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Course Portfolio - Discrete Event Simulation

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Course Portfolio for

IMSE 440/840
Discrete-Event Computer Simulation

by

Dr. Paul Savory
Industrial and Management Systems Engineering
University of Nebraska-Lincoln

2009
Part 1: Goal of this Portfolio

I have two key objectives in writing this portfolio:

(1) to document my students’ learning and the effectiveness of my classroom approaches.

(2) to explore approaches for how best to present documentation of my teaching and how students are meeting my expectations.

Part 2: Introduction to my Course

2.1 Course Context

My course, IMSE 440/840 (Discrete-Event Simulation), is our department’s only required discrete-event simulation course for undergraduate students. This course is helpful to undergraduate students in that it allows them to combine and apply many of the concepts they have learned in other courses. For example, they use probability distributions for incorporating randomness into their models, use confidence intervals for evaluating results, they can easily test the impact of changing a facility layout, and they can explore opportunities for improving a system. This course is especially beneficial to graduate students. These students, who often have a mechanical engineering background where the focus is on improving a part or a machining process, develop a better understanding of how machines, people, and systems interact with one another and the ramifications for changes within it.

2.2 Course History

I have taught this course 19 times in the past 15 years. Upon my arrival at UNL in 1994, I started teaching the course using the SIMAN simulation language. My decision for this simulation language was based on factors such as availability, execution speed, and high industry use. In the subsequent years, many schools/industries went away from using simulation programming languages and started using integrated simulation environments called simulators. I steadfastly refused to teach simulators in this introductory course. The key reason for my stubbornness was that there are ten ways of modeling any situation using a simulation language. With a simulator, there are at most only one or two approaches. Thus, I would
rather teach my students the more general approach. In support of my decision, previous students demonstrated an ability to learn a simulator in one to two days after having learned SIMAN.

Despite my reluctance, given the advancement of computer processing speed and graphics, in 2003, I finally decided to start using an animation-based simulator called simul8. I reviewed all the available packages on the market (e.g., Arena, ProModel, AutoMod) and felt that this package was the best fit for my teaching. The unique thing about this package is that it easily allows a modeler to access a code/programming level to perform advanced programming within it. In addition, I gave serious consideration to where my students were getting jobs — many in Nebraska companies. These companies will pay $3,500 to $5,000 for a simulation program (simul8’s cost), but they will not pay the average $15,000 price for a more advanced program. I have now taught the course using simul8 on five occasions.

### 2.3 Course Goals

My objective in this course is to teach students how to develop discrete-event simulation models of manufacturing, healthcare, and service-oriented systems. Each semester I require that the students model 15 to 18 different real-world systems using simul8. The goal for each problem is to expand the critical thinking skills of the students by requiring them to apply the following general problem solving steps: (1) define the problem, (2) analyze the problem, (3) synthesize the concept, (4) develop alternatives and select one, (5) implement the solution, and (6) follow-up. In unison with the programming assignments are exams testing students on their basic understanding of discrete-event simulation concepts such as model formulation and accuracy verification. Additionally, students are required to complete a semester-long group project.

**Specific course topics and the level of coverage are:**

<table>
<thead>
<tr>
<th>Course Topic</th>
<th>Level of Topic Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploring the steps (and process) involved in a simulation project</td>
<td>Advanced</td>
</tr>
<tr>
<td>Building models and animations using the Simul8 simulation software</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Reviewing how a discrete-event calendar works for running a simulation model</td>
<td>Advanced</td>
</tr>
<tr>
<td>Discussing how random numbers are generated – uniform numbers and other stochastic distributions</td>
<td>Beginner</td>
</tr>
<tr>
<td>Collecting and computing of time-persistent and observation-based statistics</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Working on a team-based semester-long project</td>
<td>Advanced</td>
</tr>
<tr>
<td>Developing a professional project report</td>
<td>Advanced</td>
</tr>
<tr>
<td>Giving a professional presentation to an audience</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Critiquing how others answer questions and give presentations</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Modeling conveyors and transporters in Simul8 simulation software</td>
<td>Intermediate</td>
</tr>
</tbody>
</table>

Key questions students should be able to answer once finished with the course include:

1. How do I take a system description and create an animated simulation model for representing it?
2. What are the advantages and disadvantages of using simulation?
3. What type of problems are suited for simulation?
4. What is a definite overall approach for conducting a simulation study?
5. How do you decide on an appropriate level of model detail?
6. What do you do if there is no input data available?
7. How do you determine the correct length of a simulation run?
8. How are random numbers generated?
9. What are good strategies for answering a question and giving a presentation?

2.4 Student Demographics

My class typically ranges in size from 20 to 30 students. At least 75% are seniors in Industrial Engineering. This is a required course for them. The remainder are graduates students – most are industrial engineering students, with some from Civil Engineering.

2.5 Course Topics

To meet my courses objectives, the course is divided into several major themes:

<table>
<thead>
<tr>
<th>Topic</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is a Model?</td>
<td>Provide an understanding of how models describe a system, how different types of models exist and compare with one another, and introduce principles for developing a model.</td>
</tr>
<tr>
<td>What is Computer Simulation?</td>
<td>Provide an overview of computer simulation, a discussion on the goals/objectives of simulation, simulation uses and disadvantages, simulation components.</td>
</tr>
<tr>
<td>The Simulation Process</td>
<td>Provide an understanding of the steps involved in developing a simulation model in a specific language and validating the model.</td>
</tr>
</tbody>
</table>

In defining simulation, I place considerable emphasis on when to and not to use it. Specifically, I demonstrate that one approach to studying a system is to use analytical techniques (i.e., operations research techniques - linear programming, queueing theory, Markov chains, etc.) which seeks to get some unique and/or optimal solution of the variables. Unfortunately, many times a system has multiple attributes of interest, is highly complex, has processing times modeled by probability distributions, has different routings of parts, has limited queue capacity, and has multiple competition for limited resources. In such a case, mathematical modeling of the system may have no practical analytical or numeric solutions. In fact, analytical tools may be too complex or unavailable for modeling the system.

Given the diverse topics for the course, I do not use a textbook. Rather, the students purchase a course note packet I have developed over subsequent offerings of the course. The packet is 175 pages long.

[Click to view an outline of the major sections of the course note packet.]
Part 3: Course Activities

3.1 Teaching Format

As mentioned before, I do not require the students to purchase a textbook for the course. Rather, they purchase a course note packet I have developed over the years. This packet consists of a typed “shell” of my notes that integrates all examples combined with an outline of each lecture. In class, I complete and expand the discussion in the notes. The students appreciate this approach since by the end of a class period they have a complete set of notes which is superior to any textbook. Such an approach also offers the advantage that a greater depth and breadth of course material can be covered in a limited time. Sometimes I wonder if I am “spoon-feeding” the students, but I have only received praise from students for this presentation style. Click to see an example of the course note packet.

Within the notes, the missing blocks of text are what I would present in class.

3.2 Typical Class Day

On a typical day, I will first ask if there are any questions. After answering those, I will focus on the topic of the day. In terms of the course note packet, I will jump around a lot. One day might be focused on covering simul8 topics with my demonstrating software features using a computer/projector and doing examples in class. Another day might be talking though a large example (from my consulting work) or stepping through an example of how the event calendar works.

As I have taught more online/distance courses, my format for this course has changed. I have converted several of the more mundane topics into narrated PowerPoint presentations that the students now review outside of class. This frees more class time for questions and allows me to schedule class days in the computer lab where I can help students while they are working on their programming labs.

3.3 Course Website

For this course, I have developed an extensive website (on Blackboard) for posting of homework assignments, solutions, simul8 examples, narrated PowerPoint presentations, and practice problems for the exams. Click to see an outline of the key areas of the site and the content.

3.4 Point Breakdown

Class points are divided as follows:
- Labs = 20%
- Lowest Midterm Examination = 15%
- Highest Midterm Examination = 20%
- Final Examination = 25%
- Project = 20%

Click the below audio file to hear Dr. Savory talk about this point scale system.
### Weekly Lab Assignments

During the term, students complete 14 lab or homework assignments. The below table offers a description of each, how much each lab contributes to their lab grade, gives a link to a copy of the lab description, and a link to examples of student solutions for the lab:

<table>
<thead>
<tr>
<th>Lab</th>
<th>Overview/Objective/Description</th>
<th>Percent of Final Lab Grade</th>
<th>Link to Assignment</th>
<th>Link to Examples of Student Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab 1</td>
<td>Have students become aware of how assumptions can have a dramatic effect on the answers they derive. It is always fun to share with the class the range of student answers to each question</td>
<td>3.3%</td>
<td>Link to Lab 1</td>
<td>Link to Examples of Lab 1</td>
</tr>
<tr>
<td>Lab 2</td>
<td>Have student experience the challenge of offering estimates (budget, data, resources) to complete a project in which they know very little information</td>
<td>3.3%</td>
<td>Link to Lab 2</td>
<td>Link to Examples of Lab 2</td>
</tr>
<tr>
<td>Lab 3</td>
<td>Practice problems in which students, by hand or spreadsheet, calculate observation-based and time-persistent statistics</td>
<td>4.4%</td>
<td>Link to Lab 3</td>
<td>Link to Examples of Lab 3</td>
</tr>
<tr>
<td>Lab 4</td>
<td>Simul8 programming assignment – 4 programming problems for students to complete. The objective is to have students become familiar with the simul8 software interface and to provide them experience in building their first simul8 models and collecting system statistics.</td>
<td>11.0%</td>
<td>Link to Lab 4</td>
<td>Link to Examples of Lab 4</td>
</tr>
<tr>
<td>Lab 5</td>
<td>Since most of my students will be graduating in the coming year, I ask that students turn-in a professional resume. I offer my critique of it and suggestions for improving it.</td>
<td>2.2%</td>
<td>Link to Lab 5</td>
<td>Link to Examples of Lab 5</td>
</tr>
<tr>
<td>Lab 6</td>
<td>Simul8 programming assignment – 2 large programming problems to continue to build student skills in basic simul8 simulation models</td>
<td>11.0%</td>
<td>Link to Lab 6</td>
<td>Link to Examples of Lab 6</td>
</tr>
<tr>
<td>Lab 7</td>
<td>For this lab, students view a 70 minute online (narrated PowerPoint) presentation in which I discuss the steps/process of performing a simulation study. Once students view the presentation and reviewed their notes, they have to answer a series of review questions.</td>
<td>7.1%</td>
<td>Link to Lab 7</td>
<td>N/A</td>
</tr>
<tr>
<td>Lab 8</td>
<td>Simul8 programming assignment – 4 programming problems. This lab continues to help students building their skills in creating intermediate simul8 models (breakdowns, route-in, route-out, resources, shelf-life, interruptible work centers)</td>
<td>13.2%</td>
<td>Link to Lab 8</td>
<td>Link to Examples of Lab 8</td>
</tr>
<tr>
<td>Lab 9</td>
<td>This lab has students build upon the examples from class and complete an event calendar problem.</td>
<td>3.3%</td>
<td>Link to Lab 9</td>
<td>Link to Examples of Lab 9</td>
</tr>
<tr>
<td>Lab 10</td>
<td>Simul8 programming assignment – 3 programming problems. The focus of this lab is provide students experience using resources and modeling with visual logic</td>
<td>13.2%</td>
<td>Link to Lab 10</td>
<td>Link to Examples of Lab 10</td>
</tr>
<tr>
<td>Lab 11</td>
<td>For this lab, students watch a 45 minute online (narrated PowerPoint) presentation in which I discuss uniform random number generators and stochastic deviate generation (i.e., inverse transformation method). Once complete, students answer a series of online questions and complete a written assignment involving some simple random number generators.</td>
<td>6.0%</td>
<td>Link to Lab 11</td>
<td>Link to Examples of Lab 11</td>
</tr>
<tr>
<td>Lab 12</td>
<td>Student watch a 20 minute online (narrated PowerPoint) presentation in which I discuss the advantages and disadvantages of using animation for simulation. Once complete, students answer a series of questions.</td>
<td>2.7%</td>
<td>Link to Lab 12</td>
<td>N/A</td>
</tr>
<tr>
<td>Lab 13</td>
<td>Students watch a 30 minute online presentation (narrated PowerPoint) presentation in which I discuss approaches and techniques for validating and verifying simulation models. Once done, students answer a series of questions. In addition, I give them the description and 3 Simul8 simulation models (which have errors in them) and ask them to generate a list of all the errors they can find.</td>
<td>8.2%</td>
<td>Link to Lab 13</td>
<td>Link to Examples of Lab 13</td>
</tr>
<tr>
<td>Lab 14</td>
<td>Simul8 programming assignment – 3 programming problems. This lab seeks to have students continue to use Visual Logic and build models for systems with conveyors</td>
<td>11.0%</td>
<td>Link to Lab 14</td>
<td>Link to Examples of Lab 14</td>
</tr>
</tbody>
</table>

Students typically do well on the labs since I am available for questions and they discuss solutions and results among themselves. The below table shows that the final lab percentages for students range from a high of 96% to a low of 70%:

![Final Student Lab Percentages](chart.png)

**Comment:** The labs provide students the opportunity to learn the material. While the labs are a lot of work for the students, it is well worth it and the results can be seen when they take their exams. From my perspective, there is no easy way to grade them. Typically I have to set aside one afternoon per week for grading. Overall, I feel the labs are working well in the course.
3.6 Examinations

During the term, I administer three examination – two midterm exams and a final exam. All the exams are in the computer lab and focus on the student’s ability to read a description of a scenario and develop a simu8 model that models the description and collects the required statistics. Within each exam, I alternate between providing a picture of the scenario along with the description or just providing the description – this allows me to test a student’s ability to conceptualize a system.

EXAMINATION 1

<table>
<thead>
<tr>
<th>Exam 1</th>
<th>Link to Exam 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant items the exam tested</td>
<td></td>
</tr>
<tr>
<td>Batch output from a work arrival point</td>
<td></td>
</tr>
<tr>
<td>Route-out – label based, percent based, priority</td>
<td></td>
</tr>
<tr>
<td>Queue Capacity</td>
<td></td>
</tr>
<tr>
<td>Queue priority</td>
<td></td>
</tr>
<tr>
<td>Route-in priority</td>
<td></td>
</tr>
<tr>
<td>Travel time</td>
<td></td>
</tr>
<tr>
<td>Priority of work centers to one another</td>
<td></td>
</tr>
<tr>
<td>Conversion of units – hours to minutes and seconds to minutes</td>
<td></td>
</tr>
<tr>
<td>Changing label values</td>
<td></td>
</tr>
<tr>
<td>Rate versus means for time</td>
<td></td>
</tr>
<tr>
<td>Probability profiles</td>
<td></td>
</tr>
<tr>
<td>Label assignments for queue priority</td>
<td></td>
</tr>
<tr>
<td>Stop on limit, stop on clock</td>
<td></td>
</tr>
<tr>
<td>Output statistics</td>
<td></td>
</tr>
<tr>
<td>Confidence intervals</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grading sheet</th>
<th>Link to Grading Sheet for Exam 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examples of Exam 1</td>
<td>Link to Examples of Student Solutions to Exam 1</td>
</tr>
</tbody>
</table>

Examination 1 Results
### EXAMINATION 2

<table>
<thead>
<tr>
<th>Exam 2</th>
<th>Link to Exam 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Significant items the exam tested</strong></td>
<td></td>
</tr>
<tr>
<td>Converting arrival rate to time between arrival</td>
<td></td>
</tr>
<tr>
<td>Modeling shelf life for a queue</td>
<td></td>
</tr>
<tr>
<td>Probabilistic branching from a work center</td>
<td></td>
</tr>
<tr>
<td>Batching out from a work center</td>
<td></td>
</tr>
<tr>
<td>Assigning a unique label to identify an entity</td>
<td></td>
</tr>
<tr>
<td>Updating label values</td>
<td></td>
</tr>
<tr>
<td>Defining queue priority</td>
<td></td>
</tr>
<tr>
<td>Declaring replicated work centers</td>
<td></td>
</tr>
<tr>
<td>Modeling a work center breakdown (count based)</td>
<td></td>
</tr>
<tr>
<td>Collecting, matching items back together</td>
<td></td>
</tr>
<tr>
<td>Assigning processing time label</td>
<td></td>
</tr>
<tr>
<td>Modeling work center interrupt</td>
<td></td>
</tr>
<tr>
<td>Routing out based on label</td>
<td></td>
</tr>
<tr>
<td>Creating confidence internals</td>
<td></td>
</tr>
<tr>
<td>Logic of number of items processed</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grading sheet</th>
<th>Link to Grading Sheet for Exam 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examples of Exam 2</td>
<td>Link to Examples of Student Solutions to Exam 2</td>
</tr>
</tbody>
</table>

#### Examination 2 Results

![Bar chart showing examination results for Exam 2](chart.png)

**Student**

### EXAMINATION 3 (Final Exam)

<table>
<thead>
<tr>
<th>Exam 3</th>
<th>Link to Exam 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grading sheet</strong></td>
<td>Link to Grading Sheet for Exam 3</td>
</tr>
<tr>
<td><strong>Examples of Exam 2</strong></td>
<td>Link to Examples of Student Solutions to Exam 3</td>
</tr>
</tbody>
</table>

---

*Note: The chart is not shown in the text, but it is included in the image.*
Comment: The learning in this course occurs when students complete the labs. Unfortunately, due to the open nature of them, I have always been uncertain if a student’s work in the lab is their own effort. As such, my solution is to test student’s on their ability to develop a model doing the examination. The below table compares the examination percentage of each student to their lab percentage. In general, students typically do better on the examinations than the labs. Interestingly, Students 12 and 15 do much better on the exams than their labs. In comparison, Student 20 does exactly the same.
Semester-Long Simulation Project

For a semester project, I assign the students to teams and ask them to develop a simulation model of a real system. There are four key objectives for the project:

1. To have students apply course concepts in a real-world type of setting
2. To have students work in a group
3. To have students prepare a professional report
4. To have students make a formal class presentation

I offer them the following scenario:

Picture several years down the road....You have successfully passed IMSE 440/840 and have gone on to graduate. At graduation, a small simulation consulting company (having learned that you passed this class) hires you and your teammates as simulation consultants. Your first job is to perform a simulation study. Your deliverable to the client is a report and presentation for their system.

The choice of the system is up to the team, though I require that there be some defined objective for studying it and at least 5 sources of randomness. Click to see the project description.

To ensure that students work throughout the term on the project, it is divided into 7 separate tasks, each with a due date:

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1</td>
<td>Each team e-mails me a brief outline (maximum of one page) describing the system they want to model and indicating the modeling objective and the performance measures they want to obtain.</td>
<td>N/A</td>
</tr>
<tr>
<td>Task 2</td>
<td>Each team e-mails me an update on their project – what has been done and its current status. In general, I tell them that I expect three sections of their final report (Problems and Issues, System Description and Conceptual Model, and Input Data Collection) should be done. That is, the scope of the project should be defined and all data collection should be performed.</td>
<td>N/A</td>
</tr>
<tr>
<td>Task 3</td>
<td>Each team e-mails me an update on their project – what has been done and its current status. In general, I tell them that I would expect them have complete the Analysis of Results section of their final report. That is, developing the simulation model and writing the result analysis sections should now be complete.</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Task 4 | Each team turns in two printed copies of your draft project report – one of me to review and one for another team to review. | N/A
---|---|---
Task 5 | I have each team review the draft final report of another team and offer comment/feedback on their simulation analysis and report format. Each team returns a project report evaluation form to me. | Link to project report rubric
Task 6 | In class, each team gives a 10 minute presentation of their project - their objectives, the system they studied, their analysis, and their conclusions. I use a grading rubric for their presentation. | Link to presentation evaluation rubric
| | | Link to Example 1 of student presentation
| | | Link to Example 2 of student presentation
Task 7 | Each team turns in a final copy of their project report for grading. In addition, each team member has to turn in a self-evaluation of their performance on the team and an evaluation of each of their team members | Link to self-evaluation form
| | | Link to team-member evaluation form

**Comment:** The below table shows the distribution of grades among the three major components of the project – project report, project presentation, and team member assessment. Note: the number in the table is 17 (versus 20) due to one team of three students requiring extra time to finish due to the illness of a team member. For the extra time, I required them to expand their analysis as compared to the remainder of the class.

One can see that Students 4, 12, and 15 were on one team. There report was okay, their presentation was average, and their assessment of each other was high. Similarly, Students 9, 16, and 17 were another team. Their report was very good, the presentation was okay, and they assessed each other as good.

Click the below audio file to hear Dr. Savory talk about the challenges with this course project

![Audio Player]

**Project Results for Each Student**

<table>
<thead>
<tr>
<th>Student</th>
<th>Project Report</th>
<th>Project Presentation</th>
<th>Team Member Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80%</td>
<td>70%</td>
<td>100%</td>
</tr>
<tr>
<td>2</td>
<td>90%</td>
<td>80%</td>
<td>90%</td>
</tr>
<tr>
<td>3</td>
<td>70%</td>
<td>60%</td>
<td>80%</td>
</tr>
<tr>
<td>4</td>
<td>100%</td>
<td>90%</td>
<td>100%</td>
</tr>
<tr>
<td>5</td>
<td>80%</td>
<td>70%</td>
<td>90%</td>
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<tr>
<td>6</td>
<td>90%</td>
<td>80%</td>
<td>90%</td>
</tr>
<tr>
<td>7</td>
<td>70%</td>
<td>60%</td>
<td>70%</td>
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<tr>
<td>8</td>
<td>100%</td>
<td>90%</td>
<td>100%</td>
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<tr>
<td>9</td>
<td>80%</td>
<td>70%</td>
<td>90%</td>
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<tr>
<td>10</td>
<td>90%</td>
<td>80%</td>
<td>90%</td>
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<tr>
<td>11</td>
<td>70%</td>
<td>60%</td>
<td>70%</td>
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<tr>
<td>12</td>
<td>100%</td>
<td>90%</td>
<td>100%</td>
</tr>
<tr>
<td>13</td>
<td>80%</td>
<td>70%</td>
<td>90%</td>
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<tr>
<td>14</td>
<td>90%</td>
<td>80%</td>
<td>90%</td>
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<tr>
<td>15</td>
<td>70%</td>
<td>60%</td>
<td>70%</td>
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<tr>
<td>16</td>
<td>100%</td>
<td>90%</td>
<td>100%</td>
</tr>
<tr>
<td>17</td>
<td>80%</td>
<td>70%</td>
<td>90%</td>
</tr>
</tbody>
</table>

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Click the below audio file to hear Dr. Savory talk about the challenges with this course project
4.1 Student Pre- and Post-Assessment of their Learning

To collect student’s perceptions of their learning and my achieving the course goals, a pre/post assessment was administered. In response to each question, a student used the scale:

**Little or No Experience → Beginner Level → Intermediate Level → Advanced Level → Expert Level**

**QUESTION:** Rate your ability for understanding and following the steps (and process) involved in performing a simulation project

Comment: In the syllabus I say the level of coverage would be **Advanced**. Student perceive a large increase in their knowledge with many indicating an Advanced level of understanding at the end of the term. Based on their success with the project and having to apply each of the steps, I would concur that students achieved an Advanced level of understanding.

**QUESTION:** Rate your ability for building models and animations using the Simul8 simulation software

Comment: In the syllabus I said the level of coverage would be **Intermediate**. All students indicate large improvement with most considering themselves at the Intermediate level and a majority considering themselves Advanced or above. I would rate the students at achieving an Intermediate level. The reason they consider themselves Advanced is that they are able to program all of the scenarios I provided to them, but they did not realize that I did not ask them to program things I knew they couldn’t do based on their level of Simul8 knowledge.
QUESTION: Rate your ability for understanding how a discrete-event simulation calendar works for running a simulation model

Comment: In the syllabus I said the level of coverage would be Advanced. There is a large shift in students’ perceptions, with a majority matching my desired Advanced level, but a strong minority indicate only intermediate levels of ability by the end of the term. Given the class’s success on Lab 9 and on one of the questions in Exam 2, I believe most students are at an Advanced level.

QUESTION: Rate your ability for knowing how random numbers are generated – uniform numbers and other stochastic distributions

Comment: In the syllabus I said the level of coverage would be Beginner. Interestingly, students indicate starting the class at a beginner level. I would assume this is a result of their exposure to randomness in their introductory probability and statistics course. All student indicate improvement. While some students claim Advanced knowledge, this is certainly not the case. These students possibly mastered what we covered in class, but this is but a small subset of the vast field of random number generation (developing generators, testing them, etc.)
QUESTION: Rate your ability for collecting and computing time-persistent and observation-based statistics

Comment: In the syllabus I said the level of coverage would be Intermediate. I am very surprised at the high-level of responses for the beginning of the term. These are topics not taught in any other course and my guess is that students initially confused these titles with other data collection techniques (e.g., time study) they know. The end of the term data does show improvement and shows that all students feel they are at an Intermediate level of knowledge. Based on their performance on Lab 3, I would concur.

QUESTION: Rate your ability for working in a semester team-based group project

Comment: In the syllabus I said the level of coverage would be Advanced. Given this is a senior-level class, I am happy to see that at the beginning of the term students indicated a high ability. As a result of the course, they indicate additional capabilities. While I think the student’s worked well as teams, I am unsure now of whether Advanced is a realistic goal or one that they achieved.
QUESTION: Rate your ability for writing a project report

Comment: In the syllabus I said the level of coverage would be Advanced. A majority of students indicate an Intermediate level of ability at the beginning of the term. By the end of the term, all students indicate improvement. Given the project report was a collaborative group effort and went through two revision cycles (another team reviewing and my reviewing), the final reports were good. On reflection, I think Advanced is too high of a level to achieve in a single semester and will consider reducing this goal to Intermediate.

QUESTION: Rate your ability for giving a presentation to an audience

Comment: In the syllabus I said the level of coverage would be Intermediate. Surprisingly, there is not a lot of change. Most students start the term at a high level. The only shift appears to be those that considered themselves at the Beginner level moving to the Intermediate level by the end of the term. Only a small group of students consider themselves at less than my planned Intermediate level. Interestingly, the students thought they did better at their presentation that I graded them. The challenge I face is how to give them more experience in giving presentations when we are already stretched for available time in the course.
QUESTION: Rate your ability for critiquing or assessing a presentation given by another person

![Student Responses](image)

**Comment:** In the syllabus I said the level of coverage would be **Intermediate**. Again, students' perceptions of their skills were high at the beginning of the term. At the end of the term, all students indicate being at an **Intermediate** level. Since this was a topic we talked about a lot throughout the term, I am surprised at the number of students at the end of the term who indicate only an **Intermediate** level versus a higher level. As I reflect upon it, it is hard for students to offer honest critiques of presentations for their peers. While they might not have demonstrated it in class, I am certain that all are well versed in offering constructive criticism.

### 4.2 Final Course Grade

The following table shows the final student course percentage and course grade:

![Student Final Course Percentage and Grade](image)

**Comment:** In general, students do well in this course. The course GPA is a 3.55/4.00. While at first glance that might be high, one has to consider the context of the course. This course is for seniors (or graduate students) in Industrial Engineering and given its role in helping them apply many theoretical concepts they have learned over the years, students actually are energized by the course and the material – it is “fun” for some. Adding to this is my approach of having weekly assignments to develop their knowledge. As a result, a student either learns the material or does not. Even the one student who earned a C still has a basic understanding of the material.
4.3 Student Evaluations

At the end of the term, our college asks students to complete and assess their learning in a course. The form is divided into four sections:

- Questions relating to the student’s own interest and motivation
- Questions relating to the course
- Questions relating to the course mechanics
- Questions relating to the instructor

Here is an overview of the results for the questions:

![Course Evaluation Chart]

Here is the detailed student response for each question:

<table>
<thead>
<tr>
<th>Question</th>
<th>Student Response</th>
<th>Average Student Response (scale 1 to 5, higher = better)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I see myself as a motivated student in this course</td>
<td>4.43</td>
</tr>
<tr>
<td>2</td>
<td>I was academically prepared to take this course</td>
<td>4.64</td>
</tr>
<tr>
<td>3</td>
<td>I was challenged to think in this course</td>
<td>4.57</td>
</tr>
<tr>
<td>4</td>
<td>My course grade will be a fair representation of my learning.</td>
<td>4.14</td>
</tr>
<tr>
<td>5</td>
<td>Before taking this course, my interest in this subject was very high</td>
<td>4.31</td>
</tr>
<tr>
<td>6</td>
<td>I understand the objectives of this course.</td>
<td>4.50</td>
</tr>
<tr>
<td>7</td>
<td>The organization of the course topics is reasonable and logical.</td>
<td>4.50</td>
</tr>
<tr>
<td>8</td>
<td>The pace at which course topics are covered is reasonable</td>
<td>4.50</td>
</tr>
<tr>
<td>9</td>
<td>This course helped me improve my rational thinking, problem solving and decision making ability</td>
<td>4.43</td>
</tr>
<tr>
<td>10</td>
<td>After taking this course, my interest in this subject is very high.</td>
<td>4.36</td>
</tr>
<tr>
<td>Questions relating to Course Mechanics</td>
<td></td>
<td>Comments</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-----------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>11 The textbook, workbook, and/or lesson notes help me understand course materials</td>
<td>4.50</td>
<td>Interestingly, the response to Question 4 shows that even students who are getting lower grades (e.g., B or C) feel they have put in a significant time commitment to the course and should have earned a higher grade. Question 23 is one I was particularly concerned with for this term. Given my administrative roles at the university, I was not available much outside of class. To supplement this, I made a significant effort to respond promptly and in detail to all student phone calls and/or e-mail messages. It appears that the students did not notice a drop in my accessibility.</td>
</tr>
<tr>
<td>12 The method (or methods) of presenting information in class enhances my learning</td>
<td>4.43</td>
<td></td>
</tr>
<tr>
<td>13 The coursework helps me understand and apply the subject matter.</td>
<td>4.64</td>
<td></td>
</tr>
<tr>
<td>14 The amount of coursework is reasonable for what I am expected to learn</td>
<td>4.57</td>
<td></td>
</tr>
<tr>
<td>15 Testing methods fairly measure my understanding of the course material</td>
<td>4.36</td>
<td></td>
</tr>
</tbody>
</table>

| Questions Relating to the Instructor | | |
|-------------------------------------|-----------------------------------------------|
| 16 The instructor is prepared for the class and is concerned about his or her preparation | 4.79 | |
| 17 The instructor makes good use of class time. | 4.86 | |
| 18 The instructor is enthusiastic and interested in teaching this course. | 4.71 | |
| 19 The instructor treats students in a professional manner. | 4.79 | |
| 20 New concepts and examples are clearly explained at a level students can comprehend | 4.57 | |
| 21 The instructor motivated me to understand and apply course concepts | 4.57 | |
| 22 The instructor provides useful feedback on how I am doing in the course | 4.71 | |
| 23 The instructor is accessible for help outside of the classroom. | 4.64 | |
Having taught this course for so many years, it is helpful to compare the historical student evaluation of my instruction with that of the department. Starting in 1999, this number is calculated as an average of Questions 16 to 23 (questions regarding instruction). Prior to 1999, students were asked a single question asking them to “Grade” the instructor.

**Comment:** Overall, this class has been my passion – it is the one course that directly links my research with my teaching. Does this mean that I place more emphasis on this course than my other courses? I don’t think so and my teacher evaluation numbers for other courses (not included in this portfolio) would demonstrate this. Where I do think that it does impact it is in my passion for the topic and ability to “off the cuff” bring in examples from my consulting and research that engage students.
Part 5: Reflection on the Course Development Process

I have always been proud of this course and what I have developed. Creating this portfolio has helped me to explore the larger (and more important) perspective of whether the course has impacted student learning. *Does it impact learning?* I think the answer is yes. Could I do better – possibly. The portfolio provides me a solid foundation from which to continue to explore changes and measure their impact on student understanding and preparedness for a career as an industrial engineer.
Module A: Introduction to Simulation
- What is a Model?
- Classifications of Models
- What is Computer Simulation?
- Goals of Simulation Modeling
- When Should Simulation Be Used?
- Simulation Drawback

Module B: Discrete-Event Simulation
- Components of a Discrete-Event Simulation Model
- Types of Statistics (observation-based versus time-persistent)
  - Examples B1 and B2

Module C: Simulation Event Calendar
- Event Calendar
- How discrete-event simulation works with an event calendar
  - Examples C1 to C8

Module D: The Simulation Process
- Step 1: Problem Definition
- Step 2: Project Planning
- Step 3: System Definition
- Step 4: Conceptual Model Formulation
- Step 5: Preliminary Experimental Design
- Step 6: Input Data Preparation
- Step 7: Validation
- Step 8: Model Translation
- Step 9: Verification
- Step 10: Pilot Runs
- Step 11: Validation
- Step 12: Final Experimental Design
  - Terminating Systems - Length Of Each Simulation Run
  - Terminating Systems - Initial Conditions
  - Terminating Systems - Number Of Simulation Runs
- Step 13: Make Production Runs
- Step 14: Output Data Analysis
  - Interpreting A Confidence Interval
- Step 15: Documentation, Presentation, And Implementation

Module E: Random Number Generation
- Uniform Random Numbers
  - Numbers And Why Are They Important?
  - Why Generate Random Numbers?
Outline of the Major Sections of Course Note Packet

- Numerical Schemes for Generating U(0,1)
- The Midsquare Method
- Additive Congruential and Fibonacci Generators
- How Computers Represent Numbers
- Linear Congruential Generators
- Let’s look at a Poor Linear Congruential Random Number Generator
- Who Uses What?
- Selecting a Good Generator

- Stochastic Deviate Generations
  - Generating Samples from Distributions
  - Continuous Distributions
  - Continuous Distributions - Inverse Transform
  - Inverse Transformation and Discrete Distributions
  - Standard Normal Distribution

- Examples E1 to E4

Module F: Animation

- Purpose of Animation
- Disadvantages of Animation
- Major Benefits of Animation
- Things to Avoid with Animation

Module G: Verification and Validation

- Validation of a Simulation Model
- Verification of a Simulation Model

Module H: Job Interviewing

- Selling Yourself With Your Resume
  - Important Areas/Topics for Your Resume
  - Resume Writing Tips
  - Action Verbs Make a Difference
  - More Do’s and Don’ts for Resumes
  - Example of How to Write Your Work Experience
  - Example Parts of Resumes
- Cover Letters
  - Components of a Cover Letter
- Thank You Letter
- The Interview
  - Interviewing Tips
  - Potential Interview Questions
  - Stressful Interview Questions
  - Potential Questions for You to Ask Them

- Examples G1 to G8
Module I: Simul8 Simulation Software

- What Is Simul8?
- Sources For Help
- Simul8 Interface
- Run Speed
- File Menu
- Edit Menu
- Help Menu
- Basic Building Blocks
- Work Entry Points
  - Work Entry Menu Parameters
  - Ignore Hints About Lost Work Items
  - Batching
  - Label Action
  - Routing-Out
  - Graphics
- Storage Bins
  - Storage Bin Menu Options
  - Start-Up
  - Contents
  - Cascading Queues
- Work Center – Part 1
  - Work Center Options
  - Work Center Exit Points
- Work Exit Point Options
- Clock Properties
  - Key Clock Menu Options
- Objects Menu
  - Viewing Object Results
- Confidence Intervals
- Graphics Menu
- Custom Distributions
- Labels
  - Modifying A Label’s Value
  - System Labels
- Work Center – Part 2: Breakdowns
  - Auto Efficiency
  - Detailed Efficiency
- Work Center – Part 3 [Route-Out]
  - Route-Out Options
  - Travel Time
- Work Center – Part 4 [Route-In: Selection Method]
  - Selection Method Tab
- Work Center – Part 5 [Route-In: Options Tab]
Outline of the Major Sections of Course Note Packet

- Options Tab Options
- Work Center – *Part 6 [Route-In: Change-Over Tab]*
  - Changeover Tab Options
- Resources Block
  - Resources Options
  - Requiring Resources At A Work Center
  - Requiring Resources For A Repair Operation
  - Resource Travel Times
  - Shift Patterns
  - Shift Availability
- Debugging Your Model
  - Common Simul8 Errors
  - Tools To Help You
- Global Variables – Simul8 Information Store
- Visual Logic
- Modeling A Material Handling System with Conveyors
  - *Examples F1 to F32*
COURSE INFORMATION

Fall 2008 Course Syllabus
Fall 2008 - Course Notes

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Lab 2
Lab 2 Description
Lab 3
Lab 3 Description
Lab 3 Solution
Lab 4
Lab 4 Description
Lab 4 Solution - Problem 1
Lab 4 Solution - Problem 2
Lab 4 Solution - Problem 3
Lab 4 Solution - Problem 4
Lab 5
Lab 5 Description
Lab 6
Lab 6 Description
Lab 6 Solution - Problem 1
Lab 6 Solution - Problem 2
Lab 7
Online Lecture Module: Simulation Process
Lab 7 (Quiz on Material)
Lab 8
Lab 8 Description
Lab 8 - Solution - Problem 1
Lab 8 - Solution - Problem 2
Lab 8 - Solution - Problem 3
Lab 8 - Solution - Problem 4
Lab 9
Lab 9 Description
Lab 9 Solution
Lab 10
Lab 10 Description
Lab 10 - Solution - Problem 1
Lab 10 - Solution - Problem 2
Lab 10 - Solution - Problem 3
Lab 11
Online lecture Module: Random Number Generation
Lab 11 - Part 1 (online questions)
Lab 11 - Part 2 - Description
Lab 11 - Part 2 - Turn in

Lab 12
Online Lecture Module: Animation
Lab 12 - online questions

Lab 13
Online lecture module: Verification and Validation
Lab 13 - Part 1 (online questions)
Lab 13 - Part 2 - Description and Models
Lab 13 - part 2 - turn in
Lab 13 - Solution to simul8 model errors

Lab 14
Lab 14 Description
Lab 14 - Solution - Problem 1
Lab 14 - Solution - Problem 2
Lab 14 - Solution - Problem 3

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Additional Practice for Exam 1
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Set 1 Solution - Problem 2
Set 1 Solution - Problem 3

Examination 1
Exam 1 - Solution

Additional Practice for Exam 2
Set 2 Solution - Problem 1
Set 2 Solution - Problem 2
Set 2 Solution - Problem 3

Examination 2
Exam 1 - Solution

Additional Practice for Exam 3
Set 3 Solution - Problem 1
Set 3 Solution - Problem 2
Set 3 Solution - Problem 3

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Simul8 Example F10
Simul8 Example F11
Simul8 Example F12
Simul8 Example F13
Simul8 Example F14
Simul8 Example F15
Simul8 Example F16
Simul8 Example F17
Simul8 Example F18
Simul8 Example F19
Simul8 Example F20
Outline of Course Website - Areas and Content

Simul8 Example F21
Simul8 Example F22
Simul8 Example F23
Simul8 Example F24
Simul8 Example F25
Simul8 Example F26
“If you want to understand some aspect of the Universe, it helps if you simplify it as much as possible and include only those properties and characteristics that are essential to understanding. If you want to determine how an object drops, you don’t concern yourself with whether it is new or old, is red of green, or has on odor or not. You eliminate those things and thus do not needlessly complicate matters. The simplification you call a model or a simulation and you can present it either as an actual representation on a computer screen or as a mathematical relationship. ... Such simplified simulation make it far easier to grasp a phenomenon than it would be if we had to study the phenomenon itself.”

Hari Seldon, mathematician
(Asimov, 1988, p. 138)

What is a Model?

Before we can define what simulation is, we first need to understand the concepts of a model. A model is...

FYI - Laws

_Berra's Law:_ You can observe a lot just by watching.
_Billing’s Law:_ Live within your income, even if you have to borrow to do so.
_Billing’s Phenomenon:_ The conclusions of most good operations research studies are obvious.
_Bolton’s Law Of Ascending Budgets:_ Under current practices, both expenditures and revenues rise to meet each other, no matter which one may be in excess.
_Bonafede's Revelation:_ The conventional wisdom is that power is an aphrodisiac. In truth, it's exhausting.
Consider the following uses of a model:

Modeling is not new; mankind has been conceptualizing and developing models since he began to understand and manipulate his environment. The concept of representing some objects, system, or idea with a model, is so general that it is difficult to classify all the functions models fulfill. There are at least five common uses for models:

- 
- 
- 
- 
- 

A model may either be descriptive or prescriptive. A **descriptive** model is useful for explaining and/or understanding while a **prescriptive** model predicts and/or duplicates a systems behavior and characteristics.

### Classification of Model

There are many methods for classifying models, unfortunately none is completely satisfactory. Some of the more common classification schemes are as follows:

- discrete versus continuous
Models can also be classified based on whether they are physical or mathematical:

- **Physical**
  - Static
  - Dynamic

- **Mathematical**
  - Static
  - Dynamic
    - Analytic
    - Numeric
      - Computer Simulation

A model is said to be a **physical model** whenever the modeling representation is physical and tangible, with model elements made of material and hardware. Correspondingly, a model is said to be a **mathematical model** when a set of mathematical or logical relations are used to describe a system. A second distinction is between **static** models and **dynamic** models. In the case of mathematical models, a third distinction is the technique employed in solving the model. Specifically, a distinction is made between **analytic** and **numeric** methods.
Another way of seeing this is to view types of models using a continuous spectrum...

<table>
<thead>
<tr>
<th>Physical Models</th>
<th>Scaled Models</th>
<th>Analog Models</th>
<th>Management Games</th>
<th>Computer Simulation</th>
<th>Math Models</th>
</tr>
</thead>
</table>

**Exactness**

The spectrum goes from exact physical models or prototypes which are...

and proceeds to completely abstract mathematical models (analytical or heuristic).

---

**What is Computer Simulation?**

What is computer simulation?

---

**Goals of Simulation Modeling**

There are three major goals or objectives for a simulation study:

- prediction -
- scheduling alternatives -
- optimization -
Specifically,

<table>
<thead>
<tr>
<th>Model</th>
<th>Type</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictive Models</td>
<td></td>
<td>job volume, effect of hot jobs, bottleneck resources, breakdown effects, product quality, and absenteeism effect</td>
</tr>
<tr>
<td>Scheduling Alternative</td>
<td></td>
<td>product mix, sequencing alternatives and push versus pull inventory systems</td>
</tr>
<tr>
<td>Optimization</td>
<td>Fixed Shop Structure</td>
<td>lot size verses setup time, utilization verses cycle time, minimization of buffer stocks, minimization of work-in-process, and input data accuracy and sensitivity for fine tuning of the model</td>
</tr>
<tr>
<td></td>
<td>Optimize Structure</td>
<td>optimizing work station layout, optimizing use of material handling equipment, optimizing physical work-in-process areas, optimizing the use of secondary resources and the general layout of the facility</td>
</tr>
</tbody>
</table>

To measure the effectiveness in meeting the modeling objective, the system must be measured. Common measures of performance used in manufacturing simulation studies must be included:

- Throughput (number of parts produced per unit of time)
- Time parts spend in queues
- Time parts spend being transported
- Time parts spend in the manufacturing system
- Sizes of in-process inventories
- Utilization of equipment and personnel
- Proportion of time that a machine is broken, blocked, or starved
- Proportion of parts which must be reworked or scrapped
- Return on investment for a new or modified manufacturing system

Although not exhaustive, this list indicates the most common measures of performances.

---

**When Should Simulation Be Used?**

**BEWARE!** Computer simulation is an expensive and complicated process and should be used only under the following circumstances:

- 
- 
- 
- 
-
Lab Objectives: As engineers, you need to be aware that the assumptions you make have a dramatic effect on the answers you derive.

★★★ This is an individual homework assignment ★★★

COMPLETE THIS FORM, SAVE IT, and THEN SUBMIT VIA Blackboard

PROBLEM 1

For next year’s summer vacation you have decided to walk to Disneyworld in Orland, FL (since you summer internship with them). Assuming you start walking at 8 am on May 15, 2008, what day/time will you arrive to start working?

For this problem:

(a) identify your objective

(b) determine what data you need

(c) list any assumptions you make

(d) showing your work – develop your best answer to this question.

PROBLEM 2

How much would it cost to complete cover the outside/exterior of Oldfather Hall in duct tape?

For this problem:

(a) identify your objective

(b) determine what data you need

(c) list any assumptions you make

(d) showing your work – develop your best answer to this question.
PROBLEM 3

How many pennys would be needed if your want to lay a row of them (laying flat and touching each other) from the front door to the IMSE department to the front door of the Sears Tower in Chicago?

For this problem:

(a) identify your objective

(b) determine what data you need

(c) list any assumptions you make

(d) showing your work – develop your best answer to this question.
Lab 1 - Example of Student Solution

IMSE 440/840 – Lab #1

Due: Wed, August 27th (by midnight)

| Lab Objectives | As engineers, you need to be aware that the assumptions you make have a dramatic effect on the answers you derive. |

★★★ This is an individual homework assignment ★★★

COMPLETE THIS FORM, SAVE IT, and THEN SUBMIT VIA Blackboard

PROBLEM 1

For next year’s summer vacation you have decided to walk to Disneyworld in Orlando, FL (since you have a summer internship with them). Assuming you start walking at 8 am on May 15, 2009, what day/time will you arrive to start working? For this problem:

(a) identify your objective

Need to calculate what day/time I would arrive at Disneyworld if I walked the whole way starting at 8 am on May 15, 2009

(b) determine what data you need

I need to know the distance to Disneyworld, the exact starting and stopping points, the pace I will be using, the number of hours a day I will walk, how many days a week I will walk, if I will walk on the roads or take a straight azimuth and if I will carry my luggage or mail it ahead. I also need to know what time I will start every morning.

(c) list any assumptions you make

I will walk on the roads, eight hours a day, seven days a week, leaving from my house and arriving at Disneyworld's parking lot. I will walk a 17 minute mile and have mailed my luggage before I leave Lincoln. I will begin walking at 8 am local time everyday.

(d) showing your work – develop your best answer to this question.

Google Map lists the distance to be 1442 miles. If it takes me 17 minutes to walk a mile, I will need to walk 24,514 minutes, or 408.6 hours. And since I am only walking eight hours a day, it will take me 51.1 days to get there. Therefore, if I left May 15 at 8 am, I will arrive at Disneyworld on July 4th at 9:48 am. (including an hour for the time change)

PROBLEM 2

How much would it cost to completely cover the outside/exterior of Oldfather Hall in duct tape? For this problem:

(a) identify your objective

I need to find the cost of covering the exterior of Oldfather Hall in duct tape
(b) determine what data you need
I need to know the exterior dimensions of Oldfather Hall, the width of the duct tape, the length of the duct tape roll, the cost per roll, the number of rolls it would take, and if I have to pay the workers to complete this task, I need to know their hourly rate, how long the job will take, and supplies/equipment they would need. (i.e ladders, scaffolding) I would also need to know if the tape has to follow the building contours, or can it go over depressions in the building.

(c) list any assumptions you make
The building is assumed to be 500' long x 100' wide x 200' high. The tape comes in 100 ft roles and is 3 inches wide. It cost $5 per roll. And all labor and equipment is being volunteered by the professors from the college of engineering. It is also assumed that there is no overlap of tape and the tape does not need to follow the contours of the building.

(d) showing your work – develop your best answer to this question.

200' = 2400 inches  
500' = 6000 inches  
2400"/3" = 800 rolls are needed for the front of the building and another 800 rolls for the rear of the building.  
2*800 = 1600 rolls

Then the sides of the buildings are 5 times longer than the width, therefore, 5*800 = 4000 (4000 rolls) * (2 sides) = 8000 rolls.

Then the roof will be: 6000"/3" = 2000 rolls

The total rolls are:
1600 + 8000 + 2000 = 11,600 rolls.

The total cost will be (11,600 rolls) * (5 $/roll) = $58,000

PROBLEM 3

How many pennies are needed if your want to lay a row of them (laying flat and touching each other) from the front door to the IMSE department to the front door of the Sears Tower in Chicago? For this problem:

(a) identify your objective
Need to know how many pennies are needed to go from the front door of the IMSE department to the front door of the Sears Tower

(b) determine what data you need
I need to know the width of a penny, if I am going by the roads are using a straight azimuth to the final destination, where the starting point is on the door way (either on the side or the center), and the distance from the IMSE front door to the door of Nebraska Hall. I need to select which door of Nebraska Hall I will use.

(c) list any assumptions you make
The width of a penny is 3/4 inch. I will follow the roads. I will start in the center of the doorway. I am assuming the distance from the IMSE front door to the closest door of Nebraska Hall is 75 feet. I am also assuming the distance given to me from Google Map is starting at the door I selected and ending at the front door of the Sears Tower.

(d) showing your work – develop your best answer to this question.
Google Map lists the distance from Nebraska Hall to Sears Tower is 523 miles.

$$5,280 \text{ feet} = 1 \text{ mile}$$

$$523 \text{ miles} \times \frac{5280 \text{ feet}}{1 \text{ mile}} \times \frac{12 \text{ inches}}{1 \text{ ft}} \times \frac{1 \text{ penny}}{0.75 \text{ inch}} = 44,183,040 \text{ pennies}$$

We need to add the pennies in the 75 feet from the IMSE front door to the door leading out of Nebraska Hall.

$$75 \text{ ft} \times \frac{12 \text{ in}}{1 \text{ ft}} \times \frac{1 \text{ penny}}{0.75 \text{ in}} = 1200 \text{ pennies}$$

Therefore the total pennies needed: 44,184,240 pennies
Imagine my hiring you to do a project for my company, Fly-By-Night Manufacturing – a company that makes portable radios. You meet Brad, my production manager, and he tells you that due to incredible customer demand, we need your engineering expertise to improve the production on the R3Blue assembly line from 5000 radios per day to 9000.

A radio consists of three major components – a top plastic molding, a bottom plastic modeling and an electronic assembly (each is produced by other lines and delivered separately to this assembly line). At the R3Blue assembly line, the first step has a production operator take a top molding from a box, a bottom molding from a different box, and an electronic assembly from a storage rack. The operator placed the electronic assembly between the top and bottom moldings and snaps the case close. The operator places the assembled radio on a continuously moving conveyor where it moves to an automated testing station. When radios leave the testing station, defective radios are routed offline to a different operator who adjust the radio and send it back to the testing station. If a radio is good, it is conveyed to a packing station. At this station, an operator packages a radio into a box. The packaged radio is then conveyed to a final station in which 10 packaged radios are boxed together for shipping. From here, a box of radios is sent to the shipping dock.

[a] In terms of better understanding the operation and what happens on the R3Blue assembly line, what are 5 questions you would ask Brad? That is, what questions do you have about the operation of this assembly line?

<table>
<thead>
<tr>
<th>Question #</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td></td>
</tr>
<tr>
<td>(2)</td>
<td></td>
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<tr>
<td>(3)</td>
<td></td>
</tr>
<tr>
<td>(4)</td>
<td></td>
</tr>
<tr>
<td>(5)</td>
<td></td>
</tr>
</tbody>
</table>

[b] In terms of better understanding how you would help me with this project, what are 3 questions you would ask me and Brad? That is, what questions do you have about your doing this project?

<table>
<thead>
<tr>
<th>Question #</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td></td>
</tr>
<tr>
<td>(2)</td>
<td></td>
</tr>
<tr>
<td>(3)</td>
<td></td>
</tr>
</tbody>
</table>
[C] List 3 additional questions (not necessarily related to the operation of the line or how you would help him) you would ask Brad and me. That is, what else do you think it important to know?

<table>
<thead>
<tr>
<th>Question #</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td></td>
</tr>
<tr>
<td>(2)</td>
<td></td>
</tr>
<tr>
<td>(3)</td>
<td></td>
</tr>
</tbody>
</table>

[D] List some of the key data you will need to analyze the R3Blue assembly line:

<table>
<thead>
<tr>
<th>Number</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td></td>
</tr>
<tr>
<td>(2)</td>
<td></td>
</tr>
<tr>
<td>(3)</td>
<td></td>
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<tr>
<td>(4)</td>
<td></td>
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<tr>
<td>(5)</td>
<td></td>
</tr>
<tr>
<td>(6)</td>
<td></td>
</tr>
<tr>
<td>(7)</td>
<td></td>
</tr>
<tr>
<td>(8)</td>
<td></td>
</tr>
</tbody>
</table>

[E] Suppose the data is “raw” (that is, it is simply a table of observed processing times collected by a summer intern). What are you going to do with it?

Enter your answer

[F] What are you going to do if there is no data? What data is most likely to not have been collected?

Enter your answer

[G] Knowing very little about this system, what does your gut tell you about being able to achieve the improvement in production. Why?

Enter your answer

[H] What date will you be done with your analysis? (assume you start September 1st and as expected, there is no production data collected for this system)

Enter your answer

[I] What is the estimated project cost? That is, what do you think you are going to charge me for your analysis? (assume you have graduated and are a professional engineering consultant)

Enter your answer
Lab 2 - Example of Student Solution

IMSE 440/840 – Lab #2

Due: Tue, Sept 2 (by midnight)

| Lab Objectives | In the near future, you will be faced with having to ask questions and make estimates on very little information |

★★★ This is an individual homework assignment ★★★

COMPLETE THIS FORM, SAVE IT, and THEN SUBMIT VIA Blackboard

Your name: Jonathan Carlson

Imagine my hiring you to do a project for my company, Fly-By-Night Manufacturing – a company that makes portable radios. You meet Brad, my production manager, and he tells you that due to incredible customer demand, we need your engineering expertise to improve the production on the R3Blue assembly line from 5000 radios per day to 9000.

A radio consists of three major components – a top plastic molding, a bottom plastic modeling and an electronic assembly (each is produced by other lines and delivered separately to this assembly line). At the R3Blue assembly line, the first step has a production operator take a top molding from a box, a bottom molding from a different box, and an electronic assembly from a storage rack. The operator placed the electronic assembly between the top and bottom moldings and snaps the case close. The operator places the assembled radio on a continuously moving conveyor where it moves to an automated testing station. When radios leave the testing station, defective radios are routed offline to a different operator who adjust the radio and send it back to the testing station. If a radio is good, it is conveyed to a packing station. At this station, an operator packages a radio into a box. The packaged radio is then conveyed to a final station in which 10 packaged radios are boxed together for shipping. From here, a box of radios is sent to the shipping dock.

[a] In terms of better understanding the operation and what happens on the R3Blue assembly line, what are 5 questions you would ask Brad? That is, what questions do you have about the operation of this assembly line?

<table>
<thead>
<tr>
<th>Question #</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>How is WIP handled between stations?</td>
</tr>
<tr>
<td>(2)</td>
<td>Does the final station have another operator, making the total operators four?</td>
</tr>
<tr>
<td>(3)</td>
<td>What are the working hours/shifts in the plants?</td>
</tr>
<tr>
<td>(4)</td>
<td>How many top/bottom moldings come in a box, and can they be received differently?</td>
</tr>
<tr>
<td>(5)</td>
<td>How are the moldings/electronic assemblies received?</td>
</tr>
</tbody>
</table>

[B] In terms of better understanding how you would help me with this project, what are 3 questions you would ask me and Brad? That is, what questions do you have about your doing this project?

<table>
<thead>
<tr>
<th>Question #</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>What are examples of the analysis or input you expect from me?</td>
</tr>
<tr>
<td>(2)</td>
<td>What is the available budget for changes?</td>
</tr>
<tr>
<td>(3)</td>
<td>What responsibility would I have in the improvement implementation?</td>
</tr>
</tbody>
</table>
[C] List 3 additional questions (not necessarily related to the operation of the line or how you would help him) you would ask Brad and me. That is, what else do you think it important to know?

<table>
<thead>
<tr>
<th>Question #</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>What is the timeframe for project completion?</td>
</tr>
<tr>
<td>(2)</td>
<td>Are there any alternatives that you’ve already explored?</td>
</tr>
<tr>
<td>(3)</td>
<td>What is staff/intern availability for data collection?</td>
</tr>
</tbody>
</table>

[D] List some of the key data you will need to analysis the R3Blue assembly line:

<table>
<thead>
<tr>
<th>Number</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>Time in system</td>
</tr>
<tr>
<td>(2)</td>
<td>Testing time</td>
</tr>
<tr>
<td>(3)</td>
<td>Testing pass/fail rate</td>
</tr>
<tr>
<td>(4)</td>
<td>Adjustment time</td>
</tr>
<tr>
<td>(5)</td>
<td>Packaging time</td>
</tr>
<tr>
<td>(6)</td>
<td>Unitize (packing for shipping) time</td>
</tr>
<tr>
<td>(7)</td>
<td>WIP at each station</td>
</tr>
<tr>
<td>(8)</td>
<td>Operator/machine utilization</td>
</tr>
</tbody>
</table>

[E] Suppose the data is “raw” (that is, it is simply a table of observed processing times collected by a summer intern). What are you going to do with it?

I would enter the data into a statistical package such as SPSS and run different tests on the data to find trends or bottlenecks. I would then use these results to find a model for the situation and possible improvements.

[F] What are you going to do if there is no data? What data is most likely to not have been collected?

I would observe the system to determine what data needs to be collected, then see if it is feasible for data to be automatically collected. I would do data collection that need small samples, and try to assign large sample collection to an intern. Testing pass/fail rates, WIP at each station, and operator/machine utilization are probably the least likely to have been collected.

[G] Knowing very little about this system, what does your gut tell you about being able to achieve the improvement in production. Why?

I don't think the improvement can be acheived without either an increase in workers or machinery. The increase they are looking for is about 44%, and the line already uses some automation so most of the easy improvements have probably already been made. If they truly have almost double the capacity they are currently using, then common sense should have allowed them to make changes to reduce the discrepency.

[H] What date will you be done with your analysis? (assume you start September 1st and as expected, there is no production data collected for this system)

September 21st, 2008

[I] What is the estimated project cost? That is, what do you think you are going to charge me for your analysis? (assume you have graduated and are a professional engineering consultant)
$110/hr assuming the task takes 3 weeks, 40 hour weeks total is $13,200
Problem 1

Consider a post office counter where there is one postal clerk on duty. The counter opens exactly at 8:00 am and there are no customers in the post office. The arrival time and the required processing time of the next 10 customers is given below:

<table>
<thead>
<tr>
<th>Customer</th>
<th>Arrival Time</th>
<th>Required Processing time (in seconds) with Postal Clerk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8:01</td>
<td>34 seconds</td>
</tr>
<tr>
<td>2</td>
<td>8:03</td>
<td>96 seconds</td>
</tr>
<tr>
<td>3</td>
<td>8:05</td>
<td>121 seconds</td>
</tr>
<tr>
<td>4</td>
<td>8:09</td>
<td>31 seconds</td>
</tr>
<tr>
<td>5</td>
<td>8:10</td>
<td>130 seconds</td>
</tr>
<tr>
<td>6</td>
<td>8:11</td>
<td>24 seconds</td>
</tr>
<tr>
<td>7</td>
<td>8:17</td>
<td>40 seconds</td>
</tr>
<tr>
<td>8</td>
<td>8:18</td>
<td>56 seconds</td>
</tr>
<tr>
<td>9</td>
<td>8:19</td>
<td>76 seconds</td>
</tr>
<tr>
<td>10</td>
<td>8:22</td>
<td>116 seconds</td>
</tr>
</tbody>
</table>

*For example*, customer 3 arrives at 8:05 and will require 121 seconds with the postal clerk once he is free. In the case of an arrival occurring at the same time that a service completes, assume that the arrival occurs first.

Construct a simulation table and perform a simulation for completing the processing of all 10 customers. The objective of your simulation is to determine the following statistics:

(1) for customers that complete service and leave, what is the average time a customer is in the postal system? (waiting and being processing)
(2) for customers that complete service and leave, what is the average time in the queue for a customer?
(3) what is the average number of customers in the system (waiting in the queue and in service) for the 30 minutes from 8:00 to 8:30?
(4) what is the utilization of the postal clerk for the 30 minutes from 8:00 am until 8:30?

*Note:* You are welcome to use a spreadsheet for this problem.
Consider the express checkout lane at the local grocery store. Customers wait in a queue if the cashier is busy. In this grocery store, customers are NOT processed first-in-first-out, rather they are processed by how much items they have to check out – with priority to the customer who has the fewest items. Thus, when the cashier is finished with a customer, he selects from the queue the waiting customer who has the fewest items to check out. That is, priority for service with the cashier is given to the waiting customer with the fewest items. Once the cashier begins checking out a customer, he continues processing that customer until he/she leaves the bank.

Assuming that the grocery opens at 8:00 am, here is the information for the first seven customers of the day:

<table>
<thead>
<tr>
<th>Customer</th>
<th>Arrival Time</th>
<th>Time Needed with Teller</th>
<th>Number of Items to check out</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8:05</td>
<td>12 minutes</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>8:07</td>
<td>7 minutes</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>8:10</td>
<td>2 minutes</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>8:20</td>
<td>7 minutes</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>8:24</td>
<td>1 minute</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>8:25</td>
<td>3 minutes</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>8:33</td>
<td>2 minutes</td>
<td>2</td>
</tr>
</tbody>
</table>

In the case of an arrival occurring at the same time that a service completes, assume that the arrival occurs first.

Construct a simulation table to simulate this system for 30 minutes (from 8:00 to 8:30). Calculate the following statistics:

(1) for customers that complete service and leave, what is the average time a customer waits in the queue for service from the cashier?
(2) for customers that complete service and leave, what is the average amount of time a customer spend with the cashier? (time being checked)
(3) for customers that complete service and leave, what is the average number of items checked?
(4) what is the utilization of the single cashier from 8:00 to 8:30?
(5) what is the average number of customers in the checkout system (waiting in the queue and being service) during the 30 minute period? (8:00 to 8:30)

Note: You are welcome to use a spreadsheet for this problem.
Problem 3

Consider a simple bank system in which customers enter a bank and seek service with the single bank teller. Customers wait in a queue if the bank teller is busy. In this bank system, customers are NOT processed first-in-first-out, rather they are processed by how much money they have in the bank. Thus, when the teller finished with a customer, he selects from the queue the waiting customer who has the most money in the bank. That is, priority for service with the teller is given to the waiting customer with the most money. Once the teller begins helping a customer, he continues processing that customer until he/she leaves the bank.

Assuming that the bank opens at 8:00 am, here is the information for the first five customers of the day:

<table>
<thead>
<tr>
<th>Customer</th>
<th>Arrival Time</th>
<th>Time Needed with Teller</th>
<th>Money in the Bank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8:05</td>
<td>8 minutes</td>
<td>$2000</td>
</tr>
<tr>
<td>2</td>
<td>8:08</td>
<td>3 minutes</td>
<td>$1000</td>
</tr>
<tr>
<td>3</td>
<td>8:12</td>
<td>2 minutes</td>
<td>$5000</td>
</tr>
<tr>
<td>4</td>
<td>8:20</td>
<td>3 minutes</td>
<td>$1000</td>
</tr>
<tr>
<td>5</td>
<td>8:24</td>
<td>1 minute</td>
<td>$4000</td>
</tr>
</tbody>
</table>

Construct a simulation table to simulate this system for 30 minutes (from 8:00 to 8:30). Calculate the following statistics:

(6) the average time a customer waits in the queue for service from the bank teller
(7) the average amount of time a customer is with the bank teller (being processed)
(8) the average amount of money a customer has in the bank
(9) the utilization of the single bank teller
(10) the average number of customers in the bank during the 30 minute period (8:00 to 8:30)

Note: You are welcome to use a spreadsheet for this problem.
Time | Time (sec) | Cust # | Type | Start Time | End Time | Time in PO | # in Q | # in sys | Duration (sec) | Clerk | Status
--- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | ---
8:00:00 AM | 0 | START | | | | | | | | | Idle
8:01:00 AM | 60 | 1 | A | 60 | 94 | 34 | 0 | 1 | 34 | Busy
8:01:34 AM | 94 | 1 | D | 0 | 0 | | | | | Idle
8:03:00 AM | 180 | 2 | A | 180 | 276 | 96 | 0 | 1 | 96 | Busy
8:04:36 AM | 276 | 2 | D | 0 | 0 | | | | | Idle
8:05:00 AM | 300 | 3 | A | 300 | 421 | 121 | 0 | 1 | 121 | Busy
8:07:01 AM | 421 | 3 | D | 0 | 0 | | | | | Idle
8:09:00 AM | 540 | 4 | A | 540 | 571 | 31 | 0 | 0 | 31 | Busy
8:09:31 AM | 571 | 4 | D | 0 | 0 | | | | | Idle
8:10:00 AM | 600 | 5 | A | 600 | 730 | 130 | 0 | 1 | 60 | Busy
8:11:00 AM | 660 | 6 | A | 660 | 754 | 94 | 1 | 2 | 70 | Busy
8:12:10 AM | 730 | 5 | D | 0 | 0 | | | | | Idle
8:12:34 AM | 754 | 6 | D | 0 | 0 | | | | | Idle
8:17:00 AM | 1020 | 7 | A | 1020 | 1060 | 40 | 0 | 1 | 40 | Busy
8:17:40 AM | 1060 | 7 | D | 0 | 0 | | | | | Idle
8:18:00 AM | 1080 | 8 | A | 1080 | 1136 | 56 | 0 | 1 | 56 | Busy
8:18:56 AM | 1136 | 8 | D | 0 | 0 | | | | | Idle
8:19:00 AM | 1140 | 9 | A | 1140 | 1216 | 76 | 0 | 1 | 76 | Busy
8:20:16 AM | 1216 | 9 | D | 0 | 0 | | | | | Idle
8:22:00 AM | 1320 | 10 | A | 1320 | 1436 | 116 | 0 | 1 | 116 | Busy
8:23:56 AM | 1436 | 10 | D | 0 | 0 | | | | | Idle
8:30:00 AM | 1800 | END | | | | | | | | |

1) Time in PO = 794 = 79.4 secs
Total # custs 10

2) Time in Q = 70 = 7 secs
Total # custs 10

3) Total # in sys = 11 = 1.1 custs
Total # custs 10

4) Time Busy = 724 = 40.22%
Total Time = 1800
<table>
<thead>
<tr>
<th>Time</th>
<th>Cust #</th>
<th># Items</th>
<th>Type</th>
<th>Start Time</th>
<th>End Time</th>
<th>Time in Q</th>
<th>Time in PO</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00 AM</td>
<td>START</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:05 AM</td>
<td>1</td>
<td>5</td>
<td>A</td>
<td>5</td>
<td>17</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>8:07 AM</td>
<td>2</td>
<td>4</td>
<td>A</td>
<td>7</td>
<td>26</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>8:10 AM</td>
<td>3</td>
<td>2</td>
<td>A</td>
<td>10</td>
<td>19</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>8:17 AM</td>
<td>1</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:19 AM</td>
<td>3</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:20 AM</td>
<td>4</td>
<td>3</td>
<td>A</td>
<td>20</td>
<td>30</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>8:24 AM</td>
<td>5</td>
<td>6</td>
<td>A</td>
<td>24</td>
<td>30</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>8:25 AM</td>
<td>6</td>
<td>1</td>
<td>A</td>
<td>25</td>
<td>29</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>8:26 AM</td>
<td>2</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:29 AM</td>
<td>6</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:30 AM</td>
<td>END</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>35</td>
<td>60</td>
</tr>
</tbody>
</table>

1) Time in Q(C1 + C2 + C3 + C6) = 20 = 5 mins
   # Custs serviced = 4

2) Svc Time (C1 + C2 + C3 + C6) = 24 = 6 mins
   # Custs serviced = 4

3) # Items(C1 + C2 + C3 + C6) = 12 = 3 items
   # Custs serviced = 4

4) Time Busy = 25 = 83.33%
   Total Time = 30

5) Tot # in sys = 21 = 3.5 custs
   # of custs = 6
<table>
<thead>
<tr>
<th>Svc Time</th>
<th># in Q</th>
<th># in sys</th>
<th>Duration (min)</th>
<th>Clerk Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>Idle</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>2</td>
<td>Busy</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>3</td>
<td>Busy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>Busy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>Busy</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>Busy</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>3</td>
<td>Busy</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>4</td>
<td>Busy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3</td>
<td>Busy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>Busy</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>12</td>
<td>21</td>
<td>Busy</td>
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</tr>
</tbody>
</table>
**IMSE 440/840 – Lab #4**

**Due: Wednesday, September 24 (by 11:59 pm)**

<table>
<thead>
<tr>
<th>Lab Objectives</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>To have you identify a computer to be able to run your simul8 models</td>
</tr>
<tr>
<td>(2)</td>
<td>To have you become familiar with the simul8 software interface</td>
</tr>
<tr>
<td>(3)</td>
<td>To provide you experience in building your first simul8 models and collecting system statistics</td>
</tr>
</tbody>
</table>

**Undergraduate student may do this lab individually or with a partner. Graduate students must do this assignment individually**

**PROBLEM 1**

Phone calls that arrive to a processing office wait in a single queue until one of three operators is available to process the call. Assume calls wait in the queue on a first-in-first-out basis. Previous data suggests that calls arrive to the office following an exponential distribution with a mean interarrival time of 45 seconds. Assume it takes an operator between 45 seconds and 1 minute (uniformly distributed) to process a call. Using simul8, simulate the processing office for one day of operation (8 a.m. until 5 p.m.). Run 1 replication of your model to collect the following statistics:

1-1) average time a call is in the system (waiting and being processed by the operator)
1-2) the average utilization of Operator 1, Operator 2, and Operator 3
1-3) the average number of calls in the queue

**PROBLEM 2**

When a medical tool is returned to a hospital inventory unit, the tool needs to be cleaned/sterilized. The sterilization process cleans two types of tools – hand tools, powered tools. A hand tool arrives every 10 minutes (exponentially distributed) and requires between 3 and 5 minutes (uniform distribution) to go through the sterilization process. The first hand tool arrives at time 0. The first power tool arrives at time 0 and subsequent powered tools continue to arrive an average of every 7 minutes (exponentially distributed) thereafter. Each power tool requires at most 5 minutes, at least 2 minutes and a most likely time of 3.5 minutes (i.e., triangular distribution) to go through the sterilization process. Only one tool can be in the sterilization machine at any one time. If both a hand and power tool are waiting for the sterilization machine, the hand tool will always be given priority to be the next tool to be processed.

Using simul8, simulate 8 hours of operation. Run 20 replications of your model and collect:

2-1) a 95% confidence interval for the average time a hand tool is in the sterilization system (from arrival to departure)
(2-2) a 95% confidence interval for the average number of tools waiting to be washed
(2-3) a 95% confidence interval for the average time a tool waits in the queue before beginning its wash
(2-4) a 95% confidence interval for the utilization of the sterilization machine
(2-5) the percentage of tools that go through the system in 9 minutes or less

Hint: there are two work entry points – one for hand tools and one for powered tools. At each work entry point, assign a label to hold a sample from the respective service time distribution. Then at the work center, delay the value of that label (versus taking a sample at the work center of the processing time)

PROBLEM 3

The time between the arrival of customers to the university credit union is EXPONENTIAL(5) minutes. A customer is one of three types: 20% students, 40% are university staff and 40% are faculty.

Upon arrival, students and staff wait in one queue while faculty wait in a second queue. Once the single teller is free, his preference for selecting the next customer is: faculty → staff → student. The service time by the single teller (in minutes) is:
- student → TRIA(2,4,8) minutes
- staff → UNIF(3,4) minutes
- faculty → NORM(4.2,1) minutes

Run your simul8 model for 1 trial of 8 hour and collect statistics on the:
(3-1) average time a student is in the bank
(3-2) average time a staff person is in the bank
(3-3) the average time a faculty member is in the bank
(3-4) the average time a student spends in the queue
(3-5) the utilization of the teller

PROBLEM 4

A radio station has decided to hold a contest to give away free concert tickets. The first 200 people to complete a survey will have the chance to win the tickets in a random drawing. Assume that the radio station announces the contest at 1 p.m. in the afternoon. The first car containing contestants arrives immediately after the announcement at 1 pm. After the first arrival, assume that subsequent cars arrive every 3.5 minutes (exponentially distributed). Cars that arrive typically carry more than one person. Assume the following breakdown on how many people are in each car: 20% = 1 person, 40% = 2 people, 15% = 3 people, 25% = 4 people

Due to everyone having different reading abilities, the time for each person to complete the survey follows a triangular distribution with a minimum of 10 minutes, a maximum of 30 minutes, and a most likely time of 12 minutes. Once the survey is complete, a person leaves the radio station. The drawing results will be announced the next day over the air.

Create a simul8 model to collect statistics so that you can answer the following:
(4-1) The number of survey’s given out
(4-2) The time at which the last person completes the survey

Hint: This is the time at which the completion of the simulation stops. Remember, the contest starts at 1 p.m.

WHAT TO TURN IN: In a single e-mail message to me (psavory@unl.edu), attached all 4 of your simul8 models along with a file (with you name in it) that has all answers to each of the requested statistics. BE SURE TO RESET YOUR SIMUL8 MODELS BEFORE SAVING AND SENDING THEM (thus, smaller file size). Unless otherwise specified, run 1 replication of your model.
Example of Student Solution - Lab #4

Problem 1

Problem 2
Problem 3

Problem 4
Lab 5 - Description

IMSE 440/840 – Lab #5

Due: Friday, September 26 (by 11:59 pm)

Lab Objectives

To prepare you for a future interview or job fair.

★★★ This is an individual homework assignment ★★★

Using the computer, create a resume that you can use for applying for internships or full-time positions (whichever is appropriate for your circumstances). Turn in via BLACKBOARD. Apply the concepts talked about in class.

UNL Career Fair • October 8th - College of Engineering Career Fair
10 am - 3 pm, Nebraska Union

Career Fair Information Session (Thursday, October 2, 2008: 4:30 pm, Nebraska Union)
A panel of recruiters from a variety of industries will be on hand to share what they look for in prospective employees. You can also pick up a map of the organizations at the fairs to get a head start on your strategy. Don’t miss this great opportunity to find out...

- What to wear to the fair and/or an interview
- How to introduce yourself and make a great impression
- What to bring (ie resumes, etc.)
- What questions to ask
- How to approach a recruiter

<table>
<thead>
<tr>
<th>Adolfson &amp; Peterson Construction</th>
<th>Hamilton Sundstrand</th>
<th>Rentech Boiler Systems, Inc</th>
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<tbody>
<tr>
<td>Ag Processing</td>
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<td>Kerry Ingredients &amp; Flavours</td>
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<td>Kiewit Corporation</td>
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<td>Linbeck Group, LLC</td>
<td>Wallace Engineering</td>
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<td>Garmin International</td>
<td>Midwest Manufacturing</td>
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<td>Reinke Manufacturing</td>
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<td>Goodyear Tire &amp; Rubber Co</td>
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<tr>
<td>Geotechnical Services, Inc.</td>
<td>Nebraska Public Power District</td>
<td>Gyrodata Inc</td>
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</tbody>
</table>
Stephen XYZ
2916 Coronado Drive
Lincoln, NE 68516
(402) 617-xxx
xyz@huskers.unl.edu

EDUCATION

University of Nebraska – Lincoln (UNL)
Bachelor of Science, December 2009, 3.876 Cumulative GPA
Major: Industrial & Management Systems Engineering
Minor: General Business

EXPERIENCE

Licensing Agent, May 2008 – Present, UNL, Office of Technology Development, Lincoln, NE.
Supervisor(s): David Conrad, PhD, MBA – Associate Vice Chancellor for Technology Development
               Marvin Jaques, MBA, PE – Licensing Manager
• Evaluate a myriad of innovative university research to determine its commercial viability
• Perform methodical scientific and market analysis, utilizing industry experts and internet research
• Potentially recommend intellectual property protection strategies involving patents and copyrights
• Market protected technologies by contacting business development executives
• Exposure to the general concepts of technology transfer and intellectual property law

Treasurer, March 2008 – Present, Phi Kappa Psi Fraternity – Nebraska Alpha Chapter, Lincoln, NE.
Supervisor(s): Not Applicable
• Popularly elected to serve as chief financial officer for an organization of nearly 70 members
• Control the organization’s financial policy
• Individually manage all assets and carry out all monetary transactions
• Plan for expenses by proposing a budget for annual revenues of approximately $175,000
• Function as a liaison between the organization and dozens of vendors and service providers

Project Engineer Intern, February 2007 – August 2007, Lincoln Industries, Lincoln, NE.
Supervisor(s): Clint Boothe – Director of Integrated Finishing Services (IFS)
               Luke Sanders – Project Manager
• Helped a director and project managers integrate the company’s largest project to date
• Developed a functional knowledge of an intricate, large-scale project ($20 million annual sales)
• Exposed to trade standards and practices while working in an industrial environment
• Learned the basic science behind nickel-chromium electroplating

Telephone Interviewer, August 2005 – December 2005, Gallup Organization, Lincoln, NE.
Supervisor(s): Various
• Conducted customer satisfaction surveys for national retailers and banks
• Executed public opinion surveys for the Gallup Poll
• Polled thousands of people, representative of America’s diverse population
• Recruited potential employees for the position
HONORS AND ACTIVITIES

- Regents Top Scholar (tuition, fees, textbooks, and stipend)
- College of Engineering Dean’s List (all semesters)
- UCARE – Undergraduate Creative Activities and Research Experiences (specifically, assisted a professor and graduate students conduct studies to develop more ergonomic neutron detectors)
- University of Nebraska Honors Program
- American Leadership Academy (Spring 2008, Los Cabos, Mexico)
- Lincoln Southwest High School Salutatorian (2005)

COMPUTER SKILLS

- Microsoft Office 2003 & 2007 (including Excel, PowerPoint, and Word)
- Online conferencing software – Mikogo and Skype
- Online customer relationship management (CRM) software – Salesforce
- AutoCAD 2005

RESEARCH FUNDING

Academic Year 2008-2009: $2,400
Award: UCARE (Second Year)
Project: Development of a Handheld Neutron Detector
Faculty Sponsor: M. Susan Hallbeck, PhD – Professor of Industrial Engineering

Academic Year 2007-2008: $2,000
Award: UCARE (First Year)
Project: Ergonomic Neutron Detector Development for First Responders
Faculty Sponsor: M. Susan Hallbeck, PhD – Professor of Industrial Engineering
Lab 6 - Description

**IMSE 440/840 – Lab #6**

**Due: Wednesday, October 1 (by 11:59 pm)**

<table>
<thead>
<tr>
<th>Lab Objective</th>
<th>To continue building your skills in creating basic simul8 models</th>
</tr>
</thead>
</table>

**Undergraduate student may do this lab individually or with a (different) partner.**

**Graduate students must do this assignment individually**

**PROBLEM 1 [This problem is from the first examination in the Fall 2005 class]**

To aid the university football team, former football coach Tom Osborne has agreed to sit in a tent outside a Nebraska football game and allow fans to take a photograph with him. Photographs are taken individually with Coach Osborne (thus, a single person and him).

Fans **without reservations** wanting a photograph wait at the **West** entrance of the photo tent. Suppose that these fans arrive individually to the West tent entrance at a rate of 15 per hour (following an exponential distribution). The first fan arrives exactly when the photo tent is opened. If a fan arrives and finds that there are 15 or more people waiting in the first-in-first-out, single-file West entrance line:

- 60% of the time he/she will leave and never return to the photo tent
- 40% of the time he/she will leave and return in 15 minutes to check if the line has less than 15 people and can join. Upon his/her return, if the line still has 15 or more people, use the same probabilities to decide what this person will do.

Fans **with a reservation** have received a special invitation in the mail. In the invitation, each is scheduled to arrive to the **East** entrance of the photo tent as soon as the tent opens and then every 10 minutes afterward (constant time). Those with reservations, are allowed to bring along friends who also want a photograph with Coach Osborne. Fans with reservation arrives to the East entrance of the photo tent in groups ranging in size from 1, 2, 3, or 4 fans. The probability of each group size is 40%, 20%, 30%, and 10%, respectively. Upon arrival, fans in a group wait at the East entrance of the tent in a first-in-first-out, single file line to individually be photographed with Coach Osborne.

Only one person can be in the tent with Coach Osborne at any one time. For those **with reservations**, assume it takes UNIF(2,5) minutes for a fan to have his/her photograph taken with Coach Osborne. For a person **without reservations**, assume it takes 2 minutes (40% of the time) or 3 minutes (60% of the time). Once a photograph is taken, a fan immediately leaves the tent and Coach Osborne is available for the next photograph. An individual waiting at the East tent entrance has **higher** priority in having their photographs taken than do fans waiting at the West entrance.

After a fan has a picture taken with Coach Osborne, he/she must walk out of the tent and join a queue to pay for the photograph. Assume it takes 30 seconds to walk from the photo tent to this queue. The queue is not first-in-first-out, but rather priority is for individuals who used the East entrance (i.e., had a reservation). There are two cashiers on duty – John and Tara. The time for each to process a customer is as follows:

- John \(\rightarrow\) UNIFORM(1,3) minutes
- Tara \(\rightarrow\) TRIANGULAR(1,2,3.5) minutes

If both John and Tara are free, Tara will select the next available customer.

Write a simul8 model to simulate the above description for 9 hours. Run your model for 1 trial and answer the following questions:

1-1 The total number of times a fan **without reservations** finds more than 15 fans waiting at the West tent entrance

1-2 The total number of times a fan **without reservations** finds more than 15 fans waiting at the West tent entrance and leaves and does not return to the tent
Lab 6 - Description

[1-3] The total number of fans without reservations who successfully leave the system (get a photograph and pay a cashier)
[1-4] The total number of fans with reservations who successfully leave the system (get a photograph and pay a cashier)
[1-5] The percentage of time Coach Osborne is busy being photographed
[1-6] The percentage of time John is working
[1-7] The percentage of time Tara is working

PROBLEM 2 [This problem is from the first examination in the Fall 2006 class]

Consider the operation of the Lancaster County dump. A passenger vehicle (car or pickup) arrives to the dump following an exponential distribution with a mean of 4 minutes. Each vehicles is one of three colors: red (20%), blue (45%), or yellow (35%). Each vehicle pays $10 to unload items at the dump. A passenger vehicle is a car 20% of the time and a pickup 80% of the time.

Upon arrival, a car goes and waits in Queue: CarQ until it can unload its items into the single car dumpster (see the below discussion on this queue’s priority). Only one car can be at the dumpster at any time. The time to unload items from a car and put them into a dumpster is:

• Unload time for car: Triangular distribution with minimum 3 minutes, mode of 5 minutes, and maximum of 10 minutes

Upon arrival, a pickup truck waits in Queue: PickupQ until one of the two pickup dumpsters (short dumpster and tall dumpster) is free. Priority in the queue is by color – with yellow having the highest priority, then red, and then blue. If both dumpsters are free, preference is to use the tall dumpster (since it holds more items). Only one pickup can be at a dumpster at a time.

• Unload time for pickup at short dumpster: Uniform distribution with minimum of 6 minutes and maximum of 15 minutes
• Unload time for pickup at tall dumpster: Normal distribution with mean of 6 minutes and standard deviation of 45 seconds

After unloading, a vehicle (pickup or car) pulls away and frees the respective dumpster. A pickup truck continues and always leaves the dump. In comparison, once it has pulled away, 30% of the time, a car realizes that it forgot to unload its trunk. Hence, the car has to turn around and re-join Queue: CarQ. Correspondingly, 70% of the time a car immediate leaves the dump. It takes 1 minute for the car to turn around and re-join the queue. A car that cycles around the most times has the highest priority, followed by the first-in-first-out rule. For example, a car that has cycled four times will have higher priority than a car that has cycled two times or a car that has yet to go to the dumpster. Assume there is no limit to the number of times a car can cycle back to the queue.

A semi-truck arrives to the dump at a mean rate of 5 per hour (following an exponential distribution). The first semi-truck arrives exactly at time zero. At semi-truck carries 5000 pounds of material. Upon arrival, a semi-truck’s preference is to go to the north unload queue (Queue: NorthQ). Unfortunately, there is only space for three waiting trucks at this location. If the truck cannot join the north queue, it attempts to go to the south queue (Queue: SouthQ) where is there is space for ten waiting semi-trucks. If both queues are full, an arriving truck immediately leaves the system and does not return. Semi-trucks wait in their respective queues until a single forklift can unload it. When free, the forklift’s preference will be to unload a truck from the north queue. Hence, the south queue is only unloaded when the north queue is empty. The unload time for a truck is:

• Unload time for semi-truck: 12 minutes (50%) or 18 minutes (50%)

After unloading, a semi-truck always leaves the dump.
Lab 6 - Description

Write a simul8 model to simulate the above description for 10 hours. Running your model for 1 replication and answer the following questions:

[2-1] The total number of yellow pickups to arrive to the dump
[2-2] The utilization of the car dumpster
[2-3] The maximum number of times any car unloads and then cycles around to the dumpster
[2-4] The total number of times cars cycle back to the dumpster
[2-5] The average time a pickup waits for a dumpster
[2-6] The probability a pickup waits less than 5 minutes for a dumpster to unload
[2-7] The average number of semi-trucks in Queue: NorthQ
[2-8] The number of semi-trucks that cannot join the north or south queue and immediately leave the system
[2-9] The total number of vehicles (cars, pickup, semi-truck) to successfully unload their items and leave the system
[2-10] The average time it takes a pickup truck from arrival to leaving the dump
[2-11] The total number of cars to leave the dump

Based off of TWENTY-FIVE replications of your model, what are 95% confidence intervals for following generated statistics:

[2-12] The average time a car spends in Queue: CarQ
[2-13] The average time a pickup spends in Queue: PickupQ

WHAT TO TURN IN: In a single e-mail message to me (psavory@unl.edu), attached both of your simul8 models. BE SURE TO RESET YOUR SIMUL8 MODELS BEFORE SAVING AND SENDING THEM (thus, smaller file size). Also, in an included word processing file, list all requested statistics for each of the problems.
Example of Student Solution - Lab #6

Problem 1

Problem 2
Lab #8

IMSE 440/840 – Lab #7

**Lab Objective**
To learn about the simulation process.

Undergraduate student may do this lab individually or with a (different) partner.
Graduate students must do this assignment individually.

(1) Watch the online narrated Powerpoint presentation on the simulation process

(2) Complete the online quiz

---

**Quiz Questions for Students**

**Question** When developing a simulation model, explain why it is important to consider who the model’s end-user will be:

(text box – student offers a response)

**Question** A typical (industry) simulation project takes:

**Answer**

1. 1 week to 3 months
2. less than 1 week
3. around 1 year
4. 3 to 6 months

**Question** Novice simulation modelers tend to abstract a system (not include as much details) as a more experienced modeler

**Answer** True

**Question** Developing a simulation model where you leave out breakdowns of machines would be an example of which abstraction approach

**Answer**

simplification
aggregation
substitution
discrete-event

**Question** Developing a simulation model where you model two machines as identical-parallel servers with the same process time rather then model each individually with differing processing times is an example of which abstraction technique

**Answer**

substitution
aggregation
simplification
Answer

**Question** Discuss one of the positive impacts of aggregating data together
**Answer**

*(text box – student offers a response)*

**Question** What are three challenges/problems when collecting data on a system?
**Answer**

*(text box – student offers a response)*

**Question** The parameters for the triangular distribution are:
**Answer**

✓ minimum, mode, maximum
- minimum, median, maximum
- mean, standard deviation
- minimum, average, maximum

**Question** Describe what an assumptions document is and explain how you would use it?
**Answer**

*(text box – student offers a response)*

**Question** A terminating simulation model has a finite horizon
**Answer**

✓ True
- False

**Question** A simulation model that models a system from 7 am until 6 pm is an example of a non-terminating system
**Answer**

✓ True
- False

**Question** One of the most important factors in determining whether the simulation results will actually be implemented in the decision making process is...
**Answer**

*(text box – student offers a response)*
<table>
<thead>
<tr>
<th>Lab Objective</th>
<th>To continue building your skills in creating intermediate Simul8 models (breakdowns, route-in, route-out, resources, shelf-life, interruptible work centers)</th>
</tr>
</thead>
</table>

Undergraduate student may do this lab individually or with a (different) partner. Graduate students must do this assignment individually.

**PROBLEM 1**

Suppose you just arrived to the USA and are going through immigration and customs at the airport – a two-step process. For the first step, passengers arrive to be processed according to an exponential distribution with a mean interarrival time of 10 minutes. Upon arrival, passengers select one of three lines to be have their passport inspected – they choose Line 1, Line 2, or Line 3 based on the smallest number in queue. There is a single inspector for each line and the time she spends inspecting your immigration visa/passport follows an exponentially distribution with a mean of 22 minutes (Line 1), 26 minutes (Line 2), and 36 minutes (Line 3). Due to new chemical detection machines, everyone must stay in Line 1, Line 2, or Line 3 for at least 30 seconds – even if the associated inspector is free.

After having their paperwork inspected in Step 1, passengers from Line 1 next wait in a new queue (called Line 4), passengers from Line 2 wait in Line 5, and passengers from Line 3 wait in Line 6. Passengers are waiting in this line to get processed by a customs agent who inquires as to what they are bringing into the country and potentially inspects their luggage. There are two customs agents. Customs agent 1 inspects passengers waiting in Line 4 and Line 5. When free, customs agent 1 chooses the next passenger from the longer of their two respective lines. Customs agent 2 priority is to inspect passengers waiting in Line 6. When he is free and no one is in Line 6, he selects the next person from Line 5. If Line 5 is empty, he selects from Line 4.

The inspection time by customs agent 1 takes UNIF(4, 14) minutes; customs agent 2 takes UNIF(5, 16) minutes.

Simulate this system for 24 hours and collect the following statistics based off of 25 replications of your model:

1. the total number of people from line 4 processed by Customer Agent 1
2. the total number of people from line 5 processed by Customer Agent 1
3. the total number of people from line 4 processed by Customer Agent 2
4. the total number of people from line 5 processed by Customer Agent 2
5. the total number of people from line 6 processed by Customer Agent 2

**ALSO, improve the graphics of your animation beyond the default graphics – thus, change your entity icon, change icons of work centers, etc.**

**PROBLEM 2**

A biological warfare suit consisting of two parts – a jacket and a pair of pants. After use, it must be processed through a cleaning system. A suit arrives to the system every 5 minutes – exponentially distributed. The first task of the system is to automatically break the suit into its two parts – jacket and pant - which takes the single machine an average of one minute (exponentially distributed). Only one suit can be disassembled at any one time. Each suit component is then sent individually to be cleaned. The time to clean a jacket is normally distributed with a mean of 3.5 and a standard deviation of 1. There is only one cleaning machine for jackets and it is subject to breakdowns. Historical data suggest that a breakdown occurs every 3 to 4 hours (uniformly distributed) and takes between 10 and 14 minutes (uniformly distribute) to repair. The time to clean a pair of pants is uniformly distributed between 14 and 18 minutes and there are two cleaning machines for pants.

After cleaning, pants and jackets wait in the same queue until their respective match is available. Obviously, a jacket must be assembled with the pants from which it came from.
Once both matching items are available, the suit is automatically (assume zero time delay) sent to a bagging area. In this area, suits select one of three queues – the most expert bagging queue (with capacity to hold 2 suits), the expert bagging queue (with capacity to hold 2 suits), or a trainee bagging queue (with capacity to hold an unlimited number of suits).

Associated with each of the queues is a single bagging person. The time to perform the bagging operation for the most expert of the baggers is triangularly distributed with a mode of 25 minutes, a minimum of 22 minutes, and a maximum of 45 minutes. The second expert assembler takes UNIF(21,55). The trainee take TRIA(25,35,50).

Write a simul8 model to simulate the above system for 8 a.m. until 6 p.m. and collect the following statistics:

- (2-1) utilization of the cleaning machine for pants
- (2-2) utilization of the cleaning machines for jackets
- (2-3) the total number of suits bagged and completed

### PROBLEM 3

Create a simul8 simulation program for analyzing the performance of a simple manufacturing system with two machines for processing four types of parts. A Type 1 part arrives every 5 minutes following an exponential distribution. Starting at time zero and every 45 minutes afterward. A Type 3 part arrives every 6 hours (with the first at the sixth hour). Of the two machines – one is a new machine (faster and better accuracy and tolerance) and the other is older (slower, less accurate). If both machines are free, a part is to be processed on the newer machine. Each of the machines has the following processing times:

<table>
<thead>
<tr>
<th>Part Type</th>
<th>Newer Machine</th>
<th>Older Machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1 Part</td>
<td>UNIF(1.5,4.5)</td>
<td>UNIF(1,4)</td>
</tr>
<tr>
<td>Type 2 Part</td>
<td>TRIA(1,6,9)</td>
<td>TRIA(2,7,10)</td>
</tr>
<tr>
<td>Type 3 Part</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

In addition, each time the part type changes, there is a 20 second setup/adjustment time for the machine (Hint: route-in, setup time)

A Type 4 part arrives every 2 hours (following an exponential distribution), starting after 60 minutes. This part is a rush job and has highest priority of getting through the cell and preempts any parts currently in process. Upon arrival, a Type 4 part is immediately processed on the newer machine. If Type 1, 2, or 3 part is already being processed by the newer machine, the processing is immediately stopped, the part is set aside, and the Type 4 part is processed (for UNIF (1,2) minutes). Once the Type 4 is finished, the newer machine resumes its work for the remaining time for the preempted part (the label DUE will store the remaining time for a preempted part). An interrupted part has a shelf life of 2 minutes in the preempted queue. If still in the queue at 2 minutes, the part immediately leaves and must be scrapped.

To keep them operating efficiently, the machines are required to have scheduled maintenance performed on them. The newer machine is down (unavailable) for 5 minute break every 2.5 hours. The older machine is down for 10 minutes every 3 hours. Assume that when a scheduled maintenance occurs, the machine finishes processing the current part and is then down for the entire maintenance time.

Run the model for 9 hours and collect the following statistics:
- (3-1) the number of type 1 parts to be processed and leave the system
- (3-2) the number of type 2 parts to be processed and leave the system
- (3-3) the number of type 3 parts to be processed and leave the system
- (3-4) the number of type 4 parts to be processed and leave the system
- (3-5) the utilization of the newer machine
- (3-6) the utilization the older machine.
- (3-7) number of parts that are scrapped
Consider the operation of the exit operation of a parking structure. The time between the arrival of a car follows an exponential distribution with a mean of 5 minutes. A car is one of four types (with the associated probability): Type A (40%), Type B (30%), Type C (15%), or Type D (15%) where A = hourly parking customer, B = valet parking, C = monthly parking, and D = employee parking. Upon arrival to the parking structure exit, a car automatically joins a queue based on its type. That is, a Type A car goes to its own queue, Type B goes to a different queue, Type C to a third queue, and Type D to a fourth queue.

After a Type A car is in its queue, it waits in the order in which cars arrive (i.e., cars that have been in the system the longest time have highest priority) for Sally (the single cashier on duty) to select it and process it. Sally can only process one car at a time. The time for Sally to process a Type A car is UNIFORM(2,4) minutes. Once processed, the car leaves the parking structure.

After a Type B car joins its queue, it waits in the order in which cars arrive (i.e., cars that have been in the system the longest time have highest priority) for Sally to select it and process it. If Sally is free and a Type A and a Type B car are waiting, priority is for Sally to choose the Type B car. The time for Sally to process a Type B car is triangularly distributed with a minimum of 1 minute, a maximum of 5 minutes, and a most likely time of 180 seconds. Once complete, a car immediately leaves the system and Sally is free to process the next car.

After a Type C car joins its queue, if Sally is free, she immediately begins processing the Type C car. If Sally is already processing a Type A or Type B car, the Type C car preempts Sally’s processing of the Type A or Type B car. Else, a Type C car waits first-in-first-out in its queue. A Type A or Type B car that has Sally taken away from it is set aside. The time for Sally to process a Type C car is exponentially distributed with a mean of 3 minutes. Once processed, the car leaves the system.

After a Type D car arrives and joins its queue, if Sally is free, she immediately begins processing the Type D car. If Sally is processing a Type A or Type B or Type C car, the Type D car preempts Sally way from the car. Else, a Type D car wait in a first-in-first-out queue. A Type A, Type B, or Type C car that has Sally taken away from it is set aside. The time for Sally to process a Type D car is 2 minutes (20% of the time), 3 minutes (50% of the time), and 7 minutes (30% of the time). Once processed, the car leaves the system.

**HINT:** Remember, only simul8 work centers can interrupt another work center

If takes Sally UNIFORM(20, 30) seconds of set-up time to change her computer screen when changing from one type of car to the next. Also, for preempted cars, when Sally is free processing all newly arrived Type C and Type D cars, her highest priority is to process a preempted car before selecting a new Type A or Type B car. Assume that her processing has to completely start over for a car that was preempted. Though once she begins reprocessing an interrupted car, the car cannot be interrupted again (thus, if she is working on an interrupted Type A car and a Type D arrives, she is not interrupted). [Hint: once a car is interrupted, send to a dummy work center to reassign its priority label]

Assume Sally is the only phone operator on duty. Given the logic of this problem, if Sally is free, her priority is to process a Type D car, then a Type C car, then an interrupted car, then a Type B car, and finally a Type A car.

Write a simul8 model to simulate the above system until 5000 cars leave the parking structure (i.e., cars that leave the system) and collect the following statistics:

- (4-1) the average time a TYPE A cars is in the system
- (4-2) the average time a TYPE B cars is in the system
- (4-3) the average time a TYPE C cars is in the system
- (4-4) the average time a TYPE D cars is in the system
- (4-5) the number of cars preempted

**ALSO,** improve the graphics of your animation beyond the default graphics – thus, change your entity icon, change icons of work centers, etc.
Problem 1

Problem 2
Lab 9 - Description

Due by: Wed, Oct 29 in-class (if by hand) or 11:59 PM (if electronic)

<table>
<thead>
<tr>
<th>Lab Objective</th>
<th>To give you experience with an event calendar problem</th>
</tr>
</thead>
</table>

This lab is an individual assignment – no partners

PROBLEM 1

Consider the following event calendar problem – here is the description of how the model works:

- Type 1 parts arrive starting at time 0 and then every 3 minutes afterwards
- Set label Color = 1
- Set information store (global variable) NumInSystem = NumInSystem + 1
- Attempt to join queue, HoldingArea, which has capacity of 5
- If cannot join the queue, the global information store (global variable) NumInSystem = NumInSystem – 1. The part immediately exits the system
  - Else, the part joins the queue with queue priority FIFO

- Type 2 parts arrive starting at time 1 and then every 4.3 minutes afterwards
- Set information store (global variable) NumInSystem = NumInSystem + 1
- Set label Color = 2
- Attempt to join queue, HoldingArea → see above logic

- There is a single paint machine (work center) for processing parts waiting in the queue HoldingArea. The paint machine can process one set of parts (of the same color) at any one point in time. When free, the machine selects parts from the queue when there are 3 of the same color (i.e., route-in uses the collect option with collect = 3). Thus, three of the same color are selected and routed to the work center. The items are not assembled together. Processing time at the work center is a constant of 2.5 minutes. At the work center, the label “Color” is set to 3.

- After processing at the work center, set information store (global variable) NumInSystem = NumInSystem – 1. The part leaves the system (goes to a work exit point where results are segregated by the label color).

Run the above simulation from 0 to 25. What are the following statistics:

Observation-based statistics:
(a) the number of Color = 1 parts to arrive to the system
(b) the number of Color = 2 parts to arrive to the system
(c) the average time a part it in the queue (for parts that complete service)
(d) the average time a part is in the system (for parts that complete service)
(e) the minimum time any part is in the system (for parts that complete service)
(f) the maximum time any part is in the system (for parts that complete service)
(g) the percentage of parts that complete service and leave the system within 5 minutes
(h) the number of Color = 1 parts that go to the work exit point
(i) the number of Color = 2 parts that go to the work exit point
(j) the number of Color = 3 parts that go to the work exit point
(k) the number of parts that cannot join the queue and leave the system

Time-persistent statistics (Hint: to answer these you possibly need to create a time graph and find the area):
(a) the average number in the queue over the 25 minutes
(b) utilization of the paint machine
(c) the average value of NumInSystem
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<th>Time</th>
<th>Type</th>
<th>Entity #</th>
<th>Description</th>
<th>Label Color</th>
<th>Number in System</th>
<th>Contents of Q: Holding Area</th>
<th>Number of type 1,2 (#,#)</th>
<th>Time in Q</th>
<th>Time in System</th>
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</table>

a) # of color = 1 to arrive.
b) # of color = 2 to arrive
c) average TIQ
d) average TIS
Lab 9 - Example of Student Solution

e) min TIS 2.50
f) max TIS 11.10
g) % of parts that complete service and leave w/in 5 minutes 33%
h) # of color = 1 to go to the work exit 0.00
i) # of color = 2 that go to work exit 0.00
j) # of color = 3 that go to the work exit point 12.00
k) The number of parts that cannot join the queue and leave the system 0

Time Persistent Statistics:
a) average number in Q over the 25 minutes? 2.11
b) utilization of the paint machine? 40% 2.5*4 = 10/25 = 40%
c) average value of NumInSystem? 4.77

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</table>

average: 4.766667
PROBLEM 1

The time between cargo ships arriving to a harbor follows an exponential distribution with a mean of 1.25 days. The first cargo ship arrives at time 0 in the simulation. Passenger ship schedules are more constant and a passenger ship arrives every 36 hours, with the first passenger ship arriving at time zero. The harbor has two docks at which both types of ships birth. Ships arriving when both docks are occupied join a queue in the harbor. Within this queue, passenger ships have higher priority than cargo ships. When a passenger ship docks at a birth, the time it occupies the dock follows a normal distribution with a mean of 0.6 days with a standard deviation of 0.1 days. After a cargo ship docks, a crane is required to unload the cargo. There are two cranes available for unloading the cargo ships (note: cranes are not needed to unload a passenger ship). The time for a crane to unload a cargo ship is distributed uniformly between 0.5 and 1.5 days. If only one cargo ship is docked in the harbor, only one crane unloads the cargo ship – the other crane is idle and available if a second cargo ship should dock. Once a passenger ship unloads its passengers and a cargo ship unloads its cargo, it frees the dock and leaves the harbor.

Hint: cranes are resources in this problem

Assuming that there are initially no ships in the harbor at the beginning of the simulation. Run the simulation for 90 days and collect the following statistics:

1-1) The average time that a passenger ship is in the harbor (this includes waiting for a dock and unload time)
1-2) The average time that a cargo ship is in the harbor (this includes waiting for a dock, waiting for a crane if needed, and unload time)
1-3) The utilization of the docks
1-4) The utilization of the cranes

PROBLEM 2

Consider a one-pump gas station. The station is open from 6 a.m. to 9 p.m. During each day, two types of cars arrive to use the single gas pump – police cars and regular cars. A police car arrives every EXPONENTIAL(30) minutes starting at 6 a.m. No police cars arrive after 7 p.m. The time between regular (non-police) cars arriving follows an exponential distribution with a mean of 5.6 minutes. The first regular car arrives at the beginning of the simulation (6 a.m.). At most 160 regular cars arrive during a day.

A car arriving to find the single gas pump idle immediately begins pumping gas. A regular car arriving to find the pump busy joins the end of a queue. A police car arriving to find the pump busy goes to the front of the single queue, ahead of all regular cars in line. If there are already other police cars in the line, assume that an arriving police car gets in line ahead of them as well. That is, an arriving police car has higher priority than one that is already in the queue waiting. A car (police or regular) will only wait in the queue for at most twenty minutes. At twenty minutes, a car will balk from the queue and leave the system.

Once at the available pump, is takes a vehicle driver (of either type of car) UNIFORM(15,90) seconds to set-up the gas pump before pumping the gasoline. The time to pump gas is as follows:

- **Police Car**: normal distribution with a mean 4 minutes and a standard deviation of 20 seconds
- **Regular car**: uniform distribution with maximum of 5 minutes and minimum 2 minutes.

Due to a purchasing agreement with the gas station and an automated tracking system installed in the police car, police vehicles immediately leave the gas station once they have finished pumping. For regular cars, 75% of the time they use a credit card and pay for the gas while still at the pump, but only after having completed pumping. Assume that paying at the pump takes a constant time of 45 seconds. During this time, no other vehicle can be at the pump. The remaining 25% of regular cars must have the driver go inside to pay a cashier after they have finished pumping. Assume it takes between 30 seconds and 90 seconds (uniformly distributed) to pay the single cashier. Once the gas is paid for, a vehicle immediately leaves the gas station (and frees the pump).

Hint: model the gas pump as a resource

Using your model, report the following statistics for 1 replication:
(2-1) The average time in the system for a police car
(2-2) The average time in the system for a regular car
(2-3) The average time a police car waits for the pump
(2-4) The utilization of the pump (percentage of time it is being used and/or blocked)
(2-5) The number of cars to balk from the queue

**PROBLEM 3**

At the local QuickMart, customers arrive following an exponential distribution with a mean interarrival time of 30 seconds. A customer either drives to the store (60% of the time) or walks to the store (40% of the time). All customers enter the store through the north entrance and wait in a single line for one of the two cashiers to check them out. Though if a customer arrives and finds more than 5 people in the store and the current time is after 3 pm, the customer immediately leaves the store through the north entrance and does not join the queue. Due to numerous credit card sales, assume it takes a cashier between 30 seconds and one minute (uniformly distributed) to ring up the sale on their cash register. Each cash register is subject to random breakdown – after between 100 and 500 sales (uniformly distributed) are completed, the machine breaks down for UNIF(2,5) minutes. After processing by the cashier, a customer can either leave the store by the east exit or the west exit. The following table shows which exit a customer will use:

- if \( \leq 40 \) customer have already left, a customer uses the west exit
- if \( > 40 \), but \( \leq 80 \) customer have already left, a customer uses the east exit
- if \( > 80 \) have left, a customer uses the west exit

The QuickMart is open from 10 a.m. until 10 p.m. At 10 a.m., the store had an inventory of 5000 Hershey candy bars. Suppose each customer buys an average of 2 of these bars (following a Poisson distribution). Using simul8, simulate the QuickMart for one day of operation. Have your model display the following information (with a text box next to it providing a text label as to what the number is):

(a) the number of drive-to customers currently in the store
(b) the number of walk-in customers currently in the store
(c) the total number of customers currently in the store
(d) the current inventory level of Hershey candy bars

Have your model collect the following information:
(3-1) the number of customers who immediately leave the store (do not join the queue)
(3-2) the number of customers to exit by the east entrance
(3-3) the number of customers to exit by the west entrance

**Note:** this model requires the use of numerous “global variables”. In simul8, one declares these variables as an information store (Object menu \( \rightarrow \) Information Store option \( \rightarrow \) “new”). This will define the variable for you to be able to access and use in the visual logic code.
Lab 10 - Example of Student Solution

Example of Student Solution - Lab #10

Problem 1

Problem 2
Problem 3

Problem 4
Lab 11 - Description

IMSE 440/840 – Lab #11

Due: Thur, Nov 20 (by 11:59 pm)

<table>
<thead>
<tr>
<th>Lab Objective</th>
<th>To give you some experience of how random number generators work and in using the inverse transformation method.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>This lab is an individual assignment – no partners</td>
</tr>
</tbody>
</table>

**PROBLEM 0**

Complete the online questions/review posted on blackboard under Lab 11

**PROBLEM 1**

Consider the following linear congruential generator:

\[ X_i = 777 \times X_{i-1} \pmod{m} \]

with modulus \( m = 32768 \).

\[ U_i = X_i / m \]

Generate the first 15 uniform(0,1) numbers for this generator when the seed, \( X_0 = 221 \). From your observation (don’t do any formal testing), does this appear to be a good generator? Why or why not?

**PROBLEM 2**

Consider the following linear congruential generator:

\[ X_i = 1234 \times X_{i-1} \pmod{m} \]

with modulus \( m = 1024 \).

\[ U_i = X_i / m \]

Generate the first 15 uniform(0,1) numbers for this generator when the seed, \( X_0 = 554 \). From your observation (don’t do any formal testing), does this appear to be a good generator? Why or why not?

**PROBLEM 3**

Consider the following linear congruential generator:

\[ X_i = 1234 \times X_{i-1} \pmod{m} \]

with modulus \( m = 1025 \).

\[ U_i = X_i / m \]

Generate the first 15 uniform(0,1) numbers for this generator when the seed, \( X_0 = 225 \). From your observation (don’t do any formal testing), does this appear to be a good generator? Why or why not?

**PROBLEM 4**

Consider the following probability density function:

\[ f(x) = \frac{3x^2}{2}, \quad -1 \leq x \leq 1 \]

Using the inverse transformation technique, develop a sample scheme for this distribution. **Hint:** find the cumulative density function, set to \( U \), and solve for \( X \). This will give you the formula for sampling from this function.
Lab 11 - Example of Student Solution

Example of Student Solution - Lab #11

Problem 1

Problem 2
Problem 3

- Total Drive-thru Customers: 3
- Total Walk-in Customers: 1
- Total All Customers: 4
- Current Hershey Count: 2239
Lab 12 - Description

Lab Objective: To better understand the advantages and disadvantages of animation

Undergraduate student may do this lab individually or with a (different) partner.
Graduate students must do this assignment individually

(1) Watch the online narrated PowerPoint presentation on animation

(2) Complete the online quiz

______________________________________________________________

Quiz Questions for Students

Question: What are two advantages of a playback simulation versus a concurrent simulation?

(text box – student offers a response)

Question: What are three strategies to minimize presentation difficulties when demonstrating a simulation model to a customer/audience?

(text box – student offers a response)

Question: Explain how animation can create overconfidence in a simulation model

(text box – student offers a response)

Question: Explain how animation can build credibility with a client

(text box – student offers a response)
Lab 13 - Description

<table>
<thead>
<tr>
<th>Lab Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>To better understand the techniques for validating and verifying a simulation model</td>
</tr>
</tbody>
</table>

Undergraduate student may do this lab individually or with a (different) partner. Graduate students must do this assignment individually.

(1) Watch the online narrated Powerpoint presentation on verification and validation

(2) Complete the online quiz

Quiz Questions for Students

Question: Explain how verification and validation differ

(text box – student offers a response)

Question: Explain degeneracy

(text box – student offers a response)

Question: Explain what continuity means

(text box – student offers a response)
Example of Student Solution - Lab #13

**Problem 1**
1. The model should be run for 480 minutes (8 hours) rather than 540 minutes (9 hours).
2. Set distance travel time equal to zero.
3. The batched arrivals are set at 2. This should be set at 1.
4. There is only one work station. The replication of the work center is 2 when there should be no replication.
5. The processing time should be set at a Normal Distribution with a mean of 9 minutes and standard deviation of 2 minutes. The program shows a Normal Distribution with mean = 9 minutes and s.d.=2.5 minutes.
6. The label value that should be 20% as 4 is at 20% with the value 5.
7. There is a delay travel time from the work center to the work exit point set at 1.270. This value should be 0. There is no delay travel time from the WC to the exit point.

**Problem 2**
1. The label “lbl process time” is at a fixed value of 1. It should be set to a Normal Distribution with a mean of 7 minutes and standard deviation of 1 minute.
2. The travel time from the entry point to the first queue should be set at .75 minutes (45 seconds). It is set at 45 minutes, which is wrong.
3. Work Center #1 should have the process time with the correct label “lbl process time.” The label is entered in the process time at this work center, but the label wasn’t correctly entered at the beginning (entry point). --- This is not a problem if the label is correct at the beginning!
4. Work Center #2 should have a process time with the correct label “lbl process time” like WC #1. It is correct with following a normal distribution of mean = 7 minutes and s.d.=1 minute, but to be accurate with the model, the process time should be the “lbl process time.”
5. The queue for Work Center #2 should have infinite capacity, not a capacity of only 5 parts.
6. The route out for the Work Center #2 should be percent based with 50% going to the queue for process #1 and 50% going to work complete.
7. The simulation should run for 1000 minutes and not halt at the limit of 50.

**Problem 3**
1. The label “lbl item type” should be set to a distribution of 50% set at 1 and 50% set at 2. It is currently set at “no change,” and that is incorrect.
2. Work Center #2 should have a higher priority than Work Center #1. The priorities of both centers are set at 50, which is wrong. WC #2 should have a priority of 100 (or anything higher than 50).
3. There needs to be a dummy work station that pulls the expired parts from the queue. If the part expires, the exit won’t pull it out. That’s why there needs to be a dummy work center.
4. The resource “res cart” should be set at 1 available rather than 10 available.
5. The work centers both need to have the resource details as “normal: require and release the resource here” rather than the detail of “require here, but do not release the resource.”
6. Route out for Work Center #2 should be listed as “1: Exit 1 and 2: Exit 2” in order to follow the label action correctly. They are mixed up with “1: Exit 2 and 2: Exit 1.”
**Lab Objectives**

1. To learn how to continue to use Visual Logic
2. To model systems with conveyors

Undergraduate students may do this lab individually or with a partner. Graduate students must do this assignment individually.

---

**PROBLEM 1**

Two independent conveyors deliver completed parts to a warehouse. In the warehouse, these conveyors merge placing the parts on a third conveyor (conveyor #3) to final shipping. Parts arriving on conveyor 1 follow an exponential distribution with a mean of 8 parts per minute. Parts arriving on conveyor 2 also follow an exponential distribution with a mean of 10 parts per minute. Conveyor 1 is nonaccumulating and is 15 feet long. It runs at a velocity of 15 feet per minute. Conveyor 2 is accumulating and is 8 feet long. Its velocity is 25 feet per minute. Conveyor 3 is nonaccumulating and is 10 feet long. It runs at a velocity of 30 feet per minute. At the end of conveyor #3, the part is disposed of. Simulate for 250 minutes. Collect the following statistic:

(1-1) the average time to process a part

---

**PROBLEM 2**

A shipping department handles two types of packages: regular and express delivery. After arrival, a 20-foot-long accumulating conveyor running at 25 feet per minute delivers the packages to the shipping department. The packages arrive at a mean rate of one per minute following an exponential distribution. Thirty percent of the packages require express delivery, the rest use regular delivery. At the end of the conveyor, regular packages are transferred to a 10-foot-long, nonaccumulating conveyor running at 20 feet per minute. Express delivery packages are transferred to a 10-foot-long accumulating conveyor running at 30 feet per minute. Express delivery packages are transferred to a 10-foot-long accumulating conveyor running at 30 feet per minute.

At the end of each conveyor is a work center where John sets up the automated wrapping machine. It takes UNIF(10,15) seconds for John to set up the machine at the regular station. Once the setup is done, John is free to do other things. A regular package takes UNIF(45,55) seconds to be processed. At the express work center, it takes John a constant of 20 seconds to set up the wrapping machine. Once set-up, John is free to do other things and the machine takes TRIA(30,40,45) seconds to wrap a package. Once wrapped, a package leaves the system. Priority is for John to setup an express machine before setting up a regular machine. The time for John to walk between the express machine to the regular machine is 20 seconds.

Simulate this system for 8 hours. Collect the following statistic:

(2-1) the average time to process a regular package
(2-2) the average time to process an express package
(2-3) the utilization of John

Also:
(a) use different icons to represent the regular and express packages
(b) have a counter on screen showing the number of each type of package in the system.
PROBLEM 3

Consider a manufacturing process in which a pallet of parts arrives every \( \text{EXPO}(15) \) minutes. Once it arrives, a pallet of parts is painted either red, blue, or yellow by a single paint machine. The paint machine can only paint one pallet at a time. Forty percent of the time, a pallet of parts is painted red, 15% it is painted blue, and 45% it is painted yellow. It takes a total of \( \text{UNIF}(12,15) \) minutes to paint a pallet of parts. After a pallet has been painted, individual (painted) parts are removed from the pallet. Ninety percent of the time, a pallet has 4 pieces. Due to a poor quality control, 10% of the time a pallet has five parts. Once removed from the pallet, it takes 30 seconds to move a part from the paint machine to its first processing station.

After processing by the paint machine, each individual part is processed through a series of 3 production stations. Each production station consists of a single machine. Each color part has a unique production sequence and each has different processing times at the stations. The production sequences are:

- **Red Part:** \( 2 \rightarrow 1 \rightarrow 3 \)
- **Blue Part:** \( 1 \rightarrow 2 \rightarrow 3 \)
- **Yellow Part:** \( 2 \rightarrow 1 \rightarrow 3 \)

The processing time at each production station is given below:

<table>
<thead>
<tr>
<th>Part Type</th>
<th>STATION 1</th>
<th>STATION 2</th>
<th>STATION 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>( \text{EXPO}(3) )</td>
<td>( \text{EXPO}(2) )</td>
<td>( \text{EXPO}(5) )</td>
</tr>
<tr>
<td>Blue</td>
<td>( \text{EXPO}(4) )</td>
<td>( \text{EXPO}(1) )</td>
<td>( \text{EXPO}(3) )</td>
</tr>
<tr>
<td>Yellow</td>
<td>( \text{EXPO}(2) )</td>
<td>( \text{EXPO}(1) )</td>
<td>( \text{EXPO}(6) )</td>
</tr>
</tbody>
</table>

Travel time between station is as follows:

- **Station 1 \( \rightarrow \) Station 2:** \( \text{UNIFORM}(30,45) \) seconds
- **Station 1 \( \rightarrow \) Station 3:** an accumulating conveyor, 12 feet long, velocity of 25 feet per minute
- **Station 2 \( \rightarrow \) Station 1:** a nonaccumulating conveyor, 10 feet long, velocity of 20 feet per minute
- **Station 2 \( \rightarrow \) Station 3:** \( \text{EXPO}(4) \) minutes

After processing at Station 3, parts are reassembled onto new pallets based on color type. Red parts are accumulated 4 to a pallet, blue parts are accumulated 3 parts to a pallet, and yellow parts are accumulated 2 parts to a pallet. Once a pallet is filled to its capacity, it leaves the system.

Every 60 minutes, the paint machine must be turned off so that it can be cleaned for 5 minutes. It always takes 5 minutes to clean the machine. No pallets can be processed while the machine is being cleaned. If the machine is processing a pallet of parts when its scheduled down time occurs, the cleaning is held off until the pallet is finished processing.

Model the system for 920 minutes and collect statistics on:

- (3-1) the number of red pallets that leave the system
- (3-2) the number of blue pallets that leave the system
- (3-3) the number of yellow pallets that leave the system
- (3-4) the utilization of the paint machine

**WHAT TO TURN IN:** In a single e-mail message to me (psavory@unl.edu), attached all 3 of your Simul8 models along with a file (with you name in it) that has all answers to each of the requested statistics. **BE SURE TO RESET YOUR SIMUL8 MODELS BEFORE SAVING AND SENDING THEM** (thus, smaller file size). Unless otherwise specified, run 1 replication of your model.
Problem 1

Problem 2
Lab 14 - Example of Student Solution

Problem 3
IMSE 440/840
Discrete Event Simulation
Examination #1

Monday, October 6, 2008

Instructions:

(1) This exam is **OPEN book** and **OPEN notes**.

(2) There is 1 question in this exam – worth 20 points

(3) Turn in both this examination and a copy of your simul8 model saved on my USB drive and posted to Blackboard.

(4) It is suggested that you read through the entire exam before you begin. Budget your time carefully.

GOOD LUCK!
Four different color parts arrive to a system for a final processing step. Red parts arrive following an exponential distribution with a mean of 10 minutes. Each weighs 5 pounds. Upon arrival, a red part waits in Queue: RedandBlue.

Blue parts arrive following a normal distribution with a mean of 4 minutes and a standard deviation of 15 seconds. Each weighs 8 pounds. The first blue part arrives at the start of the simulation. Upon arrival, a blue part waits in Queue: RedandBlue.

Green parts arrive at a constant rate of 6 per hour. Each weighs 9 pounds. Upon arrival, a green part attempts to join the Queue: GreenandYellow. This queue has capacity of 8. If the queue is at capacity, the part immediately exits the system.

The time between arrival for a yellow part is 30 minutes (30% of the time) and 40 minutes (70% of the time). Each weighs 10 pounds. Due to poor quality control, upon arrival, 90% of the time an
arrival consists of one yellow part and 10% of the time two yellow parts arrive. After arrival, a yellow part attempts to join the Queue: GreenandYellow. This queue has capacity of 8. If the queue is at capacity, the part immediately exits the system.

In the Queue: RedandBlue, red parts have higher priority than blue parts. In the Queue: GreenandYellow, Yellow parts have priority over Green parts.

There are two workers (Larry and Jody) who select items from the queues and process them. The processing time for each worker is the same and is defined by the color of the part:

- **Red**: Normal(5,1)
- **Blue**: Uniform(3,4)
- **Green**: Triangular(3,4,7)
- **Yellow**: Normal(7,2)

After processing by Jody, a part’s weight increases by 0.5 pounds. After processing by Larry, a part’s weight increases by 2%. If a part is processed multiple times, its weight continually increases after each processing.

After processing by Larry or Jody, 90% of the time a part is good and leaves the system based on its color. 10% of the time the part needs to be reworked. In this case, it travels (for 20 seconds) to a third queue (Queue: rework). Priority in this queue is by the weight of the part – the higher the weight, the higher the priority.

If both are free, priority is for Jody to process the next part. When free, the preference for Larry and Jody to select the next part to process is:
- **Larry**: Queue: Rework (highest) → Queue: RedandBlue → Queue: GreenandYellow (lowest)
- **Jody**: Queue: Rework (highest) → Queue: GreenandYellow → Queue: RedandBlue (lowest)

Write a simul8 model to simulate the above description. Run your simulation for 11 hours or until 50 blue parts leave the system. Answer the following questions:

<table>
<thead>
<tr>
<th>Question</th>
<th>Your Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1] The total number of green parts that leave immediately and do not join Queue: GreenandYellow</td>
<td></td>
</tr>
<tr>
<td>[2] The total number of green parts that join Queue: GreenandYellow</td>
<td></td>
</tr>
<tr>
<td>[3] The average number of parts in Queue: RedandBlue</td>
<td></td>
</tr>
<tr>
<td>[5] The maximum number of times any part had to be reworked</td>
<td></td>
</tr>
<tr>
<td>[6] The average time a red part waits in the Queue: RedandBlue until it is processed</td>
<td></td>
</tr>
<tr>
<td>[7] The number of yellow parts that were in the system less than 12 minutes</td>
<td></td>
</tr>
<tr>
<td>[8] The number of Green parts which successfully leave the model and had to be reworked :</td>
<td>5 times</td>
</tr>
<tr>
<td>0 times</td>
<td>6 times</td>
</tr>
<tr>
<td>1 time</td>
<td>7 times</td>
</tr>
<tr>
<td>2 times</td>
<td>8 times</td>
</tr>
<tr>
<td>3 times</td>
<td>More than 8 times</td>
</tr>
<tr>
<td>4 times</td>
<td></td>
</tr>
</tbody>
</table>

Run 50 trials of your model and report 95% confidence intervals for:

<table>
<thead>
<tr>
<th>Question</th>
<th>Your Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>[9] 95% confidence interval on average time a red part was in the system (arrival to leaving)</td>
<td></td>
</tr>
<tr>
<td>[10] 95% confidence interval on the average time a part spend in Queue: RedandBlue</td>
<td></td>
</tr>
</tbody>
</table>

Please turn in your model two ways: (1) store on my USB drive, (2) go to the course Blackboard website and turn in your exam at the examination link.
Part Arrival
- **Red/Purple/Blue**: Expo(10) and weighs 5 pounds
- **Blue/pink/cyan**: NORM(4,.25) and weighs 8 pounds
- **Green/orange/gold**: 6 per hour – fixed(10) and weighs 9 pounds
- **Yellow**: (30%-30 and 70%-40), **black**: (35%-30 and 65%-42), **white**: (20%-30 and 80%-40 and weigh 10 pounds

Assign processing time:
- **Red/Purple/Blue**: Normal(5,1)
- **Blue/pink/cyan**: UNIF(3,4)
- **Green/orange/gold**: TRIA(3,4,7)
- **Yellow/black/white**: NORM(7,2)

Queues:
- **First queue**: priority to red/purple/blue parts over blue/pink/cyan
- **Second queue**: capacity of 8. Route out if full. priority to yellow/black/white parts versus green/orange/gold
- **Rework queue**: priority by weight

**Larry**
- Priority is rework → first queue → second queue
- Weight increases by 2%/3%/4%
- 90% good and 10% fail
- .3333 (20 second) travel time for those that fail

**Jody**
- Priority is rework → second queue → first queue
- Weight increased by 0.5 pounds
- 90% good and 10% fail
- .3333 (20 second) travel time for those that fail

**Jody priority over Larry**
- Turn off underlying system map
- After processing, route-out to each exit point by color
- Run for 11 hours or until 50 blue/pink/cyan parts leave

**Statistics**
- Total number of green/orange/gold parts that do not join the queue
- Total number of green/orange/gold parts that do join the queue
- The average number of parts in the first queue
- The utilization of Larry/Jody
- The maximum number of times any part has to be reworked
- The number of yellow/black/white parts that finished in less than 12/15 minutes
- The number of green/orange/gold parts that leave the model and had to be reworked

95% CI on average time a red/purple/blue part is in the system
95% CI on average time a part spends in first queue
Example of Student Solutions – Exam 1

Another Example
Who is sitting directly to your left *(if anyone)*: ________________________________

Who is sitting directly to your right *(if anyone)*: ________________________________

**IMSE 440/840**
Discrete Event Simulation
Examination #2

Monday, Nov 3, 2008

Instructions:

(1) This exam is **OPEN book** and **OPEN notes**.

(2) There is 1 question in this exam – worth 15 points

(3) Turn in both this examination and a copy of your simul8 model saved on my USB drive and posted to Blackboard.

(4) It is suggested that you read through the entire exam before you begin. Budget your time carefully.

**GOOD LUCK!**
Consider a typical day for New Student Orientation at UNL. A family (father, mother, and child) arrive at a rate of 3 per hour (following an exponential probability distribution). Upon arrival, a family joins a queue to wait for the single advisor on duty. If a family is not selected from the queue within 25 minutes, the family leaves the queue – 60% of the time they walk around campus for 12 minutes and then join the queue (a family can potentially walk around multiple times), 40% of the time they immediately leaves UNL and do not return. Once selected from the queue by the single advisor, it takes 10 minutes (exponentially distributed) to complete all the advising paperwork. Once done with the advisor, each family members leaves and goes their separate way – the child goes to the campus union, the father goes to the football stadium, and the mother goes to the library. Looking at each of these people individually:

- **Child:** Once a child leaves the advisor, she waits in a queue for coffee at the student union. There is one server on duty and the time for him to make a coffee follows a normal distribution with a mean of 5 minutes and a standard deviation of 2 minutes. Ten percent of the time a child finds the coffee is horrible. If so, the child rejoins the coffee queue at the head/top position in the queue. This continues until the child gets a good cup of coffee. Next she waits by the outside fountain for her mother and father.
• **Father:** Once a father leaves the advisor, he walks over to look at the football stadium. The time to do this follows a normal distribution with a mean of 12 minutes and a standard deviation of 2 minutes. Since it is so large, assume any number of fathers can be touring the stadium. Once done, a father waits by the fountain outside the student union for the child and mother.

• **Mother:** Once a mother leaves the advisor, she walks to the library (which takes 4 minutes) and then waits in a queue to watch a video how to check items out of the library. It takes Triangular(2,4,7) minutes to watch the interactive video. Only one person can watch the video at a time. After 25 people have watched the video, it needs to be cleaned. This is done automatically, but takes a constant time of 10 minutes. No video can be shown during the 10 minute delay. Once done with the video, the mother walks back to the union (4 minutes) and then waits at the fountain for the child and father.

Once a family is back together, they (as a group) wait (in QUEUE: FrancoQ) to meet Dr. Juan Franco (vice chancellor of student affairs). The time that Dr. Franco spends with each family is UNIFORM(4,10) minutes – he visits only one family at a time. Once done with the Dr, Franco, the family leaves the campus.

On average, every 90 minutes (exponentially distributed), a faculty member needs to see Dr. Franco. Upon arrival, a faculty member immediately interrupts Dr. Franco’s meeting with a family. A faculty member spends UNIFORM(15,20) minutes with Dr. Franco. Note: a faculty member cannot interrupt another faculty member and will have to wait for Dr. Franco. An interrupted family waits (in QUEUE: FrancoQ) at the highest rank (thus, they will be selected next once all faculty members are finished) – this is the same queue. If additional faculty arrive, a family can be interrupted multiple times. When Dr. Franco resumes his visit with a family, the processing time is the full time (versus an interrupted family’s remaining time).

**Write a simul8 model to simulate the above description for 24 hours. Run your model for 1 trial/replication and answer the following questions:**

<table>
<thead>
<tr>
<th>Question</th>
<th>Your Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1] The total number of families to arrive</td>
<td></td>
</tr>
<tr>
<td>[2] The number of families to leave UNL since they were not selected to see an advisor within 25 minutes</td>
<td></td>
</tr>
<tr>
<td>[3] The total number of times that coffee had to be remade since it was horrible</td>
<td></td>
</tr>
<tr>
<td>[4] The total number of times families are interrupted by an faculty member arriving to see Dr. Franco</td>
<td></td>
</tr>
<tr>
<td>[5] The average number of families waiting to see Dr. France (in QUEUE: FrancoQ)</td>
<td></td>
</tr>
<tr>
<td>[7] The average time a family (who sees an advisor) is at UNL</td>
<td></td>
</tr>
<tr>
<td>[8] The average time a faculty member is in the system</td>
<td></td>
</tr>
</tbody>
</table>

**Run your model for 25 trials/replications and report a 95% confidence interval for:**

<table>
<thead>
<tr>
<th>Question</th>
<th>Your Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>[9] The total number of families to see an advisor and leave UNL</td>
<td></td>
</tr>
</tbody>
</table>

**Please turn in your model two ways: (1) store on my USB drive, (2) go to the course Blackboard website and turn in your exam at the examination link**
IMSE 440/840
Discrete Event Simulation
Examination #2 – part 2

Wed, Nov 5, 2008

Instructions:

(1) This exam is OPEN book and OPEN notes.

(2) There is 1 question in this exam – worth 5 points.

(3) It is suggested that you read through the entire exam before you begin. Budget your time carefully.

GOOD LUCK!
A courier service processes three different types of package deliveries: regular, express, and freight. Regular packages arrive in batches of 3 – the first batch arrives at time 6 and then every 25 minutes afterward. An express package arrives starting at time zero and arrives every 16 minutes afterward. A freight package arrives starting at time 10 and then every 17 minutes afterward. After 3 freight packages arrive, no additional freight packages arrive.

Upon arrival, an information storage, called NumInSystem is incremented. In addition, a variable WeightToArrive is incremented by the weight of the package. Next, a package attempts to join a queue called PackageQ until the single clerk can process it one at a time. The queue PackageQ has capacity of 2 – if at capacity, an arriving package decrements NumInSystem and leaves the model. Priority for packages to be selected from the queue is: freight first, then regular, then express. Processing time and weight for a package are as follows:

<table>
<thead>
<tr>
<th>Package Type</th>
<th>Process Time</th>
<th>Package Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular</td>
<td>3 minutes</td>
<td>2 pounds</td>
</tr>
<tr>
<td>Express</td>
<td>4 minutes</td>
<td>1 pounds</td>
</tr>
<tr>
<td>Freight</td>
<td>12 minutes</td>
<td>20 pounds</td>
</tr>
</tbody>
</table>

Once processed, the variable NumInSystem is decremented and the package then leaves the system.

Run the simulation for **40 minutes** or until five packages have been processed. Collect/calculate the following statistics:

1. the time that the simulation ends: ________________________________
2. the final value of the variable NumInSystem: ________________________________
3. the final value of the variable WeightToArrive: ________________________________
4. the final number of packages in queue PackageQ: ________________________________
5. the maximum number of packages in queue PackageQ: ________________________________

For extra credit, determine:
The average number of packages waiting in the queue: ________________________________
| Problem 1 | Work for Problem 1 |
Examination 2 Description
Exam 2 grading sheet

**simul8 programming problem** (15 points possible)

(1) Family arrives (20 minutes or 15 minutes) and joins queue
(2) Shelf life of 25 minutes
   a. 40% leave
   b. 60% delay 12 minutes and rejoin queue
(3) Delay with advisor (10 or 11 minutes)
(4) Batch out 3 copies of entity

Child
(5) Wait in queue for coffee – priority in queue for reprocessing
(6) delay process time (Norm (5,2) or NORM (5,1))
(7) 10% of time coffee bad and rejoin queue, 90% good

Father
(8) Delay time to go to football stadium (Norma (12,2) or TRIA(10,12,16))

Mother
(9) travel time to library (4 minutes or 3 minutes)
(10) wait in queue
(11) Watch vide (TRIA(2,4,7) or TRIA(3,5,8))
(12) Breakdown – after 25 people, down for 10 minutes
(13) travel to fountain (4 or 3 minutes)
(14) Original Family grouped and assembled together
(15) wait in queue for Franco – priority to family interrupted
(16) get processed by Franco (UNIF(4,10) or UNIF(5,11))
(17) Faculty arrive (90 minutes or 100 minutes)
(18) faculty interrupt family
(19) faculty processed UNIF(15,20) or NORM(18,2)
(20) run for 24 hours (1440 minutes)

Statistics
(20) Total number of families to arrive
(21) Total number of families leave without seeing advisor
(22) Total number of times coffee had to be remade
(23) Total number of families interrupts
(24) the average number families in the queue
(25) Utilization of Dr. Franco
(26) Average time a family is at UNL
(27) Average time a faculty member in system
(28) Confidence interval – 25 trails: total number of families at UNL

**Event calendar Problem** (5 points possible)
Example of Student Solutions – Exam 2

Another Example
IMSE 440/840
Discrete Event Simulation
Final Examination
Fall 2008

Instructions:

(1) This exam is OPEN book and OPEN notes.

(2) There are 2 questions in this exam

(3) Be sure to turn in both this examination and a floppy disk with your simul8 model

(4) It is suggested that you read through the entire exam before you begin. Budget your time carefully and work on the easiest questions first.

GOOD LUCK!
Problem 1

Within a washing machine factory, machines that fail inspection arrive to a repair operation at a rate of 5 per hour (exponentially distributed). Upon arrival, machines wait in a first-in-first-out queue for service by Susan. Correspondingly, a problem report for this specific machine is electronically sent to Chris, the repair area supervisor. Due to glitches in the computer system, it takes 8 minutes before the system will put the problem report form for a newly arrived machine in a database/queue for Chris to be able to access it.

When Susan is free, she selects the next washing machine – she can only process at most one machine at a time. The process by which Susan repairs a machine follows three steps:

In Step 1, Susan inspects the hose connections, the electrical plug, and the regulator. Step 1 takes UNIFORM(1,3) minutes. Sixty percent of the time this inspection fixes the problem and the machine leaves her repair station and goes to wait in a queue for Chris (as such, Susan is available to select another machine to process). Chris will match the machine with the problem report form in the computer database/queue, sign off on the repair, and send the machine to the packaging area. It takes Chris NORMAL(2,0.5) minutes to match up the machine with the record and complete this task. Remember: it takes 8 minutes before Chris can access a specific machine’s problem report form.

If the Step 1 inspection does not find the problem, in Step 2, Susan removes the motor cover and checks the motor wiring. Step 2 takes TRIANGULAR(3,5,7) minutes. Seventy-five percent of the time this fixes the problem and the machine leaves Susan’s repair station (and she can select another machine to process) and goes to wait for Chris to process it.

If the Step 2 inspection does not find the problem, in Step 3, Susan replaces the washing machine motor. Step 3 takes NORMAL(15,5) minutes. This final step always fixes the problem. Once done, the machine leaves the repair station and goes to Chris to process it (Susan is available to select another machine).

Susan’s bonus pay is based on the number of machines she completes repairs on in a 12-hour day. Below is her bonus plan:

<table>
<thead>
<tr>
<th>Number of Machine’s Repaired</th>
<th>Bonus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 20</td>
<td>$2 bonus for each</td>
</tr>
<tr>
<td>21 to 30</td>
<td>$2.75 bonus for each</td>
</tr>
<tr>
<td>31 and more</td>
<td>$3.25 bonus for each</td>
</tr>
</tbody>
</table>

For example, if she processes 24 machines in a day, here bonus will be ($2 x 20) + ($2.75 x 4) = $51. Incorporate logic into your model that calculates her daily bonus.

Simulate for 1 replication of a 12 hour day and have your model collect the following statistics:

(1) the number of washing machines that go through Step 3 __________________________
(2) the percentage of time Susan is busy (her utilization) _____________________________
(3) the percentage of time the Chris is busy (his utilization) _________________________
(4) the amount of bonus that Susan earns for the day ________________________________
   (note: have your model compute this statistic)
(5) the number of machines that go to the packaging area that were in the repair operation (from arrival to Chris signing off on the repair) for a total of between 8 and 11 minutes) __________
Consider the operation of the Nebraska Credit Union. Customers arrive following an exponential distribution with a mean rate of arrival of 30 per hour. A customer is one of three types: student (40%), faculty (40%), and administrator (20%). The height of a customer is UNIFORM(50,78) inches. Upon arrival, a customer takes a staircase up to the second floor. It takes a customer TRIANGULAR (20,40,75) seconds to walk up the stairs and there can only be at most 5 people on the staircase at any point in time. Customers that arrive when it is at capacity must wait until there is an available space.

Upon arrival to the second floor, students wait in a queue (studentQ) for processing at counter 1, faculty wait in a second queue (facultyQ) for processing at counter 2, and administrators work in a third queue (adminQ) for processing at counter 3. Lewis is the only bank teller on duty. He moves between each counter as different customers come in. His priority for processing a customers is administrators, then faculty, and then students. His travel time between counters is:

- Counter 1 to Counter 2 → 15 seconds
- Counter 2 to Counter 3 → 15 seconds
- Counter 1 to Counter 3 → 30 seconds

Assume the travel from is the same to as from. **Hint: think of modeling Lewis as a resource and each counter as a separate work center**

The processing time for each type of customer is:

<table>
<thead>
<tr>
<th>Customer Type</th>
<th>Processing Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>TRIA(1, 1.2, 3) minutes</td>
</tr>
<tr>
<td>Faculty member</td>
<td>EXPO(2) minutes</td>
</tr>
<tr>
<td>Administrator</td>
<td>UNIF(1,3) minutes</td>
</tr>
</tbody>
</table>

Once done with Lewis, all customers must take a conveyor (30 feet, accumulating, 1 foot per minute) to the 1st floor entrance/exit to leave the building.

**Simulate for 1 replication of 10 hours of operation and have your model collect the following statistics:**

1. the total cumulative height of all **students** who are processed and leave the bank __________
   *(note: have your model compute this statistic)*
2. the average time a student who completes service is in the bank _______________________
3. the average time a faculty who completes service is in the bank _____________________
4. the average time an administrator who completes service is in the bank _______________
5. the percentage of time that Lewis is busy ________________________________

**Please turn in your models two ways: (1) store on my USB drive, (2) go to the course Blackboard website and turn in your exams at the examination links**
Problem 1

(1) customer arrival – expo (.75) minutes
(2) money in pocket UNIF(2.250)
(3) wait for terminal of 5
(4) five terminals – UNIF(20,75) seconds - .3333, 1.15
(5) admin to one queue and student/faculty to other
(6) Sally priority for adminQ
(7) Sally take 10 minute break after each set of 75
(8) regularQ – after 2 minutes – check to leave
  • if 2 or more in adminQ, leave
  • else go back and reorder
(9) amount of order is tria(2,4,6)
(10) run for 480 minutes
(11) statistic: cumulative amount of money of all students
(12) number that leave regularQ and leave the system
(13) utilization of sally
(14) total revenue generated in single 8 hour day

Problem 2

(1) television arrivals 6 per hour – expo(10)
(2) assign unique number
(3) go to dummy and send two out
(4) Wait for Chris
(5) grab Chris
(6) step 1 – unif(1,3), 60% fixed
(7) step 2 – tria(3,5,7), 75% fixed
(8) step 3 – NORM(15,5), 100% fixed
(9) release Chris
(10) Delay 8 minutes to Sally
(11) Sally assemble and match – NORM(2,0.5)
(12) Statistic: number whose TIS is between 8 and 11
Problem 1

Problem 2
THE PROJECT

For your semester project, you are to develop a simulation model to analyze the performance of a real system. This is an open-ended project. The choice of the system is up to your team, though there should be some defined objective for studying it and at least 5 sources of randomness. Due to the open nature of this project, when in doubt - ASK!

THE SCENARIO

Picture several years down the road....

You have successfully passed IMSE 440/840 and have gone on to graduate. At graduation, a small simulation consulting company (having learned that you passed this class) hires you and your teammates as simulation consultants.

Your first job is to perform a simulation study. Your deliverable to the client is a report of the system.

REPORT FORMAT

For the project to be considered for full credit, it should follow the below proposed major sections (see the attached grading sheet for more details of each section)

Section A: Project Summary
Section B: Problems and Issues
Section C: System Description and Conceptual Model
Section D: Input Data Collection
Section E: Analysis of Results
Section F: Conclusions

Your team’s analysis should match the following due dates and deliverables:

TASK 1 – Due By: Monday, October 9 (by midnight)

Your team is to e-mail me (psavory@unl.edu) a brief outline (maximum of one page) describing the system you want to model. Indicate the modeling objective and the performance measures you want to obtain.

TASK 2 – Due By: Monday, November 6 (by midnight)

Your team is to e-mail me an update on your project – what has been done and its current status. In general, I would expect you to be complete with Section B, C, and D of the final report. That is, the scope of the project should be defined and all data collection should be performed.
Your team is to e-mail me an update on your project – what has been done and its current status. In general, I would expect you to be complete with Section B, C, D, and E of the final report. That is, write the simulation model and analyze the results sections should now be complete.

Your team is to turn in two printed copies of your draft project report.

Your team is to return a project evaluation form from having read the project of another team.

Your team is to give a 10 minute presentation of your project - your objectives, the system you studies, your analysis, and the results your determined. See that attached grading sheet for how the presentation will be evaluated.

Your team is to turn in one printed copies of your final project report.
**IMSE 440/840 - PROJECT REPORT EVALUATION**

**Team Being Evaluated**

**REPORT CHARACTERISTIC**

<table>
<thead>
<tr>
<th>REPORT CHARACTERISTIC</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Indifferent</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Not Applicable</th>
</tr>
</thead>
</table>

**PROJECT SUMMARY**
The executive summary *briefly* summarizes the project, objectives, analysis, and conclusions without introducing any statistical or simulation jargon or a mass of numbers generated by the simulation model.

**PROBLEMS AND ISSUES**
The problem statement describing objectives/goals is clearly stated.

**SYSTEM DESCRIPTION AND CONCEPTUAL MODEL**
The system under study is described so that a person unfamiliar with it can understand it (possibly includes a picture).

Performance measures for evaluated the system are defined.

Assumptions are clearly stated.

Limitations are defined.

**INPUT DATA COLLECTION**
Input data requirements - what specific data needs to be estimated/collected.

Data collection or sampling plan is defined.

Method of sampling is appropriate.

Methods utilized in analyzing the data are correctly applied.

**ANALYSIS OF THE RESULTS**
Results are clearly stated and presented (with graphics).

Comparisons are appropriately connected.

Conclusions are substantiated by the data presented.

Generalizations are confined to the population from which the data was drawn.

Alternative hypotheses or explanations of the data are ruled out.

**CONCLUSIONS**
State your interpretation of results and offer insight on whether you met your modeling goals.

Improvements or modifications to the system are proposed.

**CLEAR COMMUNICATION**
Writing is clear, logical, and organized.

Work is written with clarity and without error.

**Overall, how would you rate the current quality of the report**

- Excellent □
- Good □
- Average □
- Poor □
- Unsatisfactory □

**Specify any improvements needed to the report**
# Project Presentation Evaluation

**Team Being Evaluated**

**Your Name**

## Presentation Organization

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Indifferent</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>The introduction gave me a clear idea of the topic.</td>
<td></td>
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<tr>
<td>The introduction gave me a clear idea of the direction the presentation would take.</td>
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<tr>
<td>The presentation presented information in logical, interesting sequence</td>
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<tr>
<td>The conclusion did a good job of summarizing the content of the presentation.</td>
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<tr>
<td>Enough essential information was given to allow me to effectively evaluate the topic</td>
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<tr>
<td>The presentation was free from irrelevant or filler information</td>
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<tr>
<td>The presentation filled the time allotted</td>
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</tbody>
</table>

## Presentation Content

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Indifferent</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>I could easily follow the main points of the presentation.</td>
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<tr>
<td>The presenter had a clear understanding of the material presented</td>
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<tr>
<td>The plans, recommendations and/or conclusions are consistent with the findings</td>
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<tr>
<td>Presenter answers all questions with explanations and elaboration</td>
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</tbody>
</table>

## Presentations Visuals

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Indifferent</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>The visuals were effective in enhancing the message</td>
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<tr>
<td>The visuals were legible and easy to read</td>
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<tr>
<td>Visuals were free from grammar and formatting errors</td>
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<tr>
<td>The number of visual aids enhanced the presentation</td>
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<tr>
<td>The visuals were displayed for an appropriate time and had no annoying transition effect</td>
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</table>

## Presentation Delivery

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Indifferent</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>The presenter spoke clearly, was easily heard, and maintained an appropriate talking rate</td>
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<tr>
<td>The presenter maintained a good posture and made effective use of hand and body gesture</td>
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<tr>
<td>The presenter maintained eye contact with the audience</td>
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</tbody>
</table>

### Overall, how would you rate the quality of this presentation

- Excellent
- Good
- Average
- Poor
- Unsatisfactory

*Please share any written comments about the presentation on the back*
IMSE 440/840 - Project Self-Evaluation

Your Name

Your Team

What do you consider are the top two accomplishments of your project team?

(1)

(2)

Did your teammates provide you enough guidance/feedback on your work?

What new skills have you learned as a result of this project?

What key strengths did you bring to your team?

(1)

(2)

(3)

What areas do you see yourself needing to improve?

(1)

(2)

Rate your project efforts for each of the below areas

<table>
<thead>
<tr>
<th></th>
<th>Excellent</th>
<th>Good</th>
<th>Average</th>
<th>Poor</th>
<th>Unsatisfactory</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude</td>
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<tr>
<td>Initiative</td>
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<td></td>
<td></td>
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<tr>
<td>Dependability</td>
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<tr>
<td>Work quality</td>
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<td>Work quantity</td>
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<tr>
<td>Technical knowledge</td>
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<td>Able to work with</td>
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<tr>
<td>Organization ability</td>
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<tr>
<td>Judgment</td>
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<tr>
<td>Responsibility</td>
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<td>Leadership</td>
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</tbody>
</table>

Rate your overall performance for the project

Excellent ☐  Good ☐  Average ☐  Poor ☐  Unsatisfactory ☐  Not Applicable ☐

Any additional comments you would like to share about your project experience?
**Name of Team Member**

**Your Name**

**Your Team**

**What are the top two project accomplishments of your team member?**

(1)  

(2)  

**What key strengths did this team member bring to your team?**

(1)  

(2)  

(3)  

**What areas do you see your team member needing to improve?**

(1)  

(2)  

(3)  

<table>
<thead>
<tr>
<th>Rate your team member’s for each of the below areas</th>
<th>Excellent</th>
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<th>Average</th>
<th>Poor</th>
<th>Unsatisfactory</th>
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<td>Work quantity</td>
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<tr>
<td>Technical Knowledge</td>
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<tr>
<td>Teamwork</td>
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<td>Organization Ability</td>
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<td>Judgment</td>
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<td>Responsibility</td>
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</table>

**Rate your team member’s overall performance for the project**

Excellent  □  Good  □  Average  □  Poor  □  Unsatisfactory  □

**Any additional comments you would like to share about your team member?**
Name of Team Member

Your Name

Your Team

What are the top two project accomplishments of your team member?

(1) 

(2) 

What key strengths did this team member bring to your team?

(1) 

(2) 

(3) 

What areas do you see your team member needing to improve?

(1) 

(2) 

(3) 

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<td>Work quality</td>
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<td>Work quantity</td>
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<tr>
<td>Technical Knowledge</td>
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<tr>
<td>Teamwork</td>
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<td>Organization Ability</td>
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<td>Judgment</td>
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<tr>
<td>Responsibility</td>
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</tbody>
</table>

Rate your team member’s overall performance for the project

Excellent ☐  Good ☐  Average ☐  Poor ☐  Unsatisfactory ☐

Any additional comments you would like to share about your team member?
Modeling the Laptop Check-Out Service at UNL City Campus Union

Kelli Kopocis, Chun Pei Lim, & Paul Pei
Overview

• Project summary
• Problems and issues
• Conceptual model
• Data collection
• Model assumptions
• Simul8 baseline & optimization models
• Analysis of the results
• Conclusions

Project Summary

• For this particular project, the flagship check-out service at the City Campus Union will be studied. (Modeling factors)
  – Number of available laptops
  – Number of check-out centers
  – Number of lab consultants
• Model parameters
  – 5 Apple MacBook Pros for overnight or weekend check-out.
  – 42 Gateway M255s for daily check-out.
  – 26 Gateway M255s for overnight and weekend check-out.
• This project will provide tools to put excess funds in to use.
• Decision to modify current model from two windows with two consultants to one window with one consultant
  – Chose latter option
Problems and Issues

• The current system has some problems.
  – Long queues at lunch to check out laptops
  – Long queues at night to check in laptops.
  – Two student consultants are not busy in regular time and overloaded in lunch time and dinner time.
• Remodel facility to create specialized room with 1 split window.
• No corresponding model to track the computer systems.
• In this project, we build simulation models to determine the system inventory levels and the utilization of the three computer systems.
• Next, we will model the utilization of the student consultant. Based on the models, the authority can determine the student consultant employment policy.

Conceptual Model
Simulation Process

1. Problems with the current system?
2. Requirement of modification
3. Recommendations

Determine the goals and objectives

1. Distribution of the arrivals
2. Distribution of the service time
3. System queuing logic

Build the conceptual model

1. System characteristics (# of queues, # of consultants, etc.)
2. State variables (# of inventory, Utilization of computers, etc.)
3. Statistics

Build the computational model

1. Distribution of the arrivals
2. Distribution of the service time
3. System queuing logic

Verify

1. Does the computational model match the conceptual model?

Validation

1. Does the computational model match the current system?
2. Can the computational model fulfill the goals and objectives?

Data collection

- Approach to collect data
  - Web-based database
  - The difference between these timestamps: the arrival rate of students.
  - Fitting into Arena to find the distributions of the arrivals.
  - The data collected was the entire data over an average week's time.

- Distribution of the service times of each of the two consultants
  - Consultants were timed for 20 repetitions.
  - These 20 repetitions were inputted into Arena to find the distributions.
Five Sources of Randomness

<table>
<thead>
<tr>
<th>Sources of randomness</th>
<th>Proposed Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check-in student Arrival</td>
<td>Lognormal (7.13 , 13.1)</td>
</tr>
<tr>
<td>Check-out student Arrival</td>
<td>Lognormal (5.19 , 8.42)</td>
</tr>
<tr>
<td>Percentage of the arrival student types</td>
<td>58% Daily Gateway system</td>
</tr>
<tr>
<td></td>
<td>35% Overnight Gateway system</td>
</tr>
<tr>
<td></td>
<td>7% MacBook</td>
</tr>
<tr>
<td>Check-in process time</td>
<td>Normal (1, 0.25)</td>
</tr>
<tr>
<td>Check-out process time</td>
<td>Normal (3.5, 2)</td>
</tr>
</tbody>
</table>

Modeling Assumptions

- Modeling regular service time
  - Sunday ~ Thursday (10:30AM to 10:30PM)
- Tracking the computer systems
  - The accessory could be serviced upon the specific request.
- Estimating the percentage of the student arrivals
  - 58% check-out Gateway daily systems
  - 35% check-out Gateway overnight windows system
  - The rest of 7% are for the MacBook Pros.
- Starting inventory levels are 42, 26 and 5 respectively.
  - Nearly all the regular computer systems will check-in at the end of the day.
  - Overnight systems will check-in before 2:00PM one day after they have been checked-out.
Assumptions (continued)

- Maximum waiting time in the queue: 15 minutes
- Two student consultants could cover both the check-in and check-out service.
- A student may change their mind about which kind of system to check-out
- The criteria to stop the simulation
  - The total inventory levels $\leq$ zero.

Baseline Model
Optimization Model

Additional Notes in Simul8 Models

- Negative numbers for the inventory levels
  - = computers are switchable

- The average utilization of the computer systems
  - = the average value of the system utilization over the accumulated number of check-out & check-in computers.

- The utilization value greater than the 1
  - = how much the systems are over-utilized during the simulation time period.
### Comparison

<table>
<thead>
<tr>
<th>Performance measures</th>
<th>Baseline model</th>
<th>Optimization model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Utilization of the regular windows</td>
<td>66%</td>
<td>56%</td>
</tr>
<tr>
<td>system</td>
<td></td>
<td>63%</td>
</tr>
<tr>
<td>Average Utilization of the overnight windows</td>
<td>38%</td>
<td>39%</td>
</tr>
<tr>
<td>system</td>
<td></td>
<td>44%</td>
</tr>
<tr>
<td>Average Utilization of the Mac. system</td>
<td>90%</td>
<td>80%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>83%</td>
</tr>
<tr>
<td>Utilization of the student consultant 1</td>
<td>46.23%</td>
<td>76.25%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>77.51%</td>
</tr>
<tr>
<td>Utilization of the student consultant 2</td>
<td>42.82%</td>
<td></td>
</tr>
<tr>
<td>Simulation time period</td>
<td>361 minutes</td>
<td>365 minutes</td>
</tr>
<tr>
<td>Students quit the queue without being service</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

### Analysis of the Results

- **Baseline Model (2 Windows/2 Consultants)**
  - The utilization of the two student consultants are below 50%
  - Not even half of the regular service time is being utilized.

- **Optimization Model (1 Window/1 Consultant)**
  - The utilization of the student consultant improve to 78%.
  - Higher working performance and idling time avoidance

- **Constraints**
  - Trade-off between the higher utilization of the student consultant and the larger number of students who quit the queue could not be considered.
Continued

- Similarity between two models
  - Over 80% utilization of the MacBook Pros
  - High demand among students

- The utilization of the two windows systems are not perfect.
  - Instant utilization of the regular system could be greater than 100% in some cases.
  - Transfer some overnight systems to regular systems to solve the problem

Inventory Level

<table>
<thead>
<tr>
<th></th>
<th>Baseline Model</th>
<th>Optimization Model (Check-out Arrival Prioritize)</th>
<th>Optimization Model (Check-in Arrival Prioritize)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Inventory of the regular windows system</td>
<td>14</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>Average Inventory of the overnight windows system</td>
<td>16</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>Average Inventory of the Mac system</td>
<td>0.5</td>
<td>1.0</td>
<td>0.8</td>
</tr>
</tbody>
</table>
Inventory level

- Generally, the average inventory levels in three cases are pretty similar.

- Baseline Model
  - Both the Gateway and MacBook Systems are best utilized in baseline model.
  - However, the overnight Gateway Systems are least utilized here.

- Optimization Model
  - Check-out with higher priority doesn’t make much sense because all three levels are highest in this scenario.
  - Check-in with higher priority is the best scenario we can find so far because all three levels are comparable to the baseline case. Moreover, it comes with other benefits.

Conclusions

- Baseline model
  - Daily Gateway and MacBook Systems are well utilized
  - Propose to purchase more MacBook Pros
  - Student consultants are not even utilized 50% of the time for the regular services.
  - Further analysis on the emergent service and extra service
    Ex: Evaluation on the weekend student consultants

- Optimization model is recommended
  - Two queues join together and serviced by only one student consultant
References

• Dr. Paul Savory (Fall, 2006), IMSE440/840 Discrete Event Simulation, Class notes.

Kodak Printer Cartridge Manufacturing

T Meredith Ross, PE
Matthew Wiley

Summary

• Process
• Problems and Issues
• System Description and Conceptual Model
• Input Data
• Model
• Analysis
• Conclusion/Suggestions
• Questions
Process

- Involves the manufacturing and assembly of a print cartridge
- Encompasses 5 subsystems:
  - Chem-make, testing procedures, printing, slitting, and packaging

Problems and Issues

- Objective:
  - Successfully recreate manufacturing process
  - Determine performance measures
    - Utilization for multiple processes (291, 292, slitters)
    - Linear footage produced
    - Waste created
    - Overall process time
  - Validate results to “real performance measures”
  - Provide different scenarios through Simul8
  - Make conclusions
  - Provide feedback to Eastman Kodak Company
System Description & Conceptual Model

- Chem-make- multiple chemical drums used to mix chemicals for multiple processes
- Testing
  - Wetlab- chemical machinery testing inks and chemicals for consistency
  - Drylab- tests finished printed product
- Printing- composed of the 291 and 292 machine
  - Each machine has a series of 8 gravure presses which prints a specific color or chemical (cyan, yellow, etc)
  - Has re-winder and un-winder to run mylar (print medium)
- Slitting- 8 slitters that slice & cut the printed rolls into sections
- Packaging-
  - Assembles the sections into cartridges
  - Puts cartridges into packages
  - Crates the packages for shipping

Assumptions

- Uniformity of all stations
- Breakdown frequency distributions
- Supply arrivals
- Facility operation period
- Both products identical except for inks
- Operators and workers do not contribute to process behaviors
- Machines and staff are always available when necessary
- Natural variations with in process are insignificant
- Product change over frequencies do not vary
- Use of batching and separating in workstations has no effect on modeling behavior.
- Machine Processing times realistically follow the chosen distributions
Input Data

- Data was previously gathered through Doug Newton (previous employer)
  - WonderWare Active Factory Trend
  - Randomly chose 5 weeks of data:
    - Arrival rates
    - Process times
    - Breakdown percentages
    - Setup times
    - Performance measures
    - Shelf life
    - Wasted chemicals & mylar
    - Batching information
- Averaged data and reported
- Using intuition and experience estimated distributions

Model
Example 2 of Student Project Presentation

Model:
Chemical Delivery Subsystem

Model:
Slitter Subsystem to Packaging and Shipping
Model Analysis

- **Simplicity**
  - Due to complexity chose high level
  - Limited simulated products
- **Useful to prioritize modeling of subsystems**
- **Simulation period based on longest cycle**
- **Pull of completed product ignored**
- **Single WetLab modeled as resource**
- **Multiple WorkCenter representation batch output**

Results Analysis

- **Objective:**
  - Successfully recreate manufacturing process
  - Determine Performance Results
  - Linear footage produced:
    - 6 – 12,000,000 lf per week
  - Waste created:
    - Ink: 1.5 x 700lb units per week (~5%)
    - Mylar: 4 rolls of 8 used per week (~50% suspicious result)
  - Overall process time:
    - Wet Lab: 100%
    - Dry Lab: 9% - 10%
Conclusions

- Model simulates high-level process
- Results mimicked reality (possible exception mylar waste)
- Useful in prioritizing subsystems' review
- Several areas of underutilization
- Raises question of need of 24-hour plant operation
- Surprises: Only tested black paint exceeds shelf life
- Worthy project - follow on work identified

Gravure Press