Version FE/2

EGT2: IIA
ENGINEERING TRIPOS PART IIA

Module 3E10

OPERATIONS MANAGEMENT FOR ENGINEERS - CRIB

1 (a) The trend is the long-term sweep or general direction of movement in a time series. Seasonality indicates that a time series exhibits a regular or repeating pattern.

(b) (i)

X_t :	The observation
E_t :	The base level
T_t :	The per-period trend
S_t :	Seasonality factor
$F_t(k)$:	The forecast of period $t+k$ carried out at the end of period t

- E_t is a convex combination of two terms, where X_t/S_{t-c}, the deseasonalised observation, is an estimate of the base obtained from the current period, and $E_{t-1}+T_{t-1}$ is our base level estimate before observing X_t.
- T_t is a convex combination of two terms. The first term $E_t - E_{t-1}$, is an estimate of trend from the current period given by the change in the smoothed base from period $t-1$ to t. The second term, T_{t-1}, is our previous estimate of the trend.
- S_t is a convex combination of two terms. X_t/E_t is an estimate of period t's seasonality and S_{t-c} is the most recent estimate of period t's seasonality (the last and the same season).
- $F_t(k)$ is set to $(E_t + kT_t)S_{t+k-c}$, where E_t is the base level, kT_t is the accumulated trend, and S_{t+k-c} is the most recent estimate of period $(t+k)$'s seasonality.

(ii) Given the data

year	index	X_t	E_t	T_t	S_t	F_t
2017	1		300	50		
	2	380				
	3					
	4					*
2018	1					
	2					*

$S_{-3} = 0.9$, $S_{-2} = 0.95$, $S_{-1} = 0.95$, $S_0 = 1.2$
$\alpha = 0.2$, $\beta = 0.4$, $\gamma = 0.5$
$c = 4$

 (cont.

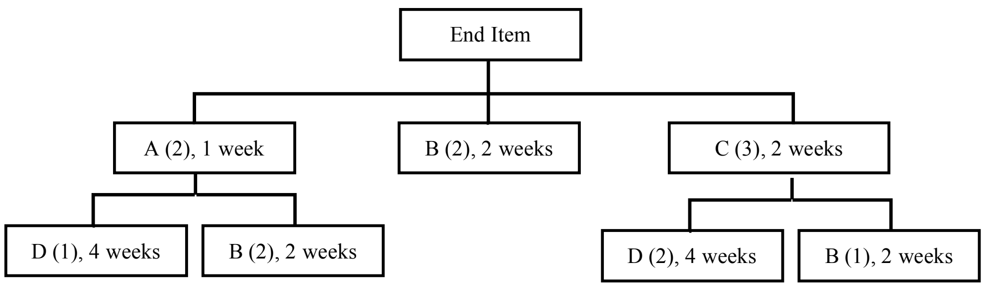
When $t = 2$,

$$\begin{aligned}
E_t &= \alpha \frac{X_t}{S_{t-c}} + (1-\alpha)(E_{t-1} + T_{t-1}) \\
&= 0.2 \times 380/0.95 + 0.8 \times (300 + 50) \\
&= 360 \\
T_t &= \beta(E_t - E_{t-1}) + (1-\beta)T_{t-1} \\
&= 0.4 \times (360 - 300) + 0.6 \times 50 \\
&= 54 \\
S_t &= \gamma \frac{X_t}{E_t} + (1-\gamma)S_{t-c} \\
&= 0.5 \times 380/360 + 0.5 \times 0.95 \\
&\simeq 1 \\
F_t(k) &= (E_t + kT_t)S_{t+k-c} \\
&= (360 + 2 \times 54) \times 1.2 \\
&= \$561.6 \text{ billion}
\end{aligned}$$

(iii) When $k = 4$, the forecast for the second quarter of 2018 is

$$\begin{aligned}
F_t(k) &= (E_t + kT_t)S_{t+k-c} \\
&= (360 + 4 \times 54) \times 1.0 \\
&= \$576.0 \text{ billion}
\end{aligned}$$

(c) (i) The product structure diagram is below:



(ii) 6 weeks

(iii)

Week	1	2	3	4	5	6	7	8	9	10
Net Requirement for End Item				100	50	100	200	100	50	100

Week	1	2	3	4	5	6	7	8	9	10
Net Requirement for A				200	100	200	400	200	100	200
Planned Order Releases			200	100	200	400	200	100	200	

Week	1	2	3	4	5	6	7	8	9	10
Gross Requirement for C				300	150	300	600	300	150	300
Scheduled Receipts				150		150				
Net Requirements				150	150	150	600	300	150	300
Planned Order Releases		150	150	150	600	300	150	300		

Week	1	2	3	4	5	6	7	8	9	10
Gross Requirement for B		150	550	550	1100	1300	950	700	500	200

(d) This statement is false. A JIT system does not cope well with changes in the demand, so is not very effective when demand is seasonal.

2 (a) (i) False. EOQ has some rigid assumptions. It assumes demand is constant and steady, and continues indefinitely. Therefore, in the described setting EOQ will lead to high inventory and stockout costs.

(ii) False. Such strategies eliminate order batching and decrease variability of orders; therefore they curb bullwhip effect.

(iii) False. The theoretical 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. The theoretical capacity of a manufacturing line is the maximum possible output rate according to the design of the equipment – defined by the slowest task or process in the line. Actual capacity is less than theoretical capacity due to a number of reasons:

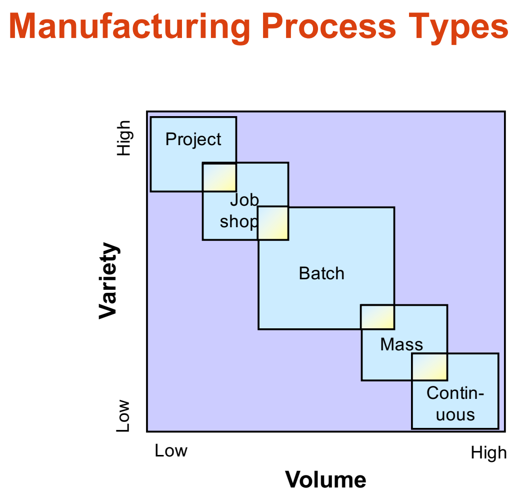
- When capacity is not balanced the capacity is limited by the bottleneck stage/equipment/process.
- Set up delays – set up times for machines limit the throughput of the machine. Increasing batch sizes can improve this but has other implications hence need to be traded off.
- Defects – product quality need to be managed
- Breakdown of equipment
- Coordination of product flows will limit capacity in a production line
- Theoretical capacity does not consider variability involved in production times
- Supply shortages

(b) (i) Using the EOQ formula $Q = \sqrt{\frac{2K\lambda}{ic}}$, we have $K = \frac{Q^2 ic}{2\lambda}$. Thus:
Classic: $K = \frac{Q^2 ic}{2\lambda} = \frac{300^2(50)(.24)}{2(1200)} = 450$
Sporty: $K = \frac{Q^2 ic}{2\lambda} = \frac{120^2(50)(.24)}{2(720)} = 120$
Yuppie: $K = \frac{Q^2 ic}{2\lambda} = \frac{40^2(200)(.24)}{2(240)} = 160$

(ii) Maximum value of K such that $Q = \sqrt{\frac{2\times K\times 240}{(0.24)(200)}}$=20; thus $K = 40$.

(iii) Order for 1 month: 140/200 = .7
Order for 2 months: (140+80)/400 = .55
Order for 3 months: (140 + 80 + 160)/600 = .633
This implies that you should order 400 units every other month. The third order will be on fifth month.

(c) Different manufacturing types based on volume-variety trade-off:



- Projects: Labour and equipment is often brought to location of assembly and re-allocated afterwards; Physical size and degree of customisation key factors. E.g., bridge construction
- Job shops: Volume does not justify dedicated lines or machinery; Parts often travel between work-shops, thus "job shop"; Work centres are grouped by type of process: welding, drilling, painting. E.g., machine tools, auto parts
- Batch: Volume key factor in justifying automation; Short life cycle (seasons) means that machines need to be flexible for re-use with next batch/product; Changeovers between products. E.g., textile.
- Mass: Volume does justify dedicated lines; Cycle time is set to pace entire factory; Multi-model lines; Limited flexibility regarding volume and new models. E.g., automobile assembly
- Continuous: Flow processes, often driven by chemical/physical needs; Individual product is often not an entity (e.g., petrol). E.g., oil refinery

(d) Little's Law states that, on average, the number of customers at the station is equal to the arrival rate multiplied by the average time for a customer spending at the station. On average, the number of customers in the queue is equal to the arrival rate multiplied by the average time for a customer waiting for the pump becoming available.

In steady state a newly arriving customer expects to see a queue (system) of length L_q (L). She is expected to be in the queue (system) for W_q (W) time units. During these W_q (W) time units one expects that λW_q (λW) new customers arrive. So the queue length is expected to be λW_q (λW) when the customer leaves the queue (system).

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Little Law applies at steady-state. It is very powerful because it hold without any distribution assumptions.

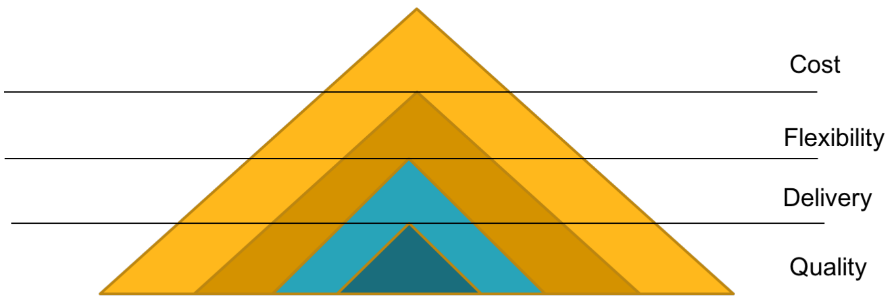
L determines the minimum pipeline stock needed to keep the factory operating at the required production rate for a particular job. Hence Little's Law directly sets minimum inventory and is implicitly critical in planning capacity of a factory.

3 (a) The Sandcone model suggests that although in the short term it is possible to trade off capabilities one against the other, there is actually a hierarchy amongst the four capabilities.

To build cumulative and lasting manufacturing capability, management attention and resources should go first towards enhancing quality, then - while the efforts to enhance quality are further expanded - attention should be paid to improve also the dependability of the production system, then - and again while efforts on the previous two are further enhanced - production flexibility (or reaction speed) should also be improved, and finally, while all these efforts are further enlarged, direct attention can be paid to cost efficiency.

Most of the traditional management approaches for improving manufacturing performance are built on the trade-off theory. Ferdows and de Meyer suggest the trade-off theory does not apply in all cases. Rather, certain approaches change the trade-off relationship into a cumulative one - i.e., one capability is built upon another, not in its place.

Applying this model requires a long term approach, tolerance and patience. It requires believing that costs will eventually come down.



(b) DMAIC (an acronym for Define, Measure, Analyse, Improve and Control) refers to a data-driven improvement cycle used for improving, optimising and stabilising business processes and designs. The DMAIC improvement cycle is the core tool used to drive Six Sigma projects. However, DMAIC is not exclusive to Six Sigma and can be used as the framework for other improvement applications.

DMAIC is the most-used Lean Six Sigma project methodology and is focused on improving an existing process, rather than creating a new product or process like DMADV.

D — Define the problem with your product or process.

M — Measure your current process and collect data.

A — Analyse your data to find the root causes of defects.

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I — Improve your process based upon your data analysis and test it. (Techniques like DOE and poka yoke are often used in this phase.)

C — Control your new process and monitor for defects. (SPC techniques are helpful in this phase.)

DMADV stands for these five phases of a Lean Six Sigma project that's aimed at creating a new product or process design:

D — Define process and design goals

M — Measure (and identify) critical-to-quality aspects of your process/product, including risks and production capabilities

A — Analyse to develop process designs and evaluate to select the best design for your process

D — Design process details and optimise your design. Test your design(s)

V — Verify the chosen design for your process with pilot-testing. Implement and monitor the new process

(c) There are four key capacity decisions:

- Sizing: How much capacity to invest in?
  Capacity investment involves long-run planning under uncertainty; Capacity requires large and irreversible investment; Measuring and valuing capacity shortfall is not obvious; Capacity is like “black art"; it depends on everything

- Timing: When to increase or reduce resources?
  Ideally, without frictions, timing is a non-issue: track/chase demand draw linear demand growth/decline graph and continuously add/subtract very small chunks of capacity
  In real life, however, there are frictions that complicate decisions: lead times, lumpiness, fixed costs

- Type: What kinds of resources are best?
  Access to knowledge and skills

- Location: Where should resources be located?
  Can be political; affected macroeconomic and non-market factors; supply availability; closeness to network

(d) Use SPT Rule, which minimises average completion/flow time on one machine.

Job	**D**	**A**	**C**	**E**	**B**	**F**
Processing time (days)	1	2	2	2	4	4
Completion time (days)	1	3	5	7	11	15
Due date (from current day)	4	6	7	10	8	9
Lateness(days)	-3	-3	-2	-3	3	6

Average flow time: 15/6 = 2.5

Average lateness: -2/6 = -0.33

(e) The elements of Toyota Production System (TPS) are:

- All processes driven to be in control and capable: Standardised work practices; “Simplify, highlight deviations, mistake-proof"
- Problems are natural and opportunities to learn, not blame!: Most problems arise from not following standards; Every problem has root cause and counter-measures
- Every activity must add value: Eliminate waste through continuous improvement
- Make what customers want when they want it, just-in-time: Smooth production “pulse"
- Select and invest in people: Managers chosen as best teachers/problem-solvers; Empowerment and multi-skilling

(f) (i) A production plan using the level strategy is:

Month	Net Demand	Cumulative Demand	Number of Workers Needed	Production	Inventory
January	3,200	3,200	10	4,160	960
February	2,400	5,600	9	4,160	2,720
March	6,400	12,000	13	4,160	480
April	4,000	16,000	13	4,160	640+1,500 = 2,140

(ii) A production plan using the chase strategy is:

 (cont.

Month	Net Demand	Cumulative Demand	Number of Workers Needed	Production	Inventory
January	3,200	3,200	10	3,200	0
February	2,400	5,600	8	2,560	160
March	6,400	12,000	20	6,400	160
April	4,000	16,000	12	3,840	1500
			or 13	or 4,160	or 320+1,500 = 1,820

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