Introduction to Automation

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Introduction to Automation

Outline

- What is automation?
- Types of automation
- Manufacturing versus service automation
- Models of production
- Why automate?
- When to and when not to automate?

Definition

It is a technology dealing with the application of

- mechatronics
- computers

for production of goods and services.

Automation is broadly classified into

- manufacturing automation
- service automation

Examples:

- robots, CNC machine tools, ASRS, security systems, CAD/CAM systems, logistics support tools, automated inspection systems, material handling systems

Types of Automation

Fixed automation

- custom-engineered, special-purpose equipment to automate a fixed sequence of operations
  - high production rates, inflexible product design

Programmable automation

- equipment designed to accommodate a specific class of product changes
  - batch production, medium volume

Flexible automation

- designed to manufacture a variety of products or parts
  - low production rates, varying product design and demand

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Programmable Automation

- Weaving
  - programmable looms
- Musical instruments

- Many batch-processed products
  - Brackets, hinges, door knobs, locks

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Types of Automation

Attributes and advantages

Automation	When to consider	Advantages	Disadvantages
Fixed	High demand volume, long product life cycles	• maximum efficiency • low unit cost	• large initial investment • inflexibility
Programmable	Batch production, products with different options	• flexibility to deal with changes in product • low unit cost for large batches	• new product requires long set up time • high unit cost relative to fixed automation
Flexible	Low production rates, varying demand, short product life cycles	• flexibility to deal with design variations • customized products	• large initial investment • high unit cost relative to fixed or programmable automation

- Fixed: GE 1.5 billion light bulbs per year
- Programmable: CNC machines used in batch production
- Flexible: Honda (113 motorcycle models in 18 months)

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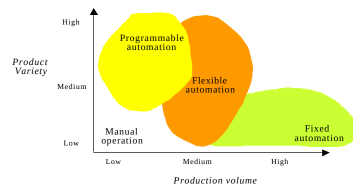
Production Volume and Variety



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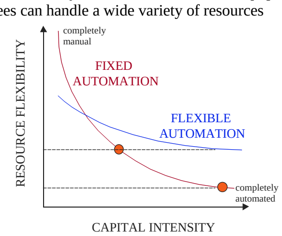
Flexible versus Fixed Automation

- Capital intensity: the mix of equipment and human skills
  - the greater the relative cost of equipment, the higher the capital intensity
  - the higher the capital intensity, the greater the degree of automation
- Resource Flexibility: the ease with which the equipment and employees can handle a wide variety of resources



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Example

Gillette South Boston Plant makes Sensor Excel Cartridges

- 1.5 to 2 billion cartridges/year
- 100 cartridges/minute/line
  - Major processes:
    - injection molding
      - 500 ton, 32 cavity molds ($ 1M) machines, 20 second cycle time
    - extrusion
    - others: grinding, stamping, welding, assembly
    - bottlenecks in assembly: injection molding and part feeding
- Time to market: 24 months
- Capital cost: $200 million
- Estimated life cycle: 6-8 years

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Types of Production

- *Job shop production*
  - specific orders from customers
  - generally characterized by low volumes
  - general purpose equipment, skilled workers
- *Batch production*
  - medium lot sizes
  - produced at regular intervals at a rate that exceeds the demand
  - general purpose equipment designed for a higher production rate
- *Mass production*
  - manufacture of products in large lot sizes
  - continuous, specialized manufacture of identical products
  - fixed automation

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Types of Mass Production

Quantity production

manufacture of single parts on standard machines (lathes, milling machines, injection molding machines, presses, etc.) with the use of special tools (dies, molds)

- screws, nuts, nails

Flow production

manufacture of complex products such as automotive engine blocks, which have to “flow” through a sequence of operations on material handling devices

- cars, bulbs, razors
- continuous products in refineries, chemical plants and food processing factories.

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Other Models for Manufacturing

Video

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Mass Production to Mass Customization

"... No longer able to generate large earnings from high-volume production of standard commodities - and unable to restore profits by protecting the American market, cutting prices, or rearranging assets - America's core corporations are gradually, often painfully, turning toward serving the unique needs of particular customers. By trial and error, by fits and starts, often under great stress, and usually without much awareness of what they are doing or why, the firms that are surviving and succeeding are shifting from high volume to high value production...."

- Robert Reich, Former U.S. Labor Secretary, 1992

Examples

- steel making:
  - corrosion resistant steels, powder for sintering lightweight crankshafts and camshafts, special alloy steels for turbomachines, and heat resistant steels for aerospace applications.
- semiconductor chips: National Semiconductors makes specialized million dollar chips
- computer industry: 80% of the cost of the computer are in the specialized software
- cars: Toyota makes 23,000 one-of-a-kind cars in the Georgetown plant
- clothing: Levi Strauss - customized jeans
- bikes: Canondale uses lot sizes of 10 in the manufacture of bicycle frames

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Plant Layout

Fixed position layout
- the product stays in one location and the fabrication equipment is brought to it
- one-of-a-kind or low volume production

Process layout
- the equipment is arranged in groups according to the function they perform
- generally used in batch production

Product flow layout
- machines are arranged to produce parts efficiently
- single product (or class of products), large volumes

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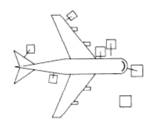
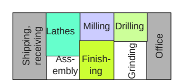
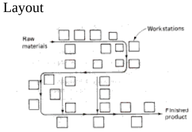
Plant Layout



Fixed Position Layout



Process Layout



Product Flow Layout

Which layout has (a) higher productivity? (b) higher flexibility? (c) more automation?

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Group Technology

A layout that achieves the economies of a product flow layout for a single product by making mutliple dissimilar products on several product flow lines
- grouping of similar parts to take advantage of their similarities in manufacturing and design
- a well designed classification and coding system for parts

Keys
- groups of parts and groups of machine cells
- better utilization of machines
- facilitates the programming of CNC machines
- permits automatic tooling setups, reduces setup time and improves production rate
- easy retrieval of designs, drawings and process plans

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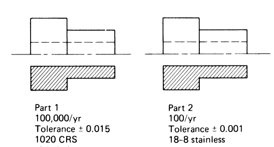
Group Technology



- Both parts are similar from a design viewpoint although they are different from a manufacturing viewpoint
- Similar fixtures, similar set up
- Can be produced in the same batch

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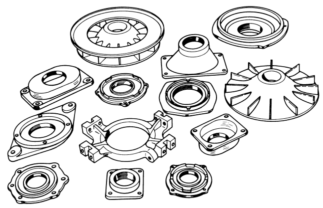
Group Technology

All parts require similar manufacturing processes, although the design process is different

- casting
- turning
- milling
- grinding
- finishing



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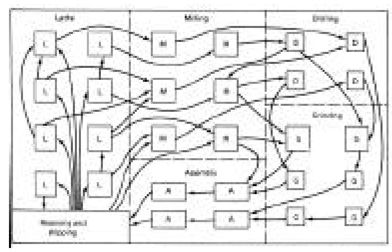
Group Technology

Example:

Manufacture of different parts needing turning, milling, grinding and finishing



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Parts Classification System: Group Technology

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1 machined part ← Type
2 round part (all diameters visible from one end)
7 one machined diameter visible from each end
0 no inside diameter
0 no secondary element (holes, grooves, flats)
41 axle ← Function
10 outside diameter (0.25 - 0.37 inch)
57 length (12.5-13.0 inch) ← Dimensions
00 inside diameter (none)
8 geometric concentricity (< 0.01 inch)
28 high strength steel ← Material/chemistry
2 round bar stock
1 production quantity (26-57) ← Volume
0 tool axis complexity (n/a) ← Manufacturing
3 thread diameter (5/16 inch)
5 threads per inch ← User defined
x others

Basic form

Manufacturing

Raw material

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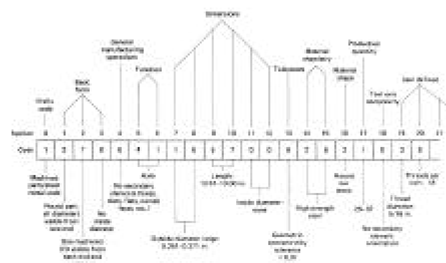
Example: Parts Classification System



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Computer Aided Design and Manufacturing

Integrated approach

- The same database is used for CAD, CAM, Process planning, quality control

Video

Examples

- windshield
- camshaft

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Reasons for Automation

- Shortage of labor
  - The ratio of the number of workers to the number of retirees in the U.S. is expected to be 2 to 1 in 2000. Main reason in Japan.
- High cost of labor
  - may not always make sense to establish plants in countries with low labor costs

Cost of labor

- Japan's labor costs are 5% more than the U.S. and over 50% higher than the U.K.
- West Germany imports cheap labor to augment domestic labor.
- Taiwan's manufacturing labor cost quadrupled from 1974 to 1984
- Korea's manufacturing labor cost doubled from 1979 to 1984, and quadrupled again between 1984 and 1996.

Country	1985	1995
Germany	9.6	31.88
Japan	6.34	23.66
France	7.52	19.34
USA	13.01	17.20
UK	6.27	13.17
Malaysia	1.08	1.59
South Korea	1.23	7.40
China	0.19	0.25
India	0.35	0.25

Reasons for Automation

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- High cost of labor
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- Increased productivity
  - value of output per person per hour increases
- Lower costs
  - reduced scrap rate
  - lower in-process inventory
  - superior quality
  - superior quality
  - shorter (compact) lines
- Reducing manufacturing lead time
  - respond quickly to the consumers' needs
  - rapid response to changes in design

Labor costs and strategic planning

Low-wage countries are not necessarily more competitive

- international trade tends to equalize labor costs per unit output
- low wages are also accompanied by lower productivity

  [U.N. study comparing wages and productivity]
  - In 1990, hourly wages in Malaysia were approx. 15% of that of the U.S. Hourly productivity was also comparable.

Need significant investment for automation even in low-wage countries

Automation in low-wage countries

Do we need automation in low-wage countries?

Capital intensity is equally high

- Fiat plant at Belo Horizonte, Brazil
- Carplastic - manufacturer of car plastic components

  Ford subsidiary in Monterrey Mexico

Case study: CARPLASTIC

- A wholly-owned Ford subsidiary in Monterrey, Mexico
- Products
  - handlamps, polycarbonate instrument panels, radiator grill, consoles
- Production
  - 1800 pieces/day, failures 10-15 parts per million
  - main process is injection molding
    - 200-4000 ton machines (Engel, Cincinnatti Milacron, Huskies)
    - largest product is 6 kg. Expedition instrument panel (shot size 12 kg)
    - cycle-time 1 min to 1 min 45 secs.
  - abrasive water-jet cutting
  - 200 workers, $1-2/hour
    - compare with $17/hour in the US, $6/hour in Brazil)
  - reasonably automated
    - material handling is not automated, main processes are automated (no option)

Case study: CARPLASTIC

Question:

Can highly automated facilities be maintained and upgraded in "low-wage countries"?

- Hi-tech machinery maintenance and repair
- Quality control, process control requires sophistication
- Material handling costs versus other manufacturing costs

Labor Costs and Strategic Planning

Why are Japanese and German auto companies building plants in the U.S.?

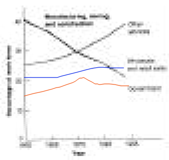
- to be more responsive to their most important export market
- to hedge against currency fluctuations
- to increase their political clout in the U.S.
- to ensure access to the U.S. market even if sanctions are imposed

Free trade agreements

- Are we loosing manufacturing jobs?
- Reality suggests that other factors dictate layoffs
  - Layoffs are mostly due to mergers, competition, restructuring, and cuts in government spending
  - Layoffs in 1995-96
    - Lockheed Martin (15,000), Boeing (13,600), Chemical Bank/Chase Manhattan (12,000), Bell South (11,300), AT&T (8,500), Kmart (6,449), CNA Financial (6,000), Chase Manhattan (6,000), Kimberly-Clark (6,000), 3M (5,000) and GM (5,000).

Is the U.S. economy becoming a service-based economy?

- Percentage of service workers has increased.
- “Office Economy” (CEOs, lawyers, janitors, etc.) accounts for 41% of all workers [WSJ, 2/24/98]



- In 1996, U.S. accounted for 39% of the world’s manufacturing output. Still world leader.
- Share in manufacturing employment has grown from 24% in 1962 to roughly 27-28% today
- Today, although fraction of workforce in manufacturing is decreasing, share of manufacturing in the GDP is increasing or constant.

Manufacturing versus service industry

More like a manufacturing organization ←	→ More like a service organization
Physical, durable product	Intangible perishable product
Output can be inventoried	Output cannot be inventoried
Low customer contact	High customer contact
Long response time	Short response time
Regional national or international markets	Local markets
Large facilities	Small facilities
Capital intensive	Labor intensive
Quality can be easily measured	Quality may not be easily measurable

Examples

- Software (often 3-5 times the cost of the equipment)
- Specialized materials
- Design of parts/machinery/processes

Reasons for Automation

- Competition
  - lower prices, better products
  - better image
  - better labor relations
- Safety
- New process technologies require automation
  - e.g., robot controlled thermal spray torch for coating engine blocks with steel with atomized steel particles
- Potential for mass customization

Reasons for not automating

- Labor resistance
- Cost of upgraded labor
  - Chrysler Detroit plant - 1 million hours of retraining
  - GM Wilmington assembly plant - $250 hours/person/year
- Initial investment
- Management of process improvements
  - Intellectual assets versus technological assets
    - Toyota versus Ford study
  - Appropriate use of technology
  - A systems approach to automation is important
  - Equipment incompatibilites

Case study: Toyota versus Ford

Toyota Georgetown Plant

- Camry/Avalon
- 20 models
- 2 lines, 2 platforms/line
- Workforce
  - 25% college grads
  - another 50% entered college
- Flexible automation
  - 20 models, 197,000 cars/year
  - 39,000 specifications
  - 23,000 one-of-a-kind specifications

Ford Atlanta Plant

- Taurus
- 2 models
- 2 lines, 1 platform/line
- Workforce
  - 50% high school drop outs

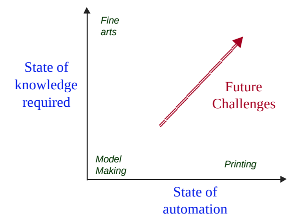
Cost of Flexible Automation

Capital costs per car in 1996

- Toyota
  - 480,000 cars/year, $3960/car
- Nissan
  - 450,000 cars/year, $2670/car
- Honda
  - 610,000 cars/year, $3300/year
- Suzuki
  - 200,000 cars/year, $2150/year

Next Generation Manufacturing

- Autonomous, not automated
- Soft tooling
- Recyclable plant



- Future Challenges

Summary

- Types of automation
  - fixed, programmable and flexible automation
- Models of production
  - mass production, batch production, job shop production
  - factory layout: fixed position layout, product flowlayout, and process flow layout
  - group technology
- Manufacturing versus service automation
- Reasons for automation
- When to and when not to automate?

Additional Reading

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  - measuring the effects of automation in dollars
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  - contrasts mass production with flexible automation
- Drucker, Peter F. “The emerging theory of manufacturing.” Harvard Business Review, May-June 1990.
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