International Journal of Advanced Research in Education and Society
e-ISSN: 2682-8138 | Vol. 3, No. 2, 138-144, 2021
http://myjms.mohe.gov.my/index.php/ijares

A Recent Senior Design Project of the Industrial and Management Systems Engineering Program at Kuwait University

Ali Allahverdi[1]

[1] Department of Industrial and Management Systems Engineering, College of Engineering and Petroleum, Kuwait University, P.O. Box 5969, Safat 13060, Kuwait

*Corresponding Author: ali.allahverdi@ku.edu.kw

Accepted: 15 July 2021 | Published: 1 August 2021

Abstract: *A senior design course is a part of the curriculum of most of the engineering programs worldwide since, in the course, the engineering students get the opportunity to identify, and next, to formulate, and finally to solve complex real-world engineering problems. This is also one of the seven student outcomes adopted by The Accreditation Board for Engineering and Technology (ABET). Therefore, it is also a required course in the curriculum of the Industrial and Management Systems Engineering (IMSE) program of Kuwait University (KU). The students, in the senior design course of IMSE program at KU, select a company and then identify some problems at the company. Next, the students formulate the identified problems and propose solutions for the problems. In this paper, the company selected in Spring 2020 is briefly described along with three identified problems. Next, the student proposed solutions are described along with annual saving by the proposed solutions. The students improved the operations of the selected company significantly. In fact, the analysis indicates that the company can save about $ 500,000 per year if the proposed solutions are implemented. The students were observed to be enthusiastic by applying the methodologies and tools of Industrial Engineering that they learned in their earlier courses to solve real life problems. The evaluation results from the employer surveys of the senior design students for the last few years indicate that the average result of the ABET outcome, of having an ability to identify, formulate, and solve complex engineering problems, is above 80%.*

Keywords: Engineering education, Senior design course, industrial engineering, saving

1. Introduction

A Senior Design course, which is a part of the curriculum of the majority of the engineering programs in the world, offers the engineering students the chance to solve practical engineering problems. Todd et al. (1995) presented a survey of senior design courses in engineering problems throughout of USA. On the other hand, the practices of the papers related to senior design courses in engineering were studied by Dutson et al. (1997). The subject of design in engineering education was addressed by many researchers such as Mahmud et al. (2012), Storbel et al. (2013), Katz (2015), Odora (2015).

Nobes et al. (2010) considered the consequence of senior design project workload on student performance. It was reported by Nobes et al. (2010) that a student, on average, has workload of 15 hours/person/week, which may reach to 40. Gruenther et al. (2009) investigated the consequence of prior industry experience and teamwork in a senior design course. Moreover, Zou and Ko (2012) assessed the teamwork development process for senior design course. They

assessed the teamwork skills by both quantitative and qualitative methods. On the other hand, Cooper et al. (2013) provided a method of evaluating different senior design projects against common outcomes.

Shin et al. (2013) discussed the advantages of developing senior design course and internship in industry. They stated that it is easier to check each student progress during the senior design course, while it is not that easy to check the progress and status of students during the period of internship. They also stated that the students have the opportunity to develop their profession and the opportunity to work on real life problems during senior design course.

The senior design course description of the Industrial and Management Systems Engineering (IMSE) program of Kuwait University (KU) and its relation to the other courses in the program was defined by Savsar and Allahverdi (2008). The syllabus of the course is given in Appendix B. Furthermore, Allahverdi (2015a) presented the answer of four questions about the senior design course; how an organization is chosen? How a problem is identified? How the course outcomes map to the ABET student outcomes? And how the course is assessed. Furthermore, Allahverdi (2018, 2020) presented samples of senior projects of industrial engineering at Kuwait University. In the current paper, we present another company where students conducted their senior design projects. The students in the course are divided into three groups where each group selected a different problem to solve in the company. The objective of the paper is to show how the students solved real life problems.

2. The Selected Company

The selected company is a paper and plastic bags factory, which was established in 1973 with space of 350-meter squares. It started with producing and printing paper and plastic bags with one machine only. By 2006, the demand started rising, and the company needed a considerable space to meet the increasing demand. Thus, the factory was moved to another area with a space of 2000 meter squares.

The senior design course students were divided into three groups. Each group identified a problem in the company. The identification of the problem is the most challenging task in the course. The identification of the problem took about two weeks by observing the company with several visits per week.

Once the problem was identified, the students proposed solutions for the their identified problems with the help of their instructor. The proposed solutions were based on what students have learned throughout the other courses. The instructor monitored the process of proposed solutions with the students throughout their weekly meetings (three times a week). Then, the proposed solutions were evaluated based on the cost analysis.

One group identified that setup times of some machines were large and hence, their objective was to reduce machine setup times. This problem is briefly described in Section 3. Another group observed that the company faces lots of problems due to its poor facility layout planning and thus, this group's objective was to redesign the facility layout. This problem is defined in Section 4. Finally, the last group of students analyzed the past data which indicated that the company has a production rate below the market demand. This group proposed a solution to increase the production. This problem is described in Section 5.

3. Reduction of Machine Setup Time

The company manufactures both paper and plastic bags. 70% of the production is paper bags while 30% of the production of the factory is plastic bags. Therefore, the group considered paper bags rather than plastic bags production. Among paper bags, there are three types. It was observed that that the paper bags with handles cover 71% of the total sales of paper bags. Thus, this group considered paper bags with handles.

Setup time can be defined as the time taken to prepare a machine for production. Setup time is an unproductive time, i.e., a non-value added activity, and hence, need to be minimized. In the company, it was observed that the setup time of the paper bag machines was large. The work on scheduling problems with setup times was summarized by Allahverdi (2015b) and Allahverdi et al. (1999, 2008).

The factory has two shifts per day with 12 hours per shift. It was observed that the average setup time of the machine was 6. 2 hours with a 95% confidence interval of (5.7, 6.7). The current scheduling policy in the company is first come first serve. It was obvious that this scheduling policy is not efficient, and hence, a new scheduling policy was developed. The following scheduling policy was proposed:

1) Process the orders that have similar paper bag dimensions next to each other.
2) Process the orders that have the same handle color next to each other.
3) Process the orders from smaller dimensions to larger dimensions or vice versa one after another

The main idea behind these policies is to place the orders that share the same features together. The proposed schedule was applied to the past 17 months data. It was observed that on average, $ 150,000 per year profit could be saved due to a saving about 34% from setup time reduction.

Moreover, on average, $ 15,000 per year could be saved from worker salaries if the proposed schedule is implemented. Therefore, in total, a total saving of about $165,000 per year could be saved if the proposed scheduling policy is implemented.

4. Layout Redesign for Efficiency Improvement

The company faces lots of problems due to its poor Facility Layout Planning (FLP). The first problem is improper storing of the raw materials and finished products inside the production area. Improper storing leads to movement obstruction of the workers which increases the time of the production process. The improper storing also makes it hard to find a space for a new automated packaging machine which is needed to reduce time and cost. The second problem is roll waste, the company losses about $ 120,000 per year because of the roll waste. Redesigning the facility layout and applying facility layout methods is required in this case to achieve the factory goal of productivity and profitability.

Systematic layout planning (SLP) approach is applied to arrange the machines and to redesign the layout properly. The results from SLP approach showed that the new design saved time and space. The time saved from the workers movement increased the company's production, thus, increased the profit. In the saved space an automated packaging machine can be installed to increase production and decrease production time. And for the raw materials an automated racking system (shelves) can be installed in the open area for storing. After calculating all fixed and variable costs and profits, we found that the breakeven point will be after 15 months. In

conclusion the goal for redesigning a facility layout is to obtain design efficiency in the operation systems. The company can save by $ 140,000 per year with the proposed layout.

5. Production Capacity Analysis

The analysis of past data indicated that the company has a production rate below the market demand. Moreover, the company has a delayed and non-conforming orders that affect their income and their reputation in the market. The study focused on the handle bag product because its demand was the highest and the demand was about 11% more than the production. The company's total lost from the shortage of production, delayed, and non-conforming orders was $245,000 in 2019. Improving the production rate is essential to reach the current and future market demand.

The proposed solution is to replace the current manual handle bag machine with a full automatic machine with higher production rate. The new machine should have newer technology and sensor/monitoring systems to reduce the defect parts. The company has an old machine which is expensive to support, and in some cases, it takes too much time to find spare parts. Replacing the machine is better than expanding the production line by adding a new machine because the current demand exceeds the production by 11%, and the new machine will utilize the current machine area so there will be no problem in the factory space.

After investigation, it was found that there are many leading companies in the industry selling the machine. Machines vary on the level of performance, they can be fully automated, semi-automated or even manual. The machines could be a fully integrated unit or a main unit and optionally adding extra unit for handle or printing. Depending on these factors the cost of the machines varies greatly and the choice to make the right decision depends on the customer's actual needs and budget. The quality of the produced bags is crucial and there is no compromise on the quality. The durability of the machines is essential since the quality of the machine to be purchased affect the quality of the product produced. Five different alternative machines, all of them satisfied the demand, from different companies were compared and one of them was selected based on decision analysis tools.

The cost of replacing is the cost of disassemble the current machine which takes 4 days and the cost of installing and testing the new machine which takes 14 days. So the cost of replacing the machine is $ 65,000. The selected machine meets the company's requirements. Moreover, the non-conforming orders will reduce because of the machine's photo eye monitor. This machine will also reduce the delayed order because it has high level of automation and its production rate exceeds the demand. By reducing the non-conforming and delayed orders, the company will save money and their market reputation.

As a result of increasing the production rate and reducing the non-conforming orders, the profit will be increased at least by $245,000 annually if the current machine is replaced by the proposed machine. The proposed machine will breakeven within 1.2 years.

6. Students Evaluation

A survey (the employer survey) is distributed to the supervisors at the company where the students conduct their senior design project. The students are asked to be evaluated based on the seven student outcomes adopted by ABET including the outcome of having an ability to identify, formulate, and solve complex engineering problems. The survey is administered by

the IMSE department which was initiated about a decade ago. A copy of the survey is given in the Appendix which include all the seven outcomes of ABET. The students, in the senior design course, are separated into three to five groups to work in a selected company where each group is assigned to a department or a division and supervised by professional top-level personnel from the company. The students frequently visit the organization to identify problems, collect data, perform analysis, and propose solutions. The company supervisors evaluate the students by filling out the employer survey; where they express their assessment of the students' achievement of the seven ABET student outcomes including the outcome of having an ability to identify, formulate, and solve complex engineering problems.

The evaluation results from the employer surveys for the last few years indicate that the average result of the outcome, of having an ability to identify, formulate, and solve complex engineering problems, is above 80%. The average results for the other six outcomes show that they also exceed 80%. The high scores provided by employers may be attributed to the fact that this is a senior design course where students apparently have achieved high level of performance. This shows that the impact of the senior design course is significant.

7. Conclusion

Similar to many engineering programs world-wide, the senior design course is a part of the curriculum of the Industrial and Management System Engineering (IMSE) program of Kuwait University (KU). In Spring 2020, the students of the senior design course of IMSE at KU selected a paper and plastic bag company to conduct their course. The objective was to improve some operations at the company by using the industrial engineering tools that the students have learned from other courses. Three different problems were identified and solutions were proposed. It was shown that the company can save about half a million US $ per year if the proposed solutions were implemented.

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Appendix

IMSE-496: Senior Design Employer Survey

Evaluator Name: _____

Company/Organization: _____

Department/Division: _____

Position: _____

Email: _____

Tel: _____

Name of the project: _____

Student names: _____

We would appreciate if you rate our students according to the following abilities where

1 = very weak, 2 = weak, 3= satisfactory, 4 = very good, 5 = excellent

1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

3) an ability to communicate effectively with a range of audiences
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5