EGT2
ENGINEERING TRIPOS PART IIA

Module 3E10

OPERATIONS MANAGEMENT FOR ENGINEERS – CRIB

1   Colour-Me-Mine is a Cambridge apparel store known for their sweaters with vibrant colours. The sweaters are all in the same style and size, but are sold in 10 different colours. The store is reviewing its ordering policy for the green sweaters.

In the past year, average sales for the green sweaters have been 500 per month. The sweaters are knitted in-house. The fixed cost of setting up the production is £500. The variable cost of production is £30 per sweater. The firm can knit sweaters at a rate of 1500 sweaters per month. The cost of keeping a sweater in stock is about 20% of its value per year.

(a)   Find the optimal size of production run for green sweaters. How often does Colour-Me-Mine have to run production?   [20%]

ANSWER: $D = 500 * 12$, $P = 1500 * 12$, $C_S = 500$, and $C_H = 30 * 0.20 = 6$.

$$EPQ = \sqrt{\frac{2 * D * C_S}{C_H * (1 - D/P)}} = \sqrt{\frac{2 * 6000 * 500}{6 * (1 - 1/3)}} \approx 1,125 \text{ sweaters.}$$

The store needs to run production every 2.25 months, about 5 times a year:

$$EPQ/D = \frac{1,125}{500} = 2.25 \text{ months.}$$

(b)   Write the total cost function. How much does Colour-Me-Mine spend per year for green sweaters?   [15%]

ANSWER: The total cost function is

$$
\begin{aligned}
TC(Q) &= \frac{Q * (1 - D/P)}{2} * C_H + \frac{D}{Q} * C_S + 30 * D \\
&= \frac{1125 * (1 - 1/3)}{2} * 6 + \frac{6000}{1225} * 500 + 30 * 6000 = 184,900.
\end{aligned}
$$

Colour-Me-Mine spends £2,449.49 per year each in set up costs and inventory holding cost. The production cost of the green sweaters is £180,000. Therefore, the total cost is approximately £184,900.

(c)   What proportion of the cycle consists of uptime?   [5%]

ANSWER: The proportion of the cycle consisting of uptime:

$$D/P = (500 * 12)/(1500 * 12) = 1/3.$$

(d)   What is the maximum level of on-hand inventory for green sweaters?   [10%]

(cont.

ANSWER: The maximum level of on-hand inventory for green sweaters is:

$$Q * (1 - D/P) = 1125 * (1 - 1/3) \approx 816.$$

A good answer would provide the sawtooth diagram and demonstrate the values on it.

(e)   State all your modelling assumptions in part (a). Discuss how each of these assumptions are unrealistic compared to the situation faced by the shop.   [15%]

ANSWER:

- Demand is constant and steady, and continues indefinitely. ==> Demand for sweaters are most likely seasonal. In addition, colours may be in and out of fashion, so most probably demand will only last for a few seasons.

- No supply uncertainties or yield problems. ==> There might be supply uncertainties; e.g., workforce problems, raw material unavailability, etc.

- Replenishment lead-time is known and constant. ==> Due to supply uncertainities, lead-time may be variable.

- Holding cost per item per period is constant. ==> The holding cost is very low; so probably this assumption is not a big issue.

- Cost of ordering/setup is constant. ==>Once again, the setup cost is quite low; so probably this assumption is not a big issue.

- Item is independent of others; benefits from joint reviews are ignored. ==>It might be better to combine the production of different colours, instead of thinking each separately.

(f)   Recently, Colour-Me-Mine executives are complaining about the inventory holding costs. Discuss how the store can reduce inventory. Justify your answer.   [15%]

ANSWER: As they have 10 different colours, they may indeed have a lot of inventory. Colour-Me-Mine executives can think about process improvement opportunities. For example, using resequencing and a modular process, they can postpone colouring the sweaters and only carry a vanilla product, which can be coloured at the last step of production. They can also consider decreasing the setup cost, which would lead to smaller batches of production.

(g)   Colour-Me-Mine executives are considering outsourcing production. Discuss the key advantages and disadvantages of outsourcing rather than keeping the production in-house. What are some factors they should consider for outsourcing?   [20%]

ANSWER: Pros of outsourcing:

- Focus on core competencies

- Harness lower labour cost at supplier

- Access to technology

- Stable and predictable financial planning in fee-for-transaction services

- Less investment risk

Cons of outsourcing:

- Loss of control over process

- Limited ability to improve processes

- Risk of opportunistic behaviour of supplier

- Loss of human capital and tacit knowledge

They should consider:

- Cost per unit, including quantity discounts

- Any administrative costs

- Lead time on orders (both mean and variance)

- Order restrictions, e.g., minimum order quantity

- Information sharing, collaboration, communication

- Quality

2   (a)   Explain the three basic strategies for long-term capacity planning. Discuss the advantages and disadvantages of each strategy.   [20%]

ANSWER: The three basic strategies for long-term capacity planning are: Capacity lead; capacity lag, and smoothing with inventory; see figure below.

(a) Capacity lead   (b) Capacity lag   (c) Smoothing with inventory
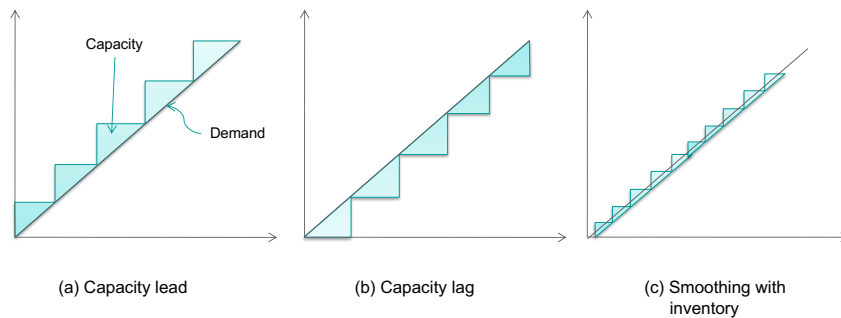
The advantagesof capacity lead are as follows:

- Sufficient capacity to meet demand
- Capacity cushion
- Low impact of start-up/yield problems

The disadvantages of capacity lead are as follows:

- Low utilisation
- Risk of over-capacity
- Early capital spending

The advantages of capacity lag are as follows:

- Sufficient demand for full working capacity
- No over-capacity risk
- Capital spending is delayed

The disadvantages of capacity lag are as follows:

- Insufficient capacity to meet demand
- High impact of start-up/yield problems
- No capacity cushion, so the system does not have any buffers.

Smoothing with inventory benefits from the advantages of leading and lagging strategies. However, it requires better planning and coordination.

(b)   Explain the differences between the characteristics of service operations and manufacturing operations. Give examples as appropriate. What extent do you think this distinction is valid?   [20%]

ANSWER: The nature of manufacturing and services differ considerably:

Pure Goods	**Pure Services**
• Tangible	• Intangible
• Can be stored	• Cannot be stored
• Production precedes consumption	• Production and consumption are simultaneous
• Low customer contact	• High customer contact → inherent variability
• Can be transported	• Cannot be transported
• Quality is evident	• Quality difficult to judge

However, very few operations are purely good or service. Many operations provide a combination of both (e.g. simple example of a restaurant), but also servitization strategies. That is, service operations and manufacturing operations are inevitably linked:

Manufacturing and Service are Inevitably Linked: Where is the "Centre of Gravity"?

Source: High-value manufacturing, IfM, 2006
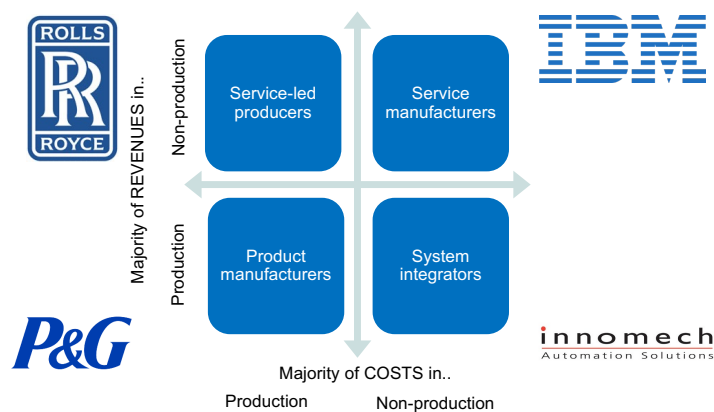
(c)   Explain the bullwhip effect in the context of global supply chain management. Discuss how its consequences may be reduced. Provide examples as appropriate.   [20%]

ANSWER: 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.

Global supply chains are longer, and thus the longer lead-time will mean it is much less likely to quickly adjust to changes. As a result, a global supply chain will have to hold more buffer stock, and is more prone to stock-outs, obsolescense, etc.
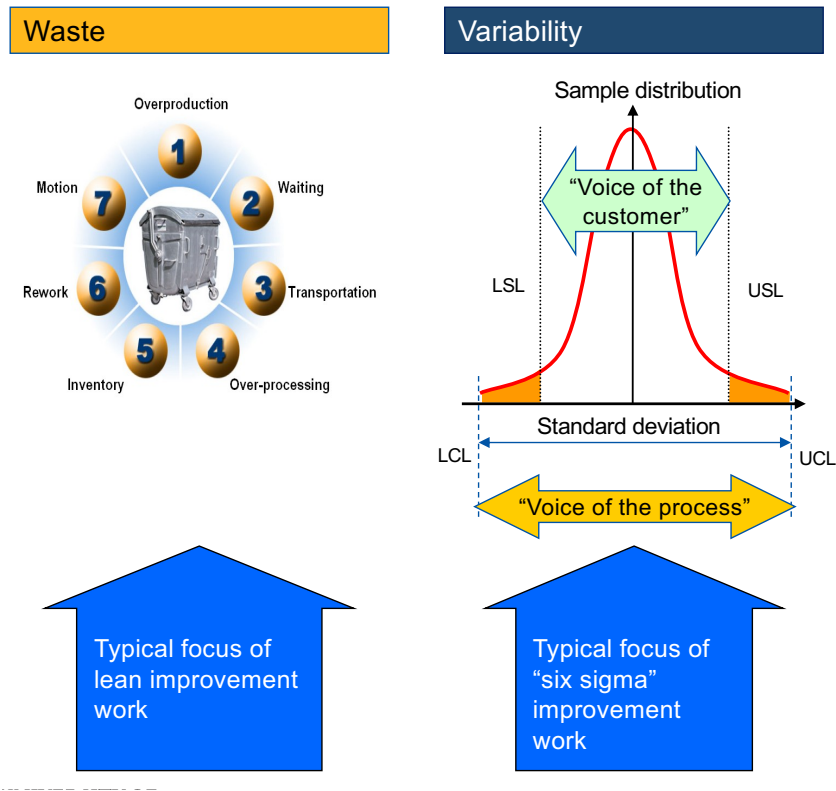
The consequences of the bullwhip effect can be reduced by:

- 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)   Discuss how Lean and Six Sigma complement each other.   [20%]

ANSWER:

Waste

Overproduction
1
Motion 7
Waiting 2
Rework 6
3 Transportation
5
4
Inventory
Over-processing

Variability

Sample distribution

"Voice of the customer"

LSL

USL

Standard deviation

LCL

UCL

"Voice of the process"

Typical focus of lean improvement work

Typical focus of "six sigma" improvement work

(e)   Consider the recent problems in long wait times in A&E departments in England. Using the basics of queueing theory, provide an explanation for long waiting times.   [20%]

ANSWER: Let ρ be the server utilisation. Using basic queueing theory, the number of customers in the system, N, is equal to $\rho/(1-\rho)$. As ρ increases, N increases exponentially. In the limit, as $\rho \to 1$, the system becomes unstable with $N \to \infty$.

3   (a)   Explain Fisher's supply chain matrix. Provide examples.   [20%]

ANSWER:

DEMAND

	FUNCTIONAL PRODUCTS [predictable, few changes, low variety, low margin, long	INNOVATIVE PRODUCTS [unpredictable, many changes, high variety, high margin, short LT …]
EFFICIENT SUPPLY CHAIN [Low cost, high use, low inv.]	**LEAN SUPPLY CHAIN**	mismatch
RESPONSIVE SUPPLY CHAIN [Fast response, low throughput, flex suppliers]	mismatch	**AGILE SUPPLY CHAIN**

(The vertical label on the left reads: **SC OBJECTIVES**)

Examples: designer jeans, sugar, mobile phones, tissues, bananas, fighter aircraft

Source: Adapted from Fisher MC, 1997, What is the right supply chain for your product?, HBR, Mar-Apr, 105-116

(b)   Explain the difference betwen qualitative and quantitative approaches to forecasting. Discuss the problems accociated with each approach.   [20%]

ANSWER: Qualitative approaches involve collecting and appraising judgements, opinions, best guesses, past trends, and predictions from experts. They are usually used for long-term planning. Examples of methods include: market surveys, Delphi study: ask the experts, scenario planning, panel approach. Problems: bias, ignorance

Quantitative approaches involve analysing patterns of data on past behaviour. They are usually used for short to medium-term planning.

- Extrinsic (based on external patterns beyond firm level): Econometrics models including contextual variables, medium term (1-2 years); Problem: will miss unusual events and short term issues.

- Intrinsic (based on patterns of actual data at firm level): Short term (up to 12 months)' Moving average, exponential smoothing (extrapolation methods) Regression analysis; Time series, decomposition analysis; Problem: almost exclusively based on historical data!

(c)   What are the five performance objectives of operations management? Explain each one by providing examples.   [20%]

ANSWER: Value = Performance/Cost, where performance is a function of:

- Quality: doing things right, to a standard

- Speed/Dependability: reliability and speed of delivery

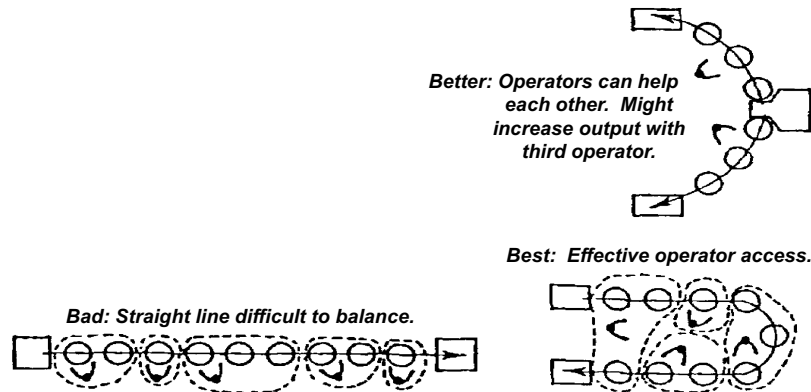- Flexibility: ability to change (volume, product mix, design)

In order to maximise value, companies may:

(i) Compete on cost: e.g. Aldi, Asda, Ryan Air, etc.

- Offering product at a low price relative to competition

- Typically high volume products

- Often limit product range and offer little customization

- May invest in automation to reduce unit costs

- Can use lower skill labour

- Low cost does not necessarily mean low quality

(ii) Compete on quality: e.g. Wait Rose, Etihad, etc.

- Superior product features

- Excellent customer service

- Consistent delivery

- Process quality; error free delivery

(iii) Compete on speed/dependibility: e.g. Amazon, UPS, etc.

- Rapid delivery: Focused on shorter time between order placement and delivery, minimal wait times

- On-time delivery: Deliver product exactly when needed every time

- Availability: Convenient and readily available when customer requires

(iv) Compete on flexibility: e.g. Dell, etc.

- Company environment changes rapidly; Company must accommodate change by being flexible

- Easily customize product/service to meet specific requirements of a customer; Ability to ramp capacity up and down to match market demands

(d) Discuss why a U-shaped assembly line may be easier to balance than a straight line.
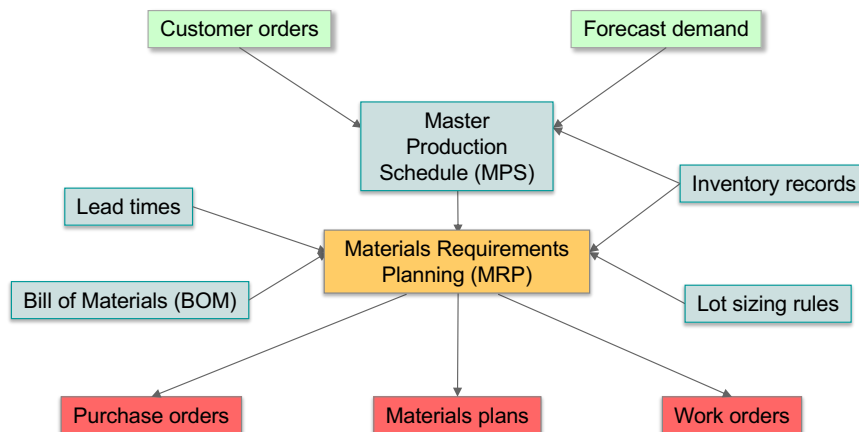
[10%]

ANSWER:

(cont.

Better: Operators can help each other. Might increase output with third operator.

Best: Effective operator access.

Bad: Straight line difficult to balance.

(e) Describe the purpose of an MRP system. Discuss the inputs, components and outputs of an MRP system.   [30%]

ANSWER: MRP calculates what you need to get and do from what you expect to sell

INPUTS: MRP requires five types of information:

- Master Production Schedule: a complete list of the volume and due dates of all expected product sales

- Bill of material file: design information relating products to components; usually expressed in hierarchical form

- Inventory record file: a record of current stocks

- 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

COMPONENTS of an MRP record:

- Gross Requirements: Total independent and dependent demand, before netting on-hand inventory and scheduled receipts

- Scheduled Receipts: Production orders and purchase orders that have already been released . On their due date, they will be added to the projected available balance. Scheduled receipts are not altered automatically by the MRP system, and are not exploded into requirements for components

- Projected Available Balance: on-hand inventory, projected into the future

- Planned Order Release: a suggested order quantity, release date and due date created by the MRP system. Planned orders at one level of the bill of material will be exploded into gross requirements for components at the next lower level.

OUTPUTS: From these, MRP packages calculate

- Gross and New material requirements plans
- Also Purchase Orders and Work Orders are generated

END OF PAPER