AC 2008-439: ASEE ABSTRACT 08 CHEN & COX - MANUFACTURING DIVISION

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Win-Win-Win Curriculum in Lean/Six Sigma Education at Iowa State University

Abstract

This paper discusses the successful outcomes of a newly developed "win-win-win" lean manufacturing curriculum at Iowa State University that foresees a need to enhance the implementation of lean manufacturing tools to strengthen the economy in the State of Iowa's manufacturing sectors. This three-credit lean course, which is comprised of a weekly two-hour lecture and two-hour lab (considering holidays and exam days), will be restructured into two major sessions:

(1) 32 hours of lecture and lab activities for learning lean tools and principles, such as visual management, 5S, standardized work, quick changeover, pull system using kanban and poyayoke, and how to cost justify a lean project.

(2) 22 hours working as a lean team at a local manufacturing company located less than 50 miles of campus, thus enabling students to conduct onsite a full- or half-day project.

The final result is a lean presentation from the team to industrial mentors at the end of the semester. It is hoped that the students will not only learn from their own lean experiences, but also from the projects of other teams working in different manufacturing settings. After a year of implementation, evidence suggests that the program effectively enhances students' industrial awareness and understanding of lean manufacturing. Recommendations made by the student teams to the companies have been well received and, in many cases, implemented. The long-term impact to local industries in the awareness and implementation of lean concepts through this type of industrial integrated lean curricula will be evaluated for future dissemination.

1. Background and Introduction

As a land grant university, Iowa State University (ISU) plays an important role in helping grow the Iowa economy. The ISU Extension Center for Industrial Research and Service (CIRAS) serves as the outreach arm of the College of Engineering, helping manufacturers in the state become more competitive in the global economy. CIRAS has been providing lean manufacturing awareness and training to many industries in the State of Iowa for over a decade. There is a great need for lean education in Iowa: Manufacturing is the largest segment of the Iowa economy and 90% of the state's manufacturers have fewer than 100 employees. Many of these companies do not have the budget to hire full-time specialists to lead Lean activities, whereas larger companies may have access to such resources. In realizing this need among Iowa's small companies, a few Extension engineers from CIRAS met with engineers and managers in small companies across the state. They discussed the prospective impact of implementing Lean and Six Sigma methodologies, hoping that companies will adopt these techniques in order to improve their productivity, the quality of their products, and their profits by continuously reducing costs. Success has been evident in this area, and now there is even more demand within the Iowa manufacturing sector for lean manufacturing resources and training.

Lean focuses on two key concepts: (1) reducing "muda" (wastes) and (2) respecting people[2]. Since its conception in the 1970s at Toyota Motor Corporation, the Lean movement has impacted many countries. Although this impact was originally seen in manufacturing-related enterprises, its reach has now flowed into other sectors such as service industries, ag-business, medicine, and even administrative offices. Lean's main philosophy is to assist all levels of a particular enterprise, to identify waste, and to understand the value of the employee. Seven types of wastes, or "muda," have been identified, and they are defined as over-production, inventory, waiting, movement, transportation, defects, and over-processing, each of which denotes a non-value added activity generally found in an organization. Non-value added activities are defined as activities that do not add market form or function or are not necessary. These activities should be eliminated, simplified, reduced, or integrated. One could easily conclude that these wastes do not simply exist in manufacturing facilities, but rather virtually everywhere, such as in hospitals, service industries, government offices, etc.

By identifying and eliminating wastes and implementing key lean tools, an organization can continuously improve their productivity, increase output quality, and instill cost effectiveness. Some of the common tools are standardization, 5S, setup reduction, Pull/Kanban system, pokayoke[7] (or defect presentation system or device), visual control, point of usage storage, value stream mapping, etc. These lean concepts or tools have been used in lectures for many years. Now, however, industries and organizations are seeking engineers and managers to not only lead lean projects but to also initiate projects to change organization culture and conduct lean training for fellow employees.

For the past 12 years, Iowa State University has delivered a lean course via lectures and homework on key lean tools and concepts. Further, lab-related lean projects, for teams of 5 to 6 students, have been developed to supplement the academic learning with hands-on experience. Such lab-based lean projects guide students in reviewing the current design and production system using an off-shelf product, brainstorming a new design so that the product can be produced in a one-piece-flow pull manufacturing system. The course has been well received by students and many graduates, most of whom have secured employment in Iowa-based companies, have leveraged their knowledge from the course to become lean manufacturing engineers. In the dynamic modern manufacturing environment, such a lab-related and lecture-based lean curriculum is key to opening students' eyes to the challenges facing a variety of industries, such as major organizational changes and global competition. Lean engineers need to be well-equipped to clearly identify waste, to be able to lead a team to resolve such waste, and to be able to sustain the implementation of lean systems to stabilize the organization. Lecture and lab-related projects may not fully be able to equip students with an understanding of the challenges facing lean engineers. Instead, a real-world, lean-related approach for engineering education is essential to fulfill such a need from both the educational and industrial perspectives.

A real-world lean project involves faculty, a group of students who understand basic lean concepts and tools, employees and industrial engineers, in this case engineers from the extension office CIRAS at ISU. Using a systematic approach combining their own expertise with that of faculty, and CIRAS, the students provide lean recommendations to the partner company. Such real-world lean projects create a win-win-win scenario. First, the employee, engineer, or the manager of the company develops a more thorough understanding of the power of lean concepts to revamp an organization. Next, CIRAS achieves its mission to heighten awareness of lean tools and enhance overall manufacturing output within the State of Iowa. Lastly, students benefit from real-world projects that allow them to achieve a practical understanding of lean processes, which, in turn, makes them more employable. Furthermore, students utilize their experience from such real-world lean projects to further implement lean changes in their future workplaces, many of which tend to be in the State of Iowa. This curriculum echoes statements from literature about hands-on, team-based projects as a key learning strategy, which has been effectively used in different disciplines to enhance student understanding of integral theories and principles[3]. This project-focused manufacturing curriculum[4] provides students with the experience of integrating technical knowledge they have learned from various subjects.

The organization of this paper is as follows: This win-win-win lean/sigma curriculum model will be demonstrated in the next session, followed by a case study of a lean project conducted in a local industry with it processes and outcomes. Finally, conclusions and discussions of future curriculum improvement strategies will be presented.

2. The proposed Lean Curriculum at ISU

This three-credit lean course, consisting of a weekly two-hour lecture and two-hour lab (considering holidays and exam days), will be restructured into two major sessions:

1) 32 hours of lecture and lab activities for learning lean tools and principles

2) 22 hours working as a lean team (5 or 6 students each) at a local manufacturing company located less than 50 miles from campus, thus enabling students to conduct an onsite full- or half-day project.

The final result is an end-of-the-semester lean presentation given by the team to the industrial mentors. It is hoped that the students will not only learn from their own lean experiences, but also from the projects of other teams' projects working in different manufacturing settings. The project outcomes and recommendations will be provided to industrial mentors for their future development needs.

It is challenging for any instructor to teach a three-credit course of 60 contact hours consisting of theory and practical, hands-on experience, Although this curriculum was just only recently implemented, it is the author's belief that there is room for continuous improvement; it is also his hope that by sharing the curriculum in this paper, more lean leaders will be educated to address future global competition in U.S. manufacturing.

2.1 Lean lecture and lab activities

The lean lectures and lab activities are broken into 4 sessions, they are as follows:

- Session 1: Ten hours of Lean 101 training
- Session 2: Six-hour hands-on training of Value Stream Mapping (VSM) training
- Session 3: Eight hours of one-piece flow, pull/kanban techniques, and river-rock theory
- Session 4: Eight hours of Cost justification and effectiveness presentation

Session 1: Ten hours of Lean 101 training

A Lean 101 training kit[8] has been available through CIRAS and the Manufacturing Extension Program (MEP) for use by Iowa industry. Various Iowa community colleges provide training to companies through a partnership with CIRAS. The one day workshop is a hands-on simulation to help attendees learn how to use lean tools to optimize production (see Figure 1). The kit, which "creates" a small electronic factory, begins with a transitional manufacturing process with very poor communication between workers and very poor layout design. Through four different rounds, with a few lean tools implemented each round, the students, as a team, gradually transform the manufacturing system into a clean and neat work environment. The company is transformed into a profitable, efficient operation that creates more jobs yielding a high quality product and 100% on time delivery. The training kit allows students to reconfirm their understanding of the Lean principle and concepts by working with an effective simulation.

Since the students enrolling in this class have two contacts per week and two hours per contact, the eight-hour tool kit training has been divided into four segments. During each contact, students will work on one round of lean training in which a new set of lean tools are introduced and utilized to improve the live simulated factory. During each contact, each student is required to review lecture notes and a textbook for on-line assessment to ensure that lean knowledge is gained to the individual level.

Further, this lean 101 kit is utilized to show students how rabbit chasing and Toyota sewing systems[1] work in assembly systems.

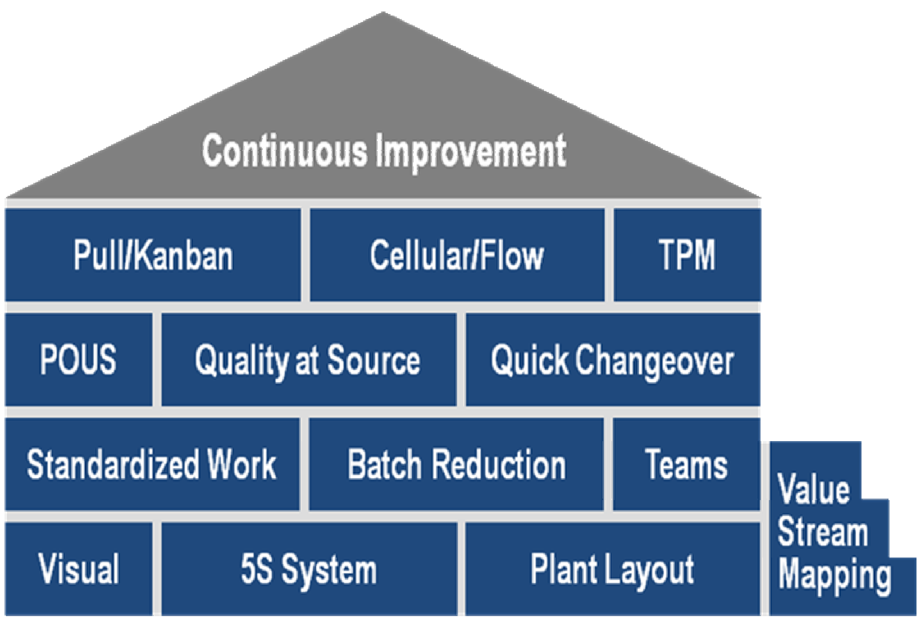

Figure 1. Lean Building Blocks Suggested in Lean 101[8]

Session 2: Six-hour hands-on training of Value Stream Mapping (VSM) training

As shown in Figure 1, Value Stream Mapping or VSM are the "stairs" leading into the lean house. In order to implement the lean tools, one needs to understand that the VSM tool enables us to "see" how the process flows through the entire manufacturing system. After VSM training, student teams (5 or 6 per team) travel to pre-arranged industrial sites to conduct their first industrial VSM. Each team is expected to finish a draft VSM with industrial members (engineer or team leaders) before the leaving the company.

The lecture will continue for students to learn how to conduct a future VSM mapping by answering eight questions (Table 1). One hands-on example is introduced before the team begins working on its industrial project. The outcome of this session is to identify a couple of key Kaizen projects in order to move the existing manufacturing system to the future proposed system shown in their proposed future mapping. Once the team proposes their current and future VSMs and Kaizen ideas, it makes a second visit to the industrial site for two major reasons: (1) to confirm all data and all proposed information; and (2) to discuss their key kaizen event with industrial mentor's expectation to at least eliminate or reduce 3 mudas in their review.

Table 1. Eight Key Questions for Developing a Future State Value Stream Map

1.	What is the takt time?
2.	Will we build to a finished goods supermarket, or directly to shipping?
3.	Where can we use continuous flow processing?
4.	Where will we need to use supermarket pull systems to control production of upstream processes?
5.	At what single point in the production chain (i.e., the "pacemaker process") will we schedule production?
6.	How will we level the production mix at the pacemaker process?
7.	What increment of work will we consistently release and take away at the pacemaker process?
8.	What process improvements will be necessary for the value stream to flow as specified by our future-state design?

Session 3: Eight hours of one-piece flow, pull/kanban[5] techniques, and river-rock theory[6]

Many local companies, particularly small Iowa manufacturers are still considered traditional companies that start with manufacturing, regardless of the requirements of a given product, and then "pushes" on to the next process. The "next process" can be another internal step or the selling of finished products to the customer. The consequence of this system is often over production because production is carried out without an actual request for the product. Over production causes higher inventory levels, which ties up cash flow and reduces the competitiveness of any manufacturing system. The opposite if this "push" system is lean manufacturing, which is based on "pull" strategies. In a pull system, the manufacturing system produces its products based solely on consumer demand. This control strategy reduces over production, consequently reducing inventory and other problems in a manufacturing system because only the required amount of product is produced. Such a manufacturing system is very responsive to customer requirements, whether the customers are internal or external. Enabling students to design a manufacturing system with such flexibility and controllability often requires them to learn about kanban systems, so they are taught how to design kanban cards and how to implement a kanban system[5]. It is often discussed in the classroom that a manufacturing engineer should be able to design a manufacturing systems that allows all decisions to be performed by the workers in the system, however, only one decision could be made, and it is never a wrong decision.

Session 4: Eight hours of Cost justification and effectiveness presentation

The bottom line for lean projects in any organization is to strengthen profits. Therefore, unless the project leads to reduced costs and an overall increase in profits, the lean project is considered a failure. Because there are very few students enrolling in this course that have adequate manufacturing economics training, a series of cost justification concepts is included in this course so that students can show the impact of their lean recommendations in their final presentations.

3. Four-stage Industrial Lean/Sigma project

Conducting a lean project from value stream mapping to completing a kaizen event for improving the system is not a one-person job. It is a team effort. The aforementioned lectures and lab activities provide information about lean tools and principles but they are not as effective without real-world training. One of the key objectives of such a curriculum is not to just provide students with knowledge of lean words and concepts but also to enable them to become leaders and to use lean tools to conduct projects and further to be able to help employees and managers understand that the "push" manufacturing strategy is not always the best strategy.

Most of the industrial lean projects involve shop workers because they know the flaws in the process since they work with it every day. Each worker has important knowledge pertaining to their area; however, it requires a good leader to be able to extract that information and guide the workers towards a common goal. Leaders also need to be able to separate useful and relevant information from bad information. Therefore, the key objective of this lean project is to ensure that every student has a chance to lead the team and acquire those skills.

The industrial project has been constructed with four stages, allowing different team members to rotate into leadership positions each stage. This may mean that each team, in order to accommodate project of different scales, may have a different schedule (see Figure 2). At the end of each stage, each team submits its work for review, allowing feedback for improvement and adjustment as needed. Through such a process, team members and leaders learn based on the nature of each industrial project. Such robust learning is very effective, yet time consuming. The requirements of each stage have been suggested to the students in such a manner that they do not to limit students' creativity into their recommendations for their industrial problems.

The following case study will provide detailed information of how such a lean project has been conducted. This case is one of the five team projects conducted in Spring 2007.

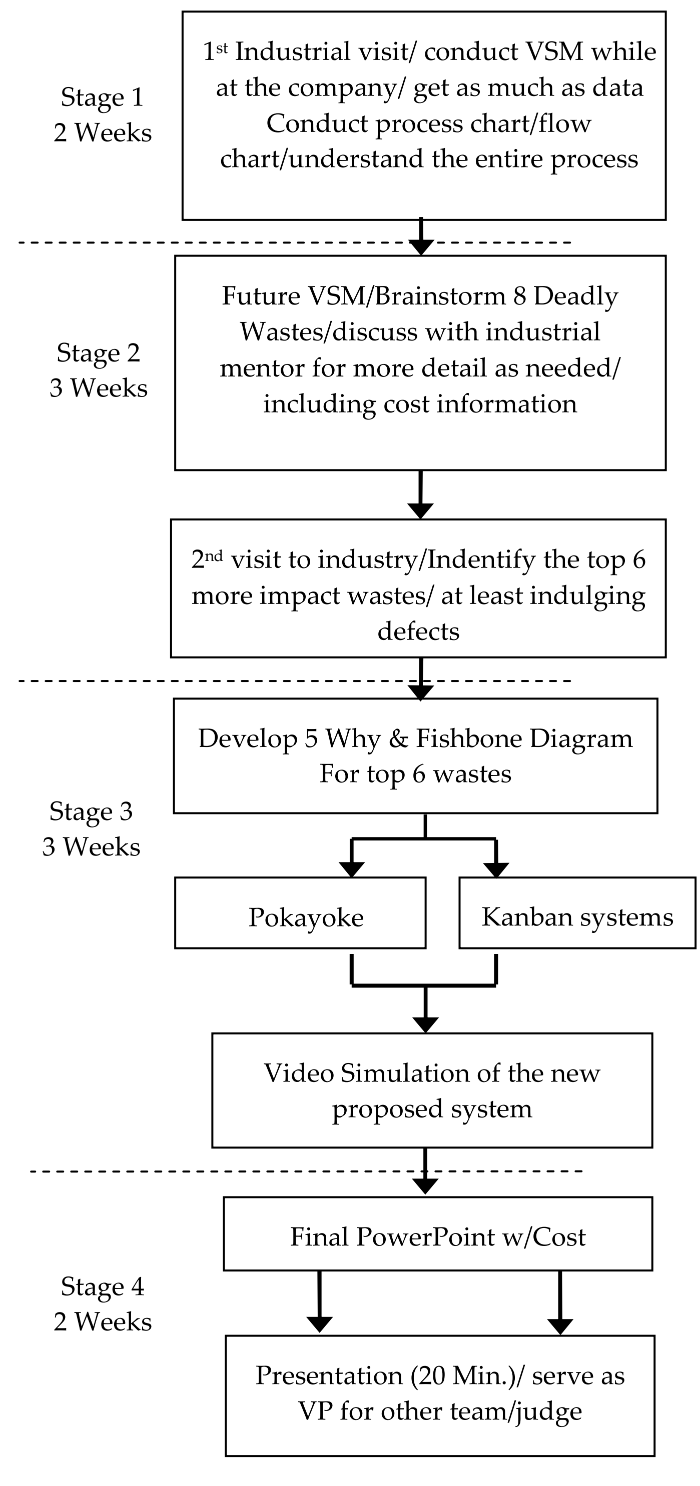

Figure 2. Four Stages of Industrial Lean Projects

3.1 Overview of Lean/Sigma Industrial Project

Company K is a small-sized, Midwest manufacturer. The major products of company K are industrial switchgears and switchboards and customers range from general contractors and industrial facilities, to large commercial power plants. Through interaction with the manager and engineers, Company K expressed interest in transforming its facility using Lean/Sigma strategy with the goal towards performance improvement. A Lean/Sigma team is therefore formed consisting of four students and the instructor of the course on ISU side, plus one plasma operator and one manufacturing manager on company K side. The outcome of the project is summarized in the preceding section.

To ensure that students have the appropriate information to complex each stage of the project, it is divided into the following four stages:

1) Stage 1: Process at a Glance and Current VSM
2) Stage 2: Future VSM and Kaizen events
3) Stage 3: Kaizen events via 5 Whys or fishbone diagram analysis
4) Stage 4: Show cases and learning from other teams

Stage 1: Process at a Glance and Current VSM

During the first visit, the Lean/Sigma student team walked with the manufacturing manager along the paths of material and information flows in the production facility of company K. This activity allowed the student team to collect information on the current status of the manufacturing system. Table 2 shows the detailed process time and roughly uptime for each process in a sequential order, from the first process to the last one when it is ready to be shipped.

Table 2. Process Time Details

Process		Process Time (unit: minute)	Change Over(C/O) (unit: minute)	Uptime (as percent)	# of workers
Fabrication area	Shearing	5	0	100	1
	Plasma Cutting	47	5	90	
	De-Burring	15	0	100	
	Braking	22.5	30	100	
Welding area	Cutting	15	0	100	2
	Welding	235	0	100	
Finishing area	De-Burring	45	0	100	1
	Washing	20	0	100	
	Drying	5	0	100	
	Painting	20	0	100	
	Baking	30	0	100	
Assembling		480	0	100	4
Wiring		2400 (5 days)	0	100	20

Based on the collected information and given facility layout of company K, the student team was able to generate a flow chart to have a clearer, more visualized understanding of each process. The flow chart also presented locations of the processes and relative distances between them. Upon obtaining all of this information and reflecting on the current status, the student team immediately started to work with the operator and manager in on a value stream map. The reason of a creating current value stream map with the presence of company staff right after collecting data is to make sure the current map represents the current status of company K to the best extent. Any error or omission of important data at this stage will lead to failure or re-work of later lean activity. The current value stream map is shown in Figure 3. It is clear that the entire production system is based on a push control strategy. There are areas on the current VSM that take long periods of time and add no value to the product. The total lead time in the company K facility is about 25 days with total processing time equaling 3398.5 min.

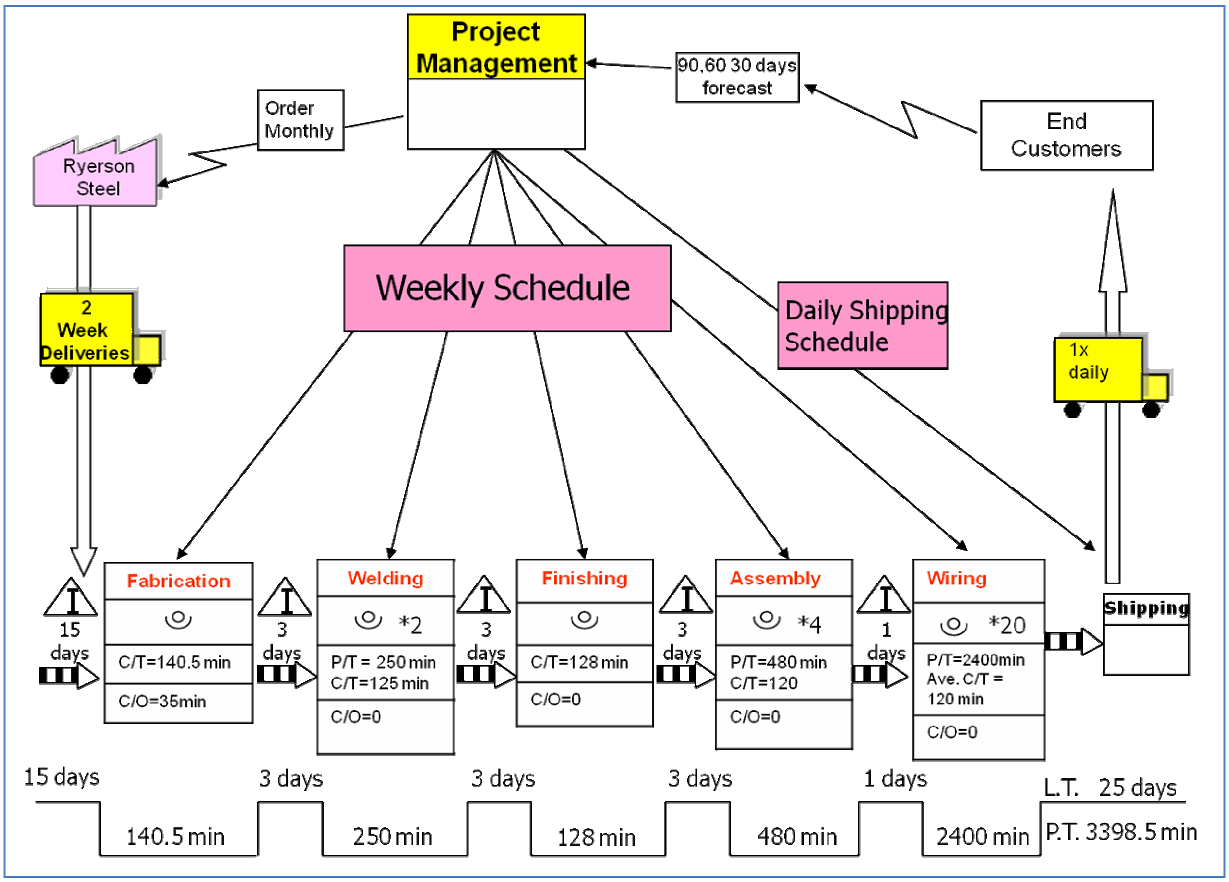

Figure 3. Current Value Stream Map

Stage 2: Future VSM and Kaizen events

Given information presented on the current map, the Lean/Sigma team is able to discover areas where improvement can be made through critically observing the operation status of Company K with the help of lean principles. By answering the eight questions in Table 1, the team and industrial mentor are then able to propose a future VSM (Figure 4) as a guide for future lean projects.

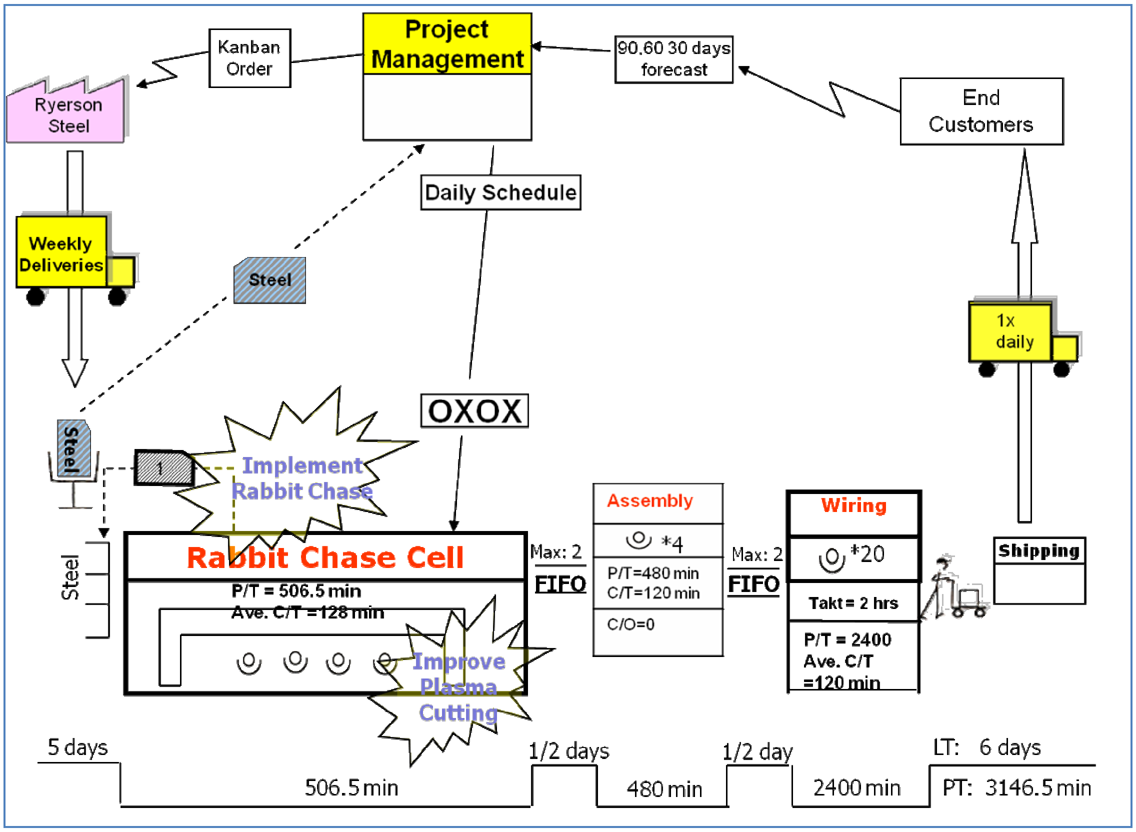

Figure 4. Future Value Stream Mapping and the Light Bursts for Kaizen

The team then brainstormed and identified a list of wastes in considering the seven "deadly" wastes mentioned in the beginning of the paper. The top three have been identified by the team. In order to move the system closer to the one proposed in the future VSM, these wastes must first be reduced or eliminated. They are:

1. **Defect** – The plasma cutting machine generated a high rate of defects, which requires operator to spend extra non-value added time to rework the products.
2. **Waiting Time** – Due to the delay or defects occurred from the plasma machine, the welders sometimes have idle time while waiting for the products from the fabrication area.
3. **Inventory** – The two welders are the only skilled welders in the shop, inventory level between fabrication and welding will build up if one or both of them on vacation or sick leave.

Based on these three key wastes, the team discussed and defined two immediate Kaizen events for eliminating or reducing these wastes, as is indicated with Kaizen light bursts shown in Figure 4. These two Kaizen events are hoped to bring company K production section closer to its future goals. In order to assist in implementing the Kaizen events, the Lean/Sigma team brainstormed using the five "whys" method for identifying the root cause of these wastes in the current existing manufacturing system.

Stage 3: Kaizen events via 5 Whys or fishbone diagram analysis

Kaizen Event 1: Reducing waiting time and defects at plasma machine

By asking why five times, the team is able to find the root cause and move to any necessary kaizen activities.

1) **Why is there waiting time?**
   The cycle times are different: 140.5 minutes in fabrication, 250 minutes in welding and 128 minutes in finishing. The fabrication stage is the bottle neck.
2) **Why is the fabrication stage a bottle neck?**
   Cycle time of the plasma cutter is 42 minutes, which creates production delays.
3) **Why is the cycle time of the plasma cutter 42 minutes?**
   The plasma cutter creates defects that need rework. Additional inspection time is needed to find the defects.
4) **Why does the plasma cutter create defects?**
   The plasma cutter is an old machine and is not working at an optimal parameter setting.
5) **Why does the plasma cutter not work at the optimal parameter setting?**
   The optimal parameter setting is not available so the machine settings are based on the programmer's experience, which might be limited. Due to the age of the machine, the optimal setting should be revisited.

After performing the 5 Whys activities, the team proposed to conduct a Design of Experiment (DOE) to identify the optimal plasma machine settings. The capability of the plasma cutter to meet the customers' quality demands will be evaluated after implementation of the findings.

The team set up a DOE in reviewing the four controllable factors of the plasma machine. They are (1) the size of the tip; (2) feed rate of the movement; (3) voltage of the machine; (4) amperage of the controller. The experiments covered three different levels of each factor. After the DOE experiments and data analysis, the team identified the optimal setting of the machine as: (1) smaller size of the plasma tip; (2) 93 in/min feed rate; (3) a voltage of 100V; and (4) an amperage of 63A. Tests confirmed that the defect rate was reduced significantly after running at the optimal settings. Consequently, the time to rework was reduced and the entire fabrication cycle time was reduced from 140.5 min to 120 min.

Kaizen Event 2: Reducing inventory waste

The team again brainstormed using the 5 why method to find the root cause of high inventories. The 5 Whys procedure is documented below.

1) **Why is there a lot of inventory between the fabrication and welding areas?**
   Inventory buildup occurs whenever welding operation delays occur.
2) **Why might weld operations be delayed?**

Two welding operators share the load. If one of them is absent because of illness or other reason, the welding operation is delayed. There is no substitution in the company when this incident occurs.

3) **Why is there no substitution?**

   Only two operators are trained to weld and skilled welders are a very limited resource in the Midwest.

4) **Why are other operators not trained welders?**

   Welding requires higher skills. There is no cross training for other operators.

5) **Why is there no cross training?**

   The company does not have a system to cross train workers. .

In addition to changing the current push control strategy, the team realizes there is a need to redesign the manufacturing system. These changes will also mandate that employees in control production, quality, inventory, and process be cross trained. It was suggested that a rabbit chasing system be implemented where one worker takes raw material from the first station and works until the part is finished and then starts over at the 1^{st} station. The process times for fabrication, welding, and finishing areas are 128 min, 250 min, and 128 min respectively. Since there are two welder stations the welding process time is about 125 minutes. Thus the three areas are much better balanced.

The full process starts with worker A starting a new job by first going to the kanban board and gathering the necessary information for the new job. The worker then gathers the required raw materials for the switchboard. The worker goes to the fabrication area and completes the fabrication operation, which requires about 128 minutes. The worker then moves the parts from fabrication to the welding area and welds them together in about 250 minutes. The worker moves the welded parts to the finishing area to complete finishing operations, which requires about 128 minutes. The product then moves to a drying area, is fully inspected, and goes to assembly. Worker A goes back to the kanban post to pick up the necessary information for a new job and the cycle starts over. If the kanban post is empty, it means the customer has not placed an order. The worker will not begin production so the company can avoid an overproduction situation. This kanban post has been suggested as a communication system between workers and the design engineer in case for a product change is needed.

The proposed rabbit chasing system has a few advantages:

(1) Every finished frame or switchboard is fully fabricated by one worker, thus quality problems from either manufacturing or design can be easily tracked.
(2) Each worker knows all the processes. If anyone is on vacation or ill the system can continue without many delays.
(3) The waiting time between fabrication, welding, and finishing areas are eliminated. Consequently, the inventory areas might be used for other manufacturing functions. The plant layout could also be redesigned to have machines closer to one another to reduce moving and transportation time.
(4) The design of the switchboard may change due to a customer request. In this case, the project manager would only need to communicate with the one worker who is working on that particular order to resolve the issue in a timely manner.

In order to show how the rabbit chasing system functions, the team developed a training video (Figure 5) showing how a four-worker rabbit chasing system is conducted. The video is shown in the company presentation and a CD in included in the final report.

Figure 5. Rabbit Chase Video for Training Purposes

Stage 4: Showcases and learning from other teams

The industrial members are invited to attend the presentation conducted by the team working in the company, but also the projects from other companies. This provides an opportunity for students and attendees to learn more about different lean projects and outcomes. It is the authors' belief that watching other group's presentations enhances the students' knowledge of lean manufacturing.

When one team is presenting their lean project, another team is designated as the company Vice Presidents, referred to as the VP team. The VP team needs to review the presenting team's PowerPoint before their presentation and prepare VP-level questions based on their respective positions within the company. For example, the VP of Human resources will need to ask questions pertaining to human resources after. This helps the students think the way top managers might think, which is helpful when he or she conducts a lean presentation for their future employer. This VP team design approach is part of the system to help students take steps toward becoming lean leaders in the future.

After the presentations, each team revises their PowerPoint presentations based on suggestions and comments from the audience and the VP team. The entire presentation is videotaped and included on a CD consisting of all of the project files. This CD serves as an e-portfolio for students in their job search and provides a record for the industrial mentors to reference. Industrial mentors also receive a copy of the CD, including video of the proposed methodology, current and future value stream map, 7 deadly wastes, 5 why's for root causes of wastes, eliminations of the wastes, details of a kanban system, pokayoke devices for the system, and a cost justification of the lean implementation. It is the authors' hope to assist small companies in becoming more proficient in lean manufacturing processes, consequently making the companies more competitive in the global marketplace. This in turn will improve the economy for the state of Iowa.

In addition to team results, each student is required to submit an essay discussion about what he or she learned through the industrial projects. Everyone enrolled in the course stated that the lean project is the greatest way of learning lean concepts because you conduct a lean project in a real world setting. Some of the students' comments are shown below in Table 3.

Table 3. Comments from Students about the Industrial Project

1	The Lean project at Company K was very educational. It was beneficial to be working with a real company, dealing with real situations.
2	This exposure to industry has provided me with valuable information that has helped with the understanding of Lean tools.
3	If we were to sit in class and visualize this concept I do not think I would have gotten the whole picture. … Now, I have a better understanding of Lean.
4	The industrial project has taught me a great deal. …. We used many lean manufacturing methods and theories to come up with the best possible solution to manufacturing problems.
5	(The industrial lean project) really reinforces what we learned in class plus it gives us a chance to propose ideas that a company wouldn't normally consider. I absolutely enjoyed working on the lean project with my teammates at Company K, we spent countless hours outside of class working on the project and proposing and debating several concepts.
6	I think the industrial project helps students learn much better than simple lectures and homework.
7	The kanban system is hard to explain on paper and once I finally got into an industrial shop and was shown how this worked, then I finally understood it.

4. Conclusions and Further Studies

The presented industrial-project driven lean curriculum provides a benefit to students' trying to become leaders in lean manufacturing because they are able to lead hands-on lean projects immediately. The project outcomes provide companies both short-term and long-term benefits from implementing lean concepts, often without a major investment.

Each year about 8-10 companies take advantage of resources provided by CIRAS, an engineering extension service unit at ISU. Through the partnership between the College of Engineering and CIRAS, more local companies are impacted each year by learning and implementing lean concepts. These companies are able to increase their productivity, increase the quality of their products, and increase on-time delivery to customers. This reduces the production cost and helps companies increase profits and market share. Although the success of the curriculum has been shared, the continuous improvement of the curriculum must be on-going so that the curriculum has better structure with more up-to-date lean practices, references, resources to assist with student learning.

Although the short-term impacts of this curriculum are evident to the stakeholders, one would be interested to see the long-term impacts. Thus, interviews will be conducted one year after completion of the projects with the participating companies and former students. This information will be analyzed and results disseminated.

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