Version FE/1

EGT2
ENGINEERING TRIPOS PART IIA

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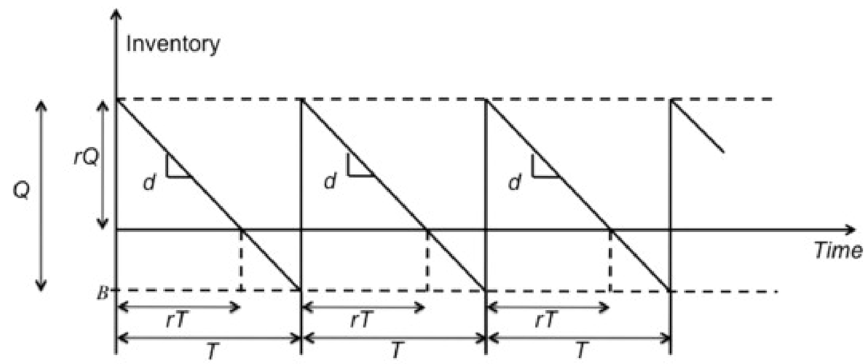
**Module 3E10**

**OPERATIONS MANAGEMENT FOR ENGINEERS - CRIB**

1 (a) Please see below

(i) Please see the figure below.




(ii)

$$\begin{aligned} TC(Q,r) &= K*\frac{D}{Q}+h*\frac{(rQ)*(rT)}{2T}+b*\frac{(Q-rQ)*(T-rT)}{2T} \\ &= K*\frac{D}{Q}+h*\frac{r^2*Q}{2}+b*\frac{Q*(1-r)^2}{2} \end{aligned}$$

(iii)

$$\begin{aligned} \frac{\partial TC(Q,r)}{\partial Q} &= -K*\frac{D}{Q^2}+h*\frac{r^2}{2}+b*\frac{(1-r)^2}{2}=0 \Rightarrow Q=\sqrt{\frac{2*K*D}{h*r^2+b*(1-r)^2}}, \\ \frac{\partial TC(Q,r)}{\partial r} &= h*r*Q-b*Q*(1-r)=0 \Rightarrow r=\frac{b}{h+b}. \end{aligned}$$

Therefore,

$$Q* = \sqrt{\frac{2*K*D*(h+b)}{h*b}}.$$

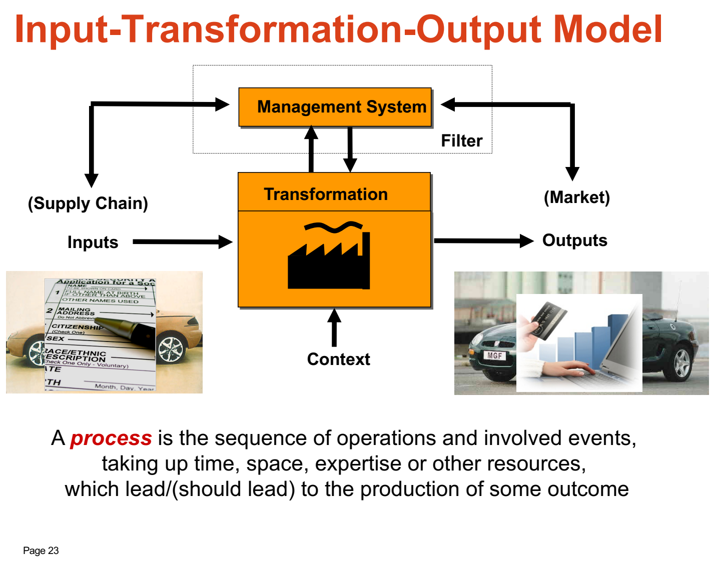
(iv)

$$B = Q*-rQ*=\sqrt{\frac{2*K*D*h}{(h+b)*b}}.$$

The optimal reorder point is $-B$.

(v) As $b$ increases, $B$ decreases and the firm relies on backorders less. In the limit, as $b \to \infty$, $B \to 0$.

(b) Please see the figure below.




The main elements connecting activities are:

- Information flow: orders, schedules, forecasts
- Material flow: raw materials, components, finished products, service parts
- Additional flows and resources: money, energy, people, etc.

It is not sufficient for a firm to design great product and services; the firm must design and improve the business processes that supply these products and services.

Transformation:

- Physical – manufacturing
- Locational – transportation
- Storage – warehousing
- Exchange – retailing
- Physiological – health care
- Informational – telecommunications

The functions of the management system in this model:

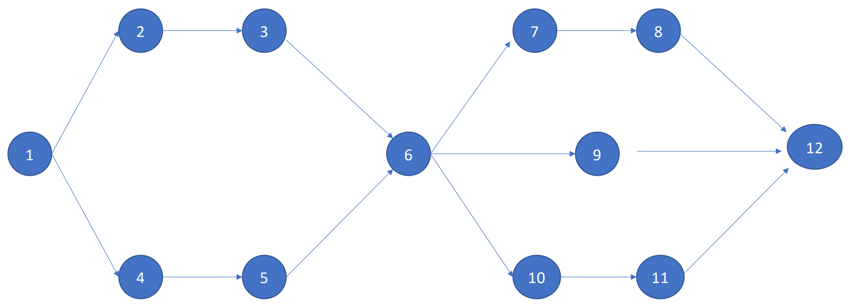
- The design of the transformation process
- The provision of resources (planning)

- The allocation of resources to tasks (scheduling)
- The control (measurement) and improvement of the transformation process

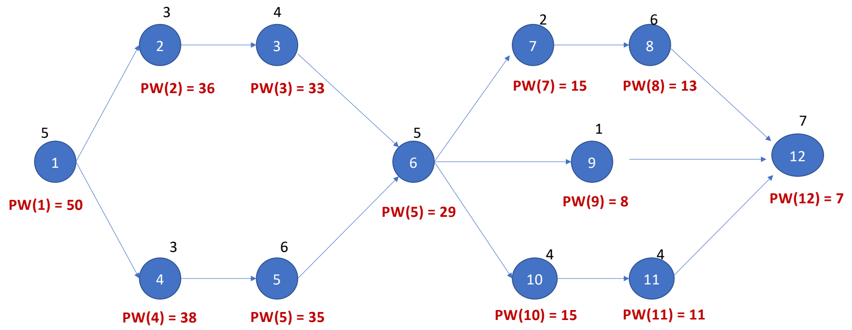
All to meet the required performance objectives, such as Quality: doing things right, to a standard; Speed: time to satisfy order; Dependability: reliable delivery when promised; Flexibility: ability to change what is delivered; Cost: price competitiveness.

2 (a) Please see below.

(i) Please see the figure below.




(ii) Please see the figure below.




| Station | Processes | Station time | Idle time |
|---|---|---|---|
| Station 1 | 1, 4 | 8 | 2 |
| Station 2 | 2, 5 | 9 | 1 |
| Station 3 | 3, 6, 9 | 10 | 0 |
| Station 4 | 7, 10, 11 | 10 | 0 |
| Station 5 | 8 | 6 | 4 |
| Station 6 | 12 | 7 | 3 |

Balance loss = 10/ 60 *100 = 16.7%

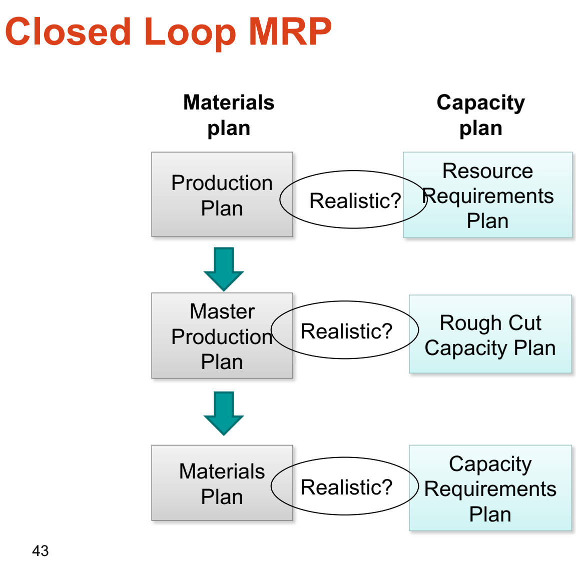
(iii) A quick inspection of the precedence diagram shows that there is no solution with a smaller number of stations. Alternatively, the minimum number of stations possible is = roundup(total process time/cycle time) = roundup(50/11) = 5, which is equal to the number of stations in the current solution.

(b) Limitations of MRP are as follows:

- It takes no account of available machine/production capacity. Assumes infinite capacity.
- Works with fixed lead times and fixed batch sizes.

- 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 checks against long, medium and short term capacity plans.
- MRP Systems inherently distort demand patterns in the supply chain.

Closed-loop MRP attempts to apply corrections to the standard MRP calculation to enable checks against long, medium and short term capacity plans.




(c) Demand variability increases as one moves up the supply chain away from the end consumer. As a result, small changes in consumer demand can result in large variations in orders placed upstream. Furthermore, timing of variations can also vary.

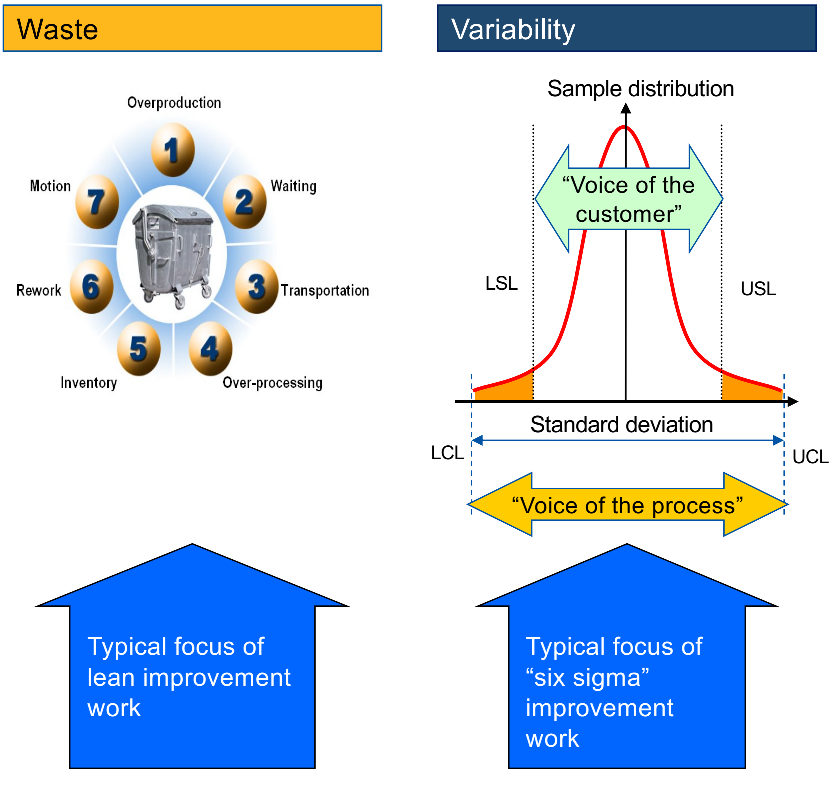
Supply network can have very large swings as each organisation in the supply chain seeks to solve the problem from its own perspective

This effect has been observed in many industries, resulting in increased costs, reduced service levels, poor use of resources, and increased inventory levels

The consequences of the bullwhip effect can be reduced by:

- Better forecasting
- Information sharing
- Channel alignment - coordination of pricing, transportation, inventory planning, and ownership between upstream and downstream sites in a supply chain
- Efficient supply chain management systems [reduction in leadtime, inventory, smaller and more frequent batches using 3PL or mixed truck loads, every day low pricing]
- Flexibility in operations
- Eliminating gaming in shortage situations
- Building strategic partnerships and trust

(d) Please see the figure below.

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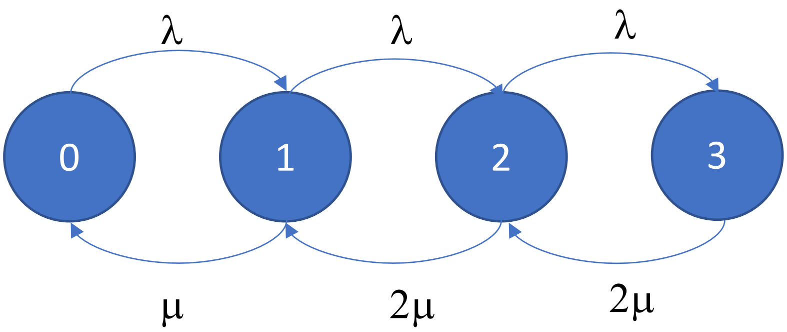
3 (a) Please see below.




(i)

$$\begin{aligned} \lambda\pi_0 = \mu\pi_1 &\Rightarrow \pi_1 = \lambda/\mu\pi_0 = \rho\pi_0 \\ \lambda\pi_0 + 2\mu\pi_2 = (\lambda+\mu)\pi_1 &\Rightarrow \pi_2 = \rho^2/2\pi_0 \\ \lambda\pi_1 + 2\mu\pi_3 = (\lambda+2\mu)\pi_2 &\Rightarrow \pi_3 = \rho^3/4\pi_0 \end{aligned}$$

(ii)

$$\begin{aligned} 1 &= \pi_0+\pi_1+\pi_2+\pi_3 = \pi_0+\rho\pi_0+\rho^2/2\pi_0+\rho^3/4\pi_0 \\ &= \pi_0\left(1+\rho+\rho^2/2+\rho^3/4\right) \\ &\Rightarrow \pi_0 = \frac{4}{4+4\rho+2\rho^2+\rho^3} \\ &\quad \pi_1 = \frac{4\rho}{4+4\rho+2\rho^2+\rho^3} \\ &\quad \pi_2 = \frac{2\rho^2}{4+4\rho+2\rho^2+\rho^3} \\ &\quad \pi_3 = \frac{\rho^3}{4+4\rho+2\rho^2+\rho^3} \end{aligned}$$

(iii) Average number of customers in the system = $\pi_1+2\pi_2+3\pi_3$

Average queue length = $\pi_3$

Arrival rate for the customers who are served in the system = $(\pi_0+\pi_1+\pi_2)\lambda$

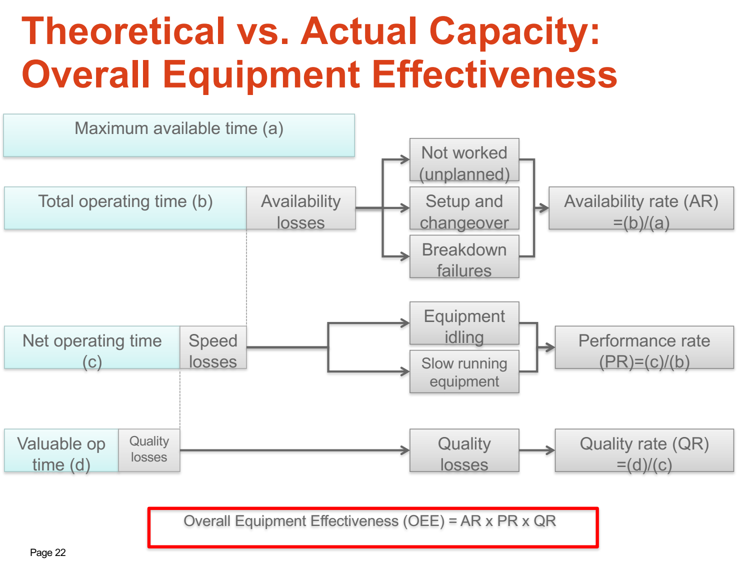
Average waiting time in the system = $\frac{\pi_1+2\pi_2+3\pi_3}{(\pi_0+\pi_1+\pi_2)\lambda}$

Average waiting time in the queue = $\frac{\pi_3}{(\pi_0+\pi_1+\pi_2)\lambda}$

(b) Theoretical capacity is the maximum possible output rate, whereas the actual capacity is a realistic estimate of the achievable output rate.

The main difficulties which inhibit perfect utilisation of a manufacturing system, i.e., which restrict the capacity are:

| | |
|---|---|
| **Lost Time (Planned)**<br>• Setup times<br>• Switchover delays | **Imbalances**<br>• Bottlenecks<br>• Imbalances in task times |
| **Lost Time (Unplanned)**<br>• Breakdowns<br>• Coordination conflicts (of equipment and labour)<br>• Supply shortages | **Reduced Yield**<br>• Quality problems<br><br>**Variable Conditions**<br>• Variability in process times causing a build up of inventory<br>• Variability in raw material arrivals<br>• Variability in order arrivals<br>• Unplanned downtime |

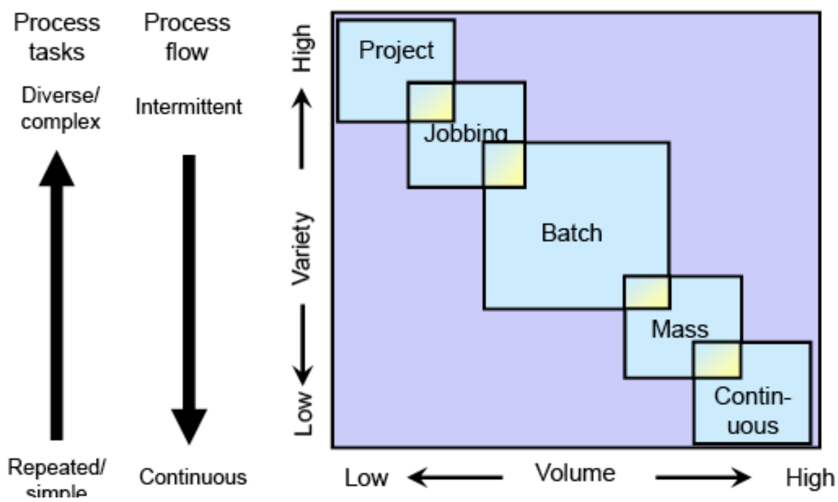



(c) A job shop is an operation that is capable of producing a wide variety of products but in small batch sizes. Example of job shops include machine shops, bakeries, printers and aerospace companies.

Different operational configurations vary on the basis of:

- Volume
- Variety
- Workers skills

- Equipment flexibility
- Layout
- Etc.




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.

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

- 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.

(e) Mass customisation is the need to "customise" mass-produced goods to customer needs. It is an umbrella concept that includes Build-to-Order, Assemble-to-Order, Late configuration/postponement/delayed differentiation, Customisation at point of use, and Customisation through service. There are different approaches to mass customisation:

- Collaborative (e.g., Paris Miki – design a system that recommends distinct designs (lens, shape, etc.)); no finished goods or WIP but raw material.
- Adaptive – standard product customised for different customers with different

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needs (e.g., My Yahoo, AOL, Scandinavian designs (bookshelves+ doors = bookshelves with doors)); point of differentiation customer

- Cosmetic (e.g., Hertz Gold Club, Planters to Walmart)
- Transparent – the customer does not know that the product is differentiated; grocery shopping cards, industrial soaps.

Effective mass customisation requires:

(i) Postponement (point of differentiation) is the key (as close as possible to customer, Delay the postponement until the latest possible point in the supply network)

(ii) Integrate the design of the products, processes, and supply chain configuration

(iii) Modular design: a product should be designed so it consists of independent modules that can be assembled into different forms of product (HP power supply. Total costs decreased by 25%)

(iv) A process should also be modular (Hardware stores, paint + colour pigments – mix them as the customer demand (postponement); Benetton (resequencing), standardise earlier proportions of products (vanilla boxes), computers)

(v) Supply network should be designed to provide the two capabilities

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