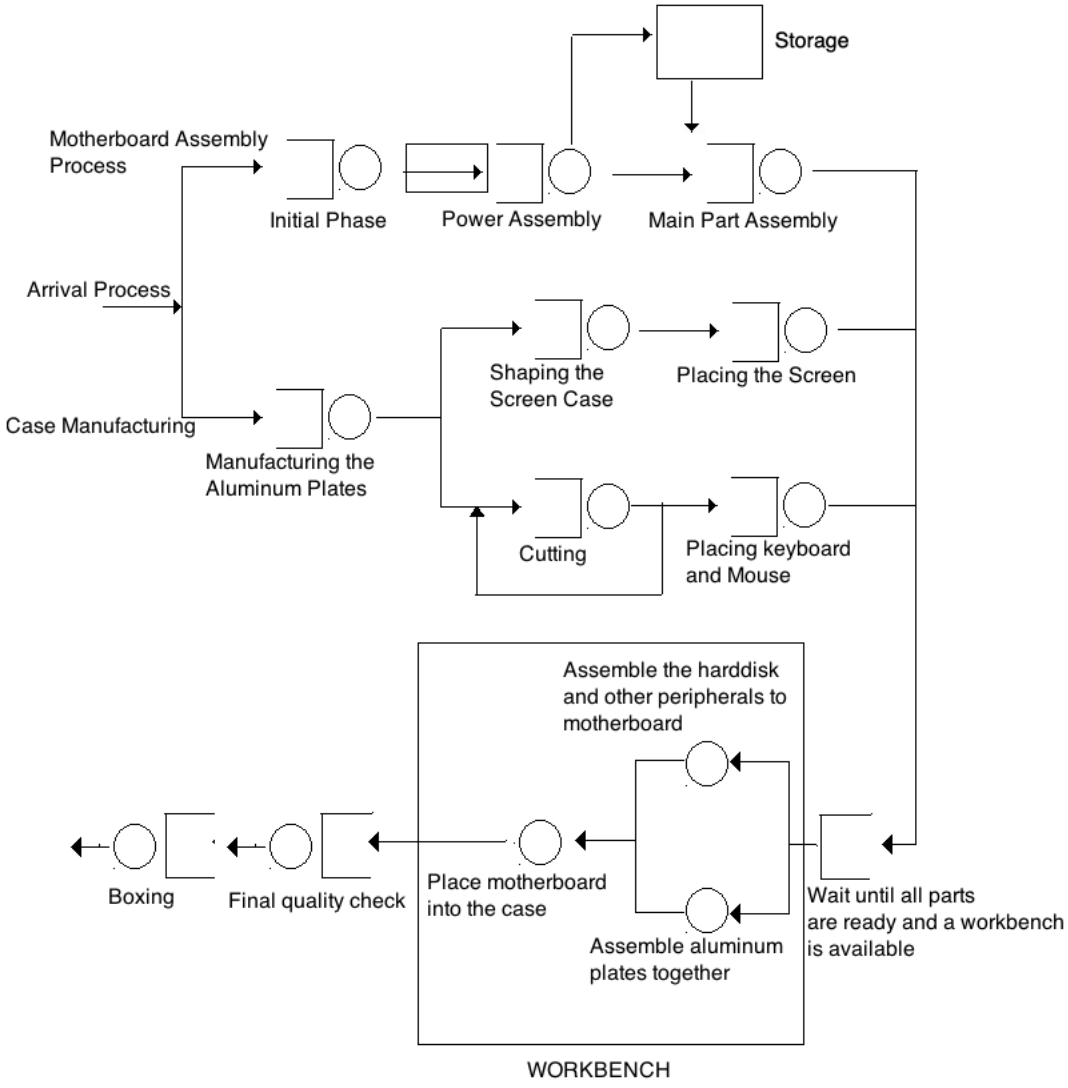
Simulation

Project

Due March 28th, 2025 at 16:00

In this project, we are trying to build a simulation model to simulate a simplified version of the laptop manufacturing process as pictured in the diagram below:



The properties of the processes in the system can be described as follows:

1 Arrival Process

By a close examination of the structure of our order arrival process, we are aware that the interarrival times follow an exponential distribution. The rate of the process is unknown, but we have the interarrival time data for the last 200 order arrivals which is given in the data spreadsheet (please see "Data" Section below to see how to obtain the spreadsheet). The arrival process has the following properties:

- When an order arrives, it may request more than one laptop. The number of laptops in each order is equal to $X+1$, where X is binomially distributed with success probability 0.6 and $n = 5$ and independent for each order. We assume that each laptop is distinct and each customer asks for a laptop with personalized specifications.
- The company has a policy that it will deal with only 100 laptop requests in total at a given time. If accepting an order means that there will be more than 100 laptop to be produced in the system, the order is rejected.

After an order is accepted to the system, two different lines of processes are started for each computer in the order to manufacture: (i) the motherboard and (ii) the case.

2 Manufacturing the Motherboard

Manufacturing the motherboard consists of three sequential processes.

2.1 Initial Phase

The initial phase is the design of the motherboard. In this phase, the motherboard is prepared for future assemblies. The slots are determined for CPU, memory and other components. Unfortunately, we do not know the distribution for the duration of this process, but we have data for the last 200 items in minutes and needs one type 1 worker to complete the task.

This process also has a special feature. There is space for only three items in front of the next process (Power Assembly). Hence, if there are three items in the Power Assembly queue, Initial Phase station stops processing items until there are three or less items in Power Assembly queue.

2.2 Power Assembly

This phase corresponds mainly to the assembly of parts related to the power system of the laptop such as power supply and connectors. In addition to these components, expansion cards and clock generators are also assembled. This process again requires a type 1 worker for each motherboard. The processing time of each motherboard is distributed uniformly distributed between 2 and 6 minutes.

2.3 Main Part Assembly

At this phase, the main components of the motherboard including the CPU, the memory and the chipset for buses are assembled. The processing time of this process is triangular with minimum and maximum possible values of 5 and 15 minutes respectively and a most likely value of 8 minutes. This process requires a type 2 worker to complete the task.

We have special feature for the queue of this process. Similar to the Power Assembly queue, the queue for this process has a capacity of 2 items. However, unlike the previous case, when the queue is full, instead of blocking the previous process, the items are stored in a nearby storage. Once the queue of Main Part Assembly becomes empty, at most two items are moved from the storage to the Main Assembly queue, if there are any items in the storage. It takes 2 minutes to take items from Power Assembly station to the storage and 3 minutes to move items from the storage to the Main Assembly queue.

3 Case Manufacturing

This phase consists of 5 different manufacturing processes some of which can be carried in parallel.

3.1 Cutting The Aluminum Plates

At this phase, one aluminum block is first rolled into a sheet (plate) and then two aluminum plates are cut for the case of the laptop (one for placing the screen and one for placing the motherboard, keyboard etc.). This process uses one aluminum block for each laptop as a row material and if this row material is not available the process cannot continue. Hence, we need to keep track of the inventory for the aluminum blocks and the inventory policy is explained below.

The process of converting aluminum block to two metal plates takes a deterministic time of 8 minutes and requires one rolling machine and one cutting machine.

3.2 Shaping the Screen

This process is done with a special machine which can both press and cut aluminum to form the upper part of the laptop which is behind the screen. As the machine is special, a type 3 worker who is trained to use this machine is needed. The process takes a uniform time between 3 an 5 minutes.

3.3 Placing the Screen

After the aluminum which will hold the screen is shaped, then the screen can be placed. This requires a type 1 worker to work a uniform time between 4 and 10 minutes for each screen.

3.4 Cutting (for the Keyboard and Mouse)

This process can be done in parallel to the manufacturing of the screen. The aim here is to cut and shape the aluminum plate for the bottom part of the laptop to place the keyboard and the mouse. This process is also done with the same special machine used in "Shaping the Screen" and hence a type 3 worker is also needed. This process takes a uniform time between 5 and 8 minutes.

Unfortunately the cutting process is not perfect. Once the keyholes for the keyboard is cut, it might be realized that they are too narrow for the keyboard to fit in with probability 0.2, so item is sent back to the queue (as pictured in the diagram) to be re-processed. After the item is processed for the second time, then the probability of being too narrow is 0.1. If an item is processed three times here, it is definite that all keyholes are in good shape and no item gets processed more than three times in this process.

To explain the queueing process consider the following example. Suppose that there is one item (call it A) being processed and two items waiting (B and C) in the queue. Also suppose we know that A needs to be processed by this station twice. Then when A leaves the service, item B is taken into the service and A gets into the queue behind C and waits to be processed for the second time. After the second time it gets processed here, it will proceed to join the next process.

3.5 Placing the Keyboard and the Mouse

This process is essentially assembling the keyboard and the trackpad/mouse to the lower body of the laptop and requires one type 1 worker. However, we don't know the distribution for the duration of this process and we have the data for the last 200 computers in minutes.

4 Main Assembly

The main assembly process is the process of manufacturing of the laptop from the parts that has been produced so far. To start this process the three main items should be ready: (i) Motherboard, (ii) Upper body of the laptop (with screen) (iii) the lower body of the laptop (with keyboard and mouse). The assembly process takes place on a workbench and there are 2 workbenches in the system. Once all the three parts are ready and a workbench is available, the parts are taken on the workbench. Then, as one type 2 worker assembles hard disk and other peripherals (e.g. fan, speakers etc.) to the motherboard, a type 1 worker assembles lower and upper body of the laptop together. After both these are done, the same type 1 worker closes the laptop and laptop is (in theory) ready to be used. Then, the laptop is taken from the workbench, i.e., the workshop is readyo to be used by another item, and assembled item is carried to the quality department for a final check. Below, we give some details to these processes.

4.1 Assembling the Hard Disk and Other Peripherals

As described above, this process requires one type 2 worker and the service time can be expressed as:

$$3X + 1(\text{in minutes}),$$

where X is a Beta(3,2) random variable. This process uses hard disk and some other raw materials. We assume that we have ample resources for the other materials, but we need to watch the inventory of hard disks closely.

4.2 Assembling the Case (Aluminum Plates)

This process requires one type 1 worker and the service times for the last 200 items are given in the data as minutes.

4.3 Place the Motherboard in the Case

This process is carried by the same type 1 worker who assembled the case. This process starts when both peripherals are assembled to the motherboard and case is ready, and takes a uniform time between 4 and 8 minutes.

5 Quality Assurance

After the laptop is completed, it is taken to the quality control department to check whether the computer is in working condition. This process is performed by specially trained employees (type 4) and takes a triangular time of (8,14,16) minutes for each computer.

6 Boxing

After all computers are finished in an order, the order is shipped. Remember that we have orders arriving and we need to make sure that we ship the right number of computers. The boxing process takes a uniform time between 4 and 8 minutes and performed by type 5 workers.

7 Raw Material Inventory

As described above, several raw materials are used in the manufacturing process. We assume that only aluminum blocks and hard disks are critical raw materials and we need to model the inventory control policy for these two raw materials. Other raw materials (e.g., CPUs, sockets, memory, etc) are always available and we do not need to worry about them.

For the aluminum blocks, we use what is called an (S, s) policy in the inventory literature. In this system, we start with $S = 200$ blocks in our system and when we realize that the

	Workers					Machines		
Process	Type 1	Type 2	Type 3	Type 4	Type 5	Roll&Cut	Special	Workbench
2.1	1							
2.2	1							
2.3		1						
3.1						1		
3.2			1				1	
3.3	1							
3.4			1				1	
3.5	1							
4.1		1						1
4.2	1							1
4.3	1							1
5				1				
6					1			
Capacity	7	3	3	2	2	2	3	2

inventory level falls below $s = 10$, we order $S = 50$ blocks to be delivered. The new blocks arrive 15 hours after we place the order. For the hard disks, we use the same structure, however in this case we have $S = 70$ and $s = 10$ and the ordered hard disks arrive 15 hours after the order is placed. You can assume that you start with 70 hard disks at time 0.

8 Resources

The following table summarizes the capacity of the resources. For convenience, you can assume that our factory is working 24 hours with the same schedule.

9 Data

Each person has a different data file on this project. To obtain your data file, you need to

1. Download DataGeneration.exe from
   `http://www.maths.ed.ac.uk/~bbuke/DataGeneration.exe`
2. Run the software on a Windows machine. If you do not have a Windows machine, please let me know and I will be happy to generate the data for you.
3. The software will ask you to enter your student number, type it without "s" up and press enter. For example if your student number is s1234567, you need to type 1234567.
4. An excel file named `Data_File.xls` will be generated in the same folder as the program.

10 Goals of the Project

Now our goal is to develop a model to assess the performance of this system and suggest some improvements to the system. For this purpose:

1. Estimate the distributions of each process. Justify the fact that your estimation is reasonable (you only need one goodness-of-fit test you prefer).

2. Design a simulation model for this system using Simul8.

3. Find out the average cycle time of a laptop. We wish to have a confidence interval whose half-width is not greater than 1% of the true average cycle time. (This is slightly different than having a fixed epsilon, and will require a very minor modification of the two-stage method studied in the class. Please see lecture notes.)

4. How can we improve the system? Suggest improvements and convince the manager that these should better be incorporated. This is the most important part of our goals.

11 Marking Scheme

In this project, you are asked to demonstrate your skills in applying simulation correctly and efficiently. Hence, the marking scheme will consist of

1. Input Analysis (15% of overall mark)

2. Modelling using Simul8 (25% of overall mark)

3. Initial Output Analysis (15% of overall mark)

4. Improvements (25% of overall mark)

5. Presentation quality (20% of the overall mark)

11.1 Deliverables

You are expected to submit:

1. a report not exceeding 20 pages which details the input analysis, model building and output analysis

2. Simul8 model

No excel spreadsheet will be submitted for the project. The information contained in the excel spreadsheet should be summarized in the report. Also, please do **not** submit compressed files.