Chapter 7

Functional, Cellular and Hybrid Cellular Layouts for any Job Shop

Functional Layout vs. Cellular Layout

In the typical high-mix low-volume manufacturing facility, such as a machine shop, forge shop, fabrication shop, mold-making shop, etc. there is a very high probability that they have a Functional Layout (Figure 1). The Functional Layout has advantages such as high machine utilization at workcenters and high flexibility in allocating operations to alternative machines in any workcenter. However, it has disadvantages such as high throughput times, high WIP levels and complex order tracking.

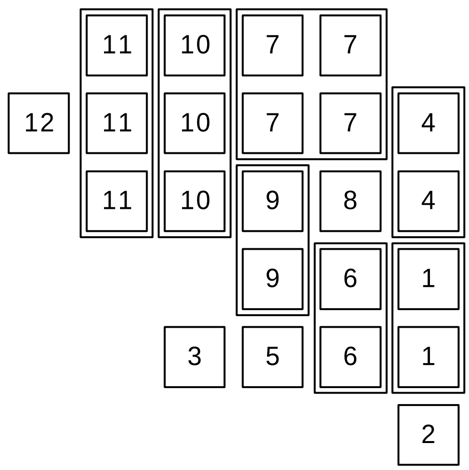


Figure 1 Functional Layout

The implementation of Lean Manufacturing usually includes changes in the factory layout, especially the implementation of one or more manufacturing cells. A Cellular Layout (Figure 2) has advantages such as low lead times and low WIP levels. However, high machine utilization is not guaranteed in all cells. Also, in case of machine breakdowns and changes in demand or product mix, a cell designed to produce a single part family is inflexible and unsuitable for reconfiguration.

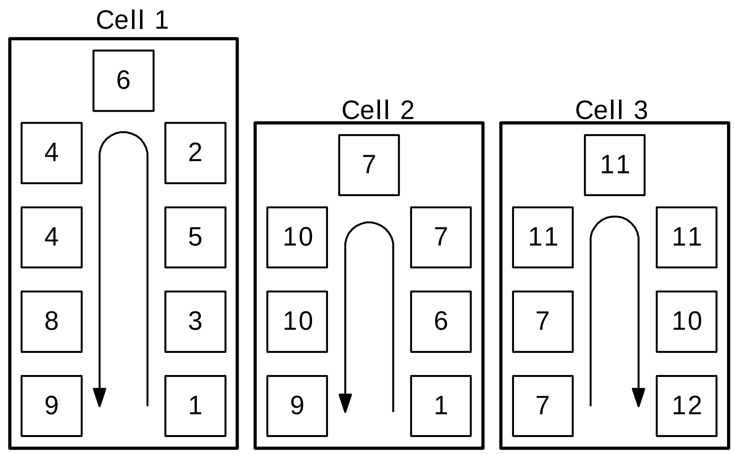


Figure 2 Cellular Layout with Three Cells

A Cellular Layout is not a Panacea!

High-mix low-volume manufacturers, especially jobshops, are ill-advised to undertake a complete reorganization into a Cellular Layout based on specific part families, unless the customer base, part mix and order volumes for the cells will be stable in the long term. Significant changes in product mix and/or order quantities are usually the downfall of a Cellular Layout. In fact, many jobshops keep their Functional Layout and rely on daily production meetings, expeditors and other fire-fighting strategies to progress and track orders! Even more importantly, advances in computer-aided factory management using Enterprise Resource Planning (ERP) systems, Finite Capacity Scheduling (FCS) and Manufacturing Execution Systems (MES) can be integrated to manage a group of machines that are not co-located physically in a cell.

Design of Flexible *and* Lean (FLean) Layouts for Jobshops

A Functional Layout is flexible but promotes batch-and-queue production. A Cellular Layout is inflexible but enables single-piece flow. Can the layout of any high-mix low-volume manufacturing facility be **both** Flexible **and** Lean (FLean)? This chapter describes a variety of Hybrid Cellular Layouts (HCLs) that (1) exploit the knowledge of families of parts with similar/identical routings ***and*** (2) avoid total re-organization of the existing Functional Layout into a Cellular Layout. *An HCL is intermediate between a Cellular and a Functional layout.* All HCLs for a factory are developed under the assumption that the product mix of the factory has been analyzed to discover the part families that are the basis for cell formation. However, during the layout design phase, creative strategies are used to place the shared machines as if they had been retained in functional departments ("process villages"). It is designed by integrating different strategies for facility layout design such as (1) some machines will be grouped into cells, (2) some of its functional departments will be retained as-is, (3) some of its functional departments will be split and distributed at two or more locations across the factory, (4) some machines will be grouped into partial cells (aka Layout Modules), etc.

Table 1 shows the routing of each product in a hypothetical facility that consists of 12 machines and produces 19 products. Figures 1 and 2 show a Functional Layout and a Cellular Layout with three cells to produce the sample of parts in Table 1, respectively.

With reference to the cells shown in Figure 2, Machines #1, #6, #7, #9 and #10 have been duplicated in several cells. This physical duplication of identical machines into cells destroys the flexibility obtained by having all machines of a shared type in a functional group, as in a Functional Layout. HCLs attempt to avoid this physical separation of machines that must be shared by two or more cells.

Table 1 Operation Sequences of Products

Product #	Sequence	Production Quantity
1	1→4→8→9	2
2	1→4→7→4→8→7	3
3	1→2→4→7→8→9	1
4	1→4→7→9	3
5	1→6→10→7→9	2
6	6→10→7→8→9	1
7	6→4→8→9	2
8	3→5→2→6→4→8→9	1
9	3→5→6→4→8→9	1
10	4→7→4→8	2
11	6	3
12	11→7→12	1
13	11→12	1
14	11→7→10	3
15	1→7→11→10→11→12	1
16	1→7→11→10→11→12	2
17	11→7→12	1
18	6→7→10	3
19	12	2

Hybrid Cellular Layouts

Cellular Layout with Reorientation of Cells (Figure 3): Here, by a simple 90-degree rotation of Cell 2, all machines of types #1 and #7 are located physically adjacent to each other, as if in a Functional layout, even as the original allocation of machines to cells is retained. Hence, in case of machine breakdowns or demand changes, parts could still be transferred quickly among machines of the same type.

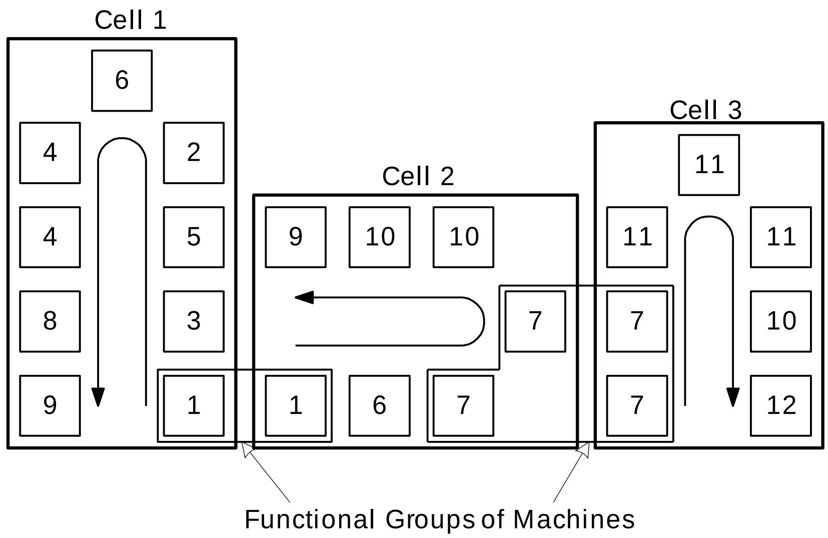


Figure 3 Cellular Layout with Reorientation of Cells

Cellular Layout with Reorientation and Reshaping of Cells (Figure 4): This is a more complicated case of an HCL since it was generated by a reorientation as well as change of shape of one or more cells. Instead of retaining the U (or rectangular) shape for all cells, cells are allowed to have L (or S) shapes, which allows more machine types *that would otherwise have been distributed among the cells* to remain co-located in functional groups.

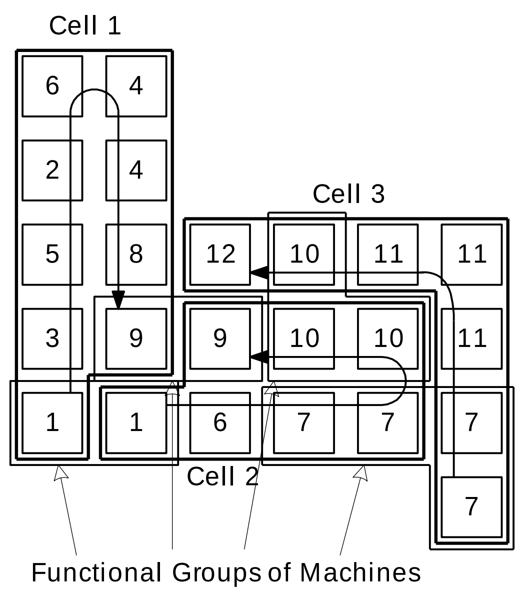


Figure 4 Cellular Layout with Reorientation and Reshaping of Cells

Cellular Layout with S-shaped Flowlines (Figure 5): This layout for embedding functional groups in a Cellular Layout is similar to Figure 4. A Flowline Layout was developed for each of the cells. Next, the cells were arranged in parallel to minimize inter-cell flows. Finally, their linear shapes were modified into S-shapes to group identical machines into functional groups.

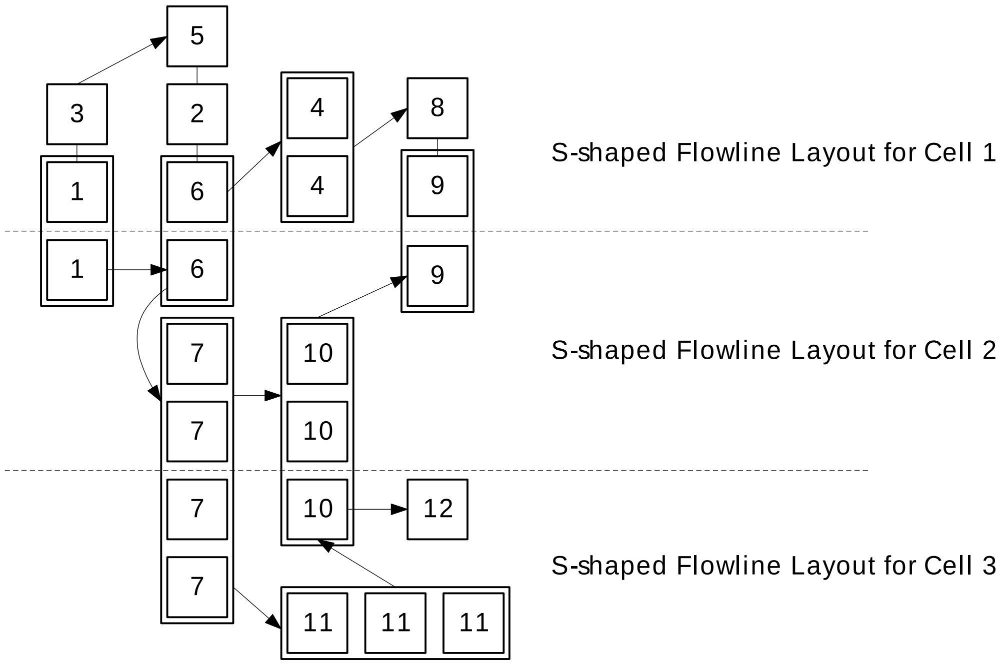


Figure 5 Cellular Layout with S-shaped Flowlines in Parallel

Hybrid Flowshop Layout (Figure 6): In this layout[1], the machines are allocated into several groups of machines and the groups are arranged in a line. However, unlike a traditional manufacturing cell, each group of machines does not process a family of parts. Rather, it can perform one or more consecutive operations occurring in the operation sequence of almost every part. In a Flowshop, the routing of every product is identical to the sequence of machines that comprises the linear layout of the flowshop. In this HCL, only the pair of operations, 7 → 4, in the routings of Parts #2 and #10 cause flow to backtrack in the layout. Otherwise, if every part routing in Table 1 is mapped onto the layout shown in Figure 6, then the travel route of each part for consecutive operations either (1) connects two consecutive groups of machines or (2) bypasses a group to connect to a group of machines that is further along. If an additional Machine # 4 could have been purchased and allocated to the third stage in Figure 6, then zero backtracking would have existed in this layout.

[1] This HCL is similar to a Mixed Model Value Stream.

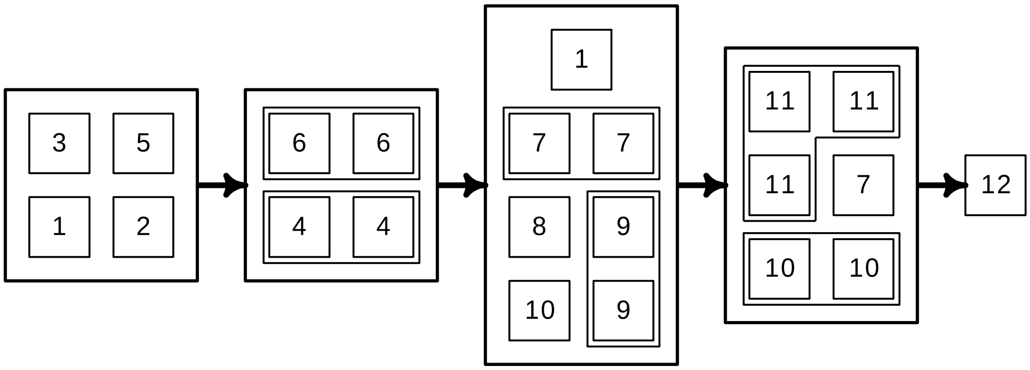


Figure 6 Hybrid Flowshop Layout

Virtual Cellular Layout (Figure 7): The layouts in Figure 3, Figure 4, Figure 5 and Figure 6 demonstrate the basic objective of HCLs to minimize the number of machine types that cannot be retained in functional departments when a Functional Layout is changed to a Cellular Layout. The goal is to have the benefits of part family-based manufacturing without necessarily co-locating machines into (rigid and inflexible) cells. In the Virtual Cellular Layout, machines shared by several cells can be retained in functional groups if the cells are located adjacent to each other. This adjacency of the cells allows the machines in any cell to be "virtually co-located" with a designated material handler moving all parts in that particular family among the different machines in the cell. Even though the shared machine types are located in functional groups, their setups can remain dedicated to a particular family of parts matched with a specific manufacturing cell.

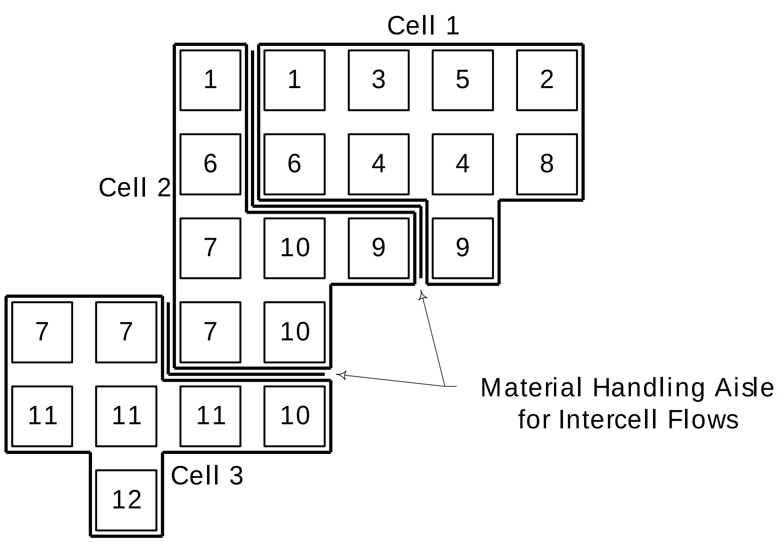


Figure 7 Virtual Cellular Layout

Cellular Layout with a Remainder Cell (Figure 8): This layout eliminates the machine duplication problem experienced with a Cellular Layout. One or more shared machine types are kept in a Remainder Cell accessible to all the cells that need to share these machines. The original compositions of Cells 1 and 2 (Figure 2) were relaxed to facilitate flows of parts through the Remainder Cell. Machines in the Remainder Cell were arranged using standard methods for design of a Functional Layout.

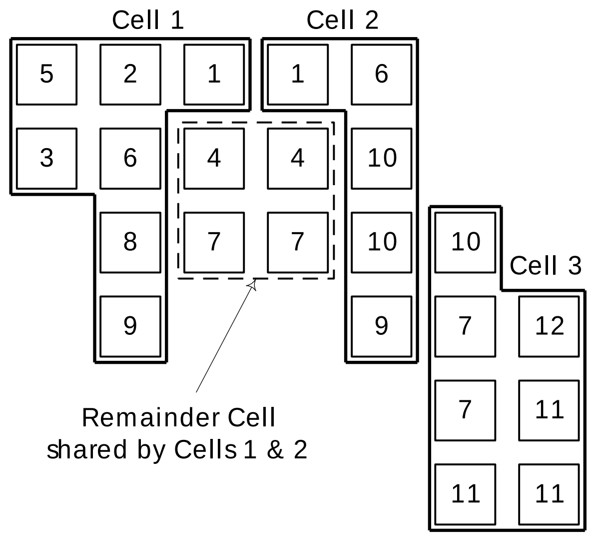
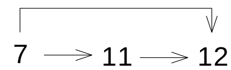
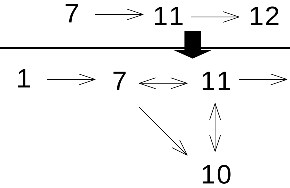
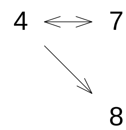
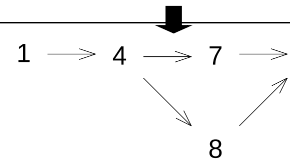
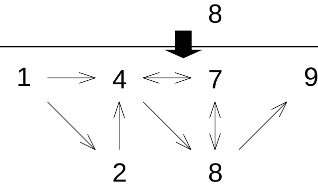
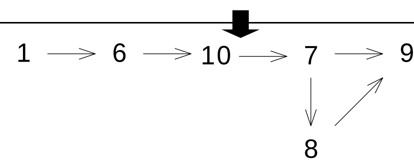
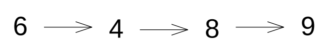
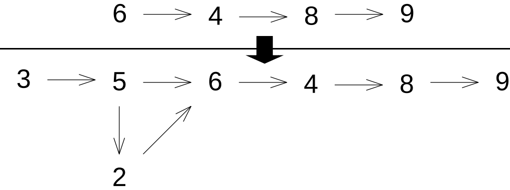


Figure 8 Cellular Layout with a Remainder Cell

Cascading Cells (Table 2): This layout depends on the similarity of the routings of parts in different families. The cells are designed such that simple parts with short routings are produced in the simpler cells and complex parts with long routings are produced in larger, more complex cells. There is no intercell movement for any part. *Every part must be completed in just one cell!* Significant machine duplication, possible requiring the purchase of additional machines, is usually necessary to implement this layout.

Table 2 Cascading Cells

Part Numbers	Cell Composition
12, 13, 17, 19	
14, 15, 16	
10	
1, 4	
2, 3	
18	
5, 6	
7, 11	
8, 9	

shows the cascading of a simple cell into a more complex cell

Conclusion

High-mix low-volume manufacturers, especially job shops, ought not to undertake a complete reorganization into a Cellular Layout where each cell is designed to make a specific part family. Significant changes in the customer base, part mix and order volumes for each of the cells are usually the downfall of a Cellular Layout. A Cellular Layout is inflexible but enables single-piece flow. A Functional Layout is flexible but promotes batch-and-queue production. A Hybrid Cellular Layout (HCL) is intermediate between these two traditional facility layouts! Any HCL is capable of being **both** Flexible **and** Lean (FLean) because it is designed using a fusion of strategies for facility layout design.