Stable Schedule

- Production must flow smoothly, meaning minimum perturbations from the fixed schedule.
- Perturbations in downstream operations tend to be magnified in upstream operations.
- Examples: rush orders, overtime, unscheduled setups, variations from normal work procedures, defects, parts shortages, and other exceptions.
On-Time Delivery, Zero Defects, and Reliable Equipment

• Owing to small lot sizes in JIT, parts must be delivered before stock-outs occur at downstream stations. Otherwise, production must be stopped.

• If parts are produced with defects, they cannot be used in subsequent stations, thus stopping production.

• Jidoka - “stop everything when something goes wrong”.
• Such a penalty forces a discipline of zero defects in parts fabrication.

• Workers control quality during production rather than inspecting to discover defects later.

• Low WIP leaves little room for equipment stoppages.
Workforce and Supplier Base

- Workers must be cooperative, committed, and cross-trained.
- Small batch sizes → workers must be willing and able to perform a variety of tasks and to produce a variety of part styles.
- They must be inspectors as well as production workers.
- They must be able to deal with minor technical problems with their equipment.
- Suppliers must be held to the same standards of on-time delivery, zero defects, and other JIT requirements as the company itself.
New Policies for Vendors in JIT

- Reducing the total number of suppliers, allowing remaining suppliers to do more business.
- Long-term agreements and partnerships with suppliers. Suppliers do not have to competitively bid for every order.
- Establishing quality and delivery standards. Selecting suppliers on their capacity to meet these standards.
- Placing employees into supplier plants to help those suppliers develop their own JIT systems.
- Selecting parts suppliers located near the company's assembly plant to reduce transportation and delivery problems.
Comparisons between Lean and Agile

Are lean and agile different?
Comparison of four principles of lean production and four dimensions of agility

<table>
<thead>
<tr>
<th>Lean Production</th>
<th>Agile Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Minimize waste</td>
<td>1. Enrich the customer</td>
</tr>
<tr>
<td>2. Perfect first-time quality</td>
<td>2. Cooperate to enhance competitiveness</td>
</tr>
<tr>
<td>3. Flexible production lines</td>
<td>3. Organize to master change</td>
</tr>
<tr>
<td>4. Continuous improvement</td>
<td>4. Leverage the impact of people and information</td>
</tr>
<tr>
<td>Lean Production</td>
<td>Agile Manufacturing</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Enhancement of mass production.</td>
<td>Break with mass production.</td>
</tr>
<tr>
<td>Flexible production for product variety.</td>
<td>Emphasis on mass customization.</td>
</tr>
<tr>
<td>Focus on plant operations.</td>
<td>Greater flexibility for customized products.</td>
</tr>
<tr>
<td>Supplier management.</td>
<td>Scope is enterprise-wide.</td>
</tr>
<tr>
<td>Emphasis on efficient use of resources. Relies on smooth production schedule.</td>
<td>Form virtual enterprises.</td>
</tr>
<tr>
<td></td>
<td>Emphasis on thriving in environment marked by continuous unpredictable change. Attempts to be responsive to change.</td>
</tr>
</tbody>
</table>
Observations

• Lean emphasizes technical and operational issues. Agility emphasizes organization and people issues.
• Lean applies mainly to the factory. Agility is broader in scope (enterprise level and virtual enterprises).
• One might argue that agility represents an evolutionary next phase of lean production.
• Certainly the two systems do not compete. If anything, agility complements lean. It extends lean thinking to the entire organization.
If there is a difference between lean and agile, it is in change and change management

- Lean tries to minimize change, at least external change. It attempts to smooth out the ups and downs in the production schedule. It attempts to reduce the impact of changeovers on factory operations so that smaller batch sizes and lower inventories are feasible. It uses flexible production technology to minimize disruptions caused by design changes.

- By contrast, the philosophy of agility is to embrace change. The emphasis is on thriving in an environment marked by continuous and unpredictable change. It acknowledges and attempts to be responsive to change, even to be the change agent if it leads to competitive advantage.
The capacity of an agile company to adapt to change or to be a change agent depends on its capabilities

- to have a flexible production system,
- to minimize the time and cost of changeover,
- to reduce on-hand inventories of finished products, and
- to avoid other forms of waste.

These capabilities belong to a lean production system.

For a company to be agile, it must also have lean capabilities.
CLASSIFICATION OF MANUFACTURING SYSTEMS

Mikell P. Groover
Department of Industrial and Manufacturing Systems Engineering
Lehigh University
Manufacturing System

Collection of operating elements working together, whose function is to add value to a starting raw material, part, or set of parts by performing one or more processing and/or assembly steps on it.

Operating elements = production machines and tools, material handling equipment, computer systems, and human resources to run the system.

There is a synergy obtained by combining operating elements to form a system. By working together, system is more productive than if single elements worked alone.
Production System

People, equipment, and procedures organized for the combination of materials and processes that constitute the firm’s manufacturing operations.

Production systems include (1) facilities and (2) manufacturing support procedures.

A larger entity than a manufacturing system.
Examples of Manufacturing Systems:

One worker tending one machine, which operates on semi-automatic cycle

A fully automated assembly machine, periodically attended by a human worker

One worker tending multiple machines, each of which operates on semi-automatic cycle

A group of workers performing assembly operations on a production line

A group of automated machines working on automatic cycles in a coordinated manner
Manufacturing System Components

Production machines plus tools, fixtures, and other related hardware

Material handling subsystem

Computer systems to coordinate and/or control the above components

Human resources

The types of processing and/or assembly operations, and the way in which the equipment is configured with the other components, determines the type of manufacturing system.
Production Machines (Workstations):

In virtually all modern manufacturing systems, the actual processing or assembly work is accomplished by machines or with the aid of tools. The machines can be classified as:

1. **Manually operated machines** - directed or supervised by human worker.

2. **Semi-automated machine** - performs a portion of work cycle under program control, and worker tends to machine for remainder of cycle.

3. **Fully automated machine** - operates for extended periods of time (longer than one work cycle) with no human attention. Worker is not required to be present during each cycle.
Material Handling Subsystem

In a system with multiple workstations, a means of moving work units from one station to the next is generally required.

MH System provides Transport + Storage

Two general categories of routing between stations:

- **Fixed routing** – same sequence of operations
- **Variable routing** – different sequence for different work units
Computer Control System

Typical Computer System Functions Include:

- Communicate instructions to workers
- Download part programs to computer-controlled machines
- Material handling system control
- Schedule production
- Failure diagnosis
- Safety Monitoring
- Quality Control
- Operations management.
Human Resources

Direct Labor:
Loading/unloading workparts
Changing tools, tool maintenance, etc.

Indirect Labor:
Maintenance and repair of equipment
Computer programming
Computer operation
CNC parts programming

Distinction between direct and indirect labor not always precise in automated systems.
Classification / Manufacturing Systems

Factors and Parameters:
- Types of operations performed
- Number of workstations and system layout
- Level of automation
- Part or product variety.
Types of Operations Performed

Processing operations vs assembly operations

In machining systems, Rotational parts vs Nonrotational (also called prismatic) parts.
Number of Workstations

Convenient measure of system size.
As number of stations is increased, amount of work accomplished increases.
There must be a synergistic benefit obtained from multiple stations working in a coordinated manner rather than independently.
More stations mean system is more complex, and thus more difficult to manage.
Layout of stations is an important factor in determining most appropriate MH system.
Let $n =$ number of workstations.
Classification Scheme with Number of Workstations and Layout

**Type I - Single station.** Simplest case - one workstation \((n = 1)\), usually includes a production machine manually operated, semi-automated, or fully automated.

**Type II - Multiple stations with variable routing.** Two or more stations \((n > 1)\) organized to accommodate processing or assembly of different part or product styles.

**Type III - Multiple stations with fixed routing.** Two or more workstations \((n > 1)\) organized as a production line.
Level of Automation

Three categories of workstation (machine) automation:

**Manually operated** – powered machine supervised by human worker (Example: conventional machine tool).

**Semi-automated** – machine performs a portion of work cycle under program control, human worker performs rest of cycle.

**Fully Automated** – machine can operated for extended periods of time with no human attention.

Additional issue is degree to which manufacturing system itself is automated by computer control.
Manning Level

Indirect measure of automation.

\[
M = \frac{w_u + \sum_{i=1}^{n} w_i}{n} = \frac{w}{n}
\]

where \(M\) = average manning level; \(w_u\) = number of utility workers assigned to system, \(w_i\) = number of workers assigned to station \(i\), \(w\) = number of workers.
Manning Level (continued)

In general,
Low \( M \) values \((M_i < 1)\) imply high level of automation.
High \( M \) values \((M_i \geq 1)\) imply low level of automation.
where \( M_i \) = manning level at station \( i \).
Level of Flexibility

Degree to which system is capable of dealing with differences in parts or products produced by the system.

Examples of possible differences that a manufacturing system may have to cope with include:

- Differences in part geometry in a machining operation
- Differences in parts and options that make up an assembled product on a final assembly line
- Differences in electronic components that are placed on a printed circuit board
- Differences in type of plastic in an injection molding machine.
Flexibility in Manufacturing Systems

To be flexible, a manufacturing system must possess the following capabilities:

- Identification of the different work units.
- Quick changeover of operation instructions (part program).
- Quick changeover of physical setup (fixtures, dies, tooling).
Three types of mfg. system, according to capacity to deal with product variety

<table>
<thead>
<tr>
<th>System Type</th>
<th>Symbol</th>
<th>Typical Product Variety</th>
<th>Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single model</td>
<td>S</td>
<td>No product variety</td>
<td>None required</td>
</tr>
<tr>
<td>Batch model</td>
<td>B</td>
<td>Hard product variety typical</td>
<td>Most flexible</td>
</tr>
<tr>
<td>Mixed model</td>
<td>X</td>
<td>Soft product variety typical</td>
<td>Some flexibility</td>
</tr>
<tr>
<td>Type Description</td>
<td>Operation</td>
<td>Product Variety</td>
<td>Example</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------</td>
<td>-----------------</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td><strong>IM</strong> Single-station manned cell</td>
<td>Processing</td>
<td>B or X</td>
<td>Wrkr at CNC lathe&lt;br&gt;Wrkr at press&lt;br&gt;Welder &amp; fitter at arc welding setup</td>
</tr>
<tr>
<td></td>
<td>Processing</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assembly</td>
<td>S or B or X</td>
<td></td>
</tr>
<tr>
<td><strong>IA</strong> Single-station automated cell</td>
<td>Processing</td>
<td>B or X</td>
<td>Unattended CNC machining center w. parts carousel.</td>
</tr>
<tr>
<td></td>
<td>Assembly</td>
<td>S or X</td>
<td>Assembly system: robot performing several tasks to complete product.</td>
</tr>
<tr>
<td>Type Description</td>
<td>Operation</td>
<td>Product Variety</td>
<td>Example</td>
</tr>
<tr>
<td>------------------</td>
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<td>---------</td>
</tr>
<tr>
<td><strong>II M</strong> Multi-station manual system w. variable routing</td>
<td>Processing</td>
<td>X</td>
<td>Group technology machine cell.</td>
</tr>
<tr>
<td></td>
<td>Processing</td>
<td>B</td>
<td>Small job shop could be considered type II M. It produces a variety of parts &amp; products requiring a variety of process routings.</td>
</tr>
<tr>
<td><strong>II A</strong> Multi-station automated system w. variable routing</td>
<td>Processing</td>
<td>X</td>
<td>Flexible mfg. System</td>
</tr>
<tr>
<td>Type Description</td>
<td>Operation</td>
<td>Product Variety</td>
<td>Example</td>
</tr>
<tr>
<td>---------------------------</td>
<td>--------------------</td>
<td>-----------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>III M</strong> Multi-station manual system w. fixed routing</td>
<td>Assembly</td>
<td>S or B or X</td>
<td>Manual assembly line that produces small power tools</td>
</tr>
<tr>
<td><strong>III A</strong> Multi-station automated system w. fixed routing</td>
<td>Processing, Assembly</td>
<td>S, S</td>
<td>Machining transfer line. Automated assembly machine w. carousel transfer system</td>
</tr>
<tr>
<td><strong>III H</strong> Multi-station hybrid system w. fixed routing</td>
<td>Assembly and Processing</td>
<td>X</td>
<td>Automobile final assembly plant, w. automated spot welding &amp; spray painting, but manual assembly.</td>
</tr>
</tbody>
</table>
Examples of Manufacturing Systems:

One worker tending one machine, which operates on semi-automatic cycle
A fully automated assembly machine, periodically attended by a human worker
One worker tending multiple machines, each of which operates on semi-automatic cycle
A group of workers performing assembly operations on a production line
A group of automated machines working on automatic cycles in a coordinated manner
FLEXIBLE MANUFACTURING SYSTEMS (FMS)

M. P. Groover
MSE 438
Terminology on Model Variations

Single model case – One product or model is produced that is identical from one unit to the next

Batch model case – Different products or models produced in batches
  • Requires changeover between models

Mixed model case – Different products or models produced on same line or equipment with no changeovers between models
Enablers for Unattended Operation in Single Model and Match Model Cases

Programmed work cycle
Parts storage subsystem
Automatic transfer of workparts between storage subsystem and production machine
Periodic attention of worker
  • Resupply and removal of workparts, tool changes, minor repairs, maintenance
Built-in safeguards to protect the system itself and the work units processed by the system
Enablers of Mixed Model Case – Flexible Manufacturing Systems

Identification of different models
- No problem for human workers
- For automated system, some means of product identification is required

Quick changeover of operating instructions
- For automated system, change part program

Quick changeover of physical setup
- Change tooling and fixtures in very short time
FMS technology can be applied in situations similar to those for cellular manufacturing:

- Presently, the plant either (1) produces parts in batches, or (2) uses manned GT cells and management wants to automate.
- It must be possible to group a portion of the parts made in the plant into part families, whose similarities permit them to be processed on the machines in the flexible manufacturing system.
- The parts or products made by the facility are in the mid-volume, mid-variety production range. The appropriate production volume range is 5000 to 75,000 parts per year.
Figure 17.1
Application characteristics of flexible manufacturing systems.
The differences between implementing a manually operated machine cell and installing a flexible manufacturing system are:

The FMS requires a significantly greater capital investment because new equipment is being installed rather than existing equipment being rearranged.

The FMS is technologically more sophisticated for the human resources who must make it work.
Benefits that can be expected from a FMS include:

- Increased machine utilization
- Fewer machines required
- Reduction in factory floor space required
- Greater responsiveness to change.
Benefits (continued)

- Reduced inventory requirements
- Lower manufacturing lead times
- Reduced direct labor requirements and higher labor productivity
- Opportunity for unattended production
What is a FMS?

A flexible-manufacturing system is a highly automated GT machine cell, consisting of a group of processing workstations, interconnected by an automated material handling and storage system, and controlled by a distributed computer system.

The reason the FMS is called flexible is that it is capable of processing a variety of different part styles simultaneously at the various workstations, and the mix of part styles and quantities of production can be adjusted in response to changing demand patterns.
What is a FMS? (continued)

The initials FMS are sometimes used to denote the term *flexible machining system*.

The machining process is presently the largest application area for FMS technology.
Figure 16.14 FMS at Vought Aircraft (line drawing courtesy of Cincinnati Milacron).
Figure 16.15 Flexible fabricating system for automated sheet metal processing (based on line drawing provided courtesy of Wiedemann Division, Cross & Trecker Co.)
A FMS relies on the principles of group technology. No manufacturing system can be completely flexible. There are limits to the range of parts or products that can be made in a FMS. A FMS is designed to produce parts (or products) within a defined range of styles, sizes, and processes. In other words, it is capable of producing a single part family or a limited range of part families.

PO: A more appropriate term for FMS would be flexible automated manufacturing system.
The word “automated” would distinguish this technology from other manufacturing systems that are flexible but not automated, such as a manned GT machine cell.

The word “flexible” would distinguish it from other manufacturing systems that are highly automated but not flexible, such as a conventional transfer line. However, the existing terminology is well established.
What Makes It Flexible?

Some highly automated manufacturing systems are not flexible, and this leads to confusion in terminology; for example, a transfer line.

Consider a machine cell consisting of two CNC machines that are loaded and unloaded by an industrial robot from a parts carousel. The cell operates unattended for extended periods of time. Periodically, a worker must unload completed parts from the carousel and replace them with new parts.

This is an automated manufacturing cell, but is it a flexible manufacturing cell?
Figure 16.1 Automated manufacturing cell with two machine tools and robot. Is it a flexible cell?
To qualify as being flexible, a manufacturing system should satisfy several criteria.

Four reasonable tests of flexibility:

1. **Part variety test.** Can the system process different part styles in a non-batch mode?

2. **Schedule change test.** Can the system readily accept changes in production schedule: changes in either part mix or production quantities?
Tests of flexibility (continued)

3. Error recovery test. Can the system recover gracefully from equipment malfunctions and breakdowns, so that production is not completely disrupted?

4. New part test. Can new part designs be introduced into the existing product mix with relative ease?

If the answer to all of these questions is “yes” for a given manufacturing system, then the system can be considered flexible.
If the automated system does not meet at least the first three tests, it should not be classified as a flexible manufacturing system. The robotic work cell satisfies the criteria if it:

1. can machine different part configurations in a mix rather than in batches;
2. permits changes in production schedule and part mix;
Robotic work cell satisfies the criteria if it (continued):

3. is capable of continuing to operate even though one machine experiences a breakdown - for example, while repairs are being made on the broken machine, its work is temporarily reassigned to the other machine; and

4. as new part designs are developed, NC part programs are written off-line and then downloaded to the system for execution.
<table>
<thead>
<tr>
<th>Types of Flexibility in Manufacturing</th>
<th>Definition</th>
<th>Depends on factors such as</th>
</tr>
</thead>
</table>
| **Machine flexibility**              | Capability to adapt a given machine (workstation) in the system to a wide range of production operations and part styles. The greater the range of operations and part styles, the greater the machine flexibility. | - Setup or changeover time.  
- Ease of machine reprogramming (ease with which part programs can be downloaded to machines).  
- Tool storage capacity of machines.  
- Skill and versatility of workers in the system. |
| **Production flexibility**           | The range or universe of part styles that can be produced on the system. | - Machine flexibility of individual stations.  
- Range of machine flexibilities of all stations in the system. |
<table>
<thead>
<tr>
<th>Flexibility Type</th>
<th>Description</th>
<th>Related Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix flexibility</td>
<td>Ability to change the product mix while maintaining the same total production quantity; that is, producing the same parts only in different proportions.</td>
<td>Similarity of parts in the mix. Relative work content times of parts produced. Machine Flexibility.</td>
</tr>
<tr>
<td>Product flexibility</td>
<td>Ease with which design changes can be accommodated. Ease with which new products can be introduced.</td>
<td>How closely the new part design matches the existing part family. Off-line part program preparation. Machine flexibility.</td>
</tr>
<tr>
<td><strong>Volume flexibility</strong></td>
<td><strong>Expansion flexibility</strong></td>
<td></td>
</tr>
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<td>------------------------</td>
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<td></td>
</tr>
<tr>
<td>Ability to economically produce parts in high and low total quantities of production, given the fixed investment in the system.</td>
<td>Level of manual labor performing production.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amount invested in capital equipment.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Expense of adding workstations.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ease with which layout can be expanded.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type of part handling system used.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ease with which properly trained workers can be added.</td>
<td></td>
</tr>
</tbody>
</table>
Comparison of four criteria of flexibility with the seven types of flexibility.

<table>
<thead>
<tr>
<th>Flexibility tests or criteria</th>
<th>Type of flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part variety test</td>
<td>Machine flexibility</td>
</tr>
<tr>
<td>Can the system process different part styles in a non-batch mode?</td>
<td>Production flexibility</td>
</tr>
<tr>
<td>Schedule change test</td>
<td>Mix flexibility</td>
</tr>
<tr>
<td>Can the system readily accept changes in production schedule: changes in either part mix or production quantities?</td>
<td>Volume flexibility</td>
</tr>
<tr>
<td>Error recovery test</td>
<td>Expansion flexibility</td>
</tr>
<tr>
<td>Can the system recover gracefully from equipment malfunctions and breakdowns, so that production is not completely disrupted?</td>
<td>Routing flexibility</td>
</tr>
<tr>
<td>New part test</td>
<td>Product flexibility</td>
</tr>
<tr>
<td>Can new designs be introduced into the existing product mix with relative ease?</td>
<td></td>
</tr>
</tbody>
</table>
Types of FMS

Each FMS is designed for a specific application; that is, a specific family of parts and processes.

Therefore, each FMS is custom-engineered; each FMS is unique.
FMSs can be distinguished according to the number of machines.

- **Single machine cell** - One CNC machining center combined with a parts storage system for unattended operation.

- **Flexible manufacturing cell** - Consists of two or three processing stations plus a parts handling system connected to a load/unload station.

- **Flexible manufacturing system** - Four or more processing workstations connected mechanically by a common parts handling system and electronically by a distributed computer system.
Figure 16.2  Single machine cell consisting of one CNC machining center and parts storage unit.
Figure 16.4 Features of the three categories of flexible cells and systems.
Figure 16.3 A flexible manufacturing cell consisting of three identical processing stations (CNC machining centers), a load/unload station, and a part handling system.
Differences between FMC and FMS

Number of machines: a FMC has two or three machines, while a FMS has four or more.

FMS generally includes non-processing workstations that support production but do not directly participate in it (e.g., part/pallet washing stations, coordinate measuring machines).

Computer control system of a FMS is generally larger and more sophisticated, often including functions not always found in a cell, such as diagnostics and tool monitoring.
## Flexibility criteria applied to the three types of manufacturing cells and systems.

<table>
<thead>
<tr>
<th></th>
<th>Part variety</th>
<th>Schedule change</th>
<th>Error recovery</th>
<th>New part</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single machine cell (SMC)</strong></td>
<td>Yes, but processing sequential, not simultaneous</td>
<td>Yes</td>
<td>Limited recovery due to only one machine</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Flexible mfg cell (FMC)</strong></td>
<td>Yes, simultaneous production of different parts</td>
<td>Yes</td>
<td>Error recovery limited by fewer machines than FMS</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Flexible mfg system (FMS)</strong></td>
<td>Yes, simultaneous production of different parts</td>
<td>Yes</td>
<td>Machine redundancy minimizes effect of machine breakdowns</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Another classification of FMSs is by level of flexibility:

**Dedicated FMS** –

Designed to produce a limited variety of part styles, and the complete universe of parts to be made on the system is known in advance.

Part family is likely to be based on product commonality rather than geometric similarity.
Product design is stable, so the system can be designed with a certain amount of process specialization to make the operations more efficient.

The machine sequence may be identical or nearly identical for all parts processed, and so a transfer line may be appropriate, in which the workstations possess the necessary flexibility to process the different parts in the mix ("flexible transfer line")
More appropriate when the part family is large, substantial variations in part configurations, new part designs introduced into the system and engineering changes in parts currently produced, and production schedule is subject to change.

More flexible than the dedicated FMS.

General purpose machines to deal with the variations in product.

More sophisticated computer control system is required.
# Flexibility criteria applied to dedicated FMS and random-order FMS

<table>
<thead>
<tr>
<th></th>
<th>Part variety</th>
<th>Schedule change</th>
<th>Error recovery</th>
<th>New part introduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dedicated FMS</td>
<td>Limited. All parts known in advance.</td>
<td>Limited changes can be tolerated.</td>
<td>Limited by sequential processes.</td>
<td>New part introduction is difficult.</td>
</tr>
<tr>
<td>Random-order FMS</td>
<td>Yes. Substantial part variations possible.</td>
<td>Frequent and significant changes possible.</td>
<td>Machine redundancy minimizes effect of machine breakdowns</td>
<td>Yes. System designed for new part introductions</td>
</tr>
</tbody>
</table>
Figure 16.5 Comparison of dedicated and random-order FMS types.
Basic Components of a FMS:

Workstations
Material handling and storage system
Computer control system
People are required to manage and operate the system.
Workstations

**Load/Unload Stations** - Physical interface: FMS and factory.

**Machining Stations** - Most common is the **CNC machining center**.

**Other Processing Stations** - Sheetmetal fabrication, forging.

**Assembly** - Industrial robots, component placement machines.

**Other Stations and Equipment** - Inspection stations, cleaning stations, central coolant delivery and chip removal systems.
Material Handling and Storage System

**Functions of the Handling System**

*Random, independent movement of workparts between stations.*

*Handle a variety of workpart configurations.*

*Temporary storage.*

*Convenient access for loading and unloading workparts.*

*Compatible with computer control.*
FMS Layout Configurations

- In-line layout
- Loop layout
- Ladder layout
- Open field layout
- Robot-centered cell