INTRODUCTION

Computer-integrated manufacturing (CIM) blends recent developments in manufacturing with information technology to achieve competitive advantage. Exhibit S2.1 defines CIM’s component technologies and identifies the stand-alone objectives of each. When properly organized, CIM offers more than its component technologies. Exhibit S2.2 describes CIM as having engineering design, flexible manufacturing, and production planning and control components.

To merge these components into one coordinated whole, staff from the information systems function needs to integrate engineering, manufacturing, and business databases into a cross-functional decision support system. Once accomplished, the flexibility to respond to customer demands with low-cost, high-quality specialized products becomes a powerful competitive advantage.

ENGINEERING DESIGN WITH CAD

Computer-aided design (CAD) is the effective use of a computer to create or modify an engineering design, including geometric modeling, stress and strain analysis, and simulation of part movement. An interactive CAD terminal can be used for dimensional analysis, interference checking between two or more objects, and examination of cross-sections of a part. These activities are accomplished without building a physical model or making drawings. With computer power and speed, design changes can be made in a matter of seconds.

The major advantages of CAD are that it greatly improves the designer’s productivity, significantly reduces design errors, and cuts the lead time for designing new parts from weeks to days or even hours. Connecting the computer with an appropriate plotting device permits the user to generate finished drawings in a very short time. These improvements
### Computer-aided design (CAD)

Computer-aided design is the application of computer technology to automate the design process, including geometric modeling, analyzing stress and strain, drafting, storing specifications, and allowing simulation of a mechanism’s parts.

- Improves design productivity
- Reduces design lead time
- Improves design quality
- Improves access to and storage of product designs
- Increases capability to design a variety of products

### Flexible manufacturing system (FMS)

Flexible manufacturing systems can react quickly to product and design changes. An FMS includes a number of workstations, an automated material-handling system, and system supervisory computer control. Central computer control provides real-time routing, load balancing, and production scheduling logic. An FMS can incorporate AGV, AS/RS, and robotics to decrease time to change tools and fixtures, load and unload machines, and move materials to and from manufacturing cells.

- Increases capability to produce a variety of products while at the same time reducing delivery lead times and inventory requirements
- Enables manufacturing to build volume across products to achieve economies of scope
- Enables firms to produce specialized designs for more finely tuned market segments
- Responds more rapidly to frequent changes in product design, production requirements, and market demands
- Ensures more consistent product quality

### Cellular manufacturing

Cellular manufacturing is the physical layout of the factory into product-oriented work centers. Each center or cell includes the machines and tools necessary to produce a family of parts efficiently.

- Reduces material handling
- Simplifies tool control
- Reduces expediting and in-process inventory
- Improves operator expertise

### Group technology (GT)

Group technology is a process of coding and classifying families of parts according to similarities in their geometric characteristics or in their material or manufacturing requirements.

- Enables scheduling within families of parts to:
  - Reduce setup time
  - Reduce lead time
  - Improve productivity
  - Simplify process planning (reduce complexity of sequencing operations, simplify routings, eliminate unnecessary routings)

### Computer numerical control (CNC)

Computer numerical control is the application of computer technology to numerical controlled (NC) machines by utilizing computer hardware and software to control machine operation.

- Reduces direct labor costs
- Improves product quality/precision
- Reduces time to load NC software

### Computer-aided manufacturing (CAM)

Computer-aided manufacturing is the application of computer and communications technology to enhance manufacturing by linking CNC machines monitoring the production process and providing automatic feedback to control operations.

- Improves manufacturing control and reporting
- Enhances coordination of material flow between machines
- Enhances rerouting capabilities

### EXHIBIT S2.1 CIM Component Technologies

<table>
<thead>
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<th>Components</th>
<th>Definition</th>
<th>Stand-Alone Objectives</th>
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<tbody>
<tr>
<td>Computer-aided process planning (CAPP)</td>
<td>Computer-aided process planning is a decision support system that generates instructions for the production of parts. Based on information concerning machining requirements and machine capabilities, CAPP plans machining operations and determines routings between machines.</td>
<td>Enables manufacturing to cope with the complexity of process planning in a multiple-product environment, Reduces the cost and effort required to create and revise process plans</td>
</tr>
<tr>
<td>Automated guided vehicles (AGV)</td>
<td>Material-handling systems may include AGV and AS/RS components. An AGV is a computerized cart system capable of delivering parts and tools to and from multiple work centers. AGVs may be used with an AS/RS, which is a computerized system for storing and retrieving parts or tools.</td>
<td>Reduces material handling costs, Improves inventory control, Reduces land and building costs, Improves safety and control of material movement, Reduces work-in-process inventory on the shop floor</td>
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<tr>
<td>Automated storage and retrieval system (AS/RS)</td>
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<tr>
<td>Robotics</td>
<td>An industrial robot is a general-purpose, programmable machine possessing certain human-like capabilities (e.g., grasping, sensing, and vision).</td>
<td>Reduces direct labor costs, Improves quality/precision in repetitive tasks, Avoids risk to humans in hazardous working conditions, Increases throughput</td>
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<tr>
<td>Just-in-time (JIT)</td>
<td>Just-in-time is a business strategy for designing manufacturing systems that are more responsive to precisely timed customer delivery requirements. This strategy focuses on reducing lead times, reducing setup times, and improving product quality.</td>
<td>Improves customer service, Reduces delivery lead time, Reduces setup time, Improves product quality, Reduces work-in-process, raw-material, and finished-goods inventories, Improves factory design (i.e., distance between work centers and factory floor space requirements), Uncovers workflow problems hidden by work-in-process inventory</td>
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<tr>
<td>Manufacturing resource planning (MRP II)</td>
<td>Manufacturing resource planning is an integrated decision support system for planning and controlling manufacturing operations. MRP II provides feedback from the shop floor to manage equipment, personnel, material, and information resources. MRP II also includes the data and software capabilities to interface manufacturing decisions with marketing and finance.</td>
<td>Improves customer service, Improves production and cost control, Enhances decision making, Improves inventory control, Improves coordination among purchasing, receiving, scheduling, production, and shipping</td>
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enable the firm to change designs quickly in response to customer need. CAD is a very good example of applying computer and information technology to improve performance. When you read the chapter on product development, you will see that CAD plays an important role in developing a teamwork approach. CAD’s flexibility allows product
designers to consider many alternatives. CAD makes it possible for design engineers to sit down with marketing managers to determine if a design meets customer expectations. If changes are suggested, their impact on costs, durability, and ease of production can quickly be estimated using the what-if powers of CAD. Input from operations managers, financial analysts, and cost accountants can be integrated in a decision-making process that can improve the part's manufacturability, costs, and quality.

**FLEXIBLE MANUFACTURING SYSTEMS**

Flexible manufacturing systems (FMSs) use computer and information technology to integrate material handling, robotics, and computer-aided process planning (CAPP) with cellular manufacturing, which is defined in Exhibits S2.1 and S2.2. The manufacturing cell and its associated family of parts provide the base around which an FMS can be built. A family of parts is a group of parts that require similar machining operations. Parts are placed in families based on similarities in size, shape, use, type of material, and/or method of manufacturing. An FMS has flexibility to produce this family of parts using "smart" automation. As a result, an FMS can quickly and efficiently make switches among parts in the family.

Flexibility in an FMS is achieved through the use of two or more reprogrammable computer numerically controlled machines coupled with automated material handling.
Computer numerical control (CNC) is a machining system that utilizes a dedicated computer to store programs. The programs control the machine so it can shape the finished part. For example, the compressor in a refrigerator has machined surfaces that must fit together precisely. These finished surfaces are probably formed on CNC machines. The control program holds the detailed instructions required to process a part. As a result, a CNC machine with an automatic feed for parts can run without an operator. A CNC machine can repeat the same operation many times over, or a new control program can be downloaded from a dedicated computer to machine a different part.

CNC machines can be connected to an integrated computer network that provides information, including data about which parts to process, the tools that require changing, and the computer program for the next part. Robots can provide flexibility for loading and unloading parts and changing tools. Automated guided vehicles can move material to and from the cell. As technology improves, FMSs will have increased flexibility and be capable of accepting wider variations in the parts included in a family.

Computer-Aided Manufacturing

Computer-aided manufacturing (CAM) is the effective use of computer technology in the management, control, and operation of the production facility through either direct or indirect computer interface with physical and human resources. CAM systems can monitor the production process and the operation of machines by machines.

In metal shaping, CAM goes beyond the usual advantages of CNC machines to provide monitoring and automatic feedback. For example, the quality of a part can be routinely checked against a standard. The results can be given to the computer controlling the machine, and adjustments can be made automatically, without human intervention. CAM implies communication links between CNC machines that enable them to function as a coordinated whole.

By establishing links between CAD and CAM, engineering designs located in the CAD computer can quickly be converted to the specific instructions required by the CNC machine. These instructions for shaping the part can be transferred directly and quickly, often within a few minutes, from the CAD computer to the computer controlling the CNC machine.

Group Technology and Cellular Manufacturing

In group technology (GT), families of parts that require similar machining operations are identified. Production managers have long realized the scheduling advantages of grouping parts into families with similar setup and machining requirements. Setup prepares the machine for the required operations on a part. As an example, the setup on a CNC machine could include loading a new program and changing a tool.

With GT, parts can be grouped into families for design as well as manufacturing. These groupings are based on similarities in size, shape, use, and/or method of manufacturing, as illustrated in Exhibits S2.3 and S2.4. Once these families of parts are established, duplicate parts can be eliminated. Parts can also be redesigned and substituted for similar parts. Group technology thus has several advantages:

- Designs can be organized into families so they can easily be retrieved.
- Some parts that were thought to be different can be eliminated.
- One manufacturing system or cell can be designed to make an entire family of parts.
- Robots can be programmed and reprogrammed easily to adapt to differences within a family.
A larger volume of parts can pass through a set of machines, thus reducing unit production costs.

The batch scheduling of parts within a family reduces setup time, and people gain expertise in their area because the parts they handle are similar.

A simple example of grouping for production is a print shop that prints in several colors. Here, jobs are grouped by color to reduce setup time and to eliminate unnecessary color changes, which require extensive downtime for cleaning the press.

**EXHIBIT S2.3** Similar Parts Based on Shape

Source: Reprinted courtesy of the Society of Manufacturing Engineers. Copyright 1982, from the CASA/SME Westec '82 Conference Proceedings.

**EXHIBIT S2.4** Similar Parts Based on Manufacturing Process
GT simplifies the problems of organizing both product design (CAD) and the manufacturing floor (cellular manufacturing). **Cellular manufacturing** is the physical layout of the facility into compact groups of machines that will produce families of parts. Within each compact cell, material handling costs are reduced. Throughput time, work-in-process inventory, and expediting needs are reduced. Storing the tools necessary to produce a family of parts at the cell simplifies tool storage, transportation, and control procedures.

John Deere has been involved with the implementation of GT for several years. In a recent application of GT to metal-shaping operations at its tractor works, the following results were achieved: a 70 percent reduction in the number of departments involved in handling the part, a 25 percent reduction in the number of machines required for processing, a reduction in setup time, a reduction in material handling costs, and a substantial reduction in lead time. These actions help Deere increase productivity, improve quality, and cut production lead time, which increases profits and enhances its competitive position in the global market.

**COMPUTER-AIDED PROCESS PLANNING**

**Computer-aided process planning (CAPP)** is an expert system that can generate routings and machining instructions for parts. An expert system is capable of remembering large amounts of data, has rapid recall, and is capable of remembering complex patterns of logic without error. It does not get tired, forget, or go home early. What sets an expert system apart from other computer-based information systems is its ability to learn from its successes and its mistakes.

A **routining** is a sequence of machines or processes through which a part travels. **Machining instructions** are the procedures and specifications for each machine in the sequence. In a complex multiple-product facility, process planning requires a tremendous amount of detailed information on cell layouts, machining requirements for each part, and the capabilities of each machine. A quality CAPP database captures the special expertise the workforce has developed through years of working with particular parts.

GT can play an important role in helping organize and standardize routings. Properly applied, GT will group parts with the same or similar routing. Thus, GT is important for good process planning.

**ROBOTICS AND AUTOMATED MATERIAL HANDLING**

A **robot** is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks. The use of robots in strenuous, dirty, or dangerous jobs is common today. Robots work in foundries and in welding, forging, machine-tool loading, and spray-painting applications. In the future, robots will become part of integrated manufacturing systems that will move materials and assemble finished products.

Cellular manufacturing reduces and organizes the flow of material. Robots can improve material handling within a cell by loading and unloading machines. Robots should be carefully designed and applied to solve problems in a way that avoids injury to people. Robots do not understand human frailties and have caused injuries when used improperly.

**EXAMPLE**

Robots are not just for traditional manufacturing applications. Merck, one of the largest drug companies in the world, has turned to robots to help it produce a chicken pox vaccine. The robots, the same ones used to produce silicon chips for microcomputers,
work in a sterile, climate-controlled environment. They siphon infected host cells and nutrients into and out of the containers used to grow the vaccine. The robots can easily tolerate the climate, which is not what humans would consider room temperature. Plus, the robots make it easier for Merck to maintain a sterile environment. With the robots, the number of human technicians drops from 120 to 50.

Pressure to cut inventory and material handling costs has increased interest in low-cost, flexible means of transporting material to and from manufacturing cells. **Automated guided vehicles (AGVs)** are driverless and flexible transportation devices, resembling forklift trucks, that can transport parts between manufacturing cells. Under computer control, AGVs can interface with automated storage and retrieval systems (AS/RS) to coordinate the flow of tools and parts from storage to the manufacturing cell.

Presently, technology is available for computerized control and delivery of materials to the production process. Guided vehicle systems and computerized storage and handling systems allow materials to be delivered to and removed from a work area untouched by human hands. Linking these systems with robotized manufacturing centers presents the opportunity for facilities without direct labor. People would be responsible for other jobs, including carrying out preventive maintenance, repairing machines, and planning.

### PRODUCTION PLANNING AND CONTROL SYSTEMS

Flexibility to quickly and easily change to produce different products enables firms to match production with customer requirements. Organizations should be able to deliver a large number of different products with a short lead time if they are to fully realize the benefits of an FMS. An organization needs to develop information systems for managing customer orders, purchasing, material flow, scheduling, and shipping.

Just-in-time (JIT) and manufacturing resource planning (MRP II) are two approaches to designing such systems, and they can be combined in a complementary manner. JIT can be used for short-term scheduling to match precisely timed customer delivery requirements. In contrast, MRP II is useful for longer term planning of labor availability, material procurements, and capacity requirements.

Although it can be used as a basis for planning and scheduling, just-in-time is more properly viewed as a strategy for designing manufacturing systems that are responsive to customer requirements. Applying JIT forces a reexamination of operating philosophy. The JIT philosophy focuses on reducing lead times, reducing setup times, and improving product quality to minimize raw material, work-in-process, and finished goods inventories. Minimizing inventory uncovers hidden workflow problems, reduces working capital requirements, and reduces floor space requirements. It also requires a more reliable manufacturing system.

**Manufacturing resource planning (MRP II)** provides an integrated decision support system that ties together such departments as engineering, finance, personnel, manufacturing, and marketing via a computer-based dynamic simulation model. MRP II works within the limits of an organization’s present production system and with known orders and demand forecasts.

### PEOPLE, TECHNOLOGY, AND COMPUTER-INTEGRATED MANUFACTURING

In its earlier forms, CIM was heavily cloaked in the mantle of automation. For many proponents, the vision of the factory of the future was interconnected computers that controlled
machines. In this view, human labor and decision making became less and less important. But as managers focused more carefully on their vision of CIM, it became apparent that people grew more important in this CIM factory, not less. While the number of people in this futuristic factory may be fewer than in a similar-sized traditional factory, the impact of the people will be more important.

The design of this sophisticated factory is based on the efforts of managers, engineers, and laborers who understand the process very well. Because a CIM factory can respond quickly to customer needs, workers cannot wait for information to pass up the hierarchy and decisions to be handed down. The people on the factory floor need to have the ability and the authority to make their own decisions. The key to effective decision making is access to information. Organizations that are initiating CIM are recognizing that integrating information across the production chain is often more important than beginning with the most sophisticated and newest equipment. Proponents of CIM often argue that information integration is more than half the battle in the successful application of CIM.

Managers are realizing that the most flexible resource on earth is the person who is given the knowledge to understand and the freedom to act.

SOFT AUTOMATION ENHANCES FLEXIBILITY AND IMPROVES PRODUCTIVITY

A new approach to factory automation is allowing many U.S. firms to leapfrog their competitors. The new approach to automation involves more emphasis on computer software and networks and less on sophisticated production equipment and robots. Information technology is being used to coordinate and integrate operations. Rather than forcing robots and sophisticated machines into a production process, managers are carefully studying processes to best utilize the unique capabilities of people and machines. In many cases, people are back doing complex assemblies because they are more intelligent and more flexible than robots. Robots are doing simple, repetitive tasks, such as painting and welding, because they do not forget, get bored, or get tired.

Soft manufacturing can bring amazing agility to a firm. Companies are able to customize products in quantities of one while churning them out at mass production speed. At IBM's Charlotte, North Carolina, plant, a team of forty workers on an assembly line can make as many as twenty-seven different products simultaneously. A typical morning's output might include handheld barcode scanners, portable medical computers, fiber-optic connectors for mainframe computers, and satellite communications devices for truck drivers. Each assembler is presented “kits” of parts that have been organized by other workers to match customer orders. To keep things moving efficiently, each worker faces a computer screen that is hooked into the network. It displays an up-to-the-minute checklist of the parts that must be assembled, and it guides the worker through the assembly steps. When the worker is finished, the product is taken via conveyor to the next assembly station on the line.

At Motorola’s Boynton Beach, Florida, facility, orders for customized, pocket-sized pagers stream in from customers via an 800 line or electronic mail. As the salesperson spells out what the customer wants, the data are digitized and flow to the assembly line. Pick-and-place robots select the proper components for the different models of pagers, but people assemble the pagers. Often, the orders are completed within eighty minutes and can be mailed the same day.

U.S. firms are learning how to mass-produce customized products by employing information technology, integration and, where appropriate, robots and other sophisticated equipment.
SUMMARY

- Computer-integrated manufacturing combines engineering design, flexible manufacturing, and production planning and control systems to improve flexibility, increase speed, and enhance productivity.
- CAD is the effective use of computer software to create or modify an engineering design, including geometric modeling, stress and strain analysis, and simulation of part movement.
- Flexible manufacturing systems use computer and information technology to integrate material handling, robotics, and computer-aided process planning with cellular manufacturing to improve performance.
- Production planning and control systems combine elements of JIT and MRP II to provide integrated decision support systems.

KEY TERMS

automated guided vehicles  computer-integrated  just-in-time
cellular manufacturing  manufacturing (CIM)  machining instructions
computer-aided design  computer numerical  manufacturing resource
(CAD)  control (CNC)  planning (MRP II)
computer-aided manufacturing (CAM)  family of parts  robot
computer-aided process  flexible manufacturing  routing
planning (CAPP)  system (FMs)  setups
group technology

QUESTIONS

1. What is computer-integrated manufacturing?
2. What is the role of CAD?
3. What are the components of flexible manufacturing systems and how are they related to each other?
4. How does group technology help organizations create families of parts?
5. What is computer-aided process planning?
6. What are the elements of production planning and control systems and how are they related?
7. How are manufacturing firms using soft automation to improve performance?