Met 2a, Paper 3

2015

Crib

Section A

Q1

(a)

(i)

Production capacity: The 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 [Slack] i.e. How much can the factory make! Examples of production capacity are:

Air-conditioner plant – Number of units per week (output)

Brewery – Litres of beer produced per month (output)

Steel Mill – tonnes per hour (output)

Electricity company – Megawatts of electricity generated (output)

Capacity Planning: is the process of determining the production capacity needed by an organization to meet changing demands for its products. Often there are three types of Capacity planning: Long, medium and short term

(ii) The following issues were discussed in some detail in lectures and students could chose any five of these and discuss accordingly:

FACTOR	APPROACH to MANAGING
Bottlenecks - and more generally imbalances in task times	Line balancing
Setup/Switchover delays	Introduce SMED practices
Breakdowns	Introduce regular machine maintenance – e.g. TPM
Line / Machine Idle Time	May not always affect capacity. Re balance line. Find other products that can use idle reources
Quality problems	Root cause analysis
Variability in process times causing a build up of inventory	Systematize production practices including manual handling operations
Unplanned downtime	Address causes of downtime. Develop procedures to make

	operation more robust to these causes
Variability in raw material arrivals	Tighten supplier programme. Increase RM stock levels
Variability in order arrivals	Forecast. Work with customers to balance order profile.

Impact on production capacity will always be downward. Some of the factors listed above are predictable/unpredictable, frequent/infrequent, significant/insignificant, controllable/uncontrollable. The approach to managing will depend on these type of factors. Good responses will discuss these issues.

(b)

(i)

In the following calculation it is assumed that there was one person setting up each type of machine – hence the same person would be needed to set up the three machines of Type C in Option B [and similarly Type D]. (Other variations will be permitted in the marking which could include a) a different person available to set up every single machine meaning that all machine set up can be done in parallel Or b) a single person available to set up machines of Type A, B and another for Type C,D.

Option		Machine	Process Time	Set up Time	no Machines
	1	A	6	1500	1
		B	8	1000	1
	2	C	30	50	3
		D	60	20	3

On this basis the capacity calculation is as in table:

Batch Size	100	1000
Option 1		
Total time on A (set up + no of prods x process time)	2100	7500
Total time on B	1800	9000
Longer Time	2100	9000
Ave Time / Prod	21	9
Daily Capacity (seconds avail / ave time	1371	3200
Option 2		
Total time on C	1150	10150
Total time on D	2060	20060

Longer Time	2060	20060
Ave Time / Prod	20.6	20.06
Daily Capacity	1398	1435

Hence for a batch size of 100, Option 2 would be preferred and for a batch size of 1000 Option 1 would be preferred.

(ii)

For the same assumptions as above, the utilisation calculation is as in table:

Batch Size	100	1000
Option 1		
Total process time on A	600	6000
% utilisation A (=proc time on A / longer time A,B x 100)	29	67
Total process time on B	800	8000
% utilisation B	38	89
Option 2		
Total process time on C	1000	10000
% utilisation C	49	50
Total process time on D	2000	20000
% utilisation D	97	100

The results differ in the two cases because of the different number of items per batch and the ratio of set up time to processing time in each case. Although it appears that Option 2 is better utilising the machines – because of shorter set up times – this may not be a useful measure on its own as the productivity for Option 2 would be lower as batch sizes rise.

(iii)

Generally, variation in processing times leads to higher levels of work in progress, longer average cycle times, and hence reduced capacity and utilisation. This is because a shorter than expected processing time may lead to a period of waiting for the next job to arrive – time which can't be recovered later. Systems with predictable degrees of variability can have compensation designed into them through managed levels of inventory. In this case, option 1 is more vulnerable than option 2 – assuming that all machines have similar variability. Having four machines in option 2 will lead to an averaging out of the variability, so the variability of the cluster of machines will be less than that of the single machine in option 1. Thus, although option 1 has higher capacity at both batch sizes, as calculated in part a, this capacity will be reduced more substantially by process time variability than for option 2, and the two systems will become more similar.

Examiners Comments

Mean 64%

This question related to capacity planning and machine utilisation in production. Part a) relating to some key concepts in capacity planning was generally answered well with students able to provide examples to support their interpretations. Students also did well at identifying different factors that reduce theoretical capacity.

In Section b) part i) Many candidates struggled with understanding that in either production option the machines in each of the pairs (A - B) or (3Cs - 3Ds) would usually be running at the same time and this affected their responses - students were not penalised for different assumptions. Consequently there were some different answers for b)iii). Machine utilisation was generally calculated well and students were thus were able to comment on the relatively utilisations in each of the production options.

Q2

a)

(i)

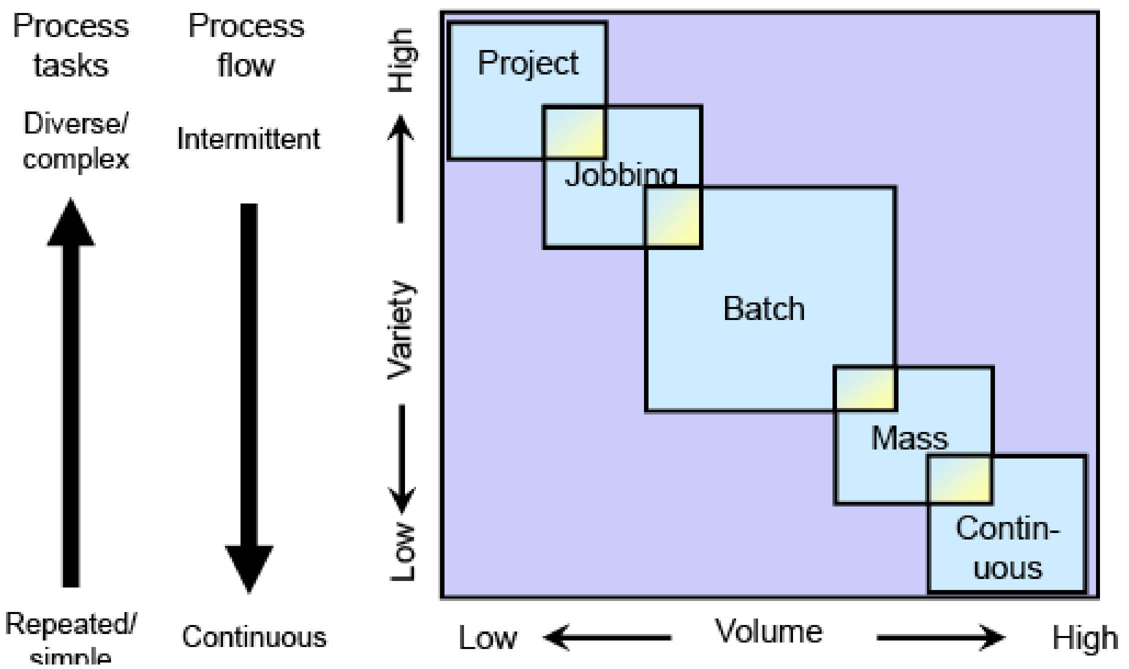
A job shop is an operation that is capable of producing a wide variety of products but in small batch sizes. Example of job shops include machine shops, bakeries, printers and aerospace companies.

(ii)

Different operational configurations vary on the basis of:

- Volume
- Variety
- Workers skills
- Equipment flexibility
- Layout
- Etc.

Volume and variety are typically the prime differentiators:



Job shops hence require significantly more effort for sequencing and scheduling jobs than mass production for example. Assignment of labour will be dependent on the work load and there will be a significant need for load balancing of both labour and equipment.

(iii) Possible examples of job shop scheduling from outside of manufacturing include

- (CPU) Processor scheduling
- Airport gate scheduling
- Repair crew scheduling
- Elective surgery scheduling

The key features needed are high variety, reasonably low volumes, flexibility of equipment for dealing with multiple order types.

(b)

(i)

All jobs that are processed on or before their due date make a full £1000 contribution to profit. Additional jobs that will be late should be accepted and scheduled provided that they make a net contribution to the total profit.

Moore's Algorithm would be used if we solely wanted to minimise the number of late jobs. However given that we can have some lateness the **Modified Due Date** heuristic should be used for this problem.

The jobs are reordered here by due date (NB this is not essential)

Job	D	A	C	B	F	E
Processing time (days)	3	1	2	5	4	2
Due date (days hence)	6	7	7	8	9	10

Chose jobs with the lowest MDD = $\max(d_i, t+p_i)$

At t=0

Job	D	A	C	B	F	E
Processing time (p)	3	1	2	5	4	2
Due date (d)	6	7	7	8	9	10
MDD	6	7	7	8	9	10

D has the smallest MDD and completes at t=3.

At t=3

Job	D	A	C	B	F	E
Processing time (p)	3	1	2	5	4	2
t+p		4	5	8	7	5
Due date (d)	6	7	7	8	9	10
MDD	X	7	7	8	9	10

A has the smallest MDD and completes at t=4.
MDD schedule now D_3A_4

At t=4

Job	D	A	C	B	F	E
Processing time (p)	3	1	2	5	4	2
t+p			6	9	8	6
Due date (d)	6	7	7	8	9	10
MDD	X	X	7	9	9	10

C has the smallest MDD and completes at t=6.
MDD schedule now $D_3A_4C_6$

At t=6

Job	D	A	C	B	F	E
Processing time (p)	3	1	2	5	4	2
t+p				11	10	8
Due date (d)	6	7	7	8	9	10
MDD	X	X	X	11	10	10

Take E rather than F as it has the shortest processing time. Completes at t=8
MDD schedule now $D_3A_4C_6E_8$

At t=8

Job	D	A	C	B	F	E
Processing time (p)	3	1	2	5	4	2
t+p				13	12	8
Due date (d)	6	7	7	8	9	10
MDD	X	X	X	13	12	X

F has the smallest MDD so the final MDD schedule is $D_3A_4C_6E_8F_{12}B_{17}$

Now considering lateness and profit for the MDD schedule

Job	D	A	C	E	F	B
Processing time	3	1	2	2	4	5
Due date	6	7	7	10	9	8
Completion date	3	4	5	8	12	17
Lateness	n/a	n/a	n/a	n/a	3	9
Profit contribution	£1000	£1000	£1000	£1000	-£500	-£3500

So accept DACE and process them in that order

(ii)

Jobs DACE will always be profitable with this schedule
Job F will be profitable if the reduction in profit drops to less than £1000/3 per day
Job B will be profitable if the reduction in profit drops to less than £1000/9 per day

So, in summary

Reduction in profit/ job/day	Accept and schedule
> £333	DACE
£111-333	DACEF
<£111	DACEFB

(iii)

With no penalties at all the schedule should could be generated using

Shortest Processing Time Rule i.e. ACEDFB

NB. C and E have the same processing time so the job with the earliest due date is scheduled first

Job	A	C	E	B	F	B
Processing time (days)	1	2	2	3	4	5

There are no penalties for lateness so only the processing time needs to be considered.

Using the SPT Rule:

- Increases revenue/ speeds up collection
- Reduced WIP inventory and therefore inventory costs

Examiners Comments

Mean *67%*

Overall this question was answered very well.

In this question, Part a) was answered moderately effectively. This part related to some general issues in job shop scheduling and ask candidates to consider both manufacturing and non manufacturing applications of job shop scheduling.

Section b) then required to perform a scheduling task for a job shop for a set of orders and dues dates. The best candidates generally distinguished themselves with strong answers in this section, identifying the items that could be profitably scheduled and then providing an acceptable scheduling approach and production sequence. Some candidates misread the question and thought that there would be no benefit at all for late jobs, and consequently b)ii) was often poorly answered.

Section B

Q3

(a)

The basic principles are consideration for the use of the human body, design of the workplace and design of tools and equipment. The good practices can be chosen from the list below:

- Use of the Human Body
    - Both hands should start and stop work at the same time
    - Motions of the arms should be symmetrical and in opposite direction
    - Hand and body motions should be minimized.
    - Momentum should be employed to help the worker
    - Continuous curved movements are better than straight line movements
    - Ballistic or free swinging movements are easier than controlled movements
    - Rhythm is essential to smooth performance of repetitive operations.
    - The work should be arranges to provide easy and natural rhythm where possible
    - Work should be arranged so that eye movements are confined to a comfortable area, without the need for frequent changes of focus
- Arrangement of the workplace
    - Definite and fixed stations should be provided for all tools and materials
    - Gravity feed, bins and containers should be used to deliver the materials as close to the point of use as possible
    - Materials and tools should be arranged to permit the best sequence of motion and placed in the reachable area
    - Drop deliveries or ejectors should be used wherever possible so the operator does not have to use his hands or feed to dispose of finished work
    - Provision should be made for adequate lighting and the colour of the workplace should contrast with the work
    - A chair of suitable height should be provided and the workplace should be arranged to allow alternate sitting and standing.
- Design of tools and Equipment
    - The hands should be relieved of holding work where this can be done by a jig fixture or foot operated device

- Two or more tools should be combined where possible
- Where each finger performs some specific movement such as typewriting the load should be distributed in accordance with the inherent capacities of the fingers
- Handles should be designed so that as much of the hand as possible comes into contact with the handle
- Levers, crossbars and hand-wheels should be placed so that the operator can use them with the least possible change in body position and to maximize mechanical advantage.

(b)

Lack of attention is usually caused by boredom, causal factors include:

- Short Cycle times
- Low requirements for body movement
- Warm Environment
- Lack of contact with other workers
- Low motivation
- Low lighting levels in the workplace

Factors to overcome them can include rotating the operators between different tasks, good ventilation, building in a periodic task to move away from the line, depending on the type of work positioning operators so that they can have conversations, motivation and incentive schemes including performance measurement and building in competition between groups.

(c)

Illuminance decreases with distance from the light source:

$$E = I/d^2$$

Where E = illuminance, l = luminous intensity and d = distance.
Therefore if one light has a luminous intensity of l
Currently E = 50l/25 if the height is reduced to 3 metres then E = xl/9
Therefore x = 9 x 50/25 = 18

The advantages would be a reduction in the energy consumption, the cost of light fittings and replacement costs of bulbs, the ease of changing bulbs. The disadvantages would be that the light distribution would be more uneven and the positioning would be more critical, the radiant heat given off by the lights would be more noticeable to the operators and lights would be more vulnerable to damage from collisions with goods being moved around.

(d)

TPM is a method for continuously improving the effectiveness of production equipment and processes. It aims to achieve 100% on-demand equipment availability by eliminating:

- Equipment Breakdowns and other unplanned downtime
- Scrap and rework by poor equipment performance
- Reduced productivity due to running at reduced speeds, idling or stoppages requiring operator attention
- Equipment startup losses

It have potential benefits through increased uptime which gives greater capacity and since the unit manning can either remain the same or be reduced it gives greater productivity. Reducing stoppages allows less buffer inventory to be held and reducing the number of starts and stops reduces the amount of waste. The overall effect should be an lower operating costs and therefore an increase in profitability. It addition TPM programmes can be used to improve operator motivation and to introduce an attitude that values continuous improvement.

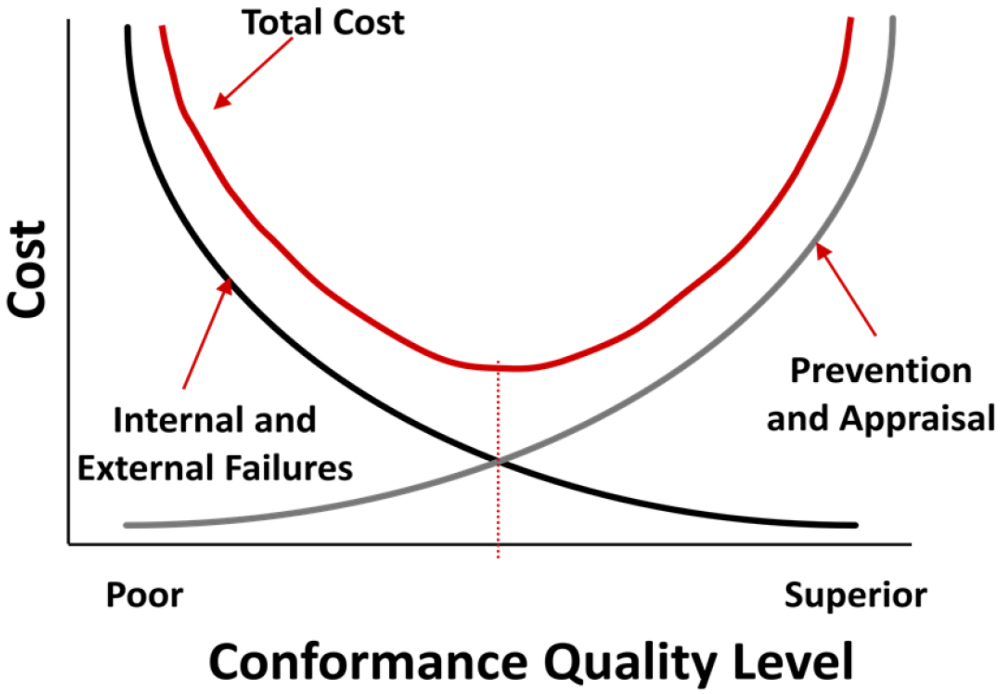
(e)

A good answer will define Juran's 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.

This results in the idea of an Acceptable Quality Level (AQL) which is defined by maximizing the financial return to manufacturer.

In contrast Phillip Crosby states that the target should be to produce no defects (the Zero Defect) philosophy. He acknowledges that this may be impossible in some situations but should still remain the long term goal even if intermediate targets have to be introduced. Crosby's financial quality targets are the Price of Non Conformance (PONC) which should be eliminated if Zero Defects is achieved and Price of

Conformance (POC) which can be reduced after Zero Defects has been achieved.



(f)

The DMAIC technique has the following steps:

- Define – Problem Definition
  - Identify Project critical to business parameters (CTBs')
  - Develop Team Charter
  - Define Process Map
- Measure – What is the frequency of defects?
  - Select CTB characteristic
  - Validate Measurement System
  - Establish Process Capability
- Analyse – When, where and why do defects occur?
  - Define performance objective
  - Identify sources of variation
- Improve – How can we improve the process?

- Screen potential causes
    - Discover variable relationships
    - Establish operating tolerances
- Control – How can we maintain the improvement?
    - Validate measurement system
    - Determine process capability
    - Implement process controls

Six sigma has methodological and organisational limitations. From the methodological perspective it encourages the application of basic generic statistical techniques to a wide range of contexts without considering the contextual fit. For example the normal distribution is a basic assumption in the methodology, other distributions occur in practice. The concept of parts per million failure rates is only relevant to high volume situations. The organizational limitations include the time/cost to gather large amounts of clean data, the problem of focusing on optimizing a single element of the system rather than optimizing the system as a whole.

Examiners Comments

Mean 62%

This question related to method study and quality management improvement techniques. Parts a-b) covered basic method study concepts and was in general answered well with a small number of mis-apprehensions in how to alleviate worker lack of attention. Part c) was answered well both numerically but also with some advantages and disadvantages of light positioning being identified.

In Part d) which covers Total Productive Maintenance some candidates got confused with preventative maintenance rather than TPM as an improvement methodology. Other candidates just wrote somewhat randomly about maintenance in general.

In the quality parts e & f) most candidates could identify the different philosophical positions of Juran and Crosby but were reluctant to compare and contrast them. The part discussing Six Sigma techniques was not well answered with candidates tending to list rather than discuss the steps, and when discussed just use generalised explanations of the terms rather than specifically related to Six Sigma.

Q4

(a)

Time study may be required for:

- Production planning
    - Capacity
    - Loading

- o Scheduling
- o Machine and Operation Balancing

- o Costing and Estimating
- o Comparison of alternative methods
- o Incentive and payment schemes

(b)

(i)

For the engineers study since it is a small sample the student t distribution should be used. The formula for the 95% confidence limits is:

$$\bar{x} \pm \frac{t_{n-1}^{1-\alpha/2} s}{\sqrt{n}}$$

Mean = 50.72 Std Dev 2.99

For 4 degrees of freedom and α = 0.05 from the tables of student t distribution t = 2.776

95% confidence interval is 50.72 ± 2.776 (2.99)/√5 = 50.72 ± 3.71

The 95% confidence interval is 47.01 to 54.43

(ii)

For the foremans study the sample size is large enough to use the normal distribution. From the Cumulative normal distribution function table the u value for 1- α/2= .975 is 1.96 therefore the 95% confidence interval is √(((1.96^2 * .745 * (1- .745))/400 = 0.042

95% confidence limits for the proportion of productive vs. non productive are .703 to .787.

The TAKT time for the worker is (70 x 60 x 60)/3400 = 74.12 secs. If the worker is productive for 298/400 of the time the mean assembly time for the product is .745 x 74.12 = 55.2 secs.

Applying the confidence limits to the proportion of productive time to predict the assembly times suggests the 95% confidence interval times are :

74.12 x 0.703 = 52.11 secs
74.12 x 0.787 = 58.33 secs

(c)

The Learning Curve is the reduction in cycle time that occurs in a repetitive work activity as the number of cycles increases. At first the learning effect is rapid and the cycle time decreases significantly but as more and more cycles are completed the reduction in cycle time becomes less and less. The importance of this in production is that when introducing a new product the rate of production will be slower that predicted by MTS, when studying a job it is important to know whether the learning curve effect needs to be taken into account and when introducing a new worker to a process allowance will have to be made for their learning.

Individual Sources of Learning

- Practice – Worker becomes familiar with the task
- Worker makes fewer mistakes
- Hand and body movements become more efficient
- Minor adjustments in workplace layout
- Coaching and feedback

The steps taken depend on the complexity of the task and the quality requirements of the output. For examples for a expensive and complex part it may be worthwhile to practice on scrap parts and off-line until a certain skill level is achieved. Certainly extra surveillance and quality inspection should be provided in the early stages. Personalising the workplace to the body size parameters of the individual will help. Coaching and feedback will be useful but should be in a measurement framework so the operator can see how they are improving and how near the target they are.

Group

- Bringing new members into the group
- Method improvements
- Fine tuning of machinery and tooling
- Development of special tooling
- Technological improvements
- Product design improvements
- Leadership and better motivation of workers.

Group learning can be improved by bringing the operators together to discuss methods and to involve them in performance improvements. This can take the form of pre-shift briefings, problem resolution meeting or formal improvement activities such as Kaizen blitz.

(d)

Systematic Layout Planning as developed by Richard Muther is an appropriate techniques and comprises a 9 step process. However the important issue is to recognize the activities rather than the specific framework.

Step 1 – Identify the requirements and data sources – the products, number and variety of of, to be produced, the manufacturing processes required and the details of the supply network for inbound and outbound logistics.

Step 2 Analyse Material flows using charting techniques such as operations charts, flow process charts, from/to charts.

Step 3 – Activity relationships - define the need for activities to be close to each using parameters such as: shared equipment, supervision, need for high levels of ventilation, etc.

Step 4 Activity Relationship chart - graphical representations that allows analysts to optimize which activities need to be located near to each other

Step 5 Space Requirement – Taking the production process and volume data derive the number of workstations and their physical footprint.

Step 6 Space Relationship - Extension of the activity relationship diagram that sizes the blocks in proportion to the space requirements

Step 7 Adjustments and Allowances – This adds in the site specifics such as heavy power availability, potential for mezzanine space etc and overhead space such as gangways and offices.

Steps 8 & 9 – Develop and evaluate different design proposals based on the space relationship diagrams, optimizing and selecting the best.

Other important factors that may be included are cellular versus flow layouts, the use of computer packages to layout and/or simulate the proposed layout. Provision of floor space and its impact on the level of inventory held.

Examiners Comments

Mean 62%

This question covered work study and factory layout.

Part a) was reasonably well covered with the candidates being able to identify a good range of reasons for time study, weaker candidates preferred to list rather than discuss.

Part b) was a numerical to compare a small sample study using the t-test with a larger number of observations using a normal distribution. There were a number of numerical mistakes in the candidates working but these were only penalised once. Generally the candidates showed a good grasp of this with the major error being confusing the TAKT time with the assembly time in the mass observation part of the study.

Part c) was answered well with many of the candidates reproducing the learning curve with its mathematical formula as well as correctly identifying steps to improve learning.

Part d) suffered from being the last part of the paper and a number of candidates ran out of time or gave superficial answers. The majority of the candidates appeared to have memorised the SLP framework very well and describe it at various levels of detail.