Part IV
MANUFACTURING SYSTEMS

Chapters:
13. Introduction to Manufacturing Systems
14. Single-Station Manufacturing Cells
15. Manual Assembly Lines
16. Automated Production Lines
17. Automated Assembly Systems
18. Cellular Manufacturing
19. Flexible Manufacturing Systems
Manufacturing Systems in the Production System

[Diagram showing the relationship between Enterprise level, Factory level, and Manufacturing systems, including Manufacturing support systems, Quality control systems, Automation and control technologies, Material handling technologies, and Manufacturing processes and assembly operations.]
Ch 13  Introduction to Manufacturing Systems

Sections:

1. Components of a Manufacturing System
2. A Classification Scheme for Manufacturing Systems
3. Overview of the Classification System
“A collection of integrated equipment and human resources, whose function is to perform one or more processing and/or assembly operations on a starting raw material, part, or set of parts”

- Equipment includes
  - Production machines and tools
  - Material handling and work positioning devices
  - Computer systems

- Human resources are required either full-time or periodically to keep the system running

- A Manufacturing System is where the value added work is accomplished on the parts and the products.
Examples of Manufacturing Systems

- Single-station cells
- Machine clusters
- Manual assembly lines
- Automated transfer lines
- Automated assembly systems
- Machine cells (cellular manufacturing)
- Flexible manufacturing systems
- **Single Station Cell**: One worker tending one production machine that operates on semi-automatic cycle
- **Machine Cluster**: One worker tends a group of semi-automatic machines
- **Manual Assembly Line**: A production line consisting of a series of workstations at which assembly operations are performed by humans to gradually build a product as it moves the line.
- **Automated Assembly Line**: It performs a sequence of automated or mechanized assembly operations.
- **Automated Transfer Line**: Production line consisting of automated workstations that perform processing operations.

- **Machine Cell**: It performs operations on a family of parts or products that are similar but not identical (Cellular Manufacturing)

- **Flexible Manufacturing System (FMS)**: A highly automated machine cell that produces parts/product families.
Components of a Manufacturing System

1. Production machines, tools, fixtures, etc.
2. Material handling system
3. Computer system to coordinate and/or control the preceding components
4. Human workers to operate and manage the system
Production Machines

- In virtually all modern manufacturing systems, most of the actual processing or assembly work is accomplished by machines or with the aid of tools.

- **Classification of production machines** (worker participation):
  1. *Manually operated machines* are controlled or supervised by a human worker.
  2. *Semi-automated machines* perform a portion of the work cycle under some form of program control, and a worker tends the machine the rest of the cycle.
  3. *Fully automated machines* operate for extended periods of time with no human attention.
Manually operated machines are controlled or supervised by a human worker. The machine provides the power for the operation and the worker provides the control. The entire work cycle is operator controlled.
A semi-automated machine performs a portion of the work cycle under some form of program control, and a worker tends to the machine for the remainder of the cycle. Typical worker tasks include loading and unloading parts.
Fully-Automated Machine

Machine operates for extended periods (longer than one work cycle) without worker attention (periodic tending may be needed).
In a manufacturing system, the term WORKSTATION refers to a location in the factory, where a well-defined task or operation is accomplished by an automated machine, a worker and a machine combination, or a worker using hand tools and/or portable power tools.

A given manufacturing system consists of one or more workstations.

A system with multiple workstations is called a production line, machine cell depending on its configuration and function.
Material Handling System

In most manufacturing systems that process or assemble discrete parts and products, the following material handling functions must be provided:

1. Loading work units at each station
2. Positioning work units at each station
3. Unloading work units at each station
4. Transporting work units between stations in multi-station systems
5. Temporary storage of work units
Work Transport Between Stations

- Two general categories of work transport in multi-station manufacturing systems:
  
  1. **Fixed routing**
     - Work units always flow through the same sequence of workstations
     - Most production lines (flow shop) exemplify this category
  
  2. **Variable routing**
     - Work units are moved through a variety of different station sequences
     - Most job shops exemplify this category
(a) Fixed Routing (flow shop), and
(b) Variable Routing (job shop, cells, fms)
Computer Control System

Typical computer functions in a manufacturing system:

- Communicate instructions to workers (receive processing or assembly instructions for the specific work unit),
- Download part programs to computer-controlled machines,
- Control material handling system,
- Schedule production,
- Failure diagnosis when malfunctions occur and preventive maintenance,
- Safety monitoring (protect both the human worker and equipment),
- Quality control (detect and reject defective work units produced by the system),
- Operations management (manage overall operations).
Classification of Manufacturing Systems

Factors that define and distinguish manufacturing systems:

1. Types of operations performed (assembly/process)
2. Number of workstations
3. System layout
4. Automation and manning level
5. Part or product variety
Types of Operations Performed

- Processing operations on work units versus assembly operations to combine individual parts into assembled entities
- Type(s) of materials processed
- Size and weight of work units
- Part or product complexity
  - For assembled products, number of components per product
  - For individual parts, number of distinct operations to complete processing
- Part geometry
  - For machined parts, rotational vs. non-rotational
**Number of Workstations**

- Convenient measure of the size of the system
  - Let $n =$ number of workstations
    - ($n$=1 single station, $n>$1 multi station system)
  - Individual workstations can be identified by subscript $i$, where $i = 1, 2, \ldots, n$

- Affects performance factors such as workload capacity, production rate, and reliability
  - As $n$ increases, this usually means greater workload capacity and higher production rate
  - There must be a synergistic effect that derives from $n$ multiple stations working together vs. $n$ single stations
The **WORKLOAD** is the amount of processing or assembly work accomplished by the system, expressed in terms of the time required to perform the work.

It is the sum of the cycle times of all the work units completed by the system in a given period of interest.

**Work content** is the total time of all work elements that must be performed on the line to make one unit of the product.
System Layout

- Applies mainly to multi-station systems
- Fixed routing vs. variable routing
  - In systems with fixed routing, workstations are usually arranged linearly (product)
  - In systems with variable routing, a variety of layouts are possible (process, cellular)
- System layout is an important factor in determining the most appropriate type of material handling system
Automation and Manning Levels

- Level of workstation automation
  - Manually operated
  - Semi-automated
  - Fully automated

- Manning level $M_i = \text{proportion of time worker is in attendance at station } i$
  - $M_i = 1$ means that one worker must be at the station continuously
  - $M_i \geq 1$ indicates manual operations
  - $M_i < 1$ usually denotes some form of automation
Part or Product Variety: Flexibility

“The degree to which the system is capable of dealing with variations in the parts or products it produces”

Three cases:

1. **Single-model case** - all parts or products are identical (sufficient demand/fixed automation)

2. **Batch-model case** - different parts or products are produced by the system, but they are produced in batches because changeovers are required (hard product variety)

3. **Mixed-model case** - different parts or products are produced by the system, but the system can handle the differences without the need for time-consuming changes in setup (soft product variety)
Three Cases of Product Variety in Manufacturing Systems

(a) Single-model case, (b) batch model case, and (c) mixed-model case
Enablers of Flexibility

- **Identification of the different work units**
  - The system must be able to identify the differences between work units in order to perform the correct processing sequence

- **Quick changeover of operating instructions**
  - The required work cycle programs must be readily available to the control unit

- **Quick changeover of the physical setup**
  - System must be able to change over the fixtures and tools required for the next work unit in minimum time
### Manufacturing Systems for Medium or High Product Complexity

<table>
<thead>
<tr>
<th>Product variety</th>
<th>Low Annual production quantity</th>
<th>Medium Annual production quantity</th>
<th>High Annual production quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard</td>
<td>Job shop with multiple single-station cells, manned</td>
<td>(Multiple systems required)</td>
<td>(Multiple systems required)</td>
</tr>
<tr>
<td>Soft</td>
<td>Job shop with multiple single-station cells, manned</td>
<td>Multi-station system with variable routing, manned or automated</td>
<td>Multi-station system with fixed routing, manned or automated</td>
</tr>
<tr>
<td>None</td>
<td>(Craft shop)</td>
<td>Job shop with multiple single-station cells, manned or automated</td>
<td>Multi-station system with fixed routing, manned or automated</td>
</tr>
</tbody>
</table>
### Manufacturing Systems for Low Product Complexity

<table>
<thead>
<tr>
<th>Product Variety</th>
<th>Annual Production Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hard</strong></td>
<td></td>
</tr>
<tr>
<td>Single-station cell, manned, batch production</td>
<td>Single-station cell, manned or automated, batch production</td>
</tr>
<tr>
<td><strong>Soft</strong></td>
<td></td>
</tr>
<tr>
<td>Single-station cell, manned, batch- or mixed-model production</td>
<td>Single-station cell, manned or automated, mixed-model production</td>
</tr>
<tr>
<td><strong>None</strong></td>
<td></td>
</tr>
<tr>
<td>(Not feasible, system would be grossly underutilized)</td>
<td>Single-station cell, manned (system would be underutilized)</td>
</tr>
</tbody>
</table>
Overview of Classification Scheme

- Single-station cells
  - \( n = 1 \)
  - Manual or automated
- Multi-station systems with fixed routing
  - \( n > 1 \)
  - Typical example: production line
- Multi-station systems with variable routing
  - \( n > 1 \)
Single-Station Cells

- \( n = 1 \)
- Two categories:
  1. **Manned workstations** - manually operated or semi-automated production machine \((M = 1)\)
  2. **Fully automated machine** \((M < 1)\)
- Most widely used manufacturing system - reasons:
  - Easiest and least expensive to implement
  - Most adaptable, adjustable, and flexible system
  - Can be converted to automated station if demand for part or product justifies
Multi-Station Systems with Fixed Routing

- $n > 1$

- Common example = **production line** - *a series of workstations laid out so that the part or product moves through each station, and a portion of the total work content is performed at each station*

- Conditions favoring the use of production lines:
  - Quantity of work units is high
  - Work units are similar or identical, so similar operations are required in the same sequence
  - Total work content can be divided into separate tasks of approximately equal duration
Multi-Station Systems with Variable Routing

- $n > 1$
- Defined as a group of workstations organized to achieve some special purpose, such as:
  - Production of a family of parts requiring similar (but not identical) processing operations
  - Assembly of a family of products requiring similar (but not identical) assembly operations
  - Production of a complete set of components used to assemble one unit of a final product
- Typical case in cellular manufacturing