Factory Automation and Control Methods
Lecture 2: Manufacturing Operations

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Outline

1. Manufacturing Industries and Production
2. Manufacturing Operation
3. Production Facilities
4. Product/Production Relationships
5. Lean Production

1. Manufacturing Industries and products

Classification of Industries

- Primary industries – cultivate and exploit natural resources
  Ex. Agriculture, mining
- Secondary industries – convert output of primary industry to products
  Ex. Manufacturing, power generation, construction
- Tertiary industries – service sector
  Ex. Banking, education, government, legal services, retail trade, transportation
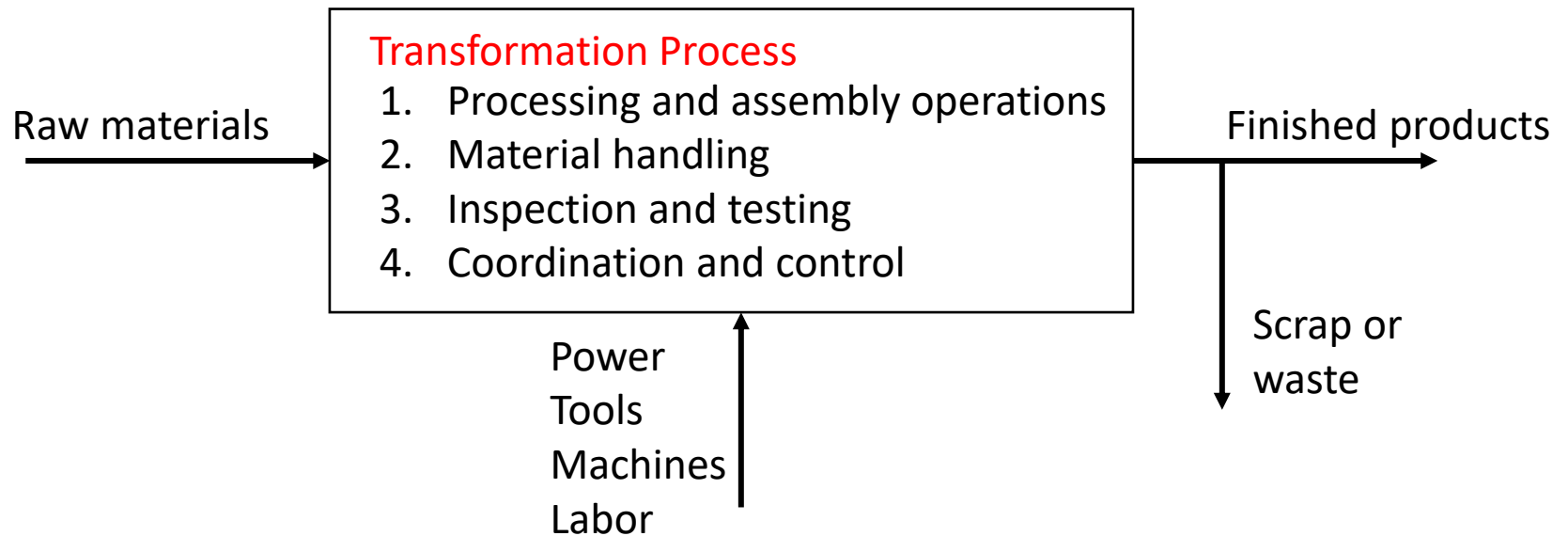
1. Manufacturing Industries and products

TABLE 2.2 International Standard Industrial Classification Codes for Various Industries in the Manufacturing Sector

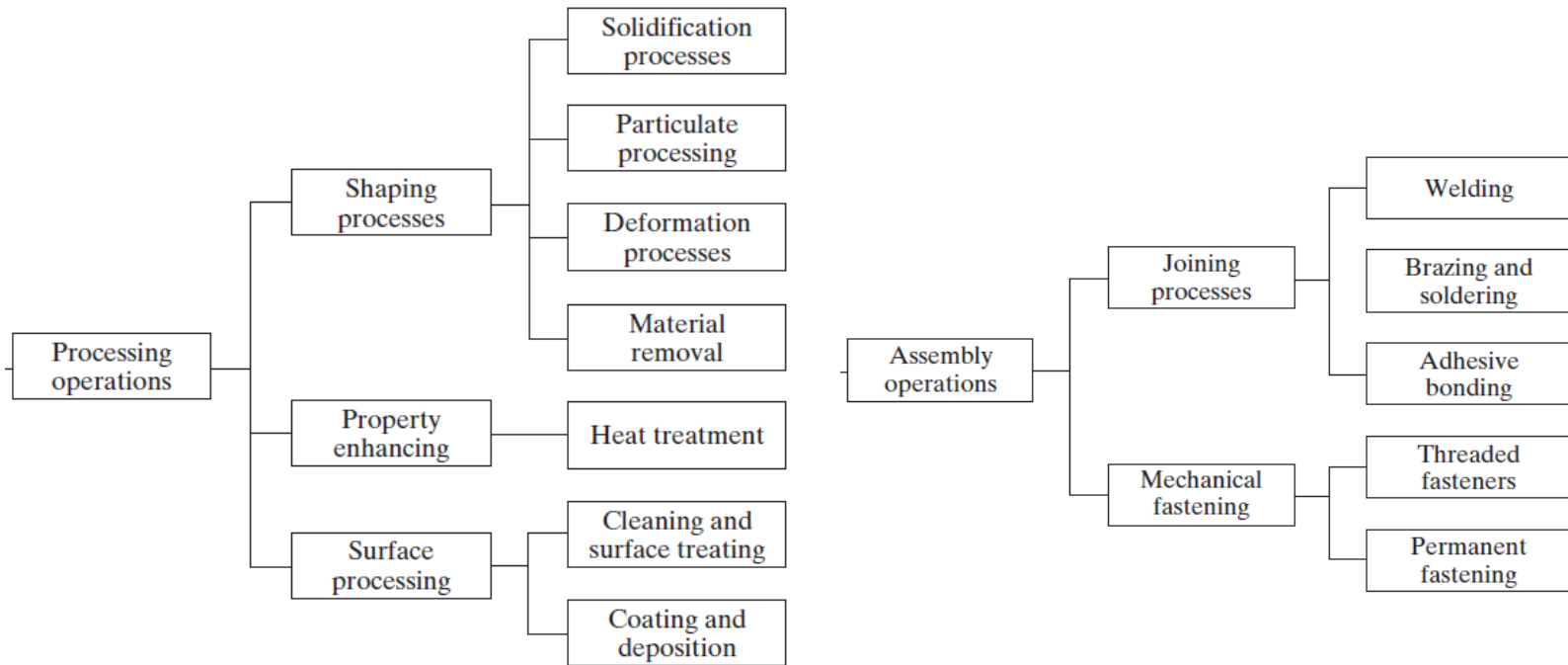| Basic Code	Products Manufactured
31	Food, beverages (alcoholic and nonalcoholic), tobacco
32	Textiles, clothing, leather goods, fur products
33	Wood and wood products (e.g., furniture), cork products
34	Paper, paper products, printing, publishing, bookbinding
35	Chemicals, coal, petroleum, plastic, rubber, products made from these materials, pharmaceuticals
36	Ceramics (including glass), nonmetallic mineral products (e.g., cement)
37	Basic metals (steel, aluminum, etc.)
38	Fabricated metal products, machinery, equipment (e.g., aircraft, cameras, computers and other office equipment, machinery, motor vehicles, tools, televisions)
39	Other manufactured goods (e.g., jewelry, musical instruments, sporting goods, toys)

2. Manufacturing industry and products

- Process industries, e.g., chemicals, petroleum, basic metals, foods and beverages, power generation

- Discrete product (and part) industries, e.g., car, aircraft, appliances, machinery, and their component parts

2. Manufacturing Operations

Raw materials →

Transformation Process *(in red)*
1. Processing and assembly operations
2. Material handling
3. Inspection and testing
4. Coordination and control

→ Finished products

↓ Scrap or waste

↑ Power
Tools
Machines
Labor

2. Manufacturing Operations
Processing and Assembly Operation

2. Manufacturing Operations
Processing Operation

- Shaping operations
    - Solidification processes
    - Particulate processing
    - Deformation Processes
    - Material removal processes
- Properties-enhancing operation (heat treatments)
- Surface processing operation
    - Cleaning and surface treatments
    - Coating and thin-film deposition

2. Manufacturing Operations
Assembly Operation

- Joining processes
    - Welding
    - Brazing and soldering
    - Adhesive bonding
- Mechanical assembly
    - Threaded fasteners (e.g., bolts and nuts, screws)
    - Rivets
    - Interference fits (e.g., press fitting, shrink fits)
    - other

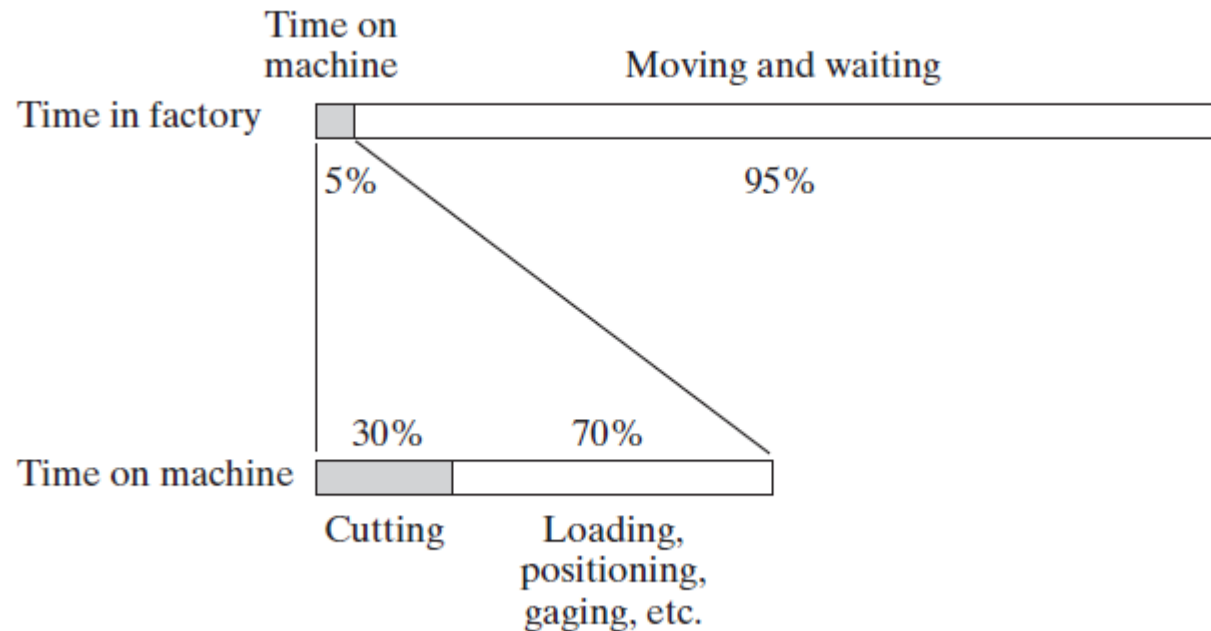# 2. Manufacturing Operations
Other factory operations

Material handling

- Material transport
  - Vehicle, e.g., forklift trucks, monorials
  - Conveyors
  - Cranes…
- Storage systems
- Unitizing equipment
- Automatic identification and data capture
  - Bar codes….

2. Manufacturing Operations
Other factory operations

Time Spent in Material handling

2. Manufacturing Operations
Other factory operations

Inspection and testing

Inspection – conformance to design specifications
- Inspection for variables – measuring
- Inspection of attribute – gauging

Testing – observing the product (or part, material, subassembly) during operation

2. Manufacturing Operations
Other factory operations

Coordination and Control

- Regulation of the individual processing and assembly operations
  - Process control
  - Quality control
- Management of plant level activities
  - Production planning and control
  - Quality control

3. Production Facilities

- Facilities organized in the most efficient way to serve the particular mission of the plant and depends on:
  - Type of products manufactured
  - Production quantity
  - Product variety

3. Production Facilities

Production quantity (IQ)

- Number of units of a given part or product produced annually by a plant
- Three quantity ranges
  - Low production – 1 to 100 units
  - Medium production – 100 to 10,000 units
  - High production – 10,000 to millions of units

3. Production Facilities

Production variety (P)

- Number of different product or part designs or types
- 'Hard' product variety – products differ greatly
    - Few common components in an assembly
- 'Soft' product variety – small differences between products
    - Many common components in an assembly

3. Production Facilities

Low production quantity

Job shop – makes low quantities of specialized and customized products
- Products are typically complex (e.g., specialized machinery, prototypes, space capsules)
- Equipment is general purpose
- Plant layouts
    - Fixed position
    - Process layout

3. Production Facilities

Medium production quantity

Batch production – a batch of a given product is produced, and then the facility is changed over to produce another product
- Changeover takes time – setup time
- Typical layout – process layout
- Hard product variety

Cellular manufacturing – A mixture of products is made without significant changeover time between products
- Typical layout – cellular layout
- Soft product variety

3. Production Facilities

High production

Quantity production – Equipment is dedicated to the manufacturing of one product
- Standard machines tooled for high production (e.g., stamping presses, molding machines)
- Typical layout – process layout

Flow line production – Multiple workstations arranged in sequence
- Product requires multiple processing or assembly steps
- Production layout is most common

4. Product/Production Relationships
4.1 Production Quantity and Production Variety

- Let Q_j = annual quantity of variety 'j'
- P = variety of product from '1' to 'j'
- Total number of product units is defined as

$$Q_f = \sum_{j=1}^{p} Q_j$$

The total number of product models is given by
$$P = \sum_{j=1}^{p_1} P_{2j}$$

4. Product/Production Relationships
4.1 Production Quantity and Production Variety

The parameter P can be divided into two levels called P_1 and P_2. P_1 refers to the number of distinct product lines produced by the factory, and P_2 refer to the number of models in a product line.

The total number of product models is given by

$$P = \sum_{j=1}^{p_1} P_{2j}$$

4. Product/Production Relationships
4.1 Production Quantity and Production Variety

EXAMPLE 2.1   Product Lines and Product Models

A company specializes in home entertainment products. It produces only TVs and audio systems. Thus $P_1 = 2$. In its TV line it offers 15 different models, and in its audio line it offers 5 models. Thus for TVs, $P_2 = 15$, and for audio systems, $P_2 = 5$. The totality of product models offered is given by Equation (2.2):

$$P = \sum_{j=1}^{2} P_{2j} = 15 + 5 = 20$$

4. Product/Production Relationships
4.1 Production Quantity and Production Variety

- Product complexity n_p = number of components in product
- Part complexity n_0 = number of processing operations per part

4. Product/Production Relationships
Factory Operation Model

Simplified

- Total number of product units $Q_f = PQ$
- Total number of parts produced $n_{pf} = PQn_p$
- Total number of operations $n_{of} = PQn_pn_0$

Where
P = Production variety
Q = Production quantity
n_p = Number of parts in product
n_0 = Number of operations in product

4. Product/Production Relationships
Factory Operation Model

EXAMPLE 2.2   A Production System Problem

Suppose a company has designed a new product line and is planning to build a new plant to manufacture this product line. The new line consists of 100 different product types, and for each product type the company wants to produce 10,000 units annually. The products average 1,000 components each, and the average number of processing steps required for each component is 10. All parts will be made in the factory. Each processing step takes an average of 1 min. Determine (a) how many products, (b) how many parts, and (c) how many production operations will be required each year, and (d) how many workers will be needed in the plant, if each worker works 8 hr per shift for 250 days/yr (2,000 hr/yr)?

4. Product/Production Relationships
Manufacturing Capability

- Technological processing capability – the available set of manufacturing processes
- Physical size and weight of product
- Production capability (plant capability) – production quantity that can be made in a given time

4. Product/Production Relationships
Lean Production

Operating the factory with the minimum possible resources and yet maximizing the amount of work accomplished

- Utilization of resources – workers, equipment, time, space, materials
- Minimizing time
- Maximizing quality (accuracy)
- Minimizing cost
- Doing more with less, and doing it better

4. Product/Production Relationships
Programs Associated with Lean Production

- Just-in-time delivery of parts
- Worker involvement
- Continuous improvement
- Reduced setup times
- Stop the process when somethings is wrong
- Error prevention
- Total productive maintenance

References

Mikell P. Groover, "Automation, Production Systems and Computer-integrated Manufacturing" , 4th edition, Pearson, chapter 2