

Chapter 11. Facilities Design Introduction

11.1. Facilities Design Definition

Facilities Design is the planning and design of the physical environment of an activity to best support the execution of this activity.

In other words, facilities design attempts to organize the tangible fixed assets of an activity in such way as to provide maximal support for the achievement of the activity's objectives at the present time and in the future at the lowest possible cost. This activity can take many different forms, e.g. manufacturing (plant layout), health care (hospital layout), transportation (airport layout) and services (bank layout).

Objectives of a Good Facilities Design

1. The facilities design should first and foremost enable and support the activity. This implies that it must enable the throughput requirements, storage requirements, and flow time requirements.
2. A secondary characteristic is that the activity can be executed at minimal cost for the given set of throughput, storage, response time requirements. Conflicting objectives at this level are increasing server utilization and decreasing the material handling cost, which consists of storage and transportation costs.
3. Finally, a good facility is flexible and robust enough so that it can accommodate server and material handling device breakdowns and that it can be adapted to a different product mix.

Cost Associated with a Facilities Design

A facilities design has associated fixed and variable costs. Fixed costs are incurred if an activity is executed at all. Examples are the server acquisition costs for the production function and the device acquisition costs and costs for buffer, inventory storage, aisles and transportation space for the material handling function.

Variable costs depend on the intensity of the executed activity. Examples are the unit production costs for the production function and the unit transportation costs for the material handling function.

Characteristics of a Facilities Design Project

Facilities design is a typical engineering design project and as such exhibits the main characteristics of any (large) engineering design project.

1. Facilities design is a ***complex problem***. The problem is ill defined, the objectives and constraints are fuzzy. Different people have different definitions and objectives of the project. Some constraints are implicitly assumed. Hence, there does not exist an optimal mathematical solution as in linear programming. Many, very different solutions can be equally good.
2. Facilities design is an ***interdisciplinary team effort***. No engineer can do all the work or has all the expertise. Many different groups will be using the facility and have different requirements for the facility. Communication between all the user groups and the design team is essential for the later acceptance of the facility.
3. Activities and their supporting facilities ***change constantly*** over time and the facilities design project will be redefined accordingly. Integration in a spatial and temporal master plan is essential for future efficient use of the facility.
4. The mathematical models for such a complex, fuzzy, and dynamic design problem are very hard to formulate and solve.
5. Most computer algorithms require a clear and precise statement of the problem, objectives, and constraints. The facilities design problem does not any of these, so there has been very limited success with the application of Computer Aided Layout (CAL) programs.
6. As a consequence, the design engineer is still very important in the facilities design process.

11.2. Main Facilities Design Principle

Optimize & Minimize the Material Flow

One of the major objectives of facilities design is to arrange the processing centers in such a way that the cost of material handling operations between the centers is minimized. A good facility design will always be characterized by a simple and intuitive material flow. In most instances, facilities design tries to minimize the distances traveled between processing operations.

11.3. Steps in the Facility Design Process

Facilities Design Process Steps

The facility design process follows the same steps as any engineering design process.

Most facilities design projects identify the following elements during the first two phases of the engineering design process:

1. **Identify the major “material handling flows” in the project.** This “material flow” can be many different things depending on the facilities design application. In a hospital, patients, medical personnel, drugs, and medical supplies are all important material flows. In an airport, passengers (arriving and departing), crew, planes, and luggage are all important material flows. In a bank customer, personnel, documents, and money are examples of important material flows. Finally, in manufacturing, parts, personnel, and tools can be examples of the major material handling flows.
2. For each of the material handling flows in step 1, **identify the major processing steps.** Again this includes a wide variety of task depending on the application. Examples are customer dining in a restaurant, luggage carousel in an airport, drug storage in the pharmacy of a hospital, etc.. The processing steps are executed in activity centers or departments.
3. Construct a graph with a column for each of the material handling flows and a row for each of the activity centers. For each of the material handling flow a line is drawn between the activity centers to indicate the order in which the centers are visited. An example of such a graph is a **multiproduct process chart.**
4. Given the material handling flows and the activity centers **determine the affinities between the activity centers** in a common unit. If only material handling flows are present, then this is a relatively easy step. The material handling load such as a pallet of fork lift truck trip might be the common material handling unit. If other affinities are also present, then their size must be carefully determined to be consistent with the material flow units. Examples of positive affinities are the desirability of having windows in offices and cafeterias, which implies a location on the perimeter of the layout. Examples of negative affinities are welding (which produces sparks) and painting (which produces combustible vapors) departments, vibration pollution between a stamping and a measuring department and noise pollution between a sawing and an office department. Once a common handling unit has been defined, the flows in the above graph can now be quantified. All material handling flows and other affinities are then summarized in a relationship matrix also called a from-to matrix, which has as elements the sum of the affinities between two departments for all major material handling flows.
5. Given the material handling flows that need to be processed in each of the activity centers, compute the number of individual servers required in each activity center. Finally, based on the number of servers and the required area for each server and possible space for waiting area for the server, compute the required area for each activity center.

11.4. Characteristics of a Good Facilities Design

Growing Cost of Modifications

The cost of making changes to a design project grows exponentially over time. This can best be illustrated by Figure 11.1.

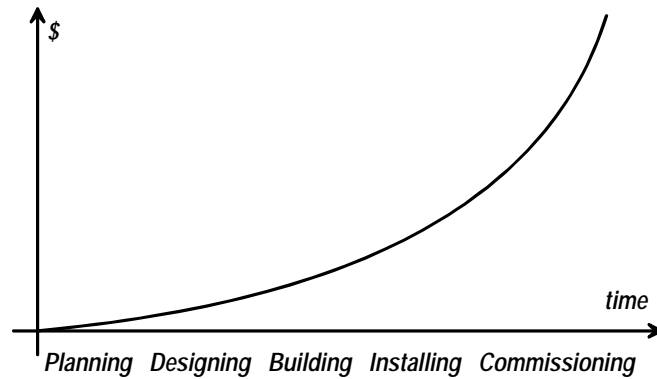


Figure 11.1. Exponential Cost of Design Changes

Design for Integration

Hence the current facilities design project should be integrated with the overall spatial and temporal master plan of the organization. Future expansions, contractions, and relocations of the material flow should be anticipated and planned for.

Design for Flexibility

To adapt to the constantly changing environment, business systems themselves must also change. The changes in product, production techniques and equipment have accelerated in the recent years. To minimize the long-term costs the facilities should accommodate this change. Hence facilities should be designed with flexibility and change in mind. One might call such easily reconfigurable facilities “agile facilities.” Designing for future flexibility must be traded off with designing for maximal efficiency for the current system.

11.5. Product, Process, Schedule, and Facilities Design

Product Design

Product design involves both the determination of which products are to be produced and the detailed design of individual products. It answers the basic question *WHAT* will be produced.

Process Design

Process design involves the determination of required type and sequence of production steps to manufacture a product. This includes the classical "make-or-buy" decision. It answers the basic question **HOW** will be produced.

Schedule Design

Schedule design involves the determination of which quantities at what times will be produced. Schedule design philosophies such as "Material Requirements Planning" (MRP) and "Just In Time" (JIT) can help answer these questions. It answers the basic question **HOW MUCH** and **WHEN** will be produced.

Facilities Design

Facilities Design involves the determination of the design of the physical environment of an activity. It answers the basic question **WHERE** will be produced.

Integrated Design

To achieve the highest efficiency, the design of product, process, schedule and facilities should occur concurrently and in an integrated way. This principle is also partially expressed by "designing for manufacturability" concept. The principle is illustrated graphically by Figure 11.2.

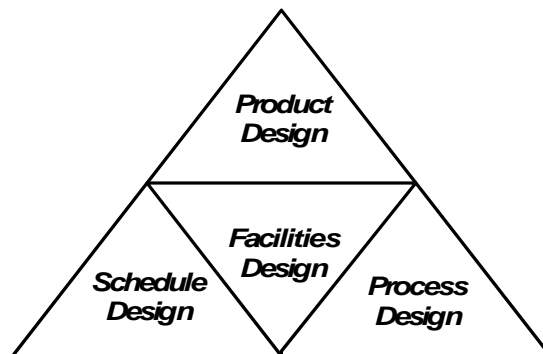


Figure 11.2. Integration of All Design Activities

The major manufacturing production system types and their associated layouts will be discussed in the next chapter on Manufacturing Systems.

11.6. Facilities Design Phases

Facility Location

Facility location determines the location of the production facility to be designed. This placement is important with respect to customers, suppliers, labor force, and other facilities with which it interfaces. Facilities location decisions are often made by the highest level of management and are based very often on political and financial considerations. A schematic illustration the facilities location problem is given in Figure 11.3. Facilities location will not be further discussed in this text.

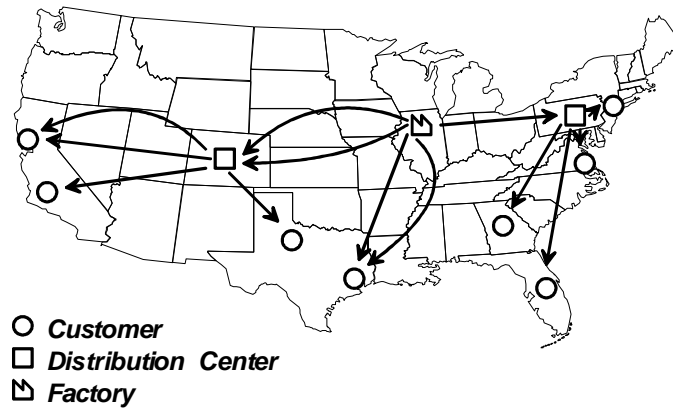


Figure 11.3. Facility Location

Conceptual Block Layout

Based upon the major flow patterns and the required areas, the general shape, relationships and location of each department are established. Each functional unit or department is represented by a simple block without any further details. An example of a conceptual block layout is given in Figure 11.4. The design of the conceptual block layout is the major task and opportunity for contribution of the industrial engineer.

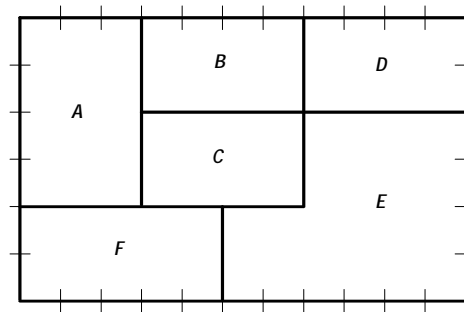


Figure 11.4. Conceptual Block Layout

Material Handling Layout

This layout shows the block layout of the departments and the major material handling areas such as aisles and storage systems, and the location of the interface points between the departments and the material handling system. An example of a material handling layout is given in Figure 11.5.

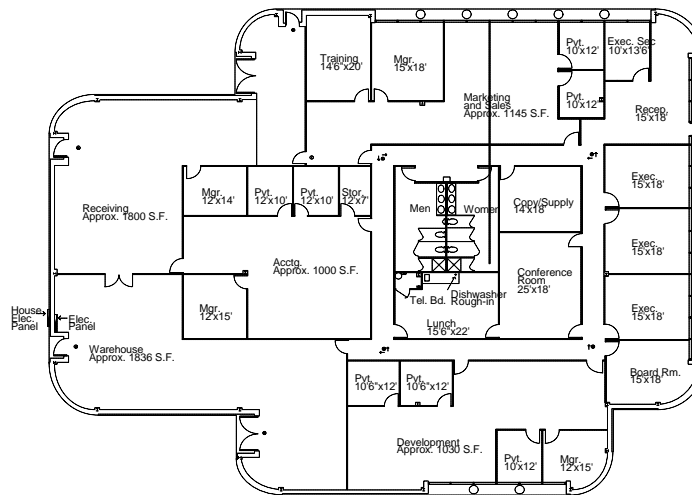


Figure 11.5. Office Material Handling Layout Example

Detailed Technical Layout

This layout is based on the material handling layout and includes all the details such as construction materials and details, exact position of production and material handling equipment, support networks such as electricity, water, sewer, local area networks, etc... The detailed technical layout is the result of a team effort of many engineering disciplines such as civil, electrical, industrial, mechanical, etc...

Layout Implementation

The layout is approved, scheduled and executed, i.e., the facility is constructed.

11.7. Facilities Design Types

Manufacturing Facilities

In this case the term *Plant Layout* is also frequently used instead of facilities design.

Warehousing Facilities

Design of distribution centers, warehouses for raw materials and finished products. The warehousing function is responsible for storage, handling and control of the material. The design of container ports is also included with warehousing facilities.

Office and Service Facilities

Examples are office layouts, health care layouts such as hospitals, service layouts such as banks and airports. In this case the material flow can correspond to the flow of people or documents.

Military Facilities

Historically, military facilities have the added requirements that have to be easily defended and that access can be tightly controlled.

11.8. Layout Types

Continuous Production Layout

A continuous production layout involves directly connected processes without intermediate storage or revisiting a particular process. This type of layout is very specialized and mostly applies to the manufacturing of bulk, gas, and liquid products. The typical example is a chemical plant or oil refinery.

This type of layout is important to the discrete parts manufacturing because it represents the goal of discrete parts manufacturing, since inventory and system flow time are at their minimal levels. On the other hand, these facilities are highly specialized and changing the products usually involves fundamentally changing the facility.

The following layout types are used in discrete parts manufacturing and to illustrate their characteristics an example with seven products is used. The process sequences for the different products of the example are illustrated in the next figure. The graphical illustrations for this example were created Montreuil and are here used with permission.

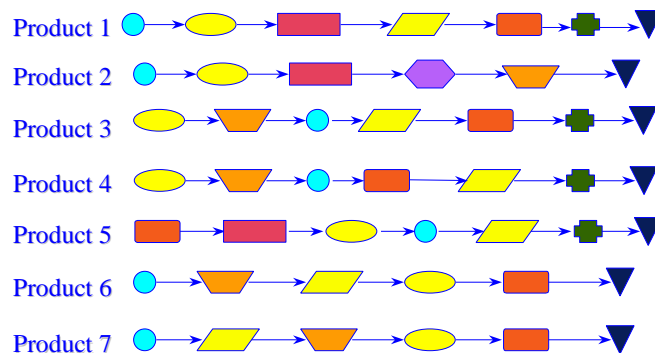


Figure 11.6. Processing Sequences for the Various Products

Product Layout

In a product layout, all characteristics are dominated by the various products. Another name often used is flow shop. This production and layout type is mostly used for mass production of products. Examples are automotive assembly lines and manufacturing lines for consumer goods. The layouts are characterized by extremely simple material flows, either in a straight line or in simple line patterns such as U and L shapes.

The processing centers are organized following the sequence of processing steps for each of the products. One or more processing steps may be combined into a single processing center, but the sequence is never modified. The allocation of the processing steps to processing centers for the first product is illustrated in the next figure and the product layout for all products in Figure 11.8.

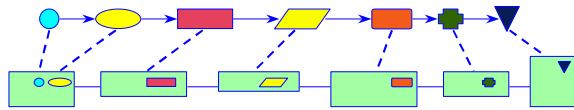


Figure 11.7. Processing Steps to Processing Center Allocation for Product 1

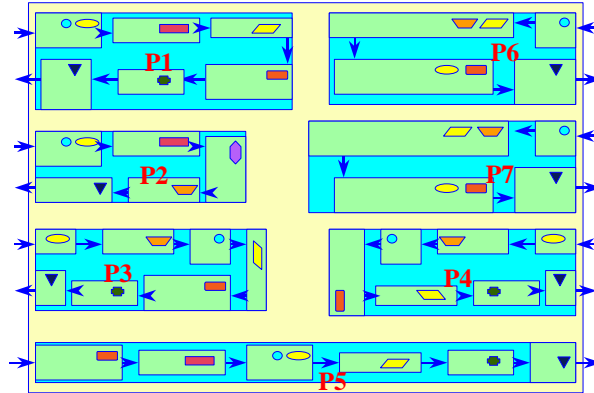


Figure 11.8. Product Layout

Process Layout

In a process layout, all the characteristics are determined by the various processes. The activity centers consists of one or more servers that execute the same process. Another name for this production mode is job shop. Typical applications are small batch manufacturing. Examples are the wafer manufacturing for integrated circuits and microprocessors and a residential kitchen. The major disadvantage of the process layout is a very complex material flow all over the manufacturing facility.

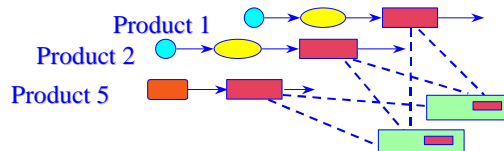


Figure 11.9. Processing Steps to Processing Center Allocation for a Process Layout

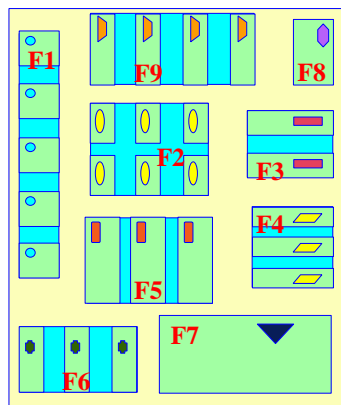


Figure 11.10. Process Layout

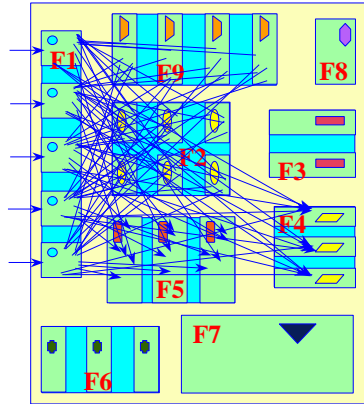


Figure 11.11. Product Flows In and Out of Activity Center F1

Cellular Layout

A cellular layout attempts to combine the advantages of the product and the process layout by creating groups of related products and cell of all the machines required for the production of a single group of products. The cells are heterogeneous since they contain different types of servers and machines. Typical application are batch production of related products. An example is the manufacturing of various models and sizes of industrial pumps. Clearly, the success or failure of the cellular layout depends on the quality of the group formation process. This is the topic of group technology. To remain efficient, the groups have to remain stable. The material flows between the different manufacturing cells are minimal and very simple, the material flows inside a cell are more dense but still linear because all products in the group have a similar or identical sequence of processes.

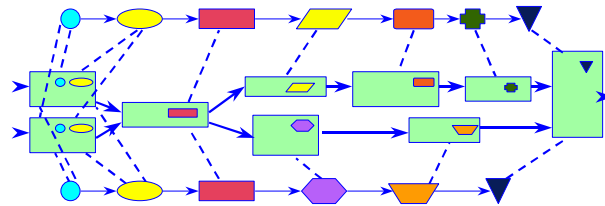


Figure 11.12. Processing Steps to Processing Center Allocation for a Cellular Layout

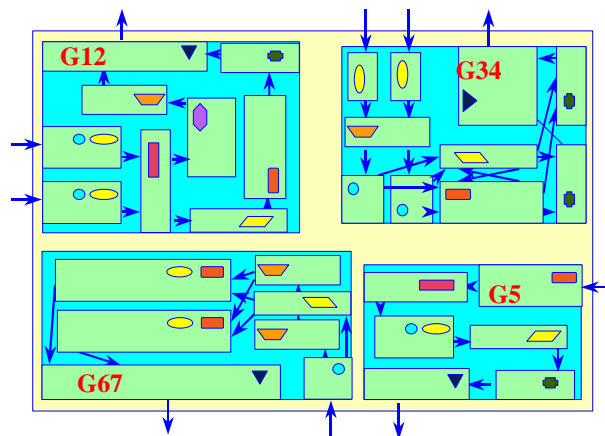


Figure 11.13. Cellular Layout

Fractal Layout

In a fractal layout near-identical and heterogeneous cells of machines are repeated in the manufacturing plant. Since each cell has nearly all of the machines, it can handle any product in the plant. A new product or a product with expanding volume can be assigned to a cell that is less utilized. The main advantage of a fractal layout is that it remains efficient when the product families change.

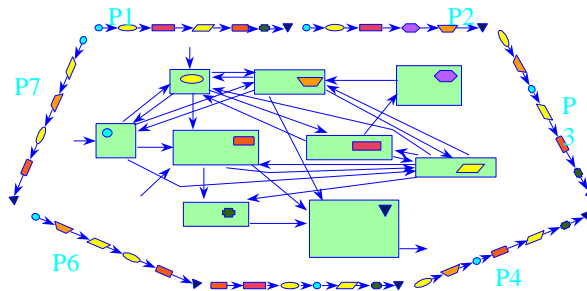


Figure 11.14. Processing Steps to Processing Center Assignment for a Fractal Layout

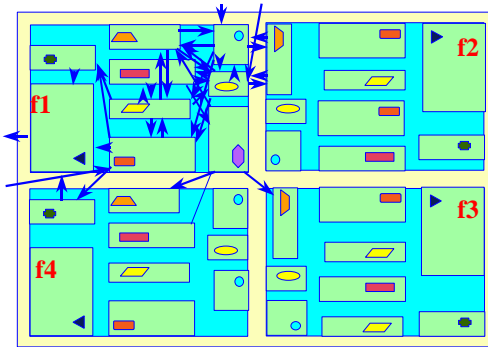


Figure 11.15. Fractal Layout

Holonic Layout

In the process layout the principle was to concentrate all servers of a particular type in one region of the layout. The holonic layout has exactly the opposite principle in that all servers of a particular type are uniformly distributed throughout the plant. When a particular product needs a server of a particular type, such a server is assigned based on its proximity and utilization. The main advantage of the holographic layout is that it can handle varying and unpredictable product mixes. The holonic layout also has been called a holographic layout by several authors.

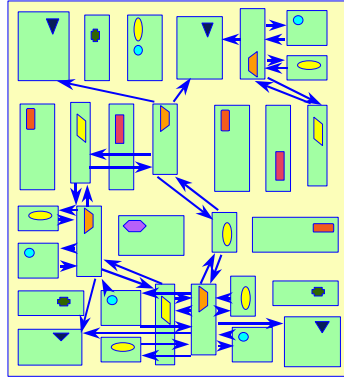


Figure 11.16. Holonic Layout

Up to this point we have only discussed cells that were assigned permanently to a particular product. The factory can also be organized in a set of virtual cells, that are responsible for the production of a group of products but the grouping of these cells is only at the logical level. No physical rearrangement is done. When those products are currently not produced, the cells are disbanded and the individual processors get assigned to another virtual cell. The main advantage of the holonic layout is that the virtual or temporary cells have a relative compact shape. If the same virtual cells were formed in a process layout, the cells would not have a compact shape.

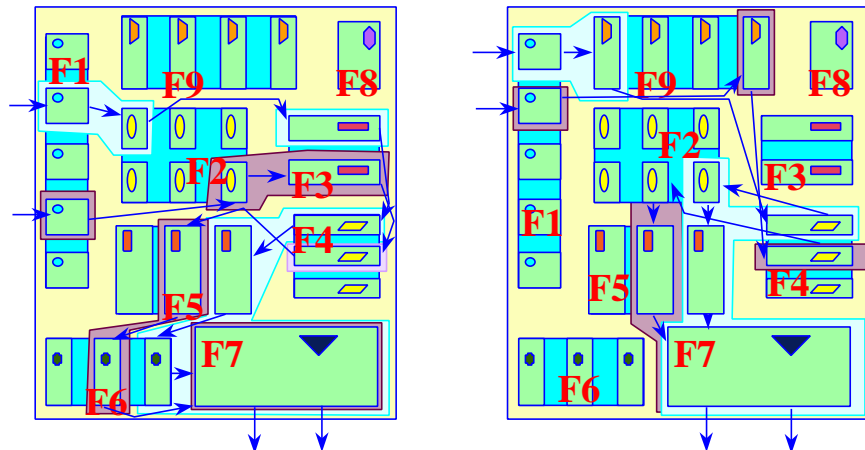


Figure 11.17. Two Possible Virtual Cells for Products 1 and 6 in a Process Layout

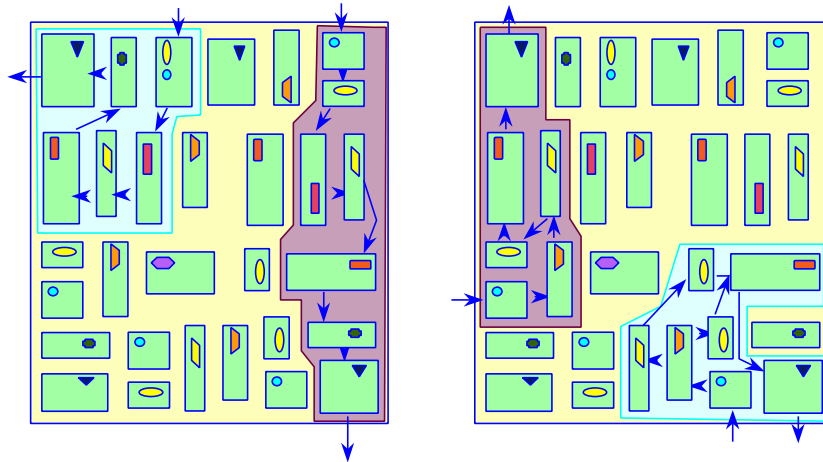


Figure 11.18. Two Possible Virtual Cells for Products 1 and 6 in a Holonic Layout

Project Layout

In a project layout a unique or immobile product dominates all characteristics. Usually only a single type of product is produced in the plant. An example is satellite assembly or the assembly of heavy engines for rail transportation. The material flow has a radial pattern like the hub and spokes of a wheel, with the assembly site at the hub.

This page left intentionally blank.