Manufacturing System

Contents

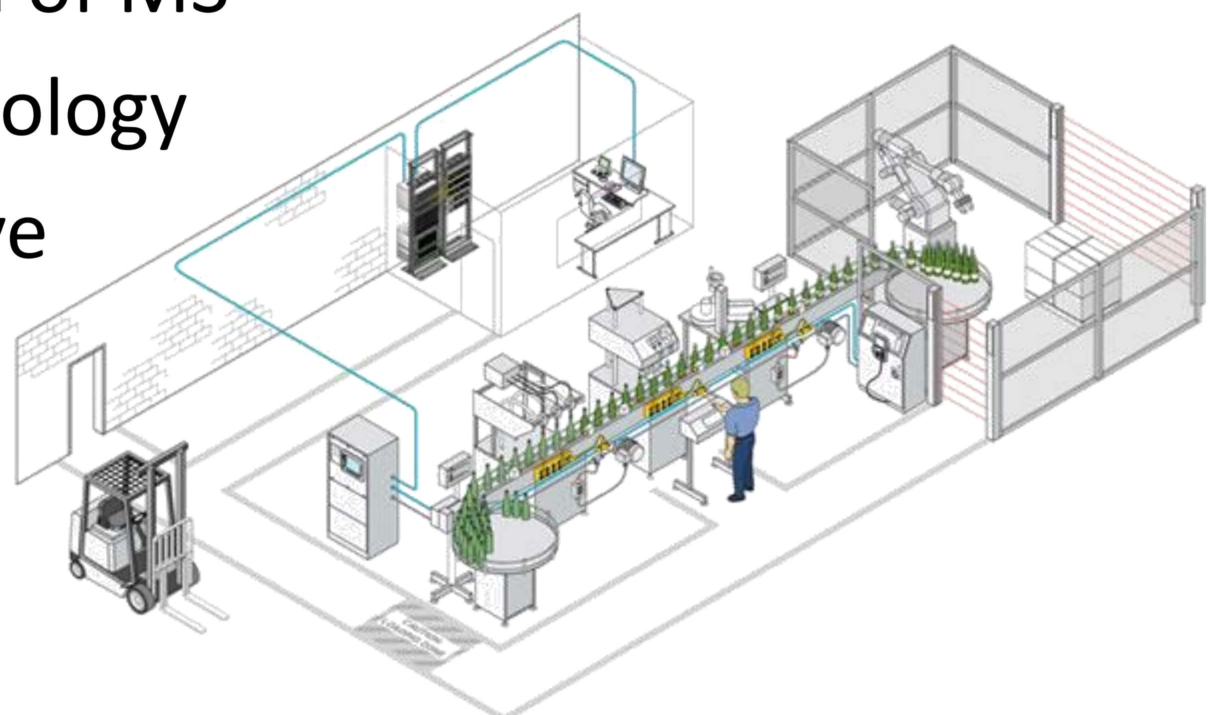
I - Introduction

II - Components of MS

III - Classification of MS

IV - Group Technology

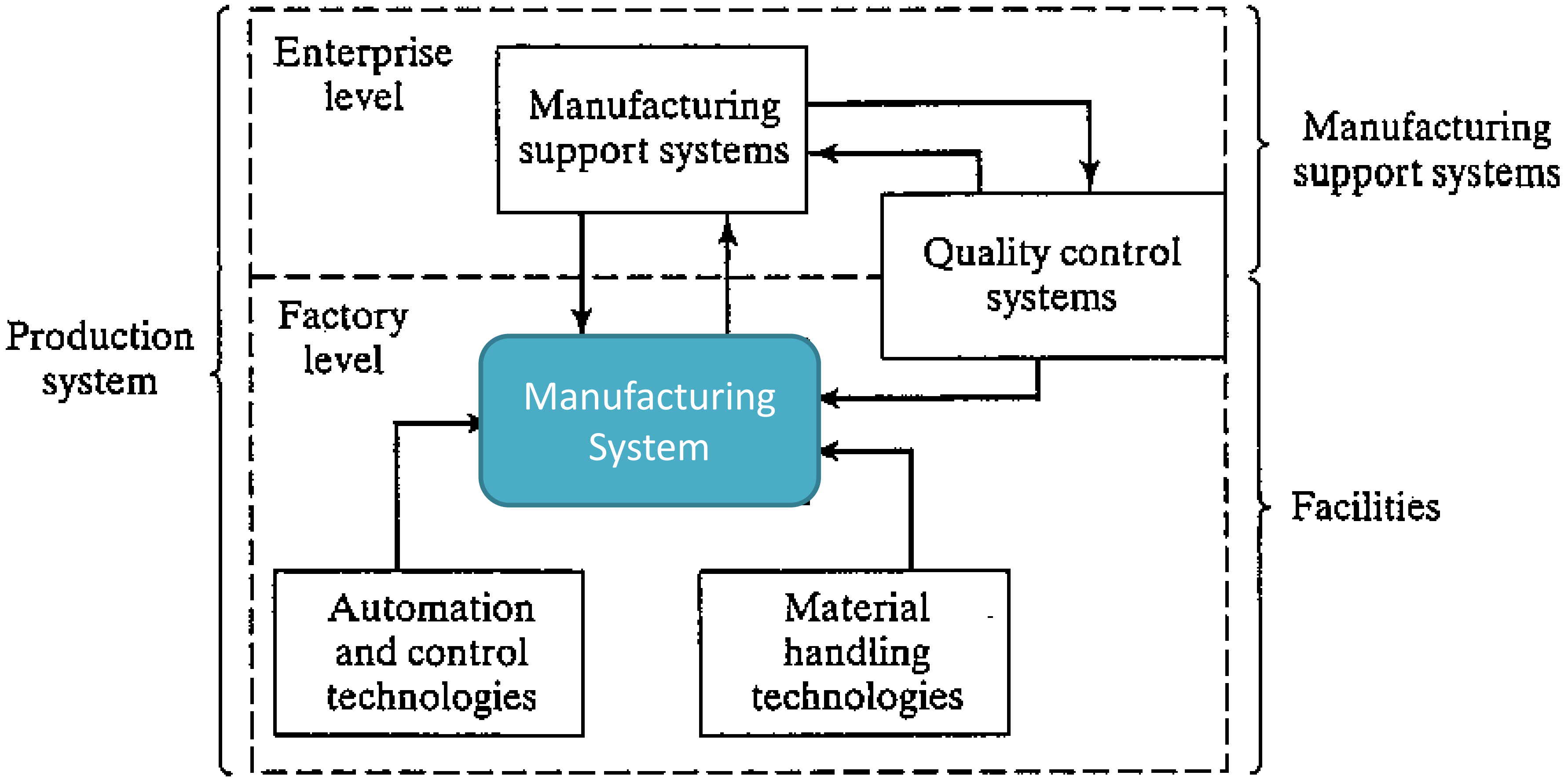
V - Learning curve



I - Introduction

- MS is defined as a collection of integrated equipment and human resources, whose function is to perform one or more processing and/or assembly operations on a starting raw material, part, or set of parts.

Position of MS in Production System



Examples of MS

- One worker attends one machine, he/she operates on semi-automatic cycle.

[redacted]

Examples of MS

- A cluster of semi-automatic machines, attended by one worker.

Examples of MS

- A group of automated machines working on automatic cycle to produce a family of similar parts.

Examples of MS

- A team of workers performing assembly operations on a production line.

II - Components of MS

There are variety of type for each category and these components can be combined and organized in different way to achieve various of objective in production.

- Production machines
- Material handling system
- Computer system
- Human workers

1# Production Machines

- The machine or with the aid of tools to accomplish the actual processing or assembly works.
- There are three operations of the machine: manually, semi-automated and full automated.
- **Manually operated** – machine operated by power and worker manages to control continuously.

1# Production Machines$_2$

- **Semi-automated operation** – performs a portion of work cycle and a worker responsible for the remainder cycle such loading and unloading the finish part. Example of time calculation
- **Automated operation** – significant differ from semi is capacity to operate for extended periods of time with no human attention. But may be after tenth or hundredth cycle worker need to tend the machine.

Analysis of Single Station System

- Two analysis issues are related to the system;

1) Number of single stations required to satisfy specified production requirements.
2) Number of machines to assign to a worker in a machine cluster.

Number of Workstations

- A basic approach is

1) Determine the total workload in accomplishing for certain period (hr, wk, mth or yr).
2) Divide the workload by the hours available on one workstation in the same period.

Workload is defined as the total hours required to complete a given amount of work.

Number of Workstations2

Step 1

$$WL = Q\,T_c$$

(hr of work/hr or hr of work/wk)

Quantity of work units to be produced during the period of interest (pc/hr or pc/wk, etc)

Time (hours) required for each work unit.
This is a cycle time on the machine (hr/pc).

$$WL = \sum_j Q_j T_{cj}$$

Quantity of part or product style j produced during the period.

Cycle time of part or product style j .

Step 2

Number of workstation, $n = \dfrac{WL}{AT}$

Available time on one station in the period (hr/period)

Example$_1$

- A total of 800 shafts must be produced in the lathe section of the machine shop during a particular week. Each shaft is identical and requires a machine cycle time $T_c = 11.5$min. All of the lathes in the department are equivalent in terms of their capability to produce the shaft in the specified cycle time. How many lathes must be devoted to shaft production during the given week, if there are 40 hr of available time on each lathe?

Number of Workstations[3]

- There are several factors present in most real life manufacturing systems that complicate the computation of the workstation and required workers;

1) Setup time
2) Availability
3) Utilization
4) Worker efficiency
5) Defect rate

Example2

- In example 1, suppose that a setup will be required for each lathe that is used to satisfy the production requirements. The lathe setup for this type of part takes 3.5 hr. How many lathe are required during the week?

Example3

- A total of 800 shaft must be produced in the lathe section of the machine shop during a particular week. The shafts are of 20 different types, each type being produced in its own batch. Average batch size is 40 parts. Each batch requires a setup and the average setup time is 3.5 hr. The average machine cycle time to produce a shaft T_c = 11.5 min. how many lathes are required during the week?

Time available per lathe during the week AT = 40 hr

Number of Workstations4

Availability and utilization tend to reduce the available time on the workstation. The available time become,

$$AT = T\,A\,U$$

Actual time during the period (hr).

Worker efficiency is defined as the number of work units actually completed by the worker in a given time period divided by the number of units that would be produced at standard performance.

Defect rate is the fraction of parts produced that are defective. The relationship between the starting quantity and the quantity produced is,

$$Q = Q_o(1 - q)$$

Quantity of good units made in the process.

Original or starting quantity.

Fraction defect rate.

Number of Workstations5

If we want to produce good units, we must process a total of starting units,

$$Q_o = \frac{Q}{(1 - q)}$$

With consideration on effect of worker efficiency and defect rate,
which amends the workload formula,

$$WL = \frac{QT_c}{E_w(1 - q)}$$

The CNC grinding section has a large number of machines devoted to grinding shafts for the automotive industry. The grinding machine cycle takes 3.6 min. At the end of this cycle an operator must be present to unload and load parts, which takes 40 sec.

(a) Determine how many grinding machines the worker can service if it takes 20 sec to walk between the machines and no machine idle time is allowed.

(b) How many seconds during the work cycle is the worker idle?

(c) What is the hourly production rate of this machine cluster?

Solution:

(a) $n = \dfrac{3.6(60)+40}{40+20} = 256/60 = 4.27$ Use $n_1 =$ **4 grinding machines**

(b) Worker idle time $IT = 256 - 4(60) = 256 - 240 =$ **16 sec**

(c) $T_c = 256 \text{ sec} = 4.267 \text{ min}$ $R_c = 4\left(\dfrac{60}{4.267}\right) =$ **56.25 pc/hr**

Example4

- Suppose in example 3 that the anticipated availability of the lathes is 95%, and the expected utilization for calculation purposes is 100%. The expected worker efficiency during production = 110% and during setup = 100%. The fraction defect rate for lathe work of this type is 3%. Other data from Example 1 are applicable. How many lathes are required during the week, given this additional information?

Workload for 20 setups:

$$WL = 20(3.5)/1.0 = 70 \text{ hrs}$$

Available time :

$$AT = 40(1.0)(1.0) = 40$$

Total number of lathes during setup :

$$n = 70/40 = 1.75 \text{ lathes} \quad \text{-------} \ (1)$$

Workload during production:

$$WL = \frac{20(40)(11.5/60)}{1.10*(1-0.03)} = 143.7 \text{ hrs}$$

$$WL = \frac{QT_c}{E_w(1-q)}$$

Available time with 95% availability:

$$AT = 40(0.95) = 38 \text{ hr/machine}$$

Total number of lathes during production :

$$n = 143.7/38 = 3.78 \text{ lathes} \quad \text{-------} \ (2)$$

From (1) and (2), total machine required during setup and production stage:

$$n = 1.75 + 3.78 = 5.53 \text{ lathes} \approx 6 \text{ lathes}$$

Example5

A stamping plant must be designed to supply an automotive engine plant with sheet metal stampings. The plant will operate one 8 hour shift for 250 days per year and must produce 15,000,000 good quality stampings annually. Batch size = 10,000 good stampings produced per batch. Scrap rate = 5%. On average it takes 3.0 sec to produce each stamping when the presses are running. Before each batch, the press must be set up, and it takes 4 hr. to accomplish each setup. Presses are 90% reliable during production and 100% reliable during setup. How many stamping presses will be required to accomplish the specified production?

Example$_5$

A stamping plant must be designed to supply an automotive engine plant with sheet metal stampings. The plant will operate one 8 hour shift for 250 days per year and must produce 15,000,000 good quality stampings annually. Batch size = 10,000 good stampings produced per batch. Scrap rate = 5%. On average it takes 3.0 sec to produce each stamping when the presses are running. Before each batch, the press must be set up, and it takes 4 hr. to accomplish each setup. Presses are 90% reliable during production and 100% reliable during setup. How many stamping presses will be required to accomplish the specified production?

WL = 13,157.9 hr
AT = 1800 hr/yr

Setup: number of batches/yr = 15,000,000/10,000 = 1500 batches
WL = 1500(4) = 6000 hr/yr
AT = 250(8) = 2000 hr/per press

n = 13,157.9/1800 + 6000/2000 = 7.31 + 3.0 = 10.31 = 11 stamping presses

Machine Clusters

- A machine cluster is defined as a collection of two or more machines producing parts or products with identical cycle times and is serviced (usually loaded and unloaded)by one worker.
- Four condition must be satisfied to organize a collection of machine;

1) semi-automatic machine cycle is long relative to the service portion of the cycle that requires the worker's attention
2) semi-automatic machine cycle time is same for all machines
3) the machines that the worker would service are located in close to allow time to walk between them
4) the work rules of the plant permit a worker to service more than one machine.

Material handling system

- For processing and assembly operations on discrete parts, these function must be provided;

1) Loading and unloading work units and
2) Positioning the work units at each station
3) Transporting work units between stations is also required if it is a multiple workstation
4) A temporary storage function.

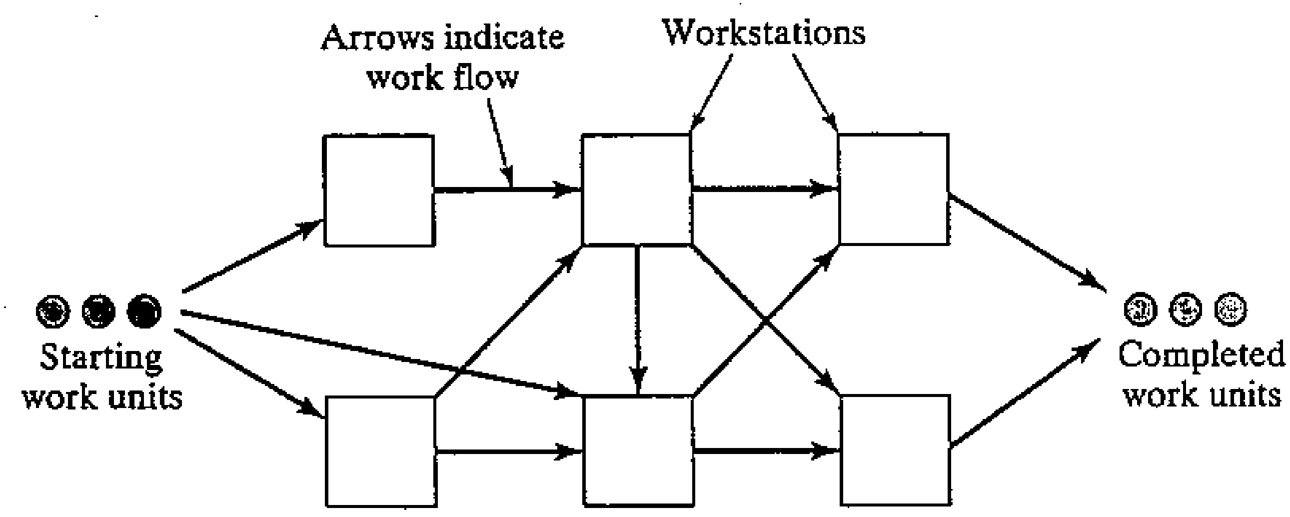
Loading, Positioning and Unloading

- Loading involves moving the work units into the production machine or processing equipment from a source inside the station.
- Positioning provides for the parts to be in a known location and orientation relative to the workhead or tooling that performs the operation.
- Unloading involves removing the completed parts from the production machine and either placed in a container at the workstation or prepared for transport to the next workstation in the processing sequence.

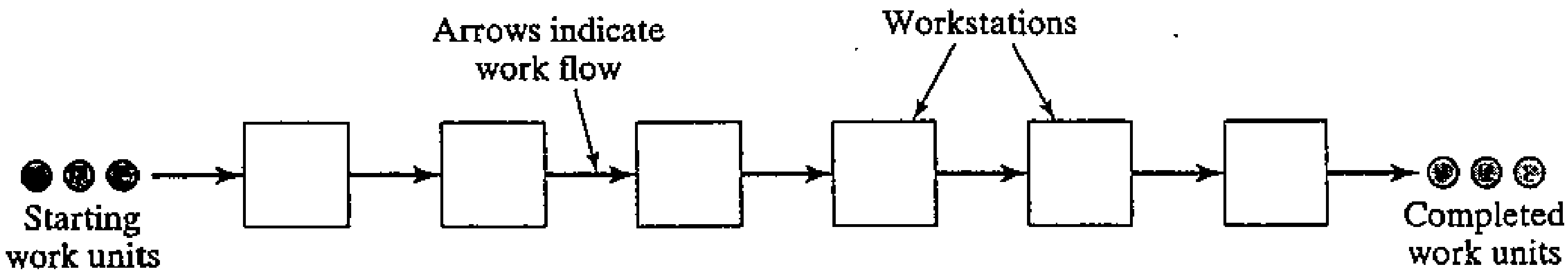
Work Transport Between Stations

- Work transport means moving parts between workstations in a multi-stations system.
- There are two general work transports according to the type of routing between station; variable routing and fixed routing.
- In VR, work units are transported through a variety of different station sequences (different work unit).
- In FR, the work units always flow through the same sequence of stations.

Work Transport Between Stations₂



Variable Routing



Fixed Routing

Variable and Fixed Routings

Common Material Transport Equipment Used for Variable and Fixed Routing in Multiple Station Manufacturing Systems

Type of Part Routing	*Material Handling Equipment**
Variable routing	Automated guided vehicle system Power-and-free overhead conveyor Monorail system Cart-on-track conveyor
Fixed routing	Powered roller conveyor Belt conveyor Drag chain conveyor Overhead trolley conveyor Rotary indexing mechanisms Walking beam transfer equipment

Variable and Fixed Routings

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Temporary Storage

- Pallet Fixtures and Work Carriers in Transport Systems.
- Pallet fixture is a work-holder. It is designed to be transported by the material handling system. It also designed with modular features to be used for different work-part geometries and ideal for use in FMS.
- Work carrier is a container. It is provided to hold one or more parts and can be moved in the system.
- An alternative way by using Direct Transport. It is designed to move the work unit itself especially in manually operated manufacturing system.

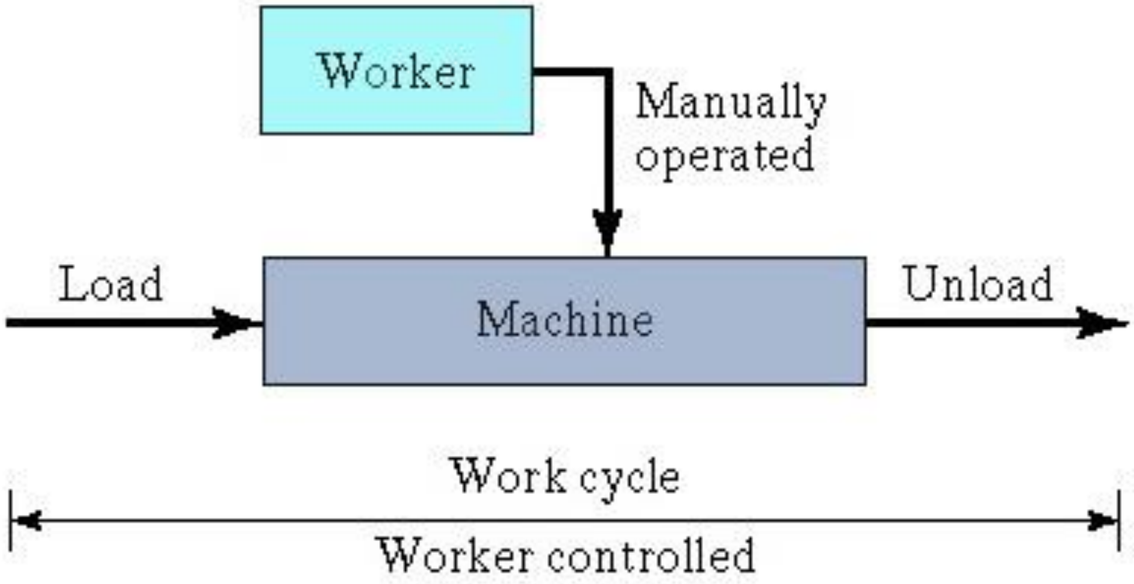
Computer System

- To control the automated and semi-automated equipment and to participate in the overall coordination and management of the manufacturing system.
- Detail function: communicate instructions to workers, download part programs to computer-controlled machines, material handling system control, schedule production, failure diagnosis, safety monitoring, quality control and operations management.

Human Resources

- Even thought fully automated operation of the system but still need to the human workers as direct labor. Why?. Controlling, loading, unloading, changing tools, etc.
- Also needed to manage or support the system as computer programmers, computer operators, part programmers for CNC machines, maintenance and repair. This workers as indirect labor.

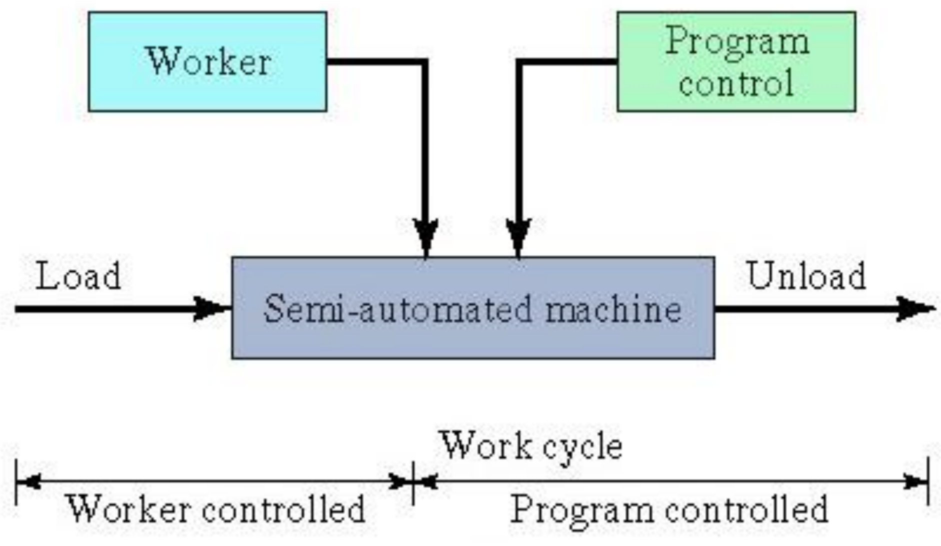
Manually Operated Machine



Manually operated machines are controlled or supervised by a human worker. The machine provides the power for the operation and the worker provides the control. The entire work cycle is operator controlled.

Manually Operated Machine

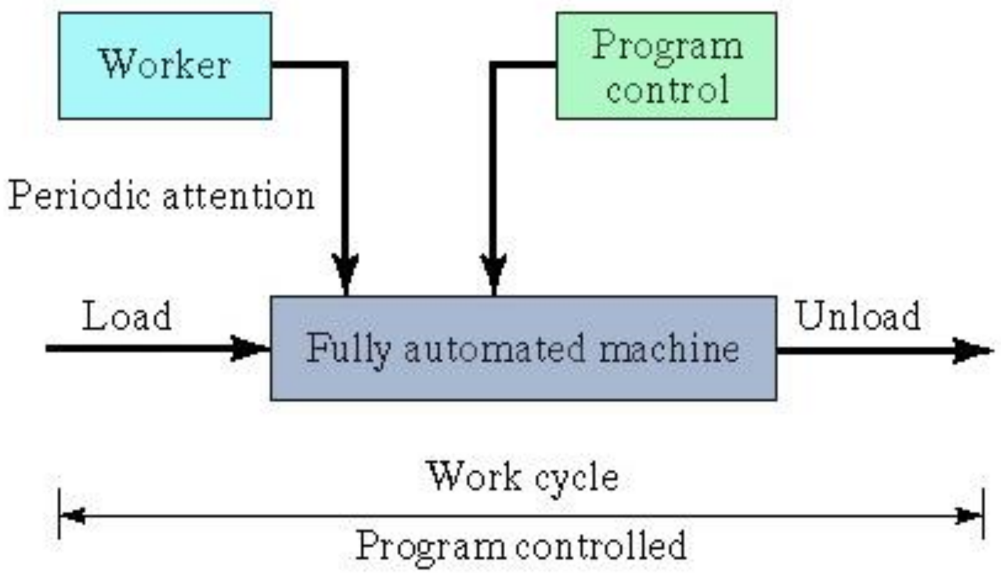
Semi-Automated Machine



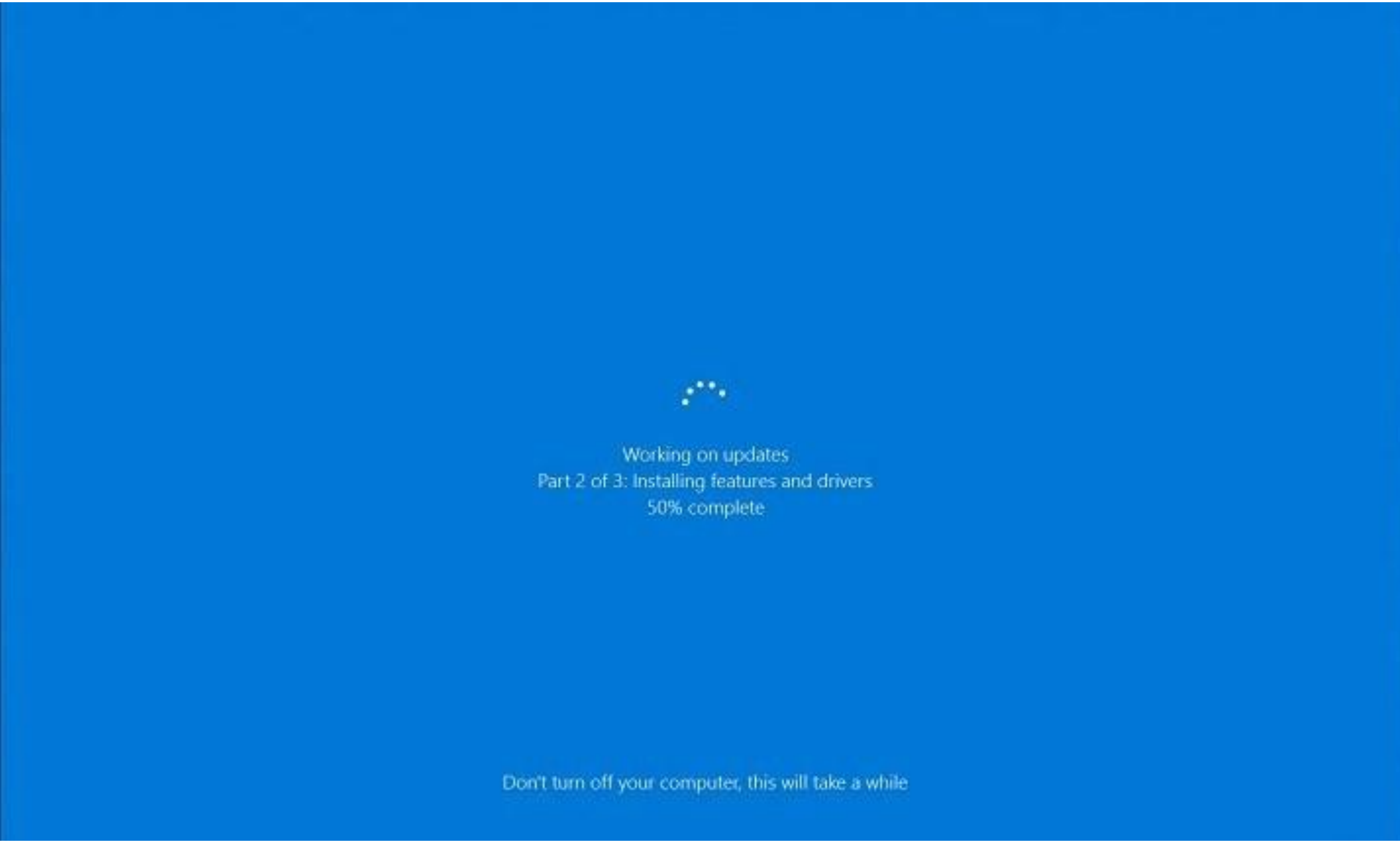
A semi-automated machine performs a portion of the work cycle under some form of program control, and a worker tends to the machine for the remainder of the cycle. Typical worker tasks include loading and unloading parts

Semi-Automated Machine

Fully-Automated Machine



Machine operates for extended periods (longer than one work cycle) without worker attention (periodic tending may be needed).


Working on updates
Part 2 of 3: Installing features and drivers
50% complete
Don't turn off your computer, this will take a while

A

A n,
t first
maneuver: engineers at Israeli space organization SpaceIL found that the on-board computer rebooted unexpectedly,

The 1,290 pound lander deployed from a SpaceX Falcon 9 rocket last week. Shortly afterward, it sent its first signals back to Earth as part of a first round of in-orbit tests.

The on-board computer was supposed to control a three minute engine fire that would take the lander farther away from Earth on its months-long trip to the Moon. But then something unexpected happened.

"At this stage, the spacecraft's computer conducted an independent reset, so the maneuver was cancelled," SpaceIL CEO Ido Anteby said in a press conference call,

Long Journey Ahead

Material Handling System

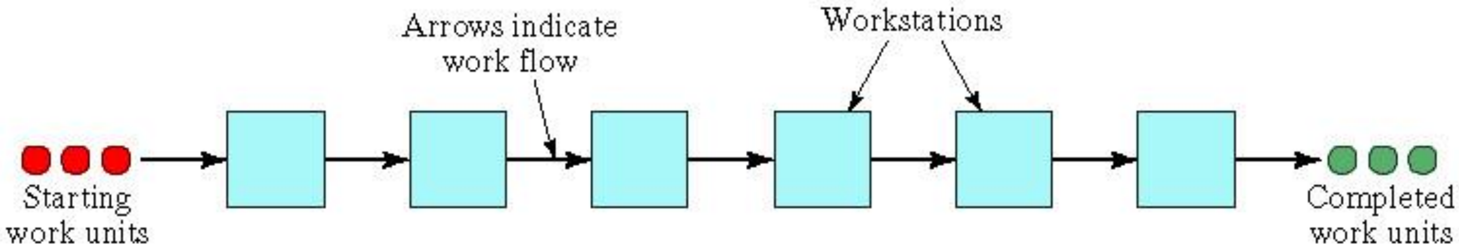
- In most manufacturing systems that process or assemble discrete parts and products, the following material handling functions must be provided:
    1. Loading work units at each station
    2. Positioning work units at each station
    3. Unloading work units at each station
    4. Transporting work units between stations in multi-station systems
    5. Temporary storage of work units

Work Transport Between Stations

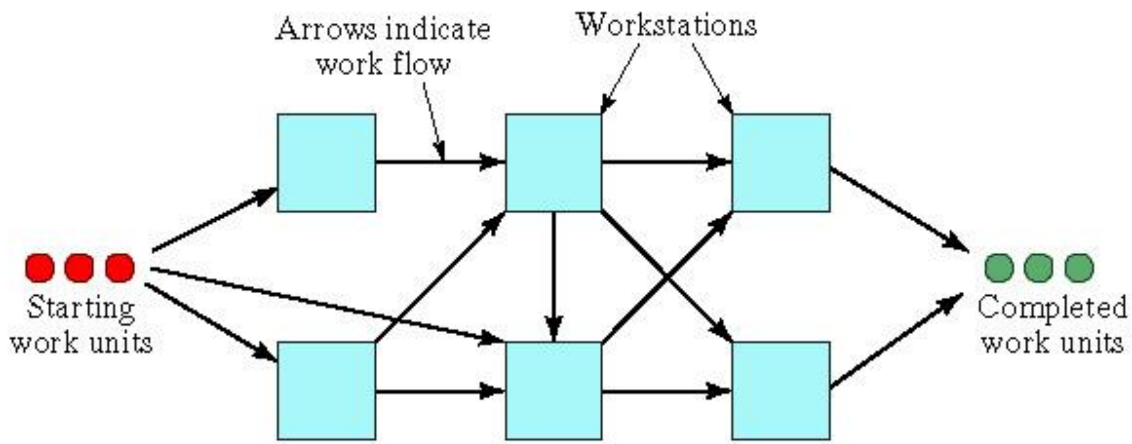
- Two general categories of work transport in multi-station manufacturing systems:

1. Fixed routing
    - Work units always flow through the same sequence of workstations
    - Most production lines exemplify this category
2. Variable routing
    - Work units are moved through a variety of different station sequences
    - Most job shops exemplify this category

Fixed vs Variable Routing



(a)



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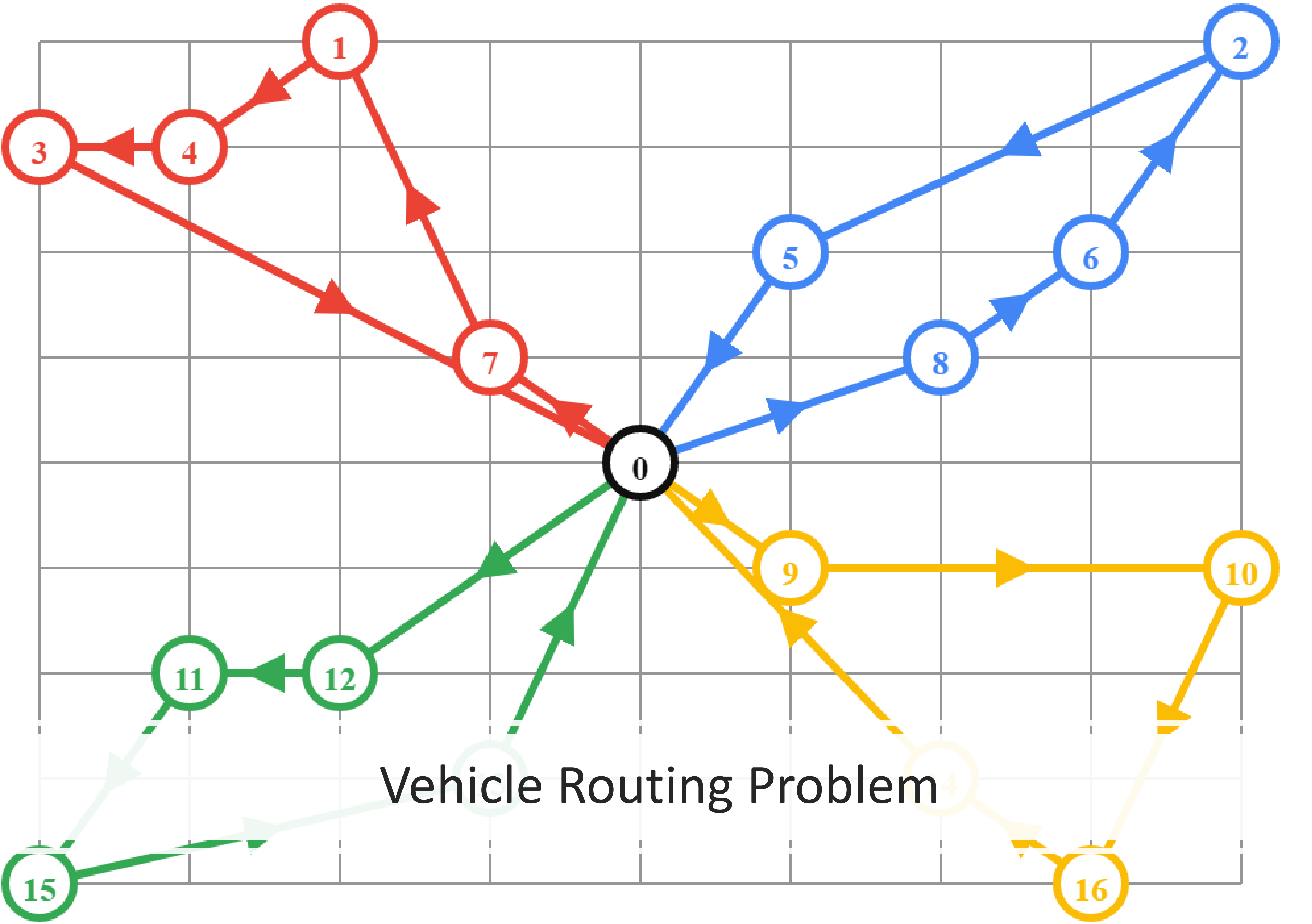
1
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16
Vehicle Routing Problem

Exploring OR-Tools

https://developers.google.com/optimization

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Route. Schedule. Plan. Assign. Pack. Solve.

OR-Tools is fast and portable software for combinatorial optimization.

Get started with OR-Tools

Learn how to solve optimization problems from C++, Python, C#, or Java.

Get started

Install OR-Tools

See the Release Notes for the latest updates.

Install OR-Tools

OR-Tools won four gold medals in the 2021 MiniZinc Challenge, the international constraint programming competition.

About OR-Tools

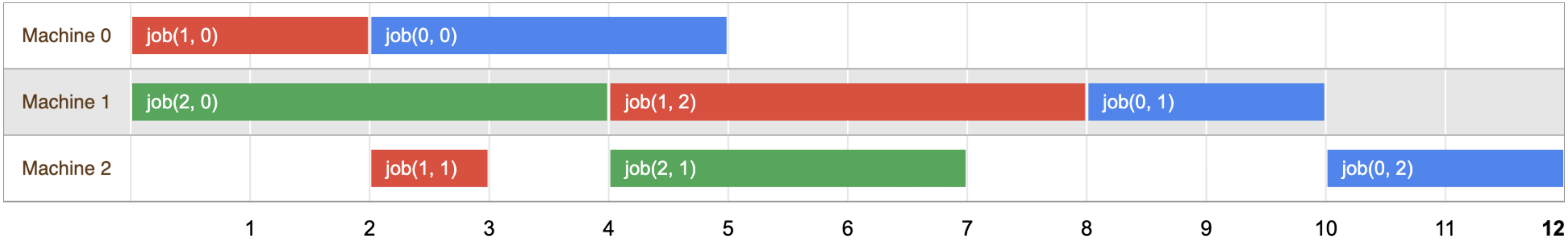
OR-Tools is an open source software suite for optimization, tuned for tackling the world's toughest problems in vehicle routing, flows, integer and linear programming, and constraint programming.

After modeling your problem in the programming language of your choice, you can use any of a half dozen solvers to solve it: commercial solvers such as Gurobi or CPLEX, or open-source solvers such as SCIP, GLPK, or Google's GLOP and award-winning CP-SAT.

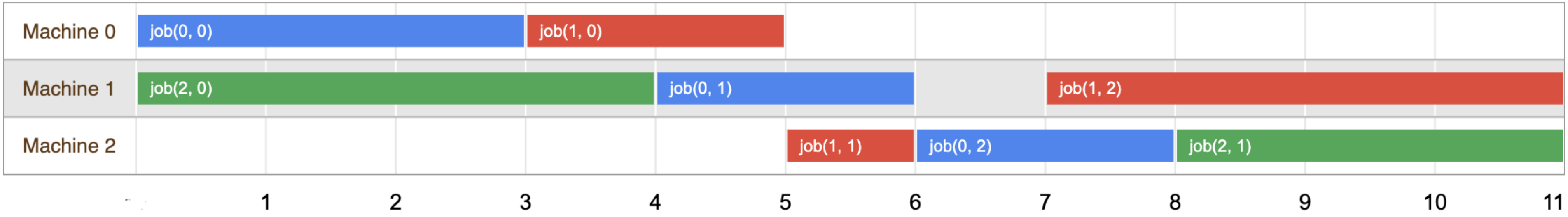
Google AI

Job Shop Problem

Before



After



Classification of Manufacturing Systems

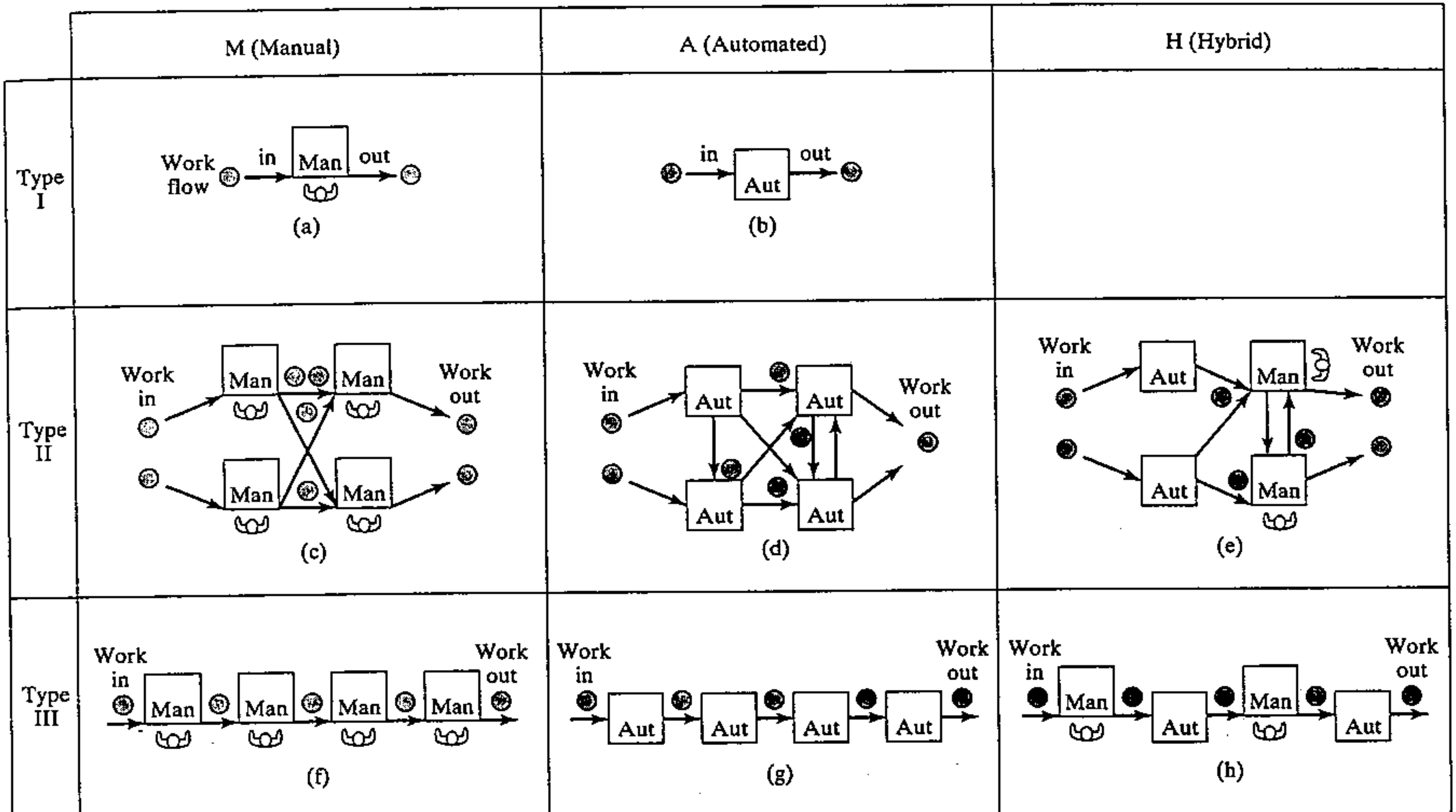
- Factors that define and distinguish manufacturing systems:
  1. Types of operations performed
  2. Number of workstations
  3. System layout
  4. Automation and manning level
  5. Part or product variety

Classification of Manufacturing Systems

- The classification scheme is based on the factors that distinguish the classes.

Factor	*Alternatives*
Types of operations performed	Processing operations versus assembly operations Type of processing or assembly operation
Number of workstations and system layout	One station versus more than one station For more than one station, variable routing versus fixed routing
Level of automation	Manual or semi-automated workstations that require full-time operator attention versus fully automated that require only periodic worker attention
Part or product variety	All work units identical versus variations in work units that require differences in processing

Automation in the Classification Scheme



Classification of manufacturing systems: (a) single station manned cell, (b) single station automated cell, (c) multi-station manual system with variable routing, (d) multi-station automated system with variable routing, (e) multi-station hybrid system with variable routing, (f) multi-station manual system with serial operations, (g) multi-station automated system with serial operations, and (h) multi-station hybrid system with serial operations. Key: Man = manned station, Aut = automated station.

Types of Operations Performed

- Processing operations on work units versus assembly operations to combine individual parts into assembled entities
- Type(s) of materials processed
- Size and weight of work units
- Part or product complexity
  - For assembled products, number of components per product
  - For individual parts, number of distinct operations to complete processing
- Part geometry
  - For machined parts, rotational vs. non-rotational

Number of Workstations and System Layout

- Most important rules in measuring the performance of the manufacturing system in terms of **production capacity, productivity, cost per unit** and **maintainability**.
- System layout is a way the stations are laid out in arrangement of number of workstations. The arrangement either for variable routing or fixed routing. For VR, can have a variety of possible configurations, while FR are usually arranged linearly as in a production line.

Number of Workstations and System Layout[1]

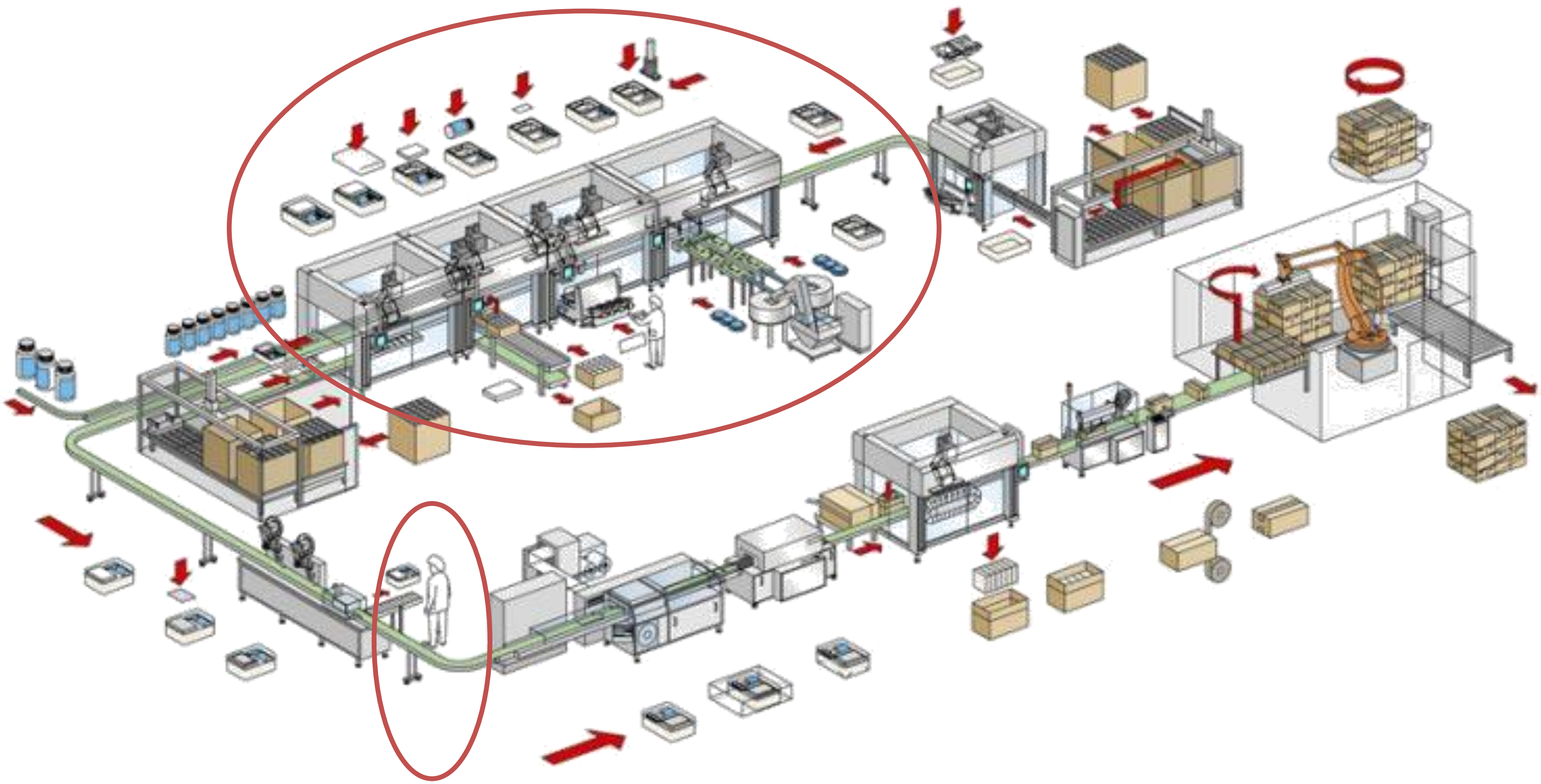
- The classification scheme has three levels;

Type I *Single station.* This is the simplest case, consisting of one workstation ($n = 1$), usually including a production machine that can be manually operated, semi-automated, or fully automated.

Type II *Multiple stations with variable routing.* This manufacturing system consists of two or more stations ($n > 1$) that are designed and arranged to accommodate the processing or assembly of different part or product styles.

Type III *Multiple stations with fixed routing.* This system has two or more workstations ($n > 1$), which are laid out as a production line.

Number of Workstations and System Layout



Number of Workstations

- Convenient measure of the size of the system
  - Let n = number of workstations
  - Individual workstations can be identified by subscript i, where $i = 1, 2,\ldots,n$
- Affects performance factors such as workload capacity, production rate, and reliability
  - As n increases, this usually means greater workload capacity and higher production rate
  - There must be a synergistic effect that derives from n multiple stations working together vs. n single stations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System Layout

- Applies mainly to multi-station systems
- Fixed routing vs. variable routing
  - In systems with fixed routing, workstations are usually arranged linearly
  - In systems with variable routing, a variety of layouts are possible
- System layout is an important factor in determining the most appropriate type of material handling system

Automation and Manning Levels

- Level of workstation automation
  - Manually operated
  - Semi-automated
  - Fully automated
- Manning level M_i = proportion of time worker is in attendance at station i
  - $M_i = 1$ means that one worker must be at the station continuously
  - $M_i \geq 1$ indicates manual operations
  - $M_i < 1$ usually denotes some form of automation

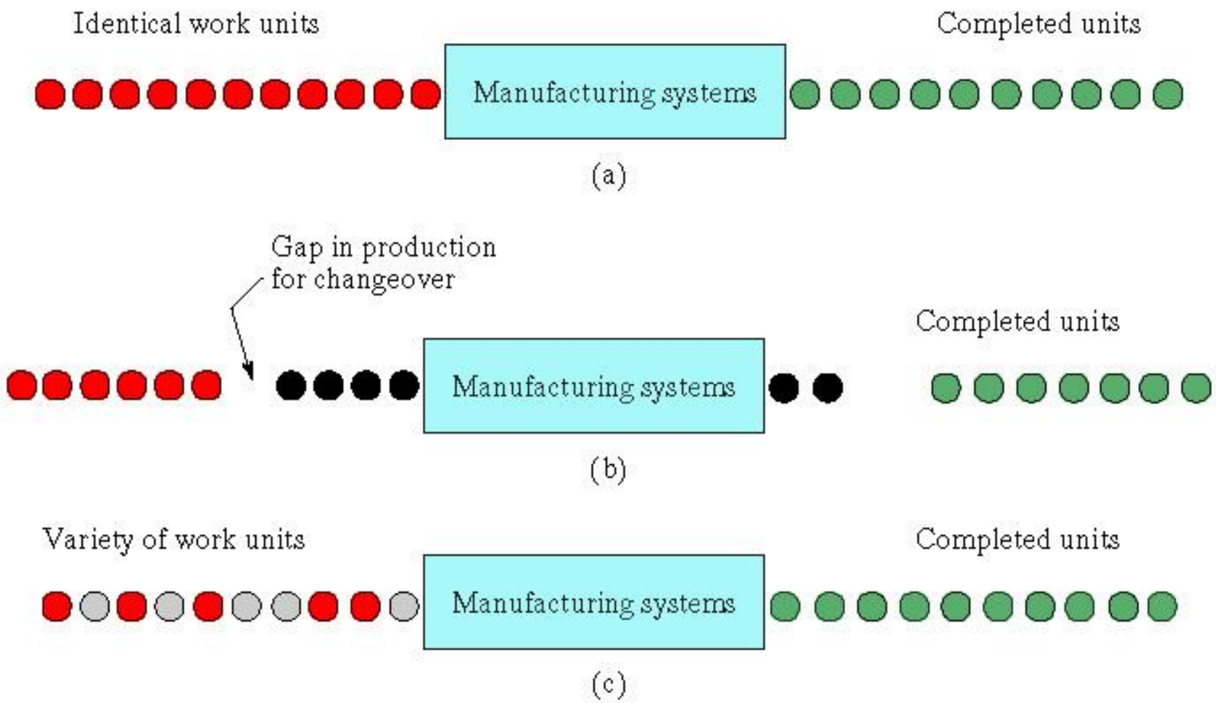
Part or Product Variety: Flexibility

"The degree to which the system is capable of dealing with variations in the parts or products it produces"

- Three cases:

1. Single-model case - all parts or products are identical (sufficient demand/fixed automation)
2. Batch-model case - different parts or products are produced by the system, but they are produced in batches because changeovers are required (hard product variety)
3. Mixed-model case - different parts or products are produced by the system, but the system can handle the differences without the need for time-consuming changes in setup (soft product variety)

Three Cases of Product Variety in Manufacturing Systems



(a) Single-model case, (b) batch model case, and (c) mixed-model case

Enablers of Flexibility

- Identification of the different work units
  - The system must be able to identify the differences between work units in order to perform the correct processing sequence
- Quick changeover of operating instructions
  - The required work cycle programs must be readily available to the control unit
- Quick changeover of the physical setup
  - System must be able to change over the fixtures and tools required for the next work unit in minimum time

Manufacturing Systems for Medium or High Product Complexity

Product variety (P)	Low	Medium	High
Hard	Job shop with multiple single-station cells, manned	(Multiple systems required)	(Multiple systems required)
Soft	Job shop with multiple single-station cells, manned	Multi-station system with variable routing, manned or automated	Multi-station system with fixed routing, manned or automated
None	(Craft shop)	Job shop with multiple single-station cells, manned or automated	Multi-station system with fixed routing, manned or automated

Annual production quantity (Q)

Manufacturing Systems for Low Product Complexity

Product variety (P)	Low	Medium	High
Hard	Single-station cell, manned, batch production	Single-station cell, manned or automated, batch production	(Reverts to multiple single stations dedicated to each part or product)
Soft	Single-station cell, manned, batch- or mixed-model production	Single-station cell, manned or automated, mixed-model production	(Reverts to multiple single stations dedicated to each part or product)
None	(Not feasible, system would be grossly underutilized)	Single-station cell, manned (system would be underutilized)	Single-station or multi-station system, automated, single model production

Annual production quantity (Q)

Overview of Classification Scheme

- Single-station cells
  - $n = 1$
  - Manual or automated
- Multi-station systems with fixed routing
  - $n > 1$
  - Typical example: production line
- Multi-station systems with variable routing
  - $n > 1$

Single-Station Cells

- $n = 1$
- Two categories:
  1. Manned workstations - manually operated or semi-automated production machine ($M = 1$)
  2. Fully automated machine ($M < 1$)
- Most widely used manufacturing system - reasons:
  - Easiest and least expensive to implement
  - Most adaptable, adjustable, and flexible system
  - Can be converted to automated station if demand for part or product justifies

Multi-Station Systems with Fixed Routing

- $n > 1$
- Common example = production line - a series of workstations laid out so that the part or product moves through each station, and a portion of the total work content is performed at each station
- Conditions favoring the use of production lines:
  - Quantity of work units is high
  - Work units are similar or identical, so similar operations are required in the same sequence
  - Total work content can be divided into separate tasks of approximately equal duration

Multi-Station Systems with Variable Routing

- $n > 1$
- Defined as a group of workstations organized to achieve some special purpose, such as:
  - Production of a family of parts requiring similar (but not identical) processing operations
  - Assembly of a family of products requiring similar (but not identical) assembly operations
  - Production of a complete set of components used to assemble one unit of a final product
- Typical case in cellular manufacturing

Level of Automation

- The workstation in a manufacturing system can be manually operated, semi-automated and automated.
- Related to these levels, determining manning level should be found. Manning level of workstation M_i, is the proportion of time that a worker is in attendance at the station.
- In general, high value of M_i ($M_i >= 1$) indicates manual operations at the workstation, while low values ($M_i < 1$) denote some form of automation.

Level of Automation[1]

The average manning level of a multi-station manufacturing system is a useful indicator of the direct labor content of the system.

$$M = \frac{w_u + \sum_{i=1}^{n} w_i}{n} = \frac{w}{n}$$

M = average manning level for the system

w_u = number of utility workers assigned to the system

w_i = number of workers assigned specifically to station i, for $i = 1, 2, \ldots, n$

w = total number of workers assigned to the system

Utility (Indirect) workers are workers who are not specifically assigned to individual processing or assembly stations, instead they perform functions such as relieving workers at station for personal breaks, maintenance and repair of the system, tool changing and loading and/or unloading work units to and from the system.

Exercise 1

Production rate for an assembled product = **47.5 units per hour**.
Total work content time = **32 minutes** of direct manual labor.
The line operates at **95% uptime**. Ten workstations have **two workers** on opposite sides of the line so that both sides of the product can be worked on simultaneously. The remaining stations have one worker.
Repositioning time lost by each worker is **0.2 min/cycle**.
It is known that the number of workers on the line is two more than the number required for perfect balance. Determine:

(a) number of workers,
(b) number of workstations,
(c) balancing efficiency, and
(d) average manning level

Solution 1

(a) Number of Workers, w:

$T_c = 0.95*(60)/47.5 = 1.2$ min

$T_s = T_c - T_r = 1.2 - 0.2 = 1.0$ min

$w = T_{wc}/E_b*T_s = 32/ (1.0 \times 1.0) = 32$ workers

With additional 2 workers = 32 +2 = 34 workers

(b) Number of Workstation, n:

$n = 10 + (34 - 2 \times 10) = 24$ stations

(c) Balance Efficiency, Eb:

$E_b = T_{wc}/w*T_s = 32/(34 \times 1.0) = 0.941$

(d) Average Manning Level, M:

$M = w/n = 34/24 =$ **1.417 – Require manual operation (M>1)**

Exercise 2

The required **production rate = 50 units/hr** for a certain product whose assembly work **content time = 1.2 hr** of direct manual labor.

It is to be produced on a production line that includes **four automated workstations**.

Because the automated stations are not completely reliable, the line will have an expected uptime **efficiency = 90%.** The remaining manual stations will each have one worker.

It is anticipated that **8% of the cycle time** will be lost due to **repositioning** at the bottleneck station. If the balance delay is expected to be ***d* = 0.07**, determine:

(a) the cycle time;
(b) number of workers;
(c) number of workstations needed for the line;
(d) average manning level on the line, including the automated stations.

Solution 2

(a) Cycle time, T_c:

$T_c = 0.9*(60)/50 =$ **1.08 min**

(b) Number of Workers, w:

$T_s = T_c – T_r = (1-0.08)*T_c = 0.92*T_c$

$E_b = 1 – d = 1- 0.07 = 0.93$

$w = 1.2(60)/ (0.92*0.93*1.08) = 77.9$ or **78 workers**

(c) Number of Workstation, n:

$n = 78 + 4 =$ **82 workstations**

(d) Average Manning Level, M:

$M = w/n = 78/82 = 0.951$ – **Automation Process (M<1)**

Part or Product Variety

- A degree of capability of dealing with variation in the parts or products it produces.

Three types of Manufacturing System According to Their Capacity Deal with Product Variety

System Type	*Symbol*	*Typical Product Variety*	*Flexibility*
Single model	S	No product variety	None required
Batch model	B	Hard product variety typical*	Most flexible
Mixed model	X	Soft product variety typical*	Some flexibility

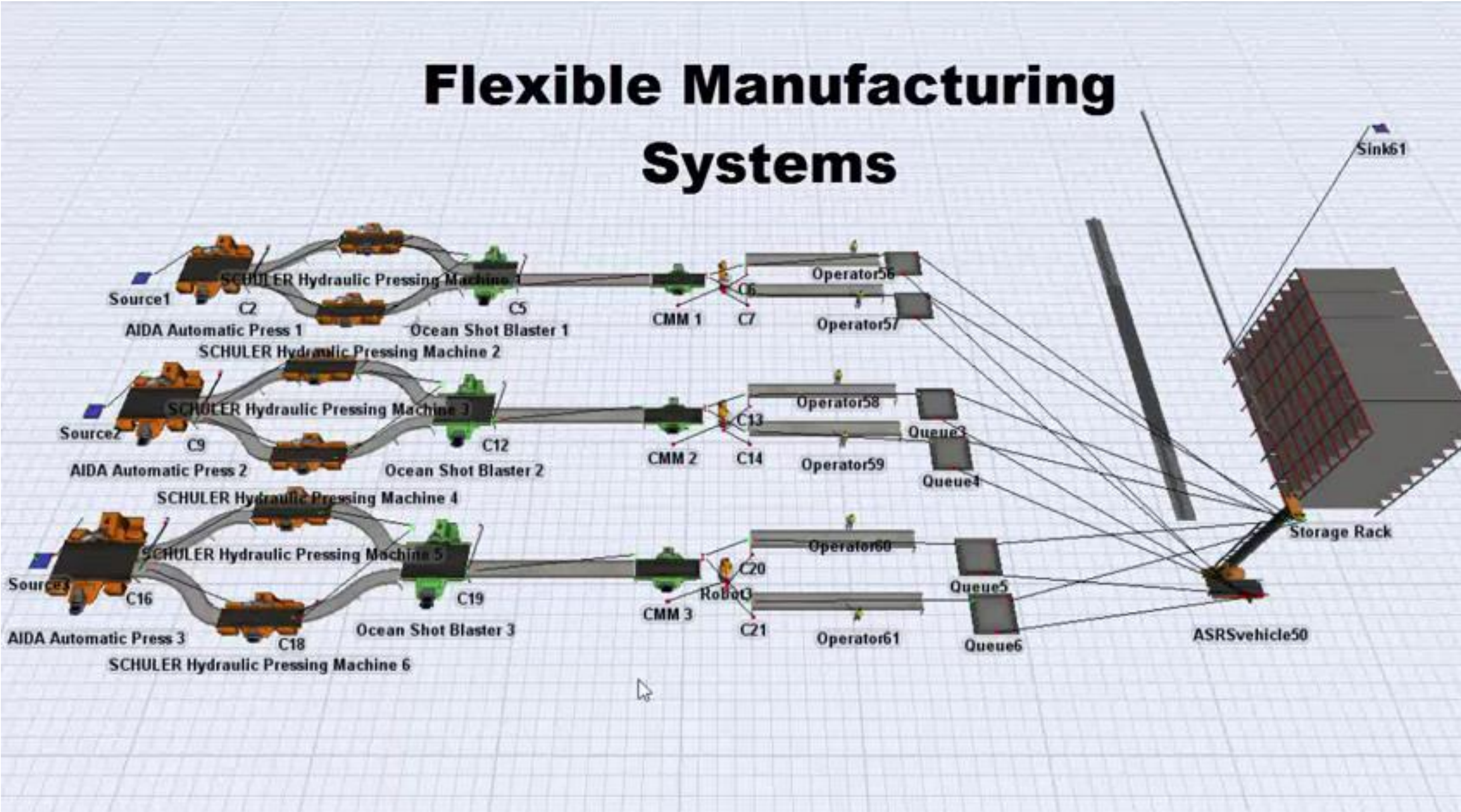
Examples in the Manufacturing Systems Classification Schemes

Type	Description	Operation	Product Variety Case	Example
I M	Single station manned cell	Processing (machining)	S or B	Worker at CNC lathe
		Processing (stamping)	S or B	Worker at stamping press
		Assembly (welding)	S or B or X	Welder and fitter at arc welding setup
I A	Single station automated cell	Processing (machining)	B or X	A CNC machining center with parts carousel operating in an unattended mode
		Assembly (mechanical)	S or X	An assembly system in which one robot performs multiple assembly tasks to complete a product
II M	Multi-station manual system with variable routing	Processing (machining)	X	A group technology machine cell that machines a family of metal parts
II A	Multi-station automated system with variable routing	Processing (machining)	X	A flexible manufacturing system
		Processing (machining)	B	A small job shop with a process layout might be considered a type II M system. It produces a variety of different part or product styles requiring a variety of process routings

III M	Multi-station manual system with fixed routing	Assembly	S or B or X	A manual assembly line that produces small power tools
III A	Multi-station automated system with fixed routing	Processing (machining)	S	A machining transfer line
		Assembly	S	An automated assembly machine with a carousel-type transfer system for work transport
III H	Multi-station hybrid system with fixed routing	Assembly and processing (spot welding, spray painting, and mechanical assembly)	X	An automobile final assembly plant, in which many of the spot welding and spray painting operations are automated while other assembly is manual

IV – Group Technology

- GT is a manufacturing philosophy in which similar parts are identical and grouped together to take advantage of their similarities in design and production.
- Part families – similar parts that possesses similar design and/or manufacturing characteristics. This should result in manufacturing efficiencies and also by arranging the production equipment into machine group or cells.
- Each cell specializes in the production of a part family, is called cellular manufacturing.


Flexible Manufacturing Systems
Sink61
Source1
C2
SCHULER Hydraulic Pressing Machine 1
C5
AIDA Automatic Press 1
Ocean Shot Blaster 1
CMM 1
C7
Operator56
C6
Operator57
SCHULER Hydraulic Pressing Machine 2
SCHULER Hydraulic Pressing Machine 3
Source2
C9
C12
AIDA Automatic Press 2
Ocean Shot Blaster 2
CMM 2
C13
C14
Operator58
Operator59
Queue3
Queue4
SCHULER Hydraulic Pressing Machine 4
SCHULER Hydraulic Pressing Machine 5
Source3
C16
C19
C18
AIDA Automatic Press 3
Ocean Shot Blaster 3
SCHULER Hydraulic Pressing Machine 6
CMM 3
Robot3
C20
C21
Operator60
Operator61
Queue5
Queue6
Storage Rack
ASRSvehicle50

Group Technology
-Applying Under The Conditions-

1) The plant currently uses traditional batch production and a process type layout and this results in much material handling effort, high in-process inventory and long manufacturing lead time.
2) The parts can be grouped into part families.

GT
-Two Major Tasks-

1) Identifying the part families
2) Rearranging production machines into machine cells.

GT
-Benefits-

- GT promotes standardization of tooling, fixturing and setups.
- Material handling is reduced parts are moved within a machine cell rather than within the entire factory
- Process planning and production scheduling are simplified.
- Setup times are reduced, resulting in lower manufacturing lead times.
- Work-in-process is reduced.
- Worker satisfaction usually improves when workers collaborate in a GT cell.
- Higher quality work is accomplish using group technology.

V - Learning Curves
(Manufacturing Progress Function)

- This phenomena occurs when the cycle time required to perform a given activity decreases as the number of cycle increases.
- The expected time can be calculated from the N_{th} work unit by this equation;

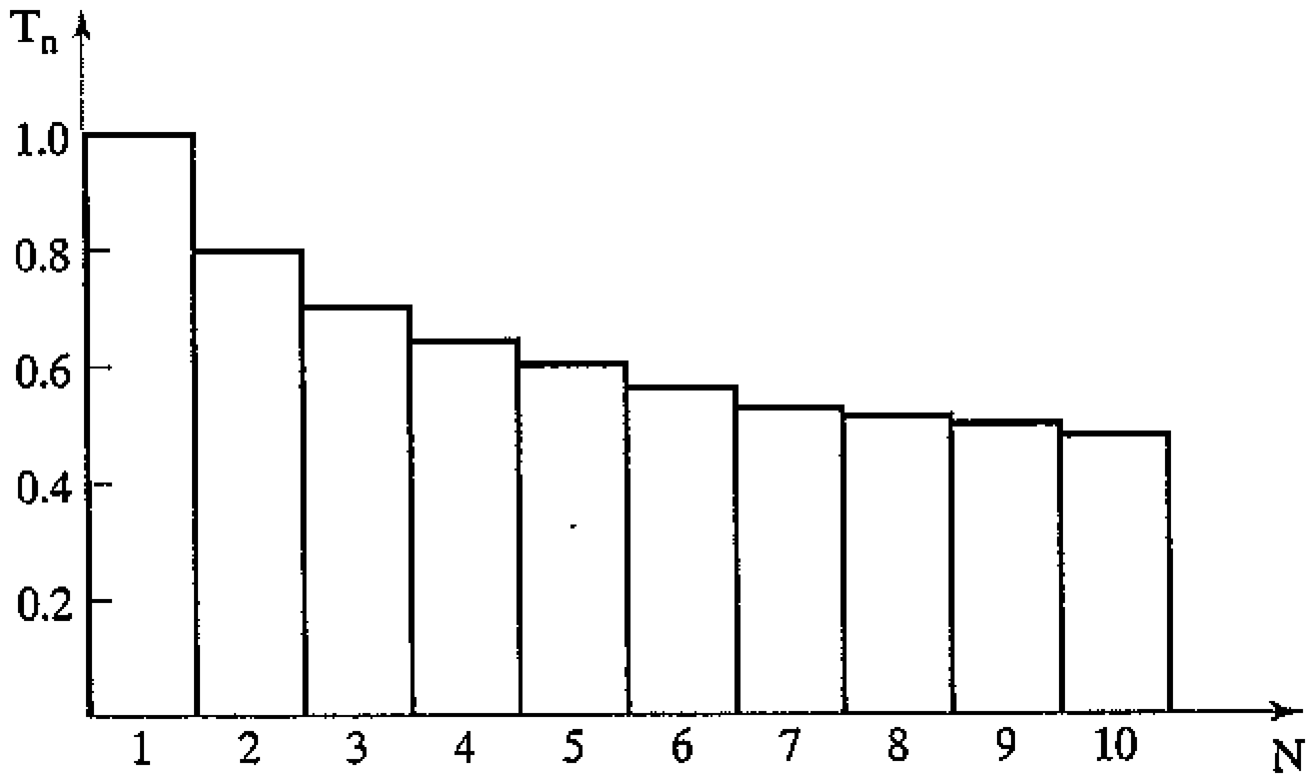
$$T_N = T_1(N)^m$$

where T_N = task time for the Nth unit of work; T_1 = task time for the first work unit; N = the number of the unit produced in the series; and m = an exponent that depends on the learning rate. The value of m can be determined as follows:

$$m = \frac{\ln(LR)}{\ln(2)}$$

LR = Learning rate

Learning Curves



The learning curve phenomenon for learning rate of 80%

Learning Curves

Type of Work	*Typical Learning Rate (%)*
Assembly, electrical harness	85
Assembly, electronic	85
Assembly, mechanical	84
Assembly of prototypes	65
Inspection	86
Machining	90–95
Sheet metal working	90
Welding	85

Typical Learning Rates for Various Types of Work

Example5

A certain mechanical assembly task required 3.75 min to complete when a skilled worker did it for the first time. The task will be performed on an assembly line used to produce 1000 units of a particular product. The line is currently operating on a pilot basis, while workers are learning their respective tasks. The line will run on this basis for 50 units, after which it will go into regular production. If the learning rate for tasks of this type is 84%, what will the task time be for 50^{th} unit and for the 1000^{th} units?

To determine the task time for any numbered unit, we need to compute the exponent m

- $m = \ln(0.84)/\ln(2) = -0.2515$

The task time for the 50th unit is

- $T50 = 3.75(50)^{-0.2515} = 3.75(0.3738) = 1.402$ min

The task time for the 1000th unit:

- $T1000 = 3.75(1000)^{-0.2515} = 0.660$ min