2012 Manufacturing Engineering Tripos IIA Paper 3

(3P4) Operations Management & (3P5) Industrial Engineering

Prof. Duncan McFarlane & Prof. Sir Mike Gregory

1

a) centralized versus localized distribution: students should discuss issues raised in lectures and provide appropriate examples

- Centralised
  - Risk pooling leads to lower safety stock
  - Economies of scale in terms of overhead
  - Reduced transportation costs to warehouse
- Local
  - Reduced lead time to market
  - Reduced transportation costs to customer

b) centre of gravity: the key issue behind centre of gravity is that it performs a production volume weighted distance calculation:

- Used to find a location that minimises transportation costs
- Based on the idea that all possible locations have a "value" which is the sum of all transportation costs to and from that location
- The best location, the one which minimises costs, is represented by the weighted centre of gravity of all points to and from which goods are transported

$$\bar{x} = \frac{\sum x_i V_i}{\sum V_i}$$

$$\bar{y} = \frac{\sum y_i V_i}{\sum V_i}$$

x_i = the coordinate of source or destination

y_i = the coordinate of source or destination

V_i = the amount to be shipped to or from source or destination

c) i) In convention use of the Centre of Gravity technique, factories are provided and warehouse or distribution centre is located. Here the warehouse location is provided and it is necessary to follow a procedure along the lines of

- Determine as below the three centres of gravity corresponding to
  - the four existing factories and factory E option 1
  - the four existing factories and factory E option 2

- the four existing factories and factory E option 3

	xi	yi	Wi [tons]	xi Wi	yi Wi
A	20	120	200	4000	24000
B	15	130	150	2250	19500
C	50	110	270	13500	29700
D	40	105	320	12800	33600
E-Option 1	65	105	440	28600	46200
Total			1380	61150	153000
Centre of Gravity Option 1				44.3115942	110.8695652

	xi	yi	Wi [tons]	xi Wi	yi Wi
A	20	120	200	4000	24000
B	15	130	150	2250	19500
C	50	110	270	13500	29700
D	40	105	320	12800	33600
E-Option 2	45	50	440	19800	22000
Total			1380	52350	128800
Centre of Gravity Option 2				37.93478261	93.33333333

	xi	yi	Wi [tons]	xi Wi	yi Wi
A	20	120	200	4000	24000
B	15	130	150	2250	19500
C	50	110	270	13500	29700
D	40	105	320	12800	33600

E-Option 3	80	90	440	35200	39600
Total			1380	67750	146400
Centre of Gravity Option 3				49.0942029	106.0869565

Note that a good student will not repeat the whole calculation three times but just amend successive solutions with the appropriate xi Wi, yi Wi contributions

- Determine the (Euclidean) distance between each centre of gravity and the warehouse e.g.

$$d_{AB} = \sqrt{(x_A - x_B)^2 + (y_A - y_B)^2}$$

where A denotes warehouse and B denotes factory.

For the three options the distances are:

	xd	yd	[xd2+yd2] 1/2
Op 1	-9.311594203	-10.86956522	14.31269488
Op 2	-2.934782609	6.666666667	7.284050618
Op 3	-14.0942029	-6.086956522	15.3524459

Hence, Factory Option 2 provides the best fit to the current warehouse location.

ii) Halving the capacity of the new factory requires a recalculation of each of the centres of gravity. However a good student might simply observe that in the case of Option 2 reducing the capacity of the factory can only improve its performance compared to the other options.

	xd	yd	[xd2+yd2]1/2
Op 1	-5.387931034	-11.98275862	13.13835245

Op 2	-1.594827586	-1.551724138	2.22515681
Op 3	-8.232758621	-9.137931034	12.29959748

d) If the warehouse capacity is limited and no further warehouse space is available then the company will need to reduce the volumes of at least some of finished goods stocks it will maintain in its warehouses. Hence it may need to reconsider its approach to level capacity planning and consider either chase demand planning [e.g. using overtime] or use demand management to try to change the demand pattern

2. Good answers should include the following, but are not limited to:

a.

John D.C. Little's Theorem (or Little's Law) gives a simple relation between inventory and lead-time. Applies to all types of systems!

$N = \lambda * T$

_ N is the number of items or inventory in a system [units]
_ λ is the production rate at which items arrive/leave [units/day]
_ T is the lead-time a job spends in the system [day]
_ (all of this assuming steady-state).

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

b.

According to Little's Law, the minimum inventory in this process is N=Lamda*T = 23,437.5.

A good student should mention that inventory is a cause, not an effect. Thus cutting lead-time is the right approach to improvement in this case.

In order to cut WIP inventory down to 15,000 units, the processing lead-time T would have to be reduced to 48 minutes (from 75 minutes).

c.

i.) A "pull" system uses the customer demand signal to trigger replenishment. It is an autonomous system that purely works by replenishing goods that have been consumed by the preceding process. The demand signal is the only trigger for production, not forecasts or centrally planned work orders. The demand signal is conveyed by a "kanban", which could be an empty bin, a card or electronic signal.

In a “push” system, production is planned centrally using a Master Production Schedule (MPS), which generally comprises of a combination of actual customer orders and forecasts. Based on the MPS and standard routing and lead-time data, work orders are centrally issued that “push” the material forward towards the customer end.

Thus, the key differences are twofold: (1) what triggers the replenishment, and (2) what information the “schedule” is based on.

ii.

In a "pull" system inventory buffers are needed to convey the pull signal from a downstream process to an upstream process. Essentially the process needs some small buffers "to pull from", in order to convey the replenishment signal upstream. A kanban supermarket is a typical example of inventory in a pull system.

iii.

In a "push" system, production is scheduled according to a Master Production Schedule (MPS). The MPS generally is a combination of actual orders and forecast orders, thus the main function of inventory in a push system is to buffer against any forecast errors.

Also, as production orders are based on fixed lead-times, WIP inventory between processes exists as actual lead-times will vary from those set in the planning system.

d. (this question was not entirely covered in the lectures and is aimed at challenging the students to think beyond the taught material)

The main financial implications are:

- inventory leads to a working capital requirement
- inventory is an operating expenses due to holding and handling costs
- obsolescence, decay/quality degradation and depreciation are further inventory-related costs
- returned products incur further handling costs
- inventory can be used to alter price, for example by "flooding" the market with product to drive competitors out of the market, or inventory can be held back in order to restrict supply and keep prices high.

Section 3

Question Number 3

(a) A method study should be carried out to systematically record and examine the current methods of production so that they can be improved and recreated in an alternative location. This should include

- selecting the key production methods to be examined.
- record the facts about the current methods of production including for example Material/Flow process charts mapping: operation, inspection, movement, delay and storage.
- other tools might include multiple activity charts, value stream mapping; and two handed process charts.

Where available Standard Operating Procedures should be captured including layout of workplace, tools and equipment, procedures and inspections.

Current methods should be reviewed to identify any contextual factors which might not be present in the new location.

The type of machine layout should also be observed and recorded eg Is there a process or product layout or is a cell layout (using group technology) in place? Material handling methods should also be examined.

The factory layout can also be analysed using activity relationship charts and diagrams, space relationship diagrams and consideration of proximity requirements (e.g. using the Adjacency Score).

Work measurement on key production activities should also be carried out to provide a basis for redesign in the new environment including potentially:

- Time studies using direct observation and measurement
- Predetermined Motion Time Studies (PMTS) using standard times
- Activity sampling using statistical sampling of activity over a period
-

(b) Now that the current production methods have been systematically recorded and critically examined, they should be developed to come up with a more efficient and cost effective method of doing the work, before they are re-implemented into the new factory.

The analysis undertaken above provides the foundations for the manufacturing system design in the new location. Three aspects might be considered

- Uses of human body: including hand movements, positioning of work, safety, comfort etc
- Design of workplace: including seating position, environment, glare etc
- Design of tools and equipment: including for example use of jigs

Once the method has been developed and optimised it should be implemented as standard operating procedure (SOP) to reduce variations in time and quality and provide a basis for training and continuous improvement.

Designing of the new manufacturing system will also involve systematic layout planning (SLP) for factory level design. The first stage of SLP involves looking at material flows. Then the activity relationships might be considered using a closeness rating. An activity relationship chart could be used to analyse the closeness ratings of all the separate operations. Then a space relationship diagram can be developed to analyse how the production layout could fit into the new factory.

Finally adjustments and allowances should be made to take account limiting factors such as the shape/site of the building, locations of drop off points, fire exits, regulations etc.

(c) When moving to a new location the following might be considered:

- Labour force: what are the available levels of skill and how much available labour is there?
- Local culture: what is the local culture like? This will have effects on the attitude of the labour and the attitudes of locals towards the installation of a new factory.
- Supply: availability of raw materials and sub-assemblies
- Regulations: environmental regulations may influence things like waste and pollution; minimum wage rates will affect labour costs.
- Proximity to markets, transportation costs and lead times will be affected by distances from suppliers to buyers.
- Infrastructure: existing roads, railways, etc. will affect transportation of goods and people.
- Financial: what are the financial implications of moving to this new location?

Question No. 4

Taichi Ohno's 7 key forms of waste are:

Transportation – unnecessary movement of goods during distribution/handling within the factory.

Inventory – excess inventory - a cause of inefficiency and unnecessary costs.

Motion – unnecessary material handling, product flow, distances and labour movements.

Waiting – delays and waiting - direct wastes of time and labour/efficiency costs.

Overproduction – finished goods inventory or stock that cannot be sold/is not demanded.

Over processing – putting material through unnecessary steps without optimising flow or layout.

Defects – which waste time, reduce OEE and increase quality problems.

With the rise of the service industry, these may sometimes be extended to include customer time wasted, office space (heating, water, insurance) waste and wasted potential of workers. Such factors may have some relevance to the manufacturing sector too.

SMED was a concept first coined by Shingo . Single minute exchange of dies' aims to dramatically reduce set up times and create much higher OEEs through increased machine availability. It includes the following steps:

1. Choose a process to apply SMED to. Analyse this process closely, recording the stages required for a set up to take place meticulously.
2. Break down the process into elements or small tasks separating:
   - variable and constant tasks e.g. (typing a word/code = variable time, pressing button = constant)
   - machine tasks/automated tasks and manual tasks
   - regular (every cycle) and irregular tasks (periodic tasks)
   - internal and external tasks
   - tasks using different tools, body parts
   - independent tasks
3. Categorise all of these tasks/elements into 3 types:
   (i) Internal tasks – these must be completed whilst the machine has stopped.
   (ii) External tasks – these must be completed while the machine runs.
   (iii) Waste/'MUDA' tasks – processes that add no value to the set up.
4. Then
   - eliminate all mudas tasks (waste)
   - externalise internal set ups as far as possible
   - minimise the times taken for all the internal tasks.

   Do external tasks before machine stops running. Techniques include:

   Internal Tasks

   - use quick fit connections
   - use jigs, pre fixed parts or previously set-up products
   - use 7 turn bolts, U-shaped washers instead of O-shaped washers
   - avoid fiddly fixtures
   - use 2 workers instead of 1 to perform tasks

External Tasks

- pre-program the machine; don't stop the machine until absolutely ready to perform internal tasks
- use a tool layout or standardised set-up trolley or kit to allow quick access to all tools upon use. Arrange tools for easy grasp and ergonomic use.
- combine tools.

When the optimum set-up procedure has been established, this should be documented in a standard operating procedure. This is how the set-up will be taught to trainees. This should be periodically reviewed and continuously improved (kaizen).

Shingo achieved some reductions in set-up times of up to 90% using this approach – it reduces many factors in line with lean manufacture, notably waiting (the machine during idle internal task time), motion and over processing. Having a clear SOP also reduces defects and increases quality, in line with lean manufacture.

Lean approaches do have some potential disadvantages.

- Reputation and intangible effects may also make lean manufacturing less appealing. It is likely that any shop with a store on e.g. Regent Street or Oxford Street in London incurs large wasted transportation costs due to the high traffic and limited access problems for delivery. However, due to the reputation of these shopping venues, it is profitable for the company to incur this waste.
- Lead times may be really important e.g. MK Electric was happy to incur higher transportation costs and motion costs to fly plugs to the Middle East if a low lead time was of significant value to the deal.
- Inventory has several benefits – it is a buffer against uncertainty of supply or demand, allows lower commodity costs/economics of scale to be taken advantage of, and allows the EOQ model to be used. These benefits may all suggest that inventory 'waste' will be financially viable and increase stability in volatile markets e.g. Mars and cocoa buying.
- Competitive effects – Nokia bought up the whole remaining stock when a key component provider's factory burnt down, forcing Ericsson to be bailed out by Sony as this was the sole provider. This was not lean but allowed them market domination.