MIT 2.008 Design and Manufacturing II

Spring 2025

Homework 6 – Manufacturing Systems III and IV

Released: April 9th, 2025 3:00 PM

Learning Objectives

- *Understanding principles of manufacturing systems including limiting factors to production rate and the difference between throughput and time in the system.*
- *Understanding how to apply system improvements from the lean game and how they impact a production system differently.*
- *Understand how to identify bottlenecks and how to adjust a production system to account for them.*
- *Gain some experience with placing buffers in a transfer line and seeing how they affect inventory levels and throughput within the line.*
- *Gain some experience with computational modeling for both continuous long lines and parallel lines.*

General Notes

- *For qualitative answers, we're not looking for long essays. Please answer using short (1-2 sentences per answer) bullet points.*
- *For quantitative answers, show your work as clearly as possible. When possible, keep answers in algebraic form until plugging in numbers at the very end; this way, it is much easier for graders to understand where you make mistakes and provide meaningful feedback.*

HOMEWORK TOTAL POINTS: 100 pts

Problem 1 – Manufacturing Systems Short Questions – (12 pts)

Please choose the correct option below. Please give a brief rationale behind your choice.

a. Increasing the size of any given buffer for inventory/WIP (**increases/decreases**) time needed to detect defects in the production line, if defects are detected downstream of the buffer.

Brief Rationale

b. Decreasing the rate of the slowest machine (**increases/decreases**) the production rate of the entire line. Assume no buffer is present and machines are in series.

Brief Rationale

c. If I am interested in knowing how long a single unit of a product takes to go through the entire manufacturing process in a line with multiple processes, I should be looking at (**Average Production Time/Cycle time**)

Brief Rationale

d. **(Cycle Time/Takt Time/Process Time)** is usually utilized by manufacturers to estimate if they can meet a requested demand.

Brief Rationale

Problem 2 – Lean Manufacturing Game Review – (21 pts)

The first set of questions will serve as a review of the Lean Manufacturing game activity you explored in class. If you need a refresher, feel free to play a demo game for more insight at the following link: https://zensimu.com/lean-game/**.** The link to your results: https://play.zensimu.com/session/gfWDTAEqDjZSFo9SZHMk/lobby

a. The default settings for revenue and costs were the following:

Unit Sales Price: +$100
Late Penalty: -$30
Defective Penalty: -$50

Labor cost: -$50
WIP inventory cost: -$60
Rework operation cost: -$5

Considering the three costs above, which are fixed costs and which are variable costs?

Use the tables below to discuss what would increase those costs and also how you would decrease them.

12 points total: (1 point for each correct identification, 1 point for each justification, and 2 points explanation what would increase/decrease them)

Labor Cost

Fixed or variable:	
What increases cost:	
How you decrease cost:	

WIP Inventory Cost

Fixed or variable:	
What increases cost:	
How you decrease cost:	

Rework Operation Cost

Fixed or variable:	
What increases cost:	
How you decrease cost:	

b. The following improvements were automatically implemented across the different rounds you played of the Lean Game:

Move stations
Reduce batch size
Auto-inspect work/Jidoka (be able to remove dots)
Balance workload (make all stations 100% flexible)
Level production plan (Heijunka)
Add click-guides to reduce defects (poka-yoke / error-proofing)
Kanban (pull-system)
Reduce tool-changeover time (SMED)

Discuss briefly (1-2 sentences) how each change impacted your game compared to Round 1, and explain which single change you think had the largest impact.

Problem 3 – Factory Layout– (24 pts)

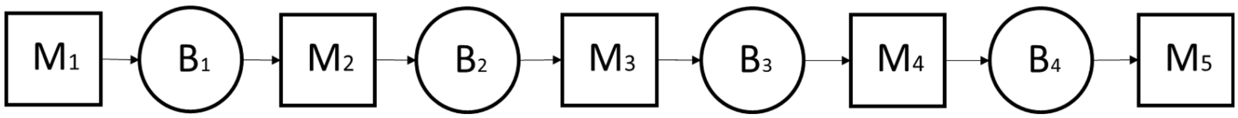
Building on your great success playing the beer game, you are an operations consultant hired by a widely successful brewery to help out with their factory operations. The two managers at the factories have been getting into heated arguments over how they can improve the efficiency of their operations.

a. To improve the factory operations, you need to put together a proposal for factory leadership to showcase the level of queuing at the factory. You pull together the following for the past year.

Month	Average Inventory [cases]	Average Production Rate [Case/month]
1	711	429
2	73	432
3	12	463
4	669	690
5	526	989
6	591	877
7	94	440
8	725	861
9	372	302
10	260	171
11	319	537
12	759	656
Monthly average	426	571

What is the average wait (in days) to receive a case of beer from the factory?
Hint: Little’s Law

b. You get approval to fix the problem, now you need to figure out what is going on. You study the brewery process and come up with the following schematic. Assume the **buffers are infinite**. Calculate the **machine efficiency and production rate** for each machine. Which machine is the **bottleneck**?



Machine	Process	MTTF [hour]	MTTR [hour]	Cycle Time [hour]	Machine Efficiency	Average Production Rate [batch/hour]
M1	Mashing	1000	40	3		
M2	Boiling	500	80	40		
M3	Fermentation	2000	20	40		
M4	Filtering	1000	20	10		
M5	Packaging	300	10	5		

Bottleneck:

c. What is the production rate for the entire process?

d. What is one way in which the production rate can be increased? Answer this in terms of which part of the production rate formula you are changing, and then also indicate what this change might physically represent in beer production.

e. Why are buffers used in flow lines? Qualitatively, explain the relationship between machine repair time and buffer size.

Problem 4 –Buffer placement – (20 pts)

As part of a semiconductor manufacturing process, a silicon wafer is glued to a non-reactive substrate as shown in Figure 2.

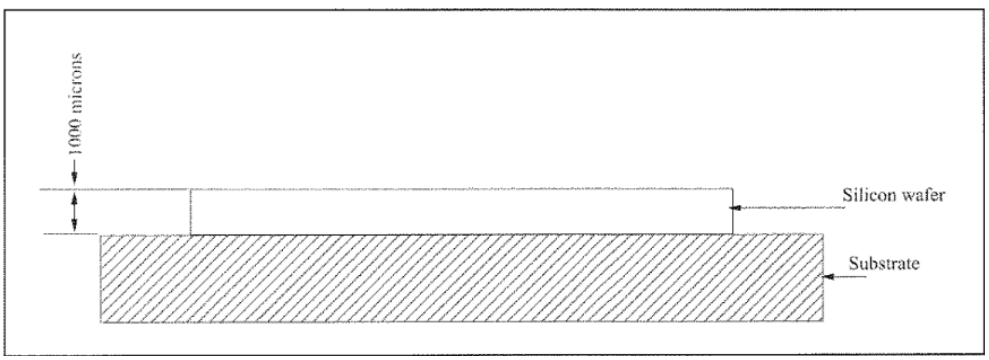


Figure 2. Silicon Wafer Glued to a Substrate

You are tasked with managing the production system required to make the wafers. The wafer is processed by transferring it through six machines in sequence. The transfer line is balanced with the following tasks being performed on each machine:

1. Machine M1: Positive photoresist, expose, and develop.
2. Machine M2: Anisotropic etching
3. Machine M3: Stripping the photoresist.
4. Machine M4: Negative photoresist, expose, and develop.
5. Machine M5: Thermal oxidation of silicon.
6. Machine M6: Stripping the photoresist.

The transfer line is shown in Figure 3.

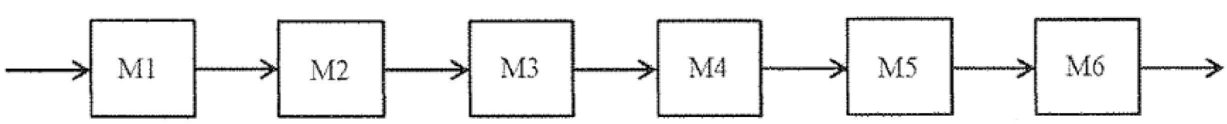


Figure 3. Six-machine Zero Buffer Transfer Line

Each machine can process 130 wafers a day when it is operational. However, the machines are unreliable. The **efficiency of each individual machine is 0.96**. The target production rate for the system is 120 wafers per day.

a. What is the production rate for the system as drawn? Are buffers needed to meet the target production rate?

b. What is the minimum number of infinite buffers that would be needed to meet the target production rate? Note: We are not asking for the size of any buffer (assume they are infinite), but only the minimum number of buffers required.

c. Suppose there is a finite buffer between each pair of machines. That is, there are a total of five finite buffers in the transfer line. Assume that the buffers are equally sized. Sketch roughly what the average inventory distribution looks like on the graph in Figure 4. You need not have numerical labels on the Y-axis. Explain qualitatively why the graph looks like it does.

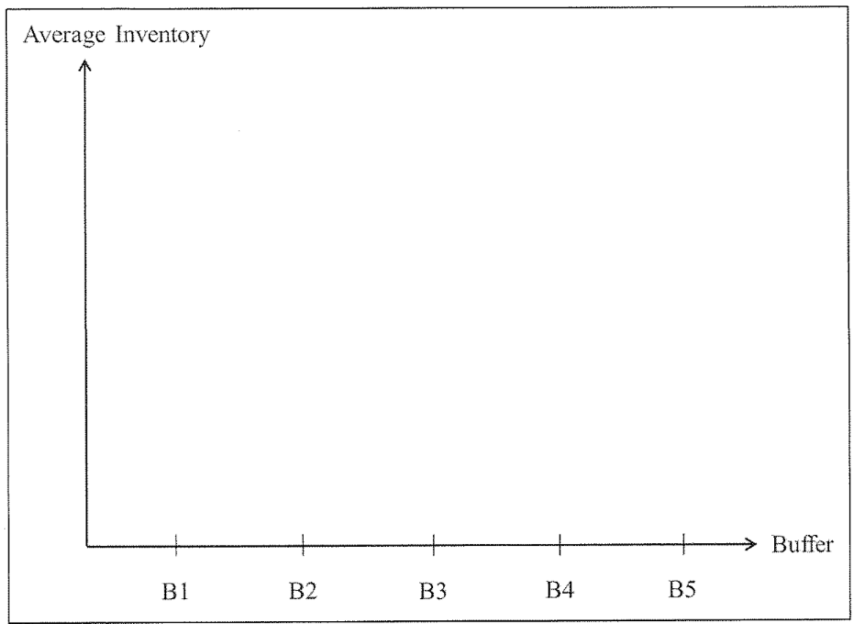


Figure 4. Buffer Space Distribution

Problem 5 – Computational Modeling (23 pts)

You have been asked to design a production line, which combines the best features of two product lines in a single convenient package. Consider a two-machine deterministic processing time production line. The demand on the system requires a long run production rate of .58 parts per minute. In the following, all the r's and p's are in units of events per minute.

To avoid complicated financial issues like depreciation and taxation, we will evaluate the cost of a line as the sum of the purchase prices of the machines and the value of the average number of parts in the buffer. Therefore, we interpret optimal as meaning that the system is able to meet the specified demand rate, with those two costs minimized. For this purpose, consider the inventory cost as simply the dollar value of the average buffer level.

For line speed of 1 part per minute.

If we want to run the line at 1 part per minute, we have a choice of two models for the first machine:
(a) $M1$a with (r, p) = (.01, .008) and a cost of $10,000
(b) $M1$b with (r, p) = (.01, .006) and a cost of $20,000

There is only one model available for the second machine:
$M2$ with (r, p) = (.01, .006) and its cost is $20,000

a. Assuming that both machines must operate at the same production rate μ, what is the optimal combination of machines? If one or both of the M1-M2 combinations are infeasible, briefly explain why?

b. What is the optimal buffer size and the cost of holding inventory, if the inventory cost per part is $50?

For line speed of 2 parts per minute.

If we run it at 2 parts per minute, we have a choice of two models for the first machine:
(a) M1a with (r, p) = (.005, .009) and a cost of $20,000
(b) M1b with (r, p) = (.005, .007) and a cost of $30,000

There is only one model available for the second machine:
M2 with (r, p) = (.005, .007) and its cost is $30,000

c. Assuming that both machines must operate at the same production rate μ, how does doubling the line speed impact production rate? What is the optimal combination of machines? If one or both of the M1-M2 combinations are infeasible, briefly explain why?

d. What is the optimal buffer size and the cost of holding inventory, if the inventory cost per part is $50?

Regardless of line speed.

e. The inventory costs increase to $400 per part in the buffer. What is the cost of the optimal line now, and What conclusions can be drawn about desired machine choice at high inventory cost?

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