THE DESIGN CORE

MANUFACTURE

Plant location

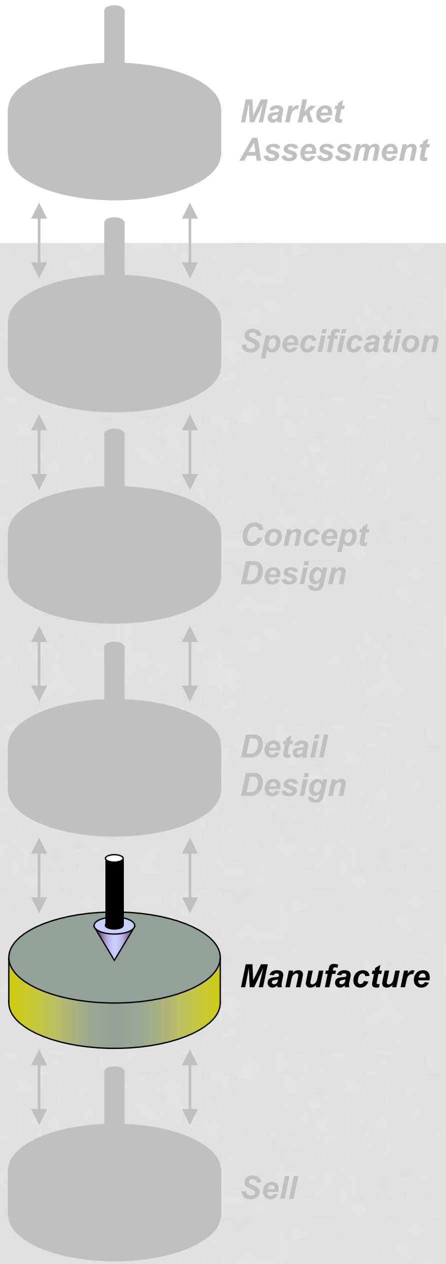
Plant layout

Production scheduling

Critical path analysis

Materials requirement planning

Just in Time management

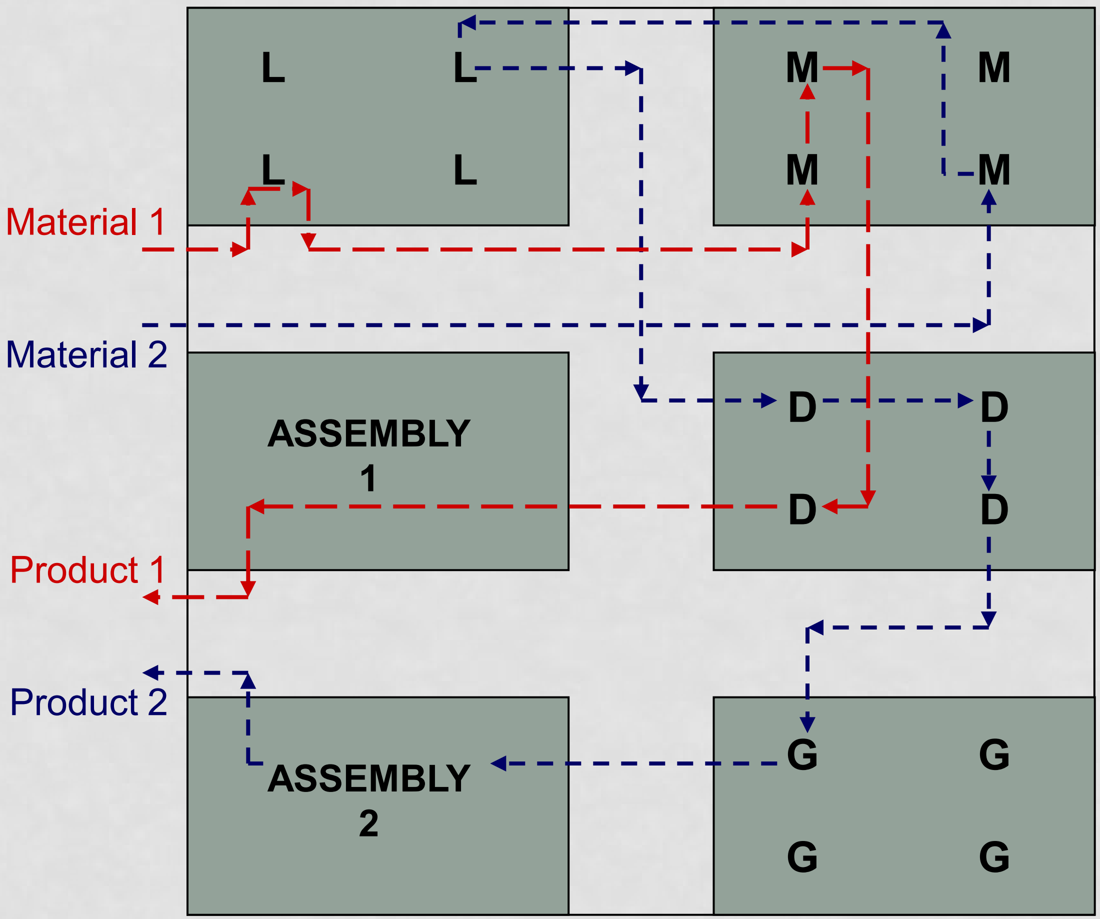


PLANT LOCATION

	Criterion	Weighting	Possible Factory Location									
			A		B		C		D		E	
PROXIMITY TO:	Skilled labour	7	2	14	3	21	0	0	1	7	4	28
	A pool of unskilled labour	8	5	40	2	16	0	0	4	32	2	16
	A motorway	7	3	21	2	14	1	7	3	21	4	28
	An airport	4	1	4	3	12	4	16	2	8	2	8
	The sea / a river	0	2	0	5	0	5	0	2	0	1	0
	Housing	5	4	20	3	15	0	0	3	15	4	20
	Amenities	5	3	15	2	10	0	0	2	10	3	15
Potential for expansion		7	2	14	1	7	5	35	3	21	2	14
Availability of grants/incentives		8	1	8	2	16	5	40	1	8	3	24
Safety		2	3	6	2	4	5	10	2	4	2	4
Planning constraints		5	2	10	3	15	5	25	4	20	2	10
Environmental impact		4	3	12	2	8	4	16	1	4	2	8
		TOTAL		164		138		149		150		175

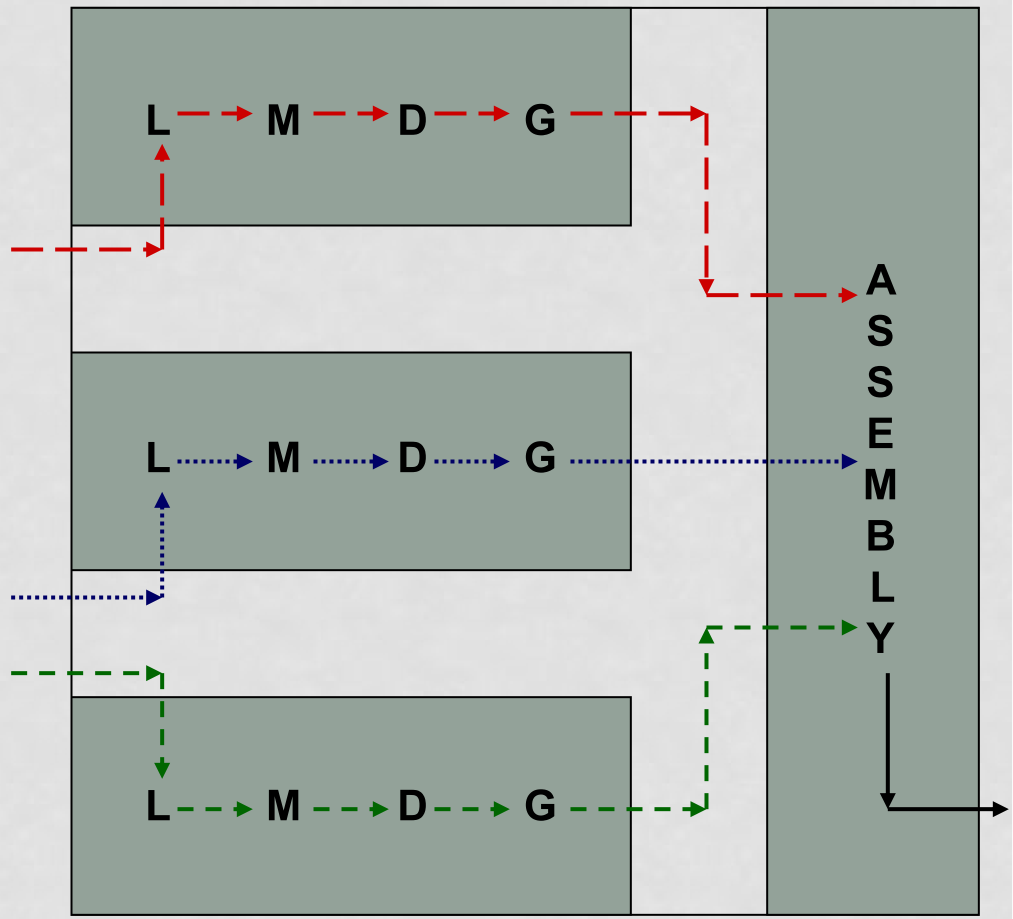
'FUNCTIONAL' PLANT LAYOUT

- Common for a large variety of products in batch volumes.
- Similar processes are grouped together.
- Inefficient: Long material transport routes from dept. to dept. Work in progress is high. Tracking of orders can be difficult.
- Advantages: Specialist labour and supervision. Flexibility as material can be rerouted in any sequence.



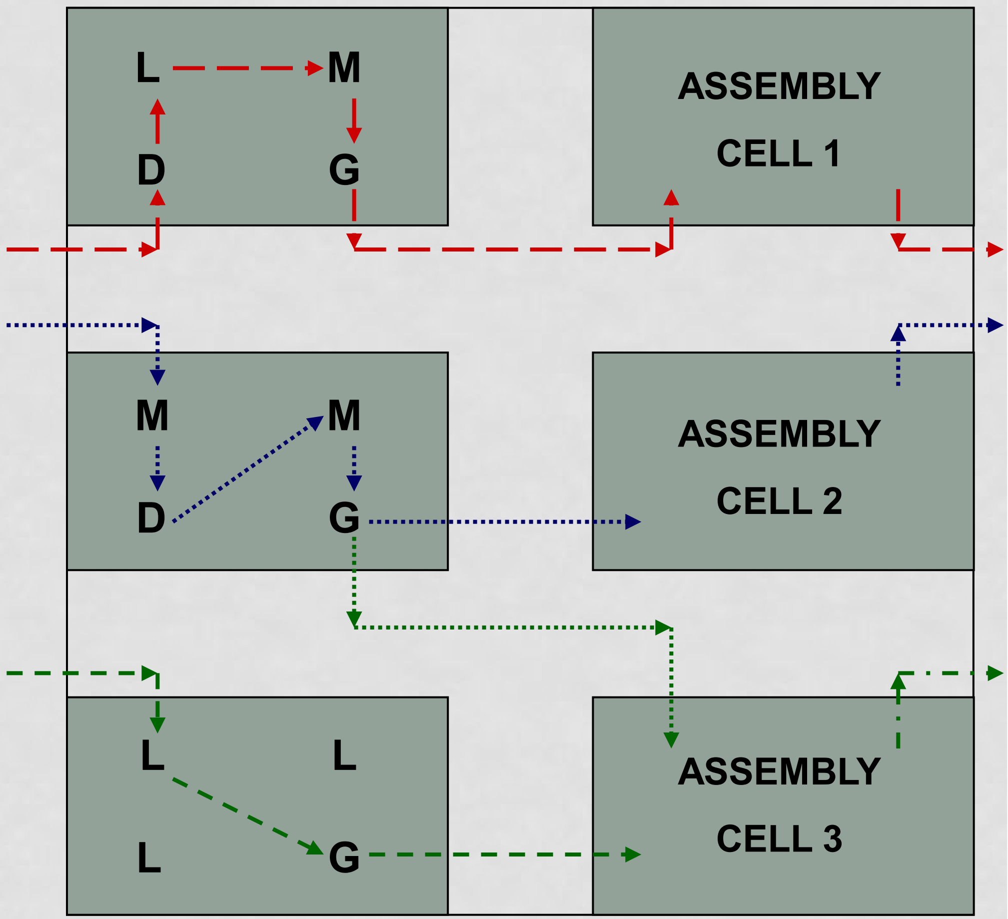
‘PRODUCT’ PLANT LAYOUT

- Mass production where variety is small and production volumes are very high.
- AKA ‘flow’ or ‘line’ layout.
- More efficient, but less flexible than ‘functional’ layout.
- Work in progress is minimised, and jobs are easily tracked.
- Investment in specialised capital equipment is high, so a reliable and steady demand is required.
- Very sensitive to machine breakdown or disruption to material supply.



'CELLULAR' PLANT LAYOUT

- AKA 'Group Technology'
- Each cell manufactures products belonging to a single family.
- Cells are autonomous manufacturing units which can produce finished parts.
- Commonly applied to machined parts.
- Often single operators supervising CNC machines in a cell, with robots for materials handling.
- Productivity and quality maximised. Throughput times and work in progress kept to a minimum.
- Flexible.
- Suited to products in batches and where design changes often occur.



DESIGNING A 'CELLULAR' LAYOUT

A company produces 16 specialist tools.
The company is planning to relocate and reorganise production with a 'cellular' layout, with cells containing 5-7 machines each.
Production involves 10 types of machine: L1, L2, L3, D1, D2, M1, M2, G1, G2, F.
4 machines of each type are used, except D2 of which there is only 1.

First draw up a table of part routes.

Part	Route	Part	Route
1	L1,L2,M1,D1,G1,F	9	L3,M1,G2,M1,D1,G2
2	L1,M1,D1,G2,F	10	L2,L3,M1,G1,G2,F
3	L2,M1,D1,M2,G1	11	L2,M1,G1,M1,G2,F
4	L2,D1,M1,M2,G2,G1	12	L1,L2,M1,D1,M2,G1
5	L1,L2,M2,G1,D2,G2	13	L1,L3,M1,D1,G2,F
6	L2,M1,D1,G2,G1	14	L3,M1,G1,M1,G1,G2,F
7	L1,M1,D1,G1,D1,G1,F	15	L1,M2,D2,G1,G2
8	L2,D2,G1,D2,G1,G2	16	L1,M1,D1,M2,G1,F

DESIGNING A 'CELLULAR' LAYOUT

Draw-up a machine-part incidence matrix

Part	Machine									
	L1	L2	L3	D1	D2	M1	M2	G1	G2	F
1	1	1		1		1		1		1
2	1			1		1			1	1
3		1		1		1	1	1		
4		1		1		1	1	1	1	
5	1	1			1		1	1	1	
6		1		1		1		1	1	
7	1			1		1		1		1
8		1			1			1	1	
9			1	1		1			1	
10		1	1			1		1	1	1
11		1				1		1	1	1
12	1	1		1		1	1	1		
13	1		1	1		1			1	1
14			1			1		1	1	1
15	1				1		1	1	1	
16	1			1		1	1	1		1

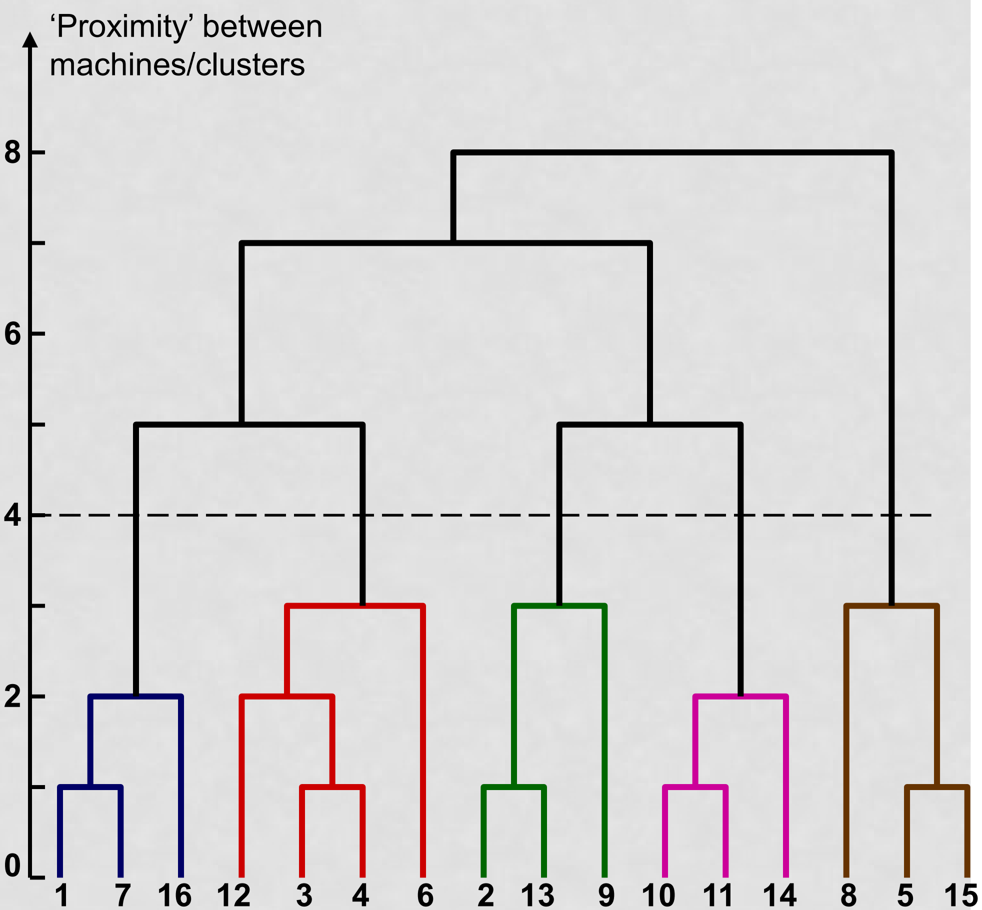
'Proximity' between machines

$$d_{pq} = \sum_{j=1}^{n} \left| a_{pj} - a_{qj} \right|$$

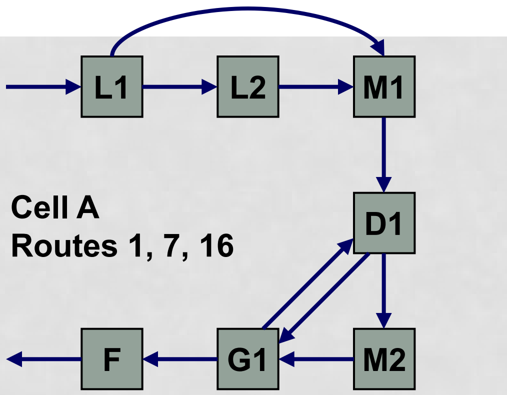
a=1 used
a=0 not used

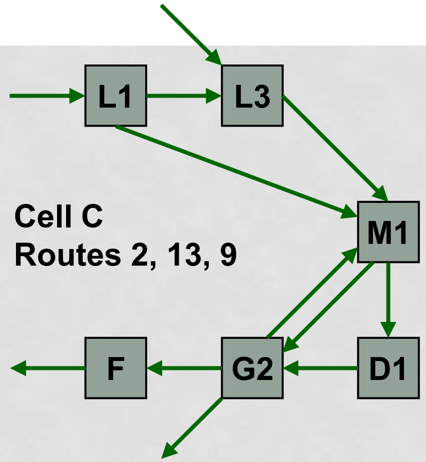
e.g. p=1, q=2 then d_{12}=3 (L2,G1,G2)

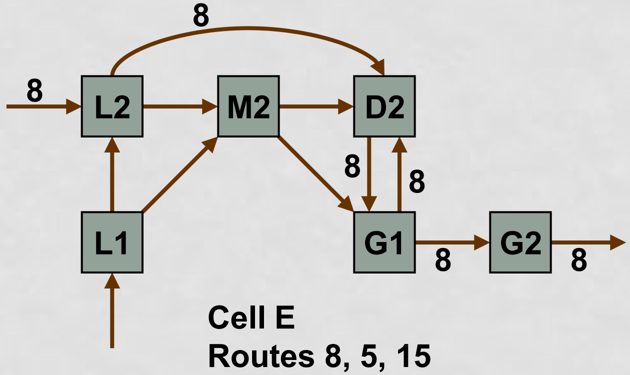
Construct a dendrogram based on pairs of closely related machine routes

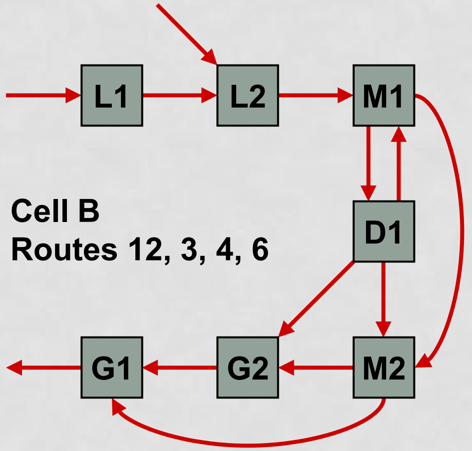


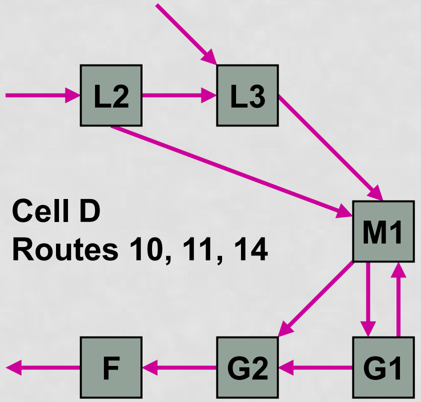
DESIGNING A 'CELLULAR' LAYOUT











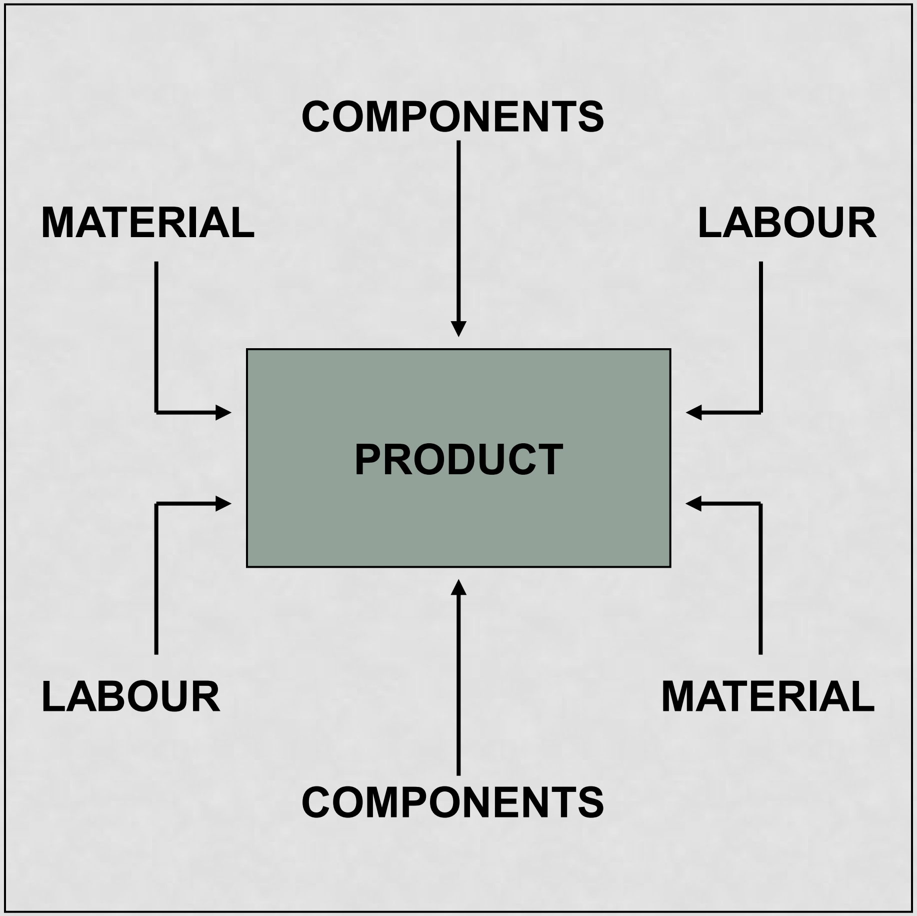
Machine	No. before	No. after
L1	4	4
L2	4	4
L3	4	2
D1	4	3
D2	1	1
M1	4	4
M2	4	3
G1	4	4
G2	4	4
F	4	3
Total	37	32

OTHER PLANT LAYOUTS

'Fixed Position' Layout (right)
• Single large, high cost components or products.
• Product is static. Labour, tools and equipment come to the work rather than vice versa.

'Random' Layout
• Very inefficient
• Small factories, start-up companies.

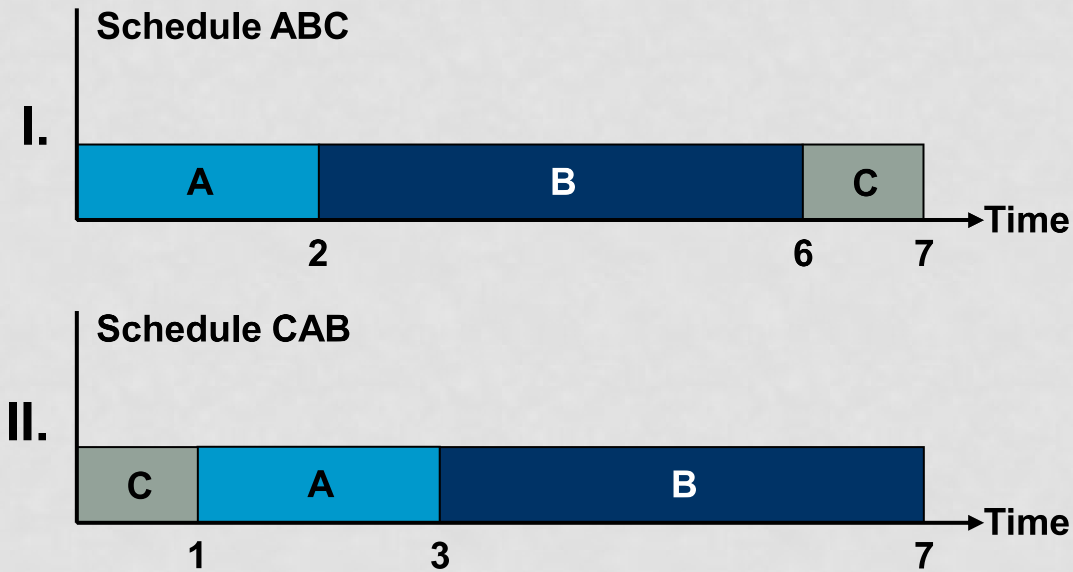
'Process' Layout
• Process industries, e.g. steelmaking.
• The process determines layout.



SINGLE MACHINE SCHEDULING

Shortest Processing Time (SPT)

Henry L. Gantt, Frankford Arsenal, USA



+ 1 h delivery time to customer

Average customer waiting time:

I. (3+7+8)/3 = 6 h

II. (2+4+8)/3 = 4 $^{2}/_{3}$ h

$\Rightarrow$ Shortest jobs before longer jobs

Others

Minimise average processing time

WSPT Schedule in order of weighted shortest processing time

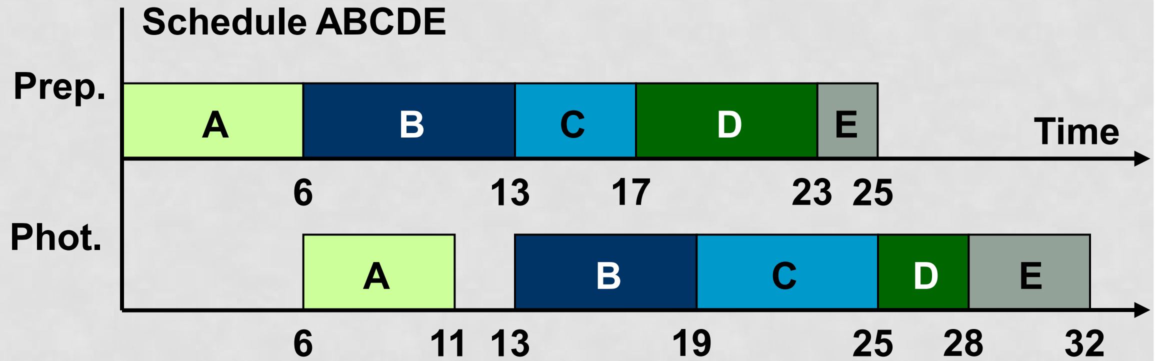
Minimise average delay

EDD Schedule in order of earliest due date

WEDD Schedule in order of weighted earliest due date

SCHEDULING OPERATIONS IN SERIES

Sample:	A	B	C	D	E
Time to prepare (h)	6	7	4	6	2
Time to photograph (h)	5	6	6	3	4

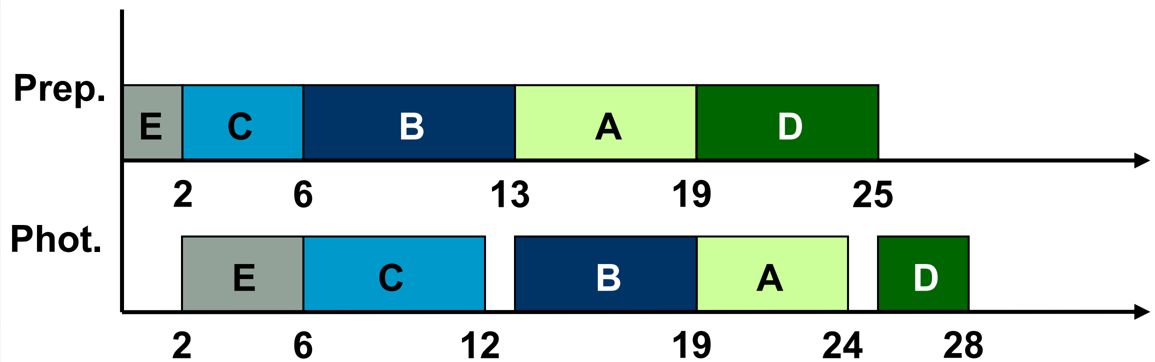


Johnson's Algorithm

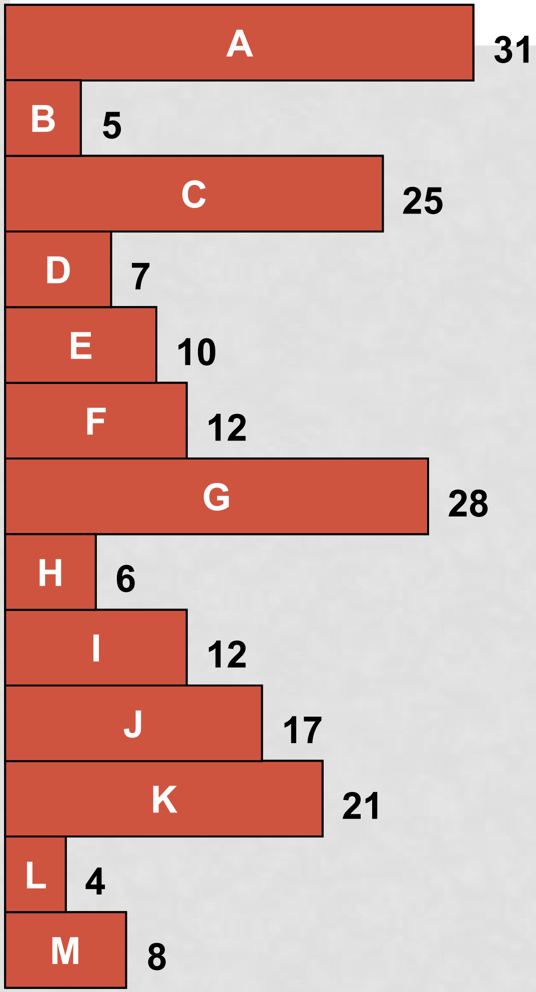
Step 1. Find next job with the shortest processing time on either machine.

Step 2. If on 1st machine then schedule at next earliest position.

Step 3. If on 2nd machine then schedule at next latest position.



SCHEDULING MACHINES IN PARALLEL



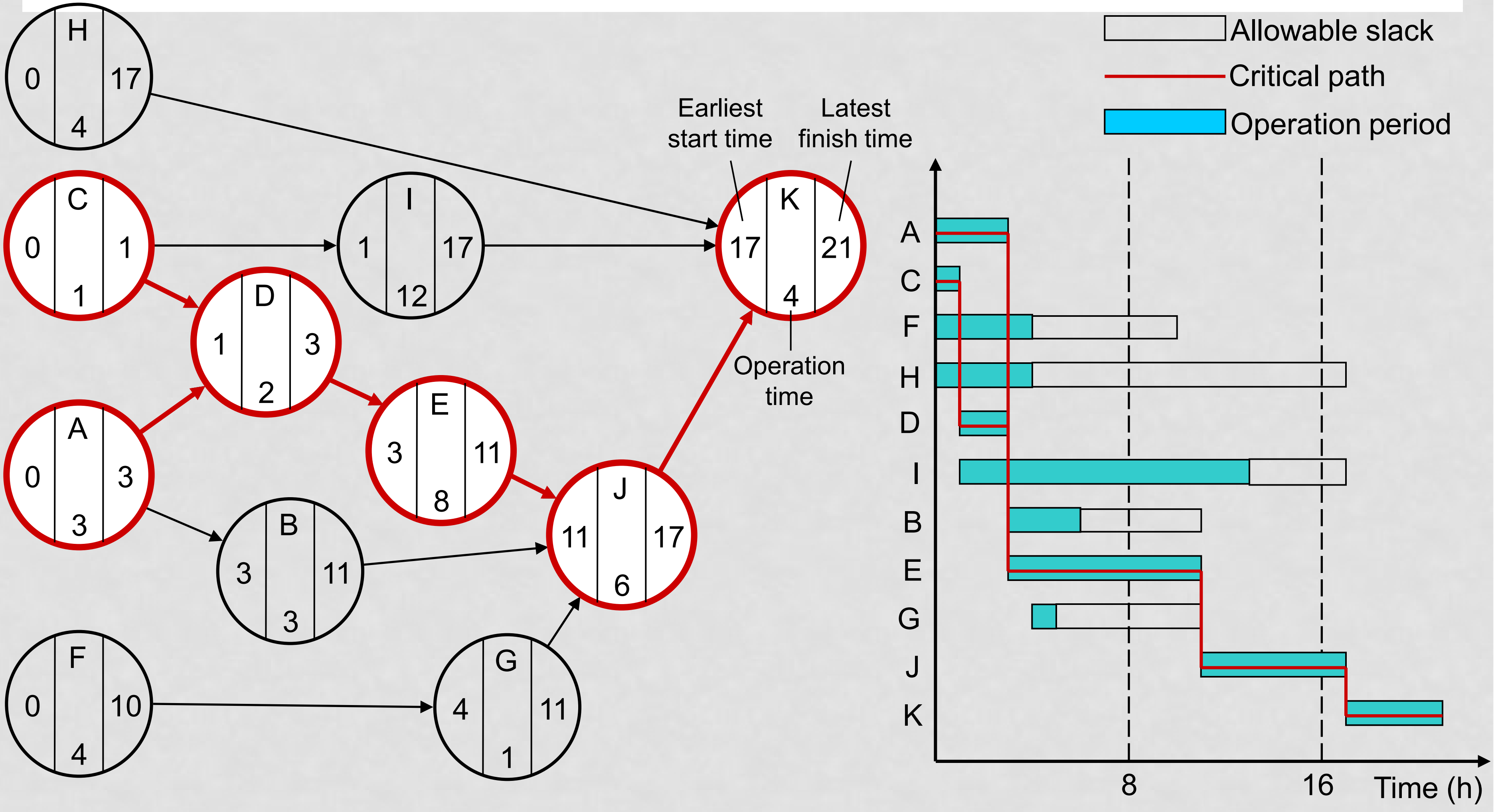
Greedy heuristic: Biggest job first.
Schedule next longest job
on next available machine

CRITICAL PATH ANALYSIS

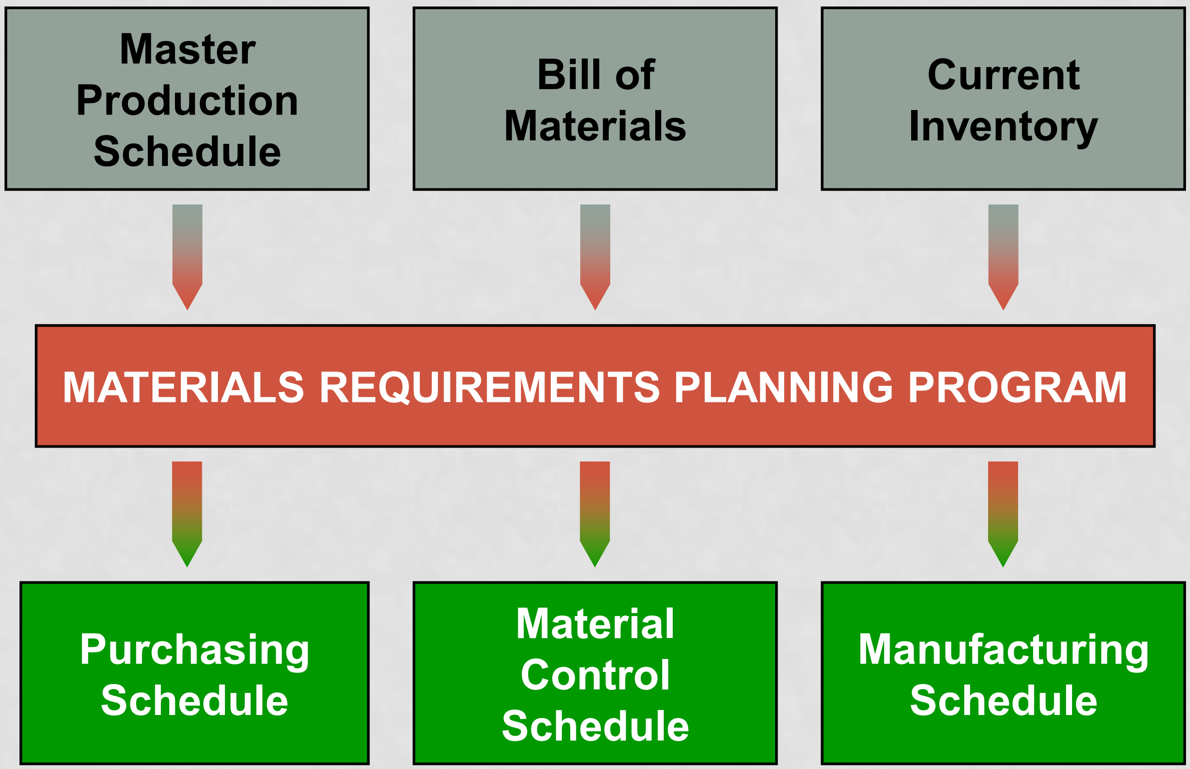
More complex scheduling involving operations in parallel and in series

Operation	Time Required (h)	Predecessors	Earliest finish time of predecessors	Earliest Start
A	3	-	-	0
B	3	A	3(A)	3
C	1	-	-	0
D	2	C	1(C)	1
E	8	A, D	3(A), 1+2(D)	3
F	4	-	-	0
G	1	F	4(F)	4
H	4	-	-	0
I	12	C	1(C)	1
J	6	B, E, G	3+3B, 3+8(E), 4+1(G)	11
K	4	H, I, J	4(H), 1+12(I), 11+6(J)	17

CRITICAL PATH ANALYSIS



MATERIALS REQUIREMENT PLANNING (MRP)



MASTER PRODUCTION SCHEDULE (MPS)

A production plan showing period by period anticipated production of finished items

N.B. It is not a sales forecast, though expected sales are a consideration

Planning period depends on manufacturing lead time etc.

Week	5	6	7	8	9	10		41	42			
Product P65	10	0	20	0	20	0		20	0			
Product K92	15	20	20	25	15	20		20	20			
Product U37	30	35	5	45	30	30		30	30			

Current week

MPS is updated in a rolling fashion: adding one or more periods to the far end of the production schedule as well as updating the amounts to be produced

MASTER PRODUCTION SCHEDULE (MPS)

Product P65

Current stock on hand =

Current week: **4**

Week	5	6	7	8	9	10		41	42			
Forecast demand	10	10	10	10	10	10		10	10			
MPS		0	20	0	20	0		20	0			
Orders accepted			5	0	2	0		0	0			
Available to promise		0	15	0	18	0		20	0			

(Current stock + MPS) – (Total orders to next production run) = Stock available to promise

[10 + 10] - [8 + 8] = 4

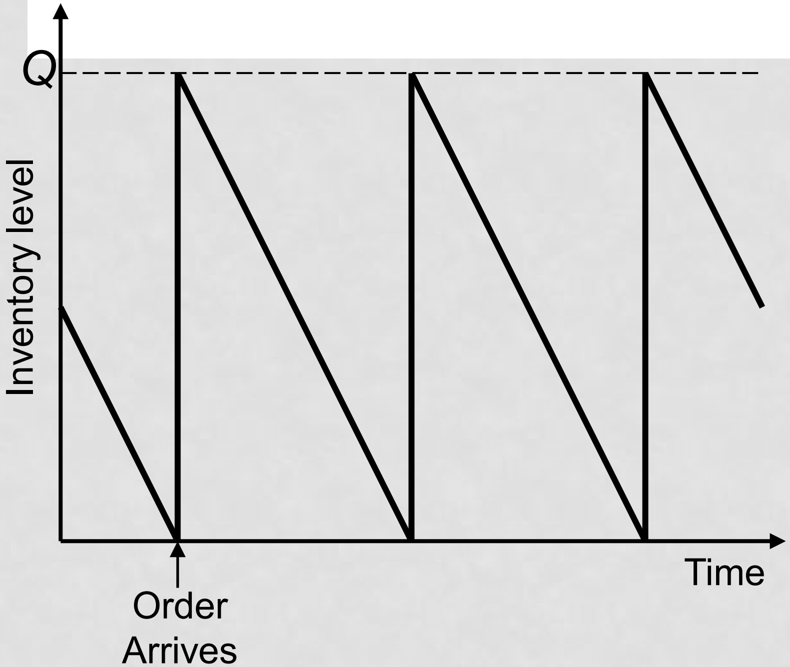
MASTER REQUIREMENTS PLANNING (MRP)

Product P65
Current stock on hand = 10

Planning period (weeks 4–6)

Week		1	2	3	4	5	6	…	37	38			
Gross requirements		10	20	10		0			20	20			
Scheduled receipts		10	25										
Net requirements									20	20			
Planned order receipts									40				
Planned order releases			35										
Projected inventory	10	10	15						20	0			

ECONOMIC ORDER QUANTITY



For a given continuous demand rate, inventory can be controlled with large order sizes Q ordered at low frequencies or small order sizes ordered at high frequencies. What is the optimum value of $Q = Q^*$?

Let
C_0 = Cost of placing an order,
C_H = Cost (per year) of holding a single unit in stock
D = Demand rate (no. units per year)

No. orders per year = D/Q

Total cost of ordering stock per year = $C_O D/Q$
Holding cost per year is $C_H \times Q/2$ (average stock level)

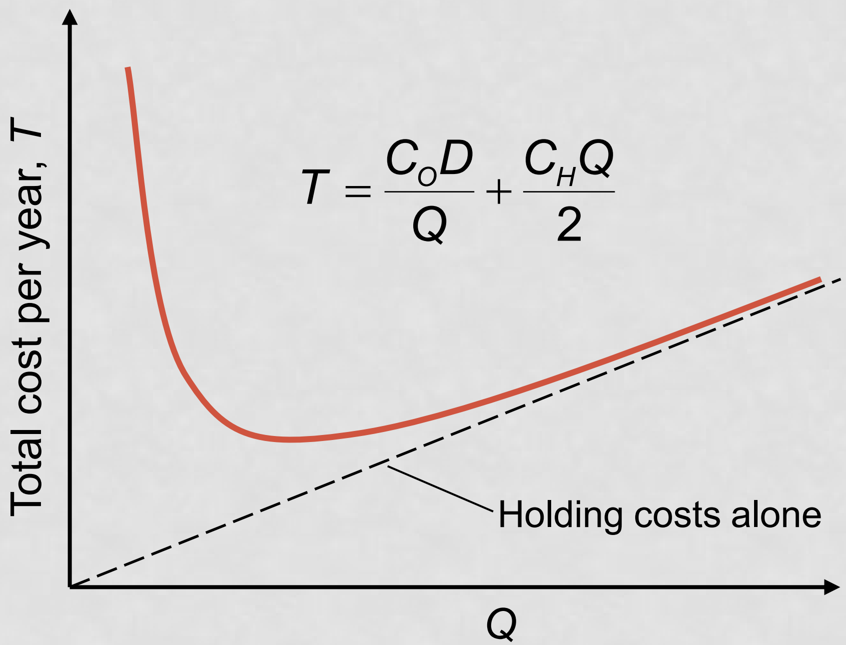
Total cost per year, $$T = \frac{C_O D}{Q} + \frac{C_H Q}{2}$$

To minimize cost set $$\frac{dT}{dQ} = -\frac{C_O D}{Q^2} + \frac{C_H}{2} = 0$$

So the **economic order quantity**, $$Q^* = \left(\frac{2C_O D}{C_H}\right)^{1/2}$$

ECONOMIC ORDER QUANTITY

The flat minimum phenomenon



Demand is never truly predictable.
What happens if we get the value of Q slightly wrong?

Suppose that instead of ordering Q^*, we order an amount $Q = Q^*(1+\delta)$

$$T = \frac{C_O D}{Q^*(1+\delta)} + \frac{C_H Q^*(1+\delta)}{2}$$

$$= \frac{C_O D}{(1+\delta)}\left(\frac{C_H}{2DC_O}\right)^{1/2} + \frac{C_H(1+\delta)}{2}\left(\frac{2C_O D}{C_H}\right)^{1/2}$$

$$= \left(\frac{DC_O C_H}{2}\right)^{1/2}\left[\frac{1}{1+\delta} + 1 + \delta\right]$$

$$= \left(\frac{DC_O C_H}{2}\right)^{1/2}(1 - \delta + \delta^2 - \delta^3 \ldots + 1 + \delta)$$

So, $T \approx (2DC_O C_H)^{1/2}(1 + \delta^2/2)$

Even if we over-order by 10%, the cost of the stock is only increased by about 0.5%.

JUST IN TIME MANUFACTURE (JIT)

A system of organising manufacturing, the essence of which is to remove waste, particularly in the waste of time and resources associated with stocks held at different stages of the manufacturing process.

Reduction of batch sizes

Large batch sizes are costly to produce (large amounts of stock, long time to produce the whole batch before reaping a return). JIT philosophy is to reduce batch sizes towards unity.

Reduction of set-up times

Each batch is costly in set-up time. Achieving small batch sizes requires the strive towards reduced set-up times. Achieved with, e.g. reprogrammable equipment, quick change tooling, storage of tooling close to machine etc.

Reduction of buffer inventories

Materials, sub assemblies, part processed parts etc. in queues/storage are costly and inefficient. They cost money rather than make money.

Frequent deliveries and long term relationships with suppliers

Reduced batch sizes and buffer inventories require small, but frequent deliveries often on demand. Suppliers viewed as partners rather than adversaries.

JUST IN TIME MANUFACTURE (JIT)

Short lead times

Results in increased responsiveness to customer requirements and therefore increased competitiveness.

Simple material flows and reduced floor space

'Product' or 'cellular' plant layouts are essential to ensure smooth flow of material through the factory. The 'functional' layout results in too much work in progress.

Teamwork and a motivated workforce

The sensitivity of the system to down-time requires that problems are solved quickly, and by all concerned. Problem solving and continual improvement cannot be achieved without consultation and involvement of the workforce who are the people on the shop floor that know the operations best.

Workers responsible for the quality of their own work

Workers on the shop floor should think of themselves as making parts rather than just operating a machine. 'Non-productive' costs such as education of the workforce should be viewed as necessary.

Visibility of performance

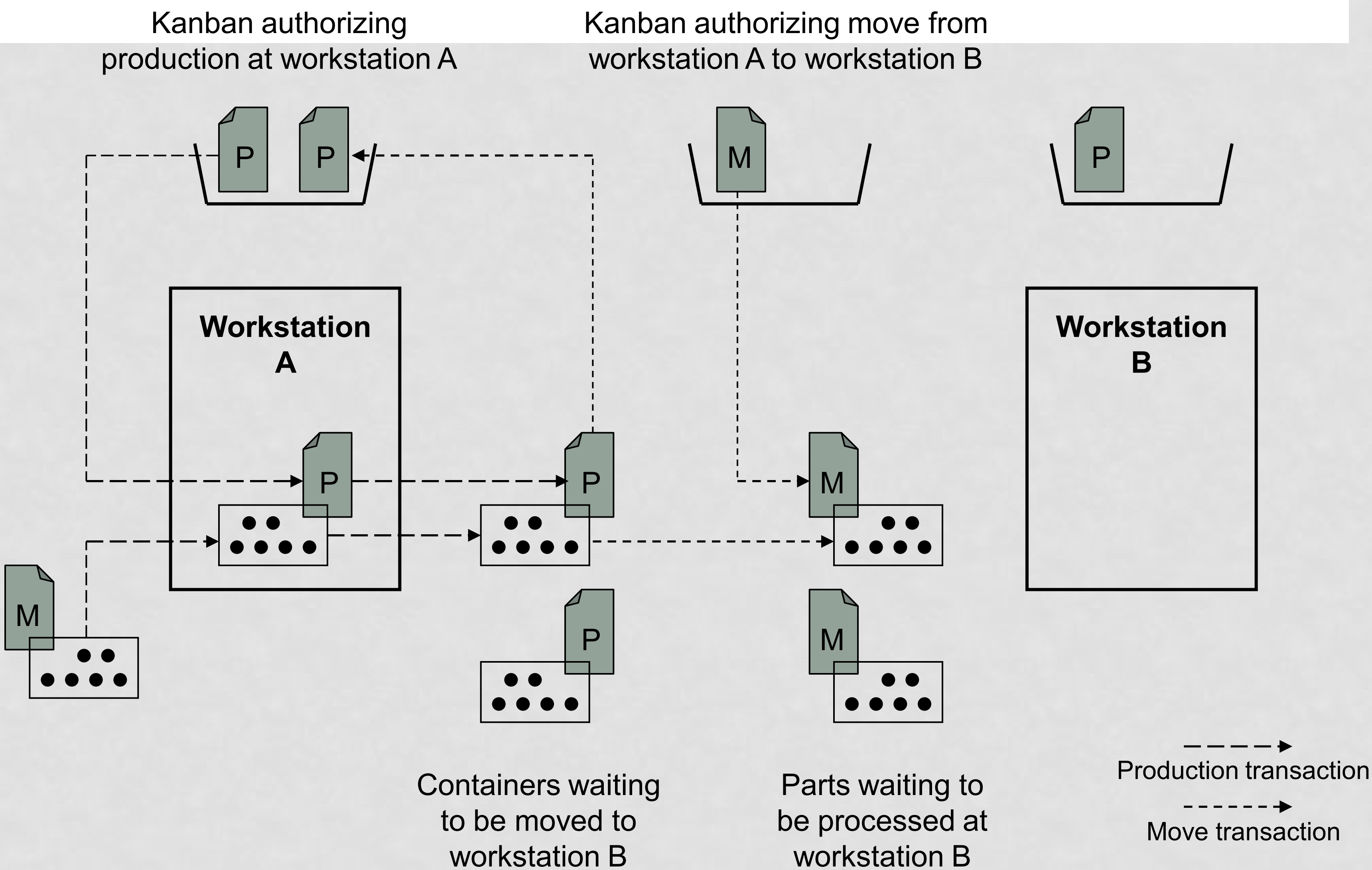
Simple flow of material allows each member of the workforce to see how their work fits into the rest of the factory, and therefore allows rapid problem solving.

MATERIAL CONTROL IN JIT: KANBAN

Kanban
A card or docket that authorizes either processing of a part at a particular workstation, or movement of parts between workstations.

- Nothing can be made without an authorizing kanban from the next process in line.
- Kanban system ensures nothing is made that is not required, and everything is made just in time.
- Kanbans specify the item, number to be used in each batch, stocking locations, the material required and where to find it.
- Production-kanbans move with the parts as they are processed, with a different production-kanban for each operation.
- Move-kanbans remain between one workstation and the next.
- In both cases there is a well defined quantity of parts referred to that are kept in a container holding exactly that number.

A KANBAN SYSTEM



THE KANBAN SYSTEM

The amount of inventory in the system is determined by the number of kanbans.

If demand stops suddenly then production continues until every kanban is attached to a full container. Represents the maximum amount of inventory possible.

If a reduction in inventory of the system is required then it is achieved by simply reducing the number of kanbans.

Kanban system is highly visible. No need for extensive computation to track requirements in the factory.

Only works well for repetitive production, and for a relatively stable level of demand.

Kanban is a 'pull system' where parts are only processed at one workstation when there is a requirement from the following workstation. In a 'push system' parts are continued to be processed at workstation A whether or not they are required at workstation B. If they are not required at B, e.g. due to machine failure, then parts processed at A queue up to be processed at B and inventory levels rise unnecessarily and control of inventory becomes difficult. However, in the kanban system if one workstation fails then authorization for movement to that workstation stops and the whole process comes to a halt. The system therefore demands strict discipline in maintenance.

THE DESIGN CO

SELL

That’s another story!