MIT 2.008 Design and Manufacturing II

Quiz 2 - Part B, Take-Home Component

Spring 2024

- This portion of the exam is open book/notes (since we cannot monitor you), but you are expected to work on it individually and cannot collaborate with classmates.
- All work for CREDIT must be completed in this quiz document.
- Please contact the TAs via Slack if you have any questions or difficulties.
- We will NOT be granting extensions for this portion of the exam, once you have received it. If you anticipate any difficulties with completing this question on time, please inform the TAs prior to picking this component up; within reason, we will arrange to send it to you exactly 48 hours before you need to submit it.

General Notes

- *For qualitative answers, we're not looking for long essays. Please answer using short (1-2 sentence 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* ***(and partial credit)****.*

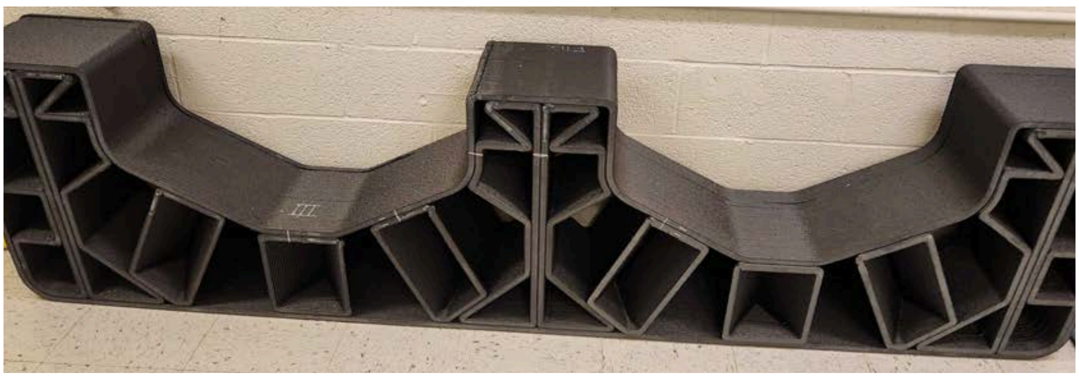
Name: ____________________________

Part A, In-Class Component		
Problem 1		Out of 15 points
Problem 2		Out of 31 points
Problem 3		Out of 24 points
Part B, Take-Home Component		
Problem 4		Out of 30 points
Total		**100 points**

Problem 4 - Manufacturing Systems Analysis (30 points) (Est. Time: 50 minutes)

One proposed solution to the nearly 2 billion homeless or poorly housed people in the world is to create low-cost, rapidly and sustainably manufactured homes using recycled polymers. A study of candidate materials suggests that PET-GF (polyethylene terephthalate and glass fiber composite) would be ideal given both its abundance and material properties. It has further been proposed that this goal could be met using large scale additive manufacturing. You propose setting up a small factory based around extrusion using the Big Area Additive Manufacturing (BAAM) 3D printer from Cincinnati Incorporated.

To simplify setting up a production line for this process, we will focus on one module: a foundation structure for the home (example photo below).



Assume that you have an abundance of PET-GF available, and that it is ready for use as 3D printer material. The production line is arranged according to the following steps:

- Printing
- Breakaway support removal using sandblasting
- Surface smoothing and finishing using CNC machining
- Excess support and contaminant removal using hot washing

A block diagram of these steps along with their efficiency metrics is provided below:

Extrusion (T = 45 minutes) → Sandblasting (T = 15 minutes) → Machining (T = 90 minutes) → Hot Wash (T = 15 minutes)

Station	Tau (min)	MTTR (min)	MTTF (min)	P (parts/min)
Extrusion	45	240	2880	0.02051
Sandblast	15	60	720	0.06154
Machine	90	180	1440	0.00988
Hot Wash	15	60	600	0.06061

a) What is the production rate of the line, assuming a scenario with no buffers between operations?

b) If you had the option to place a single infinite buffer in this manufacturing line, where would you place it and why? What will be your production rate after placing this buffer?

c) Because of the high demand for affordable homes, investors funding a factory for this line insist that the production rate needs to get closer to the rate of the fastest machines; they are willing to invest in additional equipment to get closer to balancing the line.

   i) Fill in the updated table of metrics below, assuming that investments are made so that during steady state production, every section of the line has the same cycle time. We have filled in some portions of the table already, to make it easier to check your work.

Station	# machines	Tau (min)	MTTR (min)	MTTF (min)	p	r	e	P (parts/min)
Extrusion			240	2880			0.92308	0.06154
Sandblast	1		60	720	0.02083	0.25	0.92308	0.06154
Machine			180	1440			0.88889	0.05926
Hot Wash	1		60	600	0.025	0.25	0.90909	0.06061

ii) How does your answer to part b change with a more balanced line? Is your single infinite buffer placement different? What is your new production rate assuming this buffer?

d) Conveniently, the investment in additional machines now makes it possible to represent the production line in Markov chain form, which means we can use our analytical MATLAB tools to analyze some additional decisions. Your investors are comfortable with diminishing profit given the altruistic nature of the project; however, they still want to ensure a profit of $1600 per simulation cycle to cover any overhead of running the factory.

Open up the long line program on Canvas and populate r and p with your values from part c. ***Note:*** by default, the long line program does not include profit/cost calculations. However, you can paste in the following code beneath the long line script to compute estimates for revenue and inventory cost:

```
%Calculate hypothetical profit
pCoeff = 4000;    % Assume revenue of $4,000 per foundation
c = [50 70 100];      % Inventory holding cost per cycle
revenue = pCoeff*prodrate(1);
C_array = c.*nbar;
C_total = sum(C_array);
profit = revenue - C_total
```

After pasting these lines of code, your script in Canvas should look like this:

Script

Reference Solution | Save | Reset | MATLAB Documentation

```
% Input parameters:
% Change the values for k, r, p, and N
% Click "Run Script" to calculate prodrate and nbar
k = ;
r = ;
p = ;
N = ;

% Calculate deterministic processing time
[prodrate,nbar] = detlong(k,r,p,N)

%Calculate hypothetical profit
pCoeff = 4000;     % Assume revenue of $4,000 per foundation
c = [50 70 100];      % Inventory holding cost; modify this to fit the question
revenue = pCoeff*prodrate(1);
C_array = c.*nbar;
C_total = sum(C_array);
profit = revenue - C_total
```

Run Script

i) Firstly, suppose you can only place one buffer as in parts b and c, but this buffer must be finite. What is the maximum buffer size which still meets the profit target? What will be the average inventory in that buffer over a simulation cycle?

ii) How does your answer change if, instead of a single buffer, you can have finite buffers after each production step? The foundation has roughly the same form factor after all post-extrusion steps, so assume that all finite buffers are the same size.

iii) Which of the two possibilities (3 smaller buffers or 1 larger buffer) is the better option which meets the profit target?

iv) One of your vendors comes to you with an extrusion barrel with a larger feed throat, which makes it much easier to clean excess polymers out of the barrel. As a result, your MTTR for the extrusion process is cut in half, from 4 hours all the way down to 2 hours. Assuming you have space for 3 identically sized finite buffers on your line, what is your new optimal buffer size, after making this upgrade?

e) Having not actually built the factory yet, your investors want to explore 2 alternatives for this line before spending money on equipment:

- Still invest in the extrusion-based BAAM but switch to a larger default nozzle size
- Base the production line on a large photopolymerization process instead of extrusion

Very briefly, provide one benefit and one tradeoff of each decision.

Change 1: Larger nozzle size

Benefit:	
Tradeoff:	

Change 2: Shift to photopolymerization line

Benefit:	
Tradeoff:	