WORKFLOW AND BATCH PROCESSING

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SEQUENTIAL OPERATIONS AND WORK FLOW

- ***sequential operations*** refers to a work system in which multiple processing steps are accomplished in order to complete a work unit, and the processing steps are performed sequentially (rather than simultaneously).
- ***precedence constraints*** limitations on the order in sequential operations in which the operations can be performed, where some operations must be completed before others can be started.
- Examples:
  - *A hole must be drilled before it can be tapped to cut the threads.*
  - *The internal components of a product must be assembled to the base part before the cover is attached.*
  - *Passengers must be checked in and then processed through security at the airport before being allowed to board an aircraft.*
  - *A surgery patient must be anesthetized before the scalpel is used.*

SEQUENTIAL OPERATIONS AND WORK FLOW

- In a manufacturing plant (production work): different locations refer to the locations of the various processing machines and workstations used in the sequence.
- In a distribution center (logistics work): the various locations include the unloading dock, receiving stations, storage racks, and loading docks through which a product is moved inside the facility before being shipped to the retail store.
- In a hospital (service work): a surgery patient is first admitted and then moved to a waiting room before arriving in the operating room for the procedure.
- ***Work flow*** refers to the physical movement of work units in sequential processing. Associated with the physical flow is an information flow to monitor and control the movements of work units.

Work flow patterns

- ***Network diagram:*** used here to show the flow of work units through a series of operations.

Work Flow and Batch Processing

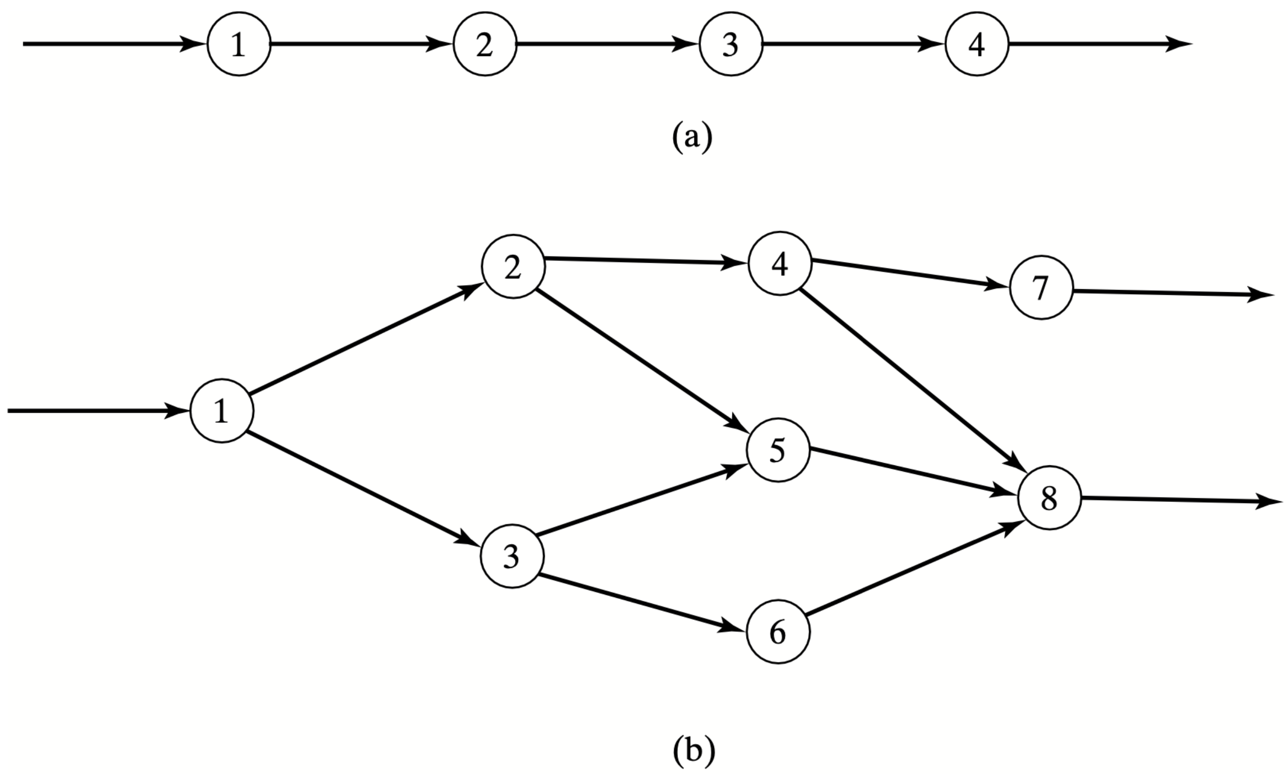


Figure 1 Network diagrams representing (a) pure sequential work flow and (b) mixed sequential work flow.

Work flow patterns

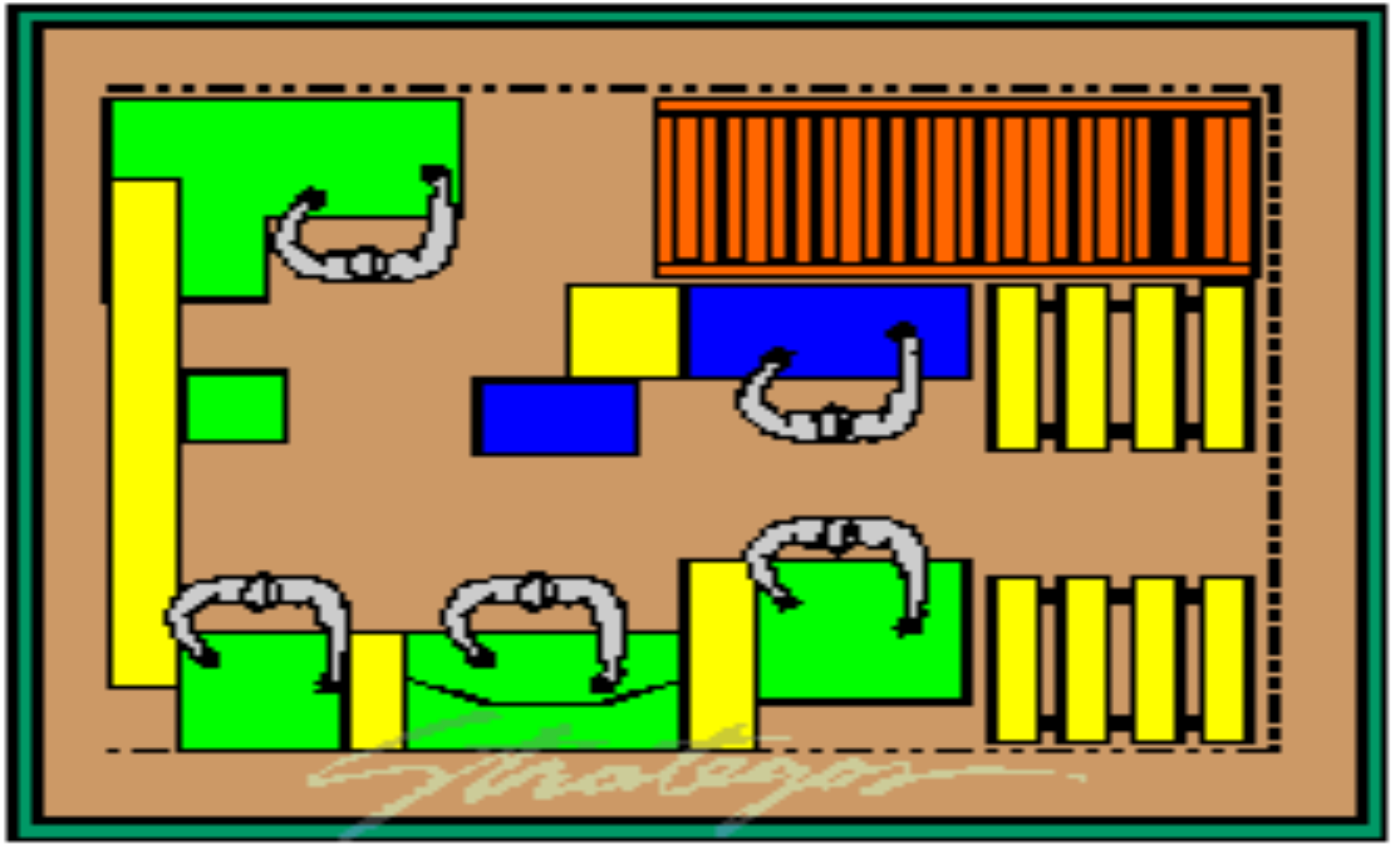
- Two basic types of work flow patterns can be distinguished: (1) pure sequential and (2) mixed sequential.
- In a ***pure sequential pattern***, all work units follow the same exact sequence of workstations and operations. There is no variation in the processing sequence.
- In a ***mixed sequential pattern***, there are variations in the work flow for different work units.

Work flow patterns

- The nodes (circles) represent operations and the arrows indicate the direction of work flow.
- Several types of movements experienced by different work units can be distinguished in a sequential work flow. There are four types of moves:

In-sequence	A transport of the work unit from the current operation (work- station) to the neighboring operation immediately downstream. It is a move in the forward direction in the sequence.
Bypassing	A move in the forward direction but beyond the neighboring work- station by two or more stations ahead of the current station.
Backflow	A move of the work unit in the backward direction by one or more stations.
Repeat operation	An operation that is repeated at the same workstation. This might imply that several attempts are required to complete the operation, or that two (or more) operations are performed at the same station and the operations must be separated for some reason (e.g., a different setup is required for the two operations).

Work flow patterns



Work flow patterns

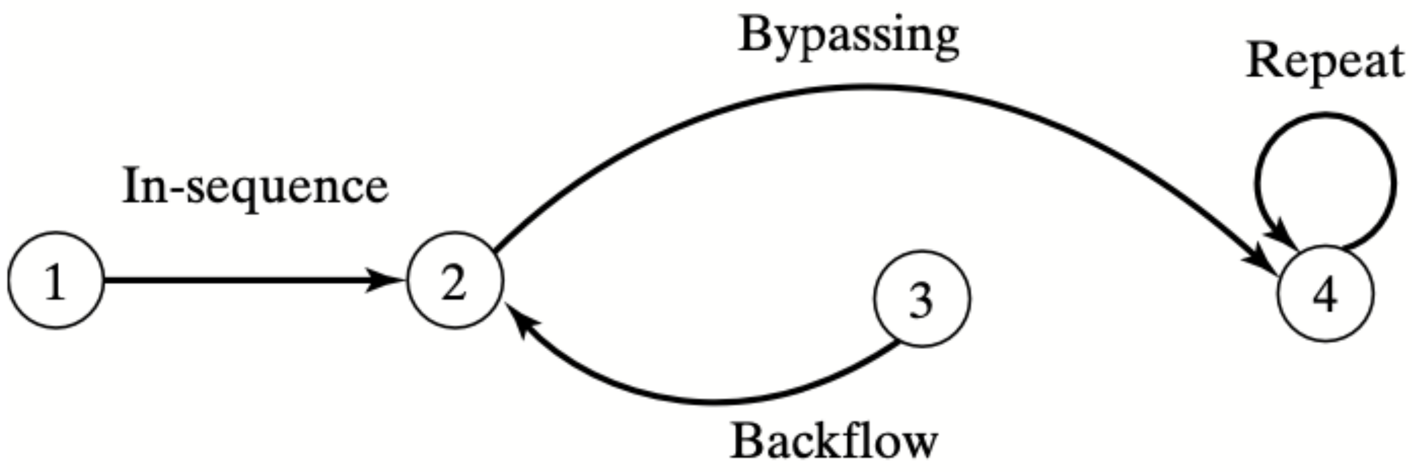


Figure 2 Four types of movements in a sequential work flow: in-sequence, bypassing, backflow, and repeat operation.

Work flow patterns

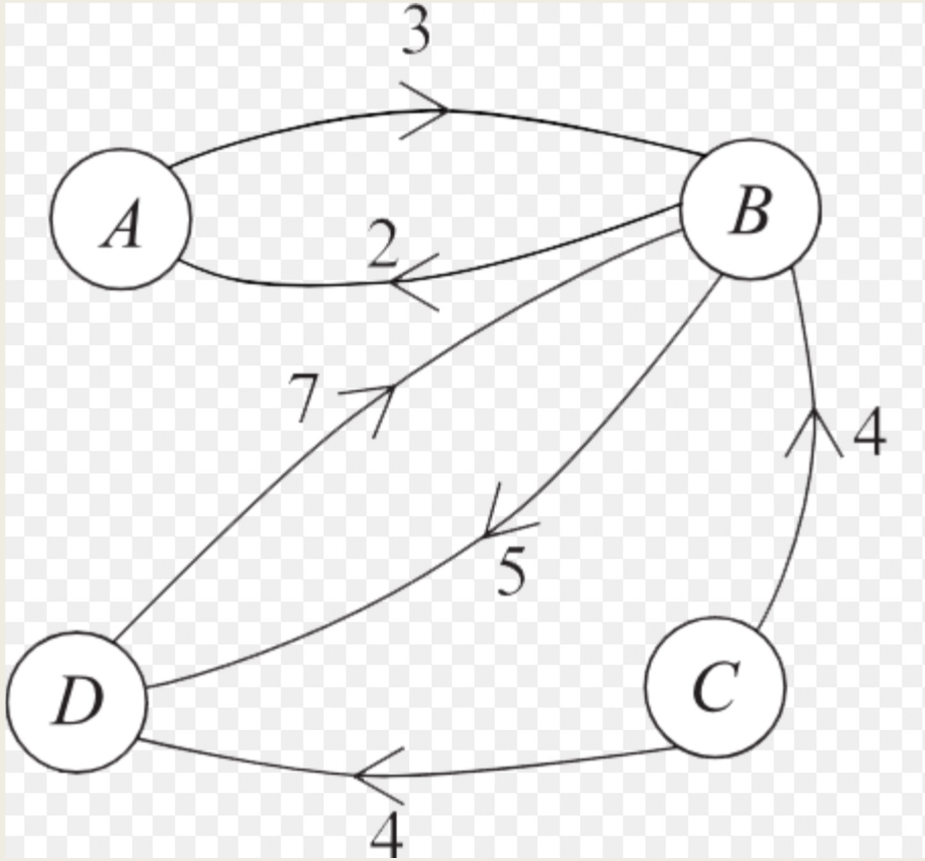
AB : In-sequence

BD: Bypassing

BA: Backflow

CD: In-sequence

CB: Backflow



From – To Chart

- ***From-To chart*** is a table that can be used to indicate various quantitative relationships between operations or workstations in a multistation work system.

TABLE 1 From-To Chart Showing Daily Quantities Q_{ij} of Work Units Moving Between Five Workstations

		To operation j				
		1	2	3	4	5
From operation i	1	—	40		15	
	2		—	30		
	3		10	—	20	
	4				25	50
	5					—

From – To Chart

- Possible variables (and the corresponding symbols for the values) that can be displayed in a From-To chart include the following:
  - *Quantities of work units (or other measures of material quantity, e.g., pallet loads) moving between operations or workstations (Qij)*
  - *Flow rates of materials(e.g., quantities per hour) moving between operations or workstations (Rfij)*
  - *Distances between workstations (Lij)*
  - *Combinations of these values (e.g.,Rfij Lij)*

From – To Chart

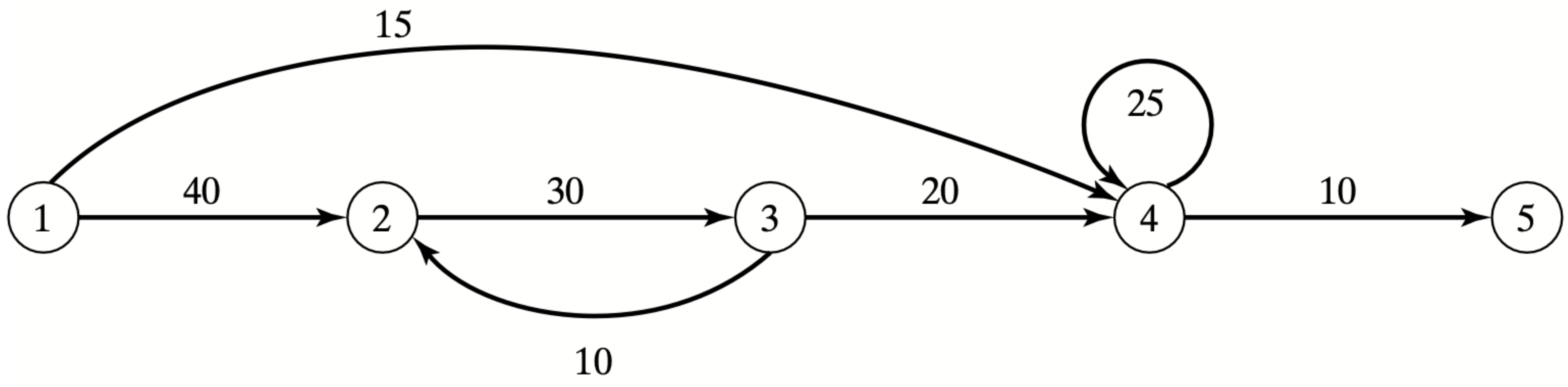
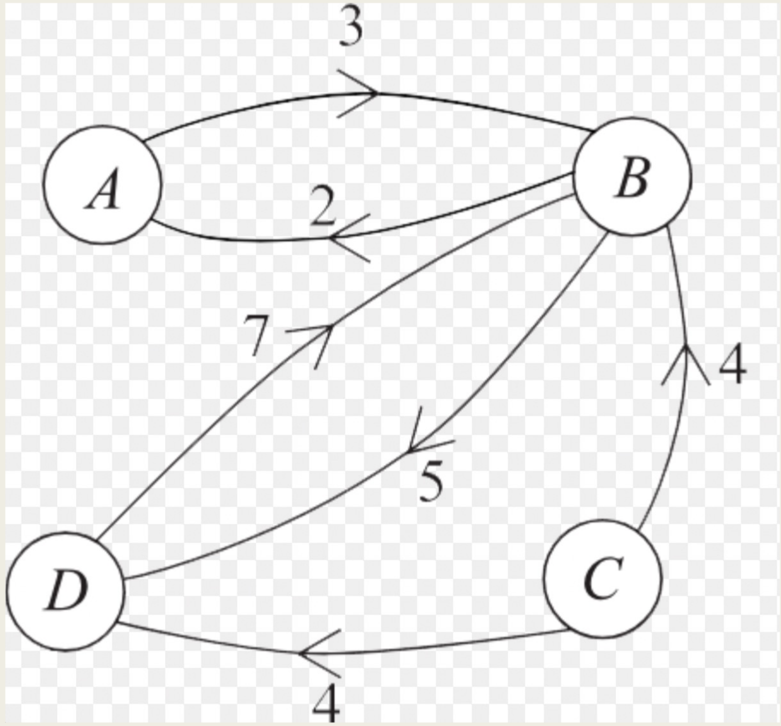


Figure 3 Network diagram of the data in the From-To chart of Table 1.

From – To Chart

- Repeat operations are represented by values along the main diagonal—that is, $Q11$, $Q22$, $Q33$, $Q44$, and $Q55$. For example, $Q44 = 25$ is a repeat operation.
- In-sequence moves are indicated by values immediately above the main diagonal— that is, $Q12$, $Q23$, $Q34$, and $Q45$. For example $Q12 = 40$, $Q23 = 30$, $Q34 = 20$, and $Q45 = 50$ are all in-sequence moves.
- By passing moves are indicated by values located above the in-sequence moves— that is, $Q13$, $Q14$, $Q15$, $Q24$, $Q25$, and $Q35$. For example, $Q14 = 15$ is a bypassing move.
- Back flow moves are indicated by values below the main diagonal—that is, $Q21$,$Q31$, $Q41$, $Q51$, $Q32$, $Q42$, $Q52$, $Q43$, $Q53$, and $Q54$. For example, $Q32 = 10$ is a backflow move.

Work flow patterns

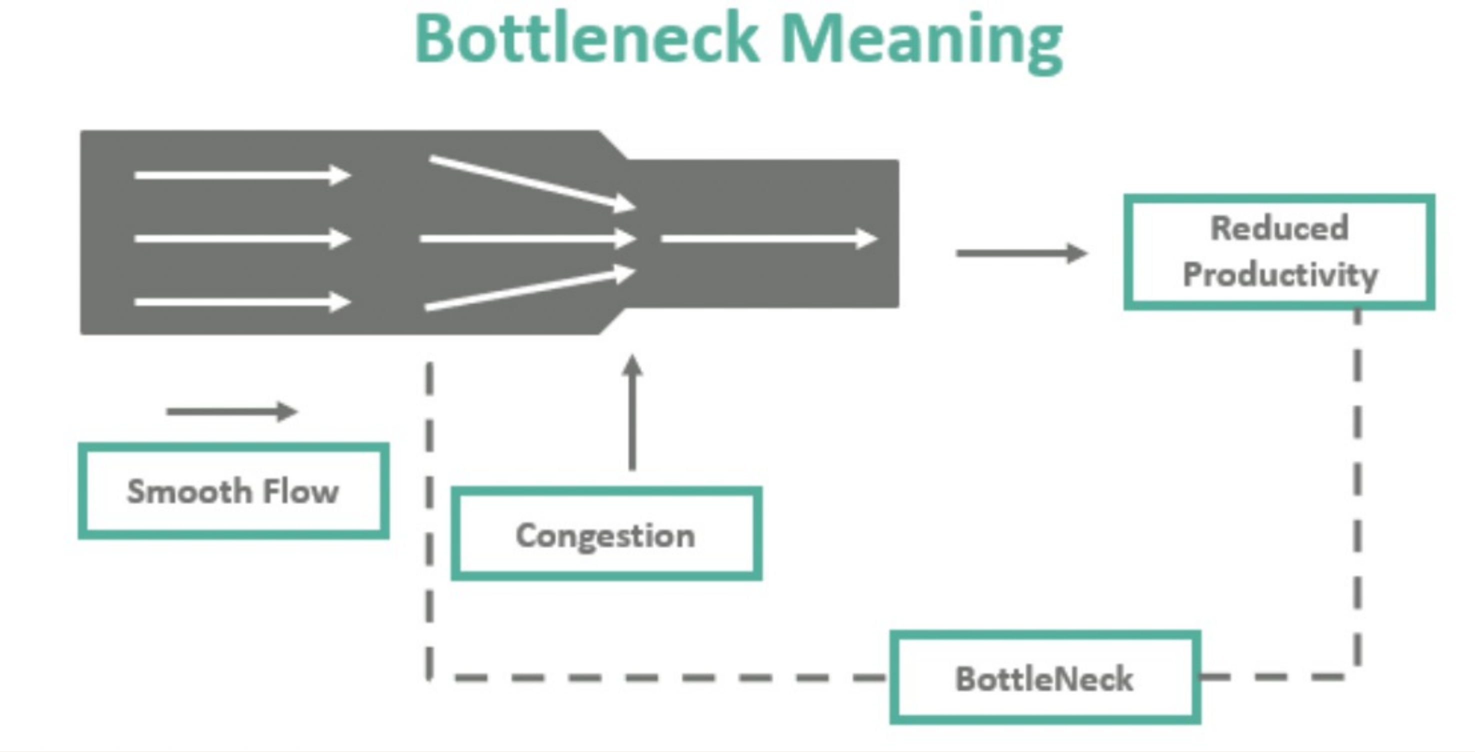


	A	B	C	D
A		3		
B	2			5
C		4		4
D		7		

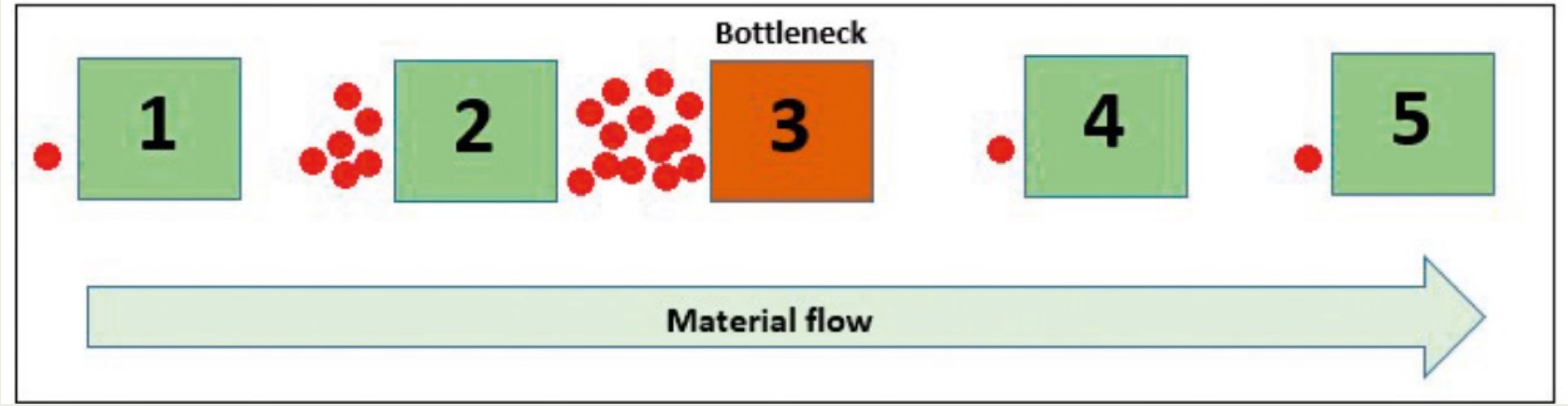
Bottlenecks Operations

- Bottleneck operation: operation with the lowest production rate in the production line that limit/restrict the flow rate.
- Why is it important to define bottleneck operations:
  - *Decrease revenue*
  - *Increase cost*
  - *Loose customers*
  - *Increase waiting time*
  - *Poor quality products*

Bottlenecks Operations



Bottlenecks Operations



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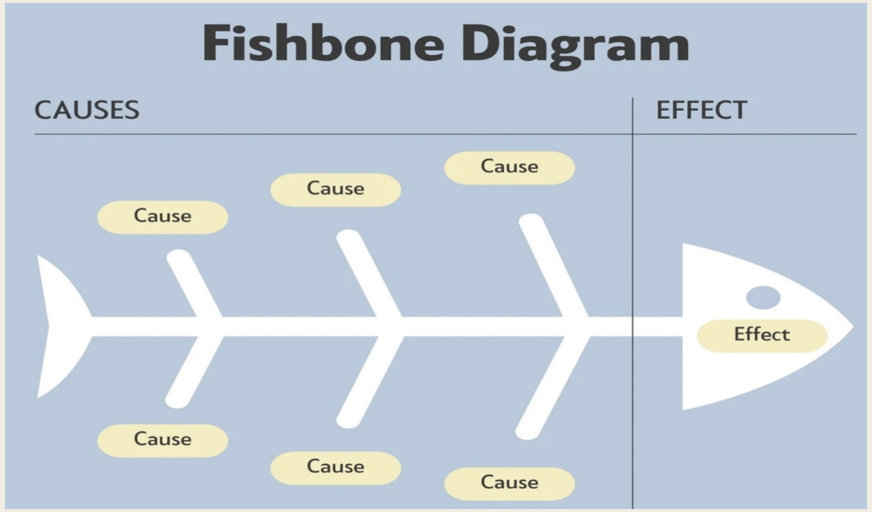
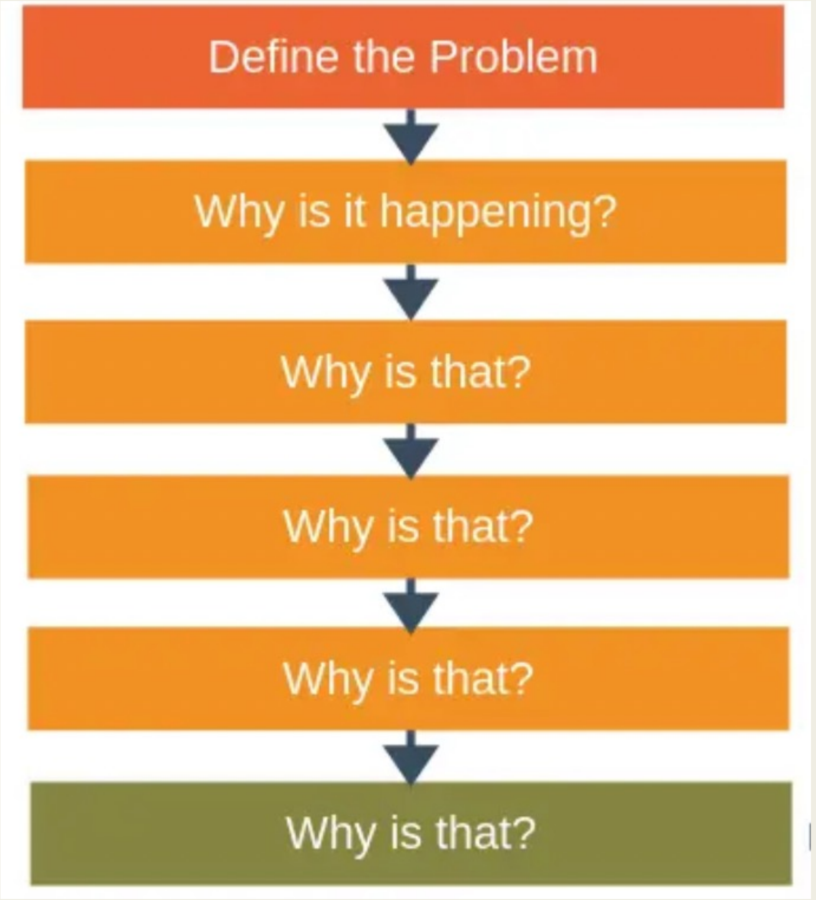
Bottlenecks Operations

- Causes of bottleneck operations:
  - *Lack of appropriate technology*
  - *Lack of funds*
  - *Lack of workforce*
  - *Supplier related issues*
  - *Unorganized workforce and materials*
  - *Less trained workers*

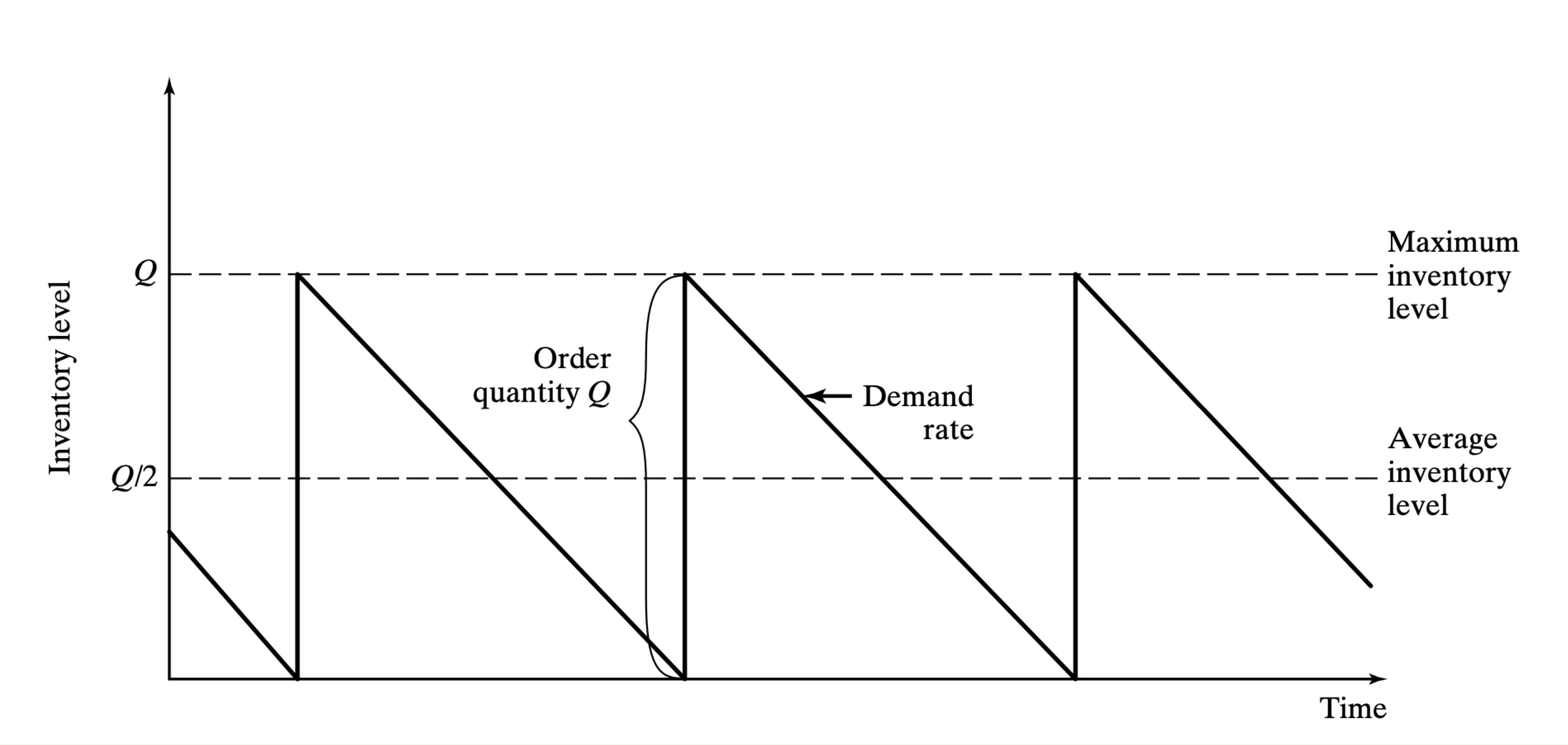
Bottlenecks Operations

- Bottleneck analysis tools:
  - *5 whys root cause analysis*
  - *Fish bone diagram (cause - effect diagram)*





Economic Order Quantity



Economic Order Quantity

- The figure assumes that demand rate is constant, so that inventory is gradually depleted over time and then quickly replenished to some maximum level determined by the order quantity. Because of the triangular shape of inventory cycle, the average inventory level is one-half the maximum level *Q* in our figure, and this average is multiplied by the inventory carrying cost per item.

- The formula for EOQ is:

$$Q = \sqrt{\frac{2DS}{H}}$$

- Where: Q=EOQ units, D=Demand in units (typically on an annual basis)
S=Order cost (per purchase order), H=Holding costs (per unit, per year)

Economic Order Quantity

- The goal of the EOQ formula is to identify the optimal number of product units to order. If achieved, a company can minimize its costs for buying, delivering, and storing units.
- Economic order quantity is important because it helps companies manage their inventory efficiently. Without inventory management techniques such as these, companies will tend to hold too much inventory during periods of low demand while also holding too little inventory during periods of high demand. Either problem creates missed opportunities.

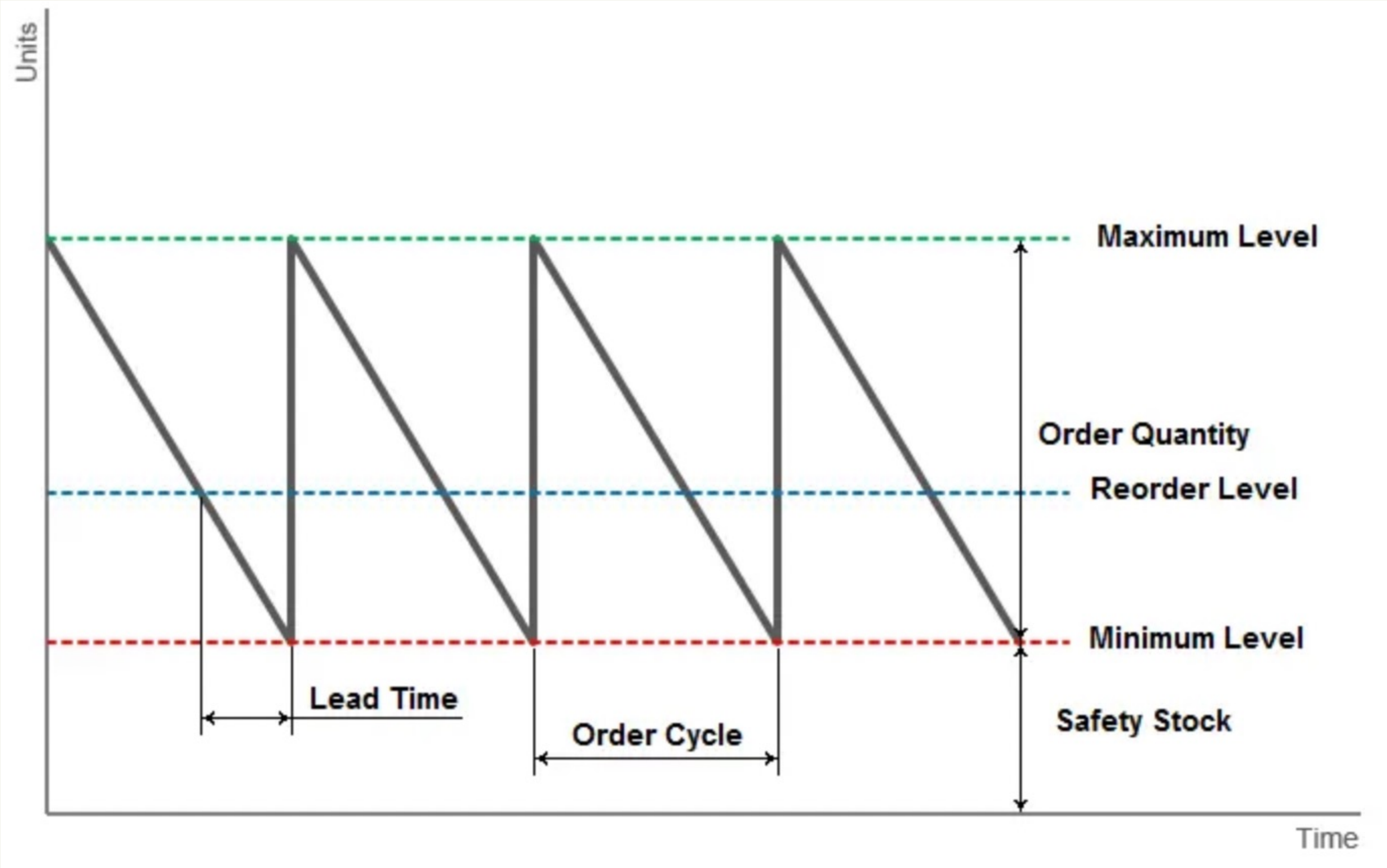
Economic Order Quantity

- Example:

Assume a retail clothing shop carries a line of men’s jeans, and the shop sells 1,000 pairs of jeans each year. It costs the company $5 per year to hold a pair of jeans in inventory, and the fixed cost to place an order is $2.

The EOQ formula is the square root of (2 x 1,000 pairs x $2 order cost) / ($5 holding cost) or 28.3 with rounding. The ideal order size to minimize costs and meet customer demand is slightly more than 28 pairs of jeans.

Economic Order Quantity



Economic Order Quantity

- XYZ Ltd. is a structural steel retailer. The average daily sales of reinforcing bar is 25 tons. The inventory's daily consumption rate is constant, and the lead time of 7 days is also constant. The management of XYZ Ltd. has refused to hold safety stock.

  Reorder point = Safety stock+ (Average daily sales x Lead time in days)

  Reorder point = 25 × 7 = 175 tons

- Let's assume that XYZ Ltd. has irregular sales of reinforcing bar:

  minimum daily sales: 15 tons, average daily sales: 25 tons, maximum daily sales: 40 tons

  The lead time also varies between 5 and 9 days. To avoid disruption in sales, we should use both maximum daily usage and maximum lead time. Thus, the reorder point should be in tons.

  Reorder point = 40 × 9 = 360 tons

- As we can see, irregular daily usage forces companies to have more stock to avoid disruption in sales or production.

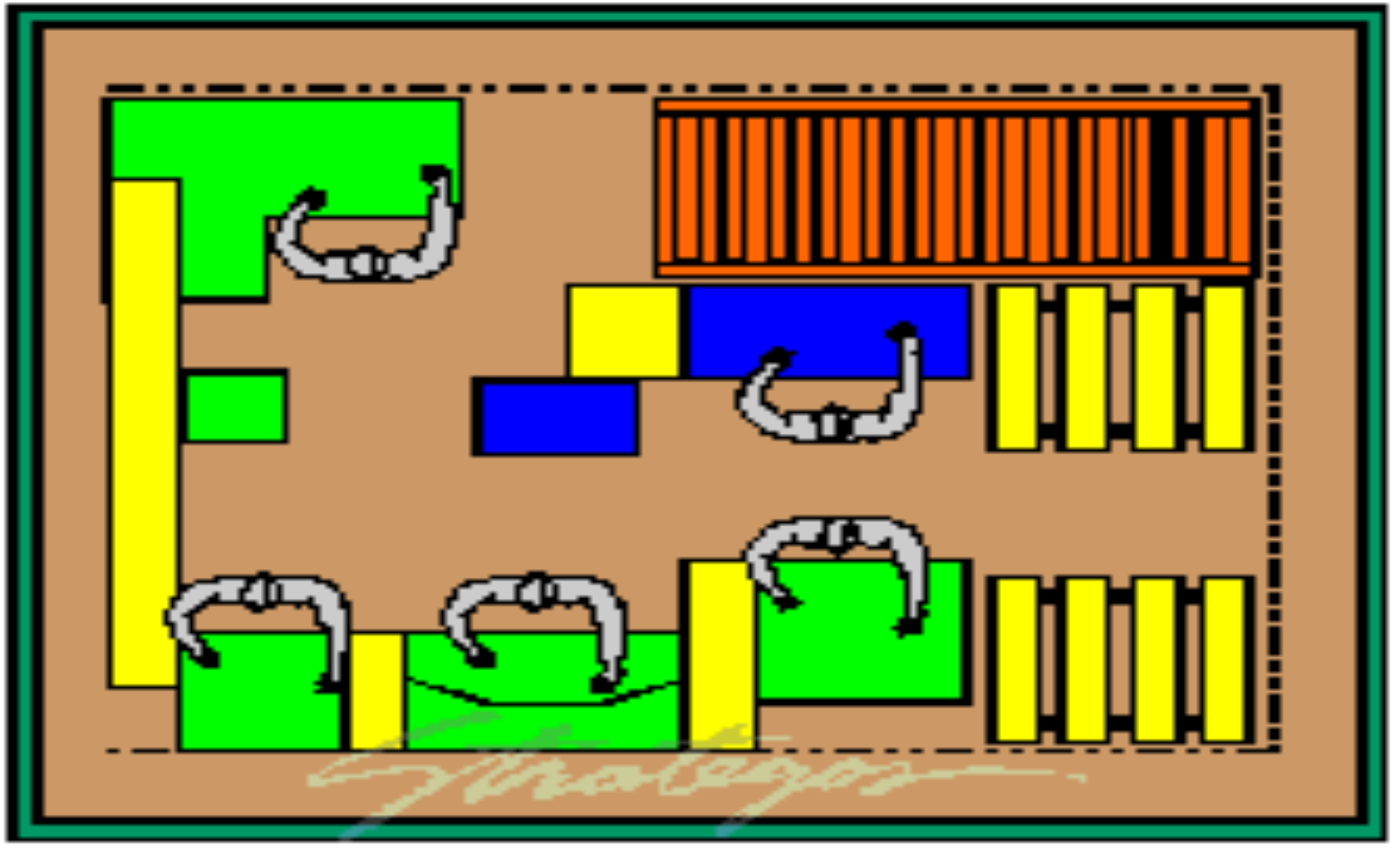
Economic Order Quantity

- **Example**
- To avoid overstocking and an increase in cost, a company's management can hold safety stock and use it to compensate for the extra usage of inventory.
- Let's consider Example 2 and assume that XYZ Ltd. has set up safety stock for an average usage of 5 days. Because the company has safety stock, it can use both average daily sales and average lead time to determine reorder point.
- Reorder point = $25 \times 7 + 5 \times 25 = 300$ tons
- As we can see, the setup of safety stock allows holding a lower stock balance and reducing holding costs.

WORK CELLS

- A ***work cell*** is a group of workstations dedicated to the processing of a range of work units within a given type. The processing is typically performed as a sequence of operations.
- In production, where work cells are often employed, the work units are parts, and the range of parts is called a ***part family***.
- The members of the part family possess similarities that permit them to be processed by the work cell. The processing of part families is associated with an approach to manufacturing called ***group technology***, in which similar parts are identified and grouped together to take advantage of their similarities in design and production
- This is made possible by (1) the similarity of parts within a part family and (2) the adaptability and flexibility of the workers and equipment in the cell that can accommodate the moderate differences among part family members.

WORK CELLS



WORK CELLS

- Because the range of parts or products in a work cell is limited, the processing (or assembly) of work units consists of operations that are **similar but not identical**. Thus, although the layout of the cell is fixed, the operations and their sequence are not. We are dealing with a mixed sequential work flow system.
- The workstations in the cell are usually arranged to facilitate the flow of work from one operation to the next. In some cases, the stations are connected by a mechanized material-handling system. In other cases the work is carried from station to station by hand.

WORK CELLS

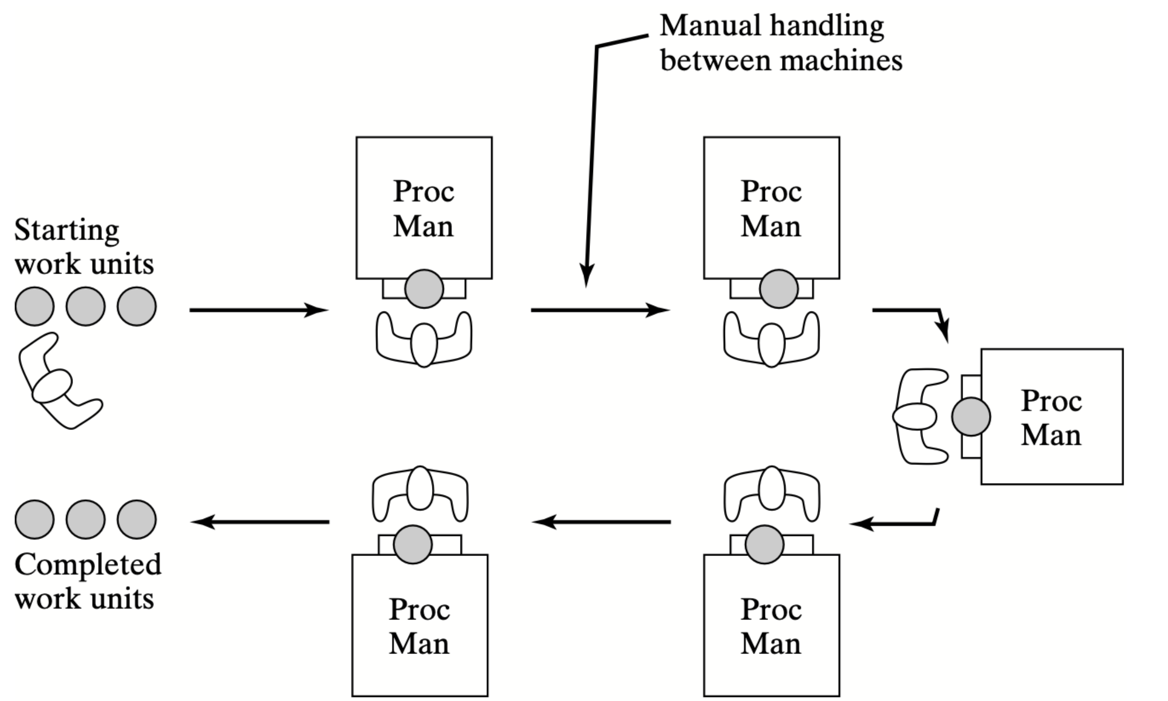
- Work cells can be distinguished according to the following factors: (1) number of workstations in the cell, (2) material-handling method, and (3) layout of the cell.

- One of the advantages of a work cell is that it promotes teamwork and a sense of mission among its workers, and this advantage tends to be diminished if the cell becomes too large. If the number of workstations is very large (e.g., several dozen to several hundred) , then the work is more likely to be organized as a manual assembly line.

MATERIAL HANDLING WORK CELLS

- The material-handling method in a work cell can be **manual** or **mechanized**.
- Manual material handling consists of the workers in a cell moving the work units between stations. This is appropriate when one worker performs all of the operations to complete a given work unit, so it is logical for the worker to carry the units through the sequence of stations, stopping at those stations where processing is required.
- **Manual handling** can also be used when workers are assigned to specific workstations. Either the station operators themselves are responsible for moving the work units forward, or designated material-handling workers are assigned to move the units between stations.
- Manual work cells are often organized into a U-shaped layout, as shown in Figure 8. This arrangement has been found to promote teamwork among the workers. It also allows for variations in operation sequence among different part or product styles.

MATERIAL HANDLING WORK CELLS

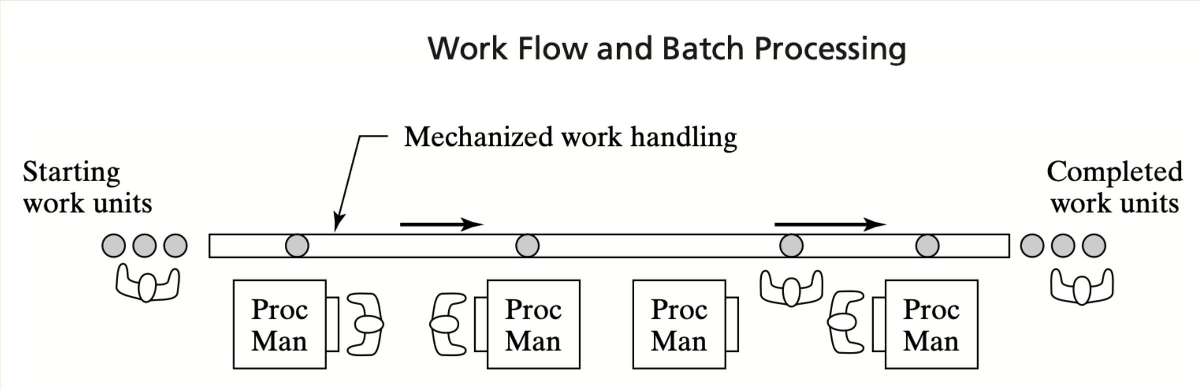


Proc = processing operation (e.g., mill, drill), Man = manual operator, arrows indicate predominant work flow.

Figure 8 U-shaped work cell with manual handling between stations.

MATERIAL HANDLING WORK CELLS

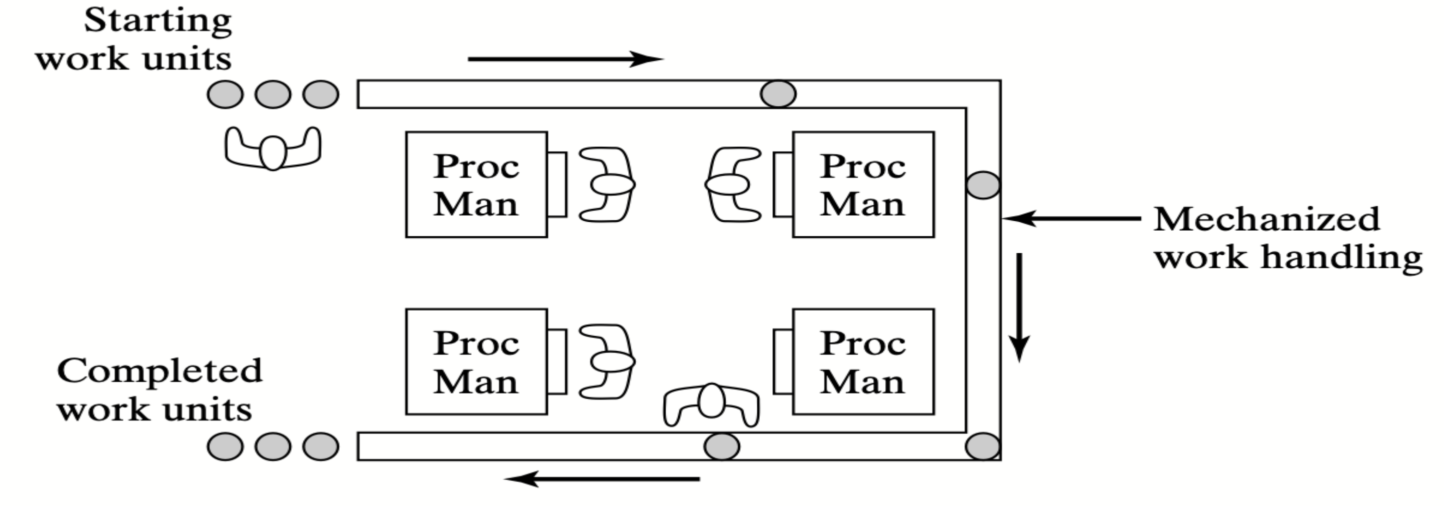
- **Mechanized handling** is usually achieved by means of a powered conveyor, such as a belt conveyor. A variety of layouts are possible in work cells with mechanized handling, including in-line, U-shaped, loop, and rectangular, as shown in Figure 9.
- In an in-line layout, the workstations are arranged in a straight line, as in Figure 9 (a). This layout type is appropriate when all work units are processed in the same basic operation sequence. It does not facilitate variations in work sequence as readily as other layout configurations.



(a)

MATERIAL HANDLING WORK CELLS

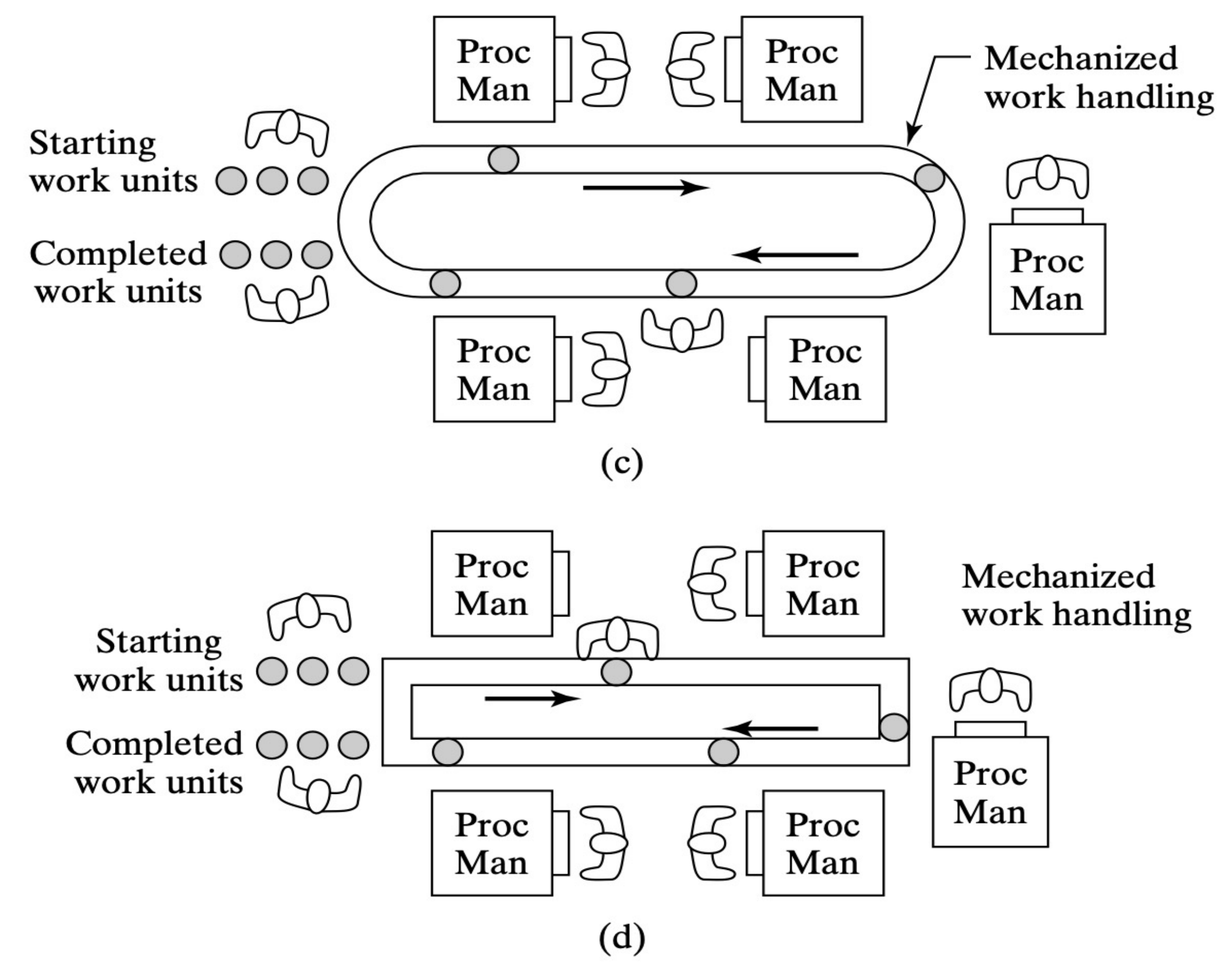
- The U-shaped layout, Figure 9 (b), is an adaptation of the in-line type that allows some flexibility in processing sequence. If the work units move through the system attached to work carriers, then some means of returning the carriers to the beginning of the sequence is required.



(b)

MATERIAL HANDLING WORK CELLS

- Loop and rectangular layouts accommodate this return requirement, as seen in Figure 9 (c) and (d).



Operation Sequence in a Work Cell

- We can use data contained in From-To charts to arrange the stations in an order that maximizes the proportion of forward moves (in-sequence and bypassing moves) within the cell.

1. Develop the From-To chart from part routing data. The data contained in the From-To chart indicates numbers of part moves between the workstations (or machines) in the cell. Moves into and out of the cell are not included in the chart.

2. Determine the From-To ratio for each workstation. This is accomplished by summing up all of the “From” and “To” trips for each workstation. The From sum for a station is determined by adding the entries in the corresponding row, and the To sum is determined by adding the entries in the corresponding column. For each station, the From-To ratio is calculated by taking the From sum for each station and dividing by the respective To sum.

3. Arrange workstations in order of decreasing From-To ratio. Stations with high From-To ratios distribute work to other stations in the cell but receive work from few of them. Conversely, stations with low From-To ratios receive more work than they distribute. Therefore, stations are arranged in order of descending From-To ratio; that is, stations with high ratios are placed at the beginning of the work flow, and stations with low ratios are placed at the end of the work flow. In case of a tie, the workstation with the higher From value is placed ahead of the station with a lower value.

Operation Sequence in a Work Cell

- Example:

Four workstations, 1, 2, 3, and 4, have been assigned to a work cell. An analysis of 50 parts processed in these stations has been summarized in the From-To chart of Table 3. Additional information is that 50 parts enter the cell at station 3, 20 parts leave after processing at station 1, and 30 parts leave after station 4. Determine a logical workstation arrangement using the Hollier algorithm.

Table 3 is repeated in Table 4 along with the From-To sums. The From-To ratios are given in the last column on the right. Arranging the stations in order of descending From-To ratio, the cell is sequenced as follows:

$$3 \rightarrow 2 \rightarrow 1 \rightarrow 4$$

Operation Sequence in a Work Cell

- Example: Cont…

Work Flow and Batch Processing

TABLE 3 From-To Chart for Example 3

	To: 1	2	3	4
From: 1	0	5	0	25
2	30	0	0	15
3	10	40	0	0
4	10	0	0	0

TABLE 4 From-To Sums and Ratios for Example 3

	To: 1	2	3	4	**From Sums**	**From-To Ratios**
From: 1	0	5	0	25	**30**	**0.60**
2	30	0	0	15	**45**	**1.0**
3	10	40	0	0	**50**	**∞**
4	10	0	0	0	**10**	**0.25**
To Sums	**50**	**45**	**0**	**40**	**135**	

Operation Sequence in a Work Cell

- Example: Cont…

It is helpful to use a network diagram (Figure 10) to conceptualize the workflow in the cell. The workflow consists of mostly in-sequence moves; however, there is some bypassing and backflow of parts that must be considered in the design of any material- handling system that might be used in the cell. A powered conveyor would be appropriate for the forward flow between machines, with manual handling for the back flow.

Work Flow and Batch Processing

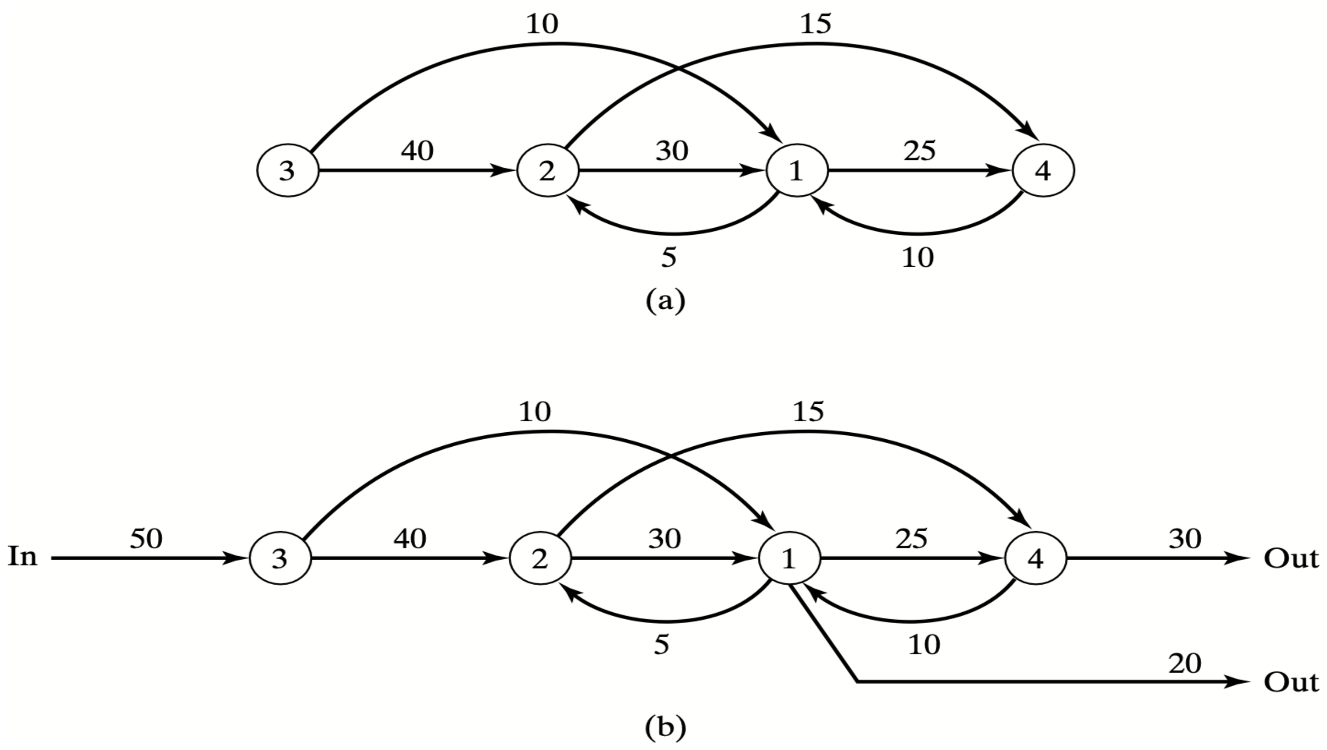


Figure 10 Network diagram for the work cell station sequence in Example 3: (a) internal work flow given in Table 3 and (b) work flow including work units into and out of the cell.

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Operation Sequence in a Work Cell

- Several performance measures can be used to compare alternative solutions to the machine sequencing problem. The measures are based on the types of moves:

  1. *Percentage of in-sequence moves, computed by adding all of the values representing in-sequence moves and dividing by the total number of moves.*

  2. *Percentage of bypassing moves, found by adding all of the values representing bypassing moves and dividing by the total number of moves.*

  3. *Percentage of backflow moves, determined by summing all of the values representing backflow moves and dividing by the total number of moves.*

  4. *Percentage of repeated operations, which is the sum of all repeated operations divided by the total number of moves.*

- It is desirable for the layout arrangement to have high proportions of in-sequence and bypassing moves since these both represent forward work flow (in-sequence moves are more desirable than bypassing moves). The layout should minimize the percentage of backflow moves. The percentage of repeated operations will have the same value for all solutions.

Operation Sequence in a Work Cell

- Example: Compute (a) the percentage of in-sequence moves, (b) the percentage of bypassing moves, and (c) the percentage of backflow moves.

  From Figure 10, the total number of moves is 135 (totaling either the From sums or the To sums).

  (a) The number of in-sequence moves = 40 + 30 +25 = 95; percentage of in- sequence moves = 95/135 = 0.704 = 70.4%.

  (b) The number of bypassing moves = 10 + 15 = 25; percentage of bypassing moves = 25/135 = 0.185 =18.5%.

  (c) The number of backflow moves = 5 + 10 = 15; percentage of backflow moves =15/135 = 0.111 = 11.1%.

- There are no repeated operations, so all of the part moves between workstations are accounted for by the three measures in (a), (b), and (c).

Operation Sequence in a Work Cell

- Example: Four parts (A, B, C, and D) are processed through a sequence of four operations (1, 2, 3, and 4). Not all parts are processed in all operations. Part A, which has weekly quantities of 70 units, is processed through operations 1, 2, and 3 in that order. Part B, which has weekly quantities of 90 units, is processed through operations 2, 4, and 1 in that order. Part C, which has weekly quantities of 65 units, is processed through operations 3, 2, and 4 in that order. Finally, part D, which has weekly quantities of 100 units, is processed through operations 2, 1, and 4 in that order.

(a) Draw the network diagram

(b) prepare the From-To table for this work system

(c) use the Hollier algorithm to determine the most logical in-line sequence of workstations in the work system

(d) compute the percentages of in-sequence, back- flow, and bypassing moves for the sequence

Worker Teams

- A ***worker team*** is a group of employees who work together to achieve common objectives. In the case of a work cell, the common objectives of the team are to (1) meet the production or service schedule, (2) achieve high quality in the goods or services provided by the cell, and (3) make the operation of the cell as efficient as possible.
- **Production Work Teams** are generally limited in size to between five and 15 workers, and the team has a defined level of authority for operating the work for which it is responsible.
- Work teams can be organized and operated in various ways, the differences being in the level of autonomy given to them. At one end of the spectrum are ***work-unit teams*** that have little autonomy and are basically a unit in the traditional hierarchical structure of the organization. They operate with a foreman or manager who supervises the team members.
- At the other extreme are ***self-managed work teams*** that enjoy significant autonomy. They not only perform the work of the unit, they also plan and manage it. Self-managed work teams manifest a high level of worker involvement and empowerment. Team leaders are elected by the membership, and the position is often rotated among the members.

Worker Teams

- ***Project teams*** are organized for the purpose of expeditiously completing a given project. They are commonly associated with construction projects (e.g., buildings, bridges, roads), but other project areas include new product design, research, and software development. Like production work teams, the team membership consists of the workers responsible for doing the work. However, whereas production is continuous and ongoing, projects are completed one at a time and have a predictable life cycle.
- ***Cross-functional teams*** are distinguished by the fact that their members are drawn from different functional departments in the organization. Upper management is responsible for identifying the problem area to be addressed and selecting the appropriate team members who are qualified to solve it.
- The purpose of organizing a cross-functional team is to bring a diversity of knowledge and backgrounds together and to overcome functional boundaries. Examples of cross-functional teams include (1) ***concurrent engineering teams***, which are involved in the development and design of a new product; (2) ***task forces***, which are constituted to deal with an urgent problem or immediate commercial opportunity confronting the organization; and (3) ***crisis management teams***, which are a form of task force intended to cope with a particular crisis or disaster faced by the organization, such as the loss of key personnel (e.g., the unexpected death of the chief executive officer), floods and hurricanes, terrorist attacks, and liability lawsuits.

Worker Teams

- ***Improvement teams*** are organized to improve the operations of a department or process. The focus of the improvement may be on product quality, productivity and process efficiency, job design and ergonomics, safety, or some other aspect of the department. Improvement teams are usually temporary; they are instituted to address a particular problem area (e.g., product quality), and once that problem is solved, the team is disbanded.