Manufacturing Engineering Tripos Part 1, 2010 – Paper 3 CRIB

3P4 Operations Management

1 (a) Describe three approaches for managing capacity under variations in demand in the intermediate term. Under what circumstances should a plant manager use each of these approaches?

There are three options available for coping with variations in demand:

- Level capacity plan: processing capacity is set at a uniform level throughout the planning period, regardless of the fluctuations in forecast demand.
    - Capacity at uniform level throughout the planning period
    - Same number of staff operate the same processes
    - Finished goods transferred to inventory in anticipation of sales at later time
    - Suitable for non-perishable goods
    - Advantages:
        - Stable employment patterns
        - High process utilisation
        - High productivity with low unit costs
    - Disadvantages:
        - Considerable inventory costs
        - Decision-making: what to produce for inventory vs immediate sale
        - High over/under utilisation levels for service operations
- Chase demand plan: attempts to match capacity closely to the varying levels of forecast demand.
    - Common methods
        - Overtime and idle time
        - Varying the size of the workforce (hire and fire)
        - Using part-time staff
        - Subcontracting
    - Trade-offs
        - Inventory cost vs. cost of changing capacity
        - Flexibility vs. quality
        - Customer satisfaction vs. Employee satisfaction
- Demand management: change demand to suit capacity
    - Using price as a controlling mechanism
        - Increase price to reduce demand (high fashion)
        - Reduce price to increase demand (food near expiry)
    - Introduce counter-cyclical product

Examiner's note: Most candidates exhibited a good understanding of the different methods. The weaker responses focussed only on managing capacity, and did not mention anything about demand management. There was also a distinct lack of examples in most responses.

(b) The initial feasible solution of the problem by North-West corner rule is as follows:

	A	B	C	Available
1	6 6	8 8	4	14
2	4	9 2	3 10	12
3	1	2	6 5	5
Required	6	10	15	31

The corresponding cost is 6x6+8x8+2x9+10x3+5x6 = 178

Improvement potentials for each empty cell here are:

C1 = 2; A2 = -3; A3 = -9; B3 = -10.

Iteration 1:

We can improve the solution by shifting 2 units to B3

	A	B	C	Available
1	6 6	8 8	4	14
2	4	9	3 12	12
3	1	2 2	6 3	5
Required	6	10	15	31

The corresponding cost is 6x6+8x8+2x2+12x3+3x6 = 158

Improvement potentials for each empty cell here are:

C1 = -8; A2 = 7; A3 = 1; B2 = 10.

Iteration 2:

We can improve the solution by shifting 3 units to C1

	A	B	C	Available
1	6 6	8 5	4 3	14
2	4	9	3 12	12
3	1	2 5	6	5
Required	6	10	15	31

The corresponding cost is 6x6+8x5+4x3+12x3+2x5 = 134

Improvement potentials for each empty cell here are:

A2 = -1; B2 = 2; A3 = 1; C3 = 8.

Iteration 3:

We can improve the solution by shifting 6 units to A2

	A	B	C	Available
1	6	8 5	4 9	14
2	4 6	9	3 6	12
3	1	2 5	6	5
Required	6	10	15	31

The corresponding cost is 8x5+4x9+6x3+2x5+6x4 = 128

Improvement potentials for each empty cell here are:

A1 = 1; B2 = 2; A3 = 2; C3 = 8 (No further improvements possible, and hence this is the optimal solution).

Examiner's note: Most candidates did well in this question.

(c) The key problem in using the transportation model is degeneracy. This can occur where:

- when shifting assignment to achieve improvement, more than one existing assignments goes to zero
- initial solution does not meet the n+m-1 condition

To overcome this:

- we should assign an extremely small (ε) allocation to one square

– does not affect rim conditions, but breaks the tie/makes it possible to meet m+n-1 condition. Other problems faced are unmodelled errors and mismatches in the supply and demand requiring the introduction of dummy variables to balance the calculation.

Examiners note: For full marks, candidates should explain how the epsilon allocation works, not just say this is what should be done.

2

(a) The EOQ model has been criticised due to its ‘unrealistic’ assumptions. Outline ways in which the various assumptions of EOQ are not matched by reality. To what extent is the validity of the EOQ inventory model affected by these issues?

- Assumptions of relatively stable and known demand. The EOQ model is based on the assumption of constant demand over the year, which is hardly the case in reality. Demand is rarely constant, nor is it known a year in advance.
- Holding costs are estimates. How to determine appropriate opportunity cost of holding inventory, for example? (ie, the bank rate or return on capital?). This results in the model tendering to favour large batch sizes, in particular if the holding cost is based on interest rates only (i.e. omits warehousing, obsolescence, handling and quality cost).
- Assumes only one part purchased, independent of all others. Does not consider interactions/synergies between parts sharing the same transportation equipment
- Assumes all inventory arrives in one delivery. Does not consider any supply chain implications of the batches (synchronisation with suppliers).
- Assumes no part shortages. This assumption may not be correct, particularly for purchasing commodities or industries of restricted supply.
- The cost factors for placing an order for one period are very hard to determine exactly. Estimating the cost of administrative processes is in particular very hard to quantify, as often fractions of a person’s work time need to be estimated. Therefore, the cost data the model is based on often draws on inaccurate assumptions.
- However, despite the ‘unrealistic’ assumptions the EOQ model is robust to errors in estimation of its parameters – a key advantage. Errors in annual demand, ordering costs or holding costs have to be estimated, with risk of inaccuracy. However, because of the square root in the model, it mathematically mitigates this risk resulting in the model being less sensitive to deviations from estimated cost factors. Wrong estimates only move the EOQ marginally away from the optimal position. Results from part f might be included as evidence of this robustness.
- The EOQ model is also adaptable. For example, where demand or lead time is not constant, application of the perpetual inventory model with reorder point can help minimise the costs of variability. The model can also be adapted for quantity discounts, or situations of product interdependence. These modifications help overcome departures from EOQ’s underlying assumptions.

(b)

(i) How many rolls of paperboard should you order at one time? What is the reorder point?

$$EOQ = \sqrt{\frac{2DS}{H}} == \sqrt{\frac{2*1500*75}{500*.12}} = \sqrt{\frac{225000}{60}} = \sqrt{3750} = 61.23$$

Round to nearest whole integer = 61 rolls is the EOQ

Reorder point = Annual Demand / Time unit * lead time
= 1500/50 = 30 rolls per week * 1.5 week lead time
= 45 rolls is the reorder point

(ii) What would be the change in annual cost if CPS had storage space for only 50 rolls of paperboard, and thus was forced to use an order quantity of 50?
[15%]

Current EOQ Policy:

$$\text{Total Annual Cost} = PP + S\frac{D}{Q} + \frac{Q}{2}\text{H} = 1500 * 500 + 75\frac{1500}{61} + \frac{61}{2}60$$

= 750,000 + 1844.26 + 1830

= £753,674.26

Restricted Order Quantity:

$$\text{Total Annual Cost} = PP + S\frac{D}{Q} + \frac{Q}{2}\text{H} = 1500 * 500 + 75\frac{1500}{50} + \frac{50}{2}60$$

= 750,000 + 2250+ 1500

= £753,750

Change in annual cost: = 753,750 - 753,674.26 = £75.74

(c) In a <u>fixed-order quantity system</u> (Q-system) the order quantity remains constant, but the time between orders varies, depending on the demand for items. Orders are thus event triggered when inventory decreases to a predetermined reorder point. E.g. buying eggs when 2 left.

In a <u>fixed period system</u> (P-system) the time period between orders remains constant, but the order quantity varies. Orders are thus "time triggered". Inventory is only reviewed at the end of the period, with only the amount necessary to bring total inventory up to a pre-specified target level is ordered. E.g. refilling petrol tank, refilling vending machine, buying newspaper

Major differences include:

- 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. The fixed-order quantity model has no review period

- The fixed-order quantity model is preferred for more expensive items because average inventory is lower

- 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-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-period system 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). 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.

(d) The quantity discount model takes into consideration the fact that the purchase cost of an item can vary with order size. To determine the optimal quantity to order with this model, we first calculate the EOQ for each unit cost. If the EOQs fall within their respective quantity ranges, then we select the EOQ that is associated with the lowest unit cost. Procedurally, the largest order quantity (lower unit price) is solved first; if the resulting

EOQ is valid or feasible, that is the answer. If not, the next largest order quantity (second lowest price) is derived. The total cost of this EOQ is then compared to the total cost of using the order quantity at the price break above, and the lowest total cost determines the optimal EOQ.

One practical consideration in quantity-discount problems, is that he cost reduction from volume purchases frequently makes it seem economical to order amounts larger than the EOQ. When applying the model, care should be taken to obtain a valid estimate of product obsolescence and warehousing costs.

Examiner's note: Responses to parts (a) and (c) were reasonably good. Part (b) was numerical and was very well done, with many candidates scoring full marks. Part (d) was poorly attempted by most candidates, with a majority of them clearly not exhibiting a good understanding of quantity discounts. This part was a true differentiator.

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14/06/2010

3P5 Industrial Engineering

Question 3

(a) *Define 'manufacturing strategy'. Explain why it is essential to understand the manufacturing strategy of a company before applying industrial engineering techniques to the redesign of a production system.*

Manufacturing strategy is a pattern of decisions, both structural and infrastructural, which determine the capability of a manufacturing system and specify how it will operate in order to meet a set of manufacturing objectives which have been derived from business objectives.

It is essential to understand the strategy so that we have a clear identification of the objectives of the production system that we are designing.

(b) *Describe the principles of motion economy that relate to the use of the human body.*

Use of the Human Body

1. The two hands should begin and complete their movements at the same time.

2. The two hands should not be idle at the same time except during periods of rest.

3. Motions of the arms should be symmetrical and in opposite directions and should be made simultaneously.

4. Hand and body motions should be made at the lowest classification at which it is possible to do the work satisfactorily.

5. Momentum should be employed to help the worker, but should be reduced to a minimum whenever it has to be overcome by muscular effort.

6. Continuous curved movements are to be preferred to straight-line motions involving sudden and sharp changes in direction.

7. "Ballistic' (i.e. free-swinging) movements are faster, easier and more accurate than restricted or controlled movements.

8. Rhythm is essential to the smooth and automatic performance of a repetitive operation. The work should be arranged to permit easy and natural rhythm whenever possible.

9. Work should be arranged so that eye movements are confined to a comfortable area, without the need for frequent changes of focus.

(c) *Describe the '5S' tool, and explain its use, in the context of Lean Production.*

Japanese word	English equivalent
Seiri	Sort

Seiton Set in order, simplify access

Seiso Shine, sweep, scrub

Seiketsu Standardize

Shitsuke Self-discipline, sustain

5-S is the Key to Workplace Organization. It is the first step in any improvement activity

- Removes Unnecessary Obsolescence & Clutter, Clears needed floor space
- Prepares environment for effective study
- Uncovers Waste in Process or Flow – Removes ‘Can’t see the wood for trees’
- Establishes “Action-Oriented” Pace –by involving workers ina very visible process.

(d) Why are standard times necessary in manufacturing operations?

An engineer times an operation and observes it takes 1 minute. He estimates the workers rating at 110 on the BSI scale. He assesses the fixed allowances at 10% and the variable allowances also at 10%. There are no contingencies for extra work. Calculate the standard time for the operation.

Standard times are required for:

- Production Planning
  - Capacity
  - Loading
  - Scheduling
  - Machine and operation balancing
- Costing and estimating
- Comparison of alternative methods
- Incentive and payment schemes

Std time =1*1.1*1.2= 1.32mins.

(e) Discuss the benefits of Predetermined Motion Time Systems compared to other methods of work measurement.

Advantages of Predetermined Time Standards

1. The detailed systems produce a more detailed description of the work than other methods.

2. As each basic motion is described along with its variables, so alternative methods can be readily compared using time as a criterion.

3. Methods can be developed and standards established before production operations start.

4. PTS do not require the assessment of rate of working and the use of the stop watch as is required in time study. This can remove one of the impediments to good industrial relations.

5. PTS are objective and consistent

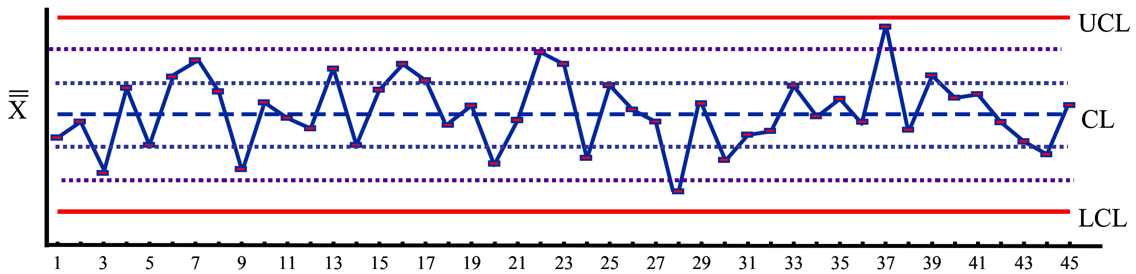
(f) *An activity sampling study is required to determine the utilisation of a crane to an accuracy of +/- 5%, with a 90% confidence. A pilot study shows the utilisation to be around 70 %. How many observations should be planned for the study.*

From the normal approximation to the binomial distribution

$$c = (z_{\alpha/2})\sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \qquad \text{hence} \qquad n = \frac{(z_{\alpha/2})^2\,\hat{p}(1-\hat{p})}{c^2}$$

p=0.7, c=0.05*0.7 z= 1.645 (for 90% conf) hence n= 464

(g) *Interpret the following control chart, explaining whether or not the process is in control. Give any recommendations for action*



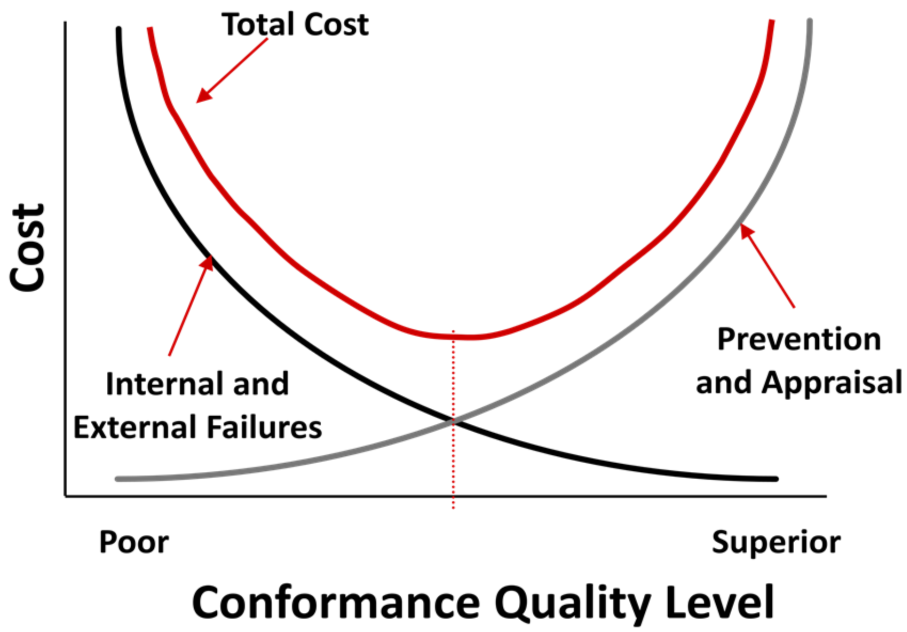
A qood answer will recognize that this chart displays normal/random variation and is therefore in control.

However, this is only the X-bar chart and to know if the process is in control you need to also examine the R chart.

Recommendation: Look at the R chart. If the R chart is in control then keep running the process as is and monitoring. If the R chart is not in control, then the range/standard deviation has changed (rather than the mean) and should be investigated

(j) *Explain Juran's Cost of Quality Model. Contrast with Taguchi's Loss to Society notion.*

A good answer will define the Cost of Quality model stating that prevention and appraisal costs can be balanced against internal and external failure costs and that there is an optimal conformance level based on that balance.



Juran's COQ is about costs to the firm and the trade-off with quality. Taguchi's Loss to Society idea is that, when there are quality problems within the firm, society also suffers. There is no trade-off and the impact of poor quality is much broader than within the firm.

Comments:
Questions on the following topics were well answered:

- Activity sampling
- 5S framework
- Standard times
-

Questions on the following topics were reasonably well answered, but with some surprisingly weak answers:

- Principles of motion economy – this showed great variation, either students knew them, and scored highly , or had only a sketchy idea and scored poorly.
- Quality control charts – weak answers forgot that you also need to monitor range to check for control
-

Questions on the following topics were poorly answered by almost all candidates:

- Manufacturing strategy
- Juran/Taguchi quality models

These both exhibited the lowest variability of answers, and gave the impression that the material had not been well learnt, perhaps candidates did not expect these areas to be tested.

4 (a) Describe the stages of 'Systematic Layout Planning' (R.Muther), clearly stating the objectives of each stage, and identifying the tools used.

(b) Discuss how ergonomic considerations of the following factors influence the design of factories:

i) The visual environment

ii) The auditory environment and noise

iii) The climate

(c) A worker operates a machine in an environment with a background noise of 88 dBA. The machine runs on a 15 minute cycle, producing an additional noise of 89dBA, for 10 minutes, and 70 dBA for 5 minutes. What is the maximum length of time the worker could operate the machine to comply with Health and Safety guidelines?

Describe 3 different approaches that could be taken to allow the worker to operate the machine for a full 8 hour shift.

a) Steps in systematic layout planning

1. Determine requirements and collect data
2. Analyze material flows
3. Define activity relationships and develop activity relationship chart
4. Construct activity relationship diagram
5. Determine space requirements
6. Construct space relationship diagram
7. Make adjustments and add allowances
8. Optimise Block Layout
9. Develop detailed layout alternatives, evaluate and detailed plan

Step 1 to get base data. Use P,Q,R,S,T – P - product - what products will be made; Q - quantity - how many of each product; R - routing - manufacturing processes through which parts and products will be routed; S - supporting services,Utilities, toilets, offices, etc.,T – times.

Step 2 Possible charting techniques to analyze material flows:

- Operation chart - shows sequence of processing, assembly, and inspection operations for products
- Flow process chart - shows processing steps and other details for parts production
- From-To chart - shows quantities and directions of material flows between departments

- Part routing matrix - shows which operations each part is routed through during production

Step 3 To indicate relative need to place activities or departments in close proximity to each other. Use Activity relationship Chart

Step 4 Visualise relationships using activity relationship diagram

Step5 Objective is to determine area requirements for each activity (department). Mulipy up from base data.

Step 6 Visualise space - extension of activity relationship diagram in which nodes representing departments are now assigned areas that are proportional to areas calculated in previous step - tool space relationship diagram.

Step 7 Adjustments to cover things such as:

- Personnel requirements - toilets, locker rooms, canteen, plant entrances and exits
- Material handling methods - may affect floor space and building height
- Storage facilities - add allowance
- Gangways - add allowance
- Offices - for individual departments
- Building features - walls, column locations
- Site conditions - parking, landscaping

Step 8 and 9 To develop and evaluate possible alternative layouts. Use for example adjacency score.

b)Visual - need to ensure the correct levels of illumination for the task

need to consider contrast and glare, aim max 10:1 contrast ratio to avoid glare

implications for location of departments, eg on outside walls, and for lighting systems installed.

Auditory

Need to ensure that background noise is as low as possible and that background noise plus operation noise does not contravene Noise at Work act 2006, max 85dBA for 8 hour exposure. Must provide ear protection for all who want it above 80dBA.

Implications for siting of noisy operations and for sound insulation if required.

Climate

Need to maintain comfortable temp and humidity.

- Air temperature = 19 to 26°C (66 to 79°F)
- Relative humidity = 50%

– Slow air movement = 0.2 m/s (0.64 ft/sec)

Also minimize heat gain from radiation.

Implications for heating and cooling systems, and for direction and style of windows. (North light factory)

c) SPL average= 10 log10{1/To ∑Ti($10^{0.1SPLi}$)} Ti is the time at SPLi and To is 8 hours

Subs values, antilog and rearrange

$8*10^{8.5} = 2T\ 10^{8.3}$

$T = 4*10^{8.5-8.3} = 6.34$ hours

Three approaches

1) reduce noise at source – identify and address vibrations, add damping etc.
2) provide barrier to noise – between the noise source and the operator, eg machine enclosure
3) Supply personal hearing protection

Comment

This was a good question with high discrimination. Most candidates were able to answer part a) reasonably well. Part b) was, on the whole, less well answered. Part c) provided the best discrimination with most candidates scoring either very high or very low marks, depending on whether they were able to successfully perform the noise calculation.

In part c) The final answer depends on the assumptions made. The crib answer assumes that when not working the machine, the operator leaves the workplace. Some students assumed that the worker stays in the workplace subject to a noise level of 83 dBA, this gives a shorter operating time for the machine of 4.7 hours . Both approaches were equally acceptable and if done correctly gained full marks

K.W. Platts, June 2010