Sheet 3

Review Questions

1. What is the cycle time in a manufacturing operation?
2. What is a bottleneck station?
3. What is production capacity?
4. How can plant capacity be increased or decreased in the short term?
5. What is utilization in a manufacturing plant? Provide a definition.
6. What is availability and how is it defined?
7. What is manufacturing lead time?
8. What is work-in-process?
9. How are fixed costs distinguished from variable costs in manufacturing?
10. Name five typical factory overhead expenses?
11. Name five typical corporate overhead expenses?

PROBLEMS

1. A certain part is routed through six machines in a batch production plant. The setup and operation times for each machine are given in the table below. The batch size is 100 and the average nonoperation time per machine is 12 hours. Determine (a) manufacturing lead time and (b) production rate for operation 3.

Machine	Setup time (hr.)	Operation time (min.)
1	4	5.0
2	2	3.5
3	8	10.0
4	3	1.9
5	3	4.1
6	4	2.5

2. Suppose the part in the previous problem is made in very large quantities on a production line in which an automated work handling system is used to transfer parts between machines. Transfer time between stations = 15 s. The total time required to set up the entire line is 150 hours. Assume that the operation times at the individual machines remain the same. Determine (a) manufacturing lead time for a part coming off the line, (b) production rate for operation 3, (c) theoretical production rate for the entire production line?

3. The average part produced in a certain batch manufacturing plant must be processed sequentially through six machines on average. Twenty (20) new batches of parts are launched each week. Average operation time = 6 min., average setup time = 5 hours, average batch size = 25 parts, and average nonoperation time per batch = 10 hr/machine. There are 18 machines in the plant working in parallel. Each of the machines can be set up for any type of job processed in the plant. The plant operates an average of 70 production hours per week. Scrap rate is negligible. Determine (a) manufacturing lead time for an average part, (b) plant capacity, (c) plant utilization, (d) How would you expect the nonoperation time to be affected by the plant utilization?, (f) Based on your answers to that problem, determine the average level of work-in-process (number of parts-in-process) in the plant.

4. An average of 20 new orders are started through a certain factory each month. On average, an order consists of 50 parts that are processed sequentially through 10 machines in the factory. The operation time per

machine for each part = 15 min. The nonoperation time per order at each machine averages 8 hours, and the required setup time per order = 4 hours. There are a total of 25 machines in the factory working in parallel. Each of the machines can be set up for any type of job processed in the plant. Only 80% of the machines are operational at any time (the other 20% are in repair or maintenance). The plant operates 160 hours per month. However, the plant manager complains that a total of 100 overtime machine-hours must be authorized each month in order to keep up with the production schedule. (a) What is the manufacturing lead time for an average order? (b) What is the plant capacity (on a monthly basis) and why must the overtime be authorized? (c) What is the utilization of the plant according to the definition given in the text? (d) Determine the average level of work-in-process (number of parts-in-process) in the plant.

5. One million units of a certain product are to be manufactured annually on dedicated production machines that run 24 hours per day, five days per week, 50 weeks per year. (a) If the cycle time of a machine to produce one part is 1.0 minute, how many of the dedicated machines will be required to keep up with demand? Assume that availability, utilization, worker efficiency = 100%, and that no setup time will be lost. (b) Solve part (a) except that availability = 0.90.

6. The mean time between failures and mean time to repair in a certain department of the factory are 400 hours and 8 hours, respectively. The department operates 25 machines during one 8-hour shift per day, five days per week, 52 weeks per year. Each time a machine breaks down, it costs the company $200 per hour (per machine) in lost revenue. A proposal has been submitted to install a preventive maintenance program in this department. In this program, preventive maintenance would be performed on the machines during the evening so that there will be no interruptions to production during the regular shift. The effect of this program is expected to be that the average MTBF will double, and half of the emergency repair time normally accomplished during the day shift will be performed during the evening shift. The cost of the maintenance crew will be $1500 per week. However, a reduction of maintenance personnel on the day shift will result in a savings during the regular shift of $700 per week. (a) Compute the availability of machines in the department both before and after the preventive maintenance program is installed. (b) Determine how many total hours per year the 25 machines in the department are under repair both before and after the preventive maintenance program is installed. In this part and in part (c), ignore effects of queuing of the machines that might have to wait for a maintenance crew. (c) Will the preventive maintenance program pay for itself in terms of savings in the cost of lost revenues?

7. There are nine machines in the automatic lathe section of a certain machine shop. The setup time on an automatic lathe averages 6 hours. The average batch size for parts processed through the section is 90. The average operation time = 8.0 minutes. Under shop rules, an operator can be assigned to run up to three machines. Accordingly, there are three operators in the section for the nine lathes. In addition to the lathe operators, there are two setup workers who perform machine setups exclusively. These setup workers are kept busy the full shift. The section runs one 8-hour shift per day, 6 days per week. However, an average of 15% of the production time is lost is lost due to machine breakdowns. Scrap losses are negligible. The production control manager claims that the capacity of the section should be 1836 pieces per week. However, the actual output averages only 1440 units per week. What is the problem? Recommend a solution.

8. A certain job shop specializes in one-of-a-kind orders dealing with parts of medium-to-high complexity. A typical part is processed sequentially through ten machines in batch sizes of one. The shop contains a total of eight conventional machine tools and operates 35 hours per week of production time. The machine tools are interchangeable in the sense that they can be set up for any operation required on any of the parts. Average time values on the part are: machining time per machine = 0.5 hour, work handling time per machine = 0.3 hour, tool change time per machine = 0.2 hour, setup time per machine = 6 hours, and nonoperation time per machine = 12 hours. A new programmable machine has been purchased by the shop that is capable of performing all ten operations in a single setup. The programming of the machine for this part will require 20 hours; however, the programming can be done off-line, without tying up the machine. The setup time will be 10 hours. The total machining time will be reduced to 80% of its previous value due to advanced tool

control algorithms; the work handling time will be the same as for one machine; and the total tool change time will be reduced by 50% because it will be accomplished automatically under program control. For the one machine, nonoperation time is expected to be 12 hours. (a) Determine the manufacturing lead time for the traditional method and for the new method. (b) Compute the plant capacity for the following alternatives: (i) a job shop containing the eight traditional machines, and (ii) a job shop containing two of the new programmable machines. Assume the typical jobs are represented by the data given above. (c) Determine the average level of work-in-process for the two alternatives in part (b), if the alternative shops operate at full capacity. (d) Identify which of the ten automation strategies (Section 1.5.2) are represented (or probably represented) by the new machine.

9. A factory produces cardboard boxes. The production sequence consists of three operations: (1) cutting, (2) indenting, and (3) printing. There are three machines in the factory, one for each operation. The machines are 100% reliable and operate as follows when operating at 100% utilization: (1) In ***cutting***, large rolls of cardboard are fed into the cutting machine and cut into blanks. Each large roll contains enough material for 4,000 blanks. Production cycle time = 0.03 minute/blank during a production run, but it takes 35 minutes to change rolls between runs. (2) In ***indenting***, indentation lines are pressed into the blanks to allow the blanks to later be bent into boxes. The blanks from the previous cutting operation are divided and consolidated into batches whose starting quantity = 2,000 blanks. Indenting is performed at 4.5 minutes per 100 blanks. Time to change dies on the indentation machine = 30 min. (3) In ***printing***, the indented blanks are printed with labels for a particular customer. The blanks from the previous indenting operation are divided and consolidated into batches whose starting quantity = 1,000 blanks. Printing cycle rate = 30 blanks/min. Between batches, changeover of the printing plates is required, which takes 20 minutes. In-process inventory is allowed to build up between machines 1 and 2, and between machines 2 and 3, so that the machines can operate independently as much as possible. Based on this data and information, determine the maximum possible output of this factory during a 40-hour week, in completed blanks/week (completed blanks have been cut, indented, and printed)? Assume steady state operation, not startup.

10. A manufacturing plant having 24 machines produces a part being processed through six machines in batch of 40 parts. 30 batches of parts are launched each week. Average operation time = 7 min., average setup time per machine = 5hr, non-operation time per machine = 12 hr, scrap rate =3%, and Plant Operation time 10 hr / day, 6 days / week. Determine:
    a) Manufacturing lead-time.
    b) Plant utilization.
    c) The WIP in the plant
    d) Comment on your finding of utilization and analyze to improve the system

11. A plant contains 20 machines and produces two products according to the data given in Table1. Machine and labor cost= 80 SR/hr, raw material cost 300 SR/part, holding cost rate = 35%/year. Determine:
    a) MLT for each product type.
    b) The plant capacity.
    c) The utilization.
    d) The average WIP for each product type.
    e) Products cost for each product type.
    f) Holding cost for each product type.

Table 1		
Product type	**P1**	**P2**
Number of order per month	**30**	**40**
Average quantity per order, units	**30**	**20**
Number of processes	**10**	**12**
Average operating time, min	**12**	**15**
Non operation time per order, hr	**5**	**8**
Setup time per order, hr	**5**	**8**
Average mean time between failure, hr	**250**	
Average mean time to repair, hr	**10**	
Plant Operation time =10 hr / day, 6 days / week		

12. A plant contains 15 machines and produces two products according to the data given in Table (2). Determine:
    a) MLT for each product type.
    b) The plant capacity. Is this capacity meet production? If not suggest a solution.
    c) The utilization.
    d) The average WIP for each product type.

Table (2)

Product type	**P1**	**P2**
Number of order per month	**10**	**15**
Average quantity per order, units	**30**	**30**
Number of processes	**7**	**9**
Average operating time, min	**8**	**7**
Non operation time per order, hr	**5**	**5**
Setup time per order, hr	**5**	**8**
Average mean time between failure, hr	**235**	
Average mean time to repair, hr	**15**	
Plant Operation time	**10 hr / day, 6 days / week**	

13. A plant having 18 machines produces a part being processed through six machines in batch of 25 parts. 20 batches of parts are launched each week. Average operation time = 30 min, average setup time per machine = 5hr, non-operation time per machine = 12 hr, and scrap rate =3%. Plant Operation time 10 hr / day, 6 days / week. Machine and labor cost= 80 SR/hr, raw material cost 300 SR/part, holding cost rate= 35%/year. Determine:
    a) MLT, WIP, holding cost and part cost
    b) If the machines are replaced by CNC machines on which operation time = 15 min., setup time per machine =8hr, and non-productive time per machine =8hr, and scrap rate= 1%. Machine and operation cost = 150 SR/hr and material cost is the same. What is the number of CNC machines? Then determine MLT, WIP, holding cost and part cost.

Parameters	M/cs	CNC
Number of batch per week, N	**20**	**20**
Average parts per batch , units, Q	**25**	**25**
Number of processes, n_0	**6**	**1**
Average operating time, T_0 , hr	**0.5**	**0.25**
Non operation time per order,T_{n0}, hr	**12**	**8**
Setup time per batch,T_{su} , hr	**5**	**8**
Scrap %	**3**	**1**
Material Cost, SR/part	**300**	**300**
Machine and operation cost, SR/hr	**80**	**150**
Plant Operation time	**10 hr / day, 6 days / week**	

14. A manufacturing plant having 24 conventional machines produces a part being processed through six machines in batch of 30 parts. 20 batches of parts are launched each week. Average operation time = 30 min., average setup time per machine = 5hr, non-operation time per machine = 12 hr, and scrap rate =3%. Determine:-
    a) MLT, PC, U, WIP
    b) How would you expect the non-operation time to be affected by the plant utilization?
    c) If the machines are replaced by CNC machines on which operation time = 15 min., setup time per machine =8hr, and non-productive time per machine =10hr. What is the number of CNC machines? Then determine MLT, PC, U, WIP

Table (1)

Product type	**Conventional M/c**	**CNC** M/c**
Number of batch per week, N	**20**	**20**
Average quantity per batch, units, Q	**30**	**30**
Number of processes, n	**6**	**6**
Average operating time/process, min ,To	**30**	**15**
Non operation time per batch, hr, Tno	**12**	**10**
Setup time per batch, hr, Tsu	**5**	**8**
scrap %	**3**	**0**
Plant Operation time	**8 hr / day, 5 days / week**	

** Assume all processes are done in one set up

15. Costs have been compiled for a certain manufacturing company for the most recent year. The summary is shown in the table below. The company operates two different manufacturing plants, plus a corporate headquarters. Determine (a) the factory overhead rate for each plant, and (b) the corporate overhead rate. The firm will use these rates in the following year.

Expense category	Plant 1	Plant 2	Corporate headquarters
Direct labor	$1,000,000	$1,750,000	
Materials	$3,500,000	$4,000,000	
Factory expense	$1,300,000	$2,300,000	
Corporate expense			$5,000,000

16. The hourly rate for a certain work center is to be determined based on the following data: direct labor rate = $15.00/hr; applicable factory overhead rate on labor = 35%; capital investment in machine = $200,000; service life of the machine = 5 years; rate of return = 15%; salvage value in five years = zero; and applicable factory overhead rate on machine = 40%. The work center will be operated two 8-hour shifts, 250 days per year. (a) Determine the appropriate hourly rate for the work center. (b) if the workload for the cell can only justify a one shift operation, determine the appropriate hourly rate for the work center.

17. In the operation of a certain production machine, one worker is required at a direct labor rate = $10/hr. Applicable labor factory overhead rate = 50%. Capital investment in the system = $250,000, expected service life = 10 years, no salvage value at the end of that period, and the applicable machine factory overhead rate = 30%. The work cell will operate 2000 hr/yr. (a) Use a rate of return of 25% to determine the appropriate hourly rate for this work cell. (b) Suppose that the machine will be operated three shifts, or 6000 hr/yr, instead of 2000 hr/yr. Note the effect of increased machine utilization on the hourly rate compared to the rate determined in the previous problem.