KS SUPPLY CHAIN FUNDAMENTALS

06 Process Selection and Facility Layout

SS 2025

PLM Institute of
Production and
Logistics Management

Learning goals

Being able to ...

- ... explain the strategic importance of process selection and the influence it has on the organization and its supply chain.
- ... name the two main factors that influence process selection.
- ... compare the basic processing types.
- ... describe their main advantages and disadvantages.
- ... define and calculate cycle time.
- ... compute the required number of workstations.
- ... use simple heuristics to design product layouts.

Literature

Stevenson, WJ: Operations Management. McGraw-Hill Education Ltd; latest edition - Chapter 6

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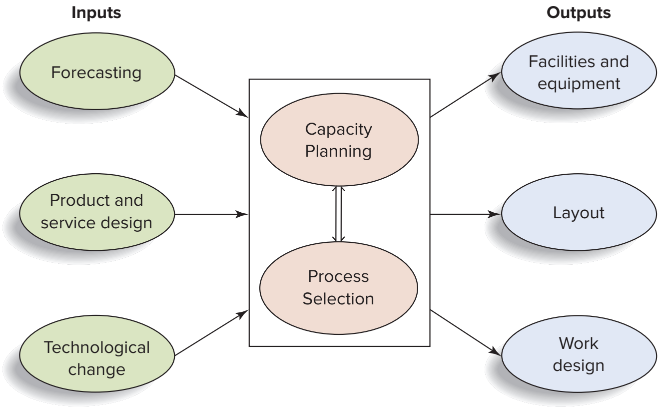
Process selection

... refers to deciding the way production of goods or services will be organized.



Organization of manufacturing processes (1)

1. How much **variety** will the process need to be able to handle?
2. How much **volume** will the process need to be able to handle?

Organization of manufacturing processes (2)

Four process types

Job Shop low volume of high-variety goods, eg manufacturing machines, specialized tools, veterinarian's office.

Batch moderate volume of goods and services with moderate variety, eg paint, beer, books

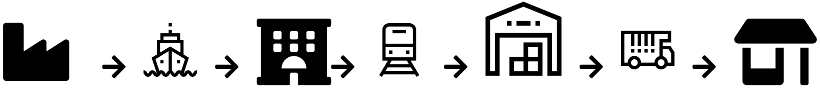
Repetitive higher volumes of standardized goods, eg cars, television, mass customization.

Continuous very high volume of nondiscrete, highly standardized output, eg steel, sugar.

Mass production

Impact on the supply chain

- repetitive/continuous manufacturing processes require continuous input in large quantities. Reliability of deliveries concerning quality and time is essential.
- Job shop and batch processing means suppliers have to be able to handle fluctuating quantities as well as order times. Seasonality can be a huge factor (periodically high demand).



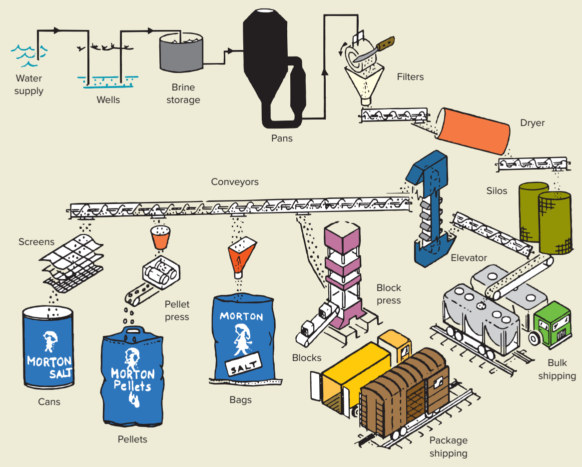
Example: Morton Salt (1)

Morton Salt owns a salt-processing facility in Silver Springs, New York. The plant employs about 200 people and it produces salt products for water conditioning, grocery, industrial, and agricultural markets. The salt production process runs continuously for about six weeks. Initially, salt is produced at a rate of 45 tons per hour. But the rate of output decreases due to scale buildup, so that by the sixth week, output is only 75 percent of the initial rate. At that point, the process is halted to perform maintenance on the equipment and remove the scale, after which salt production resumes. Conveyors move the salt to each of four dedicated production areas.

Annual round can production averages roughly 3.8 million cans of salt. Production is completely standardized and made on two high-speed production lines. Each line can handle 9600 cans per hour. The only variable is the label applied to the can. Every line has 12 production workers, while both lines can be operated by 18 workers because of common processes.

Quality is checked at several points in the production process. Everything that is produced can be sold.

Example: Morton Salt (2)



Stevenson (2017)

Automation

Process design is influenced by process and information technology (innovations), eg use of bar codes, RFIDs to obtain POS information.

1. **Computer-aided manufacturing (CAM)** Use of computers in process control, ranging from robots to automated quality control.
2. **Flexible manufacturing system (FMS)** A group of machines that include supervisory computer control, automatic material handling, and robots or other automated processing equipment. These systems produce a variety of similar products.

https://www.agilox.net/en/products/

3D Printing (example for innovation)

- A 3D printer is a type of industrial robot that is corntroled using computer-assisted design (CAD).
- Also known as *additive manufacturing*.
- Creates three-dimensional objects by applying successive layers of materials to create objects.
- The objects can be of almost any size or shape.
- Applications: Rapid prototyping, dental implants, robot parts, chocolate, pasta, ...
- Supply Chain: enables *distributed manufacturing*: products “on-demand” at different places.

Layout Decisions

Layout Configuration of departments, work centers, and equipment, focusing on material flow through the system.

Layout decisions

1. require substantial investments of money and effort.
2. are long-term commitments, mistakes are difficult to overcome.
3. have significant impact on the cost and efficiency of operations.

Objectives of layout design

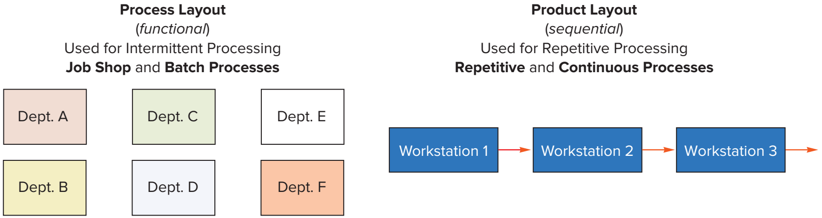
Core objective: facilitate a smooth flow of work, material, and information through the system.

Further objectives:

1. Facilitate attainment of product and service quality.
2. Use workers and space efficiently.
3. Avoid bottlenecks.
4. Minimize material handling costs.
5. Eliminate unnecessary movements of workers and materials.
6. Minimize production time and customer service time.
7. Design for safety.

Layout types

1. **Product Layouts** (sequential) Layout corresponds to the requirements of the product or service. [repetitive processing, eg production/assembly lines]
2. **Process Layouts** (functional) Processes change from order to order, stations grouped by function [job shop and batch processes]; eg hospitals.
3. **Fixed Position Layout** the item being worked on remains stationary, and workers, materials, equipment are moved as needed; eg aircraft production.



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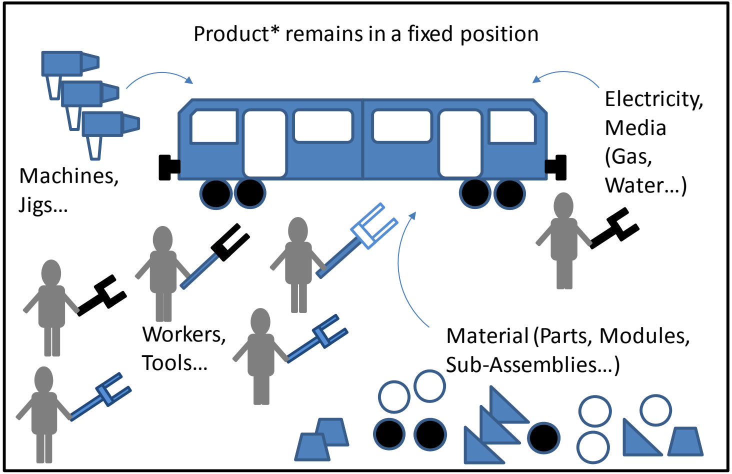
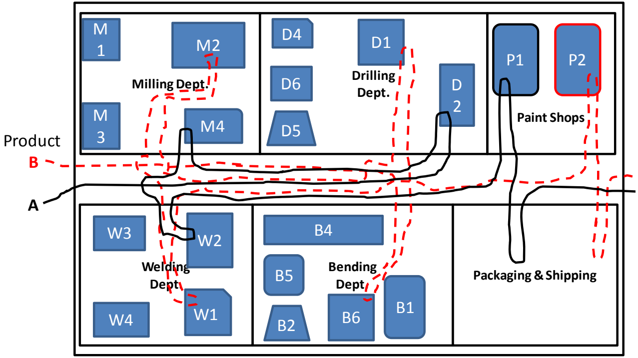
Fixed Position Layout



*Useful for heavy, bulky products such a a locomotive, for example

Ivanov D., Tsipoulanidis A., Schönberger J. (2017). Global Supply Chain and Operations Management, Springer, 1st. Edition

Process Layout



Process flow for A: D2 – M4 – W2 - P1 - shipment

Process flow for B: B6 – D1 – M2 – W1 – P2 - shipment

Legend

This symbolizes Milling Machine number 2, for example

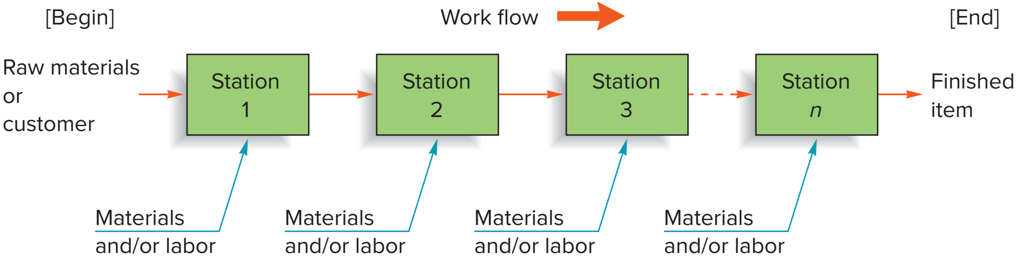
Ivanov D., Tsipoulanidis A., Schönberger J. (2017). Global Supply Chain and Operations Management, Springer, 1st. Edition

Product Layouts

Highly standardized products that allow highly standardized, repetitive processing.

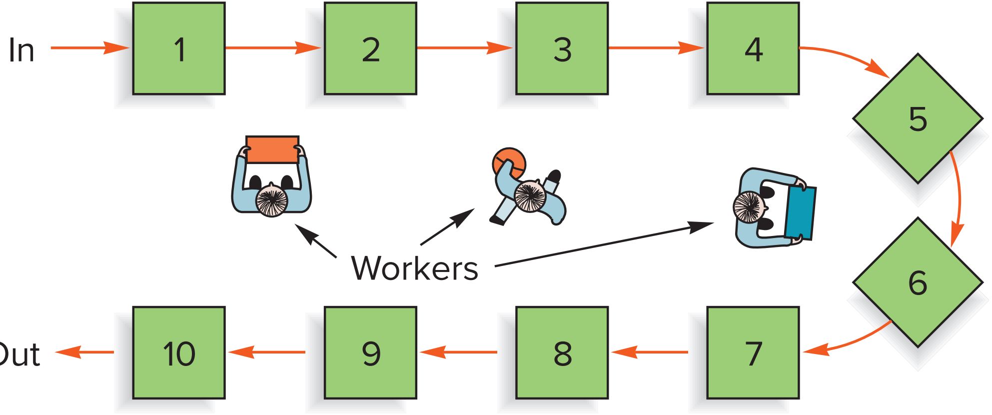
Use of conveyors for transport, high labor division.

- **Assembly line** Standardized layout arranged according to a fixed sequence of assembly tasks.
- **Production line** Standardized layout arranged according to a fixed sequence of production tasks.



Stevenson (2017)

Product Layout: U-shaped



Stevenson (2017)

Product Layout: Pros and Cons

Advantages

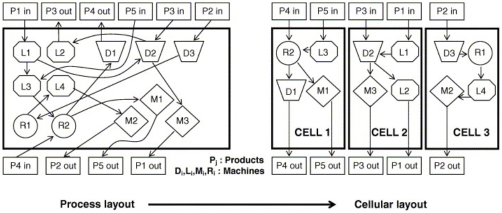
1. High rate of output
2. Low unit cost
3. Labor specialization.
4. Low material-handling cost per unit.

Disadvantages

1. Intensive divison of labor.
2. Fairly inflexible.
3. Highly susceptible to disruptions caused by equipment breakdowns because workstations are interdependent.

Cellular Production (1)

- Workstations are grouped into cells.
- A cell is a miniature version of a product layout.
- Cellular manufacturing enables companies to produce a variety of products with as little waste as possible.
- Cell layout provides a smooth flow of work with minimal transport/delay.
- **Benefits:** low work in progress (WIP), reduced space requirements and lead times, productivity and quality improvement, increased flexibility.



Vitanov, V., Tjahjono, B., & Marghalany, I. (2007). A decision support tool to facilitate the design of cellular manufacturing layouts. Computers & Industrial Engineering, 52(4), 380-403.

Cellular Production (2)

- **Single-minute exchange of die (SMED)** quick conversion of a machine or process to produce a different (but similar) product. (one cell can produce a variety of products)
- **Right-sized equipment** Smaller, mobile equipment that can be quickly reconfigured.
- **Group technology** is a strategy for product and process design, identifying items with similarities in either design characteristics or manufacturing characteristics, and grouping them into part families.
- **Flexible manufacturing systems** more fully automated versions of cellular manufacturing.

Designing product layouts

... arrange workers and machines in the sequence that operations need to be performed (production line/assembly line).

Line Balancing: Process of grouping and assigning tasks that represent approximately equal time requirements to minimize idle time along the line.

Cycle time The maximum time allowed at each workstation to perform the assigned tasks before the work moves on.

In the car industry assembly lines are very long, e.g., for the **Ford Mustang** it is several km long.

Cycle time

Every task has a different length:

→ 0.1 min. → 0.7 min. → 1.0 min. → 0.5 min. → 0.2 min. →

Stevenson (2017)

Minimum cycle time Length of the longest task time

1 minute

Maximum cycle time Length of all task times

(grouping together all tasks at one station)

0.1 + 0.7 + 1.0 + 0.5 + 0.2 = 2.5 minutes

Output rate

$$\text{Output rate} = \frac{\text{Operating time per day}}{\text{Cycle time}}$$

Example: Assume that the line will operate for eight hours a day (480 minutes). With a cycle time of 1 minute, output would be:

$$\frac{\text{480 minutes/day}}{\text{1 minute per unit}} = \text{480 units per day}$$

With a cycle time of 2.5 minutes, the output would be

$$\frac{\text{480 minutes/day}}{\text{2.5 minute per unit}} = \text{192 units per day}$$

The minimum and maximum cycle time define the minimum and maximum output.

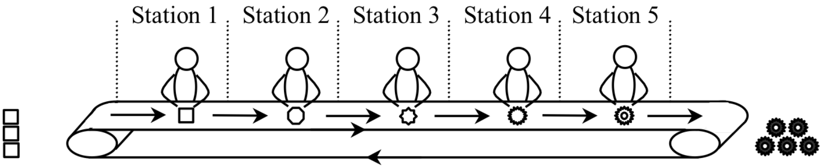
Assigning cycle time

As a general rule, the cycle time is determined by the desired output.

$$\text{Cycle time} = \frac{\text{Operating time per day}}{\text{Desired output rate}}$$

To achieve a desired outpt of 480 units per day, the cycle time has to be set to 1 minute.

Cycle time C



The product has to be processed at stations 1 through 5. Each station passes the (partial) product to the next station after C units of time.

A finished product leaves the last station (station 5) every C units of time.

Youtube Video Ford Model T:

`http://www.youtube.com/watch?v=IXkxl8dSXb4`

Calculating the number of workstations

The *theoretical minimum number* of workstations needed is:

$$N_{min} = \left\lceil \frac{\sum_{i=1}^{n} t_i}{C} \right\rceil$$

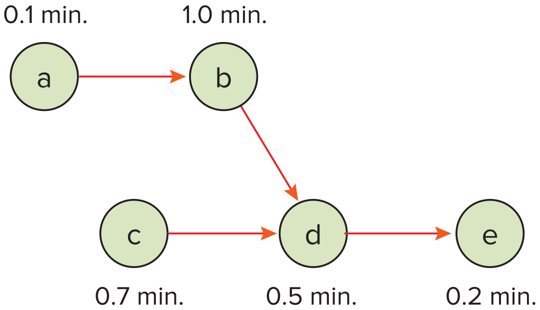
t_i is the length of task i.
n is the number of tasks.
C is the cycle time.

N_{min} for an output of 480 units? Required cycle time: 1 minute

$$N_{min} = \left\lceil \frac{0.1 + 0.7 + 1.0 + 0.5 + 0.2 = 2.5}{1} \right\rceil = \lceil 2.5 \rceil = 3 \text{ stations}$$

Precedence diagram

Tasks may not be performed in arbitrary order:



For instance, tasks a, b, and c have to be completed in order to start d.

Line Balancing

Two common line-balancing heuristics:

1. Assigning tasks according to greatest number of following tasks
2. Assigning tasks in order of greatest positional weight (Positionswertverfahren)

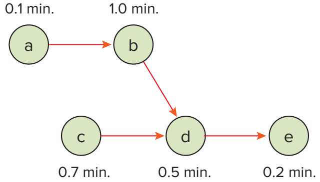
Assigning tasks according to greatest number of following tasks (1)

Arrange the tasks into three workstations.

Cycle time: 1 minute.

Number of successors:

a	b	c	d	e
3	2	2	1	0



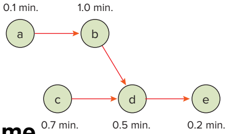
Approach

1. Calculate the number of successors of each task.
2. Check which tasks are currently assignable.
3. Choose the task with the highest number of following tasks.
4. If the chosen task may not be assigned to the current station, start a new station.
5. Repeat steps 2 through 4 until all tasks have been assigned.

Assigning tasks according to greatest number of following tasks (2)

Cycle time: 1 minute.
Number of successors:

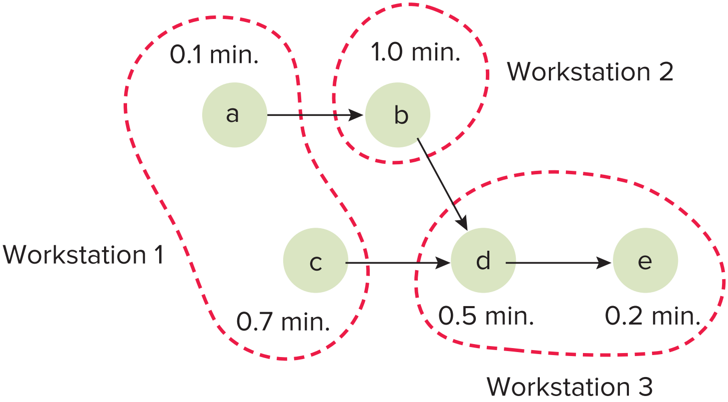
a	b	c	d	e
3	2	2	1	0



Station	Time remaining	Eligible	Assign task	Idle time
1	1.0	a,c	a	
	0.9	b,c	c	
	0.2	-		0.2
2	1.0	b	b	0.0
3	1.0	d	d	
	0.5	e	e	
	0.3	-	-	0.3
			Sum:	0.5

$N_{new} = 3$ stations

Assigning tasks according to greatest number of following tasks (3)



Measures: efficiency and balance delay

The **efficiency** of the system is computed as follows:

$$\text{Efficiency} = \frac{\sum_{i=1}^{n} t_i}{N_{new} C}$$
$$= \frac{0.1 + 0.7 + 1.0 + 0.5 + 0.2 = 2.5}{3 \times 1} = 0.833 = 83.3\%$$

or

100% - Percentage of idle time = 100% - 16.7% = 83.3%

The **Balance delay** is the percentage of idle time:

$$\text{Percentage of idle time} = \frac{0.5}{3 \times 1} \times 100 = 16.7\%$$

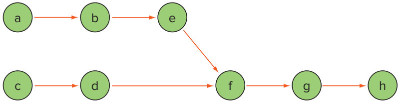
Example

Task	Immediate Predecessor	Task Time (in minutes)
a	—	0.2
b	a	0.2
c	—	0.8
d	c	0.6
e	b	0.3
f	d, e	1.0
g	f	0.4
h	g	0.3
		$\Sigma t = 3.8$

1. Draw a precedence diagram.
2. Assuming an eight-hour workday, compute the cycle time needed to obtain an output of 400 units per day.
3. Determine the minimum number of workstations required.
4. Assign tasks to workstations according to greatest number of following tasks.

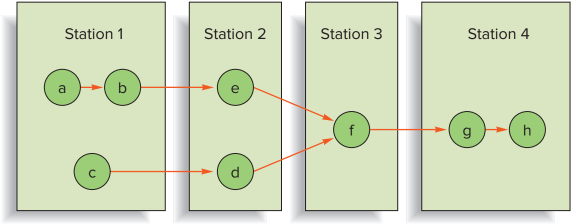
Stevenson (2017)

Example - solution

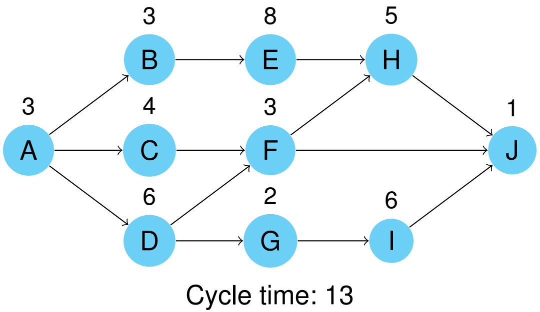


Cycle time $C = 1.2$ minutes

$N_{min} = 4$ stations



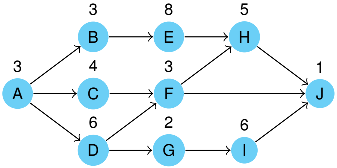
Assigning tasks in order of greatest positional weight



Positional weight: Sum of the task’s time and the times of all following tasks.

Rank: based on positional weights in descending order (to select the next task in step 3).

Example (1)



Task	A	B	C	D	E	F	G	H	I	J
Pos. weight	41	17	13	23	14	9	9	6	7	1
Rank	1	3	5	2	4	6	7	9	8	10

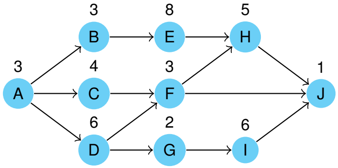
Calculation of positional weights:

A: Sum of all times of successors of A as well as A itself. Successors of A: all other tasks.

$3 + 3 + 4 + 6 + 8 + 3 + 2 + 5 + 6 + 1 = 41$

B: Successors of B: E, H, J $\rightarrow 3 + 8 + 5 + 1 = 17$

Example (2)



Task	A	B	C	D	E	F	G	H	I	J
Pos. weight	41	17	13	23	14	9	9	6	7	1
Rank	1	3	5	2	4	6	7	9	8	10

To distinguish between F and G, we look at their times. F takes longer than G and was therefore ranked higher.

Station	Time remaining	Eligible	Assign Task	Time	Idle Time
1	13	A	A	3	
	10	B, C, D	D	6	
	4	B, C, G	B	3	
	1	(C, E, G)	-	-	1
2	13	C, E, G	E	8	
	5	C, G	C	4	
	1	(G, F)	-	-	1
3	13	G, F	F	3	
	10	G, H	G	2	
	8	H, I	I	6	
	2	(H)	-	-	2
4	13	H	H	5	
	8	J	J	1	
	7	-	-	-	7

Example (3)

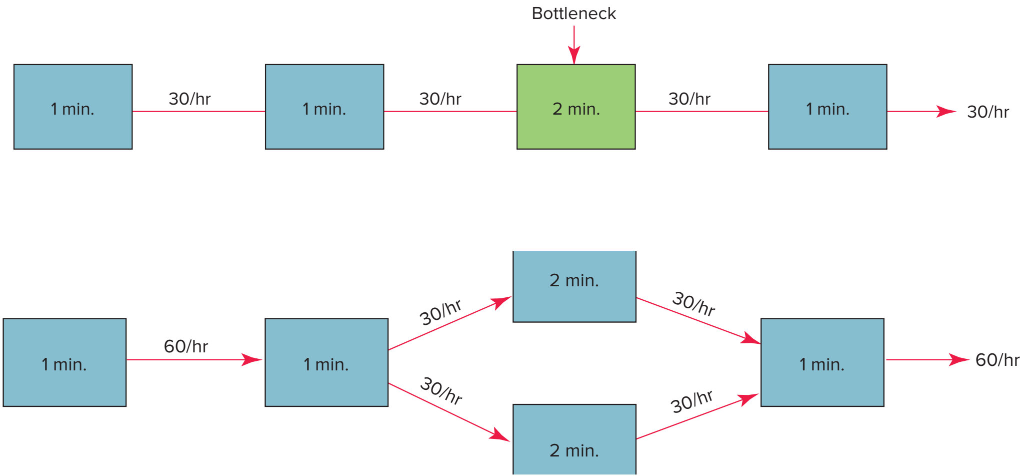
Efficiency

$$\text{Efficiency} = \frac{41}{4 \times 13} = 0.788 = 78.8\%$$

Every station has an idle time of at least 1 $\rightarrow$ Cycle time can be reduced to 12. $(C_{new} = 12)$

$$\text{Efficiency} = \frac{41}{4 \times 12} = 0.85 = 85\%$$

Additional option: parallel stations



Designing process layouts

Development of standardized layouts (e.g., in supermarket chains)

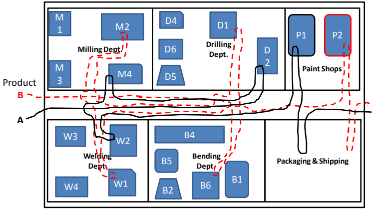
Customized designs aim at **minimizing length of transportation routes**:

Locations

A	B	C
D	E	F

Work centers to be assigned

1
2
3
4
5
6



Process flow for A: D2 – M4 – W2 - P1 - shipment
Process flow for B: B6 – D1 – M2 – W1 – P2 - shipment

Legend
M2 This symbolizes Milling Machine number 2, for example

Which “Work Center” should be built where?
Large number of possible assignments (solutions methods: heuristics, linear/quadratic programming)

Summary

- Process type and layout depend on the expected demand volume and the degree of customization (variety/variants) that will be required.
- Each process type and layout has advantages and limitations. These have to be understood when deciding on process type and layout.
- Process design is critical in a product-centered systems (process follows product requirements). In a process-focused system, managing is critical.