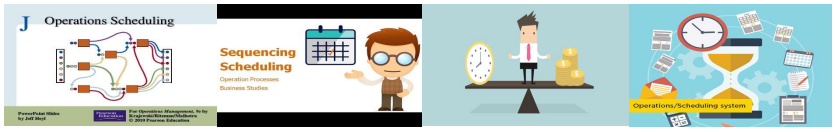
# Lecture 4
# Operations Scheduling

Kazi Wahadul Hasan





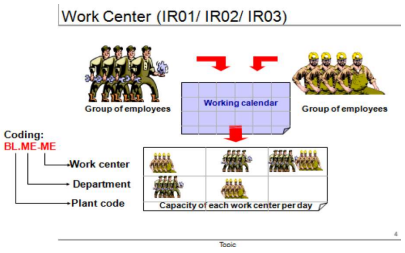

# Introduction

- Scheduling is the allocation of resources over time to perform a collection of tasks
- Resources
  - Workers, Machines, Tools
- Tasks
  - Operations that bring some physical changes to material in order to eventually manufacture products
  - Setups such as walking to reach the workplace, obtaining and returning tools, setting the required jigs and fixtures, positioning and inspecting material, cleaning etc.

# Introduction

## Work Center

- Area in a business in which productive resources are organized and work is completed.
- May be a single machine, a group of machines, or an area where a particular type of work is done.






# Introduction

## Objectives of Work Center Scheduling

- To meet due dates
- To minimize lead time
- To minimize setup time or cost
- To minimize work-in-process inventory
- To maximize machine or labor utilization

# Responsibilities of Production Control Department

- Loading
  - Allocate orders to workers and machines, worker and machines to work centers etc.
- Sequencing
  - Release work orders to shop & issue dispatch lists for individual machines
- Monitoring
  - Maintain progress reports on each job until it is complete



# Loading

- Allocate orders to workers and machines, workers and machines to work centers, etc.
- Perform work on most efficient resources
- Use assignment method of linear programming to determine allocation
- Hungarian method is the method of assigning jobs by a one for one matching to identify the lowest cost solution

# Assignment Method

1. Perform row reductions
   - Subtract minimum value in each row from all other row values
2. Perform column reductions
   - Subtract minimum value in each column from all other column values
3. Line Test
   - Cross out all zeros in matrix using minimum number of horizontal & vertical lines. If number of lines equals number of rows in matrix, optimum solution has been found, stop.
4. Matrix Modification
   - Subtract minimum uncrossed value from all uncrossed values & add it to all cells where two lines intersect. Go to Step 3.



# Assignment Example

Cooker

| Food | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Beans | 10 | 5 | 6 | 10 |
| Peaches | 6 | 2 | 4 | 6 |
| Tomatoes | 7 | 6 | 5 | 6 |
| Corn | 9 | 5 | 4 | 10 |

Row reduction

| | | | |
|---|---|---|---|
| 5 | 0 | 1 | 5 |
| 4 | 0 | 2 | 4 |
| 2 | 1 | 0 | 1 |
| 5 | 1 | 0 | 6 |

Column reduction

| | | | |
|---|---|---|---|
| 3 | 0 | 1 | 4 |
| 2 | 0 | 2 | 3 |
| 0 | 1 | 0 | 0 |
| 3 | 1 | 0 | 5 |

Line Test

| | | | |
|---|---|---|---|
| 3 | 0 | 1 | 4 |
| 2 | 0 | 2 | 3 |
| ~~0~~ | ~~1~~ | ~~0~~ | ~~0~~ |
| 3 | 1 | 0 | 5 |

Number lines <> number of rows so modify matrix

# Assignment Example

Modify matrix

| | | | |
|---|---|---|---|
| 1 | 0 | 1 | 2 |
| 0 | 0 | 2 | 1 |
| 0 | 3 | 2 | 0 |
| 1 | 1 | 0 | 3 |

Line Test

| | | | |
|---|---|---|---|
| 1 | 0 | 1 | 2 |
| 0 | 0 | 2 | 1 |
| 0 | 3 | 2 | 0 |
| 1 | 1 | 0 | 3 |

# lines = # rows
so at optimal solutio

Cooker

| Food | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Beans | 1 | [0] | 1 | 2 |
| Peaches | [0] | 0 | 2 | 1 |
| Tom | 0 | 3 | 2 | [0] |
| Corn | 1 | 1 | [0] | 3 |

Cooker

| Food | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Beans | 10 | [5] | 6 | 10 |
| Peaches | [6] | 2 | 4 | 6 |
| Tomatoes | 7 | 6 | 5 | [6] |
| Corn | 9 | 5 | [4] | 10 |

Orders completed within 6 hours

Total number of hours = 21



# Practice Problem

Refer to the matrix which shows Jobs 1,2,3 and 4 with Work center A, B, C and D.

| Jobs | A | B | C | D |
|---|---|---|---|---|
| **1** | 8 | 6 | 2 | 4 |
| **2** | 6 | 7 | 11 | 10 |
| **3** | 3 | 5 | 7 | 6 |
| **4** | 5 | 10 | 12 | 9 |

Apply the Hungarian Method to make appropriate assignments.

# Sequencing

- Prioritize jobs assigned to a resource
- If no order specified use first-come first-served (FCFS)
- Many other sequencing rules exist
- Each attempts to achieve to an objective



# Priority Rules for Sequencing

**Sequencing n jobs on one machine**

- FCFS - first-come, first-served
- SOT - shortest operating time
- DDATE - earliest due date
- STR - slack time remaining
  - (due date - today's date) - (remaining processing time)
- LCFS - last come, first served
- CR- critical ratio
- QR- queue ratio
- Random order

# Schedule Performance Measures

- Meeting due dates of customers or downstream operations.
- Minimizing the flow time (the time a job spends in the process).
- Minimizing work-in-process inventory.
- Minimizing idle time of machines or workers.



# Job Sequencing Example

***First-Come First-Served***

| Jobs (in order of arrival) | Processing Time (days) | Due Date (days hence) |
|---|---|---|
| A | 4 | 5 |
| B | 7 | 10 |
| C | 3 | 6 |
| D | 1 | 4 |

Orders submitted at beginning of week

*n-jobs on one machine*

FCFS Schedule

| Jobs (in order of arrival) | Processing Time (days) | Due Date (days hence) | Flow Time (days) |
|---|---|---|---|
| A | 4 | 5 | 4 |
| B | 7 | 10 | 11 |
| C | 3 | 6 | 14 |
| D | 1 | 4 | 15 |

# Job Sequencing Example

***Shortest Operating Time***

| Jobs (in order of arrival) | Processing Time (days) | Due Date (days hence) |
|---|---|---|
| A | 4 | 5 |
| B | 7 | 10 |
| C | 3 | 6 |
| D | 1 | 4 |

Orders submitted at beginning of week

*n-jobs on one machine*

Shortest Operating Time Schedule

| Jobs (in order of OT) | Processing Time (days) | Due Date (days hence) | Flow Time (days) |
|---|---|---|---|
| D | 1 | 4 | 1 |
| C | 3 | 6 | 4 |
| A | 4 | 5 | 8 |
| B | 7 | 10 | 15 |



# Job Sequencing Example

***Last-Come First-Served***

| Jobs (in order of arrival) | Processing Time (days) | Due Date (days hence) |
|---|---|---|
| A | 4 | 5 |
| B | 7 | 10 |
| C | 3 | 6 |
| D | 1 | 4 |

Orders submitted at beginning of week

*n-jobs on one machine*

*Last-Come First-Served*

| Jobs (in order of arrival from last) | Processing Time (days) | Due Date (days hence) | Flow Time (days) |
|---|---|---|---|
| D | 1 | 4 | 1 |
| C | 3 | 6 | 4 |
| B | 7 | 10 | 11 |
| A | 4 | 5 | 15 |

# Job Sequencing Example

***Earliest Due Date First***

| Jobs (in order of arrival) | Processing Time (days) | Due Date (days hence) |
|---|---|---|
| A | 4 | 5 |
| B | 7 | 10 |
| C | 3 | 6 |
| D | 1 | 4 |

Orders submitted at beginning of week

*n-jobs on one machine*

*Earliest Due Date First*

| Jobs (in order of due date) | Processing Time (days) | Due Date (days hence) | Flow Time (days) |
|---|---|---|---|
| D | 1 | 4 | 1 |
| A | 4 | 5 | 5 |
| C | 3 | 6 | 8 |
| B | 7 | 10 | 15 |



# Job Sequencing Example

***Slack Time Remaining(STR)***

| Jobs (in order of arrival) | Processing Time (days) | Due Date (days hence) |
|---|---|---|
| A | 4 | 5 |
| B | 7 | 10 |
| C | 3 | 6 |
| D | 1 | 4 |

Orders submitted at beginning of week

*n-jobs on one machine*

*STR Method*

| Jobs (in basis of STR) | Processing Time (days) | Due Date (days hence) | Flow Time (days) |
|---|---|---|---|
| A | 4 | 5 | 4 |
| B | 7 | 10 | 11 |
| C | 3 | 6 | 14 |
| D | 1 | 4 | 15 |

# Job Sequencing Example

***Random Order***

| Jobs (in order of arrival) | Processing Time (days) | Due Date (days hence) |
|---|---|---|
| A | 4 | 5 |
| B | 7 | 10 |
| C | 3 | 6 |
| D | 1 | 4 |

Orders submitted at beginning of week

*n-jobs on one machine*

| Jobs (in random order) | Processing Time (days) | Due Date (days hence) | Flow Time (days) |
|---|---|---|---|
| B | 7 | 10 | |
| C | 3 | 6 | |
| D | 1 | 4 | |
| A | 4 | 5 | |



# Comparison of Priority Rules

| Criteria | FCFS | SOT | LCFS | DDATE | STR | RND |
|---|---|---|---|---|---|---|
| Total Flow Time(Day) | 44 | 28 | 31 | 29 | 44 | |
| Average Flow Time | 11 | 7 | 7.75 | 7.25 | 11 | |
| Average Lateness | 5 | 2 | 2.75 | 1.75 | 5 | |

# Practice Problem

| Job (in order of arrival) | Processing time (Days) | Due date (days hence) |
|---|---|---|
| A | 3 | 5 |
| B | 4 | 6 |
| C | 2 | 7 |
| D | 6 | 9 |
| E | 1 | 2 |



# Sequencing Jobs in Two Machines

## Johnson's Rule:

1. List time required to process each job at each machine. Set up a one-dimensional matrix to represent desired sequence with no. of slots equal to no. of jobs.
2. Select smallest processing time at either machine. If that time is on machine 1, put the job as near to beginning of sequence as possible.
3. If smallest time occurs on machine 2, put the job as near to the end of the sequence as possible.
4. Remove job from list.
5. Repeat steps 2-4 until all slots in matrix are filled & all jobs are sequenced.

# Johnson's Rule Example

| Job | Machine Center 1 | Machine Center 2 |
|---|---|---|
| A | 6 | 8 |
| B | 11 | 6 |
| C | 7 | 3 |
| D | 9 | 7 |
| E | 5 | 10 |



# Johnson's Rule Example

| Job | Machine Center 1 | Machine Center 2 |
|---|---|---|
| A | 6 | 8 |
| B | 11 | 6 |
| D | 9 | 7 |
| E | 5 | 10 |

C

# Johnson's Rule Example

| Job | Machine Center 1 | Machine Center 2 |
|---|---|---|
| A | 6 | 8 |
| B | 11 | 6 |
| D | 9 | 7 |

| | | | | |
|---|---|---|---|---|
| E | | | | C |



# Johnson's Rule Example

| Job | Machine Center 1 | Machine Center 2 |
|---|---|---|
| B | 11 | 6 |
| D | 9 | 7 |

| | | | | |
|---|---|---|---|---|
| E | A | | | C |

# Johnson's Rule Example

| Job | Machine Center 1 | Machine Center 2 |
|---|---|---|

| E | A | D | B | C |
|---|---|---|---|---|



# Johnson's Rule Example

| Job | Machine Center 1 | Machine Center 2 |
|---|---|---|
| E | 5 | 10 |
| A | 6 | 8 |
| D | 9 | 7 |
| B | 11 | 6 |
| C | 7 | 3 |

| E | A | D | B | C |
|---|---|---|---|---|

# Johnson's Rule Example

## Total Flow time and Idle time calculation

| Job Seq. | M1 (In) | M1 (Out) | M2 (In) | M2 (Out) |
|---|---|---|---|---|
| **E** | 0 | 5 | 5 | 15 |
| **A** | 5 | 11 | 15 | 23 |
| **D** | 11 | 20 | 23 | 30 |
| **B** | 20 | 31 | 31 | 37 |
| **C** | 31 | 38 | 38 | 41 |

- Total flow time (Minimized) = 41 days
- Machine 1 Idle time = 41-38 = 3 days
- Machine 2 Idle time = 5+1+1=7 days



# Shop-Floor Control

## Major Functions

1. Assigning priority of each shop order
2. Maintaining work-in-process quantity information
3. Conveying shop-order status information to the office

# Shop-Floor Control

## Major Functions

4. Providing actual output data for capacity control purposes
5. Providing quantity by location by shop order for WIP inventory and accounting purposes
6. Providing measurement of efficiency, utilization, and productivity of manpower and machines



# Practice Problem

**Job times (hours)**

| Job | Work center A | Work center B |
|---|---|---|
| A | 3.2 | 4.2 |
| B | 4.7 | 1.5 |
| C | 2.2 | 5.0 |
| D | 5.8 | 4.0 |
| E | 3.1 | 2.8 |

Each of five jobs needs to go through work center A and B. Find the optimum sequence of jobs using **Johnson's** rule.