Chapter 12. Manufacturing Systems

12.1. Manufacturing Facilities Introduction

Main Manufacturing Systems Characteristics

Plant layouts for manufacturing operations can be divided into five general types depending on two main characteristics:

1) The ***number of different products*** manufactured. The larger the number of different products that can be manufactured, the more ***flexible*** the production system is.

2) The ***number of units manufactured*** of each product type. This is also called the batch or lot size. The more units manufactured of each product, the more ***efficient*** and specialized the production process can be.

Manufacturing Efficiency

Manufacturing efficiency is the percentage of the time a plant is actually producing, i.e. adding value to the products. This percentage is averaged over the whole year and includes vacation, weekends, nights, intermediate product storage, etc.. For example, a plant which operates a single shift of 8 hours during the regular work week has a efficiency of approximately 22 %. This assumes continuous production on a part during the 8 hour shift, i.e. the products are never stored or waiting during this shift.

This number is arrived at by subtracting 104 days for weekends, 5 days for holidays, and 10 workdays for vacation from 365 days in a year to yield 246 work days. Each day is equivalent to 8 hours for a total of 1968 hours. The total number of available hours in a year is $365 \cdot 24 = 8760$. The ratio of 1968 hours worked over 8760 hours available yields 22 %. A first order approximation of this efficiency can be found by taking the number of working hours in a week (40 hours) and dividing it by the length of a week in hours (168 hours) which yields 24 %.

12.2. Manufacturing Operations Charts

Conversion of a Multiproduct Process Chart to From-To Matrix

All the flows for the different products have to be expressed in a common unit. If the products are about the same size and weight, then these units can be the product flow, otherwise volume (cubic feet) or weight (pounds) can be used as common unit.

For each pair of origin and destination departments, the flow for all the products is added and placed in the corresponding cell of the from-to matrix.

Conversion Example

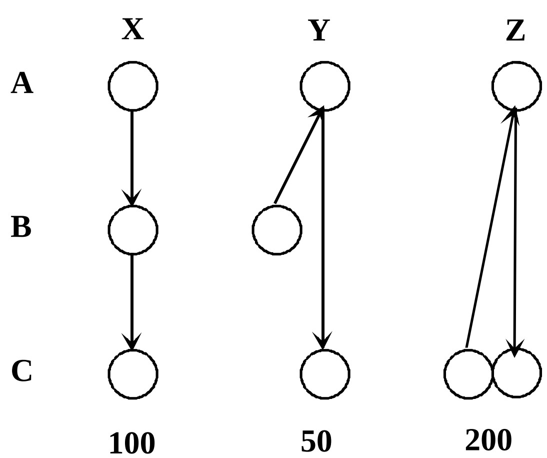

Figure 12.1. Multiproduct Process Chart

Table 12.1. From-To Matrix

	A	B	C
A	-	100	250
B	50	-	100
C	200	0	-

12.3. Manufacturing Production and Layout Types

In most production operations there is always a tradeoff between the conflicting objectives of maximizing the utilizations of the production equipment versus maximizing the throughput and minimizing the flow time of the products. For example, the extremely expensive processing equipment in the manufacturing of printed circuit wafers focuses all the attention on its utilization and causes very long production flow times for the wafers and complex material flows. On other side of the spectrum, the overriding concern in the manufacturing of incandescent light bulbs is maintaining the high production volume, without product delays or detours.

Continuous Production

In a continuous production system the products flow through a series of directly connected processes or operations, without intermediate storage or material movement. This type of operation is very common in the chemical industry, like refineries and chemical processing plants.

Continuous production is usually only applicable to bulk, gas, or liquid products, but it is the goal for many of the current day discrete part manufacturing philosophies. JIT (Just-In-Time), POU (Point-Of-Use) all attempts to produce a product in one smooth and uninterrupted sequence.

The material flow is very inflexible and there is no intermediate storage of products (i.e. all products are always being worked on or change status). The number of different products that can be manufactured is very limited and determined at the time the plant is build. One of the major cost and engineering design challenges occurs when a product with a slightly different processing sequence has to be manufactured in the plant, since there usually is not sufficient place to insert new processing equipment in the original layout. If a truly different product has to be manufactured, very often the facility has to be broken down and rebuild to suit the new product. Manufacturing efficiency is very high (96 %) since very large quantities of each product are manufactured 24 hours a day, 7 days a week.

Even though the layout of continuous production facilities in the chemical and petrochemical industry has a number of specific characteristics and constraints, the main objectives and methodologies of facilities design remain valid. See Georgiadis et al. (1997) for a discussion of layout in the chemical industry.

Mass Production Flow Shop

The overall production planning and layout is determined by the ***product***. Successive production units undergo the very similar sequences of operations and the processing equipment is arranged in the sequence required for producing the products. The manufacturing environment consists of large quantities manufactured on specialized machines for mass production. There is a limited number of different products with only minor variations.

The material flow diagram follows the production process and is very simple and linear in most cases. No back flow of products is allowed, i.e. units never visit the same machine twice during the production process and there is minimal distance between equipment that executes successive operations. Such a layout is called a product layout. An example is the transfer line in a car assembly line. Manufacturing efficiency is high for discrete parts manufacturing, up to 22 % for each shift. More than one shift is usually in operation.

Batch Production Job Shop

The overall layout is determined by the ***different processes***. Machines are grouped by function to produce a multitude of products and they are located without regard for the material movements of the products. The manufacturing environment consists of small order quantities with varying production routings. The number of units of each product is very small, typically less than a dozen. This layout is associated with a job shop and is called a process layout. A very large variety of products is being produced and most of the manufacturing experience is accumulated in the labor force. Hence, the objective is to keep all the workers familiar with a particular process concentrated in one area where they may control more than one machine.

The material flow is very dense and complex and is sometimes called spaghetti flow. An example is a machining tool manufacturing shop.

The actual manufacturing efficiency is very low (around 6 % for each shift) and only one shift is usually used because of resistance of the higher labor grades.

Project Layout

Manufacturing of a unique or immobile product. Instead of the product being transported to the machines, the machines are being transported to the product. The material flow is radial, i.e. like the spokes of wheel, towards the product that is located in the hub of the wheel. Typical examples are ship building, diesel engine assembly for locomotives, or satellite assembly. The lot size is almost always one or very small.

Efficiencies are very hard to measure, but are considered to be even lower than with process layouts.

Cellular Layout

Clusters of machines are grouped together into machine cells to perform a specific group of operations on a specific group of similar products, which is called a product family. This operation is associated with batch production, where a limited number of similar products based on group technology is manufactured intermittently in limited quantities. The material flow has a two level, hierarchical structure. The material flow is very simple, almost linear, and sparse between the machining cells. The material flow inside the cell can be very complex and dense, but is usually handled by a single material handling device. The cells are usually circular or U-shaped. Because of the proximity of the machines in a cell, internal material transport can be executed very quickly and efficiently even with the dense and complex internal material flow.

The standard examples are small industrial machines or tools such as engine blocks and pumps.

The efficiency is the highest for discrete parts manufacturing, up to 25 % per shift (usually two to three shifts are in operation because of the large degree of automation). The key factor for efficiency is the correct identification of machine cells and product groups.

Comparison of Product and Process Layouts

Two main criteria for judging manufacturing operations are flexibility versus efficiency. Flexibility is ability to make many different products in different order quantities. Efficiency is the ability to make products at a low marginal cost and high throughput rates. In Table 12.2 the product and process manufacturing operations are compared with respect to several criteria.

Table 12.2. Comparison of Product and Process Manufacturing

Characteristic	Product	Process
Flexibility		
Efficiency		
Order Quantities		
Number Different Products		
Number Machine Types		
Machine Downtime Cost		
Material Flow Complexity		
Work in Process		
Product Flow Time		
Machine Utilization		
Unit Production Cost		
Quality Consistency		

Common Acronyms in Manufacturing Operations

MRP

POU

Point-Of-Use or POU denotes the warehousing philosophy where the parts, that are to be used in a manufacturing process, are not delivered to a central receiving department and then stored in a warehousing department but instead are delivered directly to the department where they will be assembled into the product. An example is the delivery of tires or seats to automotive assembly plants. Seats and tires have a low value to volume ratio and cost can be significantly reduced by not storing and handling the tires inside the assembly plant. The tires remain stored in the trailer, which is parked at a truck dock in the workstation area where the tires are put on the cars. Four tires are removed from the trailer and put directly on the car without ever having been stored in the assembly plant. From a layout perspective, this means that many departments now have a positive relationship or affinity with the outside and must be located on the perimeter of the building. It also means that the building will have many truck docks all around its perimeter instead of just in the shipping and receiving departments. This layout characteristic is also denoted by perimeter access.

JIT

CAL

CAD

CAM

CADAM

FMS

TQM

GT

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