AC 2007-709: A COLLABORATIVE CASE STUDY FOR TEACHING "ACHIEVING LEAN SYSTEM BENEFITS IN MANUFACTURING AND SUPPLY CHAINS" TO ENGINEERING MANAGEMENT STUDENTS

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A Collaborative Case Study for Teaching "Achieving Lean System Benefits in Manufacturing and Supply Chains" to Engineering Management Students

Abstract

With the ongoing global pressure of cost cutting and quality focus, many companies have been implementing "lean manufacturing" concepts to survive in this competitive marketplace. "Lean" concepts have found their place in manufacturing and service industries; an important key to eliminating waste and delivering value to the customers. Thus, it is imperative that engineering management graduates are equipped with the lean principles and be ready to take ownership of lean initiatives as they transition to the industry.

This paper presents a lean supply chain case study for a bicycle manufacturing company; created in an effort to expose students to a real life lean implementation experience. The project was initiated and completed with collaborations from the academia and the industry. The case study introduces four scenarios related to Forecasting, Inventory Control, Product Design issues and Manufacturing constraints. The scenarios are based on actual global business challenges a Project Facilitator may encounter with a traditional business enterprise before the introduction to Lean Supply Chain Management and Lean Manufacturing. The paper summarizes the business challenges presented by the case study and discusses how the lean business scenarios were analyzed to develop effective solutions that deliver significant business benefits. The lean supply chain case study not only demonstrates that being "lean" requires going beyond the four walls of a manufacturing company, but also presents a good working model for university and industry integration in an effort to jointly develop qualified lean professionals.

1. Introduction

The word 'lean production' was first used by Krafcik[8] and then it was popularized with the works of Womack et al.[13] and Womack and Jones[14]. Many industry professionals and researchers agree that "Lean is doing more with less". Today, lean production strategies are not optional for companies anymore but rather a must-do to survive in the global economy. Initially recognized by Toyota (thus also referred as the Toyota Production System), "lean production" has become more and more popular in the US, starting with the automotive industry[13] but propagating into every industry sector, including services.

In order to have a smooth transition to the industry and confront the industry challenges, graduates from engineering and business schools need to be well trained in "lean" concepts. More and more programs are recognizing this need, and including courses on "lean" into their curriculum[1,4,5,6,7,10,11,12].

Production Principles and Strategies such as "lean" can be taught using some of the traditional approaches such as industry projects, case studies, computer simulations, class projects, and company visits to name a few. Ormrod[9] describes a discovery learning approach which can be helpful as well, where he defines discovery learning as "an approach to instruction through which students interact with their environment-by exploring and manipulating objects, wrestling with questions and controversies, or performing experiments". Bonwell and Eison[2] emphasize the importance of active learning (as opposed to passive learning) where the students "are doing things and thinking about what they are doing". One way of active learning is "simulating the real experience", which is the foundation of Dale's[3] "Cone of Learning", resulting in best memory recollection among other learning activities.

While industry projects can be considered as one of the most effective means to learn the lean concepts with hands-on experience, it can be quite challenging to identify a sponsoring company and to scope a project that fits within a semester's timeframe. Given some of the uncertainties with respect to the scope, it may also be challenging to find students for the project teams as well. Case studies may work well when analyzed in sufficient detail. Since many existing case studies are aimed to provide a descriptive analysis and strategic evaluation of a business, they would not necessarily provide the hands-on experience to the students. Computer simulations help analyzing dynamics of a business problem under uncertainties, but the potential danger is having these simulations becoming a "black-box" or "magic" model, not revealing the physical aspects of the problem. In order to combine some of the strengths of these aforementioned approaches, we developed a manual simulation case study in collaboration with the industry experts. The case study mimics a realistic business that is facing the typical challenges in the industry. It is implemented as a semester-long project to provide students several business scenarios, which they need to analyze through analytical and computational lean techniques.

The rest of the paper is organized as follows: after describing the case study, we will present and analyze the results. Then we will discuss classroom implementation challenges, and finalize with a summary and conclusions.

2. Lean Case Study: Ral-Lee Inc.

The case study that is named "Ral-Lee Inc., A Lean Enterprise Simulation Exercise" includes a case description, solutions report, associated solution files and a presentation. The case study emphasizes the following major lean thinking objectives:

- Lean principles need to be implemented beyond the four walls of a company across its supply chain.
- In order to improve the supply chain and manufacturing operations, one needs to identify and manage the system constraints.
- Collaboration with suppliers and customers early in the product design cycle can have drastic impact on company performance.
- Listen to the voice of the customer
- Understand that speed in supply chains and manufacturing operations is utmost importance for making companies successful.
- Get familiar with lean terminology and learn strategies that can help companies to become leaner.

Next, we will provide a brief description of the case and present some of the analysis that can be done by the project teams, and discuss results.

2.1 Case Description

This case study is about a bicycle manufacturing company named Ral-Lee Inc. that has been recently acquired by a major part supplier KingCorp Inc.. Ral-Lee was owned by a very traditional family that applied only classical business methods. The main products are standard single and multi-speed bicycles, welded and assembled in Charlotte, NC, with components coming from Ral-Lee's own component manufacturing plants in Detroit, MI, Juarez Mexico and Shanghai, China, as well from other suppliers located in Taiwan, China, Japan, and Mexico (Figure 1). Ral-Lee produces about 220,000 bikes per year and has annual sales of $44 Million to various customers including Walmart, Sears, K-Mart. They supply bikes from three regional warehouses in Charlotte, NC, El Paso, TX, and Detroit, MI. Table 1 provides the current throughput, lead time, inventory, and transportation cost information for different Ral-Lee facilities.

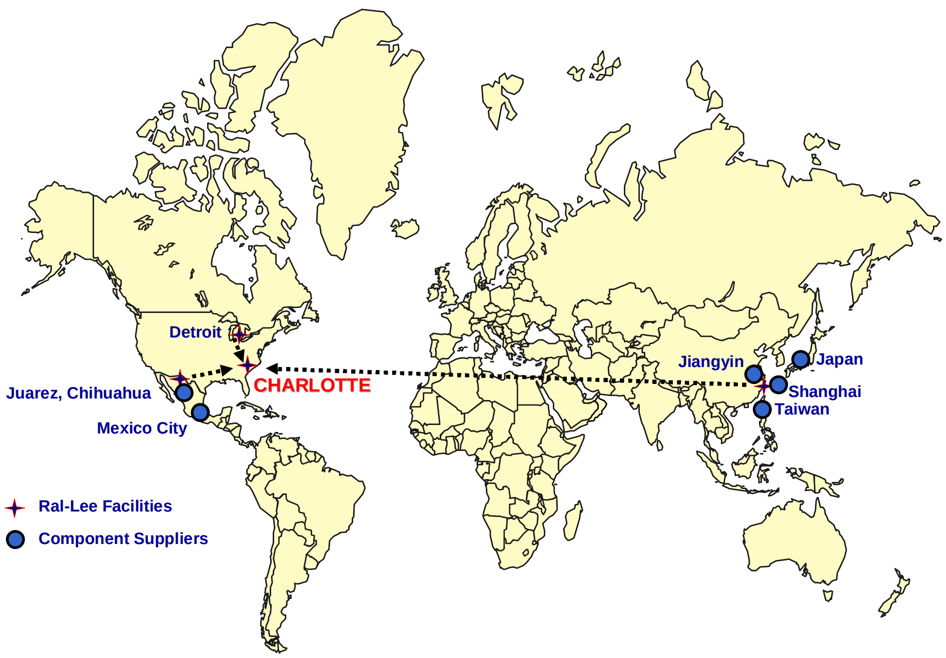


Figure 1. Ral-Lee's Supply Chain

Throughout the case, Ral-Lee faces several challenges which are presented to the students in four different scenarios:

- Scenario 1: Exploiting Capabilities for Growth
- Scenario 2: Product Development Process Optimization
- Scenario 3. Introducing a New Product Line
- Scenario 4. Production Line Optimization

Location Code	Current Through-put per day	Max Through put per day	Order Lead Time (days)	Avg. Pipeline Inventory (units)	Avg. Pipeline Inventory (months)	Avg. Pipeline Inventory ($)	Avg. Charlotte On-hand Inventory (months)	Trans-portation Time (days)	Transpor-tation Type (LTL, FTL, Sea)	Cost/ Unit ($)	Trans-portation Cost/Unit ($)
Charlotte	1,000	1,500	63								
R-M-M	250	500	45				1	5	FTL	$ 20.00	$ 7.00
R-M-P	250	500	45	45,000	2	$1,440,000	1	5	FTL	$ 5.00	$ 7.00
R-D-M	550	1,000	30				1	2	FTL	$ 40.00	$ 5.00
R-D-P	150	250	30	42,000	2	$2,310,000	1	2	FTL	$ 10.00	$ 5.00
R-C-M	200	250	60				1	30	LTL	$ 15.00	$ 10.00
R-C-P	600	1,000	60	96,000	2	$2,688,000	1	30	LTL	$ 3.00	$ 10.00

Table 1. Throughput, lead time, inventory, and transportation cost for Ral-Lee. Location codes use the first letter of company name (R: Ral-Lee), location (M: Mexico, D: Detroit, C: China) and product (M: Metal, P: Plastic) e.g. R-M-M : **R**al-Lee – **M**exico - **M**etal

Next, each of these business scenarios is briefly described.

Scenario 1: Exploiting Capabilities for Growth

Ral-Lee has been growing steadily over the past years, and is expecting that the growth trend will continue. The company has reached a point where the current supply chain capabilities are stretched to its limits to meet the sales volume. This is detected in the alarming increase in lead times and decrease in on-time delivery and order fill rate performance to retailers (Figure 2). While the management team is anticipating that sooner or later additional manufacturing and distribution capacity will be needed, the management feels that based on the theoretical capacities, the existing facilities are far from their true capabilities. Therefore, before going into a capacity expansion, Ral-Lee would like to see how the current capabilities can be exploited.

Figure 2. Performance Metrics of Ral-Lee over the past five years.

Scenario 2: Product Development Process Optimization

Ral-Lee has been suffering from long product development cycle times over the past years. As the market competition is increasing, major rivals of Ral-Lee are coming up with innovative bicycles in half the time using the latest technology. There have been occasions that company missed the critical product launch dates to capitalize on holiday season sales and those products that were on time, came short of expected sales resulting in losses. Current practice is building-to-stock (BTS) based on demand forecasts but the company would like to evaluate other business strategies to deal with uncertain demand on especially high-end innovative bikes.

Scenario 3. Introducing a New Product Line

The main product is a very standard 10-speed bicycle, welded and assembled in Charlotte, NC with components from US, China, and Mexico. This product has not been improved in many years in order to reduce costs. The financial statements show degrading profits caused by increasing manufacturing, distribution, and overhead costs, and reduced sales. Your responsibility is to review the product line, and expand the product line with a new bicycle selecting one of the two options (Chopper Bike and Racing Bike) as shown in Figure 3.

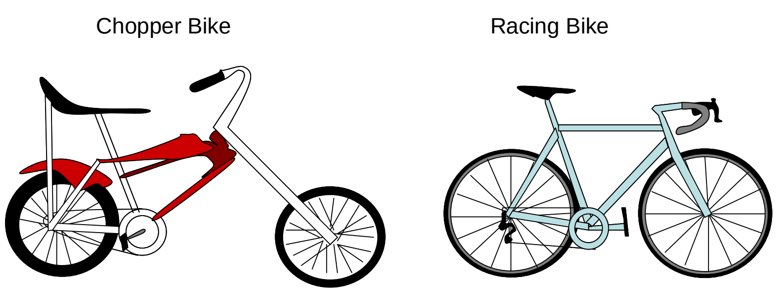


Figure 3. Product line options

Scenario 4. Production Line Optimization

You have visited the bicycle manufacturing operations in Charlotte (Figure 4) to start the production planning for you new product and found a very traditional departmental system with large work-in-process (WIP) queues and long lead times. This plant's primary function is to produce frames and forks, and to assemble with outsourced components, creating a completed and boxed bicycle. There are no formal instructions or communication systems for managing the operations. All personnel work at their own rate and quality is suspect. Your responsibility is to transform the operation into a Lean flow system using all the Lean concepts that apply.

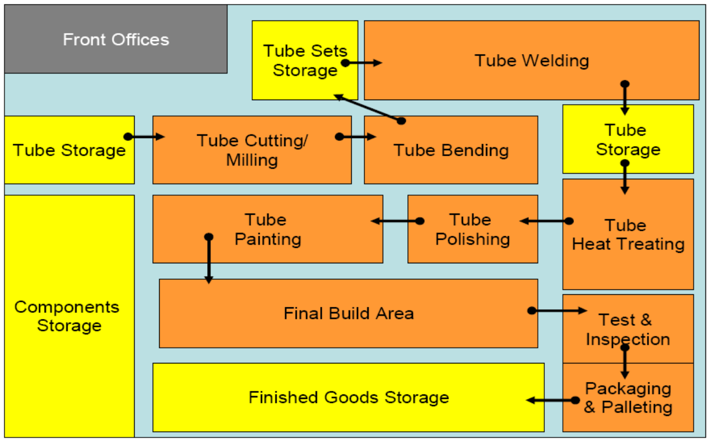


Figure 4. Ral-Lee Charlotte assembly plant layout.

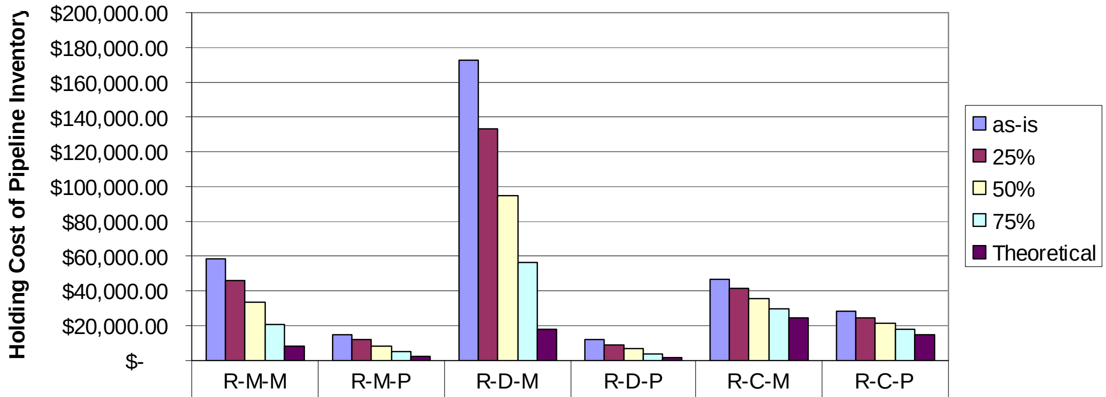
2.2 Case Analysis

The following are typical outcomes derived analyzing Ral-Lee's business scenarios:

Scenario 1: Exploiting Capabilities for Growth

In order to exploit the capabilities for Ral-Lee's growth, one of the first things students would want to do is forecasting the expected sales based on the historical data using different techniques. A quick analysis will indicate that Ral-Lee could target approximately $47 M in sales over the next year. Unfortunately, simply targeting growth will only fuel Ral-lee's ongoing problems as shown by several key performance indicators (Figure 2). Therefore the students will need to find a way to identify and fix Ral-Lee's operational deficiencies first perhaps by asking what part of the supply chain should Ral-Lee focus on to solve these operational deficiencies first. Based on Table 2, except for China Metal, the other facilities and products have low utilizations, with lowest at the Mexico plant. It seems that Ral-Lee has more capacity than needed to run the business but this capacity does not seem to be correctly managed as it happens in many companies. In addition analysis of lead times indicates that significant opportunity to reduce lead times exist especially in Americas.

Finally, one can recommend analyzing the inventory policy that dictates the pipeline inventory in the upstream of the supply chain. One can analyze here several inventory policies. For example, a two-bin procurement Kanban implementation (shown in Figure 5) indicates that 48-90% inventory reduction can be achieved. Similar analysis for a continuous review policy (not shown) indicates 28-70% inventory reduction.



	R-M-M	R-M-P	R-D-M	R-D-P	R-C-M	R-C-P
as-is	$58,649.18	$14,662.29	$172,254.5	$11,744.63	$46,889.63	$28,133.78
25%	$45,973.95	$11,493.49	$133,643.0	$9,112.03	$41,234.58	$24,740.75
50%	$33,298.56	$8,324.64	$95,030.29	$6,479.34	$35,579.51	$21,347.71
75%	$20,622.69	$5,155.67	$56,413.89	$3,846.40	$29,924.42	$17,954.65
Theoretical	$7,944.22	$1,986.06	$17,772.61	$1,211.77	$24,269.29	$14,561.57

Location

Figure 5. Inventory Reduction through Procurement Kanban implementation.

Scenario 2: Product Development Process Optimization

In this part of the analysis, the students can apply several techniques and strategies such as quality function deployment (QFD), Collaborative Planning, Forecasting and Replenishment (CPFR) and build-to-order (BTO). QFD should improve the customer requirements gathering process. Similarly, CPFR should improve the demand forecasting process, and BTO should enable the company to differentiate the products later in the supply chain thus making Ral-Lee more flexible and responsive to changing market demand.

Finally, a value stream mapping analysis for the overall product development process can be done to understand the root-causes of long time-to-market and disconnect between different units within and outside of Ral-Lee's organization (Figure 6). It is estimated that a 40% reduction in product development lead time is possible when a collaborative process is implemented including suppliers and customers. The end result is not only a shorter time-to-market but also improved product quality, minimized shortages and excess inventories, increase in profits and market share.

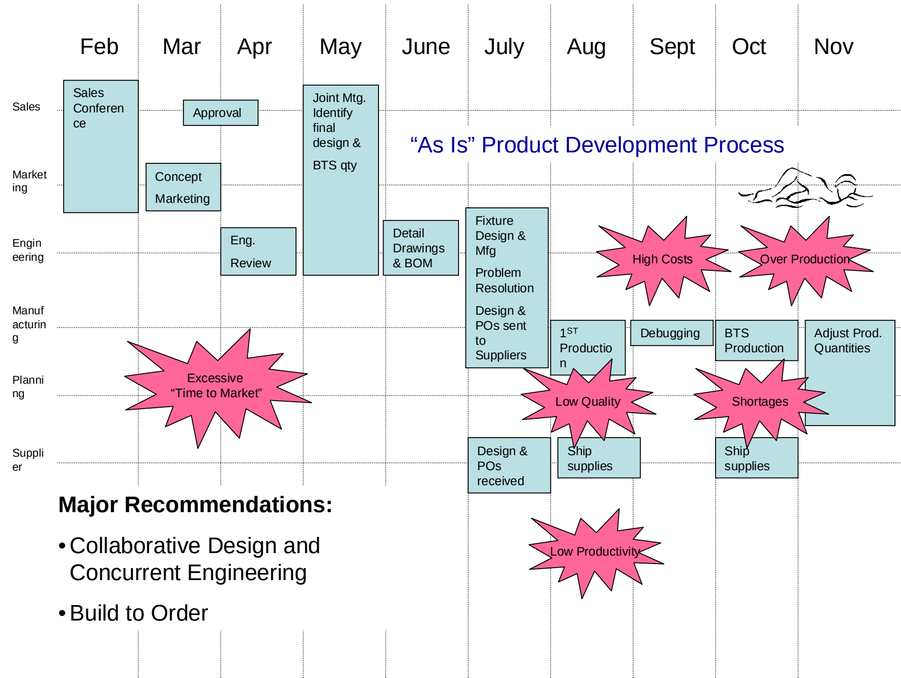


Figure 6. "As Is" Product Development Process

Scenario 3. Introducing a New Product Line

In this scenario, the analysis focuses on selecting one of the two bike type (Chopper Bike and Racing Bike as shown in Figure 3) for Ral-Lee's new production line. To make a decision, one can perform a cost-profit analysis as shown in Table 3 for the Racing Bike. A similar analysis (not shown) indicates that the Chopper Bike would not be a profitable option, thus making the decision fairly straightforward in favor of the Racing Bike.

				unit cost			cost per bike		
No	Component Name	Type of Material	Quantity per bike	min	avg	max	min	avg	max
1	Wheel	Metal	2	$ 15.00	$ 30.00	$ 40.00	$ 30.00	$ 60.00	$ 80.00
2	Deraillers	Metal	1	$ 55.00	$ 55.00	$ 55.00	$ 55.00	$ 55.00	$ 55.00
3	Chain	Metal	1	$ 5.00	$ 5.00	$ 5.00	$ 5.00	$ 5.00	$ 5.00
4	Spoke	Plastic	2	$ 30.00	$ 32.50	$ 35.00	$ 60.00	$ 65.00	$ 70.00
5	Reflectors	Plastic	1	$ 3.00	$ 4.55	$ 10.00	$ 3.00	$ 4.55	$ 10.00
6	Foot Pedal	Metal	1	$ 15.00	$ 30.00	$ 40.00	$ 15.00	$ 30.00	$ 40.00
7	Handlebar	Metal	1	$ 15.00	$ 30.00	$ 40.00	$ 15.00	$ 30.00	$ 40.00
8	Brakes	Metal	2	$ 18.00	$ 18.00	$ 18.00	$ 36.00	$ 36.00	$ 36.00
9	Seat	Plastic	1	$ 3.00	$ 4.55	$ 10.00	$ 3.00	$ 4.55	$ 10.00
10	Handle Grip	Plastic	2	$ 3.00	$ 4.55	$ 10.00	$ 6.00	$ 9.10	$ 20.00
11	Tires	Plastic	2	$ 10.00	$ 12.50	$ 15.00	$ 20.00	$ 25.00	$ 30.00
12	Cables	Metal	2	$ 14.00	$ 14.00	$ 14.00	$ 28.00	$ 28.00	$ 28.00
13	Shocks	Metal	1	$ 20.00	$ 20.00	$ 20.00	$ 20.00	$ 20.00	$ 20.00
						Total cost	$ 296.00	$ 372.20	$ 444.00
	revenue per bike	$ 500.00				**Expected profit per bike**	**$ 204.00**	**$ 127.80**	**$ 56.00**

Table 3. Cost-Profit Analysis for Racing Bike

As mentioned in the previous scenario, Ral-Lee needs to deploy the QFD process to understand what the customer's expectations are. Students can conduct QFD by surveying other students on campus. This analysis would reveal the priority on the final design requirements as shown in Figures 7.

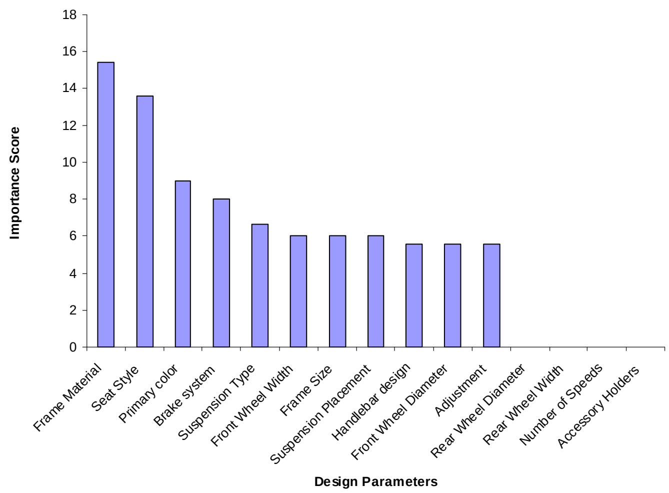


Figure 7. Pareto chart for design requirements for the Racing Bike.

Scenario 4. Production Line Optimization

This scenario requires detailed analysis and optimization of the manufacturing processes in the Charlotte assembly plant. The assembly process has nine stages: 1. Tube cutting, 2. Tube Bending, 3. Tube welding, 4. Heat Treatment, 5. Tube Polishing, 6. Tube Painting, 7. Final Assembly, 8. Final Inspection, 9. Pack & Pallet. Some considerations for improvement in each area can be reduction in setup and rework, additional shift, adjustment in material transfer batches, implementation of a Kanban system, dedicated material handler (also referred as the Water Spider), cross-training of staff and layout changes.

Based on the analysis, it turns out that Tube Welding process is the assembly plant's bottleneck with current throughput of 205 units per day compared to the daily target of 400 units. Throughput improvement results shown in Figures 8 indicate that setup reduction in this process will yield significant increase in throughput. An additional shift can be a solution in the short terms to achieve throughput targets. It can be seen that the throughput through the combined solution (when all solutions are implemented simultaneously) can be 972 units per day, which is promising for future growth.

Implementation of a Kanban system is recommended, as it can reduce the inventory space between 25% and 98% depending on the area. This gained space should enable future growth with the addition of a new production line within the existing facility.

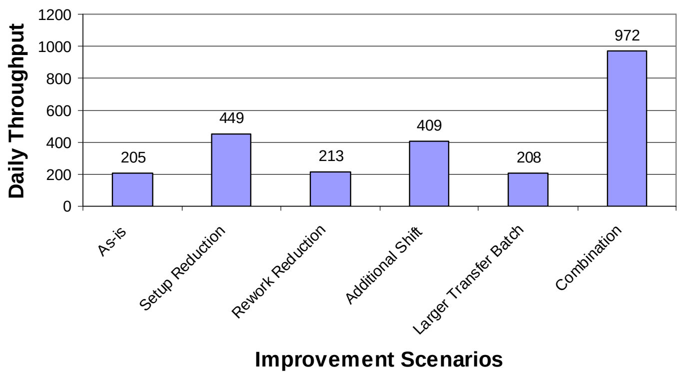


Figure 8. Tube Welding throughput analysis for different improvement options.

3. Classroom Implementation

The presented case study was developed during Fall of 2005 and was simultaneously implemented in the EMGT 6090 Lean Supply Networks course at the Engineering Management Program (http://www.coe.uncc.edu/mem) at the University of North Carolina at Charlotte (UNC Charlotte). A student team of two people was selected to work on the case study as part of their class project requirements. The student team was provided guidance throughout the semester from both industry and academic advisors who acted as a steering committee for the project.

3.1. Teaching Challenges and Suggestions

Based on our teaching of the lean case study, some of the major challenges and related suggestions can be listed as follows.

Building the right team: Based on our experience, it is suggested to have two to three people student teams. It is also recommended to have a steering committee including at least the course instructor acting as the academic advisor, and an industry advisor who has lean implementation experience, ideally as a lean project lead. There can be other academic advisors besides the course instructor as well as other industry advisors. Since in some cases it can be challenging to find the industry advisors, it is recommended to work with the local chapters of professional societies such as the American Society for Quality (ASQ), Institute for Industrial Engineers (IIE) and Society of Manufacturing Engineers (SME), and local companies to identify the right people. With the sponsorship from some of these professional societies, the end result can be presented by the project team in a local chapter meeting, which usually provides a good forum to bring together lean subject matter experts, and help to further cultivate fruitful discussions. Again, based on our experience, it is a good practice to complement these projects with site visits to companies that have been implementing lean. The benefit of visiting a business that is implementing lean manufacturing is that it helps put some of the concepts for the course into real-life context which strengthens the overall understanding and learning. In our case, we were fortunate to have all of the above, which made it a successful project.

Managing Scope: In order to keep the scope more manageable, the case can be focused on the analysis on the Ral-Lee owned assembly and component manufacturing plants. There are certainly additional analyses that can be done based on the discretion of the instructor. For example, one natural next step in the assembly plant analysis would be a detailed layout analysis to organize the manufacturing cells based on the opened up space. In addition, depending on the interest of the instructor, the analysis can involve more advanced inventory control, optimization, simulation, and decision analysis techniques.

Assignments of Scenarios: Although, the project management and assignment of tasks within the team can be left up to the students, the instructor can provide some guidance as well as follows: Since scenarios 1 and 4 are more involved compared to scenarios 2 and 3, one can assign scenarios 1 and 4 to different people. When working with teams of two, each student can select in addition one of the scenarios 2 and 3. With teams of three students, the third student can be assigned scenarios 2 and 3. As the number of students increases in the team, the depth of the analysis and deliverables can be increased.

Prerequisites: In order to complete the case study, the students need timely exposure to lean concepts. So it is very important for the instructor to schedule the related background within the course outline. An alternative implementation could be conducting the lean case study in an “Advanced Lean Implementation” course which can follow a traditional lean manufacturing or lean supply network courses. In our case, we followed the former approach embedding the lean case study as a course project within the EMGT 6090 Lean Supply Network course and sequencing the topics such that the student team is provided the right background timely.

3.2. Feedback

While we did not conduct separate evaluations for the lean case study, the course it was implemented in, EMGT 6090 Lean Supply Networks, received an average score of 4.5 out of 5. Based on the positive feedback and nomination from the students, industry and colleagues, this course received the 2006 IIE (Institute of Industrial Engineers) Lean Division’s Excellence in Teaching Award. It is clear that the Lean Supply Networks course includes many other adult learning features, but we believe that the lean case certainly was one of the important contributors to the overall success of this class.

4. Summary and Conclusions

In this study, we developed a new interactive case study that can be used in manufacturing and supply chain operations related classes to support teaching of lean concepts. The case emphasizes several important lean thinking objectives including elimination of waste, reduction of inventories, and increasing speed in supply chain and manufacturing operations. Future research can include creating extensions for the lean case study that can incorporate additional scenarios. We believe that as-is, the case study provides instructors a good basis to start and include their extensions without loss of generality.

Acknowledgments

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