2013 Manufacturing Engineering Tripos Part IIA
Paper 3: Operations Management (3P4) & Industrial Engineering (3P5)
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SECTION A (3P4)

1. 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.

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

[30%]

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.

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

(c) A common perception in service firms is that service processes should be as responsive as possible to meet specific customer requirements. To what extent do you agree or disagree with this statement? Discuss.

[25%]

Here students should refer to the Service-Process Matrix to argue that the volume of a service process also determines its variety. While a high degree of responsiveness to customer needs may indeed be needed/applicable for the low-volume/high interaction processes, for higher volume processes this would lead to an overinvestment in flexibility, and thus increased cost. Hence offering a high degree of responsiveness to customer requirements for

(d) It has been argued that internal company, or "overhead" processes, such as accounting or human resources are also service processes, and should be treated as such. Do you agree? Discuss.

[25%]

In principle it is correct to argue that overhead processes are also service processes. The key distinction is that these processes serve internal customers, and as such there is no "market" for these. Without any external reference or competition it is thus very hard to measure the performance of these processes, and to improve them in relation to a benchmark.

2 (a) Manufacturing Requirements Planning provides a means for scheduling the ordering of raw materials and parts.

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

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

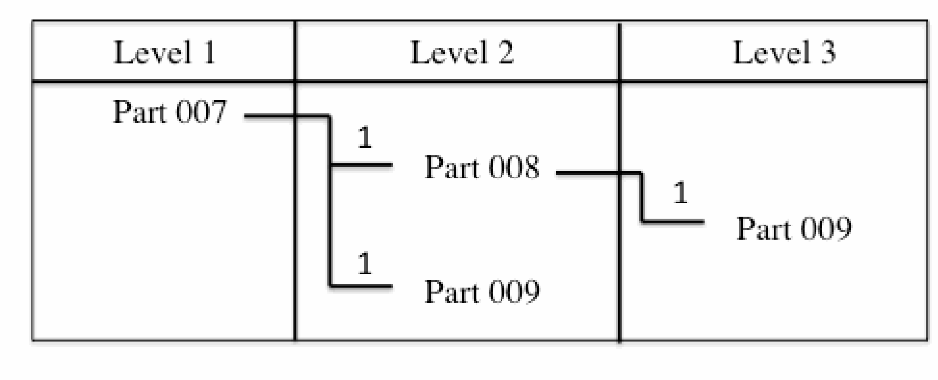
[20 %]

(i) 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) 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) Part of the Bill of Materials for a vacuum coating machine includes the following structure:



The following ordering details are known about each part:

- *Part 007 has a lead time of 2 weeks and a Minimum Order Quantity of 50.*
- *Part 008 has a lead time of 1 week and Economic Order Quantity of 65.*
- *Part 009 has a lead time of 2 weeks and a fixed order period of 3 weeks i.e. there is always 3 weeks between orders.*

The gross requirements for part 007 over the following 10 weeks are:

Week	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Number of parts	*40*		*30*	*60*		*20*	*80*		*70*	*30*

There are scheduled receipts in week 1 of 50 of Part 007, 65 of Part 008 and 165 of Part 009.

Construct the MRP records for all three parts over the ten week planning horizon. *[50 %]*

(b) A typical MRP calculation for the system outlined is given below. There might be minor variants if students chose to use an approach from one of the course text books rather than that described in lectures but the outcomes are the same.

Part 007		1	2	3	4	5	6	7	8	9	10
	Gross requirements	40		30	60		20	80		70	30
LT=2	Scheduled Receipts	50									
MOQ=50	Projected available balance	10	10	30	20	20	0	0	0	0	20
	Planned order release	50	50			80		70	50		
Part 008		1	2	3	4	5	6	7	8	9	10
	Gross requirements	50	50			80		70	50		
LT=1	Scheduled Receipts	65									
EOQ=65	Projected available balance	15	30	30	30	15	15	10	25		
	Planned order release	65			65		65	65			
Part 009		1	2	3	4	5	6	7	8	9	10
	Gross requirements	115	50		65	80	65	135	50		
LT=2	Scheduled Receipts	165									
Fixed order period=3	Projected available balance	50	0	0	145	65	0	50	0		
	Planned order release		210			185					

(c) (i) Discuss the limitations of MRP.

(ii) Describe what is meant by closed-loop MRP, and discuss to what extent it addresses some or all of the limitations you have identified?

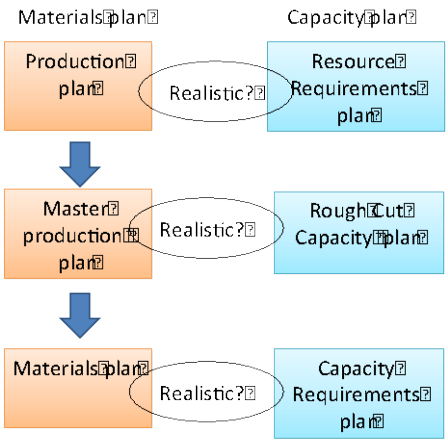
[30 %]

i) Limitations of MRP

- It takes no account of available machine/production capacity
- It has no feedback - having issued the plan, it assumes that this will work. This can be countered by re-calculating the schedule often to account for the current position

- The accuracy of the data provided, including sales forecasting data, cannot be guaranteed. Keeping accurate records of inventory - both stock and in-process is notoriously difficult.
- Any delay in any component prior to an assembly operation will prevent completion of assembly - so shortages always deny the master production schedule.
- …. MRP pushes production – production is not triggered by specific orders

(ii) closed loop MRP attempts to apply corrections to the standard MRP calculation to enable checks against long, medium and short term capacity plans.



SECTION B (3P5)

3 (a) Outline the systematic questioning technique used in method study to critically assess manufacturing operations. Explain the rationale behind the questions. [15%]

The systematic questioning technique is as follows:
Each activity is assessed for
the PURPOSE for which the activity is undertaken
the PLACE at which the activity is undertaken
the SEQUENCE in which the activity is undertaken
the PERSON by whom the activity is undertaken
the MEANS by which the activity is undertaken

The rationale is to pursue the options of ELIMINATING, COMBINING, REARRANGING or SIMPLIFYING those activities
Hence
Query PURPOSE with the initial view of elimination
What is actually done, what is achieved? Why is the activity necessary at all?

Query PLACE, SEQUENCE and PERSON with the view of combining or rearranging:
Where is it being done? Why is it done at that particular place?
When is it done? Why is it done at that particular time?
Who is doing it? Why is it done by that particular person?

Query MEANS with a view to simplifying
How is it being done? Why is it being done in that particular way?

A second stage of questioning then inquires:
What else might be done? And, hence: **What** should be done?
Where else might it be done? **Where** should it be done?
When might it be done? **When** should it be done?
Who else might do it ? **Who** should do it ?
How else might it be done? **How** should it be done?

Examiners Comment: Generally well done by those that answered the question asked, however many students instead described all the steps of method study.

(b) Describe the principles of motion economy that relate to the Arrangement of the Workplace
[15%]

1. Definite and fixed stations should be provided for all tools and materials to permit habit formation.
2. Tools and materials should be pre-positioned to reduce searching.

3. Gravity feed, bins and containers should be used to deliver the materials as close to the point of use as possible.
4. Tools, materials and controls should be located within the maximum working area and as near to the worker as possible.
5. Materials and tools should be arranged to permit the best sequence of motion
6. "Drop deliveries" or ejectors should be used wherever possible, so that the operative does not have to use his hands to dispose of the finished work.
7. A chair of the type and height to permit good posture should be provided.The height of the workplace and seat should be arranged to allow alternate standing and sitting.
8. Provision should be made for adequate lighting The colour of the workplace should contrast with that of the work and thus reduce eye fatigue.

Examiners Comment: Reasonably well answered by most, but several talked about principles relating to 'Use of the human body' rather than design of the workplace. Read the question carefully and answer what is asked!

(c) In the context of manual work, discuss the difference between static and dynamic muscular activity, describe the physiological effects and give examples of each. *[10%]*

	Static muscular activity	Dynamic muscular activity
Description	Sustained contraction	Rhythmic contraction and relaxation
Examples	Holding a part in a static position Squeezing a pair of pliers	Cranking a pump handle Turning a screwdriver
Physiological effect	Reduced blood flow to tissue restricts oxygen supply and waste removal. Lactic acid is generated. Metabolism is anaerobic.	Adequate blood flow allows oxygen supply and waste removal needs to be satisfied. Metabolism is aerobic.

Examiners Comment: Description and examples well covered, few students knew the physiological effect well.

(d) A worker is exposed to two coexisting sources of noise, one at 81 dBA and the other at 84 dBA. What is the maximum length of exposure to this, to avoid exceeding an eight hour average of 85dBA?

$SPL_{tot} = 10 \log_{10}(10^{8..1} + 10^{8.4}) = 10 \log_{10}(125892541 + 251188643)$
$SPL_{tot} = 10 \log_{10}(377081185) = 85.764$ dBA
Time permissable (T) $8*10^{8.5} = T\ 10^{8.5764}$ $T= 8*\ 10^{8.5-8.5764}$ hr = 6.71hr.

Examiners Comment: A straightforward question, well answered. 90% of students achieved full marks.

e) An engineer times an assembly operation, and observes the following:

Operation	*Observed Time(s.)*	*Observed Rating (BSI scale)*

Load components to assy fixture	*40*	*110*
Insert 10 bolts, hand tighten	*50*	*100*
Tighten to specified torque	*30*	*110*
Unload Assembly	*10*	*120*

Total allowances are 15%.

i) *Calculate the standard time for the machining activity.*

ii) *How many components would be machined in an 8 hour shift, by an operator working at 90 BSI.*

i)

Operation	Time(s.)	Rating (BSI scale)	Basic Time (s.)
Load	40	110	44
Insert	50	100	50
Tighten	30	110	33
Unload	10	120	12
Total Basic Time			139

Standard time = 139*1.15=160s.

ii) No of components produced =(8*60*60/160)*0.9 = 162

Examiners Comment: Another straightforward question, well answered.

f)*An activity sampling study is required to determine the utilisation of a crane to an accuracy of +/- 5%, with 80% confidence. A pilot study shows the utilisation to be around 80%. How many observations should be planned for the study?* [10%]

From the normal approximation to the binomial distribution

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

p=0.8, c=0.05*0.8 z= 1.28 (for 80% conf) hence n= 164

Examiners Comment: About 2/3 of students could remember or derive the formula, for these it was a straightforward question, well answered. The other attempts were poor.

(g) *Discuss the two requirements for a process to consistently produce outputs that meet specifications. Define accuracy and precision, and explain the difference between C_p and C_{pk}.* [15%]

The process must be: i)capable, ie the specified tolerance must exceed 3 times the standard deviation of the process; and ii) in control, exhibiting only random variation around the desired output.

Accuracy refers to the mean output of a process variable in relation to the nominal or specified value of that variable.
Precision refers to the standard deviation, **σ,** or spread of the output variable.

C_P compares the natural variation of a process to the specifications.
C_P = engineering tolerance/6σ
A C_P of 1 denotes a capable process – but to allow for drift, 1.33 is often used as the acceptable minimum.

Disadvantage: C_P doesn't account for process centring and so C_{Pk} is used.
C_{Pk} takes the minimum value of the difference between the value of the process mean and the specification limits and divides by 3σ
.

(h) A manufacturing process has a defect rate of 5 percent, based upon 10 samples of 20 data points each. Calculate the control limits for a p-chart, and explain how it would be used to detect changes in the process performance. [15%]

For attribute data

$$UCL = \overline{p} + 3\sqrt{\frac{\overline{p}(1-\overline{p})}{n}}$$

$$CL = \overline{p}$$

$$LCL = \overline{p} - 3\sqrt{\frac{\overline{p}(1-\overline{p})}{n}}$$

P chart

p	0.05		
n	20	UCL	0.196
1-p	0.95	LCL	0
p*(1-p)/n	.002375		
sigma	.0487		

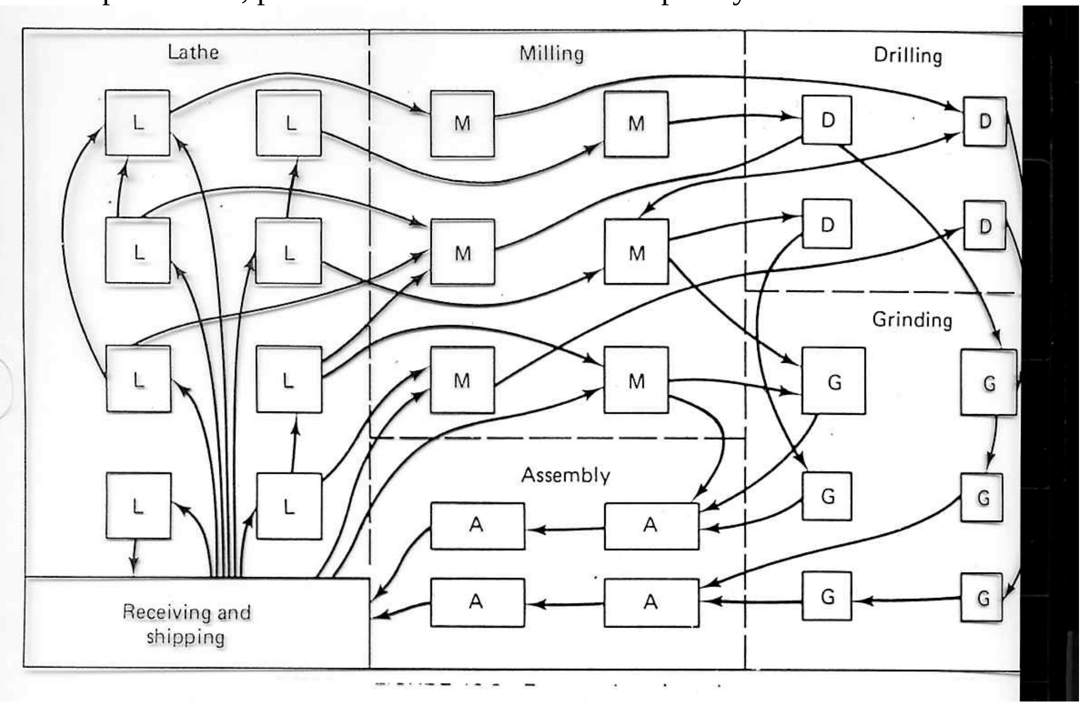
Note: for a p chart n is calculated from the number of data points per sample, not the number of samples which can vary dependent on how long the process had been assessed. The lower control limit cannot be negative so is set at zero.
Samples of 20 are taken at intervals and the % defective calculated. This % is plotted on a control chart. While the process remains 'in control' subsequent plots should be randomly distributed around the 5% line. Changes to the process will be shown by variation from this, for example, by trends, or several subsequent samples being between warning and control limits. There are various rules used to interpret the significance of such variation, better students might give examples

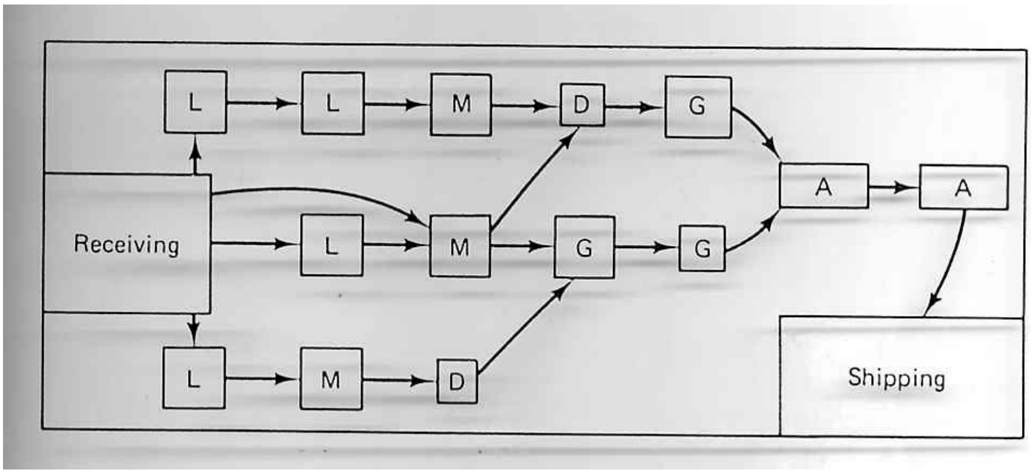
Examiners Comment on g) and h): Whereas many students understood the theory of process capability and process control, fewer were able to calculate the limits for a control chart and explain how it would be used.

4 (a) *Describe the differences between a functional layout, and a cellular layout based on the principles of group technology. What are the advantages and disadvantages of each?*
[30%]

A functional layout consists of departments containing operations with the same function,. Products move around the factory, from department to department .having operations performed in sequence
A cellular layout co-locates all the operations required to manufacture a group of products. Diagrams illustrate.

'Group technology' (GT) is a method of grouping together components having similar design characteristics or manufacturing processing requirements. When GT is combined with cellular production, products are manufactured completely in one cell.





Typical advantages of a cellular layout, compared to a functional layout
Shorter Throughput times – overlapping operations, reduced queues
Reduced inventory
Simplified planning and control at factory level

Reduction of set-up times – similarity of parts, common tooling
Improved quality
Improved productivity
Improved tooling
Improved designs
All due to familiarity, repetition, ownership

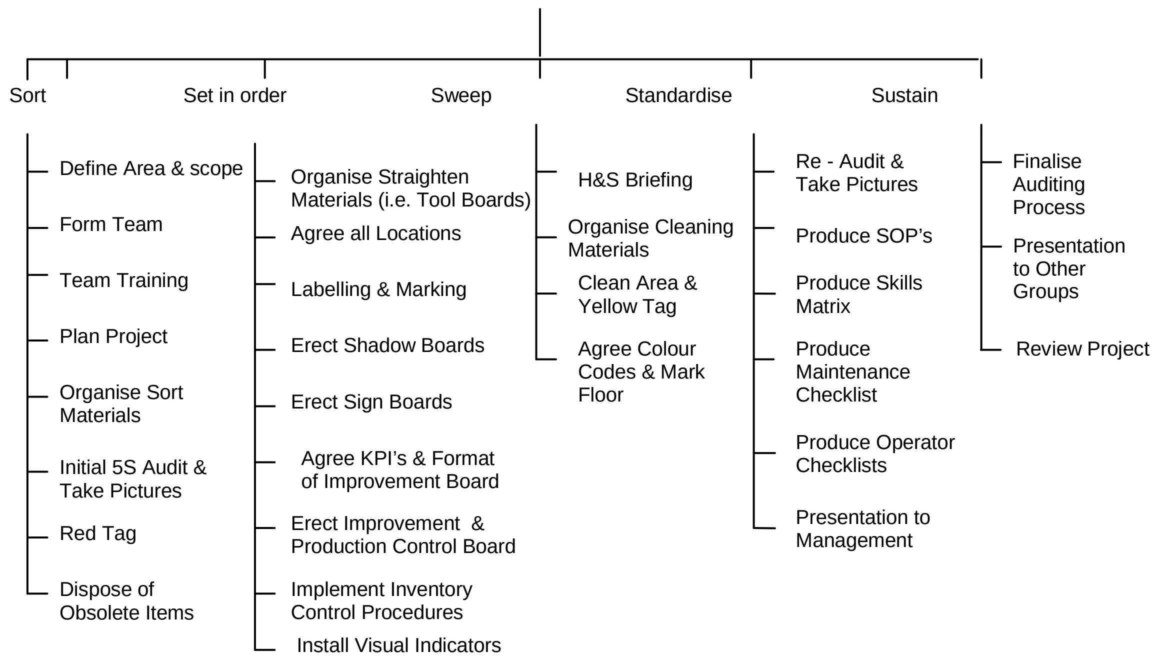
Disadvantages, or issues to be resolved

Skill levels –multi skilling is usually required, and difficult to reach same skill levels as in a functional layout with sp[ecialisation
Plant Utilisation – likely to be lower than with a functional layout
Control at Cell level more difficult
Product change may require reconfiguration of cells

(b) *You have just taken over as the cell leader for a poorly performing production cell. Scrap levels are high, mainly due to careless mistakes by operatives; and efficiencies are low due to short runs. The cells performance shows no sign of improving. The factory manager has instructed you to carry out a 5S implementation and to come up with a six month improvement plan based on the principles of the Toyota Production System.*

(i) Outline how you would carry out the 5S implementation;
Answer should be structured around the following.

5S Task Structure



(ii) Describe and prioritise three initiatives that would form the basis of your improvement plan.

[70%]

There is some scope for variation here but I would expect the improvement plan to address

1)Quality issues
2) Efficiencies
3) Continual Improvement

1) **Reduce Quality issues are due to carelessness**. The first step should be to introduce Poka-Yoke. Simply training and exhorting is unlikely to be sufficient, although this needs to be done in parallel.

- “Poka-yoke”is Japanese word meaning prevention of errors using low cost devices to prevent or detect them

- Common mistakes in manufacturing, that can be addressed by poka-yoke
  - Omitting processing steps
  - Incorrectly locating a part in a fixture
  - Using the wrong tool
  - Neglecting to add a part in assembly

There are several different approaches to poka yoke. The initiative should look at the major areas where errors occur and then implement an appropriate prevention or detection method.

- *Contact* method - identifies product defects, or operational mistakes by testing the product's physical attributes eg. shape, size, colour.
-
- The *fixed-value* (or *constant number*) method - alerts the operator if a certain number of movements are not made.
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- The *motion-step* (or *sequence*) method - determines whether the prescribed steps of the process have been followed.
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- Warning Poka-yoke - operator is alerted when a mistake is about to be made,
-
- Control Poka Yoke - the poka-yoke device actually prevents the mistake from being made.
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2) Improve efficiencies

Efficiencies are stated to be due to short runs. The key activity here would be a set-up time reduction program such as SMED.

Set-up time reductions has 3 phases

Identify and separate external and internal set up activities
Convert internal to external set-up where possible
Reduce time for internal set up

External set-up

- Can be accomplished while previous job is still running

- Strategy: Design the setup tooling and plan the changeover procedure to permit as much of the setup as possible to consist of external elements
- Examples:
  - Obtain tooling for next job
  - Pre - Assemble tools for next job
  - Pre-load parts to fixtures
  - Reprogram machine for next job
  - Collect all paperwork

Internal set-up

- Use work study to minimize the sum of the internal work element times
- Use multiple workers rather than one
- Improve tooling eg use quick-acting fasteners rather than bolts and nuts, use U-shaped washers instead of O-shaped washers
- Eliminate adjustments in the setup

3.**Introduce Kaizen –** continual improvement.

- "Kaizen" – Japanese word meaning continuous improvement of production operations

- Usually implemented by worker teams, sometimes called "quality circles"
  - Encourages worker sense of responsibility
  - Allows workers to gain recognition among colleagues
  - Improves worker's technical skills

This is less formulaic than the previous two initiatives – its about changing mindsets as much as about applying technique.

Examiners Comment: a) Although most students could distinguish between a functional layout and a product layout, a surprisingly large number of students did not really understand the advantages of combining a cellular layout with the principles of Group Technology.
b)i) Most students knew what 5s stood for, but only the better students outlined a process for doing it (which is what the question asked for.)
b)ii)The question very clearly points to quality and efficiency as being the two key issues to address, yet surprisingly only 10% of students picked up on this. All these produced answers very close to that outlined above, and scored close to full marks. Quite a lot of students identified one of the issues, (slightly more picking up on efficiency rather than quality). A few answered in general terms about applying the Toyota productions system, and one or two poor answers described general approaches such as method study, with very little reference to the question.