2019 MPS Qualify Exam

- The examination will be four hours long.
- There will be eight questions in all. **Students must select 7 out of 8 questions to answer.**
- The exam is open book and open notes. The students can bring any relevant written materials.
- No computer, iPad, and internet access are allowed.
- Calculator is allowed.
**ISyE 415 Problem 1**

A manufacturing firm owns a production line with \( n \) identical consecutive machines. Each machine needs a setup every \( x \) jobs. The manager tested a series of setup time spent over one machine as

<table>
<thead>
<tr>
<th>Setup</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
<th>#7</th>
<th>#8</th>
<th>#9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>1.3</td>
<td>0.8</td>
<td>2.1</td>
<td>0.5</td>
<td>1.4</td>
<td>1.1</td>
<td>0.9</td>
<td>1.8</td>
<td>0.6</td>
</tr>
</tbody>
</table>

(hours)

The manager noticed that it is easy to be disrupted. Similarly, the repair time is tested as follows

<table>
<thead>
<tr>
<th>Status</th>
<th>working</th>
<th>repair</th>
<th>working</th>
<th>repair</th>
<th>working</th>
<th>repair</th>
<th>working</th>
<th>repair</th>
<th>working</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>5</td>
<td>1.2</td>
<td>10</td>
<td>0.8</td>
<td>8</td>
<td>3</td>
<td>10</td>
<td>1.8</td>
<td>11</td>
</tr>
</tbody>
</table>

(hours)

Assume processing each job takes an average of \( t_0 \) hour with standard deviation \( s_0 \) hour for each machine. Also assume the job arrives on average every \( t_\alpha \) hours with standard deviation of \( s_\alpha \) hour.

For all machines,

a. What is the average effective process time and its standard deviation for each machine?

b. What is the utilization?

c. What is the average waiting time in the queue (buffer)?

For the entire production line

e. What is the throughput (TH), total cycle time (CT), and total work in process (WIP)?

**ISyE 415 Problem 2**

Consider a retailer selling a product. Suppose the annual demand rate is \( D \) with a replenishment lead time \( L \). Historical sale data shows that the lead time demand approximately follows a discrete UNIFORM distribution of \( 0,1,2,\ldots,2LD \). (Suppose \( 2LD \) is an integer). Given the inventory holding cost \( h \), fixed ordering cost \( A \), and stock out cost \( b \), find the optimal reorder point \( r \) and order quantity \( Q \).

(a). Derive the optimality condition (equilibrium) for \( Q,r \).

(b). Solve \( Q,r \) in an explicit form, noting that you may need to discuss the range of parameters.
ISyE 510 Problem 3(a).

The layout area for a new plant is shown below. The coordinates of the corners are shown in the figure. The unit is feet. There are two possible tool crib locations as indicated as stars. Assume the operators walking speed is 12,000 feet per hours. Then what is the average round-trip walking time for these two alternatives? Note in each case, there is only one crib in the layout.

Problem 3(b) Consider the following initial layout and flow chart.

(a) What is the cost of the layout if we use CRAFT method?
(b) What the efficiency rating of the layout?

<table>
<thead>
<tr>
<th>From</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From-to chart

<table>
<thead>
<tr>
<th>A</th>
<th>A</th>
<th>A</th>
<th>B</th>
<th>B</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>A</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
<td>A</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>D</td>
<td>D</td>
<td>D</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>D</td>
<td>D</td>
<td>D</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
</tbody>
</table>

Initial layout
ISyE512 Problem 4.

Samples of n = 4 items are taken from a process at regular intervals. A normally distributed quality characteristic is measured and \( \bar{x} \) and s values are calculated for each sample. After 50 subgroups have been analyzed, we have

\[
\sum_{i=1}^{50} \bar{x}_i = 1000
\]

\[
\sum_{i=1}^{50} s_i = 72
\]

m=50 subgroups

(a) Compute the control limits for the \( \bar{x} \) and s control charts

(b) Assume that all points on both charts plot within the control limits. What are the natural tolerance limits of the process?

(c) If the specification limits are 19 ± 4.0, what are your conclusions regarding the ability of the process to produce items conforming to specifications?

(d) Assuming that if an item exceeds the upper specification limit it can be reworked, and if it is below the lower specification limit it must be scrapped, what percent scrap and rework is the process now producing?

(e) If the process were centered at \( \mu = 19.0 \), what would be the effect on percent scrap and rework?
ISyE 605 Problem 5 (a): (3 points)

Fill in the blanks in the CNC program to machine this block.

Note: 🟢 represents the coordinate frame origin (0,0,0)

```
G01000
T1 M6
G0 G90 G40 G21 G17 G94 G80
G54 X-75 Y-25 S500 M3 (Start Point)
G43 Z100 H1
Z5
G__ Z__ F100
X_____ M8 (Position 1)
_____ (Position 2)
X0 Y50 (Position 3)
X50 Y0 (Position 4)
X0 Y-50 (Position 5)
X-50 Y0 (Position 6)
_____ (Position 7)
X-75 (Position 8)
G0 Z100
M____
```

Problem 5 (b): (7 points)
The shaft shown below is to be machined on a turning center from a 25mm diameter bar stock. Calculate the machining time if speed V is 60 m/min., turning operations feed is 0.2 mm/rev, drilling feed is 0.08 mm/rev and knurling feed is 0.3 mm/rev. (Note: Machining operations involved are facing, turning, drilling, knurling and parting; Also, assume same feed rate for OD turning, facing and parting operations.)
ISyE 615 Problem 6

Consider a five-machine serial line with Bernoulli reliability model. Each machine $m_i, i=1,\ldots,5$, has probability $p_i$ to be up and $1-p_i$ to be down during each time slot. All buffers have same capacity $N$. The status of the machine is determined at the beginning and buffer at the end of each time slot. Each machine status is determined independently from the other. A machine is starved if it is up and upstream buffer is empty, and is blocked if it is up, the downstream buffer is full and the downstream machine does not take a part. The first machine is never starved and the last machine is never blocked. Block before service and time-dependent failures are assumed.

-bottleneck machine

a) Assume all $p_i=p, i=1,\ldots,5$, identify the bottleneck machine.

b) Under the workforce constraint $\prod p_i=p^5$, is this system (i.e., $p_i=p$) unimprovable with respect to workforce or not? If yes, justify it. If not, how should one adjust $p_i$ to maximize line production rate?

c) Let $\sum N_i=4N$ be the buffer capacity constraint. Is this system unimprovable with respect to workforce and buffer capacity simultaneously or not? If yes, justify it. If not, how should one adjust $p_i$ and $N_i$ to maximize line production rate?

ISyE 641 Problem 7. A production system for a product family is described below. Do you think this product family is a good candidate for application of Quick Response Manufacturing (QRM) principles and techniques? Explain why or why not. Document any assumptions you make relative to your decision.

Current Production System: The parts to be made are a family of metal chassis to be used in cabinets that hold electronic components. There are twelve variations of the chassis (referred to as Type A through Type L; see Figure 1 for an image of the Type A Chassis). The raw materials for the production system consist of aluminum extrusions that have already been cut to length. The top half and bottom half of the chassis are extruded separately. The processes to be performed in this system are contouring and tapering of outside geometry; milling of pockets and slots; and drilling, tapping, and countersinking of holes. The production system has 4 CNC machining centers with an integrated conveyor system between them that can automatically transfer parts to and from the machines. An inspection process is also required, which is done using an inspection probe on one of the CNC machining centers. When a part arrives at a CNC machine, a bar
code on the pallet is read, and the appropriate program is loaded. When parts are completed within this CNC machining system, they are sent to a separate area of the facility for welding (travel distance of 50 meters) and another area for painting (travel distance of 80 meters). The total anticipated customer demand for the whole family of products is 225,000 per year, with 40% of the demand associated with the Type A chassis.

**ISyE 615 Problem 8 (replace ISyE 643)**

Consider a flexible machine making two types of products, 1 and 2, where the parts are processed in batches with size 3. The machine has an identical cycle time to process a part, where the time axis is slotted with the cycle duration. In each cycle, for a type \( j \) part, \( j=1,2 \), the machine has probability \( p_j \) to be up to process a part, and probability \( 1-p_j \) to fail. The machine status changes at the beginning of the time slot. When the machine finishes the last part in a batch, it will switch to a setup state of another part type. The probability to finish setup for type \( j \) parts and start processing is \( s_j \).

If we model the steady state of the system using a discrete Markov chain, then

a) Define the system states.

b) Provide a state transition diagram.

c) Explain the procedure how to derive the production rate of the machine.
2018 MPS Qualify Exam

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- There will be eight questions in all. **Students must select 7 out of 8 questions to answer. Please also note that: problem (605) has two options, if you select (605), you need to take only one of them.**
- The exam is open book and open notes. The students can bring any relevant written materials.
- No computer, iPad, and internet access are allowed.
- Calculator is allowed.
Problem 1. (415)

A manufacturing firm owns a production line with two consecutive machines, A and B. The first machine, Machine A, is inflexible, which needs a setup after every 10 jobs. The manager recorded a series of time spent over the past week as

<table>
<thead>
<tr>
<th>Setup #</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
<th>#7</th>
<th>#8</th>
<th>#9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (hours)</td>
<td>1.3</td>
<td>0.8</td>
<td>2.1</td>
<td>0.5</td>
<td>1.4</td>
<td>1.1</td>
<td>0.9</td>
<td>1.8</td>
<td>0.6</td>
</tr>
</tbody>
</table>

The second machine, Machine B, is flexible, but the manager noticed that it is easy to be disrupted. Similarly, the repair team recorded the working/repair history as follows

<table>
<thead>
<tr>
<th>Status</th>
<th>working</th>
<th>repair</th>
<th>working</th>
<th>repair</th>
<th>working</th>
<th>repair</th>
<th>working</th>
<th>repair</th>
<th>working</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (hours)</td>
<td>5</td>
<td>1.2</td>
<td>10</td>
<td>0.8</td>
<td>8</td>
<td>3</td>
<td>10</td>
<td>1.8</td>
<td>11</td>
</tr>
</tbody>
</table>

Assume processing each job takes an average of 1 hour with standard deviation 0.25 hour for both machines. Also assume the job arrives on average every 2 hours with standard deviation of 1 hour.

For both machines,

a. What is the average effective process time and its standard deviation?

b. What is the utilization?

c. What is the average waiting time in the queue (buffer)?

For the entire production line

d. What is the throughput (TH), total cycle time (CT), and total work in process (WIP)?

Problem 2. (415)

Novak and Juan are two summer interns competing for the same full-time position in a manufacturing company. The interviewer asks them to determine the optimal production policy for a manufacturing line that makes injection molded parts. The daily demand is 10 units per day and is steady (negligible uncertainty). The production rate of the injection molding machine is 10 units per hour. The setup cost for a production run is $50 per setup. Holding costs are estimated to be $1 per unit-year, and backorder costs are $2 per unit-year. (Assume 360 days a year and 10 hours per day.)
a) Novak proposes to setup the machine as soon as he runs out of inventory and decides to run a production quantity that will satisfy two months of demand each time. Compute the total average annual costs of ordering, holding inventory and backorders for this policy. What is the fill-rate under this policy?

b) Juan proposes to setup the machine only after he has 180 units of backorders and run production quantities of 600 units each time. Compute the total average annual costs of ordering, holding inventory and backorders for this policy. What is the fill-rate under this policy?

c) Which policy has lower total annual costs?

**Problem 3. (510)**

**Part 1.**

The factory has the shape as illustrated below (unit: yards). The existing two tool cribs are located at (150,75) and (250, 75), respectively. The customers are uniformly distributed throughout the shop and walks at an average speed of about 5000 yards per hour. What is the average round-trip travel time of an employee to a tool crib?

![Diagram of the factory](image)

**Part 2.**

Machine 1, 2, 3, 4, 5 are located at the points (8, 9), (9, 1), (6, 0), (2, 5), (8, 1), respectively. There are 4, 9, 7, 9, 6 trips per week, respectively, between the machines and a new facility. Find the optimal location of the new facility. Please consider the rectilinear distance and use the Minisum criteria.
Problem 4. (512)

In the following $\bar{x}$ control chart, most of the points cluster round the center line.

(a) Is it normal for the operation of a control chart? If it is not normal, what is the most likely reason for this situation?

To detect this situation in a control chart, a manufacturer decides to use the following rule on the $\bar{x}$ chart to decide if their process is in control or not. The rule is

Rule: *If at least seven among eight consecutive points lie within $\mu + \sigma_{\bar{x}}$ and $\mu - \sigma_{\bar{x}}$, the process is considered as out of control.*

Assume the quality characteristic is independent, normally distributed. The process mean is $\mu$ and the standard deviation of $\bar{x}$ is $\sigma_{\bar{x}}$. Answer the following questions.

(b) What is the probability of 8 consecutive points fall between $\mu + \sigma_{\bar{x}}$ and $\mu - \sigma_{\bar{x}}$ when the process is in-control?

(c) What is the Type I error of this rule?

(d) Given the sample size $n=4$, if the mean of the quality characteristic shifts one process standard deviation ($\sigma$), and remains there during the collection of the next 8 samples, what is the type II error associated with this rule?
Problem 5. (605) (if you choose to do (605), select one of the following sub-problems)

Sub-problem 1 (415):

Question a:
John Doe wants to establish a new manufacturing job shop/company to produce fabricated metal components. He anticipates receiving production orders from two major customers as outlined below. Based on this information regarding the parts to be manufactured, identify the types of manufacturing equipment/processes that John will need for his manufacturing company, and explain why you feel each of them is necessary.

Customer A wants you to produce the following 4 parts (see figure on right).
- Material is sheet steel of 0.05 inch thickness.
- Order quantity for each part is in the range of 250,000 to 350,000 per year.
- The parts are relatively small in size, approximately 2 inches or less in length and width.

Customer B sells industrial metal cabinets (see figure on left) and wants you to produce the door panels, walls and shelves which Customer B will assemble to make the cabinets.
- Material is sheet steel of 0.17” thickness.
- Order quantity for each part is in range of 80 to 300 per year.
- The parts to be produced are relatively large in size – The cabinets are roughly 8 feet tall, 4 feet wide and 2 feet deep.

Question b:
Consider the steel part shown below; It is roughly 8 inches in diameter and 2 inches in height. There are several potential options for manufacturing this part. Specifically, the part can be machined to this final shape by starting with either (i) a sand casting, or (ii) a forging, or (iii) a solid rectangular block of steel. What are the factors that you will consider in order to decide which option (i, ii, or iii) is most appropriate as the starting workpiece for machining? Based on these factors, explain when each of these three options is a suitable choice.
Sub-problem 2. (510)

A furniture manufacturing company wants to introduce two new stools in the market. The first one has a wooden top and four 30" legs (bar height); the second one has a wooden top and four 20" legs (regular height). The two operations involved in the production of these new stools are in sequence: (1) Cut four legs simultaneously to the right lengths; (2) Pack the customer’s order including the four legs, the wooden top received from a supplier, a set of screws and the assembly manual. The marketing department forecasts an annual demand of 50,000 bar height-stools per year and 35,500 regular height-stools per year.

<table>
<thead>
<tr>
<th>Type of operations</th>
<th>Set-up time</th>
<th>Cycle time</th>
<th>Load time</th>
<th>Unload time</th>
<th>Scrap rate</th>
<th>Process Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bar height</td>
<td>Cutting</td>
<td>Auto</td>
<td>3</td>
<td>3.5</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>Packing</td>
<td>Manual</td>
<td>0</td>
<td>7</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Regular heights</td>
<td>Cutting</td>
<td>Auto</td>
<td>1</td>
<td>8</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>Packing</td>
<td>Manual</td>
<td>0.5</td>
<td>5.4</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Notes:

(i) The company works two 8-hour shifts per day, 5 days per week 50 weeks per year.
(ii) The company’s policies establish a 90%-utilization cushion and a batch size equals to 2-week of customer demand
(iii) For auto operation, operator time will be needed for set-up, load, and unload operations; while for manual operations, operator time will be needed for all the operations.
(iv) All times given in the table are in minutes

You are asked to size a possible cell to perform these two operations (i.e., cutting and packing) for these two new products; using the provided information, determine:

a) The number of machines/assembly benches required for each operation
b) The minimum number of operators required to run the cell
c) The average machine utilization at each operation

Problem 6 (615):

Consider a flexible machine making two types of products, type 1 and type 2. For each product type, the machine has probabilities \( P(g) \) and \( P(d) \), \( i=1,2 \), to produce a good and a defective part, respectively. The transition probabilities from producing a good type \( i \) part to making a defective type \( j \) part are denoted as \( \lambda_{ij} \), \( i, j=1,2 \). The machine has probabilities \( v_{ij} \) to continue making a good type \( j \) part after producing a good type \( i \) part. Similarly, the machine has probabilities \( \mu_{ij} \) from producing a defective type \( i \) part to making a good type \( j \) part, and probabilities \( \eta_{ij} \) to still making a defective type \( j \) part after producing a defective type.
i part. Assume the incoming part flow is identically and uniformly distributed with probabilities $P(1)$ and $P(2)$ for part types 1 and 2, respectively. If we model the steady state of the system using a discrete Markov chain, then

a) Define the system states.
b) Provide a state transition diagram.
c) Derive the balance equations.
d) Explain ideas to derive the probability producing a good part $P(g)$.
e) Answer questions a), c) and d) for $n$ product type scenarios.

**Problem 7 (641):**

In a facility manufacturing high variety or custom engineered products, lead time for office operations such as quoting, engineering and order processing could be quite high. Significant reduction in lead times can be achieved by implementing quick response office cells that are closed loop, collocated and cross trained to execute office operations for a focused target market segment in small batches.

a) Explain the term “closed-loop” in the context of a quick response office cell. Give an example to illustrate this concept.
b) Give an example to illustrate how cross training across multiple functions in office operations could open opportunities for process improvement, that might not have been identified otherwise.
c) Give one example of batching in the following office functions: (a) cost estimating and (b) planning
d) Using a suitable focused target market segment (FTMS), provide an example that illustrates the following concept “After finding an FTMS, look for sub-segments that are amenable to simpler processing steps.”

**Problem 8 (643):**

A work center has two machines $i=1,2$. A repair worker is responsible for repairing these two machines when they fail. The up time of both machine 1 and machine 2 are exponential distributed, wherein machine 1 has an average up time 2 hours and machine 2 has an average up time 1 hour. Then machine $i$ fails and requires the worker to repair it in an exponential service time. The repair work takes 10 minutes for machine 1 and 15 minutes for machine 2 to be repaired. Since machine 1 has higher production speed such that it has higher priority to be repaired. For example, if machine 1 fails while machine 2 is being repaired, the worker will stop the repairing work of machine 2 immediately and begin to work on machine 1.

a. Define state space and draw the state transition diagram;
b. Calculate the proportion of time that machine 2 is down;
c. If the repairing work of machine 2 is break off because of the failure of machine 1, machine 2 requires an exponential time with rate 8/hour to be repaired after machine 1 is repaired (regardless of how many times the repairing work of machine 2 has been interrupted). What’s the proportion in question b?
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Problem 1 (415)

Consider a retailer selling a product. Suppose the annual demand rate is \( D \) with a replenishment lead time \( L \). Historical sale data shows that the lead time demand approximately follows a UNIFORM distribution within range 0 to some positive value \( U \). Given the inventory holding cost \( h \), fixed ordering cost \( A \), and stock out cost \( b \), find the optimal reorder point \( r \) and order quantity \( Q \).

(a) What is the expression for \( U \)?

(b) Derive the optimality condition (equilibrium) for \( Q, r \).

(c) Solve \( Q, r \) in an explicit form, noting that you may need to discuss the range of parameters.

Problem 2. (415)

Adrian is a lead operator at a milling cell that has a 3-axis milling machine and an inspection station. Jobs are released to the milling machine according to a Poisson process at a rate of 6 jobs per hour. Pocketing operations on this milling machine have an exponential distribution with a mean of 5 minutes. Changeover times on the machine take an average of 30 mins with a standard deviation of 10 mins. Adrian runs jobs in batches of ten before carrying out a changeover to another product. After milling the job goes to an automatic inspection station that takes exactly 5 mins for final inspection per part.

a) Determine the throughput and the bottleneck in the cell.

b) Determine the average cycle time (lead time) and WIP in the cell.
Problem 3. (ISyE 510)

(1) The Top Hat Pop Corn Company produces high quality gourmet popcorn that is delivered to independently owned specialty food shops. Popcorn is sold in 2 packages, a 2 ounce package and an 8-ounce package. The sequence of operation is popping corn, packaging it and cartoning the packages. Currently, the weekly demand is 6,000 cartons of 2-ounce bags and 5,000 cartons of 8-ounce packages. (There are 24 2-ounce packages and 12 8-ounce packages per carton). The facility where the popcorn is made is operating on a five-day-a-week, eight hour a day schedule. Currently, this facility has the following equipment and respective capacities. (1 lb = 16 ounces). Please estimate your daily demand and current capacity in terms of pounds/week.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Capacity per Machine</th>
<th>Batch Time</th>
<th>Number of Machines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn Popper</td>
<td>50 lb/batch</td>
<td>6 min</td>
<td>3</td>
</tr>
<tr>
<td>Packaging (2 oz)</td>
<td>40 pkgs/min</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Packaging (8 oz)</td>
<td>20 pkgs/min</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Carton operation (2 oz)</td>
<td>1 min/carton</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Carton operation (8 oz)</td>
<td>1 min/carton</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

a) Determine the capacity utilization of each stage in the process when the daily demand is produced, and identify any bottlenecks that exist.

b) If bottleneck(s) do exist, what are your recommendations for meeting the daily demand?

(2) There are three machines in a cell: Machine A, Machine B, and Machine C. It is known that the concurrent time between the operator and A, B, and C are 2 min, 2.5 min, and 3 min respectively. The independent time of the operator for A, B, and C are 1 min, 1 min, and 1.5 min, respectively. The processing time of A, B, and C are 7 min, 8 min, and 9 min, respectively. Show your steps in the following calculation.

Case 1: Three operators are assigned to the cell. Each operator has been assigned to one machine.

   (a) What is the percentage of idle time of each operator?
   (b) What is the average production rate per operator?

Case 2: Only one operator is assigned to the cell. The multiple activity chart for one production cycle is given below.
Problem 4 (ISyE 512)

In an \( \bar{x} \) chart, the following decision rule applies to a normally distributed quality characteristic with sample size \( n=4 \):

**Rule:** If at least 2 of the next 3 sample averages plot above the upper 2-sigma limits or at least 2 of the next 3 sample averages plot below the lower 2-sigma limits, conclude that the process is out of control.

(a) What is the type I error probability for this rule?
(b) If the mean of the quality characteristic shifts one and a half process standard deviation (1.5 \( \sigma \)), and remains there during the collection of the next 3 samples, what is the type II error associated with this rule?

Problem 5. (ISyE 605)

a) How much machining time will be required to reduce the diameter of a cast iron rod from 120 mm to 116 mm over a length of 100 mm by turning using a carbide insert. Assume a cutting speed of 100 m/min and feed of 0.2 mm/rev. Also assume a tool approach distance of 5 mm.

b) Determine the time that will be required to drill a blind hole of diameter 25 mm and depth 40 mm in a mild steel solid block by a HSS drill of 118 degrees cone angle. Assume cutting speed of 25 m/min and feed of 0.16 mm/rev. Also assumed a tool approach distance of 5 mm.

c) Calculate the machining time that will be required to finish a vertical flat surface of length 100 mm by an 8 teeth HSS end mill cutter of 32 mm diameter and 60 mm length in a milling machine. Assume cutting speed 30 m/min, and feed of 0.12 mm/tooth.
Problem 6. (ISyE 615)
Consider a transmission machining line shown in the figure below. The system consists of a main conveyor and seven sub-conveyors connected to the main one. Parts are transported within pallets by the conveyors. Sensors at the intersections identify the type of part on each pallet and the next process it needs to go to control the flow. Parts enter the system at a sub-conveyor. A worker loads the part onto a pallet on the sub-conveyor. The type of part is selected based on daily demands. The loaded part will be transported to the main conveyor if there is an available space. If there is no space, it will stay in the sub-conveyor until it becomes available. Each part should be processed in the order of machining, leak test, pressing, and cleaning machines. For the machining operations, there are two processing routes for type 1 parts. One is to be served at machine M3 and then either of machines M1 or M2. Or, it will be machined at one of machines M4, M5, and M6. Type 2 parts will be served at one of machines M7, M8, and M9. Type 3 parts are served at one of the machines M10, M11, M12, M13, M14, and M15. For leak test, pressing, and cleaning process, all the part types have the same route. That is, a part after the machining process will be served at M16 or M17, and then M18 and M19 in serial order. The parts on the main conveyor keep circulating until there is an available buffer of the processing machines. When a part completes a process and if there is an available space on the main conveyor, the part will come back to main conveyor for the next process. If there is no available space on the main conveyor, the part will stay either in the buffer of the last machines or on the sub-conveyor. After all processes is complete, it will be unloaded by a worker at the sub-conveyor and the empty pallet is ready for loading again.
Using the above information, through structural modeling, develop a simplified model for analysis. Explain the rationale and approach for simplification, what type of data to be collected on the factory floor, and the solution procedure of the potential analysis method.
Problem 7 (641)

ABC Inc. makes valves that are used in a variety of industrial applications. The office operations (planning, purchasing etc.) for releasing work orders for valves takes 5 calendar days. Manufacturing work orders are released for a batch of 100 valves and it takes 20 calendar days (from the time they are open till they are closed). Each valve involves manufacturing operations that adds up to 2 hours. The total setup time for a batch of valves is 5 hours. After manufacturing work orders are closed, these valves are put into a finished goods warehouse as stock. ABC Inc has 450 valves in stock on an average and ships roughly 10 valves per day.

a) Define the term Manufacturing Critical-path Time (MCT) and explain the difference between MCT and lead time.

b) Compute the MCT for this valve and the percentage of touch time and non-touch time in the MCT. (Assume factory operates 24x7x365 and supply chain issues/stocks can be ignored)

c) Using an illustrative example, explain the statement “Traditional measures of supplier quality do not measure suppliers’ capability to make high quality parts – measuring the suppliers MCT gives a better indicator.”

d) Total cost of sourcing parts from a supplier with long MCT could be significantly higher than the quoted price. List four costs that make this total cost of sourcing significantly higher than the quoted price.

Problem 8 (643)

A machine center has two workers. Worker 1 is the more experienced of the two, capable of handling $\mu_1$ jobs per hour; Worker 2 can complete $\mu_2$ jobs per hour, where $\mu_1 > \mu_2$. Jobs arrive according to a Poisson process with rate $\lambda$ per hour. When both workers are idle, the arrangement is that Worker 1 (the more experienced one) will always be the one to serve the next arriving customer.

a) Define an appropriate state space and draw a state transition diagram for the system.

b) Write down the rate balance equations.

c) What is the proportion of time Worker 1 spends serving jobs? (Your answer should be given in a compact form in terms of $\lambda$, $\mu_1$, and $\mu_2$.)