JOHNS HOPKINS
CAREY BUSINESS SCHOOL

Simulation for Business Applications
BU.610.625
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Individual Homework Number 1

Due date: (Sharp) at the beginning of week 2 lecture

Reminder 1: Please submit your answer in MS Word format named `FirstName-LastName.docx`. **NO Excel submission!**

Reminder 2: *No need for @Risk software! Submission via Blackboard.*

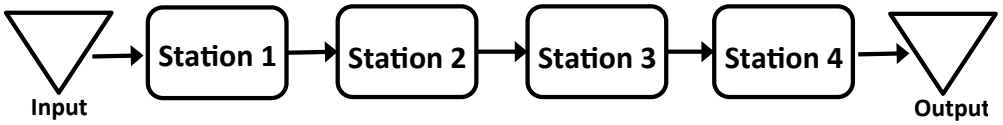
Reminder 3: Only clearly typed solutions will be accepted & graded. Any hand-written homework submission will not be accepted/graded.

Late Submission Grading Rule: (0,1] hour delay: 10% deduction of homework grade, (1,2] hours delay: 20% deduction, (2,3] hours delay: 30% deduction, ... (you got the idea)

Part 1: Assembly Line Simulation Exercise

Instructions for this question is very lengthy! However, most of it intended for review purposes. Please be patient and read the instructions carefully. In this question, you will see, report, and analyze impact of variability on process performance metrics through a simulation model. Please follow these instructions carefully.

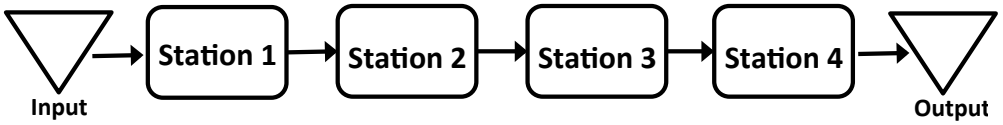
The following figure shows a process with four different machines (stations).



Question A: Suppose that average processing time in each station is 10 minutes per unit (there is no variability in processing times). This means Station 1 works on one unit for 10 minutes; then passes that unit to Station 2. While Station 2 works on that unit, Station 1 starts working on a new unit. Once Station 2 is done with one unit after exactly 10 minutes of processing, it passes it to Station 3 and this goes on. Use your understanding

of process analysis[1] concepts to determine **the bottleneck**, **cycle time (takt time)**, **throughput time (flow time)**, and **WIP (work-in-process) inventory** of this process. Determine **capacity utilization** of each station (machine). Finally, compute **total number of units of output produced by this process in 5000 minutes**. Assume that the system is in steady-state, i.e., it has been running for sometime. Please make sure to show your work. *No need to use simulation for this part!*[2]

Now, download the Excel file **Linesim.xlsm**[3] from the course web-page. We will use this file to look at the performance of the following assembly line with variable processing times.



Use this file to simulate an assembly line with the following parameters:

I. Simulation Parameters

Each workstation has one machine. Enter these parameters on the `Design` worksheet:

1. Number of machines = 4
2. Machines never fail = Yes
3. Machine processing time distributions:

	Station 1	Station 2	Station 3	Station 4
Type of probability distribution	Uniform	Uniform	Uniform	Uniform
Mean, μ (minutes)	10	10	10	10
Standard deviation, σ (minutes)	4	4	4	4

Note: Uniform processing time with average of 10 minutes and standard deviation of 4 minutes is equivalent to processing time with uniform distribution in the range of (roughly) 3.07 minutes and 16.92 minutes.[4]

4. Output storage area for each machine = 0. This denotes the number of units of WIP (Work-In-Process) inventory buffer allowed after each machine. We are currently setting it to zero. **Reminder:** Buffer is the space for inventory storage between two workstations in a system.

[1] If you haven't taken Operations Management course before, please contact your TA and she will guide you.
[2] Feel free to use Little's Law to measure some of the requested quantities.
[3] Developed at Cornell University's Johnson Graduate School of Management.
[4] Do you know why? If not, contact me or your TA with your questions.

II. Instructions

1. In the worksheet named `Run`, set *Run-In Time* equal to 200, *Run Length* equal to 1000, and *Repetitions* equal to 5.

   This means that five simulations will be run, each for 1200 minutes. Run-in time is the first 200 minutes of a simulation run when no data are collected for analysis (this is equivalent to "200 minutes of warm-up period"). The remaining 1000 minutes are the period for which data are collected for analysis. The run-in time is used to ensure that the simulation reaches a "steady state" and does not have any transient effects before data collection begins. Repetitions is the number of times that the simulation will be run; this is required in order to get a statistical average of the performance of the system.[5]

2. Each simulation can now be run by pressing the button "Start New Simulation" on `Run`. worksheet.

3. The output of the simulation is reported in the worksheets named `Cumulative`, `Inventory`, `Machines` and `Graphs`. `Cumulative` reports the aggregate performance statistics for the entire simulation. `Inventory` shows the average amount of inventory in the system (Column C) and in the output buffers after each workstation (Columns D, E, and so on). `Machines` gives the output (total number of units produced) in each simulation run. `Graphs` plots a few selected graphs that are self explanatory.

4. Further instructions and clarifications can be found in the worksheet named `Instructions`.

   Question B: Run the simulation with above given parameters and report the following statistics:

   (a) Total output (added over the 5 repetitions)[6]

   (b) % Utilization, % time blocked and % time starved for each workstation.[7]

   Explanation: Blockage: The situation when one workstation is idle because the next workstation is working at a slower pace. **Starvation:** The situation when one workstation is idle because the previous workstation is working at a slower pace.

   (c) Average throughput time.

   (d) Average WIP inventory in the system (process).

[5] This is similar to running our Gambling Python code I showed you in class for several nights.
[6] This is sum of `cells C9 to C13` in `Machines` worksheet.
[7] From `Cumulative` worksheet

Question C: Explain why total output and % capacity utilization in **Question B** deteriorate compared to the case in **Question A** despite the fact that average processing time of each machine in both **Question A** and **Question B** is 10 minutes.

Question D: Increase number of the workstations from four to five and run the simulation. What happens to the total output and % capacity utilization? Explain why.

Question E: Set number of workstations to four. Now, increase the standard deviation of processing time of each machine from 4 to 5. What happens to the total output? Explain why.

Question F: In this question we will use simulation for decision making. Assume there are four machines and processing time in each machine is uniform with mean of 10 minutes and standard deviation of 4 minutes. Suppose that you were allowed to have only 1 unit of WIP inventory buffer in the entire process[8]. That one unit of WIP could be between machine 1 and 2, or between machine 2 and 3, or between machine 3 and 4. Where would you keep this buffer in order to maximize total output? Intuitively explain your observation from this simulation.

Hint: One way to answer **Question F** is to place one unit of buffer between different stations, re-run the simulation, observe its impact on total output, then choose the spot that maximizes the total output.

Part 2: Probability Warm-up Questions

Question G: A normal die having six sides is rolled. If each of the six possible outcomes is equally likely, determine average and standard deviation of the number that appears.

A batch of 5000 computer chips is produced in a manufacturing process. Assume that each chip has probability 0.001 of being faulty and the chips are statistically independent of one another.

Question H: What is the distribution of the number of faulty chips in the batch?

Question I: What is the expected number of faulty chips?

Question J: What is the variance of the number of faulty chips?

Question K: What is the probability that there are zero faulty chips

[8] You can set this in "Output Storage Area for Each Machine" of `Design` worksheet.