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Transforming senior students to Competent Engineers through Project Based Learning

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Abstract

This paper focus on transforming the senior level engineering students to competent manufacturing engineers thru project based learning. The final project work for the manufacturing system design and simulation (MFGE-440) course is geared toward challenging the students to develop a detailed manufacturing part-process flow, optimize the process layout and develop simulation model to predict the throughput using Arena Simulation Modeling. Each group was given a typical product drawing to develop system design and simulation analysis. The part arrival times, process times, the forklift speed, part transfer times and load/unload times were given. These products require the operations like, saw cutting, drilling, vertical milling, horizontal milling, and final machining operations. The original simulation model predicted 110 parts output for 2000 minutes simulation time. The team analysed various "What-If" scenarios using the computer simulation model to improve the throughput. The revised simulation model produced 159 parts, an improvement of 43%. This team project study demonstrated student's critical thinking, product design skills, machining knowledge, layout skills, processing skills, and simulation modeling skills. This group project not only encouraged the students to work as a team but also encouraged their individual talents to shine. This group project gave students the confidence to handle product from "drawing to production". It was very satisfying to see how these senior students are transforming themselves to competent engineers.

Introduction

The engineering students are required to take various courses in general education and technical education to meet the graduation requirements. Please refer a typical manufacturing engineering program curriculum flow chart in the reference section[1]. The engineering students always challenge the reason to go through various course works during the school years. In the senior year, the same students realize the importance of knowing what they have learned in the past few years. The senior class students are required to participate in a team based project work and classroom presentation. These team-based projects help the students to develop the leadership skills, inter-personnel skills, time management, presentation and of course engineering problem-solving skills.

This team based project work was developed to train the students on feasibility studies. The manufacturing systems design and simulation (MFGE-440) course class was divided in to five teams; each team was given a different product drawing to develop a manufacturing system design and simulation. A typical part requires the following processes: saw cut, roughing, horizontal CNC machining, vertical CNC machining, final machining, and finishing. Each team was challenged to develop manufacturing layout consists of part process flow sequence of operations. Each team was required to improve the simulation model throughput based on various "What-If" scenarios.

The fresh graduate engineer's job usually requires them to estimate the cost, delivery, resources, labor and of course, and the profit. To estimate the job cost, an engineer is needed to interact with various departments to find out the cost of manufacturing. The classroom team based project intended to force the students to interact with their peers to manage the time, the team skill levels, team weaknesses, resources and delivery of the project report. This paper intends to demonstrate the students' ability to transform themselves to competent problem solvers thru project based learning. A typical classroom team project was chosen for the study.

Literature Review

There are plenty of journal articles and conference proceedings available on manufacturing system simulation. The discrete event simulation modeling (DES) techniques have been used in the industries to predict the manufacturing throughput. This project work is unique since, it integrates the student's classroom learning to solve the real world problem thru teamwork. This classroom activity reinforces the student's confidence, encourages critical thinking, and dealing with peers to solve issues in comfortable classroom setting.

Smits & Graaff (2003)[2] concluded that the engineering students need to acquire more competencies than just engineering skills, professional knowledge, society abilities, organizational and management skills as well as communicative and social skills are just as important.

The Arena modeling software is widely used in manufacturing simulation modeling. The same software V13.90 (2010)[3] is used to model the production process. There are many approaches used for validation and verification of the simulation model. Various validation techniques such as conceptual model validity, model verification, operational validity and data validity and minimum recommended procedures are discussed by Sargent (2004)[4]. For specific application, model accreditation standard DoDI 5000.61[5] is available from Department of Defense (DoD).

Product-Process Flow

The part sketch chosen for one of the team project study is shown in Figure 2.

Problem description: The raw material arrives at exponential rate with a mean of 15 minutes to a machining system. The machining system has a single machine in each cell. The process time at each machine cell assumed to be exponential with mean of 10 minutes. The transfer time between arrival, process, and exit system is 3 minutes. The load and unload times are 0.25 minute at each station. Make necessary assumptions based on the manufacturing system layout.

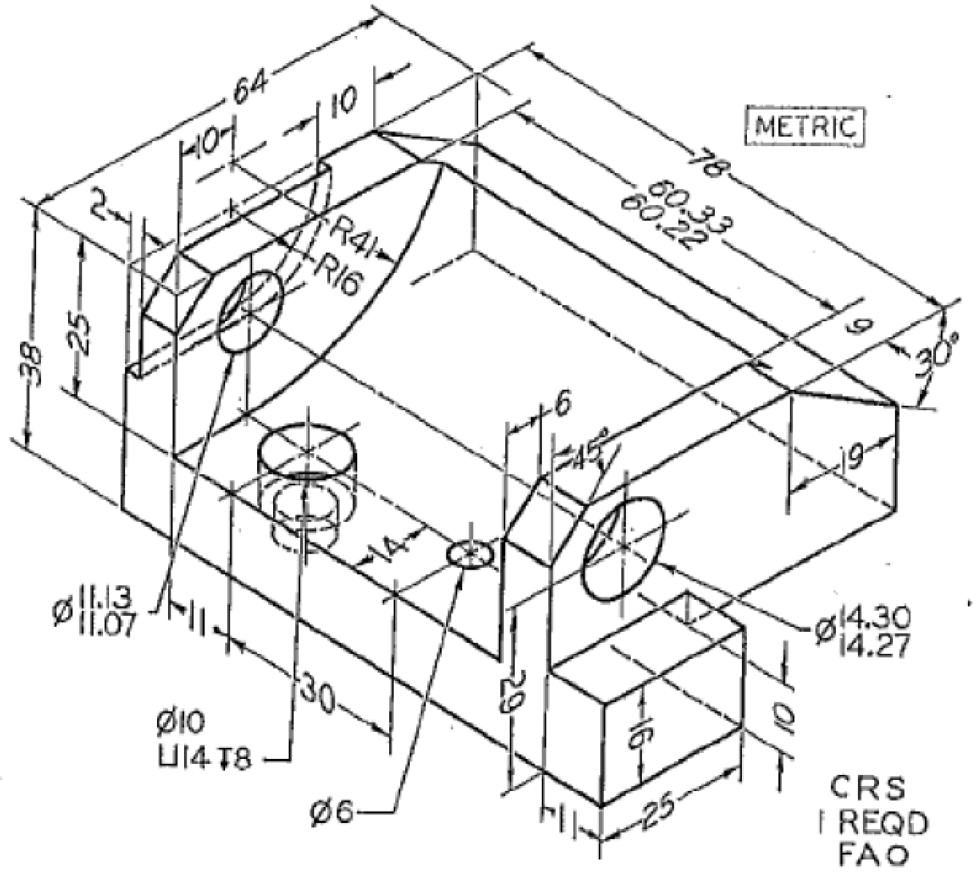

Figure 2: Hinge Block (All dimensions are in mm- Assume all unknowns)

The team has developed a solid modeling of the part at each stage of the manufacturing processes using Solid Works software program. The various stages of the production part flow processes are shown in Figure 3. The final product model from the sketch is shown in Figure 4.

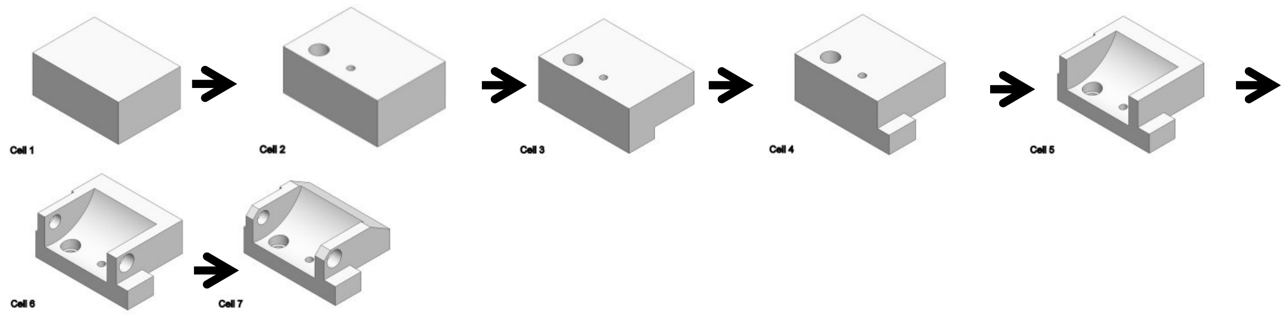

Figure 3: Part-Process flow Cell 1 thru Cell 7.

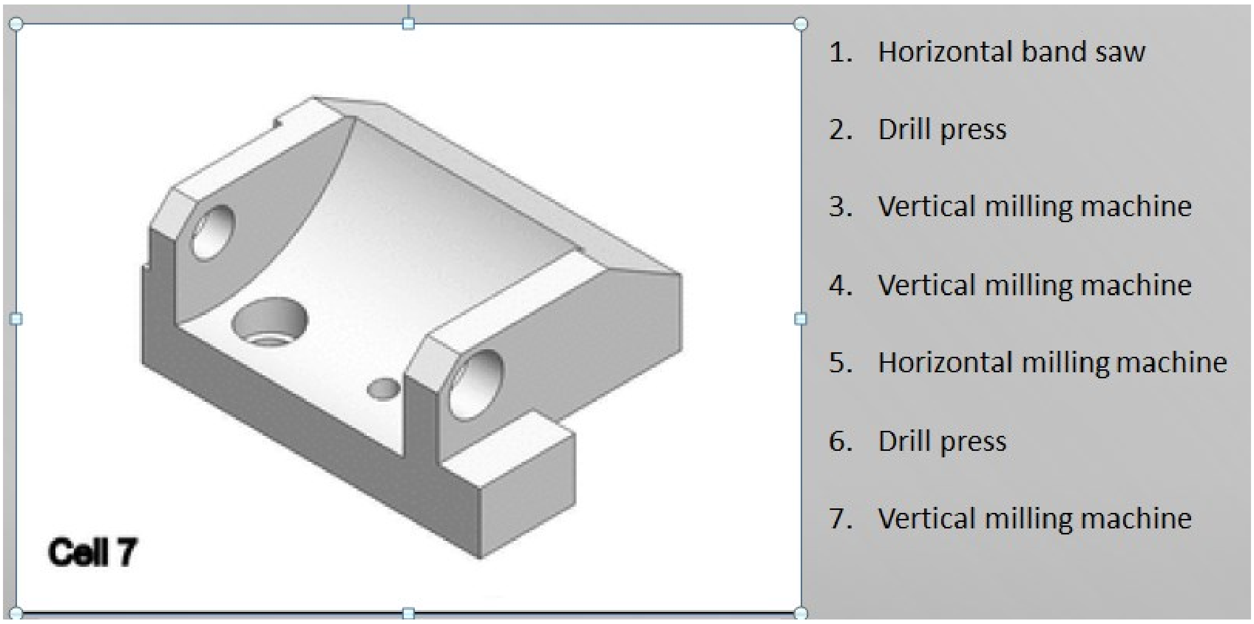

Figure 4: Hinge Block

The next step of the project is to develop a feasible layout options to produce the part. The various layout options are Figures 5, 6, and 7. The straight-line layout (option -1) as shown in Figure 5, is used because of the unidirectional process flow of the part. The parts are transported with 3 minutes transfer time using eight carts at one unit per minute. The simulation model using this layout proved to be marginally effective, producing an optimal output of 110 parts.

Order Release   Cell 1   Cell 2   Cell 3   Cell 4   Cell 5   Cell 6   Cell 7   Ship

→

Figure 5: Process flow (Option-1)

The above layout is rearranged into square shape (option -2) as shown in Figure 6. The simulation model for this layout did not prove to be advantageous due to the increased distance of the parts exit station back to the order release station.

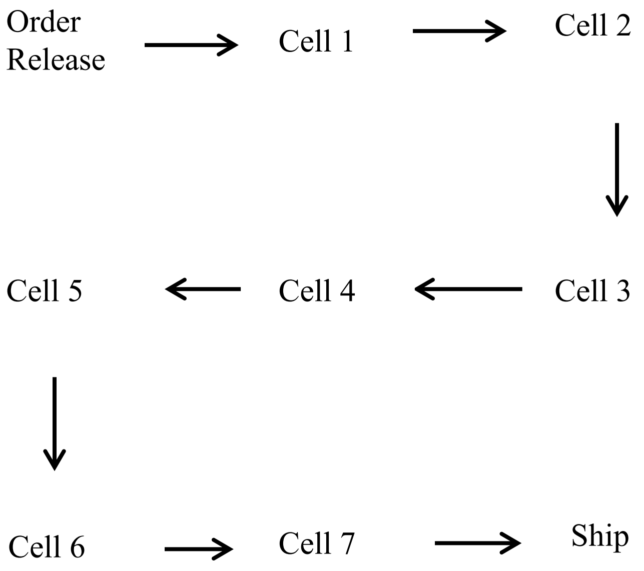

Figure 6: Process flow (Option-2)

Finally, a U-shaped layout (option -3) as shown in Figure 7 is developed in order to keep the order release station closest to the exit station. The simulation for this layout produced 122 parts output in the allotted simulation run time. The various "What-If" scenarios were analyzed for the cart speed and quantity in order to maximize the output. The cart scenario study findings are shown in Table 1.

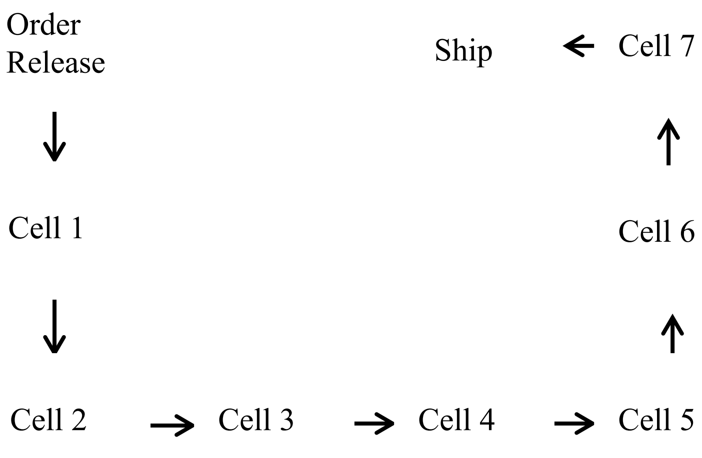

Figure 7: Process flow (Option-3)

Simulation Modeling

The simulation model was developed per process flow with given arrival and process times. The developed simulation model is shown in Figure 8. This model produced 111 parts for 2,000 minutes simulation time. The model animation is shown in Figure 9.

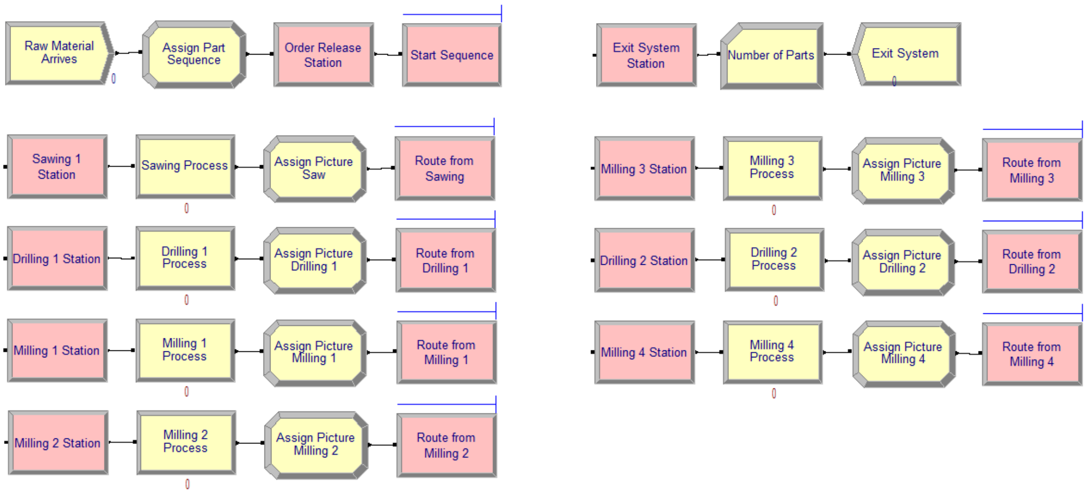

Figure 8: Simulation Model

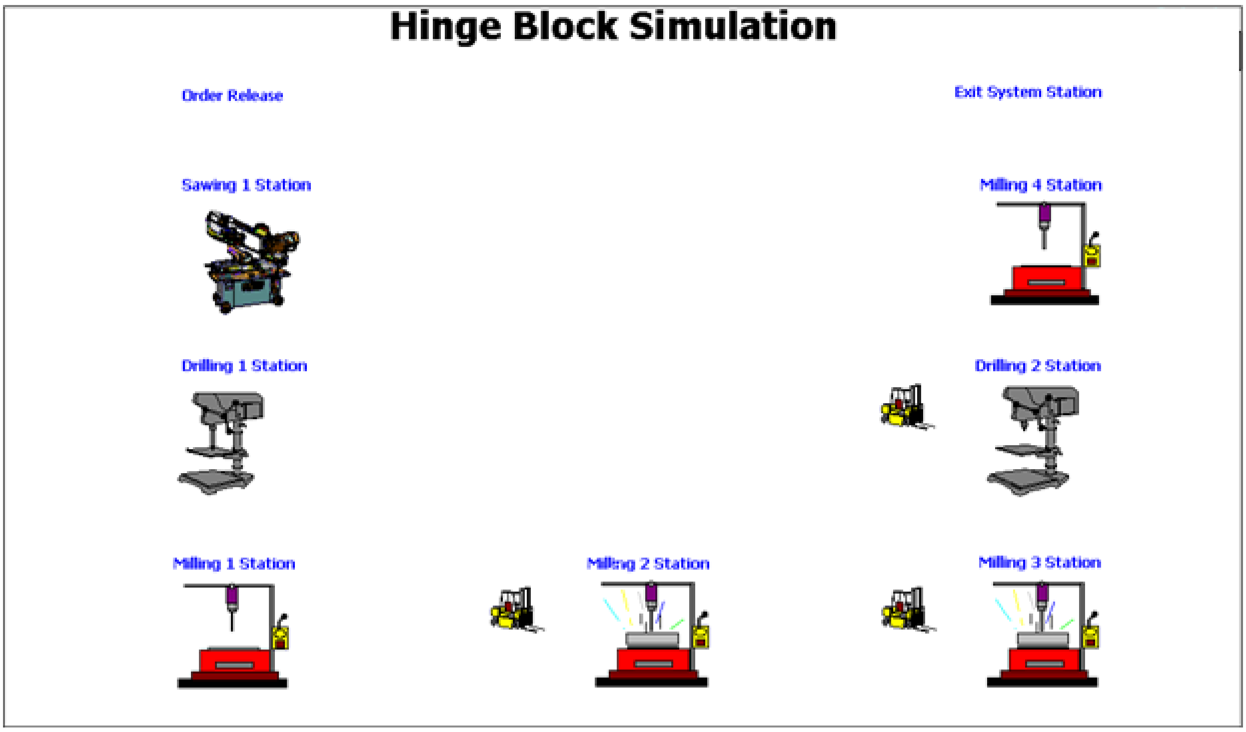

Figure 9: Model Animation

Improvement Plan

The Table 1 shows the effects of the number of carts, cart speed, and the output for the U-shaped layout with the optimal setup highlighted in bold yellow. The study revealed that it is not sufficient to stop the "What-If" analysis at this stage.

Table 1: Effects of carts and cart speed on output

Number of Carts	Speed (Units per Minute)	Output (Parts)
3	1	119
3	2	96
5	1	117
5	2	101
6	1	106
6	2	118
6	3	116
7	1	115
7	2	108
8	**1**	**122**
8	2	105
9	1	120

The team analyzed other improvement ideas to improve the throughput. Based on the team member's practical machining knowledge, the team challenged the given process time values given in the assignment. The team have determined the appropriate process times for producing the part. The revised process times based on machining data are shown in Figure 10. With the improved process times, the revised simulation model yielded 159 parts, an improvement of 43% throughput.

Revised times:

Sawing: Expo (2) minutes

Drilling 1: Expo (4) minutes

Milling 1: Expo (6) minutes

Milling 2: Expo (5) minutes

Milling 3: Expo (10) minutes

Drilling 2: Expo (3) minutes

Milling 4: Expo (4) minutes

Output: 159 parts

Figure 10: Revised process times

Results and Recommendations

The project team successfully developed the manufacturing layout, process times, sequence of operations for the given product sketch. The original simulation model produced 111 parts in 2,000 minutes based on the assumed process times. The revised simulation model based on various "What-If" scenarios study yielded 159 parts, an improvement of 43% throughput.

The following recommendations are suggested:

- Minimize transfer times based on time study
- Study the effect of using cart vs. conveyor on throughput
- Include 2nd and 3rd shift scheduling when demand grows
- Include failures for each machine based on uptime/down time data
- Combine processes to maximize profit
- Minimize the cost, maximize revenue and profit

In this team based project study, the student team was able to successfully apply the classroom learning tools such as, AutoCAD for drawing machine layout, Solid Works to develop product model in 3D, CamWorks to develop M & G codes for CNC machining and Arena simulation model for systems design and manufacturing throughput analysis. The team also revised the process times based on their machining and cutting tool knowledge. Based on the classroom survey, the students appreciated the team based project work since; it gave them overall confidence to deal with social, timing, cost, and personnel issues other than engineering function. This team based project work demonstrated that the graduating seniors were able to transform themselves to competent engineers and problem solvers in the real world. It was a shining moment for the students when they were praised by their peers and by the instructor during their class room presentation.

Acknowledgments

I would like to give my special thanks and appreciation for the reviewers for their constructive comments that helped me a lot to revise this paper.

References

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Biography

Annamalai Pandian is an assistant professor at University of Wisconsin-Stout. He received his B.E in Mech. Eng. Degree from University of Madras, Chennai, India, and M.S in Mech. Eng. Degree from Louisiana State University, Baton Rouge, LA, USA and D. Eng., in Manufacturing Systems Degree from Lawrence Technological University, Southfield, MI, USA. He has wide range of industrial experience in sheet metal stamping, robotic welding, automation, product design, project management, six sigma and lean manufacturing methods. He has very good working and certification knowledge on ISO 9000 standards and procedures. Previously, he worked in Advanced Manufacturing Engineering division in Chrysler LLC., Auburn Hills, MI, USA for 13+ years. He has wealth of experience in automotive tooling design and manufacturing. He has taught several design and manufacturing engineering courses including Jigs & Fixtures, Robotics & Machine Vision, Manufacturing Process Eng., and Manufacturing Systems Design and Simulation. Dr. Pandian's research interests include Metal forming, Simulation, DOE, Robotics, ARMA and ANN.