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Samples of senior design projects in industrial engineering

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ABSTRACT: A senior design course is part of the curriculum of the Industrial and Management Systems Engineering (IMSE) programme of Kuwait University (KU), Safat, Kuwait. The IMSE programme is an ABET (Accreditation Board for Engineering and Technology) accredited programme. The senior design course is also part of the curriculum of most of the international engineering programmes. The course provides engineering students the opportunity to solve real-world problems. The senior design course of the IMSE programme is unique as students select organisations themselves and they also identify problems themselves as opposed to the common practice of faculty members finding them. In this article, three organisations selected by the IMSE students are presented, along with student-identified problems and their solutions.

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

INTRODUCTION

ABET (Accreditation Board for Engineering and Technology) highlights the need for engineering courses providing engineering design, teamwork and communication skills in addition to other skills. The senior design course of the IMSE (Industrial and Management Systems Engineering) programme of Kuwait University (KU), which is accredited by ABET, provides students with the opportunities to develop skills including design, teamwork and communication. Students in the senior design course of the IMSE programme at KU have an opportunity to apply the techniques, methods and tools that they have learned from different courses to solve real-life problems.

A capstone/senior design course is a part of the curriculum of most international engineering programmes since it provides the engineering students the opportunity to solve real-world problems. Todd et al conducted a survey of capstone/senior design courses in engineering programmes throughout the USA [1]. Furthermore, Dutson et al described the practices and the senior design education as the result of the coverage of over 100 papers related to engineering design courses [2]. The issue of design in engineering education has been addressed by many researchers [3-6]. In order to prepare engineering graduates for practice better, teaching design in senior courses has recently increased.

The senior design course also has an impact on the students' academic performance in other courses. Nobes et al studied the effect of senior design project workload on student performance [7]. They stated that a student, on average, has workload of 15 hours/person/week. They also stated that the workload may be high as 25-40 hours/person/week.

Gruenther et al examined the effect of prior multidisciplinary teamwork and industry experience in a senior design course [8]. Moreover, Zou and Ko evaluated the teamwork development process for senior design course [9]. They evaluated the teamwork skills by both quantitative and qualitative approaches. Cooper et al presented a method of evaluating different senior design projects against common outcomes [10].

Shin et al discussed the advantages of developing an internship and capstone design course in combination with industry [11]. They stated that during the capstone design course, it is easier to check each student's progress, however, it is not easy to check the progress and status of students during the period of internship. They also stated that the students have the opportunity to work on real-life problems and the opportunity to develop their profession during the senior design course.

Savsar and Allahverdi described the senior design course of the IMSE programme at KU including the learning practices and its relation to the other courses in the curriculum [12]. They also provided a list of the organisations selected and the methods that the students utilised to complete their projects. Moreover, Allahverdi provided answers to four questions about the course: How is an organisation selected? How is a problem identified? How do the course outcomes map to the ABET student outcomes? And how the course is evaluated [13].

In the current article, the author provides samples of the organisations (companies) selected and the problems the students identified along with the solutions they proposed. The students in the course are typically divided into three to five groups (depending on the size of the class), and each group addresses a different problem in the selected organisation. In the next three sections, selected organisations, identified problems, and proposed solutions are provided. There are concluding remarks in the last section.

ORGANISATION 1

This organisation (company) manufactures air conditioning units. The company's products include ducted split series, concealed ducted split, rooftop package series, air handling units, air cooled water chillers and fan coil units. Eighty percent of the company's sales occurs within the country, and the remaining 20% are sold to other countries in the Middle East, such as Saudi Arabia, Bahrain, the United Arab Emirates, Oman, Qatar, Iran, Iraq, Egypt, Sudan and Tunisia.

The class was divided into three subgroups. Each subgroup addressed a certain problem and proposed a solution using appropriate industrial engineering tools in order to improve the overall efficiency of the company. Group 1 improved the company's warehouse efficiency, Group 2 enhanced assembly line productivity for indoor and outdoor AC units, and Group 3 reduced defects in order to improve overall production.

Group 1 suggested an improved warehouse layout for the company. This is because inefficient storage space utilisation was observed in one of the company's warehouses in which critical raw materials, which include compressors, motors, pulleys, shafts, fan blades and filters were stored. An improved layout was designed for the warehouse, which was divided into two zones; a racking system dedicated to the storage of palletised critical raw materials, and a dedicated area to store finished products by block-stacking. Three feasible racking systems were proposed: standard wide-aisle pallet racking, pallet flow racking and drive-in racking. These racking systems vary in terms of capacity utilisation, product selectivity, accessibility, cost and the associated inventory retrieval system. A thorough comparative study was conducted to find the best racking system by using multi-criteria decision-making analysis. The drive-in racking system was found to be the best alternative for the company. By implementing this racking system, the company could increase its space utilisation by 50%.

Group 2 enhanced assembly line productivity for indoor and outdoor AC units. Analysis of the assembly lines in the company revealed the possibility of productivity improvement in two assembly lines. Indoor and outdoor AC units, which represent two-thirds of the company's production, were produced in the two assembly lines that were considered. The analysis of the indoor AC assembly line indicated that the cycle time was significantly longer than the average processing time, leading to excessive labour idle time. Two solutions were proposed to increase assembly line productivity. One solution was to increase the speed of the conveyor, which was possible due to the labour idle time. This solution would increase production by 25%.

The second proposed solution was to combine some of the assembly line processes, which would result in a reduction of the required manpower on the assembly line. This would lead to an additional annual profit of about EUR40,000. Both proposed solutions would increase labour utilisation and would not incur any cost to the company. On the other hand, two bottlenecks, caused by delays and malfunctions, were identified in the outdoor AC assembly line. Solutions, with negligible cost, were proposed to eliminate the two bottlenecks. This would result in an approximate 40% increase in production.

Group 3 suggested ways to reduce defects, to improve overall production. Brazing is one of the important operations in the production of heat exchangers, which are used in the AC units the company produces. It was observed that ineffectively brazed parts result in defective products, which was about 34% of the production. Moreover, it was observed that header defects and u-bend defects were the most common defect types. This was because of the production on old machines. The possibility of purchasing two new automatic brazing machines was investigated. The purchase of the two new machines would result in a reduction of defects by 23.62%. The breakeven was about 11 months for one of the machines, while it was about nine months for the other machine. After less than a year, the company could increase its profit by about a quarter million euros yearly by reducing its defects.

ORGANISATION 2

This organisation is mainly specialised in construction and real estate. The company's projects differ in size and complexity, from simple house constructions to the most complex civil operations. The company's main objective is to exceed the clients' expectations for safety, quality and functionality. Students were divided into three groups with the objectives of minimising inventory cost, increasing profits and improving maintenance performance.

The building block industry is considered to be a wholesale market in which inventory storage plays a critical role. Group 1 identified that the current storage area (warehouse) in the region Y factory indicates inefficient utilisation. Thus, the company is renting an additional warehouse in region X, which results in the company paying for rent, transportation of inventory, and defects occurring during transportation from the production area to the warehouse in region X. Group 1 proposed modifications to the current layout of the warehouse in region Y, which would reduce all inventory storage costs. The proposed modification saved the company a significant amount. However, the company still needed to rent an additional warehouse, but of a size smaller than the one in region X. Therefore, another modification to the warehouse in region Y (to construct a second level) was proposed, which would eliminate the need for the warehouse in region X. This modification has a break-even point within a year and a half and would save the company about one third of a million euros yearly.

Group 2's objective was to increase the profit, which can be achieved by either increasing the revenue of the company or decreasing their costs. Increasing the revenue could be achieved by increasing productivity since the company is not currently covering all the market demand. Group 2 proposed a plan that speeds up the production process and adds another production line, resulting in a 20% increase in productivity and an annual profit of over half a million euros. The cost of the proposed plan with the annual additional profit would break-even in one year. Increasing the profit would also be possible by decreasing the company's costs, which could be accomplished by reducing the cost of raw materials (specifically the cost of cement). Group 2 established a plan that reduced the amount of cement used in the mixture by 16%, which would result in annual savings of half a million euros. The cost of constructing the necessarily steps to implement the plan breaks-even in eight months.

Group 3's objective was to improve maintenance performance. The company had a fleet of about 50 trucks, which were being used to deliver the blocks. Currently 20% of the orders (blocks) are being delivered late as a result of delays in repairing broken-down trucks. Late delivery resulted in unsatisfied customers. The repair workshop was analysed comprehensively. The bottleneck in the repair workshop and its causes were identified. A simulation model of the repair workshop was developed and validated. Different scenarios were proposed and evaluated. The scenarios considered include a different distribution of workers to each of the three types of breakdown, increasing the number of workers and hiring a type of worker currently not available. One of the proposed scenarios reduced the waiting time of trucks for all the breakdown types, which resulted in reducing the percentage of late delivery to 8.5 %, while saving the company EUR50,000 per year.

ORGANISATION 3

The third organisation the students conducted their senior design on was a large hospital. The students were again divided into three groups. Group 1 worked on improving the emergency department's (ED) workflow and efficiency. Group 2 worked on reducing pre-examination error in the laboratory, while Group 3 worked on increasing the efficiency of patient medical record retrieval process.

The ED in the hospital seeks to provide better urgent care services to its patients. Because of the massive number of incoming patients, small inefficiencies and errors in urgent care delivery can cause significant overcrowding and service delay. The purpose of Group 1 was to improve patient traffic and reduce their overall waiting time in queues. A random sampling technique was utilised to collect the data needed to find bottlenecks and reasons for the problems identified. After decomposing the total waiting time in the system, the main bottleneck was identified to be at the ED clinic. A simulation model, which is a logical representation of the physical system, was developed. The model was validated using various statistical analysis techniques. Several feasible improvement scenarios were then proposed. Computation analysis indicated that a significant reduction in the average waiting time in queues by over 90% could be achieved for a cost as little as EUR7,000.

Pre-examination errors are the highest proportion of errors in the laboratory system. The purpose of Group 2 was to reduce pre-examination errors by analysing the causes of rejection of blood and urine samples, resulting in repeating the tests. These errors could be reduced by using an appropriate container for urine samples in order for them to be transported through a pneumatic tube system (PTS). A decision analysis method was used to choose the best from four different appropriate containers. By using the chosen container, the turnaround time was reduced by about 40%, which reduced the current cost by 29%. Moreover, a reduction of 25% was obtained in the leakage of the urine samples. As for the blood samples, the flow chart of the blood test process was re-designed by simply applying the label immediately after tube preparation and in the presence of the patient and adding an inspection operation before sending the tube through the PTS, which reduced labelling errors of blood samples by 39%.

Group 3 studied the Medical Record Department at the hospital. The main framework used to improve the system was the define-measure-analyse-improve-control (DMAIC) model, one of the six sigma principles, where the main problem defined was the inefficient patient medical record retrieval process. This process, or transaction, was defined as either an opportunity or a defect to determine the process sigma level that is to be improved. A successful transaction or an opportunity, is a process that has an acceptable retrieval process time and the file is located and returned. A defective transaction, however, is one that is classified as *file not found* or *missing file*. According to the data collection and cause and effect analysis, reasons for defective transactions were identified. The process sigma level for the current system was determined to be 4.22. Decision analysis was used as a tool to identify the most appropriate change to the Department targeting the main reasons for defective transactions and to increase the process sigma level. Alternatives taken into consideration included mobile shelving technology through which the suggested change was the implementation of mechanically compact mobile shelving. The suggested scenario increased the process sigma level to 5.33. In practical terms, after using the decision analysis tools, the average missing files per month would be decreased from 2.1 files per day to 0.04 files per day once the scenario was implemented. This would lead to a decrease of 98.09% in average missing files.

CONCLUSIONS

The senior design course is compulsory in the curriculum of most of the international engineering programmes. It is also compulsory in the curriculum of the IMSE programme at KU. However, unlike the majority of programmes, the students in the senior design course at the IMSE programme select organisations themselves and identify real-life problems themselves. In this article, three organisations the students selected are briefly described. The student identified problems are specified and their solutions are described.

REFERENCES

1. Todd, R.H., Magleby, S.P., Sorensen, C.D., Swan, B. and Anthony, D.K., A survey of capstone engineering courses in North America. *J. of Engng. Educ.*, 84, 165-174 (1995).
2. Dutson, A.J., Todd, R.H., Mahleby, S.P. and Sorensen, C.D., A review of literature on teaching engineering design through project-oriented capstone courses. *J. of Engng. Educ.*, 86, 17-28 (1997).
3. Katz, R., Integrating analysis and design in mechanical engineering education. *Procedia CIRP*, 36, 23-28 (2015).
4. Odora, R.J. Integrating product design and entrepreneurship education: a stimulant for enterprising design and engineering students in South Africa. *Procedia Technol.*, 20, 276-283 (2015).
5. Storbel, J., Wang, J., Weber, N.R. and Dyehouse, M., The role of authenticity in design-based learning environments: the case of engineering education. *Computers & Educ.*, 64, 143-152 (2013).
6. Mahmud, J.O., Mohd, M.S. and Mohd Taib, J., Engineering education and product design: Nigeria’s challenge. *Procedia - Social and Behavioral Sciences*, 56, 679-684 (2012).
7. Nobes, D.S., Stout, C. and Ackerman, M., The impact of senior design project workload on student performance. *Proc. 3rd Inter. Symp. for Engng. Educ.*, 1-8 (2010).
8. Gruenther, K., Bailey, R., Wilson, J., Plucker, C. and Hashmi, H., The influence of prior industry experience and multidisciplinary teamwork on student design learning in a capstone design course. *Design Studies*, 30, 721-736 (2009).
9. Zou, T.X.P. and Ko, E.I., Teamwork development across the curriculum for chemical engineering students in Hong Kong: Processes, outcomes and lessons learned. *Educ. for Chemical Engineers*, 7, e105-e117 (2012).
10. Cooper, C.A., Fulton, J.M. and Homan, J.J., A multi-spectrum framework for characterizing interdisciplinary capstone design experiences. *Procedia Computer Science*, 44, 699-707 (2015).
11. Shin, Y.S., Lee, K.W., Ahn, J.S. and Jung, J.W., Development of internship and capstone design integrated program for university-industry collaboration. *Procedia - Social and Behavioral Sciences*, 102, 386-391 (2013).
12. Savsar, M. and Allahverdi, A., Senior design course in industrial engineering at Kuwait University. *Inter. J. of Continuing Engng. Educ. and Life-Long Learning*, 18, 253-263 (2008).
13. Allahverdi, A., A unique and effective way of teaching a capstone/senior design course. *Global J. of Engng. Educ.*, 17, **3**, 132-137 (2015).

BIOGRAPHY

Professor Ali Allahverdi received his BS from Istanbul Technical University, and his MSc and PhD from Rensselaer Polytechnic Institute, Troy, NY, USA. He has been a faculty member at the Industrial and Management Systems Engineering of Kuwait University since 1995. He received a Distinguished Researcher Award and Research Performance Award from Kuwait University in 2003 and 2004, respectively, and a Dissertation Prize from Rensselaer Polytechnic Institute in 1993. He has published over 100 papers in well-known international journals and presented about 100 papers at international conferences. He has been the editor of the European Journal of Industrial Engineering since 2007 and served as guest editor for the European Journal of Operational Research, the International Journal of Production Research, and the International Journal of Operations Research. He is currently serving as associate editor of several journals and on the editorial board of several other journals. He has been an ABET evaluator since 2011.