INEN 220
Introduction to Production and Manufacturing Systems

Overview

• History of Manufacturing
• Manufacturing Systems Introduction
  – Design and Operation Issues
  – Performance Measures
• Manufacturing Engineering Organization
• Manufacturing Engineering Management

What Is Manufacturing?

• Varying definitions of scope
  – *Our focus is on manufacturing systems*
• Technically complex manufacturing *processes*
  – Machining characteristics, assembly instructions...
  – Necessary to *make the product*
• Technically complex manufacturing system operations and coordination
  – Facility layout, capacity planning, production control...
  – Necessary to *make money* making the product

Why Is Manufacturing Important?

• Only real method of creating wealth
• Shift to service economy is undesirable because manufacturing is *offshored*
  – Eliminates direct manufacturing jobs and numerous manufacturing support jobs throughout the economy
• Manufacturing competition has increased
  – Japan, Europe, and Pacific Rim

Why Is Manufacturing Hard?

• Customer demands have increased
  – Traditional: “The customer can have any color as long as it’s black.” - Henry Ford
  – Modern: Customers expect large product variety, reasonable price, superior quality, comprehensive service, and responsive delivery
• Can’t depend on strength of the group
  – *Success of each individual firm is fundamentally determined by the effectiveness of its management to adapt to the new globally competitive environment*
Evolution of Manufacturing

- Completely custom - craftsman (pre 1800)
- English system (1800s)
  - Introduction of general purpose machines that could be used for a variety of products.
- American system (1850s)
  - Emphasized precision and interchangeability. Changed from a "best fit" to a "greatest clearance without loss of functionality" focus.
- Scientific management (1900s)
  - Prespecified worker motions - Moved the control totally into the hands of management.

- Process improvement (SPC) (1950s)
  - The identical procedure will produce different results on the same machine at different times. It emphasized outliers rather than mean performance.
- Numerical control (1970s)
  - Combining the versatility of general purpose machines with the precision and control of special-purpose machines.
- Computer integrated manufacturing (1980s)
- Logistics/Supply-chain management (1990s)

History of Manufacturing

- Fundamental premise
  - Make what people want better and cheaper than anybody else
  - But the times have changed
- 1st industrial revolution
  - Vertical integration
  - Move away from individual craftsmen to centralized production with all aspects performed in a common location
  - Interchangeable parts
    - Allowed manufacture of complex multi-part products on a large scale
  - Created an emphasis on mass production
    - Reduced need for workers with specialized skills
    - Specialization in machines instead of people
    - Workers were "interchangeable"
    - Contributed to rocky history of labor relations
    - Required coordination of mass production with mass distribution system to facilitate the flow of materials and goods through the economy
- 2nd industrial revolution with innovations in transportation and communication

Industrial Advances

- Railroads
  - Hierarchy of management
- Mass retailers
  - Accurate cost accounting information
- Steel business
  - Increased scale and efficient flow
- Auto assembly line
  - High speed, mass production of complex, mechanical products
- Large integrated business enterprises created need for more sophisticated managerial control techniques
  - Taylor scientific management
    - Systematic examination of work procedures
      - Measurement
      - Improvement
    - Shift from economies of scale to economies of scope
    - Using resources across multiple products
Industrial Advances

- Large, integrated business enterprises
  - Shift from technical efficiency to more complex human relations orientation
- Hawthorne studies

American Manufacturing

- Recent decline attributed to
  - Complacency - not continually improving
  - Conservative
    - Not innovative or willing to pursue high-risk ventures
    - Xerox copiers
    - Focus on short-term profits versus long-term benefits
    - Discourages innovation and capital improvements
  - Financial portfolio approach
    - Minimize risk by diversification
    - Lost focus on core competencies

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Our View of Manufacturing

Manufacturing Systems

- Design
  - Long term activities of determining the resources and their configuration to support the organization’s objectives
- Planning
  - Medium term decision making to determine the activities, and their order, that the organization should carry out to achieve its objectives

Little “m” Manufacturing

- Direct Production
  - Often referred to as “value added” operations
    - Cutting, shaping, grinding
    - Assembly
    - Necessary but not sufficient for effective manufacturing operations

Manufacturing Systems

- Operation
  - Short term detailed implementation of the planning decisions
- Control
  - Real-time execution of the operating instructions on the manufacturing shop floor
Big “M” Manufacturing

- High-level systems orientation
  - Strategic planning
  - Product design, process development
  - Plant design, capacity management
  - Plant scheduling, quality control, equipment maintenance, workforce organization
  - Product distribution, supply chain management, interplant coordination
  - Direct production

Performance Measures

- Maximize wealth
  - Ultimately, the objective of the manufacturing organization is to continually make money over time
  - How to predict impact of manufacturing engineering decisions on organization’s wealth?
- Dimensions of competition
  - Cost
  - Quality
  - Speed
  - Flexibility

Cost Elements

- Equipment and facility acquisition
- Material
- Labor
- Energy
- Maintenance
- Training
- Overhead (Support functions)
- Cost of capital

Quality Issues

- Product Design
  - Relative to customer expectations
  - Product longevity
  - Ease of maintenance/repair
- Manufacturing
  - Inspection/Rework/Scrap
  - Warranty issues
  - Customer satisfaction/loyalty

Time/Speed Issues

- Cycle time
  - Time to produce a product
- Response time
  - Time to fulfill a customer order
- Time to market
  - Time to develop and introduce new product(s)
- Adaptability
  - Time to respond to changes
    - Customer requirements, external competition, etc.

Flexibility

- Classification or Types
  - Machine flexibility
    - Ease of making changes required to produce a given set of part types
  - Process flexibility
    - Ability to produce a given set of part types in different ways perhaps with different materials
  - Product flexibility
    - Ability to change over to produce new products economically and quickly
Flexibility

Classification (cont.)
- Routing flexibility
  - Ability to handle breakdowns and continue producing a given set of part types
- Volume flexibility
  - Ability to operate profitably at different production volumes
- Expansion flexibility
  - Ability to expand the system easily and in a modular fashion

Flexibility

Classification (cont.)
- Operation flexibility
  - Ability to interchange ordering of several operations for each part type
- Production flexibility
  - Universe of part types that the manufacturing system can produce

Flexibility

- Ability to cope with external change
  - New jobs to be processed
- Ability to cope with internal change
  - Machine breakdowns

Performance Measures

- Relative importance varies among industries and companies
- Dimensions are interdependent and tradeoffs exist
  - Flexibility of the system affects time to respond to changes
  - Increased flexibility levels are usually associated with increased cost
  - Tradeoffs between time to produce and quality of production
- But, customers want it all

Manufacturing System Components

- Manufacturing System Description Model

Basic Manufacturing System

- Processes/Resources
- Facility
- Material flow
- Information
- Support functions
  - Design
  - Planning
  - Operation
  - Control
  - Business
  - Sales, marketing, finance
System Performance Metrics

- Order lead time
- Order throughput
- Order cycle time
- Theoretical cycle time
- Factory/system level work-in-process
- On-time delivery percentage
- Finished product inventory level

Basic Process View

- Process
  - Transforms product in some desirable manner
  - Elements
    - Resources
      - Machine, operator, tools, fixtures, etc.
    - Material
      - Input, output, setup
    - Information
      - Issues
        - Maintenance, setup, operation, coordination

Job/Process Performance Metrics

- Job throughput
- Job cycle time
- Job buffer inventories
- Job processing time
- Equipment utilization/availability
- Operator utilization/availability

Example Process Level Issues

- Economic Order Quantity (EOQ)
  - Determine the “optimum” batch size for the operation
  - Under some restrictive assumptions the inventory profile takes a standard “saw tooth” form

Example Issues (cont.)

- Economic Order Quantity (EOQ)
  - Average annual cost as a function of Q
    - Setup cost, purchase cost, and holding cost
      \[ g(Q) = \frac{K}{Q} + \lambda + \frac{Q}{2}, \quad \text{where } \lambda = \frac{Q}{P} \]
    - Find value of Q to minimize total cost, g(Q)
      - Take derivative of g(Q) with respect to Q and set to zero
        \[ g'(Q) = \frac{K}{Q^2} - \frac{\lambda}{2} = 0 \]
        \[ Q^* = \sqrt{\frac{2PK}{\lambda}} \]

Example Issues (cont.)

- Key Insights of EOQ
  - Tradeoff between batch (lot) size and inventory level
  - Increasing batch size increases the average amount of inventory on-hand, but reduces the frequency of orders
Example Issues (cont.)

- Operator - Machine Interference
  - Design of workstation and methods
  - Sequencing and balancing operator and machine activities
    - One operator — one machine
    - One operator — multiple machines
    - Multiple operators (team) — multiple machines

System Configurations

- Hayes and Wheelwright classification
  - Product, process, volume matrix
    - Job shop
    - Batch manufacturing
    - Flow line
    - Continuous flow

Product - Process Matrix

<table>
<thead>
<tr>
<th>Process Structure</th>
<th>Process Life-cycle Stage</th>
<th>Product Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jumbled flow (job shop)</td>
<td>Low volume, low standardization, one of a kind</td>
<td>Low</td>
</tr>
<tr>
<td>Disconnected line flow (batch)</td>
<td>Multiple products, low volume</td>
<td>High</td>
</tr>
<tr>
<td>Connected line flow (assembly line)</td>
<td>Few, major products, higher volume</td>
<td>Medium</td>
</tr>
<tr>
<td>Continuous flow</td>
<td>High volume, high standardization, commodity products</td>
<td>High</td>
</tr>
</tbody>
</table>

Product Volume vs. Product Variety

<table>
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<th>Volume (# parts)</th>
<th>Variety (# part types)</th>
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<tbody>
<tr>
<td>Low</td>
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</tr>
<tr>
<td>High</td>
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</table>

Manufacturing System Design

- Facility layout strategies
  - Process layout
    - Group like machines together — job shop
  - Group or family layout
    - Group machines to produce a set of products — cellular mfg.
  - Product or flow line layout
    - Arrange machines by sequence of production — assembly line
  - Fixed layout
    - Product remains in central location and machines are brought to it — airplane, ship building

Issues

- Which strategy to use?
- How to group machines?
- How many machines are needed?
- Where to locate machines?
- What material handling methods are used?
- Where and how big are the inventory storage points?
- How to assign products to machines or groups?