Global and Southern African Perspectives

Operations Management

3rd Edition

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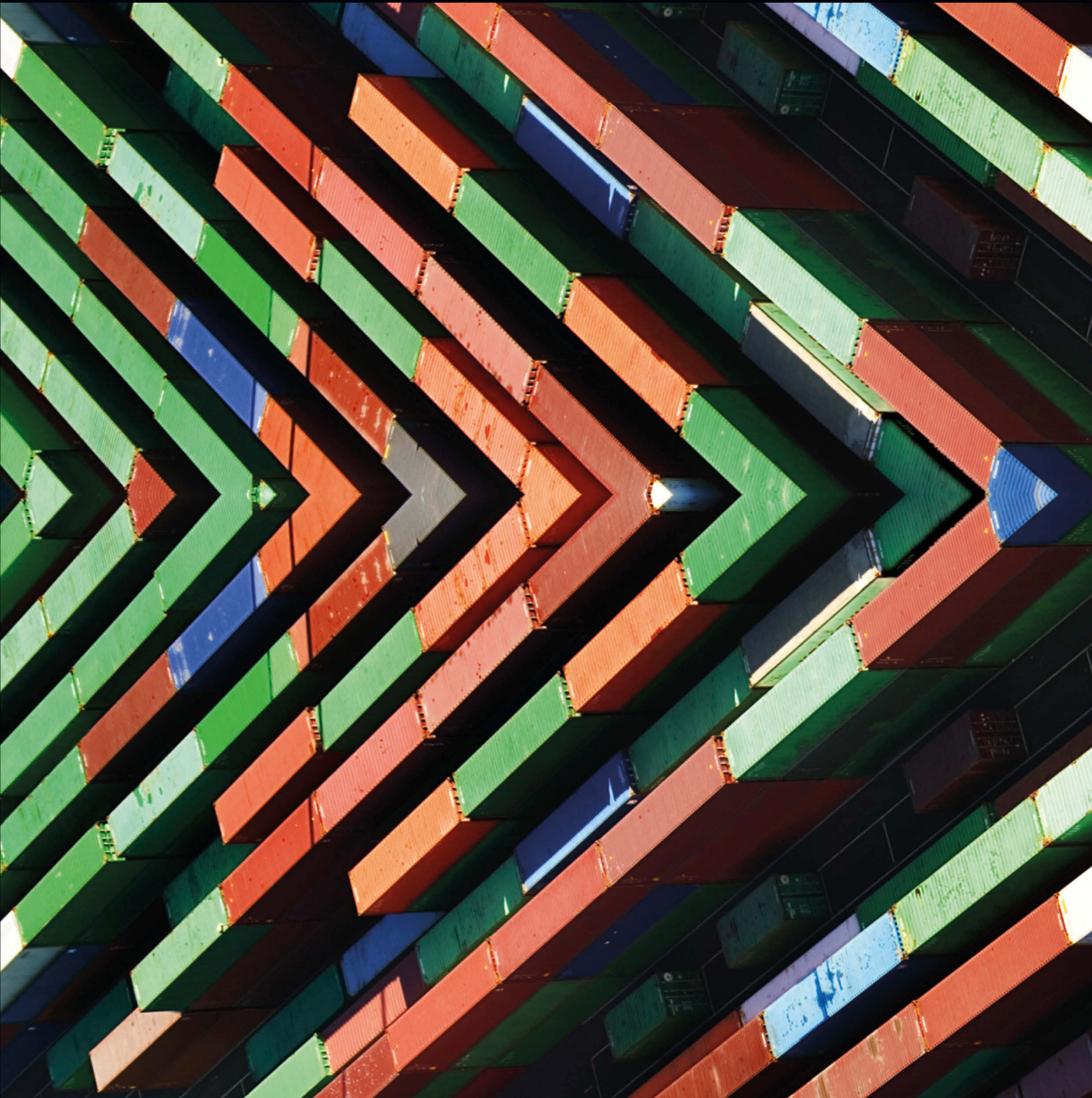

Pearson South Africa (Pty) Ltd
4th floor, Auto Atlantic Building, Corner of Hertzog Boulevard and Heerengracht, Cape Town, 8001

Offices in Johannesburg, Durban, East London, Polokwane, Bloemfontein, Rustenburg and Mbombela.

website: za.pearson.com

Authorised adaptation from the original UK edition, entitled Operations Management 07 Edition (ISBN: 978-0-273-77620-8) by Slack, Brandon-Jones & Johnston, published by Pearson Education Limited © Nigel Slack, Stuart Chambers, Christine Harland, Alan Harrison and Robert Johnston 1995, 1998; Nigel Slack, Stuart Chambers and Robert Johnston 2001, 2004, 2007; Nigel Slack, Alistair Brandon-Jones and Robert Johnston 2014.

This adaptation is published by Pearson Education South Africa © 2017 by arrangement with Pearson Education Ltd, United Kingdom.

First published in 1997
Second edition 2010
Third edition 2017

Print ISBN 978-1-775-78934-5
ePDF ISBN 978-1-775-95660-0

Publisher: Lize Terblanche
Editor: Alison Paulin
Proofreader: Derika van Biljon
Indexer: Ellen du Toit
Book design: Natalie McCulloch
Cover design: Lynn Siljeur
Artwork: Damian Gibbs
Typesetting: Natalie McCulloch
Remediation and ePDF by Deon Schutte (Publishing Collective)
Printed by

Acknowledgements
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- the degree and direction of flow between each work centre (for example, number of journeys, number of loads or cost of flow per distance travelled)
- the desirability of work centres being close together or close to some fixed point in the layout.

The degree and direction of flow are usually shown on a flow record chart like that shown in Figure 7.9(a) which records in this case the number of loads transported between departments. This information could be gathered from routing information, or where flow is more random, as in a library for example, the information could be collected by observing the routes taken by customers over a typical period of time. If the direction of the flow between work centres makes little difference to the layout, the information can be collapsed as shown in Figure 7.9(b), an alternative form of which is shown in Figure 7.9(c). There may be significant differences in the costs of moving materials or customers between different work centres. For example, in Figure 7.10(d) the unit cost of transporting a load between the five work centres is shown. Combining the unit cost and flow data gives the cost per distance travelled data shown in Figure 7.9(e). This has been collapsed as before into Figure 7.9(f).

(a) LOADS/DAY

From \ To	A	B	C	D	E
A		17	–	30	10
B	13		20	–	20
C	–	10		–	70
D	30	–	–		30
E	10	10	10	10	

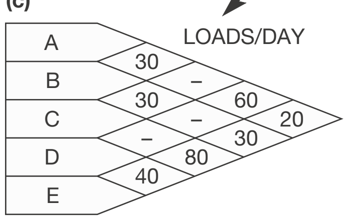
If direction is not important, collapses to

(b) LOADS/DAY

	A	B	C	D	E
A		30	–	60	20
B			30	–	30
C				–	80
D					40
E					

or alternatively

(c)



If cost of flow differs between work centres, combine with

(d) UNIT COST/DISTANCE TRAVELLED

From \ To	A	B	C	D	E
A		2	2	2	2
B	3		3	3	3
C	2	2		2	2
D	10	10	10		10
E	2	2	2	2	

to give

(e) DAILY COST/DISTANCE TRAVELLED

From \ To	A	B	C	D	E
A		34		60	20
B	39		60		60
C		20			140
D	300	–			300
E	20	20	20	20	

If direction is not important, collapses to

(f) DAILY COST/DISTANCE TRAVELLED

	A	B	C	D	E
A		73		360	40
B			80		80
C					160
D					320
E					

FIGURE 7.9 **Collecting information in functional layout**

Minimising distance travelled

In most examples of functional layout, the prime objective is to minimise the costs to the operation which are associated with flow through the operation. This usually means minimising the total distance travelled in the operation. For example, Figure 7.10(a) shows a simple six-centre functional layout with the total number of journeys between centres each day. The effectiveness of the layout, at this simple level, can be calculated from:

Effectiveness of layout = $\Sigma F_{ij} D_{ij}$ for all $i \neq j$

where F_{ij} = the flow in loads or journeys per period of time from work centre i to work centre j

D_{ij} = the distance between work centre i and work centre j.

The lower the effectiveness score, the better the layout. In this example the total of the number of journeys multiplied by the distance for each pair of departments where there is some flow is 4,450 metres. This measure will indicate whether changes to the layout improve its effectiveness (at least in the narrow terms defined here). For example, if centres C and E are exchanged as in Figure 7.10(b), the effectiveness measure becomes 3,750, showing that the new layout now has reduced the total distance travelled in the operation. These calculations assume that all journeys are the same in that their cost to the operation is the same. In some operations this is not so, however. For example, in the hospital some journeys involving healthy staff and relatively fit patients would have little importance compared with other journeys where very sick patients need to be moved from the operating theatres to intensive-care wards. In these cases a cost (or difficulty) element is included in the measure of layout effectiveness:

Effectiveness of layout = $\Sigma F_{ij} D_{ij} C_{ij}$ for all $i \neq j$

where C_{ij} = the cost per distance travelled of making a journey between departments i and j.

The steps in determining the location of work centres in a functional layout is illustrated in the worked example on the Dibeng Learning Organisation.

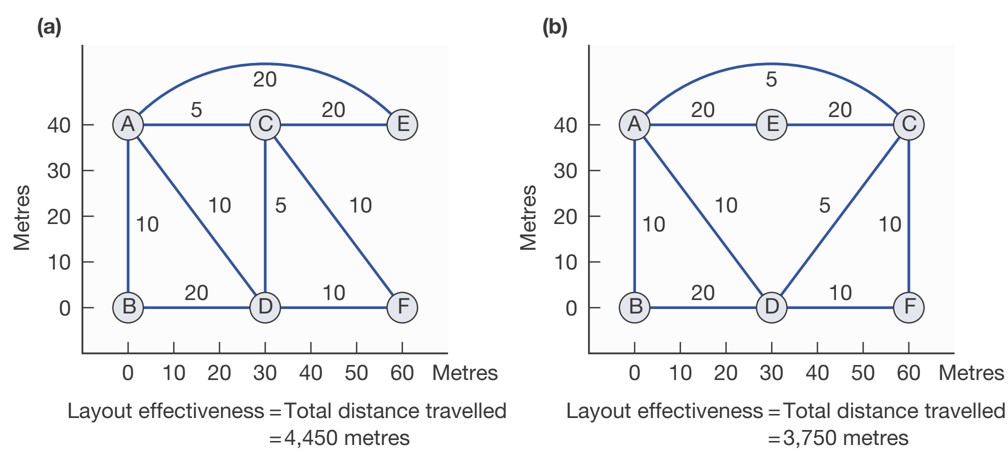


FIGURE 7.10 **(a) and (b) The objective of most functional layouts is to minimise the cost associated with movement in the operation, sometimes simplified to minimising the total distance travelled**

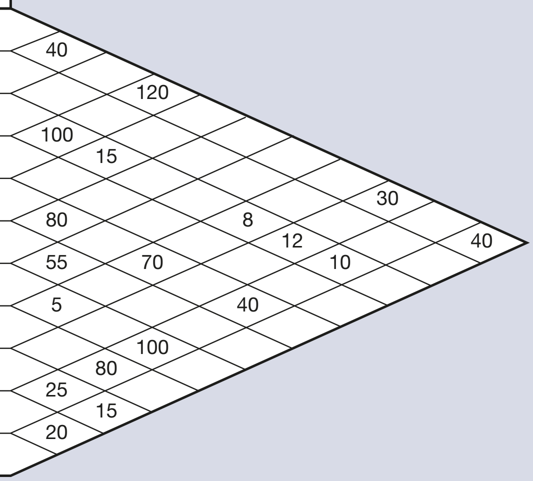
Worked example

The Dibeng Learning Organisation (DLO) is an educational group that commissions, designs and manufactures education packs for distance-learning courses and training. It has leased a new building with an area of 1,800 square metres, into which it needs to fit 11 'departments'. Prior to moving into the new building it has conducted an exercise to find the average number of trips taken by its staff between the 11 departments. Although some trips are a little more significant than others (because of the loads carried by staff), it has been decided that all trips will be treated as being of equal value.

Step 1 – Collect information

The areas required by each department together with the average daily number of trips between departments are shown in the flow chart in Figure 7.11. In this example the direction of flow is not relevant and very low flow rates (fewer than five trips per day) have not been included.

DEPARTMENT	AREA (m^2)	CODE
Reception	85	A
Meeting room	160	B
Layout and design	100	C
Editorial	225	D
Printing	200	E
Cutting	75	F
Receiving and shipping	200	G
Binding	120	H
Video production	160	I
Packing	200	J
Audio production	100	K



Dimensions of the building = 30 metres × 60 metres

FIGURE 7.11 Flow information for the Dibeng Learning Organisation

Step 2 – Draw schematic layout

Figure 7.12 shows the first schematic arrangement of departments. The thickest lines represent high flow rates between 70 and 120 trips per day; the medium lines are used for flow rates between 20 and 69 trips per day; and the thinnest lines for flow rates between 5 and 19 trips per day. The objective here is to arrange the work centres so that those with the thick lines are closest together. The higher the flow rate, the shorter the line should be.

Step 3 – Adjust the schematic layout

If departments were arranged exactly as shown in Figure 7.12(a), the building which housed them would be of an irregular, and therefore high-cost, shape. The layout needs adjusting to take into account the shape of the building. Figure 7.12(b) shows the departments arranged in a more ordered fashion which corresponds to the dimensions of the building.

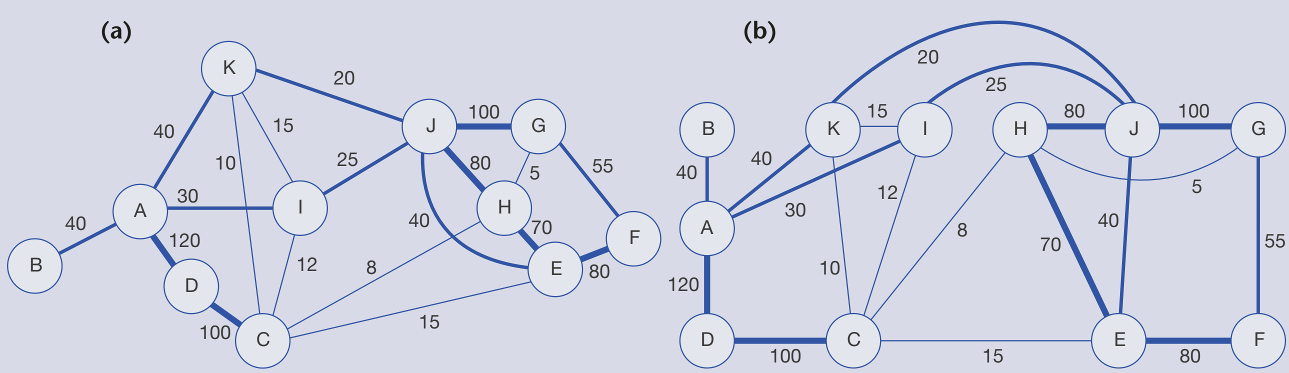


FIGURE 7.12 (a) Schematic layout placing centres with high traffic levels close to each other. (b) Schematic layout adjusted to fit building geometry.

Step 4 – Draw the layout

Figure 7.13 shows the departments arranged with the actual dimensions of the building and occupying areas which approximate to their required areas. Although the distances between the centroids of departments have changed from Figure 7.13 to accommodate their physical shape, their relative positions are the same. It is at this stage that a quantitative expression of the cost of movement associated with this relative layout can be calculated.

Step 5 – Check by exchanging

The layout in Figure 7.13 seems to be reasonably effective but it is usually worthwhile to check for improvement by exchanging pairs of departments to see if any reduction in total flow can be obtained. For example, departments H and J in Figure 7.12 might be exchanged, and the total distance travelled calculated again to see if any reduction has been achieved.

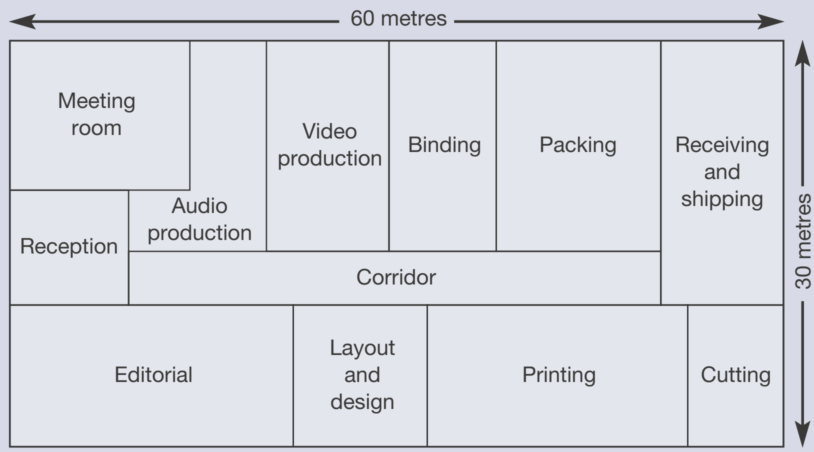


FIGURE 7.13 Final layout of building

Computer-aided functional layout design

The combinatorial complexity of functional layout has led to the development of several heuristic procedures to aid the design process. Heuristic procedures use what have been described as 'shortcuts in the reasoning process' and 'rules of thumb' in the search for a reasonable solution. They do not search for an optimal solution (though they might find one by chance) but rather attempt to derive a good suboptimal solution. One such computer-based heuristic procedure is called CRAFT (Computerised Relative Allocation of Facilities Technique). The reasoning behind this procedure is that, whereas it is infeasible to evaluate factorial n ($n!$) different layouts when n is large, it is feasible to start with an initial layout and then evaluate all the different ways of exchanging two work centres. There are:

$$\frac{n!}{2!(n-2)!}$$

possible ways of exchanging two out of n work centres. So for a 20-work-centre layout, there are 190 ways of exchanging two work centres.

Three inputs are required for the CRAFT heuristic: a matrix of the flow between departments; a matrix of the cost associated with transportation between each of the departments; and a spatial array showing an initial layout. From these:

- the location of the centroids of each department is calculated
- the flow matrix is weighted by the cost matrix, and this weighted flow matrix is multiplied by the distances between departments to obtain the total transportation costs of the initial layout
- the model then calculates the cost consequence of exchanging every possible pair of departments.

The exchange giving the most improvement is then fixed, and the whole cycle is repeated with the updated cost flow matrix until no further improvement is made by exchanging two departments.

Detailed design in cell layout

Figure 7.14 shows how a functional layout has been divided into four cells, each of which has the resources to process a 'family' of parts.

In doing this the operations management has implicitly taken two interrelated decisions regarding:

- the extent and nature of the cells it has chosen to adopt
- which resources to allocate to which cells.

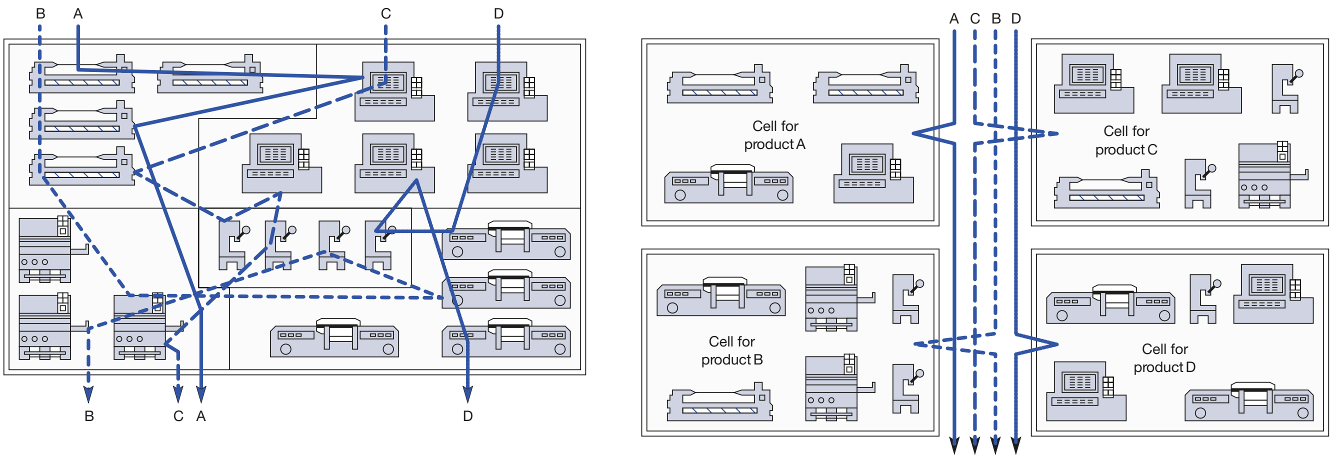


FIGURE 7.14 Cell layout groups together the processes which are necessary for a family of products/services

Production flow analysis

The detailed design of cellular layouts is difficult, partly because the idea of a cell is itself a compromise between process and product layout. To simplify the task, it is useful to concentrate on either the process or product aspects of cell layout. If cell designers choose to concentrate on processes, they could use cluster analysis to find which processes group naturally together. This involves examining each type of process and asking which other types of processes a product or part using that process is also likely to need. One approach to allocating tasks and machines to cells is production flow analysis (PFA), which examines both product requirements and process grouping simultaneously. In Figure 7.15(a) a manufacturing operation has grouped the components it makes into eight families – for example, the components in family 1 require machines 2 and 5. In this state the matrix does not seem to exhibit any natural groupings. If the order of the rows and columns is changed, however, to move the crosses as close as possible to the diagonal of the matrix which goes from top left to bottom right, then a clearer pattern emerges. This is illustrated in Figure 7.15(b) and shows that the machines could conveniently be grouped together in three cells, indicated on the diagram as cells A, B and C. Although this procedure is a particularly useful way to allocate machines to cells, the analysis is rarely totally clean. This is the case here where component family 8 needs processing by machines 3 and 8 which have been allocated to cell B. There are some partial solutions for this. More machines could be purchased and put into cell A. This would clearly solve the problem but requires investing capital in a new machine which might be under-utilised. Or, components in family 8 could be sent to cell B after they have been processed in cell A (or even in the middle of their processing route if necessary). This solution avoids the need to purchase another machine but it conflicts partly with the basic idea of cell layout – to achieve a simplification of a previously complex flow. Or, if there are several components like this, it might be necessary to devise a special cell for them (usually called a remainder cell) which will almost be like a mini-functional layout. This remainder cell does remove the 'inconvenient' components from the rest of the operation, however, leaving it with a more ordered and predictable flow.

Detailed design in product layout

The nature of the product layout design decision is a little different to the other layout types. Rather than 'where to place what', product layout is concerned more with 'what to place where'. Locations are frequently decided upon and then work tasks are allocated to each location. For example, it may have been decided that four stations are needed to make computer cases. The decision then is which of the tasks that go into making the cases should be allocated to each station.

The main product layout decisions are as follows:

- What cycle time is needed?
- How many stages are needed?
- How should the task-time variation be dealt with?
- How should the layout be balanced?

(a) Component families (columns) by Machines (rows)

Machines	1	2	3	4	5	6	7	8
1						X		X
2	X			X			X	
3		X			X			X
4			X			X		X
5	X			X			X	
6			X					X
7				X			X	
8		X			X			X

(b) Component families (columns) by Machines (rows)

Machines	3	6	8	5	2	4	1	7
4	X	X	X					
1		X	X	Cell A				
6	X		X					
3			X	X	X	Cell B		
8			X	X	X			
2						X	X	X
5				Cell C		X	X	X
7						X		X

FIGURE 7.15 **(a) and (b) Using production flow analysis to allocate machines to cells**

The cycle time of product layouts

The cycle time (as was mentioned in Chapter 4) is the time between completed products, pieces of information or customers emerging from the process. Cycle time is a vital factor in the design of product layouts and has a significant influence on most of the other detailed design decisions. It is calculated by considering the likely demand for the products or services over a period and the amount of production time available in that period.

Worked example

Suppose the regional back-office operation of a large bank is designing an operation which will process its mortgage applications. The number of applications to be processed is 160 per week and the time available to process the applications is 40 hours per week.

$$\text{Cycle time for the layout} = \frac{\text{time available}}{\text{number to be processed}}$$

$$= \frac{40}{160} = \frac{1}{4}\text{ hours}$$

$$= 15\text{ minutes}$$

So the bank's layout must be capable of processing a completed application once every 15 minutes.

The number of stages

The next decision concerns the number of stages in the layout and depends on the cycle time required and the total quantity of work involved in producing the product or service. This latter piece of information is called the total work content. The larger the total work content and the smaller the required cycle time, the more stages will be necessary.

Worked example

Suppose the bank in the previous example calculated that the average total work content of processing a mortgage application is 60 minutes. The number of stages needed to produce a processed application every 15 minutes can be calculated as follows: