EGT2
ENGINEERING TRIPOS PART IIA

Thursday 5 May 2022 2 to 3.40

Module 3E10

OPERATIONS MANAGEMENT FOR ENGINEERS (CRIB)

*Answer not more than **two** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

*Write your candidate number **not** your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Engineering Data Book

10 minutes reading time is allowed for this paper at the start of the exam.

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

You may not remove any stationery from the Examination Room.

1 (a) The primary role of the "Operations" function in a firm is to manage the processes that convert inputs into outputs that are supplied to the customer. [40%]

(i) Outline the key managerial activities in this conversion process.

Answer (20%):

The key managerial functions are to:
1. allocate resources to the processes, i.e. to develop forecasts and decide on the production volume, to procure materials, schedule the factory and workers against the predicted demand. The outputs here are purchase orders for suppliers, and work orders for the factory.
2. measure the outcome of the conversion process, in order to be able to ensure quality. Also the measurement of a process is a fundamental step in improving it (by being able to compare before and after)
3. improve the process. Based on the measurement and other data, such as customer requirements and feedback, the process is improved in order to increase its efficiency.

(ii) Discuss the key performance criteria of a process. Of these, which ones are most important? Justify your answer.

Answer (20%):

There is no one metric, or set of metrics, that can comprehensively describe the performance of any given process. Most commonly used are Quality, Cost and Delivery (QCD), often adding Service and Flexibility to it.

The importance of these performance criteria is solely dependent on customer requirements, and thus there is no standard answer that applies to all processes. In some settings neither time nor money matters (e.g. luxury goods), in others only cost matters when assuming a standard quality and delivery (e.g. commodities).

Students may also answer about difference between effectiveness and efficiency measures.

(b) Trumpington Foods offers premade salads. The following process is used to make them (see Fig. 1). There is one worker per station. Assume that units are admitted to the process at the rate of the bottleneck resource and the demand is always higher than the process capacity.

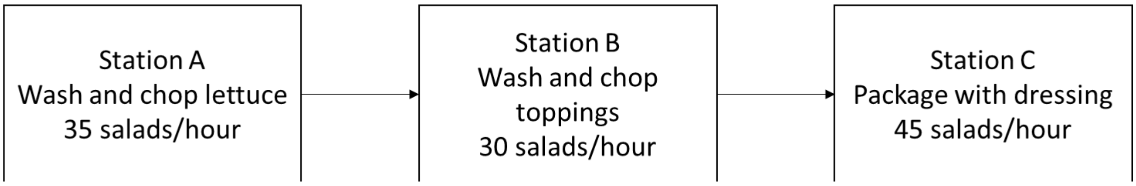

Fig. 1

[20%]

(i) Calculate the throughput time (i.e., flow time) for the 2nd unit of premade salad. Would that throughput time be sustainable?

Answer (5%):

102.857 + 120+80 + blocking time of (120-102.857)=320 sec or 5.333min

It would only be the case for the 2nd unit moving through the system? Blocking will get worse for each successive unit, so that throughput time will continue to increase.

(ii) Calculate the resource efficiency of the process.

Answer (5%):

If assume that units admitted at rate of bottleneck resource – as we have to do otherwise throughput time increases continuously, then:

Processing time / (processing time + wait time) =

= (102.857+120+80) / (17.143 + 40 + 302.857)

= 302.857 / 360

= 84.127% efficiency

(iii) Calculate the average inventory of salads in the system.

Answer (5%):

Little's Law: L=rt=30 salads/hour*302.857 sec/3600 sec per hour=9085.71/3600=2.524 salads

(iv) If the assumption is changed so that units can be admitted at a rate higher than bottleneck, and due to space limitations, you can install only one buffer (e.g., a portable table) where you can temporarily store work-in-progress (WIP) of salads. Where should you place the buffer and why?

Answer (5%):

Right before the bottleneck i.e., Station B.

And in that case would run out of buffer (table) space relatively quickly.

(c) Consider the two transformation processes shown in Fig. 2. Please briefly explain which one you think will have on average the higher total production outcome (i.e., total number of products produced in a given time period)? [10%]

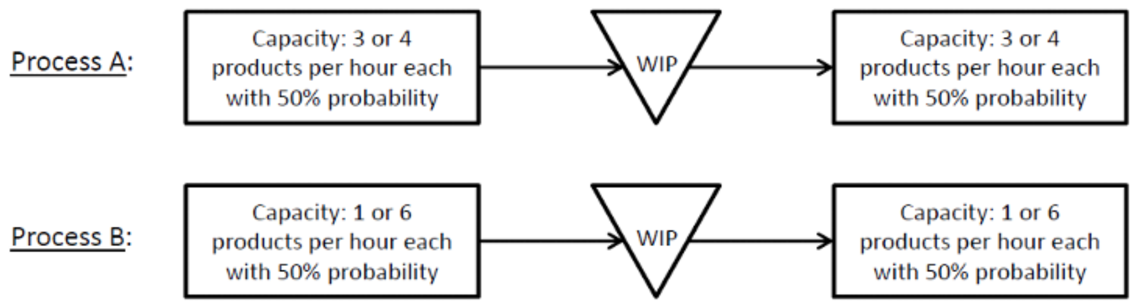

Fig. 2

Answer (10%):

Both processes have the same average, but Process A is less variable, and for that reason, it will have on average the higher total production outcome.

Alternatively, could also just say a range of integer values between 1 and 6 / 3 and 4? Would still give same answer.

(d) The product structure for an end item is described in Fig. 3. The number in parentheses indicates the lead time (in weeks) for making or purchasing each item.

End Item: Composed of 2 units of A, 2 units of B and 3 units of C.

Item A (1 week): Composed of 2 units of B and 1 unit of D.

Item C (2 weeks): Composed of 1 unit of B and 2 units of D.

Item B has a lead time of 2 weeks and item D has a lead time of 4 weeks.

What is the “order-to-delivery” lead time? [5%]

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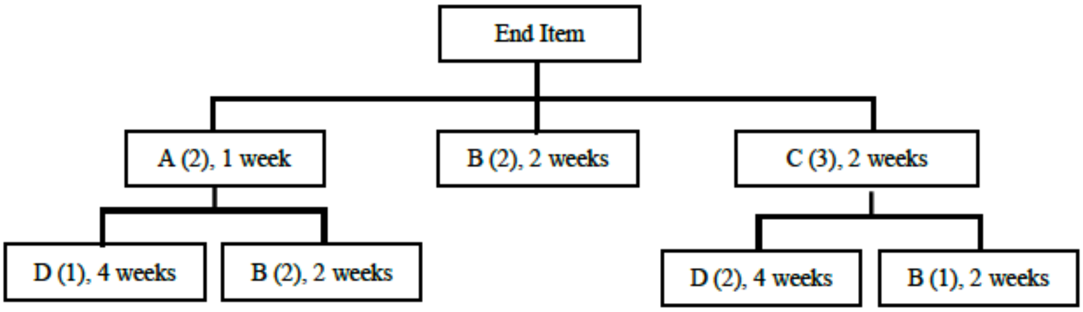


Fig. 3

Answer (5%):

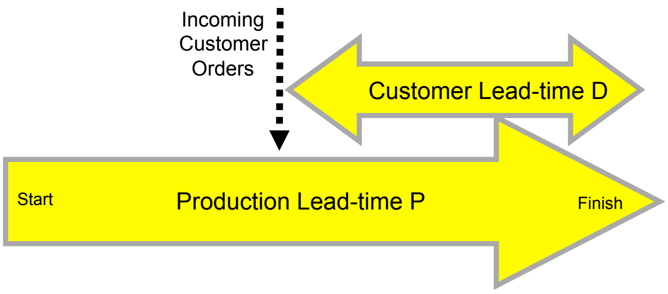
6 weeks

(e) What is a P:D ratio? What implications does the P:D ratio have for supply chain strategy? [25%]

Answer (25%):

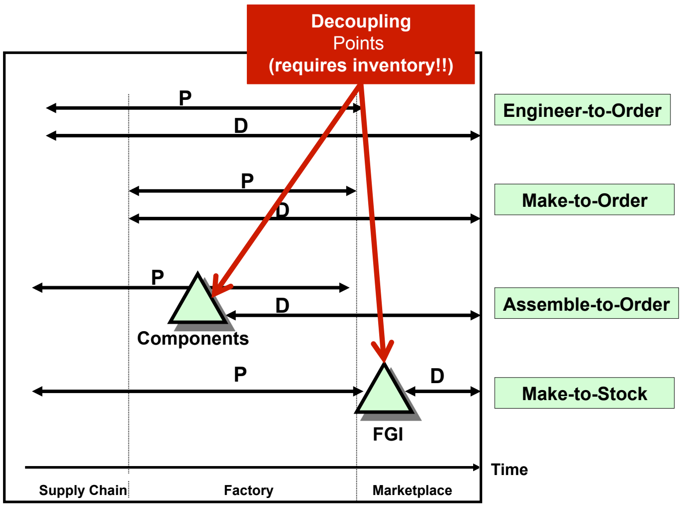
Production Lead-time P: How long does it take to make the product?

Demand Lead-time D: How long is the customer willing to wait for the product?



The P:D Ratio

P:D Ratio



Implications of the P:D ratio for supply chain strategy:

- How long customers wait?
- Degree of customization available to them?

The price customers will pay?

(cont.

2 (a) A local service station is open 7 days per week, 365 days per year. Sales of 10W40 grade premium oil average 25 cans per day. Inventory holding costs are £0.75 per can per year. Ordering costs are £9 per order. Lead time is 1.5 weeks. Backorders are not practical – motorists will simply drive away. The standard deviation of demand was determined from a data sample to be 2.5 cans per day. The manager wants a 95% service level. Determine the optimal inventory plan (i.e., calculate the economic order quantity, EOQ and reorder point, ROP) based on this information. [20%]

Answer (20%):

$$EOQ = \sqrt{\frac{2 \times D \times S}{H}} = \sqrt{\frac{2 \times 9125 \times 9}{0.75}} \approx 468 \text{ cans}$$

σ=2.5 cans per day

95%⇒z=1.645

$$ROP = D \times L + z \times \sigma \times \sqrt{L} = 25 \times 10.5 + 1.645 \times 2.5 \times \sqrt{10.5} = 275.82 \approx 276 \text{ cans}$$

(b) Fig. 4 shows optimal economic order quantity, EOQ inventory policies for two different companies and for the same time horizon. [10%]

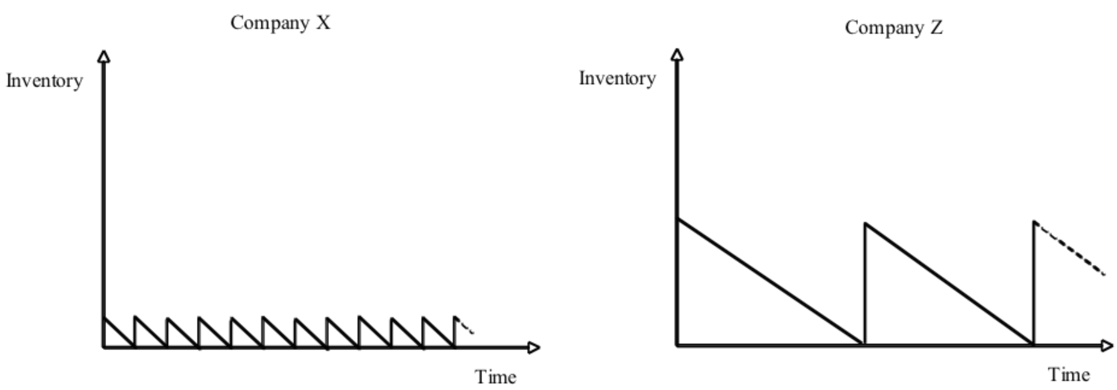


Fig. 4

(i) If both companies have the same annual demand, D, and the same fixed cost, K, per order, please briefly explain which of the companies you believe has a higher unit inventory holding cost, h?

(ii) If both companies have the same annual demand, D, and the same unit inventory holding cost, h, please briefly explain which of the companies you believe has a higher fixed cost K per order?

(iii) If both companies have the same annual demand, D, then on average, please briefly explain which of these companies you believe holds less inventory for the same time horizon?

Answer (10%):

(i) Company X because it orders smaller quantities more frequently. Only reason to do that is to avoid carrying inventory due to high h.
(ii) Company Z because it orders larger quantities less frequently. Only reason to do that is to avoid ordering frequently due to high K.
(iii) Company X because it orders smaller quantities.

(c) Annual demand for a product is deterministic and constant, but the value is not specified. A firm uses an order quantity of Q = 1,100 units. The firm's annual inventory holding cost is £900 and their annual setup cost is £1,200. Discuss whether the order quantity that the firm uses is appropriate. What inventory decisions should the firm change? [15%]

Answer (15%):

At optimal solution, the firm's annual inventory holding cost should be equal to their annual setup cost. Since the current annual holding cost is £900 and annual setup cost is £1200, we should increase Q further to increase the annual holding cost and decrease the annual setup cost. Therefore, the optimal order quantity should be larger than 1,100 units.

(d) Discuss, with examples, when the fixed time period inventory model should be preferred to the fixed-quantity inventory model and vice versa. [20%]

Answer (20%):

The fixed time period model typically requires holding more inventory on average, since it must protect against stockout during the review period and lead time from reordering. Therefore, **the fixed-order quantity model is preferred for more expensive items** because average inventory is lower.

The fixed-order quantity model has no review period. Therefore, **the fixed-order quantity model is more appropriate for important items** such as critical repair parts because there is closer monitoring and therefore quicker response to a potential stockout.

The fixed time period model is preferred when several different items are purchased from the same vendor, and there are potential savings from ordering all these items at the same time (economies of scale).

The fixed time period model has no physical count of inventory items after an item is withdrawn. By contrast, the fixed-order quantity model requires more time and resources to maintain because every addition or withdrawal is recorded (a perpetual inventory system). Therefore, **the fixed-order quantity model should be preferred only when such a monitoring is feasible**. Note that advances in information technologies (point of sale computers, bar coding, RFID) have greatly reduced the cost and facilitated the use of the fixed-order quantity model.

(e) Why is forecasting an important operations process? Illustrate with examples. [15%]

Answer (15%):

- More fundamentally, this is about understanding the nature of demand? Then about whether they can change the shape of demand (smooth peaks, lift troughs); then they worry about capacity management strategy.

- Forecasts help by making decisions about resourcing the organization for the future. Expanding or decreasing capacity mostly requires preparation and cannot be done instantaneously.

- For example, the process of hiring new employees or acquiring new machinery often takes time, and forms should instigate these processes before the new employee or machine becomes necessary.

(f) Which forecasting method would be appropriate in each of the following scenarios? [20%]

(i) Camilton is attempting to predict next year's demand for hotel rooms based on a history of demand observations.

Answer (10%):
Since Camilton is using *historical* demand observations, a time series method is the appropriate type of forecasting method for the firm.

(ii) NewPaint has developed a new type of outdoor paint. The company wishes to forecast sales based on new housing starts.

Answer (10%):

Since NewPaint does not have any historical data for their product and would like to base their forecast on new housing starts, they can use a causal model for their prediction.

3 (a) Materials Requirements Planning (MRP) provides a means for scheduling the ordering of raw materials and parts. [20%]

(i) What are the main inputs to an MRP system?

Answer (10%):
Main inputs:

- Master Production Schedule - a complete list of the volume and due dates of all expected product sales
- Inventory Record File - a record of current stocks
- Bill of Material File - design information relating products to components - usually expressed in hierarchical form
- Lead times - prediction of how long it will take to complete each task
- Lot sizing rules - to determine the size of batch to be ordered

(ii) How is a Bill of Materials used in MRP calculations?

Answer (10%):
The knowledge of the MPS and the BOM allows "explosion of requirements" for each component and each raw material item. The BOM enables a structure for the MRP calculation to be put into place.

(b) There are two fundamental approaches to scheduling production operations, pull and push scheduling. [30%]

(i) Discuss the key differences between pull and push scheduling.

Answer (10%):
A "pull" system uses the customer demand signal to trigger replenishment. It is an autonomous system that purely works by replenishing goods that have been consumed by the preceding process. The demand signal is the only trigger for production, not forecasts or centrally planned work orders. The demand signal is conveyed by a "kanban", which could be an empty bin, a card or electronic signal.

In a "push" system, production is planned centrally using a Master Production Schedule (MPS), which generally comprises of a combination of actual customer orders and forecasts. Based on the MPS and standard routing and lead-time data, work orders are centrally issued that "push" the material forward towards the customer end.

Thus, the key differences are twofold: (1) what triggers the replenishment, and (2) what information the "schedule" is based on.

(ii) What is the role of inventory in a pull-scheduled production system?

 (TURN OVER

Answer (10%):

In a "pull" system, inventory buffers are needed to convey the pull signal from a downstream process to an upstream process. Essentially the process needs some small buffers "to pull from", in order to convey the replenishment signal upstream. A kanban supermarket is a typical example of inventory in a pull system.

(iii) What is the role of inventory in a push-scheduled production system?

Answer (10%):

In a "push" system, production is scheduled according to a Master Production Schedule (MPS). The MPS generally is a combination of actual orders and forecast orders, thus the main function of inventory in a push system is to buffer against any forecast errors.

Also, as production orders are based on fixed lead-times, WIP inventory between processes exists as actual lead-times will vary from those set in the planning system.

(c) Discuss the key wastes which lean production seeks to address. Illustrate with examples of each. [20%]

Answer (20%):

Taichi Ohno's 7 key forms of waste are:

- Transportation - unnecessary movement of goods during distribution/handling within the factory.
- Inventory - excess inventory a cause of inefficiency and unnecessary costs.
- Motion - unnecessary material handling, product flow, distances and labour movements.
- Waiting - delays and waiting - direct wastes of time and labour/efficiency costs.
- Overproduction - finished goods inventory or stock that cannot be sold/is not demanded.
- Over processing - putting material through unnecessary steps without optimising flow or layout.
- Defects - which waste time, reduce OEE and increase quality problems.

With the rise of the service industry, these may sometimes be extended to include customer time wasted, office space (heating, water, insurance) waste and wasted potential of workers. Such factors may have some relevance to the manufacturing sector too.

(cont.

(d) Discuss whether a Just-In-Time (JIT) system can perform better than an MRP system when demand has a trend and is seasonal. [10%]

Answer (10%):

A JIT system does not cope well with changes/variation in the demand, so is not very effective when demand is seasonal.

What about for a trend, as distinct to seasonal? If trend is stable may not be the case.

Also, is seasonal the same as variation? Variability kills JIT, seasonality may be able to use JIT to manage inputs, and stockpile finished goods inventory.

(e) Indicate whether the following statements are true or false. Provide reasons for your answers. [20%]

(i) Assume that the demand is deterministic, time-varying, and the variability of demand between periods is high. In such a setting, use of a fixed economic order quantity, EOQ, based on the average demand during the planning horizon would be effective.

(ii) Strategies like everyday low pricing to eliminate forward buying of bulk orders can cause the bullwhip effect.

(iii) The actual capacity of a system is equal to its theoretical capacity.

Answer (20%):

(i) False. EOQ has some rigid assumptions. It assumes demand is constant and steady, and continues indefinitely. Therefore, in the described setting EOQ will lead to high inventory and stockout costs.

(ii) False. Such strategies eliminate order batching and decrease variability of orders; therefore they curb bullwhip effect.

(iii) False. The theoretical capacity of an operation is the maximum level of value added activity over a period of time that the process can achieve under normal operating conditions. The theoretical capacity of a manufacturing line is the maximum possible output rate according to the design of the equipment – defined by the slowest task or process in the line. Actual capacity is less than theoretical capacity due to a number of reasons:

- When capacity is not balanced the capacity is limited by the bottleneck stage/equipment/process.
- Set up delays – set up times for machines limit the throughput of the machine. Increasing batch sizes can improve this but has other implications hence need

to be traded off.
• Defects – product quality need to be managed
• Breakdown of equipment
• Coordination of product flows will limit capacity in a production line
• Theoretical capacity does not consider variability involved in production times
• Supply shortages

END OF PAPER