Short-Term Scheduling

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Source: Pearson Education Ltd. 2020. Chapter 15.

Outline

- Global Company Profile: *Alaska Airlines*
- The Importance of Short-Term Scheduling
- Scheduling Issues
- Scheduling Process-Focused Facilities
- Loading Jobs
- Sequencing Jobs
- Finite Capacity Scheduling (FCS)
- Scheduling Services (*reading*)

Scheduling Flights

- Alaska Airlines scheduling a major contributor to Seattle-Tacoma International Airport top ranking
- Schedule changes create a ripple effect for passengers and airports
- Latest technology to reduce cancellations and delays saves $18 million/year
- Mathematical scheduling models to develop alternate schedules and routes

Learning Objectives

When you complete this chapter you should be able to:

9.1 ***Explain*** the relationship among short-term scheduling, capacity planning, aggregate planning, and a master schedule

9.2 ***Draw*** Gantt loading and scheduling charts

9.3 ***Apply*** the assignment method for loading jobs

Learning Objectives

When you complete this chapter you should be able to:

9.4 ***Name*** and describe each of the priority sequencing rules

9.5 ***Use*** Johnson's rule

9.6 ***Define*** finite capacity scheduling

9.7 ***Use*** the cyclical scheduling technique

Short-Term Scheduling

The objective of scheduling is to allocate and prioritize demand (generated by either forecasts or customer orders) to available facilities

Importance of Short-Term Scheduling

- Effective and efficient scheduling can be a competitive advantage
  - Faster movement of goods through a facility means better use of assets and lower costs
  - Additional capacity resulting from faster throughput improves customer service through faster delivery
  - Good schedules result in more dependable deliveries

Scheduling Decisions

TABLE 9.1	Scheduling Decisions
ORGANIZATION	**MANAGERS SCHEDULE THE FOLLOWING**
Alaska Airlines	Maintenance of aircraft Departure timetables Flight crews, catering, gate, ticketing personnel
Arnold Palmer Hospital	Operating room use Patient admissions Nursing, security, maintenance staffs Outpatient treatments
University of Alabama	Classrooms and audiovisual equipment Student and instructor schedules Graduate and undergraduate courses
Amway Center	Ushers, ticket takers, food servers, security personnel Delivery of fresh foods and meal preparation Orlando Magic games, concerts, arena football
Lockheed Martin Factory	Production of goods Purchases of materials Workers

Scheduling Issues

- Scheduling deals with the timing of operations
- The task is the allocation and prioritization of demand
- Significant factors are
  1) Forward or backward scheduling
  2) Finite or infinite loading
  3) The criteria for sequencing jobs

Scheduling Flow

Figure 15.1

Capacity Planning
(Long term; years)
Changes in Facilities
Changes in Equipment
See Chapter 7 and Supplement 7

Capacity Plan for New Facilities
Adjust capacity to the demand suggested by strategic plan

Myrleen Pearson/Alamy

Aggregate Planning
(Intermediate term; quarterly or monthly)
Facility utilization
Personnel changes
Subcontracting
See Chapter 13

Aggregate Production Plan for All Bikes
(Determine personnel or subcontracting necessary to match aggregate demand to existing facilities/capacity)

Month	1	2
Bike Production	800	850

Master Schedule
(Intermediate term; weekly)
Material requirements planning
Disaggregate the aggregate plan
See Chapters 13 and 14

Master Production Schedule for Bike Models
(Determine weekly capacity schedule)

	Month 1				Month 2			
Week	1	2	3	4	5	6	7	8
Model 22		200		200		200		200
Model 24	100		100		150		100	
Model 26	100		100		100		100	

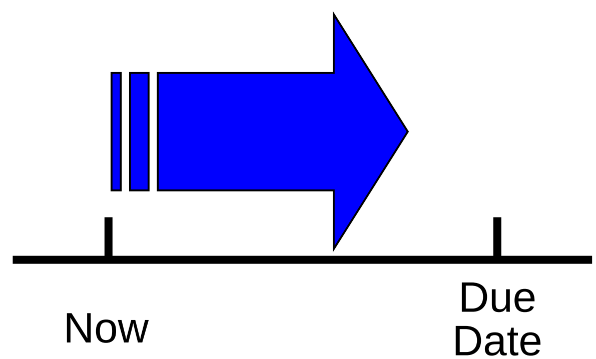
Short Term Scheduling
(Short term; days, hours, minutes)
Work center loading
Job sequencing/dispatching
See this chapter

Work Assigned to Specific Personnel and Work Centers
Make finite capacity schedule by matching specific tasks to specific people and machines

Assemble Model 22 in work center 6

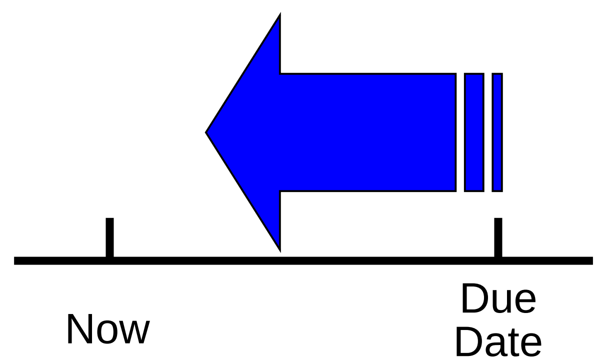
Forward and Backward Scheduling

- *Forward scheduling* starts *as soon as the requirements are known*
- Produces a feasible schedule though it may not meet due dates
- Frequently results in buildup of work-in-process inventory



Forward and Backward Scheduling

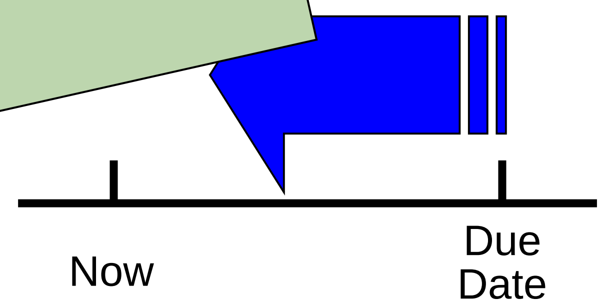
- *Backward scheduling* begins with the due date and schedules the *final* operation first
- Schedule is produced by working backwards though the processes
- Resources may not be available to accomplish the schedule



Forward and Backward Scheduling

- *Backward scheduling* begi… with the due date and sched… …peration first
- S… …ng … …s
- F… b… ac… sc…dule

Often these approaches are combined to develop a trade-off between capacity constraints and customer expectations



Finite and Infinite Loading

- Assigning jobs to work stations
- **Finite loading** assigns work up to the capacity of the work station
  - All work gets done
  - Due dates may be pushed out
- **Infinite loading** does not consider capacity
  - All due dates are met
  - Capacities may have to be adjusted

Scheduling Criteria

1. *Minimize completion time*
2. *Maximize utilization of facilities*
3. *Minimize work-in-process (WIP) inventory*
4. *Minimize customer waiting time*

Different Processes/ Different Approaches

TABLE 9.2	Different Processes Suggest Different Approaches to Scheduling
Process-focused facilities (job shops) ► Scheduling to customer orders where changes in both volume and variety of jobs/clients/patients are frequent ► Schedules are often due-date focused, with loading refined by finite loading techniques ► *Examples*: foundries, machine shops, cabinet shops, print shops, many restaurants, and the fashion industry	
Repetitive facilities (assembly lines) ► Schedule module production and product assembly based on frequent forecasts ► Finite loading with a focus on generating a forward-looking schedule ► JIT techniques are used to schedule components that feed the assembly line ► *Examples*: assembly lines for washing machines at Whirlpool and automobiles at Ford	

Different Processes/ Different Approaches

TABLE 9.2	Different Processes Suggest Different Approaches to Scheduling
Product-focused facilities (continuous) ▸ Schedule high-volume finished products of limited variety to meet a reasonably stable demand within existing fixed capacity ▸ Finite loading with a focus on generating a forward-looking schedule that can meet known setup and run times for the limited range of products ▸ *Examples*: huge paper machines at International Paper, beer in a brewery at Anheuser-Busch, and potato chips at Frito-Lay	

Scheduling Process-Focused Facilities

- *Intermittent* or *job-shop* facilities
- High-variety, low volume
- Production items differ considerably
- Schedule incoming orders without violating capacity constraints
- Scheduling can be complex

Loading Jobs

- Assign jobs so that costs, idle time, or completion time are minimized
- Two forms of loading
  - Capacity oriented
  - Assigning specific jobs to work centers

Input-Output Control

- Identifies overloading and underloading conditions
- Prompts managerial action to resolve scheduling problems
- Can be maintained using **ConWIP** cards that control the scheduling of batches

Input-Output Control Example

Figure 9.2

Welding Work Center (in standard hours)						
Week Ending	6/6	6/13	6/20	6/27	7/4	7/11
Planned Input	280	280	280	280	280	
Actual Input	270	250	280	285	280	
Cumulative Deviation	–10	–40	–40	–35		
Planned Output	320	320	320	320		
Actual Output	270	270	270	270		
Cumulative Deviation	–50	–100	–150	–200		
Cumulative Change in Backlog	0	–20	–10	+5		

Input-Output Control Example

Figure 9.2

Welding Work Center (in standard hours)						
Week Ending	6/6	6/13	6/20	6/27	7/4	7/11
Planned Input	280	280	280	280	280	
Actual Input	270	250	280	285	280	
Cumulative Deviation	–10	–40	–40	–35		
Planned Output	320	320	320	320		
Actual Output	270	270	270	270		
Cumulative Deviation	–50	–100	–150	–200		
Cumulative Change in Backlog	0	–20	–10	+5		

Explanation:
270 input,
270 output implies
0 change

Explanation:
250 input,
270 output implies
–20 change

Input-Output Control Example

Options available to operations personnel include:

- Correcting performances
- Increasing capacity
- Increasing or reducing input to the work center

Gantt Charts

- Load chart shows the loading and idle times of departments, machines, or facilities
- Displays relative workloads over time
- Schedule chart monitors jobs in process
- All Gantt charts need to be updated frequently to account for changes

Gantt Load Chart Example

Figure 9.3

Work Center / Day	Monday	Tuesday	Wednesday	Thursday	Friday
Metalworks	Job 349		← Job 350 →		
Mechanical		← Job 349 →		Job 408	
Electronics	Job 408			Job 349	
Painting	← Job 295 →		Job 408		Job 349

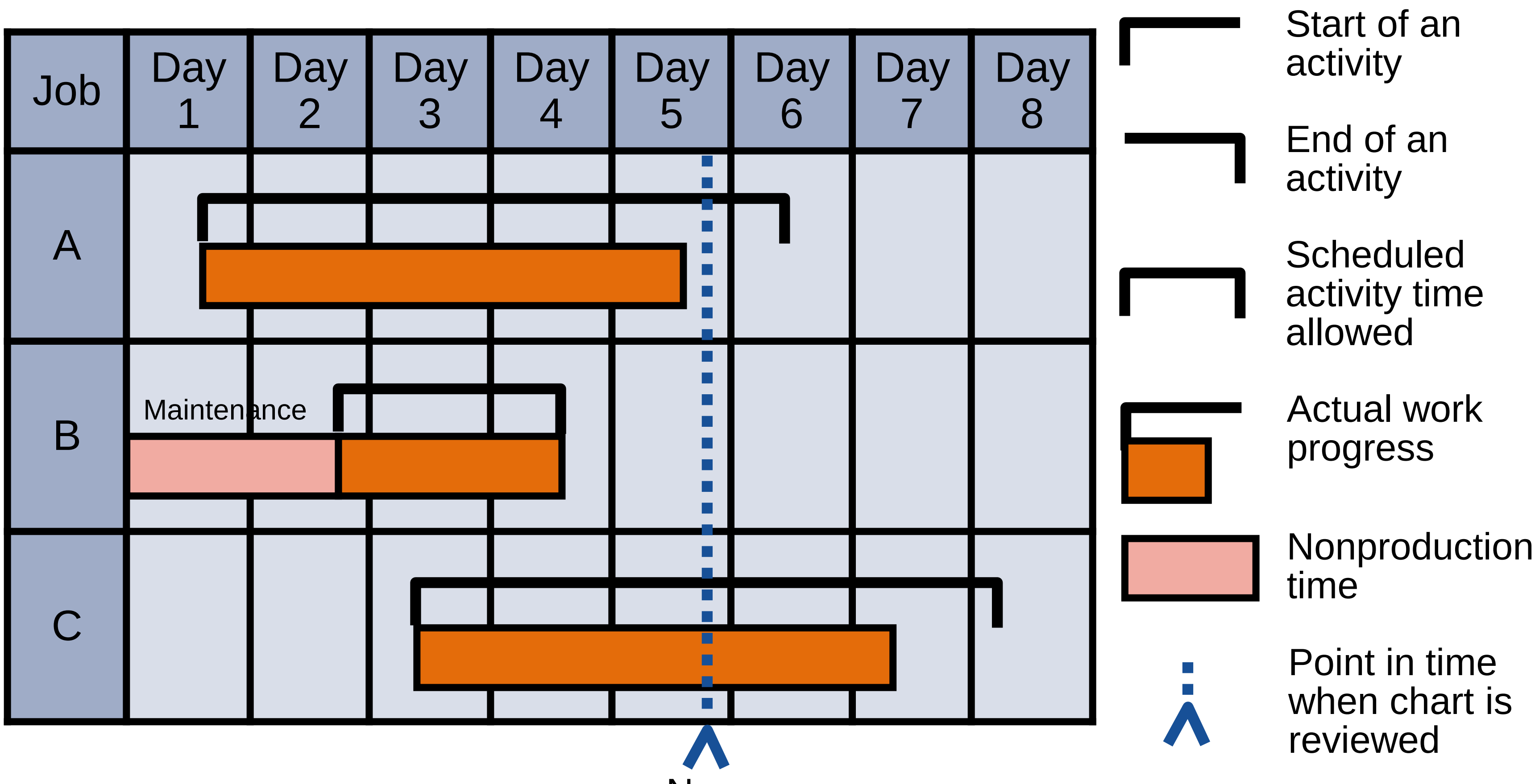
Processing

Unscheduled

Center not available

Gantt Schedule Chart Example

Figure 9.4



Sequencing Jobs

- Specifies the order in which jobs should be performed at work centers
- Priority rules are used to dispatch or sequence jobs
  - FCFS: **First come, first served**
  - SPT: **Shortest processing time**
  - EDD: **Earliest due date**
  - LPT: **Longest processing time**

Performance Criteria

- **Flow time** – the time between the release of a job to a work center until the job is finished

$$\text{Average completion time} = \frac{\text{Total flow time}}{\text{Number of jobs}}$$

$$\text{Utilization metric} = \frac{\text{Total job work (processing) time}}{\text{Total flow time}}$$

$$\text{Average number of jobs in the system} = \frac{\text{Total flow time}}{\text{Total job work (processing) time}}$$

$$\text{Average job lateness} = \frac{\text{Total late days}}{\text{Number of jobs}}$$

Performance Criteria

- **Flow time** – the time between the release of a job to a work center until the job is finished

Job lateness = Max{0, yesterday + flow time – due date}

$$\text{Average number of jobs in the system} = \frac{\text{Total flow time}}{\text{Total job work (processing) time}}$$

$$\text{Average job lateness} = \frac{\text{Total late days}}{\text{Number of jobs}}$$

Sequencing Example

Apply the four popular sequencing rules to these five jobs

Job	Job Work (Processing) Time (Days)	Job Due Date (Days)
A	6	8
B	2	6
C	8	18
D	3	15
E	9	23

Sequencing Example

FCFS: Sequence A-B-C-D-E

Job Sequence	Job Work (Processing) Time	Flow Time	Job Due Date	Job Lateness
A	6	6	8	0
B	2	8	6	2
C	8	16	18	0
D	3	19	15	4
E	9	28	23	5
	28	77		11

Sequencing Example

FCFS: Sequence A-B-C-D-E

$$\text{Average completion time} = \frac{\text{Total flow time}}{\text{Number of jobs}} = 77/5 = 15.4 \text{ days}$$

$$\text{Utilization metric} = \frac{\text{Total job work (processing) time}}{\text{Total flow time}} = 28/77 = 36.4\%$$

$$\text{Average number of jobs in the system} = \frac{\text{Total flow time}}{\text{Total job work time}} = 77/28 = 2.75 \text{ jobs}$$

$$\text{Average job lateness} = \frac{\text{Total late days}}{\text{Number of jobs}} = 11/5 = 2.2 \text{ days}$$

Sequencing Example

SPT: Sequence B-D-A-C-E

Job Sequence	Job Work (Processing) Time	Flow Time	Job Due Date	Job Lateness
B	2	2	6	0
D	3	5	15	0
A	6	11	8	3
C	8	19	18	1
E	9	28	23	5
	28	65		9

Sequencing Example

SPT: Sequence B-D-A-C-E

$$\text{Average completion time} = \frac{\text{Total flow time}}{\text{Number of jobs}} = 65/5 = 13 \text{ days}$$

$$\text{Utilization metric} = \frac{\text{Total job work time}}{\text{Total flow time}} = 28/65 = 43.1\%$$

$$\text{Average number of jobs in the system} = \frac{\text{Total flow time}}{\text{Total job work time}} = 65/28 = 2.32 \text{ jobs}$$

$$\text{Average job lateness} = \frac{\text{Total late days}}{\text{Number of jobs}} = 9/5 = 1.8 \text{ days}$$

Sequencing Example

EDD: Sequence B-A-D-C-E

Job Sequence	Job Work (Processing) Time	Flow Time	Job Due Date	Job Lateness
B	2	2	6	0
A	6	8	8	0
D	3	11	15	0
C	8	19	18	1
E	9	28	23	5
	28	68		6

Sequencing Example

EDD: Sequence B-A-D-C-E

$$\text{Average completion time} = \frac{\text{Total flow time}}{\text{Number of jobs}} = 68/5 = 13.6 \text{ days}$$

$$\text{Utilization metric} = \frac{\text{Total job work time}}{\text{Total flow time}} = 28/68 = 41.2\%$$

$$\text{Average number of jobs in the system} = \frac{\text{Total flow time}}{\text{Total job work time}} = 68/28 = 2.43 \text{ jobs}$$

$$\text{Average job lateness} = \frac{\text{Total late days}}{\text{Number of jobs}} = 6/5 = 1.2 \text{ days}$$

Sequencing Example

LPT: Sequence E-C-A-D-B

Job Sequence	Job Work (Processing) Time	Flow Time	Job Due Date	Job Lateness
E	9	9	23	0
C	8	17	18	0
A	6	23	8	15
D	3	26	15	11
B	2	28	6	22
	28	103		48

Sequencing Example

LPT: Sequence E-C-A-D-B

$$\text{Average completion time} = \frac{\text{Total flow time}}{\text{Number of jobs}} = 103/5 = 20.6 \text{ days}$$

$$\text{Utilization metric} = \frac{\text{Total job work time}}{\text{Total flow time}} = 28/103 = 27.2\%$$

$$\text{Average number of jobs in the system} = \frac{\text{Total flow time}}{\text{Total job work time}} = 103/28 = 3.68 \text{ jobs}$$

$$\text{Average job lateness} = \frac{\text{Total late days}}{\text{Number of jobs}} = 48/5 = 9.6 \text{ days}$$

Sequencing Example

Summary of Rules

Rule	Average Completion Time (Days)	Utilization Metric (%)	Average Number of Jobs in System	Average Lateness (Days)
FCFS	15.4	36.4	2.75	2.2
SPT	13.0	43.1	2.32	1.8
EDD	13.6	41.2	2.43	1.2
LPT	20.6	27.2	3.68	9.6

Comparison of Sequencing Rules

- No one sequencing rule excels on all criteria
  1. **SPT** does well on minimizing flow time and number of jobs in the system
     - But SPT moves long jobs to the end which may result in dissatisfied customers
  2. **FCFS** does not do especially well (or poorly) on any criteria but is perceived as fair by customers
  3. **EDD** minimizes maximum lateness

Sequencing N Jobs on Two Machines: Johnson's Rule

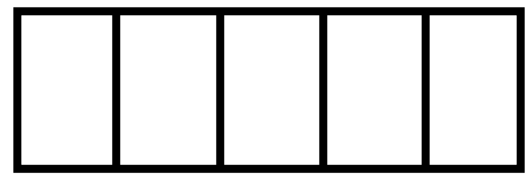
- Works with two or more jobs that pass through the same two machines or work centers
- Minimizes total production time and idle time
- An N/2 problem, N number of jobs through 2 workstations

Johnson's Rule

1. List all jobs and times for each work center
2. Select the job with the shortest activity time. If that time is in the first work center, schedule the job first. If it is in the second work center, schedule the job last. Break ties arbitrarily.
3. Once a job is scheduled, it is eliminated from the list
4. Repeat steps 2 and 3 working toward the center of the sequence

Johnson's Rule Example

JOB	WORK CENTER 1 (DRILL PRESS)	WORK CENTER 2 (LATHE)
A	5	2
B	3	6
C	8	4
D	10	7
E	7	12



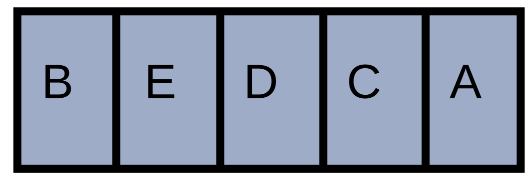
Johnson's Rule Example

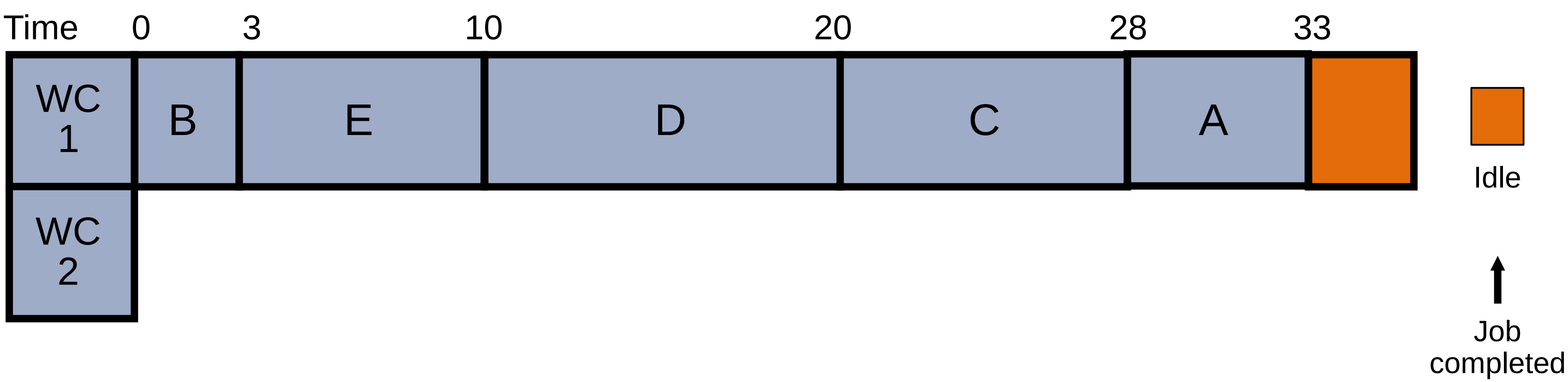
JOB	WORK CENTER 1 (DRILL PRESS)	WORK CENTER 2 (LATHE)
~~A~~	~~5~~	~~2~~
~~B~~	~~3~~	~~6~~
~~C~~	~~8~~	~~4~~
D	10	7
~~E~~	~~7~~	~~12~~

B	E	D	C	A

Johnson's Rule Example

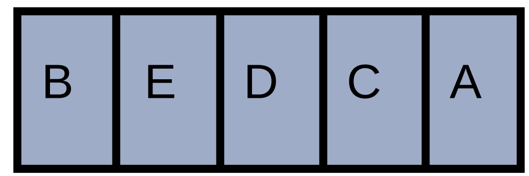
JOB	WORK CENTER 1 (DRILL PRESS)	WORK CENTER 2 (LATHE)
A	5	2
B	3	6
C	8	4
D	10	7
E	7	12

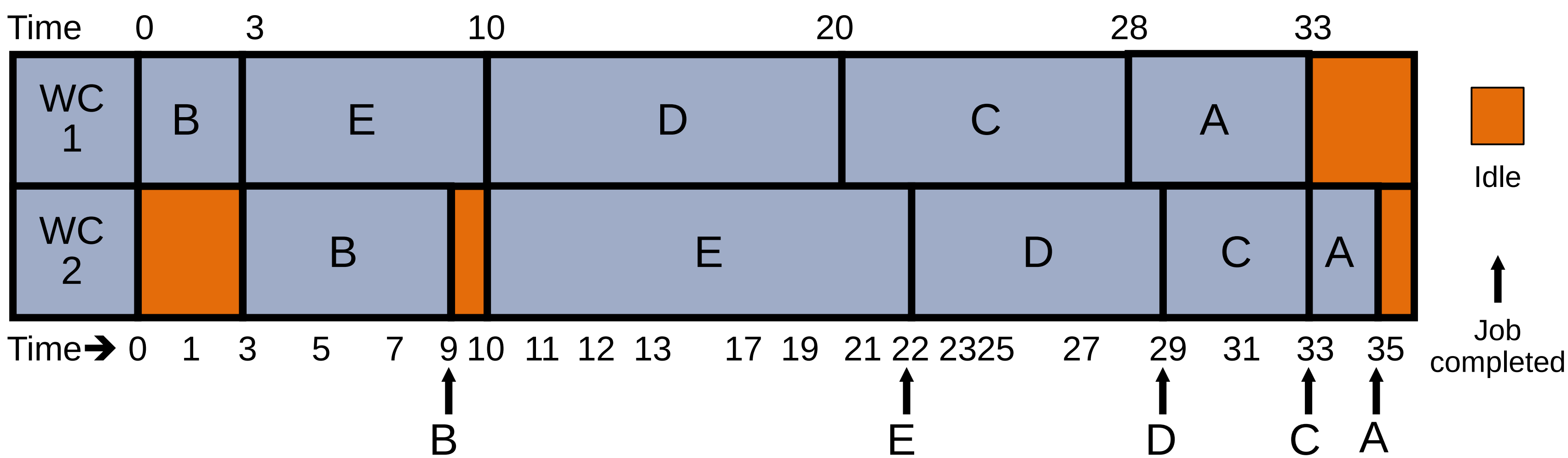




Johnson's Rule Example

JOB	WORK CENTER 1 (DRILL PRESS)	WORK CENTER 2 (LATHE)
A	5	2
B	3	6
C	8	4
D	10	7
E	7	12





Limitations of Rule-Based Dispatching Systems

1. Scheduling is dynamic and rules need to be revised to adjust to changes
2. Rules do not look upstream or downstream
3. Rules do not look beyond due dates