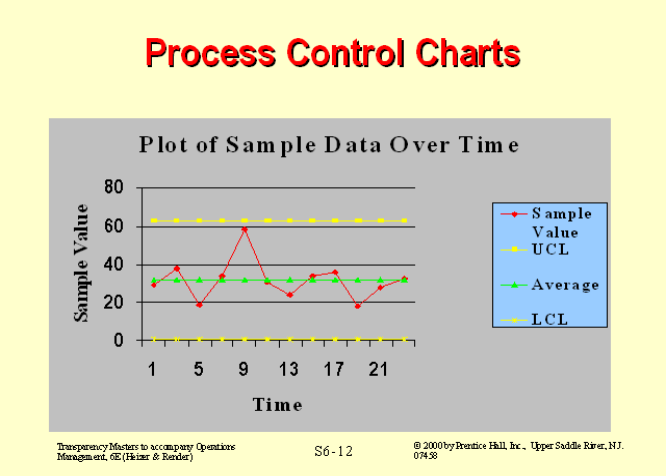

Figure 2

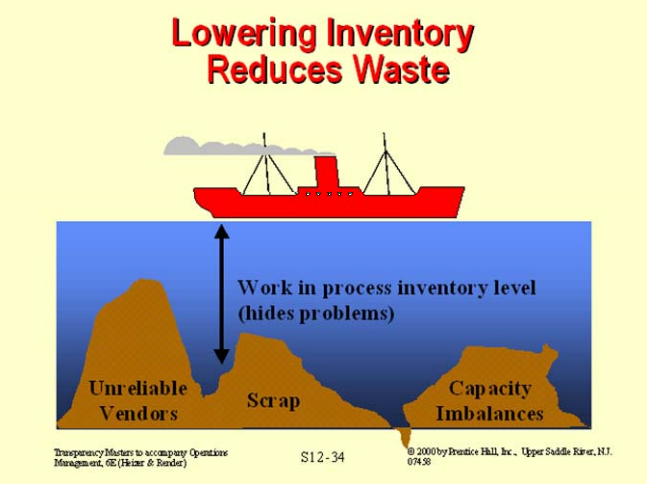

Figure 3a

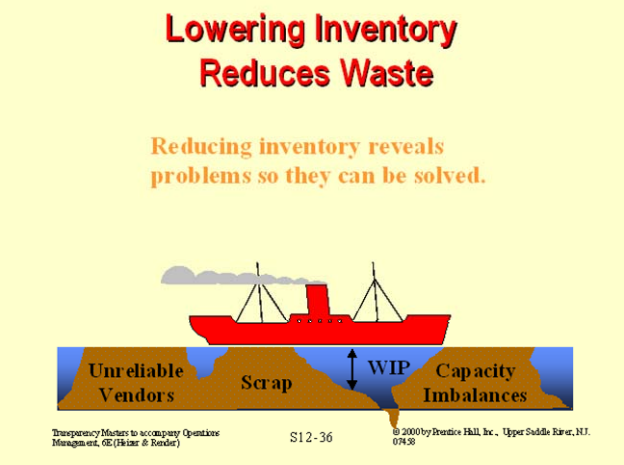

Figure 3b

3. Conclusion

Lean manufacturing gives positive values that are worth inculcating in engineering students. The concepts of productivity, continuous improvement, jidoka, *newamashi*, and *genchi genbutsu* among others, can 'create' productive, effective and efficient students. The authors believe that these added values are a benefit for the students, more so as university graduates. We believe that these graduates will be able to withstand many challenges and become more competitive in the job market. The success of lean manufacturing system has been proven with the success of the Toyota Motor Company, thus, it is no doubt that lean concepts will also succeed in education.

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