Introduction

Like all industrial activities, manufacturing facilities design requires proper planning and coordination of critical information, tools, and associated analysis for a successful result. Without proper planning, the result will not be productive for the organization. This unit explains how such tools and information are employed.
Key Information to the Plan

1. What product will be produced?
2. How many products will be produced?
3. What types of equipment will be needed?
4. How many pieces will be needed?
5. How many workers will be needed?
6. What auxiliary services will be needed?
7. How much space will they need?
Chapter 2

Sources of Information for Manufacturing Facilities Design

- Marketing
- Product design
- Management policy
- Organizational chart
Information from Marketing Department

- Selling price
- Volume
- Seasonality
- Replacement parts that an older product may require
Determining the plant rate or takt time (also called R value)

• Takt time = rate at which operation, processes, parts, components, and so on must run in order to meet the production goal

• The plant rate is used to determine the number of machines and workstations, conveyor speed, and the number of employees required to work in the facility
$T = \frac{T_a}{D}$

Where

$T = \text{Takt time, e.g. [work time between two consecutive units]}$

$T_a = \text{Net time available to work, e.g. [work time per period]}$

$D = \text{Demand (customer demand), e.g. [units required per period]}$
Information from Product Design Department

- Blueprints, sketches, pictures, CAD drawings, and model shop samples
- Exploded assembly drawings
- Parts list or bill of materials and indented bill of materials
Information from Management Policy

- Inventory policy
- Lean thinking and muda
- Investment policy (ROI)
- Startup schedule
- Make or buy decisions
- Organizational (chart) relationships
- Feasibility studies
Information from the Organizational Chart

- Executive Director
  - Deputy Director
    - Chief Technical Officer
      - Software Developer
      - Software Developer
      - Software Developer / Office IT Support
      - IT Manager
      - Network Coordinator
      - System Administrator

- Chief Program Officer
  - Head of Communications
  - Head of Public Outreach
  - Volunteer Coordinator

- General Counsel
  - Head of Community Giving
  - Development Associate
  - Head of Major Gifts
  - Head of Partnerships And Foundation Relations
  - Personal Assistant

- Chief Financial and Operating Officer
  - Head of Business Development
  - Office Manager
  - Accounting Manager and Financial Analyst

TECHNOLOGY

FINANCE/ADMIN
Chapter 3: Time Study

• A time standard is defined as the time required to produce a product at a workstation with a qualified, well trained operator working at normal pace and doing a specific task

• The process of setting time standards is called time study
Time or labor standards are generally used for:

- Cost and labor allocation and control
- Production planning and inventory management
- Performance evaluation and incentive pay
- Evaluation of alternative methods of operation
Time standards are used for five main purposes in facilities design:

- Determining the required number of people
- Determining the required number of workstations and machines
- Determining conveyor line speeds
- Loading work cells
- Balancing assembly and packout lines
Some Facts About Time Standards

- An operation that is not working toward time standards typically works 60% of the time.
- In plants that do not have time standards, employees know that no one cares how much they produce.
- Operations working with time standards work at 85% of normal performance.
Techniques of Time Study

- Predetermined time standards system (PTSS) or 17 Therbligs
- Stopwatch time study by Fredrich W. Taylor
- Work sampling
- Standard data
- Expert opinion standard and historical data
## Sample Time Standards development

<table>
<thead>
<tr>
<th>Element</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
<th>Cycle 4</th>
<th>Cycle 5</th>
<th>Performance rating (%)</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>1.57</td>
<td>1.63</td>
<td>1.48</td>
<td>1.57</td>
<td>1.65</td>
<td>100</td>
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<tr>
<td>B</td>
<td>2.48</td>
<td>2.34</td>
<td>2.37</td>
<td>2.36</td>
<td>2.40</td>
<td>90</td>
</tr>
<tr>
<td>C</td>
<td>1.85</td>
<td>3.70</td>
<td>1.82</td>
<td>1.78</td>
<td>1.75</td>
<td>95</td>
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<tr>
<td>D</td>
<td>1.25</td>
<td>1.15</td>
<td>1.32</td>
<td>1.15</td>
<td>1.23</td>
<td>115</td>
</tr>
</tbody>
</table>
Chapter 4

Process Design
Tasks of Process Engineer

- Sequence of operations using the route sheet
- The needed machinery, equipment, tools, fixture etc.
- Sequence of operations in assembly using the assembly chart or operation chart
- Time standard for each element of work etc.
Fabricating Individual Parts

- The role of the route sheets or process chart in sequencing operations
- The role of the route sheets or process chart in determining time standards
- The role of the route sheets or process chart in determining number of machines
- The role of the route sheets or process chart in determining required tooling
- Information contained in the summary of route sheets
Determining Number of Machines Needed

• To determine the number of machines needed, the following questions should be answered:
  ✓ How many finished units are needed per day?
  ✓ Which machine runs what parts?
  ✓ What is the time standard for each operation?
Determining Number of Machines Needed

Requires that a machine requirements spreadsheet be developed
Assembly and Packout Process Analysis

- This area includes subassembly, assembly, welding, painting final assembly, and packout
- The assembly or operation process chart shows the sequence of operations in putting together the product
Assembly and Packout Process Analysis

• Assembly line balancing or time standard determination (of several assembly alternatives) is required to determine which sequence is best
• The plant rate (takt time) and conveyor speed should be determined
• Paint conveyor speed should also be determined
Assembly Line Balancing

The purposes are to:

1. Equalize the workload among the assemblers
2. Identify the bottleneck operation
3. Establish the speed of the assembly line
4. Determine the number of workstations
5. Determine the labor cost of assembly and packout
6. Establish the percentage workload of each operator
7. Assist in plant layout; and reduce production cost
Assembly Line Balancing

- The objective is to give each operator as close to the same amount of work as possible.
- This is accomplished by breaking down the tasks into basic motions required to do each piece of work and reassembling them into jobs of near equal time value.
Chapter 5

Flow Analysis Techniques
A Typical Flow Path
Flow Analysis Techniques

• The flow of a part is the path that the part takes while moving through the plant.
• Flow analysis should try to minimize the distance in feet traveled by the part, backtracking, cross traffic, and cost of production.
Flow Analysis Techniques

• A core principle of lean manufacturing is the product-oriented flow layout, as compared to process-oriented flow layouts that are planned around a group of similar equipment.

• In the product-oriented layout, machines are moved and grouped according to part or product families.
Flow Analysis Techniques

- Flow analysis techniques assist manufacturing facilities designer to choose the best arrangement of machines, workstations, employee services, support services, and departments.
- The study of individual parts flow results in the arrangement of machines and workstations.
- To accomplish this, route sheets are the primary source of information.
Flow Analysis Methods

- Process chart: Used for just one part (required for Tech 045)
- String diagram technique: Can be used for multiple parts. In this, circles represent the equipment and lines between circles indicate flow
- Multicolumn process chart: Can be used for multiple parts
- From-to chart
Some Tips on Project One

Some of your required facilities are apparent while others are not. A careful study of your process charts will help to reveal the not too apparent ones. Below are some examples.
Required facilities may include:

1. Storage for raw materials (square footage to be determined)
2. Storage(s) for the 1000 products (square footage to be determined)
3. Plant manager’s office (square footage to be determined)
4. Rest rooms (square footage to be determined)
5. Aisles (square footage to be determined)
6. Locker rooms (square footage to be determined)
7. Conveyor (square footage to be determined)
8. Others (square footage to be determined)
To-be determined facilities may include:

1. Machine tools (square footage to be determined)
2. Tool crib(s) (square footage to be determined)
3. Fork truck(s) (square footage to be determined)
4. Cart(s) (square footage to be determined)
5. Bin(s) (square footage to be determined)
6. Workers of various categories (office/workstation space to be determined)
7. Others (square footage to be determined)
Key Analyses in Project 1

• Takt time and conveyor speed
• Number of Machines Needed
• Number of operators and assemblers needed
• Cost of operator & assembler wages
• Number of supervisors
• Total amount of space anticipated
• Total cost of the proposed project
Takt Time

Takt time or R value =
Effective minutes / Units per day
Conveyor Speed

Products per day divided by adjusted minutes times size of package
Summary of route sheet will:

Determine time standards in pieces per hour

Determine time standards in decimal minutes per unit
### Summary of route sheets

<table>
<thead>
<tr>
<th>Part name</th>
<th>Left roll</th>
<th>Right roll</th>
<th>Axle</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Operations</th>
<th>Time Standards in Pieces Per Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turning lathe</td>
<td></td>
</tr>
<tr>
<td>Drill lathe</td>
<td></td>
</tr>
<tr>
<td>Threading lathe</td>
<td></td>
</tr>
<tr>
<td>Knurling lathe</td>
<td></td>
</tr>
</tbody>
</table>

**Tip:** Match your estimated time from route sheet with those of **Time Standards in Pieces Per Hour**
<table>
<thead>
<tr>
<th></th>
<th>Left roll</th>
<th>Right roll</th>
<th>Axle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turning lathe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drill lathe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threading lathe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knurling lathe</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tip: Divide your Adjusted Minutes by Time Standard’s Pieces Per Hour
# Machine requirements spreadsheet

<table>
<thead>
<tr>
<th>Part name</th>
<th>Left roll(1)</th>
<th>Right roll(1)</th>
<th>Axle(1)</th>
<th>Total Machines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turning lathe</td>
<td>_______</td>
<td>_______</td>
<td>_______</td>
<td>_______</td>
</tr>
<tr>
<td>Drill lathe</td>
<td>_______</td>
<td>_______</td>
<td>_______</td>
<td>_______</td>
</tr>
<tr>
<td>Thread lathe</td>
<td>_______</td>
<td>_______</td>
<td>_______</td>
<td>_______</td>
</tr>
<tr>
<td>Knurling lathe</td>
<td>_______</td>
<td>_______</td>
<td>_______</td>
<td>_______</td>
</tr>
</tbody>
</table>

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Tip: Divide your Time Standards in Decimal Minutes per Unit by Takt Time
Steps in Determining Machine Requirements

1. Complete your process charts, assigning reasonable time values (in minutes) to processes
2. Determine which minutes should be used for machine requirements
3. Convert those minutes into time standards in pieces per hour (refer to standard time table)
4. Convert the above time standards in pieces per hour to time standards in decimal minutes per unit (i.e. divide your adjusted minutes by pieces per hour)
5. Divide the time standards in decimal minutes per unit by takt time
6. Add the different rows of like machines to get the total number of machines required
1. Design an approved product
2. Prepare make-or-buy decision BOM
3. Perform process planning (process and assembly charts)
4. Determine takt time
5. Perform workstation/machine requirements analysis/spreadsheet
6. Determine number of personnel needed
7. Determine space requirements
8. Determine total budget
9. Determine green audit scores
10. Write report
Obi, Chapter 3

Manufacturing Plants and Facilities
A Typical Manufacturing Plant
Factory Design Goals

- Elimination of Waste
- Cycle Time Reduction
- Smaller Space
- Increased Output
- Lower Cost
- Reduction in Work In-Process
- Fewer Workers
Elements of a Factory
Factors to Consider in Locating Factories

- Raw Materials Availability in or Near the Location
- Availability of Potential Market or Consumers
- Availability of Steady Supply of Energy or Power Source
- Good and Friendly Climate That Will Suit Both the Workers and the Facilities
- Availability of Efficient Transportation Infrastructure
- Steady Supply of Good Water for the Personnel and for the Facilities
- Availability of Efficient Waste Disposal Systems in the City
- Availability of Educated and Trained Labor Force
- Availability of Local Industry-Friendly Taxation and Legislations
- Community Amenities and Socio-Cultural Factors
Factory Layouts

• A plant layout is the physical arrangement of equipment and other facilities within the plant.

• It can be drawn on a floor plan to show the distances between different features of the plant.
Types of Factory Layouts

- Fixed-position layout.
- Production layout.
- Process layout.
- Cellular layout.
Fixed-position layout
Production layout
Process layout
Cellular layout
Ground Floor
3-D

Design courtesy of Sarah Susanka, AIA
“Green Manufacturing Audit” means an evaluation of a manufacturing system to determine its environmental impact or carbon footprint.
Facilities

Metrology

Processes

Materials

Tooling

Equipment

Design

People

Product
Components of Green Manufacturing Audit

- People and company policy
- Materials
- Energy usage
- Processes
- Facilities and equipment
- Public opinion survey
- Product life cycle
# Materials Green Audit Factors

<table>
<thead>
<tr>
<th>Material</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>85%</td>
</tr>
<tr>
<td>Aluminum</td>
<td>90%</td>
</tr>
<tr>
<td>Zink</td>
<td>85%</td>
</tr>
<tr>
<td>Chromium</td>
<td>40%</td>
</tr>
<tr>
<td>Wood</td>
<td>80%</td>
</tr>
<tr>
<td>Degradable plastics</td>
<td>100%</td>
</tr>
<tr>
<td>Non-degradable plastics</td>
<td>80%</td>
</tr>
<tr>
<td>Water</td>
<td>100%</td>
</tr>
<tr>
<td>Glass</td>
<td>80%</td>
</tr>
<tr>
<td>Sand or silica</td>
<td>100%</td>
</tr>
<tr>
<td>Recyclables</td>
<td>90%</td>
</tr>
<tr>
<td>Lead</td>
<td>40%</td>
</tr>
<tr>
<td>Copper</td>
<td>85%</td>
</tr>
<tr>
<td>Brass</td>
<td>80%</td>
</tr>
<tr>
<td>Others</td>
<td>80%</td>
</tr>
</tbody>
</table>
# Energy Green Audit Factors

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>80%</td>
</tr>
<tr>
<td>Diesel</td>
<td>80%</td>
</tr>
<tr>
<td>Coal</td>
<td>75%</td>
</tr>
<tr>
<td>Wood</td>
<td>70%</td>
</tr>
<tr>
<td>Hydroelectricity</td>
<td>100%</td>
</tr>
<tr>
<td>Wind</td>
<td>100%</td>
</tr>
<tr>
<td>Solar</td>
<td>100%</td>
</tr>
<tr>
<td>Algae</td>
<td>100%</td>
</tr>
<tr>
<td>Ethanol</td>
<td>100%</td>
</tr>
<tr>
<td>Geothermal</td>
<td>100%</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>100%</td>
</tr>
<tr>
<td>Other</td>
<td>80%</td>
</tr>
</tbody>
</table>
Equipment Efficiency Audit Factors

- Regular systems: 80%
- Old systems (polluters): 60%
- Hybrid engines: 90%
- Biodiesel engines: 90%
- Biofuel systems: 90%
- Others: 80%
Processes Audit Factors

- Manual: 100%
- Power-driven cutting tool: 85%
- Shearing & punching machines: 90%
- Laser welding: 95%
- Sand casting: 80%
- Other casting processes: 85%
- Arc welding: 85%
- Gas welding: 80%
- Extrusion molding: 95%
- Injection molding: 90%
- Other molding processes: 85%
<table>
<thead>
<tr>
<th>Power Source</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% solar powered</td>
<td>100%</td>
</tr>
<tr>
<td>100% wind powered</td>
<td>100%</td>
</tr>
<tr>
<td>100% water powered</td>
<td>100%</td>
</tr>
<tr>
<td>100% coal powered</td>
<td>75%</td>
</tr>
<tr>
<td>100% gasoline powered</td>
<td>80%</td>
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<tr>
<td>100% diesel powered</td>
<td>100%</td>
</tr>
<tr>
<td>100% biodiesel powered</td>
<td>90%</td>
</tr>
<tr>
<td>100% biofuel powered</td>
<td>90%</td>
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<tr>
<td>100% electric powered</td>
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<td>Other</td>
<td>80%</td>
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<tr>
<td>Factor</td>
<td>Percentage</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Highest and enforced standards</td>
<td>100%</td>
</tr>
<tr>
<td>Fairly standard requirement</td>
<td>80%</td>
</tr>
<tr>
<td>Just enough to get by</td>
<td>60%</td>
</tr>
<tr>
<td>Not readily identifiable</td>
<td>30%</td>
</tr>
<tr>
<td>Clearly non</td>
<td>0%</td>
</tr>
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Public Opinion Green Audit Factors

Highly liked by the public 100%
Company OK but can improve in some ways 80%
Company needs to do serious improvement 60%
Company has traditionally not cared but is willing to help 40%
Company is a 600 lbs. gorilla and cares about no one at all 0%
<table>
<thead>
<tr>
<th>Manufacturing Systems Components</th>
<th>Green Scores</th>
<th>Comments (Good, Poor, or Approve)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine tool</td>
<td></td>
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<tr>
<td>Manufacturing methods and processes</td>
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<tr>
<td>Materials</td>
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</tr>
<tr>
<td>Energy source</td>
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<tr>
<td>Company policy</td>
<td></td>
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<tr>
<td>Public opinion about company</td>
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</tr>
<tr>
<td>Design technique</td>
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<tr>
<td><strong>Average Score</strong></td>
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