

10

AUTOMATION

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10.1 INTRODUCTION

Automation is a technology concerned with the application of mechanical, electronic, and computer-based systems to operate and control production. This technology includes automatic machine tools to process parts, automatic assembly machines, industrial robots, automatic material handling and storage systems, automatic inspection systems for quality control, feedback control and computer process control, computer systems for planning, data collection and decision-making to support manufacturing activities.

10.2 TYPES OF AUTOMATION

Automated production systems can be classified into three basic types:

1. Fixed automation,
2. Programmable automation, and
3. Flexible automation.

1. FIXED AUTOMATION

It is a system in which the sequence of processing (or assembly) operations is fixed by the equipment configuration. The operations in the sequence are usually simple. It is the integration and coordination of many such operations into one piece of equipment that makes the system complex. The typical features of fixed automation are:

- (a) High initial investment for custom-Engineered equipment;
- (b) High production rates; and
- (c) Relatively inflexible in accommodating product changes.

The economic justification for fixed automation is found in products with very high demand rates and volumes. The high initial cost of the equipment can be spread over a very large number of units, thus making the unit cost attractive compared to alternative methods of production. Examples of fixed automation include mechanized assembly and machining transfer lines.

2. PROGRAMMABLE AUTOMATION

In this the production equipment is designed with the capability to change the sequence of operations to accommodate different product configurations. The operation sequence is controlled by a program, which is a set of instructions coded so that the system can read and interpret them. New programs can be prepared and entered into the equipment to produce new products. Some of the features that characterise programmable automation are:

- (a) High investment in general-purpose equipment;
- (b) Low production rates relative to fixed automation;
- (c) Flexibility to deal with changes in product configuration; and
- (d) Most suitable for batch production.

Automated production systems that are programmable are used in low and medium volume production. The parts or products are typically made in batches. To produce each new batch of a different product, the system must be reprogrammed with the set of machine instructions that correspond to the new product. The physical setup of the machine must also be changed over: Tools must be loaded, fixtures must be attached to the machine table also be changed machine settings must be entered. This changeover procedure takes time. Consequently, the typical cycle for given product includes a period during which the setup and reprogramming takes place, followed by a period in which the batch is produced. Examples of programmed automation include numerically controlled machine tools and industrial robots.

3. FLEXIBLE AUTOMATION

It is an extension of programmable automation. A flexible automated system is one that is capable of producing a variety of products (or parts) with virtually no time lost for changeovers from one product to the next. There is no production time lost while reprogramming the system and altering the physical setup (tooling, fixtures, and machine setting). Consequently, the system can produce various combinations and schedules of products instead of requiring that they be made in separate batches. The features of flexible automation can be summarized as follows:

- (a) High investment for a custom-engineered system.
- (b) Continuous production of variable mixtures of products.

(c) Medium production rates.

(d) Flexibility to deal with product design variations.

The essential features that distinguish flexible automation from programmable automation are: (1) the capacity to change part programs with no lost production time; and (2) the capability to changeover the physical setup, again with no lost production time. These features allow the automated production system to continue production without the downtime between batches that is characteristic of programmable automation. Changing the part programs is generally accomplished by preparing the programs off-line on a computer system and electronically transmitting the programs to the automated production system. Therefore, the time required to do the programming for the next job does not interrupt production on the current job. Advances in computer systems technology are largely responsible for this programming capability in flexible automation. Changing the physical setup between parts is accomplished by making the changeover off-line and then moving it into place simultaneously as the next part comes into position for processing. The use of pallet fixtures that hold the parts and transfer into position at the workplace is one way of implementing this approach. For these approaches to be successful; the variety of parts that can be made on a flexible automated production system is usually more limited than a system controlled by programmable automation.

The relative positions of the three types of automation for different production volumes and product varieties are depicted in Fig. 10.1.

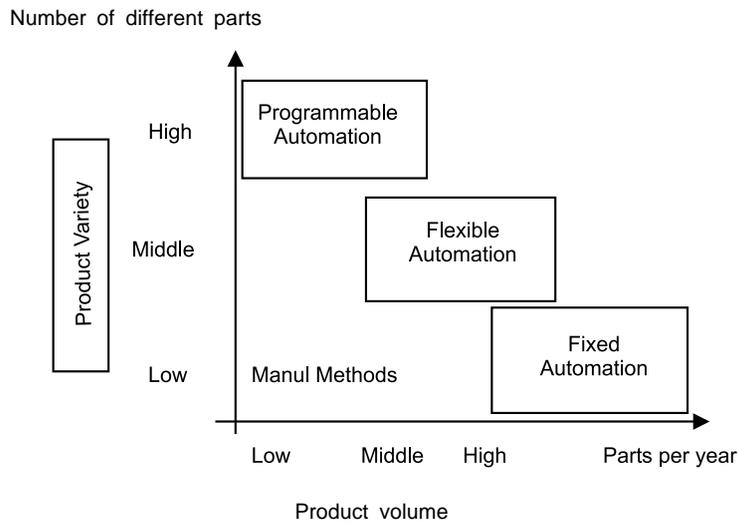


Fig. 10.1 *Types of production automation*

10.3 COMPUTER INTEGRATED MANUFACTURING

The computers had done a dramatic impact on the development of production automation technologies. Nearly all modern production systems are implemented today using computer systems. The term computer integrated manufacturing (CIM) has been coined to denote the pervasive use of computers to design the products, plan the production, control the operations, and perform the

various business related functions needed in a manufacturing firm. Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) in another term that is used synonymously with CIM.

The good relationship exists between automation and CIM with a conceptual model of manufacturing. In a manufacturing firm, the physical activities related to production that take place in the factory can be distinguished from the information-processing activities. The physical activities include all of the manufacturing processing, assembly, materials handling and inspections that are performed on the product. These operations come in direct contact with the physical activities during manufacture. Raw materials flow in one end of the factory and finished products flow out the other end. The physical activities (processing, handling, etc.) take place inside the factory. The information-processing functions form a ring that surrounds the factory, providing the data and knowledge required to produce the product successfully. These information processing functions include: (1) business activities, (2) product design, (3) manufacturing planning, and (4) manufacturing control. These four functions form a cycle of events that must accompany the physical production activities.

10.4 REASONS FOR AUTOMATION

Following are some of the reasons for automation:

1. **Increased productivity:** Automation of manufacturing operations holds the promise of increasing the productivity of labour. This means greater output per hour of labour input. Higher production rates (output per hour) are achieved with automation than with the corresponding manual operations.

2. **High cost of labour:** The trend in the industrialized societies of the world has been toward ever-increasing labour costs. As a result, higher investment in automated equipment has become economically justifiable to replace manual operations. The high cost of labour is forcing business leaders to substitute machines for human labour. Because machines can produce at higher rates of output, the use of automation results in a lower cost per unit of product.

3. **Labour shortages:** In many advanced nations there has been a general shortage of labour. Labour shortages stimulate the development of automation as a substitute for labour.

4. **Trend of labour toward the service sector:** This trend has been especially prevalent in India. There are also social and institutional forces that are responsible for the trend. There has been a tendency for people to view factory work as tedious, demeaning, and dirty. This view has caused them to seek employment in the service sector of the economy government, insurance, personal services, legal, sales, etc. Hence, the proportion of the work force employed in manufacturing is reducing.

5. **Safety:** By automating the operation and transferring the operator from an active participation to a supervisory role, work is made safer.

6. **High cost of raw materials:** The high cost of raw materials in manufacturing results in the need for greater efficiency in using these materials. The reduction of scrap is one of the benefits of automation.

7. **Improved product quality:** Automated operations not only produce parts at faster rates but they produce parts with greater consistency and conformity to quality specifications.

8. **Reduced manufacturing lead time:** With reduced manufacturing lead time automation allows the manufacturer a competitive advantage in promoting good customer service.

9. **Reduction of in-process inventory:** Holding large inventories of work-in-process represents a significant cost to the manufacturer because it ties up capital. In-process inventory is of no value. It serves none of the purposes of raw materials stock or finished product inventory. Automation tends to accomplish this goal by reducing the time a workpart spends in the factory.

10. **High cost of not automating:** A significant competitive advantage is gained by automating a manufacturing plant. The benefits of automation show up in intangible and unexpected ways, such as, improved quality, higher sales, better labour relations, and better company image.

All of these factors act together to make production automation a feasible and attractive alternative to manual methods of manufacture.

10.5 ADVANTAGES OF AUTOMATION

Following are some of the advantages of automation:

1. Automation is the key to the shorter workweek. Automation will allow the average number of working hours per week to continue to decline, thereby allowing greater leisure hours and a higher quality life.
2. Automation brings safer working conditions for the worker. Since there is less direct physical participation by the worker in the production process, there is less chance of personal injury to the worker.
3. Automated production results in lower prices and better products. It has been estimated that the cost to machine one unit of product by conventional general-purpose machine tools requiring human operators may be 100 times the cost of manufacturing the same unit using automated mass-production techniques. The electronics industry offers many examples of improvements in manufacturing technology that have significantly reduced costs while increasing product value (*e.g.*, colour TV sets, stereo equipment, calculators, and computers).
4. The growth of the automation industry will itself provide employment opportunities. This has been especially true in the computer industry, as the companies in this industry have grown (IBM, Digital Equipment Corp., Honeywell, etc.), new jobs have been created. These new jobs include not only workers directly employed by these companies, but also computer programmers, systems engineers, and other needed to use and operate the computers.
5. Automation is the only means of increasing standard of living. Only through productivity increases brought about by new automated methods of production, it is possible to advance standard of living. Granting wage increases without a commensurate increase in productivity will result in inflation. To afford a better society, it is a must to increase productivity.

10.6 DISADVANTAGES OF AUTOMATION

Following are some of the disadvantages of automation:

1. Automation will result in the subjugation of the human being by a machine. Automation tends to transfer the skill required to perform work from human operators to machines.

In so doing, it reduces the need for skilled labour. The manual work left by automation requires lower skill levels and tends to involve rather menial tasks (*e.g.*, loading and unloading workpart, changing tools, removing chips, etc.). In this sense, automation tends to downgrade factory work.

2. There will be a reduction in the labour force, with resulting unemployment. It is logical to argue that the immediate effect of automation will be to reduce the need for human labour, thus displacing workers.
3. Automation will reduce purchasing power. As machines replace workers and these workers join the unemployment ranks, they will not receive the wages necessary to buy the products brought by automation. Markets will become saturated with products that people cannot afford to purchase. Inventories will grow. Production will stop. Unemployment will reach epidemic proportions and the result will be a massive economic depression.

10.7 AUTOMATION STRATEGIES

There are certain fundamental strategies that can be employed to improve productivity in manufacturing operations technology. These are referred as automation strategies.

1. **Specialization of operations:** The first strategy involves the use of special purpose equipment designed to perform one operation with the greatest possible efficiency. This is analogous to the concept of labour specializations, which has been employed to improve labour productivity.

2. **Combined operations:** Production occurs as a sequence of operations. Complex parts may require dozens, or even hundreds, of processing steps. The strategy of combined operations involves reducing the number of distinct production machines or workstations through which the part must be routed. This is accomplished by performing more than one operation at a given machine, thereby reducing the number of separate machines needed. Since each machine typically involves a setup, setup time can be saved as a consequence of this strategy. Material handling effort and nonoperation time are also reduced.

3. **Simultaneous operations:** A logical extension of the combined operations strategy is to perform at the same time the operations that are combined at one workstation. In effect, two or more processing (or assembly) operations are being performed simultaneously on the same workpart, thus reducing total processing time.

4. **Integration of operations:** Another strategy is to link several workstations into a single integrated mechanism using automated work handling devices to transfer parts between stations. In effect, this reduces the number of separate machines through which the product must be scheduled. With more than one workstation, several parts can be processed simultaneously, thereby increasing the overall output of the system.

5. **Increased flexibility:** This strategy attempts to achieve maximum utilisation of equipment for job shop and medium volume situations by using the same equipment for a variety of products. It involves the use of the flexible automation concepts. Prime objectives are to reduce setup time and programming time for the production machine. This normally translates into lower manufacturing lead time and lower work-in-process.

6. **Improved material handling and storage systems:** A great opportunity for reducing non-productive time exists in the use of automated material handling and storage systems. Typical benefits included reduced work-in-process and shorter manufacturing lead times.

7. **On-line inspection:** Inspection for quality of work is traditionally performed after the process. This means that any poor quality product has already been produced by the time it is inspected. Incorporating inspection into the manufacturing process permits corrections to the process as product is being made. This reduces scrap and brings the overall quality of product closer to the nominal specifications intended by the designer.

8. **Process control and optimization:** This includes a wide range of control schemes intended to operate the individual process and associated equipment more efficiency. By this strategy, the individual process times can be reduced and product quality improved.

9. **Plant operations control:** Whereas the previous strategy was concerned with the control of the individual manufacturing process, this strategy is concerned with control at the plant level of computer networking within the factory.

10. **Computer integrated manufacturing (CIM):** Taking the previous strategy one step further, the integration of factory operations with engineering design and many of the other business functions of the firm. CIM involves extensive use of computer applications, computer data bases, and computer networking in the company.

10.8 AUTOMATED FLOW LINES

An automated flow line consists of several machines or workstations which are linked together by work handling devices that transfer parts between the stations. The transfer of work parts occurs automatically and the workstations carry out their specialized functions automatically. The flow line can be symbolized as shown in Fig. 10.2. A raw workpart enters one end of the line and the processing steps are performed sequentially as the part moves from one station to the next. It is possible to incorporate buffer zones into the flow line, either at a single location or between every workstation. It is also possible to include inspection stations in the line to automatically perform intermediate checks on the quality of the workparts. Manual stations might also be located along the flow line to perform certain operations which are difficult or uneconomical to automate.

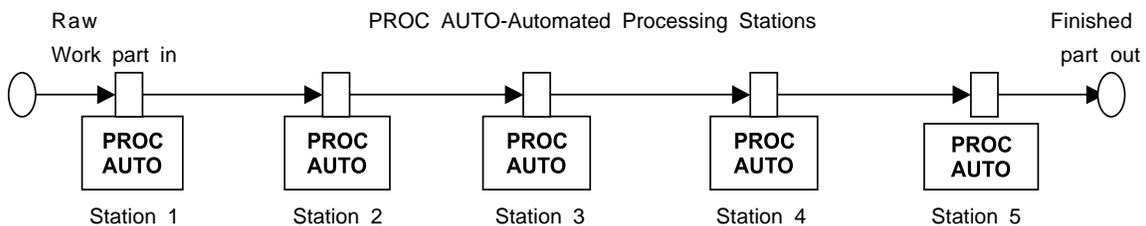


Fig. 10.2 Configuration of an automated flow line

Automated flow lines are generally the most appropriate means of productions in cases of relatively stable product life; high product demand, which requires high rates of production; and where the alternative method of manufacture would invoice large labour content.

The objectives of the use of flow line automation are:

1. To reduce labour costs;
2. To increase production rates;
3. To reduce work-in-process;
4. To minimize distances moved between operations;
5. To achieve specialization of operations; and
6. To achieve integration of operations.

There are two general forms that the workflow can take. These two configurations are in-line and rotary.

In-line Type

The in-line configuration consists of a sequence of workstations in a more-or-less straight line arrangement. The flow of work can take a few 90° turns, either for workpiece reorientation, factory layout limitations, or other reasons, and still qualify as a straight-line configuration. A common pattern of workflow, for example, is a rectangular shape, which would allow the same operator to load the starting workpiece and unload the finished workpiece.

Rotary Type

In the rotary configuration, the workparts are indexed around a circular table or dial. The workstations are stationary and usually located around the outside periphery of the dial. The parts ride on the rotating table and are registered or positioned, in turn, at each station for its processing or assembly operation. This type of equipment is often referred to as an indexing machine or dial index machine and the configurations.

The choice between the two types of configurations depends on the application. The rotary type is commonly limited to smaller workpieces and to fewer stations. There is no flexibility in the design of the rotary configuration. The rotary configuration usually involves a lower-cost piece of equipment and typically requires less factory floor space. The in-line design is preferable for larger work pieces and can accommodate a larger number of workstations. In-line machines can be fabricated with a built-in storage capability to smooth out the effect of work stoppages at individual stations and other irregularities.

10.9 AUTOMATED GUIDED VEHICLES SYSTEMS

An automated or automatic guided vehicle system (AGVS) is a materials handling system that uses independently operated, self-propelled vehicles that are guided along defined pathways in the floor. The vehicles are powered by means of on-board batteries that allow operation for several hours (8 to 16 hours is typical) between recharging. The definition of the pathways is generally accomplished using wires embedded in the floor or reflective paint on the floor surface. Guidance is achieved by sensors on the vehicles that can follow the guide wires or paint.

10.9.1 Types of AGVS

The types of Automated Guided Vehicles Systems (AGVS) can be classified as follows:

1. **Driverless trains:** The type consists of a towing vehicle (which is the AGV) that pulls one or more trailers to form a train. It was the first type of AGVS to be introduced and is still popular. It is useful in applications where heavy payloads must be moved large distances in warehouses of factories with intermediate pickup and drop-off points along the route.

2. **AGVS pallet trucks:** Automated guided pallet trucks are used to move palletized loads along predetermined routes. In the typical application the vehicle is backed into the loaded pallet by a human worker who steers the truck and uses its forks to elevate the load slightly. Then the worker who steers the truck to the guide path, programs its destination, and the vehicle proceeds automatically to the destination for unloading. A more recent introduction related to the pallet truck is the forklift AGV. This vehicle can achieve significant vertical movement of its forks reach loads on shelves.

3. **AGVS unit load carriers:** This type of AGVS is used to move unit loads from one station to another station. They are often equipped for automatic loading and unloading by means of powered rollers, moving belts, mechanized lift platforms, or other devices. The light-load AGV is a relatively small vehicle with a corresponding light load capacity. It does not require the same large aisle width as the conventional AGV. Light-load guided vehicles are designed to move small loads through plants of limited size engaged in light manufacturing. The assembly line AGVS is designed to carry a partially completed subassembly through a sequence of assembly workstations to build the product.

AGVS technology is far from mature, and the industry, and the industry is continually working to develop new systems in response to new application requirements. An example of a new and evolving AGVS design involves the placement of a robotic manipulator on an automated guided vehicle to provide a mobile robot for performing complex handling tasks at various locations in a plant.

10.9.2 Applications of Automated Guided Vehicle Systems

Automated guided vehicle systems are used in a growing number and variety of applications. Its applications can be categorised into the following types:

1. **Driverless train operations:** These applications involve the movement of large quantities of materials over relatively large distances. For example, the moves are within a large warehouse or factory building, or between buildings in a large storage depot. For the movement of trains consisting of 5 to 10 trailers, this becomes an efficient handling method.

2. **Storage/Distribution systems:** Unit load carriers and pallet trucks are typically used in these applications. These storage and distribution operations involve the movement of materials in unit loads (sometimes individual items are moved) from or to specific locations. The applications often interface the AGVS with some other automated handling or storage system, such as an automated storage/retrieval system (AS/RS) in a distribution centre. The AGVS delivers incoming items of unit loads from the receiving dock to the AS/RS, which places the items in storage, and the AS/RS retrieves individual pallet loads or items from storage and transfer them to vehicles

for delivery to the shipping dock. When the rates of incoming loads and the outgoing loads are in balance, this mode of operation permits loads to be carried in both directions by the AGVS vehicles, thereby increasing the handling system efficiency.

3. **Assembly line operations:** AGV systems are being used in a growing number of assembly-line applications. In these applications, the production rate is relatively low and there are a variety of different models made on the production line. Between the workstations, components are kitted and placed on the vehicle for the assembly operations that are to be performed on the partially completed product at the next station. The workstations are generally arranged in parallel configurations to add to the flexibility of the line. Unit load carries and light-load guided vehicles are the type of AGVS used in these assembly lines.

4. **Flexible manufacturing systems:** Another application of AGVS technology is in flexible manufacturing systems (FMS). In this application, the guided vehicles are used as the materials handling system in the FMS. The vehicles deliver work from the staging area (where work is placed on pallet fixtures, usually manually) to the individual workstations in the system. The vehicles also move work between stations in the manufacturing system. At a workstation, the work is transferred from the vehicle platform into the work area of the station for processing. At the completion of processing by that station a vehicle returns to pick up the work and transport it to the next area. AGV systems provide a versatile material handling system to complement the flexibility of the FMS operation.

Example: Using robots and automation together, manufacturing is carried out without using manpower (unmanned) from raw material to finished products.

5. **Miscellaneous applications:** Other applications of automated guided vehicle systems include non-manufacturing and non-warehousing applications, such as, mail delivery in office buildings and hospital material handling operations. Hospital guided vehicles transport meal trays, linen, medical and laboratory supplies, and other materials between various departments in the building. These applications typically require movement of the vehicles between different floors of the hospital and will use elevators for this purpose.

10.10

AUTOMATED STORAGE/RETRIEVAL SYSTEMS

An automated storage/retrieval system (AS/RS) is defined by the Materials Handling Institute as, “A combination of equipment and controls which handles, stores and retrieves materials with precision, accuracy and speed under a defined degree of automation”.

AS/R systems are custom-planned for each individual application, and they range in complexity from relatively small mechanized systems that are controlled manually to very large computer-controlled systems that are fully integrated with factory and warehouse operations.

The AS/RS consists of a series of storage aisles that are serviced by one or more storage/retrieval (S/R) machines, usually one S/R machine per aisle. The aisles have storage racks for holding the materials to be stored. The S/R machines are used to deliver materials to the storage racks and to retrieve materials from the racks. The AS/RS has one or more input stations where materials are delivered for entry into storage and where materials are picked up from the system. The input/output stations are often referred to as pickup and deposit (P&D) stations in the terminology of AS/RS systems. The P&D stations can be manually operated or interfaced to some form of automated handling system, such as a conveyor system or AGVS.

10.10.1 Types of AS/RS

Several important categories of automated storage/retrieval systems can be distinguished. These include:

1. **Unit load AS/RS:** This is typically a large automated system designed to handle unit loads stored on pallets or other standard containers. The system is computer-controlled and the S/R machines are automated and designed to handle the unit load containers. The unit load system is the generic AS/RS.

2. **Miniload AS/RS:** This storage system is used to handle small loads (individual parts or supplies) that are contained in bins or drawers within the storage system. The S/R machine is designed to retrieve the bin and deliver it to a P&D station at the end of the aisle so that the individual items can be withdrawn from the bins. The bin or drawer is then returned to its location in the system. The miniload AS/RS system is generally smaller than the unit load AS/RS and is often enclosed for security of the items stored.

3. **Man-on-board AS/RS:** The man-on-board AS/RS system represents an alternative approach to the problem of storing and retrieving individual items in the system. Whereas the miniload system delivers the entire bin to the end-of aisle pick station, the man-on-board system permits the individual items to be picked directly at their storage locations. This offers an opportunity to reduce the transaction time of the system.

4. **Automated item retrieval system:** These systems are also designed for retrieval of individual items or small unit loads such as cases of product in a distribution warehouse. In this system, the items are stored in single-file lanes rather than in bins or drawer. When an item is to be retrieved, it is released from its lane onto a conveyor for delivery to the pickup station. The supply of items in each lane is generally replenished from the rear of the retrieval system, so that there is flow-through of the items, thus permitting first in first out (FIFO) inventory control.

5. **Deep-lane AS/RS:** The deep-lane AS/RS is a high density unit load storage system that is appropriate when large quantities are to be stored but the number of separate types of material is relatively small. Instead of storing each unit load so that it can be accessed directly from the aisle, the deep-lane system stores up to 10 or so loads in a single rack, one load behind the next. Each rack is designed for 'flow-through' with input on one side and output on the other side. Loads are picked from one side of the rack system by a special S/R type machine designed for retrieval and another special machine is used on the entry side of the rack system for input of loads.

10.10.2 Basic Components of an AS/RS

All automated storage/retrieval systems consist of certain basic building blocks. These components are:

- Storage structure
- Storage/retrieval (S/R) machine
- Storage modules (*e.g.*, pallets for unit loads)
- Pickup and deposit stations.

1. The **storage structure** is the fabricated steel framework that supports the loads contained in the AS/RS. The structure must possess sufficient strength and rigidity that it does not deflect significantly due to the loads in storage or other forces on the framework. The individual storage components in the structure must be designed so to accept and hold the storage modules used to contain the stored materials.
2. The **S/R machine** (sometimes called a crane) is used to accomplish a storage transaction, delivering loads from the input station into storage, or retrieving loads from storage and delivering them to the output station. To perform these transactions, the storage/retrieval machine must be capable of horizontal and vertical travel to align its carriage with the storage compartment in the storage structure, and it must also pull the load from or push the load into the storage compartment.
3. The **storage modules** are the containers of the stored material. Examples of storage modules include pallets, steel wire baskets and containers, tote pans, storage bins, and special drawers (used in miniload AS/RS systems). These modules are generally made to a standard base size that can be handled automatically by the carriage shuttle of the S/R machine.
4. The **pickup and deposit stations** are used to transfer loads to and from the AS/RS. They are generally located at the end of the aisles for access by the S/R machine and the external handling system that brings loads to the AS/RS and takes loads away. The pickup stations and deposit stations may be located at opposite ends of the storage aisle or combined at the same location. This depends on the origination point of the incoming loads and the destination of the output loads. The P&D stations must be designed so that they are compatible with the S/R machine shuttle and the external handling system.

10.11 CAROUSEL STORAGE SYSTEMS

A carousel storage system is series of bins or baskets fastened to carries that are connected together and revolve around a long, oval track system. The track system is similar to a trolley conveyor system. Its purpose is to position bins at a load/unload station at the end of the oval. The operation is similar to the powered overhead rack system used by dry cleaners to deliver finished garments to the front of the store. The typical operation of the storage carousel is mechanized rather than automated. The load/unload station is manned by a human worker who activates the powered carousel to deliver a desired bin to the station. One or more parts are removed from the bin, and the cycle is repeated.

Carousels come in a variety of sizes, ranging between 10 and 100 ft in length of the oval. As the length of the carousel is increased, the storage density increases, but the average transaction time (Storage or retrieval) decreases. Accordingly, the typical carousel size ranges perhaps between 30 and 50 ft to achieve a proper balance between these opposing factors.

10.12 CAROUSEL STORAGE APPLICATIONS

The carousel storage system provides for a relatively high throughput rate and is often an attractive to the miniload AS/RS in the following types of applications:

1. **Storage and retrieval operations:** In certain operations individual items must be selected from the group of item stored in the bin or basket. Sometimes called 'pick and load' operations, this type of procedure is common for order picking of service parts or other items in wholesale firm, tools in a toolroom, raw materials from a stockroom, and work-in-process in a factory. In small assembly operations such as electronics, carousels are used to accomplish kitting of parts that will be transported to the assembly workstations.

2. **Transport and accumulation:** These are applications in which the carousel is used to transport and sort materials as they are stored. One example of this is in progressive assembly operations where the workstations are located around the periphery of a continuously moving carousel and the workers have access to the individual storage bins of the carousel. They remove work from the bins to complete their own respective assembly tasks, and then place their work into another bin for the next operation at some other workstation.

3. **Unique applications:** These involve specialised uses of carousel storage systems. Examples include electrical testing of components, where the carousel is used to store the item during testing for a specified period of time; and drawer or cabinet storage, in which standard drawer-type cabinets are mounted on the carousel.

Storage carousels are finding an increasing number of applications in manufacturing operations, where it's relatively low cost, versatility, and high reliability have been acknowledged. It represents a competitive to the miniload AS/RS and other AS/RS configurations for work-in-progress storage in manufacturing plant.

EXERCISES

Section A

1. What do you mean by automation?
2. What is computer integrated manufacturing?
3. What is computer aided manufacturing?
4. What is AGVS?

Section B

1. What are the advantage and disadvantage of automation?
2. Explain the types of AGVS.
3. Explain the application of automated guided vehicle systems.
4. What are the basic components of an AS/RS?
5. What are the application of AS/RS?

Section C

1. Discuss different types of automation.
2. Discuss the reasons for automation.
3. Discuss the different strategies of automation.
4. Discuss the concept of automated flow line.
5. Discuss the concept of automated storage/retrieval system.

Skill Development

FAST FOOD RESTAURANT VISIT: Get the information for the following questions:

1. Type of automation exists. (Flexibility or fixed)
2. Usage of automated guided vehicles if any.
3. How is the flow managed in automation (i.e. one or more workers).
4. Automated storage system (packing) if any.

CASELET

The following are the case studies to understand the overall functions of productions and operations management:

1. BRUEGGER'S BAGEL BAKERY

Bruegger's Bagel Bakery makes and sells a variety of bagels, including plain, onion, poppy seed, and cinnamon raisin, as well as assorted flavors of cream cheese. Bagels are the major source of revenue for the company.

The bagel business is a Rs.3 billion industry. Bagels are very popular with consumers. Not only are they relatively low in fat, they are filling, and they taste good! Investors like the bagel industries because it can be highly profitable: it only costs about Rs.10 to make a bagel, and they can be sold for Rs.50 each or more. Although some bagel companies have done poorly in recent years, due mainly to poor management, Bruegger's business is booming;

It is number one nationally, with over 450 shops that sell bagels, coffee, and bagel sandwiches for takeout or on premise consumption. Many stores in the Bruegger's chain generate an average of Rs.800, 000 in sales annually.

Production of bagels is done in batches, according to flavor, with each flavor being produced on a daily basis. Production of bagels at Bruegger's begins at a processing plant, where the basic ingredients of flour, water, yeast, and flavorings are combined in a special mixing machine. After the dough has been thoroughly mixed, it is transferred to another machine that shapes the dough into individual bagels. Once the bagels have been formed, they are loaded onto refrigerated trucks for shipping to individual stores. When the bagels reach a store, they are unloaded from the trucks and temporarily stored while they rise. The final two steps of processing involve boiling the bagels in a kettle of water and malt for one minute, and then baking the bagels in an oven for proximately 15 minutes. The process is depicted in Figure 1.

Quality is an important feature of a successful business. Customers judge the quality of bagels by their appearance (size, shape, and shine), taste, and consistency. Customers are also sensitive to the service they receive when they make their purchases. Bruegger's devotes careful attention to quality at every stage of operation, from choosing suppliers of ingredients, careful monitoring of ingredients, and keeping equipment in good operating condition to monitoring output at each step in the process. At the stores, employees are instructed to watch for deformed bagels and to remove them when they find them. (Deformed bagels are returned to the main plant where they are sliced into bagel chips, packaged, and then taken back to the stores for sale, thereby reducing the scrap rate.) Employees who work in the stores are carefully chosen and then trained so that they are competent to operate the necessary equipment in the stores and to provide the desired level of service to customers.

The company operates with minimal inventories of raw materials and inventories of partially completed bagels at the plant and very little inventory of bagels at the stores. One reason for this is to maintain a high degree of freshness in the final product by continually supplying fresh product to the stores. A second reason is to keep costs down; minimal inventories mean less space is needed for storage.

Questions

1. Bruegger's maintains relatively little inventory at either its plants or its retail stores. List the benefits and risks of this policy.
 2. Quality is very important to Bruegger's.
 - (a) What features of bagels do customers look at to judge their quality of bagels?
 - (b) At what points in the production process do workers check bagel quality?
 - (c) List the steps in the production process, beginning with purchasing ingredients, and ending with the sale, and state how quality can be positively affected at each step.
 3. Which inventory models could be used for ordering the ingredients for bagels? Which model do you think would be most appropriate for deciding how many bagels to make in a given batch?
 4. Bruegger's has bagel-making machines at its plants. Another possibility would be to have a bagel-making machine at each store, what advantages does each alternative have?
- (Source: production/Operations Management, William J. Stevenson,)

2. AN AMERICAN TRAGEDY: HOW A GOOD COMPANY DIED

The Rust Belt is back. So exports surge, long-moribund industries glow with new found profits, and unemployment dips to lows not seen in a decade. But in the smokestack citadels, there's disquiet. Too many machine tool and auto parts factories are silent; too many U.S. industries still can't hold their own.

What went wrong since the heyday of the 1960s? That's the issue Max Holland, a contributing editor of *The Nation*, takes up in his nutsy-boltsy but fascinating study, *When the Machine Stopped*. (Max Holland, *When the Machine Stopped: A Contemporary Tale from industrial America* (Boston, Mass: Harvard Business School Press, 1988))

The focus of the story is Burg master Corp., a Los Angeles-area machine tool maker founded in 1944 by Czechoslovakian immigrant Fred Burg. Holland's father worked there for 29 years, and the author interviewed 22 former employees. His shop-floor view of this small company is a refreshing change from academic treatises on why America can't compete.

The discussion of spindles and numerical control can be tough going. But Holland compensates by conveying the pany's early days and the disgust and cynicism accompanying its decline. Moreover, the fate of Burgmaster and its brethren is crucial to the U.S. industrial economy: Any manufactured item is either made by a machine tool.

Producing innovative turret drills used in a wide variety of metalworking tasks, Burgmaster was a thriving enterprise by 1965, when annual sales amounted to about Rs. 8 million. The company needed backing to expand, however, so it sold out to Buffalo-based conglomerate Houdaille Industries Inc. Houdaille was in turn purchased in a 1979 leveraged buyout led by

Khlberg Kravis Roberts & Co. By 1982, when debt, competition, and a sickly machine-tool market had battered Burgmaster badly, Houdaille went to Washington with a petition to withhold the investment tax credit for certain Japanese-made machine tools.

Thanks to deft lobbying, the Senate passed a resolution supporting Houdaille's position, but President Regan refused to go along. Houdaille's subsequent attempt to link Burgmaster up with a Japanese rival also failed, and Burgmaster was closed.

Holland uses Burgmaster's demise to explore some key issue of economic and trade policy. Houdaille's charge that a cartel led by the Japanese government had injured U.S. toolmakers, for example, became a rallying point for those who would blame a fearsome Japan Inc. for the problems of U.S. industry.

Holland describes the Washington wrangling over Houdaille in painful detail. But he does show that such government decisions are often made without much knowledge of what's going on in industry. He shows, too that Japanese producers succeeded less because of government help than because of government helps than because they made better, cheaper machines.

For those who see LBOs as a symptom of what ails the U.S. economy, Holland offers plenty of ammunition. He argues persuasively that the LBO CRIPPLED Burgmaster by creating enormous pressure to generate cash. As Burgmaster pushed its products out as fast as possible, he writes, it routinely shipped defective machines. It promised customers features that engineers hadn't yet designed. And although KKR disputes the claim, Holland concludes that the LBO choked off Burgmaster's investment funds just when foreign competition made them most necessary. As for Houdaille, it was recapitalized and sold to Britain's Tube Investments Group.

But Burgmaster's problems had started even before the LBO. Holland's history of the company under Houdaille is a veritable catalog of modern management techniques that flopped. One of the most disastrous was a system for computerizing production scheduling that was too crude for complex machine-tool manufacturing. Holland gives a dramatic depiction of supply snafus that resulted in delays and cost increases.

As an independent company, "Burgmaster thrived because the Burgs knew their business," Holland writes. Their departure under Houdaille was followed by an "endless and ultimately futile search for a better formula!" But he concludes: "No formula was a substitute for management involvement on the shop floor!"

In the end, however, Holland puts most of the blame for the industry's decline on government policy. He targets tax laws and macroeconomic policies that encourage LBOs and speculation instead of productive investment. He also criticizes Pentagon procurement policies for favoring exotic, custom machines over standard, low-cost models. This adds up to an industrial policy, Holland writes—a bad one.

The point is well taken, but Holland gives it excessive weight. Like their brethren in Detroit and Pittsburgh, domestic tool-makers in the 1970s were too complacent when imports seized the lower end of the product line. The conservatism that had for years served them in their cyclical industry left them ill-prepared for change. Even now some of the largest U.S. toolmakers are struggling to restructure. Blame the government, yes. But blame the industry, too.

Questions

1. Write a brief report that outlines the reasons (both internal and external) for Burgmaster's demise, and whether operations management played a significant role in the demise.

(Source: Reprinted from April 17, 1989 issue of *Business Week* by special permission, copyright © 1989 by The McGraw-Hill companies).

3. HOME-STYLE COOKIES

The Company

The Lew-Mark Baking Company is located in a small town in western New York State. The bakery is run by two brothers, Lew and Mark, who formed the company after they purchased an Archway Cookie franchise. With exclusive rights in New York and New Jersey, it is the largest Archway franchise. The company employs fewer than 200 people, mainly blue-collar workers, and the atmosphere is informal.

The Product

The company's only product is soft cookies, of which it makes over 50 varieties. Larger companies, such as Nabisco, Sunshine, and Keebler, have traditionally produced biscuit cookies, in which most of the water has been baked out, resulting in crisp cookies. Archway cookies have no additives or preservatives. The high quality of the cookies has enabled the company to develop a strong market niche for its product.

The Customers

The cookies are sold in convenience stores and supermarkets throughout New York and New Jersey. Archway markets its cookies as "good food" no additives or preservatives and this appeals to a health-conscious segment of the market. Many customers are over 45 years of age, and prefer a cookie that is soft and not too sweet. Parents with young children also buy the cookies.

The Production Process

The company has two continuous band ovens that it uses to bake the cookies. The production process is called a batch processing system. It begins as soon as management gets orders from distributors. These orders are used to schedule production. At the start of each shift, a list of the cookies to be made that day is delivered to the person in charge of mixing. That person checks a master list, which indicates the ingredients needed for each type of cookie, and enters that information into the computer. The computer then determines the amount of each ingredient needed, according to the quantity of cookies ordered, and relays that information to storage silos located outside the plant where the main ingredients (flour, sugar, and cake flour) are stored. The ingredients are automatically sent to giant mixing machines where the ingredients are combined with proper amounts of eggs, water, and flavorings. After the ingredients have been mixed, the batter is poured into a cutting machine where it is cut into individual cookies. The cookies are then dropped onto a conveyor belt and transported through one of two ovens. Filled cookies, such as apple, date, and raspberry, require an additional step for filling and folding.

The nonfilled cookies are cut on a diagonal rather than round. The diagonal-cut cookies require less space than straight-cut cookies, and the result is a higher level of productivity. In

addition, the company recently increased the length of each oven by 25 feet, which also increased the rate of production.

As the cookies emerge from the ovens, they are fed onto spiral cooling racks 20 feet high and 3 feet wide. As the cookies come off the cooling racks, workers place the cookies into boxes manually, removing any broken or deformed cookies in the process. The boxes are then wrapped, sealed, and labeled automatically.

Inventory

Most cookies are loaded immediately onto trucks and shipped to distributors. A small percentage is stored temporarily in the company's warehouse, but they must be shipped shortly because of their limited shelf life. Other inventory includes individual cookie boxes, shipping boxes, labels, and cellophane for wrapping. Labels are reordered frequently, in small batches, because FDA label requirements are subject to change, and the company does not want to get stuck with labels it can't use. The bulk silos are refilled two or three times a week, depending on how quickly supplies are used.

Cookies are baked in a sequence that minimizes downtime for cleaning. For instance, light-colored cookies (e.g., chocolate chip) are baked before dark-colored cookies (e.g., fudge), and oatmeal cookies are baked before oatmeal raisin cookies. This permits the company to avoid having to clean the processing equipment every time a different type of cookie is produced.

Quality

The bakery prides itself on the quality of its cookies. A quality control inspector samples cookies randomly as they come off the line to assure that their taste and consistency are satisfactory, and that they have been baked to the proper degree. Also, workers on the line are responsible for removing defective cookies when they spot them. The company has also installed an X-ray machine on the line that can detect small bits of metal filings that may have gotten into cookies during the production process. The use of automatic equipment for transporting raw materials and mixing batter has made it easier to maintain a sterile process.

Scrap

The bakery is run very efficiently and has minimal amounts of scrap. For example, if a batch is mixed improperly, it is sold for dog food. Broken cookies are used in the oatmeal cookies. These practices reduce the cost of ingredients and save on waste disposal costs. The company also uses heat reclamation: The heat that escapes from the two ovens is captured and used to boil the water that supplies the heat to the building. Also, the use of automation in the mixing process has resulted in a reduction in waste compared with the manual methods used previously.

New Products

Ideas for new products come from customers, employees, and observations of competitors' products. New ideas are first examined to determine whether the cookies can be made with existing equipment. If so, a sample run is made to determine the cost and time requirements. If the results are satisfactory, marketing tests are conducted to see if there is a demand for the product.

Potential Improvements

There are a number of areas of potential improvement at the bakery. One possibility would be to automate packing the cookies into boxes. Although labour costs are not high, automating the process might save some money and increase efficiency. So far, the owners have resisted making this change because they feel an obligation to the community to employ the 30 women who now do the boxing manually. Another possible improvement would be to use suppliers who are located closer to the plant. That would reduce delivery lead times and transportation costs, but the owners are not convinced that local suppliers could provide the same good quality. Other opportunities have been proposed in recent years, but the owner rejected them because they feared that the quality of the product might suffer.

Questions

1. Briefly describe the cookie production process.
2. What are two ways that the company has increased productivity? Why did increasing the length of the ovens result in a faster output?
3. Do you think that the company is making the right decision by not automating the packing of cookies? Explain your reasoning. What obligation does a company have to its employees in a situation such as this? What obligation does it have to the community? Is the size of the town a factor? Would it make a difference if the company was located in a large city? Is the size of the company a factor? What if it was a much larger company?
4. What factors cause Lew-mark to carry minimal amounts of certain inventories? What benefits result from this policy?
5. As a consumer, what things do you consider in judging the quality of cookies you buy in a supermarket?
6. What advantages and what limitations stem from Lew-Mark's not using preservatives in cookies?
7. Briefly describe the company's strategy.