ISyE 3104 Exam 2 – Part I of II
Instructor: Damon P. Williams, Ph.D.

Name (Print Neatly): A+ Solutions

Point values are indicated next to each problem – please take these into consideration as you budget your time during the exam. If you are having difficulty with a question, sometimes it is beneficial to work on another question, and then come back.

You must show your work in order to receive full credit. Clearly identify your final answers (with a box, etc.) A lack of neatness and legibility can result in a reduction of your grade.

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Signature: _____

Points Summary

Question	Points	Out of
True/False		14
Multiple Choice		14
Short Answer #1		25
Part I Subtotal		**53**

I. True/False – Please circle either T for 'TRUE' or F for 'FALSE'. (2 points each)

1. T -or- F The coefficient of variation of the time to process a batch is larger than the coefficient of variation of the time to process a single item

2. T -or- F The WIP of a M/M/1/b system is smaller than the WIP of a M/M/1 system with the same arrival and processing rates.

3. T -or- F The increase of the potentially good variability always degrades the performance of a production system

4. T -or- F The CONWIP system is also known as make to order system

5. T -or- F MRP system schedules the release of word based on demand, while a kanban system authorizes the release of work based on system status.

6. T -or- F The M/M/m queueing system consist of m independent queues like in most grocery stores where each server has a separate queue.

7. T -or- F For a general G/G/1 queueing system, the state of the system can be expressed as a single number n indicating the number of jobs currently in the system.

II. Multiple Choice - Please circle ONE response. (2 points each)

1. The _____ law is also known as the law of pay me now or pay me later
   a. Variability
   b. Buffering
   c. Conservation of material
   d. Capacity

2. The _____ system has a limit on the maximum amount of inventory in the system
   a. push
   b. pull
   c. CONWIP
   d. Both b and c

3. The _____ is considered as an example of potentially bad variability
   a. Product variety
   b. Technological Change
   c. Unplanned outages
   d. Demand variability

4. The _____ states that if a station increases utilization without making any other changes, average WIP and cycle time will increase in a highly nonlinear fashion
   a. Utilization law
   b. Capacity law
   c. Conservation of material law
   d. Buffering law

5. A M/M/4 system with 11.5 jobs arrivals per hour, and production rate of three jobs per hour, the cycle time is:
   a. 1.824 hours
   b. 2.157 hours
   c. 2.467 hours
   d. 2.800 hours

6. A M/M/1 system with 3.2 jobs arrivals per hour, and production rate of four jobs per hour, the average time spent in the queue is:
   a. 0.5 hour
   b. 1 hour
   c. 2 hours
   d. 4 hours

7. The _____ system looks like an open queueing network
   a. Kanban
   b. CONWIP
   c. MRP
   d. Both a and b

III. Short Answer – Solve the following. Show all of your work. Write neatly and legibly. Place a box around your final answers.

1. Consider a balanced and stable line with moderate variability and large buffer capacities between stations. The line uses an open protocol (i.e., the release rate is predetermined and new jobs are released regardless of the system status.) The raw process time of the line is T_0 and the capacity of the line is r_b and the utilization is fairly high. What happens to TH and CT when we do the following changes (one at a time.)? Write one sentence to justify your answer. **<u>You will not receive any credit for a correct answer with no justification.</u>** (25 pts)

   a. Reduce the buffer sizes and allow blocking at all stations except station 1. (5 pts)

   TH ↓ , CT ↓

   Finite buffers will result in blocking

   Consider $TH(M/M/1|b) = \frac{1-u^b}{1-u^{b+1}} r_q$.

   b. Reduce the process variability at all stations. (5 pts)

   TH ↔ , CT ↓

   TH stays the same due to no blocking in an open system. CT decreases since CT = VUT thus if variability ↓ then CT ↓.

c. Reduce T_0 but keep r_b unchanged. (5 pts)

TH stays the same as it will be unchanged while CT ↓ since CT = VUT. As time decreases, utilization decreases thus CT decreases.

d. Increase r_b but keep T_0 unchanged. (5 pts)

TH stays the same for the same reason as (b).

CT decreases since CT = VUT when utilization decreases CT decreases

e. Decrease variability in process times and reduce buffer sizes as in (a). Compare to the situation in (a) (5pts)

CT ↓ : TH ↓ for the same reason as (a)

There will be MORE reduction in CT because variability went down

ISyE 3104 Exam 2 – Part II of II
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Point Summary

Question	Points	Out of
Short Answer # 2		32
Short Answer # 3		20
Short Answer # 4		21
Part II Subtotal		**73**

Short Answer (Cont'd) – Solve the following. Show all of your work. Write neatly and legibly. Place a box around your final answers.

2. The Jacket Motors has developed an innovative process for manufacturing custom body parts for motorcycles. Designs are received as CAD files, which are used to configure a "bed of nails" fixture on which a robot places multiple layers of composite tape. Once the layup process is complete, the fixture goes through a curing process that uses ultraviolet light. Georgina Burdell, the company president, has brought you in as a consultant, because WIP levels and cycle times are excessive, leading to poor customer service, which is beginning to damage Jacket's reputation. As the senior consultant on the team, you've had your new hires from MIT collect data for you while you go to lunch with Ms. Burdell. Upon returning from lunch, you are presented with the following information:

   The shop works a single 8 hour shift and operates five days a week. The robotic layup process has an average process time of 6.5 minutes, with an SCV of 0.5. On average, once a week the robot goes down and requires a 5 hour maintenance. The UV cure process has an average process time of 8.0 minutes, with an SCV of 1.0. It's reasonably reliable, requiring only about 10 minutes of down time per day. Currently, Jacket is receiving about 288 orders per week, and the average time to turn around an order is about a day and a half. (32 pts)

   Based on the data provided by your MIT flunkies:

   a. How much WIP would you expect to see in the layup **and** curing processes? (16 pts)

Layup: $m_r = 300$ $m_f = (3)(8)(60) - (5)(60) = 2100$

$A = 87.5\ \%$

$t_e = \frac{6.5}{.875} = 7.42$ $c_e^2 = (.5) + (1+1)(.875)(.125)\frac{300}{6.5}$

$= 10.6$

$U = (r_a)(t_e) = (.12)(10.6) = .891$

$WIP = \frac{1+10.6}{2}\ \frac{.891^2}{1-.891} + .891 = \boxed{43.3}$

$c_d^2 = 1 - U^2 + U^2 c_e^2 = 1 - (.891)^2 + (.891)^2(10.6) = 8.63$

Curing:

$m_r = 10 \quad m_f = (8)(60) - 10 = 470 \quad \Rightarrow A = 97.9\%$

$t_e = 8/.979 = 8.17 \quad c_e^2 = 1.052$

$U = 0.98$

$$WIP = \frac{8.63 + 1.052}{2} \frac{(.979)^2}{1-.979} + .979 = 238.6$$

Total WIP = 282

b. What is the primary cause of WIP in layup? Justify your claim. (8 pts)

Extremely large c_e^2 due to long repair times.

c. What is the primary cause of WIP in cure? Justify your claim. (8 pts)

Either large c_a^2 (due to layup) and/or high utilization.

3. Please respond to the following (20 pts)

a. What are the 3 types of buffers. Briefly (1 sentence) describe each. (5 pts)

Inventory - WIP or finished goods held in the system to mitigate variability.

Capacity - Use of human or machine resources.

Time

b. What is the buffer flexibility corollary? Give 1 example of its implementation. (5 pts)

Flexibility reduces the amount of variability buffering required in a production system.

Example - cross trained workers

c. What is the capacity law? Briefly describe (1 sentence) why systems cannot run at full capacity. (5 pts)

In a steady state all plants will release work at an average rate that is strictly less than average capacity.

Variability is the reason we cannot run at full capacity.

d. What is the utilization law? (5 pts)

If a station increases utilization without making any other change, average WIP & cycle time will increase in a highly non-linear fashion.

4. Will & Jamison both want coffee before Damon's 8am class so they can stay awake. Will is going to Dunkin Donuts which has two M/M/1 lines to services their customers. Jamison is going to ChocoLate which services their customers with an M/M/2 configuration with only one queue. |21 pts|

a. Assuming all else is equal (arrival times, numbers of customers in store, service rates, etc.) who do we expect to get their coffee first and why? |5 pts|

Jamison is expected to get his coffee first because he is standing in a pooled queue where variability pooling can be taken advantage of

b. Suppose each system had an arrival rate of 19 customers per hour and a service rate of 20 customers per hour. Compare the WIP, CT, WIP_q, & CT_q of both systems. Do your results justify or contradict your answer to part (a). Why? |16 pts|

Consider Two M/M/1

$$U = \frac{r_a}{r_e} = .95 \qquad t_e = \left(\frac{1}{r_e}\right)(2) = .10$$

$$CT_q = \left(\frac{U}{1-U}\right)(t_e) = 1.9 \text{ hrs.}$$

$$CT = CT_q + t_e = 2 \text{ hrs}$$

$$WIP_q = (CT_q)(r_a) = 36.1$$

$$WIP = (CT)(r_a) = 38$$

Consider M/M/2

$$\upsilon = \frac{r_a}{r_e} = .95 \qquad t_e = \frac{n}{r_e} = .1$$

$$CT_q = \frac{\upsilon^{\sqrt{(2)(3)}-1}}{2(1-\upsilon)} \cdot t_e = .928 \text{ hrs}$$

$$CT = CT_q + t_e = 1.02 \text{ hrs}$$

$$WIP_q = (CT_q)(r_a) = 17.632$$

$$WIP = (CT)(r_a) = 19.53$$