Sample Senior Design Projects of Industrial Engineering Program at Kuwait University

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Abstract
A senior design course provides engineering students the opportunity to identify, formulate, and solve complex real-world engineering problems. This outcome is one of the seven student outcomes adopted by The Accreditation Board for Engineering and Technology (ABET). Therefore, the senior design course is a part of the curriculum of most of the international engineering programs. Hence, it is also a required course in the curriculum of the Industrial and Management Systems Engineering (IMSE) program of Kuwait University (KU). In the senior design course of IMSE program at KU, students select a company and conduct their project at the company. In this paper, three of these companies are briefly described along with identified problems, proposed solutions, and obtained results. Student evaluation by the company's representatives is also discussed. It has been shown that the senior design students improved the operations of the selected companies significantly. It has been also observed that the students are enthusiastic by applying the methodologies and tools of Industrial Engineering that they learned in their earlier courses to solve real life problems.

Keywords: Senior design, industrial engineering, engineering education, company

Introduction

A Senior Design course is a part of the curriculum of most of the engineering programs worldwide as it gives the students the opportunity to solve real-world engineering problems. A survey of senior design courses in engineering problems throughout of USA was given by Todd et al. (1995). Moreover, Dutson et al. (1997) described the practices of the papers related to engineering design courses. The issue of design in engineering education was discussed by many researchers including (Katz, 2015; Odora, 2015; Strobel et al., 2013; Mahmud et al., 2012). In order to prepare the engineering graduates for practical problems better, teaching design in senior courses has recently increased.

Nobes et al. (2010) studied the effect of senior design project workload on student performance. They stated that a student has workload of 15 hours/person/week on average, but it may reach to 40 hours/person/week.

Gruenther et al. (2009) studied the effect of prior teamwork and industry experience in a senior design course. Furthermore, Zou & Ko (2012) evaluated the teamwork development process for senior design course. They evaluated the teamwork skills by both qualitative and quantitative approaches. Cooper et al. (2015) presented a method of evaluating different senior design projects against common outcomes.

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

Accreditation Board for Engineering and Technology (ABET) recently redefined general engineering student outcomes as

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics,
(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,
(3) an ability to communicate effectively with a range of audiences,
(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,
(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,
(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions,
(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Senior design course of the curriculum of Industrial and Management Systems Engineering (IMSE) of Kuwait University (KU), which is accredited by ABET, provides the opportunity for the students to obtain all the seven student outcomes.

The senior design course of the IMSE program at KU including the learning practices and its relation to the other courses in the curriculum was described by Savsar & Allahverdi (2008). The syllabus of the course is given in Appendix B. Moreover, Allahverdi (2015) provided the answer of four questions about the course; how a company is selected? How a problem is identified? How the course outcomes map to the ABET student outcomes? And how the course is evaluated. Furthermore, Allahverdi (2018) provided samples of senior projects of industrial engineering at Kuwait University. In this paper, we provide three more companies (organizations) where students conducted their senior design projects. The students in the course are usually divided into three groups where each group addresses a different problem in the selected company. The objective of this research is to show how the students solve real life problems by using Industrial Engineering tools.

The class is met three times a week where the instructor monitors and helps in identifying of a problem in the company with each group. This task is the most challenging task in the course. In the identification of the problem, students may need to get some data so that the significance of the identified problem may become clear. For example, students find a problem where some products are rejected due to quality reasons. When some data are collected, it was found that if the rejection of products were reduced to a certain level, the company would save an amount which is not significant. Therefore, the identified problem was not appropriate, and another problem was identified instead. Another example is that students find a very good problem, however, the solution of the problem may not be feasible to reach within the semester period. Such cases are frequently encountered.

Once the problem is identified, students propose solutions for the identified problems with the help of their instructor. The proposed solutions are based on what students have learned throughout the other courses. The instructor monitors the process of proposed solutions with the students throughout their weekly meetings (three times a week). Then, the proposed solutions are evaluated based on the cost analysis. For example, if a certain modification of the considered system is proposed, then a break-even analysis is conducted to see if the implementation of the solution is cost effective or not.

Savsar & Allahverdi (2008) and Allahverdi (2015) described the the course in detail. Hence, it is not repeated in this paper. In the next three sections, student selected companies, their identified problems, and their proposed solutions are briefly explained. Moreover, company evaluation of the students is briefly discussed in Section 5, and the conclusions are made in the final section.

Company 1

This company is a manufacturer of plastic products. The company produces around 500 different types of products. The products range from everyday household items, to plant pots, crates, jerrycans, industrials items, and many more. It uses one of three methods to manufacture their products: Blow molding, Injection molding or Vacuum forming. The company classifies their products into two main categories; customized products, and general market products. Customized products, which are products made using molds that were designed according to the customers' requirements (around 55% of the company's sales). On the other hand, unbranded products which are made for the general market, account for 45% of the company's sales.

Each of the three groups addressed a different problem and proposed a solution for the identified problem by using suitable Industrial Engineering tools to improve the efficiency of the organization. Group 1 improved warehouse efficiency of the company, Group 2 increased the production rate, while the objective of Group 3 was to reduce defect rate.

Group 1 suggested an improvement for the warehouse of the company since it currently has several shortcomings resulting in inefficient space utilization, order processing and material handling. The analysis of the warehouse indicated that the product allocation is random, the warehouse is disorganized, and that the order process can be significantly improved. These factors contribute to delays in order collection time which costs the company a yearly loss of over $ 20,000 in worker salary only. After an intensive analysis of the warehouse, a new ordering process was presented and an effective warehouse management method (Class Based Storage Method) was proposed. By implementing the suggested ordering process and warehouse management methods, it was shown that the warehouse utilization can be increased by 12%, the time taken to locate an item can be decreased by 69%, and the total distance travelled can be decreased by 41% without any additional cost.

The objective of Group 2 was to increase production rate since the company delayed some orders. The company delay the incoming orders about a month due to a high demand for three of its products which account for 41% of its production. Moreover, about 10% of the orders of these three products is turned down. As a result, the company has a total annual loss of about $ 150,000. An analysis of the blow molding machine used to produce these products revealed that the machine

capacity is limited. Therefore, in order to increase the production of these products, the feasibility study of purchasing a new blow molding machine was conducted. The feasibility study indicated that by purchasing the new blow molding machine, the delay of orders will be eliminated, and no orders will be turned down. Moreover, the company can meet its increasing demand for the forecasted several years to come. The breakeven time was computed to be about 7 months with an annual of saving of at least $ 150,000.

The objective of Group 3 was to reduce defect rate since the defect rate was more than one third. Sleeving and Blowing are the main operations in the production of some plastic bottles that the company produce. It was observed that inefficient sleeving and blowing operations (old sleeving and blowing machines) results in about 35% defect products. 25% of products are defective as a result of sleeving operation which costs above $ 120,000 per year. On the other hand, as a result of blowing operation, 10% of products are defective which costs the company above $ 60,000 per year. Therefore, the feasibility study of purchasing a new sleeving machine or purchasing a new sleeving machine and a new blowing machine is conducted. The feasible study indicated that purchasing a new sleeving machine will result in a reduction of defects by 68%. The breakeven time of purchasing a new sleeving machine is 4.18 months with an annual saving of $ 120,000. The feasibility study also indicated that purchasing both a new sleeving machine and a new blowing machine will result in a reduction of a defect by 94%. The breakeven time of purchasing both machines is about a year with an annual saving of about $ 200,000.

Company 2

The second organization is a large bakery company which produces a wide range of products, including but not limited to macaroni, biscuits, vegetable oil, Arabic and European baked goods. The company imports wheat and other grains, processes at the company's port and silo complex, and operates its own flour mills, and bakeries. Group 1 redesigned the facility layout of the company, Group 2 reduced the customer waiting time, while Group 3 improved the packaging process for the Biscuit factory of the company.

Group 1 redesigned the facility layout of the company. The layout of a facility plays a vital role in the productivity and efficiency of a factory. A detailed analysis of the current facility layout of the company was conducted and several problems were identified; including the unsystematic warehouse and distribution area that slowed down processes in the facility, the storage rooms that are at their maximum capacity and the idle machines that take up to 66% of their production area. The aim of this project was to develop a new facility layout for the administration by addressing the identified shortcomings. The management will implement the new layout after the reconstruction of the location, which will take place soon. The new layout was developed by using several industrial engineering tools including the Systematic Layout Planning to allocate departments to locations according to their relationships scoring. The new layout plan increases space utilization, improves current operations and promotes smoother worker flow.

The objective of Group 2 was to reduce customer long wait time in the queue to buy products from the sales shop. After analyzing the system, it was observed that the worker is forced to bring orders of large quantities for the customers all the way from the raw materials storage. The sales shop products are stored in the raw materials storage which currently takes up to 50% of its space, and this leads to the extra trips to bring in raw materials from the main factory. Utilizing the storage space by reconstructing the sales shop, making it larger and converting it into a mini market would help in reducing transportation and labor cost, and get customer satisfaction. By allowing the customers to observe all the available products that they are not aware of, and selecting them directly, they would help increase the shops' sales by more than 50%. With a construction cost of less than $ 150,000 that will breakeven within 8 months and leads to an additional annual profit of about more than $ 100,000.

The objective of Group 3 was to improve the packaging process for the Biscuit factory of the company. Biscuits of different sizes, including 25-gram, are produced from the production lines of the factory. The flow rate of two production lines for the 25-gram is faster than the workers performance, which leads to having bottleneck in the packaging area. The bottleneck leads to uncollected biscuits at the end of the production lines causing defects. Analysis of the production lines revealed the possibility of replacing the manual packaging with an Automated Machine for the 25-gram biscuits. The time to breakeven of purchasing the Automated Machine is 4.78 months and the annual saving from the defects and the worker's salary is above $ 150,000. Moreover, the possibility of purchasing a multi-size Automated Machine, using sensor to identify the size of the biscuit, for the packaging for all the remaining sizes was investigated. The time to breakeven of purchasing the multi-size Automated Machine is 15.7 months and the annual saving from the defects and the worker's salary is about $ 300,000.

Company 3

The third organization is a food distribution company. It has more than two thousand products from different brands of frozen foods (poultry, meat, vegetables, potatoes, pizzas, …), cereals, chips, water, and so on as well as a variety of dry items. Group 1

worked on reducing the percentage of market return, Group 2 worked on increasing utilization of the warehouse while Group 3 addressed the issue of warehouse utilization.

The current cost of products returned from the market is one-third of a million KD per year. The objective of Group 1 was to identify the main causes and reduce the cost of the return. Analysis of the current system indicated that the most important causes were expiries in showrooms and wrong orders. The analysis also indicated that the most important factor in expiries of items was wrong forecasting. Therefore, new forecasting methods were proposed, which led to a decrease in market return by 23% that resulted in a saving of one-quarter of a million dollar per year. The analysis further indicated that high workload, on data entry labors, was the main cause of wrong orders.

Group 2 analyzed the current warehouse system which indicated an ineffective utilization and poor housekeeping, where some pallets block some aisles contributing to various problems such as misplacement and picking wrong items. The analysis also indicated that not all of the current racks were fully utilized as a result of weight and height constrains of the current rack types. In order to overcome these problems, a new rack type, Very Narrow Aisle (VNA), was proposed. The analysis showed that the proposed VNA rack type increased both rack utilization and capacity of the warehouse. Moreover, the proposed VNA rack type increased worker productivity by 50% and eliminated misplacement and blocking in storage locations within the warehouse.

The objective of Group 3 was to increase the number of processed containers per day. An arriving container to the warehouse is offloaded, and the products are stocked in the warehouse. The analysis of the current processing system indicated that, on average, it takes 1.8 hours to process a container. However, due to a big difference between the temperature of the offloading area and that of the storage area, a container has to be processed in less than or equal 1.5 hours. The main factor affecting the time of processing of a container was found to be manpower. A detailed cost analysis was conducted in finding whether increasing the number of manpower or having employees working overtime was cost effective. The analysis indicated that increasing the number of manpower was cost effective. The analysis also indicated that it was possible to reduce the time of processing a container to less than 1.5 hours just by increasing the number of manpower by 2. By doing so, the number of containers processed can be increased from the current number 15 to 20 containers per day.

Company Evaluation of the Students

The "IMSE-496: Design in Industrial Engineering – Employer Survey" is a survey completed by the supervisors at the company where the students are evaluated based on the earlier stated seven student outcomes. The survey is administered by the IMSE department which was initiated in the Fall 2011. A copy of the survey is given in the Appendix A. In this course, students are divided into groups to work in a selected organization where each group is assigned to a department or a division and supervised by professional top-level personnel from that department. The students frequently visit the organization to identify problems, collect data, perform analysis, and propose solutions. Students give three presentations; two to the faculty members and a third to the public where company representatives are present. The employer survey is completed by the company supervisors; where they express their assessment of the students' achievement of the seven aforementioned ABET student outcomes (SOs) throughout the semester at the company.

The evaluation results for the employer surveys are summarized in Table 1 from Spring 2014 to Spring 2018. The results generally show that they greatly exceed the satisfactory level of 60%, all the scores of all the seven outcomes are above 80%. The high scores provided by employers may be attributed to the fact that this is a capstone course where students supposedly have achieved high level of performance. This shows that the impact of the senior design course is significant.

Table 1: Attainment of student outcomes

SOs	2013/2014	2014/2015		2015/2016		2016/2017		2017/2018		**Avg.**	Sdv.
	S14	F14	S15	F15	S16	F16	S17	F17	S18		
1	96.3	100	76.7	90	95	93	75	80	100	**89.6**	10.9
2	90	80	80	80	80	93.3	100	80	100	**87**	8.9
3	100	100	86.7	80	80	90	90	80	100	**89.6**	8.7
4	95.8	93.3	80	33.3	93.3	91.6	100	86.7	86.7	**84.5**	23
5	100	100	86.7	100	90	86.7	100	80	100	**93.7**	7.9
6	95	80	80	80	100	96.7	80	60	80	**83.5**	12.2
7	95	100	86.7	100	70	90	80	60	80	**84.6**	13.6

Conclusion

The senior design course is a compulsory course in the curriculum of the Industrial and Management System Engineering program of Kuwait University. The students of senior design course select a company and the objective is to identify a few problems at the company and propose solutions to improve the operations at the company by using some of the industrial engineering tools. Three selected companies at different semesters were described and the student proposed solutions were briefly explained. It has been shown that the senior design students improved the operations of the selected organizations. It has been also observed that the students are enthusiastic by applying the methodologies and tools of Industrial Engineering that they learned in their earlier courses to solve real life problems.

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Appendix A

IMSE-496: Design in Industrial Engineering - 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, NAE= not able to evaluate

1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

☐1 ☐2 ☐3 ☐4 ☐5 ☐NAE

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 ☐NAE

3) an ability to communicate effectively with a range of audiences

☐1 ☐2 ☐3 ☐4 ☐5 ☐NAE

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 ☐NAE

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 ☐NAE

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 ☐NAE

7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

☐1 ☐2 ☐3 ☐4 ☐5 ☐NAE

Appendix B

IMSE 496 : Design in Industrial Engineering
Fall 2019

Instructor: Prof. Ali Allahverdi
Course Description:
This is a capstone design course. Students are exposed to creative design and synthesis in the various areas of industrial and management systems engineering. All knowledge acquired in mathematical modeling and economic techniques are utilized in conducting the design analysis.

Objectives
This course aims at developing certain skills that are both essential and helpful to new engineering graduates in their career. These skills involve

1. Problem identification, systems design, and problem solving
2. Application of different Industrial Engineering tools to real life problems
3. Effective communication
4. Presentation and documentation skills
5. Working in multi-disciplinary teams
6. Developing professional and ethical responsibility

Orientation Meeting
This meeting is held at the very first day of the class in which students get to know each other, be familiar with the course requirements, agree on fixed days in a week for meetings, and discuss the plant (organization) at which they will perform their project.

Meetings
Each group has to meet the instructor three times a week at an appropriate time in which students will present, discuss and analyze all collected data during previous periods and go over the methodologies and tools required to analyze these data. Students should inform the instructor about any problem with any team member for the work done during the previous week, as well as inform the instructor the work still in progress and all barriers that might have faced them during their visits.

Proposal Presentation
Students are required to present their proposals at the date given below. After a thorough observation of the methods of operation and organizational structure, students are required to give two presentations (along with written documentation) proposing all possible areas of improvement within the facility and the tools that they will use. The IMSE faculty members will attend the presentations.

First written report
Students are required to submit their first formal written reports before the specified time. After a thorough observation of the methods of operation and organizational structure, students are required to give a formal written documentation proposing all possible areas of improvement within the facility and the tools that they will use. These reports will be thoroughly evaluated and graded. The reports will be part of the final reports.

Final Technical Presentation to the IMSE faculty members
On a specified date, students are required to present their work, defining its objectives, explaining the methods and tools used in analyzing and evaluating all the data collected. Furthermore, students will recommend solutions for the improvement of the various production or service operations. The IMSE faculty members will attend this final technical presentation.

Presentation to the organization (public)
After final technical presentation, students are required to present their work, defining its objectives, explaining the methods and tools used in analyzing and evaluating all the data collected to the organization. Furthermore, students will recommend solutions for the improvement of the various production or service operations. This public presentation will

be attended by the people from the organization, the IMSE faculty members, students' relatives, and other people. If possible, the presentation will be held at the organization.

Final Written Report

Three copies of the written report should be submitted to the course instructor by a specified date. Failure to submit the report on time will affect the grading of team members. The report should be typed and professionally designed. It should follow a uniform structure and design in terms of font size, typeface, and graphics used throughout.

Grading

The group will receive a grade on each of the items listed below and then it will be adjusted to arrive at an individual grade that reflects the contribution of the individual and the group. The graded material consists of:

Attendance
Meeting performance
Written progress reports
Introduction report about the organization (this is going to be the introduction chapter of the first and the final reports)
First report to include identified problems and proposed solution methods
Oral presentation of the proposal
Final technical presentation to the faculty members (grades by other IMSE faculty members)
Final technical presentation to the public (grades by other IMSE faculty members)
Final report (grades also by two other IMSE faculty members)
Team member evaluation (each member will evaluate other members in the team)
College exhibition preparation
Meeting deadlines

Important Deadlines

Selection of an organization	Sept 15
Decision on selected areas and problems	Sept 22
Finalizing solution methodologies	October 6
Proposal Presentation to the IMSE faculty members	October 20
Submission of the first written report	October 27
Finishing the project	November 28
Final technical presentation to the IMSE faculty members	December 4
Submission of the final written report	December 10
General presentation to the organization (public)	December 12
Exhibition at the college	December 14-15