Scheduling

Module 12
July 23, 2014

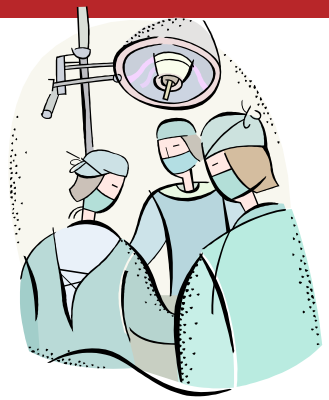
Outline

- Scheduling
  - ✓ What is it?
  - ✓ Objectives
  - ✓ Sequencing rules
    - Single resource
    - Two resources
  - ✓ Employee scheduling

Scheduling

- ✓ Deals with the timing of operations
- ✓ Specifies when resources are needed to produce a product or provide a service
- ✓ Helps us decide what order to perform jobs
- ✓ **All organizations perform scheduling to some extent…**

In service organizations, managers schedule…



Operating room use

Nursing staff

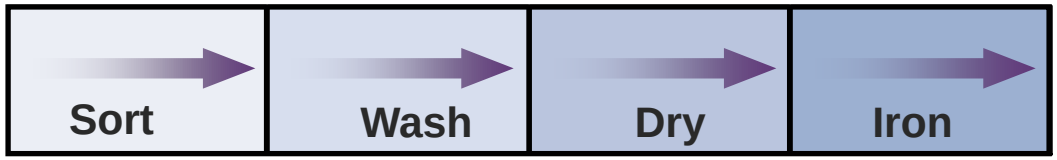
Classroom use

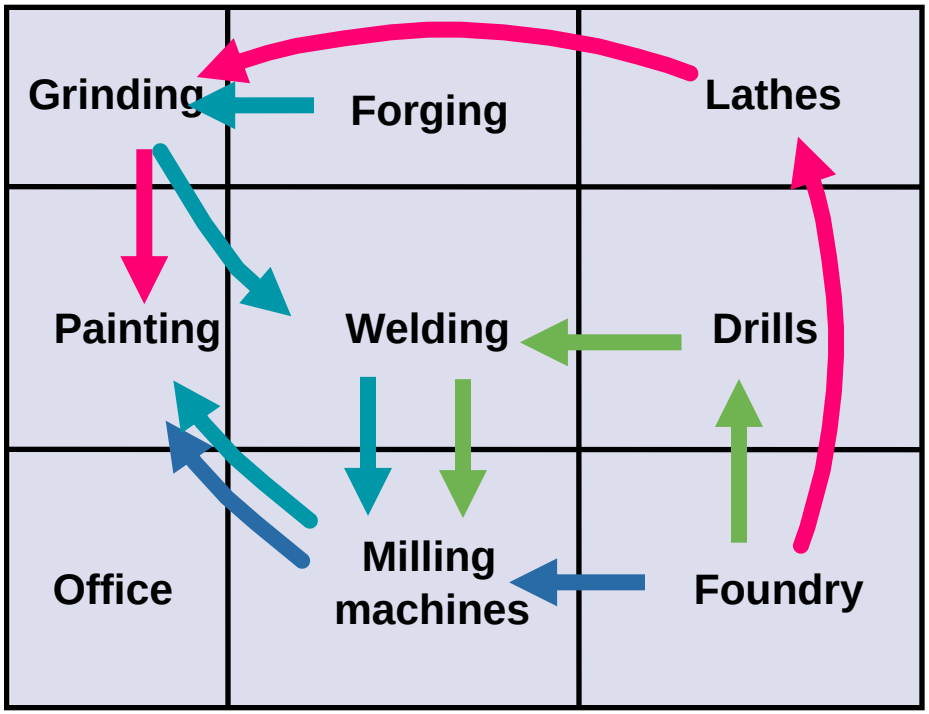
Instructor schedules

In manufacturing organizations, managers schedule…

Workers
Purchases of materials
Production of goods
…

Easier to schedule here





Harder to schedule here

Sequencing Rules

- ✓ ***Determine the order jobs are processed by a resource***
  - ✓***Which job should a machine do first, next, etc.?***
  - ✓***Which surgeries should go to the operating room first?***
  - ✓***What order should you work on your course projects in?***
- ✓ ***Many sequencing rules exist***
- ✓ ***Each attempts to achieve to an objective***

Objectives in Scheduling

- ✓ *Meet customer due dates*
- ✓ *Minimize job lateness*
- ✓ *Minimize response time*
- ✓ *Minimize completion time*
- ✓ *Minimize time in the system*
- ✓ *Minimize overtime*
- ✓ *Maximize machine or labor utilization*
- ✓ *Minimize idle time*
- ✓ *Minimize work-in-process inventory*

Types of Sequencing Rules

- Sequencing jobs at a single resource
- Sequencing jobs across multiple resources

Sequencing Rules (Single Resource)

- Local - consider only current work center operation
  - ✓ First Come First Served
  - ✓ Last Come First Served
  - ✓ Shortest Processing Time
  - ✓ Longest Processing Time
  - ✓ Earliest Due Date
- Global - consider current and all subsequent work center operations needed to complete job
  - ✓ Slack Per Remaining Operation
  - ✓ Critical Ratio

Sequencing Rules (Single Resource)

- Local
  - ✓ First Come First Served
  - ✓ Last Come First Served
  - ✓ Shortest Processing Time
  - ✓ Longest Processing Time
  - ✓ Earliest Due Date
- Global
  - ✓ Slack Per Remaining Operation
  - ✓ Critical Ratio

Sequencing Example

This semester you took 5 classes

Each has a major project due at some point in the semester

Projects are assigned during the first week of the semester

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

**Next,
You are given
an Accounting
assignment…**

Sequencing Example

This semester you took 5 classes
Each has a major project due at some point in the semester

Projects are assigned during the first week of the semester

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

What order do you work on the projects?

First Come First Served (FCFS)

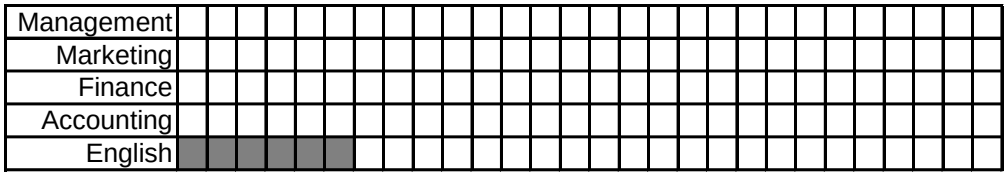
Jobs are processed in order of arrival

Which comes first?

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

What order do you work on the projects?

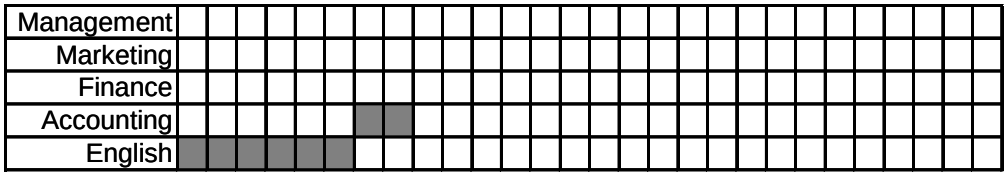
First Come First Served (FCFS)



Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**

Management ***Marketing*** ***Finance*** ***Accounting*** ***English***

First Come First Served (FCFS)

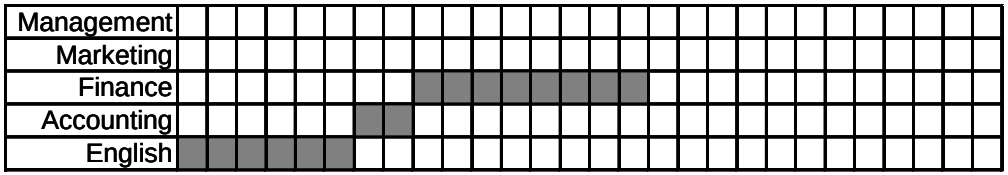


Processing time: 9 3 8 2 6

Time until due: 23 15 18 6 8

Management *Marketing* *Finance* *Accounting*

First Come First Served (FCFS)



Processing time: 9 3 8 2 6

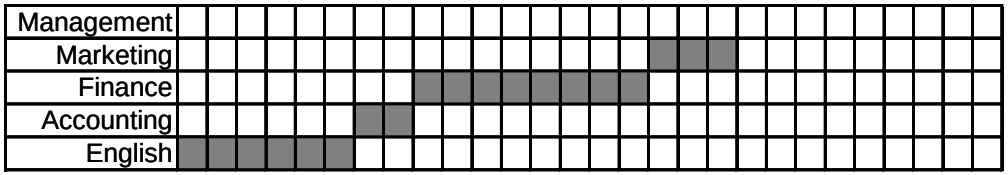
Time until due: 23 15 18 6 8

Management

Marketing

Finance

First Come First Served (FCFS)



Processing time:	9	3	8	2	6
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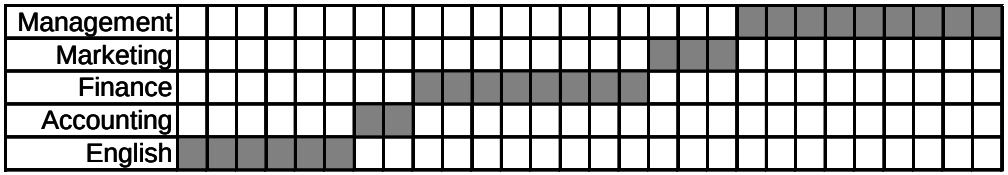
Management

Marketing

First Come First Served (FCFS)

Superimposing due dates…



Processing time:	9	3	8	2	6
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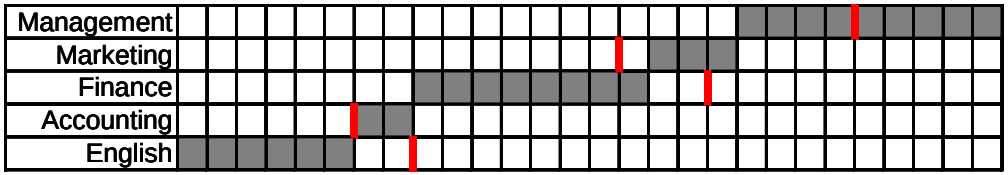
Management *Marketing* *Finance* *Accounting* *English*

First Come First Served (FCFS)

Superimposing due dates…



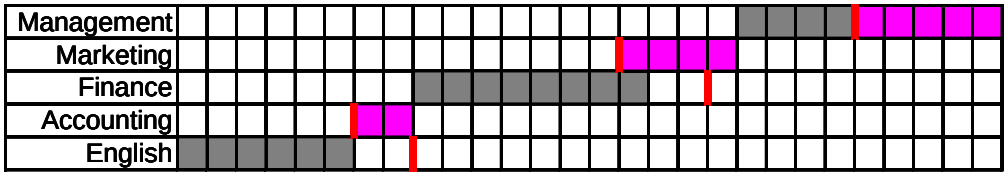
So 3 projects are late!!

How many weeks late?

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

First Come First Served (FCFS)

Superimposing due dates…

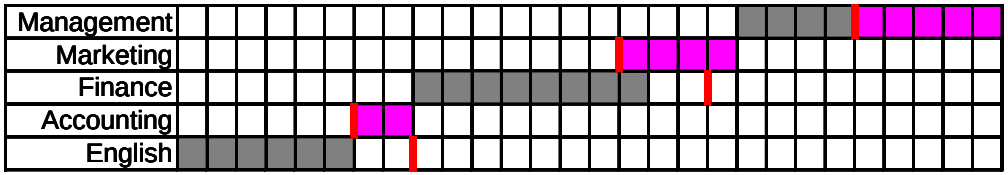


So 3 projects are late!!

How many weeks late?

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

First Come First Served (FCFS)



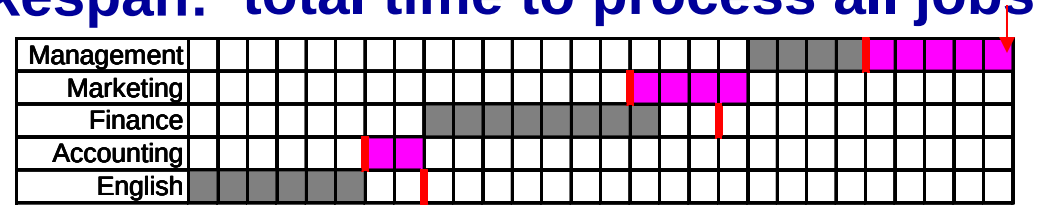
$$\text{Avg. job lateness} = \frac{\text{Total days late}}{\text{Number of jobs}} = \frac{11}{5} = 2.2 \text{ days}$$

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

First Come First Served (FCFS)

Avg job lateness = Total days late / # jobs

Makespan: total time to process all jobs = 28 days



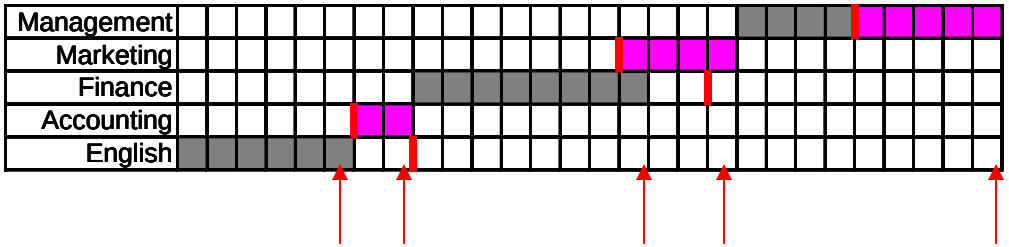
Flow time: Sum of times each job spends waiting, and being processed

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

First Come First Served (FCFS)

Avg job lateness = Total days late / # jobs

Makespan = 28 days



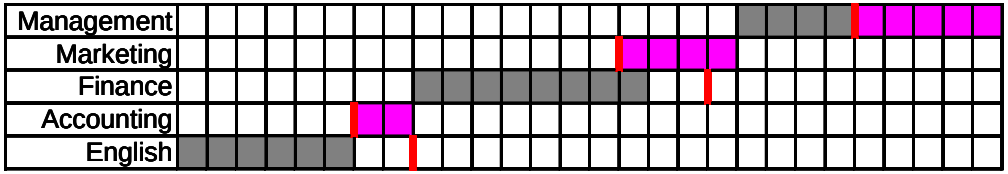
Flow time = 6 + 8 + 16 + 19 + 28 = 77

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

First Come First Served (FCFS)

Avg job lateness = Total days late / # jobs

Makespan = 28 days



Flow time = 77

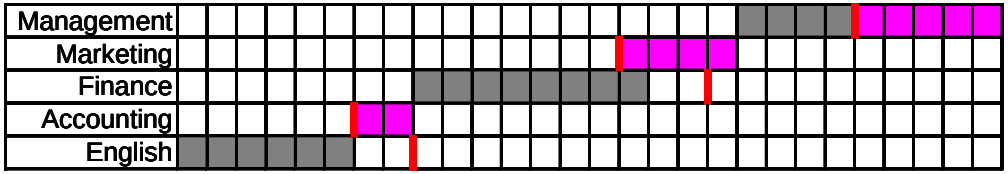
Average flow time = Sum of flow times / # jobs

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

First Come First Served (FCFS)

Avg job lateness = Total days late / # jobs
Avg flowtime = Sum of flowtimes / # jobs

Makespan = 28 days



Flow time = 77

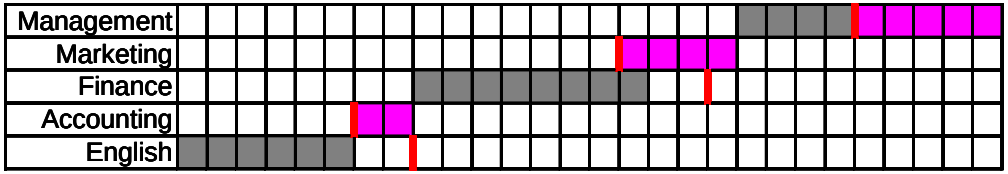
Average flow time = 77 days/5 jobs = 15.4 days/job

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

First Come First Served (FCFS)

Avg job lateness = Total days late / # jobs
Avg flowtime = Sum of flowtimes / # jobs

Makespan = 28 days



Flow time = 77

Average flow time = 15.4 days/job

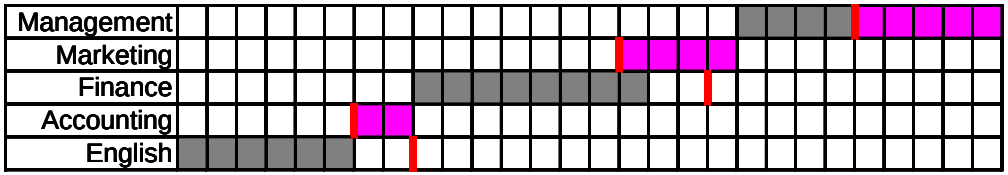
Avg # jobs in system = Sum of flow times / total processing time

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

First Come First Served (FCFS)

Avg job lateness = Total days late / # jobs
Avg flowtime = Sum of flowtimes / # jobs
Avg # jobs = Sum of flowtimes / Total processing time

Makespan = 28 days



Flow time = 77

Average flow time = 15.4 days/job

Avg # jobs in system = 77 days/28 days = 2.75

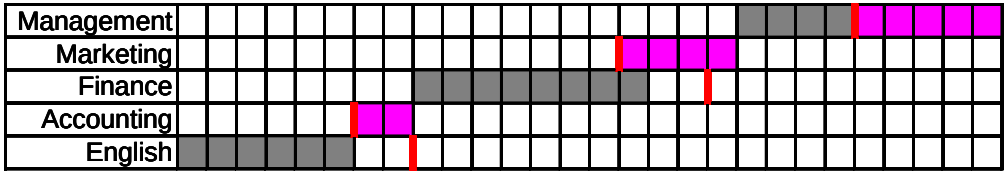
Utilization = Total processing time / sum of flow time

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

First Come First Served (FCFS)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Makespan = 28 days



Flow time = 77

Average flow time = 15.4 days/job

Avg # jobs in system = 77 days/28 days = 2.75

Utilization = 28 days/77 days = 36.4%

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

Sequencing Rules (Single Resource)

- Local
  - ✓ First Come First Served
  - ✓ **Last Come First Served**
  - ✓ Shortest Processing Time
  - ✓ Longest Processing Time
  - ✓ Earliest Due Date
- Global
  - ✓ Slack Per Remaining Operation
  - ✓ Critical Ratio

Last Come First Served (LCFS)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

As jobs pile up the operator picks the one on the top of the stack to work on

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
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Last Come First Served (LCFS)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
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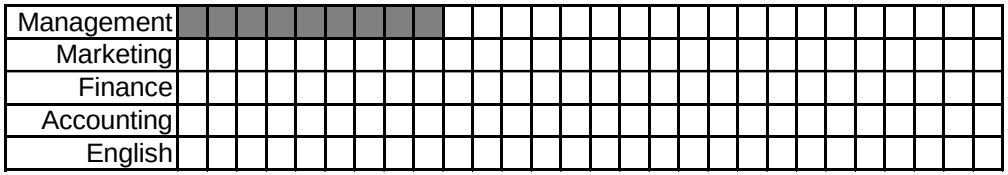

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
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Last Come First Served (LCFS)

Avg job lateness =	Total days late / # jobs
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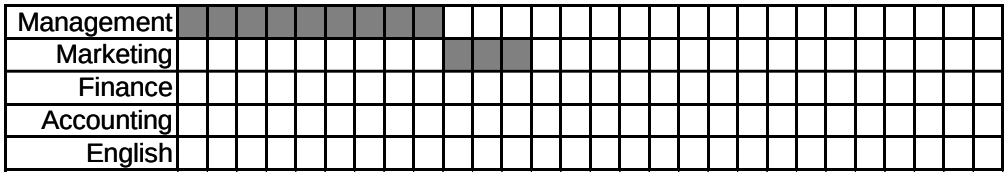

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Time until due:	**23**	**15**	**18**	**6**	**8**
	Marketing	*Finance*	*Accounting*	*English*	

Last Come First Served (LCFS)

Avg job lateness =	Total days late / # jobs
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Avg # jobs =	Sum of flowtimes / Total processing time
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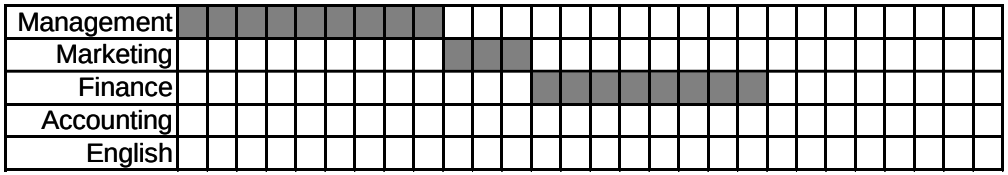

Processing time:	**9**	**3**	**8**	**2**	**6**
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Finance *Accounting* *English*

Last Come First Served (LCFS)

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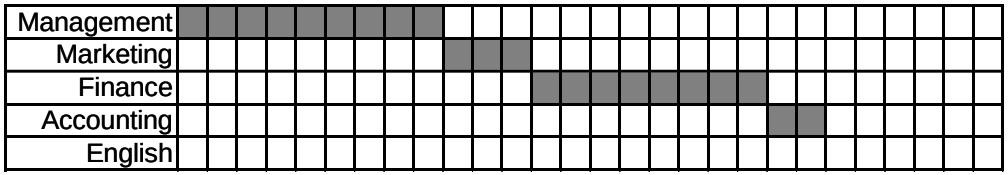

Processing time:	**9**	**3**	**8**	**2**	**6**
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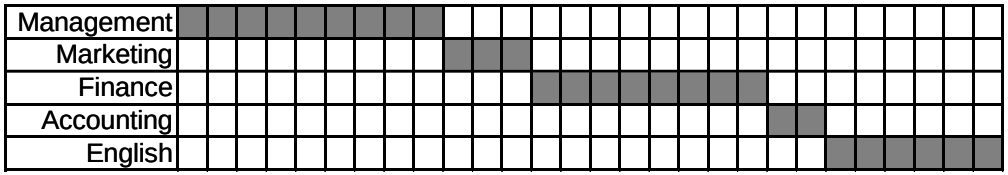
Accounting ***English***

Last Come First Served (LCFS)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Superimposing due dates…



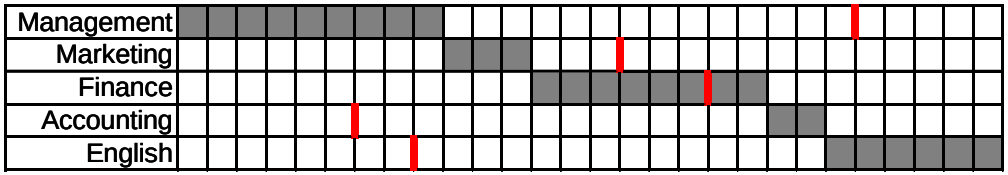
Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**

English

Last Come First Served (LCFS)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Superimposing due dates…



So 3 projects are late!!

Processing time:	**9**	**3**	**8**	**2**	**6**
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Last Come First Served (LCFS)

Avg job lateness =	Total days late / # jobs
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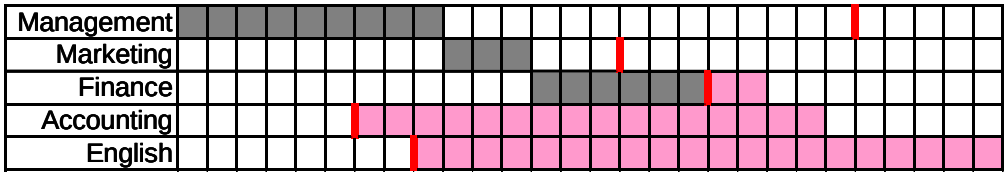
Superimposing due dates…



$$\text{Avg. job lateness} = \frac{\text{Total days late}}{\text{Number of jobs}} = \frac{38}{5} = 7.6 \text{ days}$$

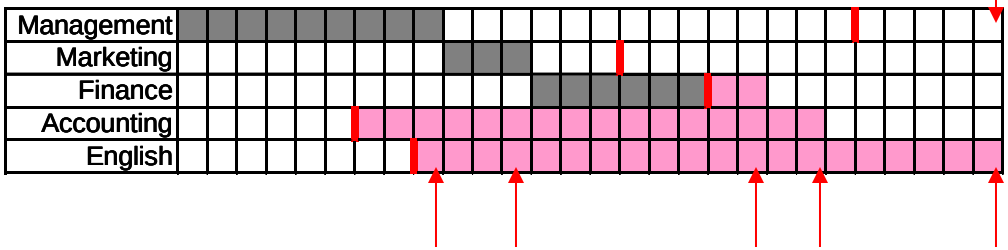
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

Last Come First Served (LCFS)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Superimposing due dates…

Makespan = 28 days



Flow time = 9 + 12 + 20 + 22 + 28 = 91

Average flow time = 91 days/5 jobs = 18.2 days/job

Avg # jobs in system = 91 days/28 days = 3.25

Utilization = 28 days/91 days = 30.8%

Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

Sequencing Rules (Single Resource)

- Local
  - ✓ First Come First Served
  - ✓ Last Come First Served
  - ✓ **Shortest Processing Time**
  - ✓ Longest Processing Time
  - ✓ Earliest Due Date
- Global
  - ✓ Slack Per Remaining Operation
  - ✓ Critical Ratio

Shortest Processing Time (SPT)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Process the job with the shortest processing time first

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

Shortest Processing Time (SPT)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Management																									
Marketing																									
Finance																									
Accounting																									
English																									

Processing time: 9 3 8 2 6

Time until due: 23 15 18 6 8

Management Marketing Finance Accounting English

Shortest Processing Time (SPT)

Avg job lateness =	Total days late / # jobs
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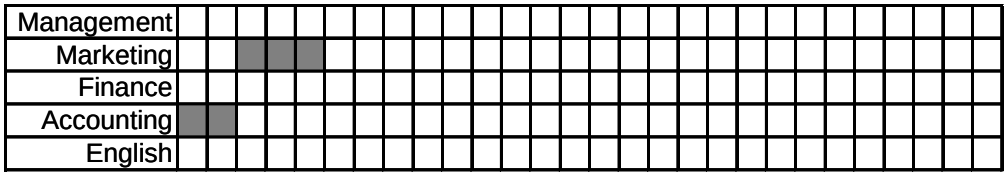

Processing time: 9 3 8 2 6

Time until due: 23 15 18 6 8

Management Marketing Finance English

Shortest Processing Time (SPT)

Avg job lateness =	Total days late / # jobs
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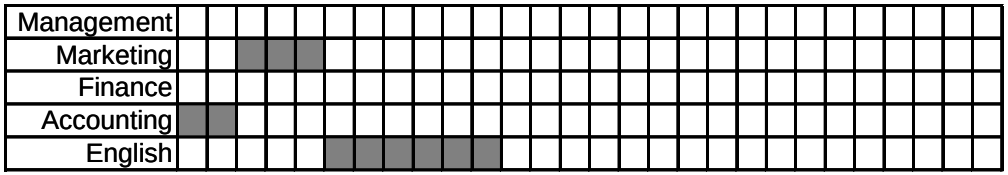

Processing time: 9 3 8 2 6

Time until due: 23 15 18 6 8

Management Finance English

Shortest Processing Time (SPT)

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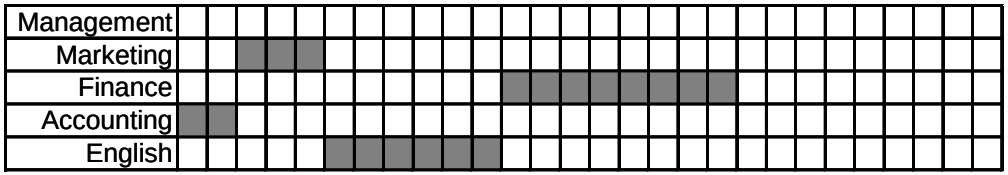


Processing time: 9 3 8 2 6

Time until due: 23 15 18 6 8

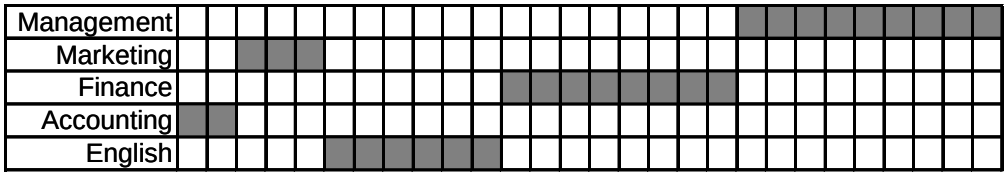
Management

Finance

Shortest Processing Time (SPT)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Superimposing due dates…



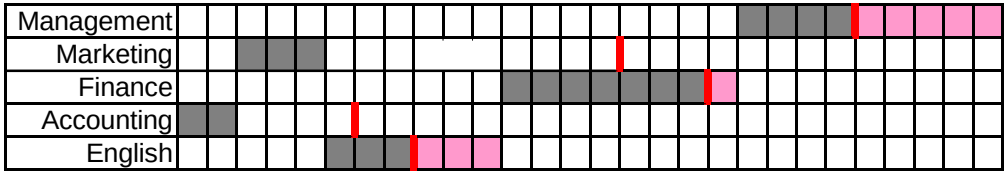
Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**

Management

Shortest Processing Time (SPT)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Superimposing due dates…



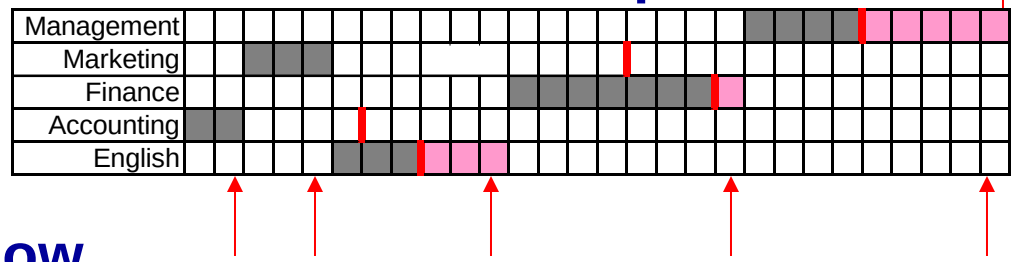
$$\text{Avg. job lateness} = \frac{\text{Total days late}}{\text{Number of jobs}} = \frac{9}{5} = 1.8 \text{ days}$$

Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

Shortest Processing Time (SPT)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Makespan = 28 days



Flow time = 2 + 5 + 11 + 19 + 28 = 65

Average flow time = 65 days/5 jobs = 13 days/job

Avg # jobs in system = 65 days/28 days = 2.32

Utilization = 28 days/65 days = 43.1%

Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

Sequencing Rules (Single Resource)

- Local
  - ✓ First Come First Served
  - ✓ Last Come First Served
  - ✓ Shortest Processing Time
  - ✓ **Longest Processing Time**
  - ✓ Earliest Due Date
- Global
  - ✓ Slack Per Remaining Operation
  - ✓ Critical Ratio

Longest Processing Time (LPT)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Process the job with the longest processing time first

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

Longest Processing Time (LPT)

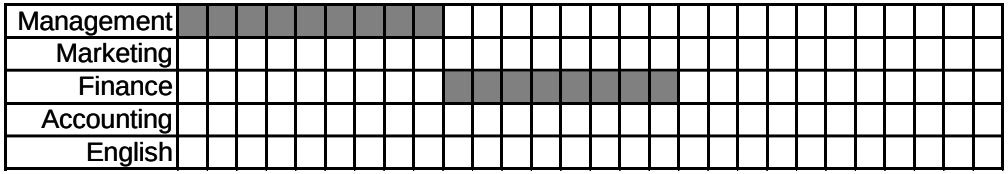
Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Management																									
Marketing																									
Finance																									
Accounting																									
English																									

Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**
	Management	***Marketing***	***Finance***	***Accounting***	***English***

Longest Processing Time (LPT)

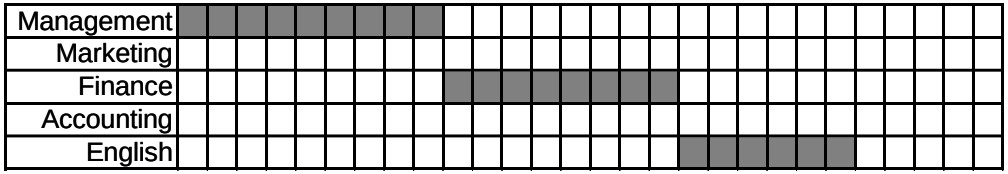
Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes



Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**
		Marketing	*Finance*	*Accounting*	*English*

Longest Processing Time (LPT)

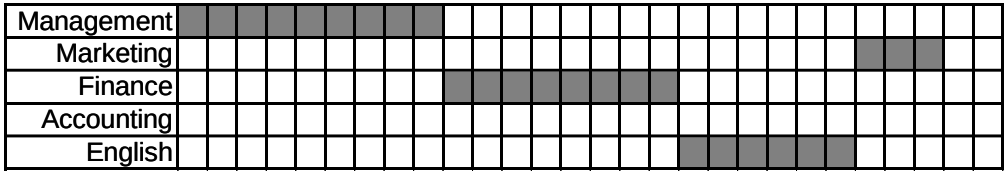
Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes



Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**
		Marketing	*Accounting*	*English*	

Longest Processing Time (LPT)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes



Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**

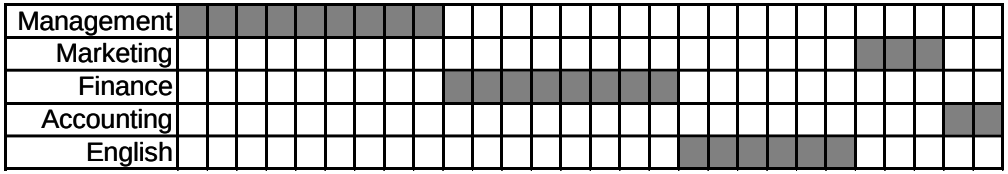
Marketing

Accounting

Longest Processing Time (LPT)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Superimposing due dates…



Processing time: 9 3 8 2 6

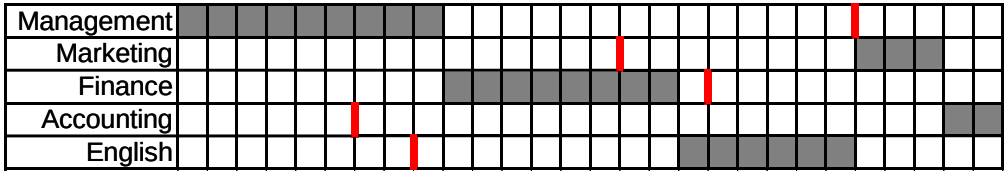
Time until due: 23 15 18 6 8

Accounting

Longest Processing Time (LPT)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

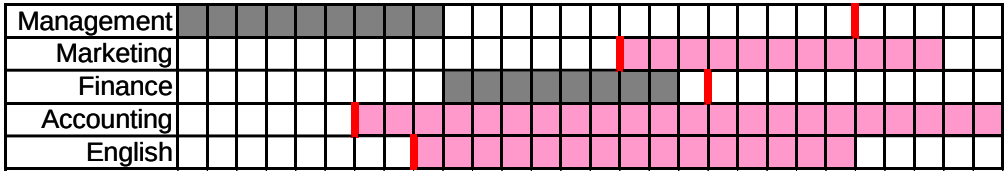
Superimposing due dates…



Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**

Longest Processing Time (LPT)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes



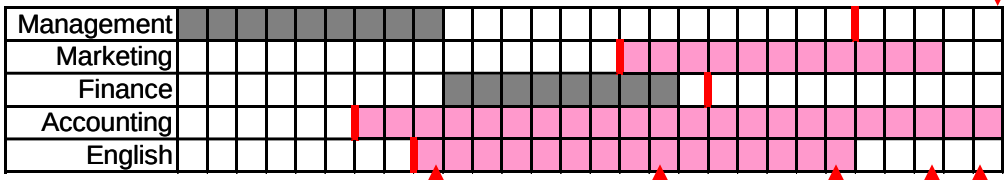
$$\text{Avg. job lateness} = \frac{\text{Total days late}}{\text{Number of jobs}} = \frac{48}{5} = 9.6 \text{ days}$$

Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

Longest Processing Time (LPT)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Makespan = 28 days



Flow time = 9 + 17 + 23 + 26 + 28 = 103

Average flow time = 103 days/5 jobs = 20.6 days/job

Avg # jobs in system = 103 days/28 days = 3.68

Utilization = 28 days/103 days = 27.2%

Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

Sequencing Rules (Single Resource)

- Local
  - ✓ First Come First Served
  - ✓ Last Come First Served
  - ✓ Shortest Processing Time
  - ✓ Longest Processing Time
  - ✓ **Earliest Due Date**
- Global
  - ✓ Slack Per Remaining Operation
  - ✓ Critical Ratio

Earliest Due Date (EDD)

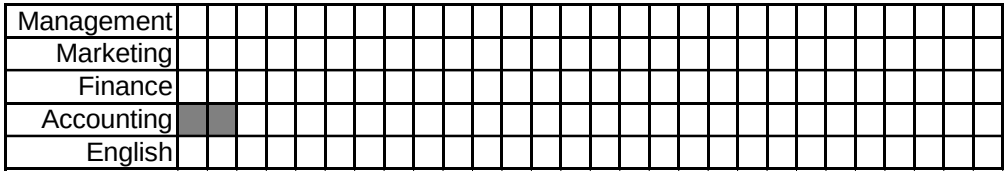
Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Process the job with the earliest due date first

	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

Earliest Due Date (EDD)

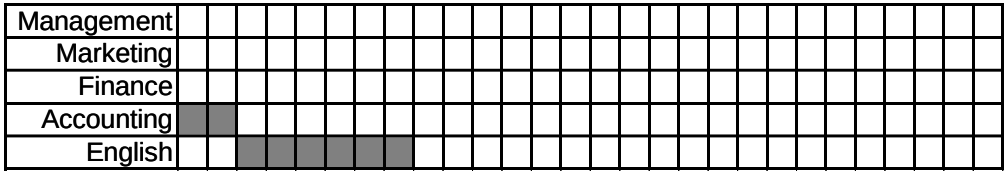
Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes



	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

Earliest Due Date (EDD)

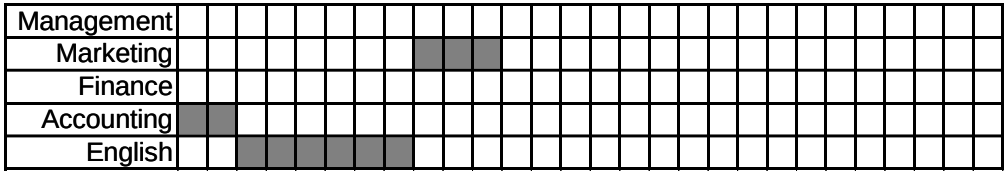
Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes



	Management	Marketing	Finance	Accounting	English
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

Earliest Due Date (EDD)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes



Processing time: 9 3 8 2 6

Time until due: 23 15 18 6 8

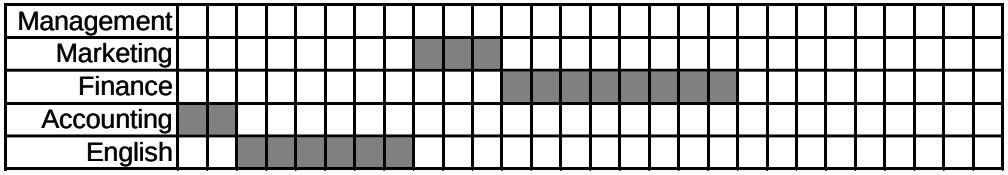
Management

Marketing

Finance

Earliest Due Date (EDD)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes



Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**

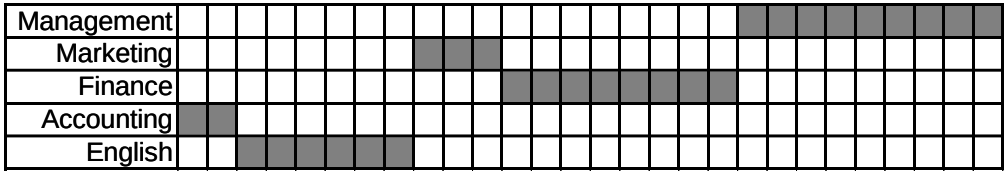
Management

Finance

Earliest Due Date (EDD)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Superimposing due dates…



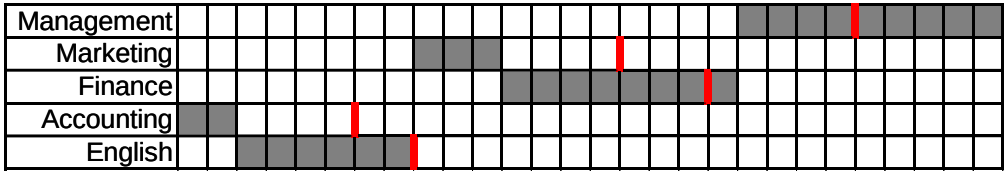
Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**

Management

Earliest Due Date (EDD)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Superimposing due dates…

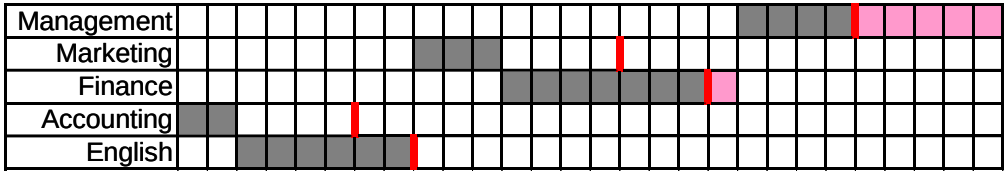


Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**

Earliest Due Date (EDD)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Superimposing due dates…



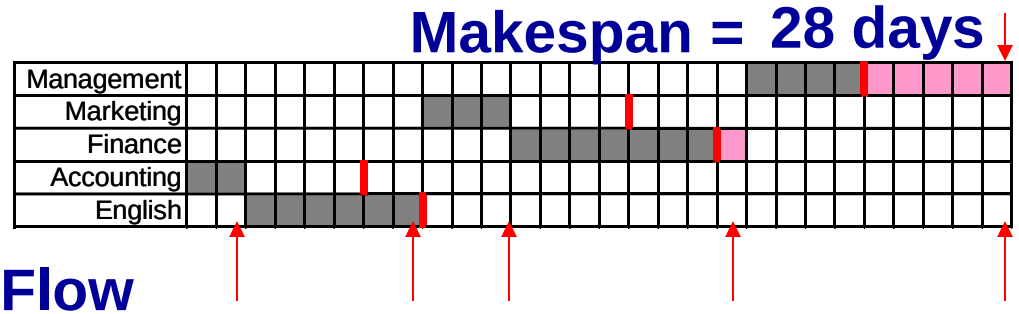
$$\text{Avg. job lateness} = \frac{\text{Total days late}}{\text{Number of jobs}} = \frac{6}{5} = 1.2 \text{ days}$$

Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

Earliest Due Date (EDD)

Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Superimposing due dates…



Flow time = 2 + 8 + 11 + 19 + 28 = 68

Average flow time = 68 days/5 jobs = 13.6 days/job

Avg # jobs in system = 68 days/28 days = 2.43

Utilization = 28 days/68 days = 41.2%

Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

Summary

	Avg lateness	Avg flowtime	Avg #jobs	utilization
FCFS	2.2	15.4	2.75	36.4%
LCFS	7.6	18.2	3.25	30.8%
SPT	1.8	13	2.32	43.1%
LPT	9.6	20.6	3.68	27.2%
EDD	1.2	13.6	2.43	41.2%

Sequencing Rules (Single Resource)

- Local
  - ✓ First Come First Served
  - ✓ Last Come First Served
  - ✓ Shortest Processing Time
  - ✓ Longest Processing Time
  - ✓ Earliest Due Date

- Global
  - ✓ Slack Per Remaining Operation
  - ✓ Critical Ratio

Global Rules

- Consider more than current operation
- Look at work at other work centers that needs to be completed before the job is done

Types of Sequencing Rules

- Sequencing jobs at a single resource
- Sequencing jobs across multiple resources

Scheduling Across Multiple Resources

- Previous rules considered scheduling (sequencing) jobs at one resource
- How can we schedule jobs across multiple resources??

Two resource problems

Suppose you work with a classmate, Kim on all projects

In each project you do the research, then Kim writes the report

You want to complete all projects asap

	Management	Marketing	Finance	Accounting	English
Processing time (you):	2	6	3	5	1
Processing time (Kim):	4	3	5	4	2

What should be the order for the projects?

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan

1. **Find the smallest processing time**
   - **If its on the 1st machine, assign the task at the beginning of the sequence and eliminate it from further consideration**
   - **If its on the 2nd machine, assign the task at the end of the sequence and eliminate it from further consideration**
2. **Repeat step 1 for all unassigned tasks**

	Management	Marketing	Finance	Accounting	English
Processing time (you):	2	6	3	5	1
Processing time (Kim):	4	3	5	4	2

What order should you do the projects in?

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan

1. **Find the smallest processing time**
   - **If its on the 1st machine, assign the task at the beginning of the sequence and eliminate it from further consideration**
   - **If its on the 2nd machine, assign the task at the end of the sequence and eliminate it from further consideration**
2. **Repeat step 1 for all unassigned tasks**

Processing time (you):	**2**	**6**	**3**	**5**	**1**
Processing time (Kim):	**4**	**3**	**5**	**4**	**2**
	Management	*Marketing*	*Finance*	*Accounting*	*English*

Sequence

English

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan

1. **Find the smallest processing time**
   - **If its on the 1st machine, assign the task at the beginning of the sequence and eliminate it from further consideration**
   - **If its on the 2nd machine, assign the task at the end of the sequence and eliminate it from further consideration**
2. **Repeat step 1 for all unassigned tasks**

Processing time (you):	2	6	3	5	1
Processing time (Kim):	4	3	5	4	2
	Management	Marketing	Finance	Accounting	English

Sequence

English

Management

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan

1. **Find the smallest processing time**
   - **If its on the 1st machine, assign the task at the beginning of the sequence and eliminate it from further consideration**
   - **If its on the 2nd machine, assign the task at the end of the sequence and eliminate it from further consideration**
2. **Repeat step 1 for all unassigned tasks**

Processing time (you):	2	6	3	5	1
Processing time (Kim):	4	3	5	4	2
	Management	Marketing	Finance	Accounting	English

Sequence

English
Management
Finance

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan

1. **Find the smallest processing time**
   - **If its on the 1st machine, assign the task at the beginning of the sequence and eliminate it from further consideration**
   - **If its on the 2nd machine, assign the task at the end of the sequence and eliminate it from further consideration**
2. **Repeat step 1 for all unassigned tasks**

	Management	Marketing	Finance	Accounting	English
Processing time (you):	2	6	3	5	1
Processing time (Kim):	4	3	5	4	2

Sequence

English

Management

Finance

Marketing

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan

1. **Find the smallest processing time**
   - **If its on the 1st machine, assign the task at the beginning of the sequence and eliminate it from further consideration**
   - **If its on the 2nd machine, assign the task at the end of the sequence and eliminate it from further consideration**
2. **Repeat step 1 for all unassigned tasks**

	Management	Marketing	Finance	Accounting	English
Processing time (you):	2	6	3	5	1
Processing time (Kim):	4	3	5	4	2

Sequence

English
Management
Finance
Accounting
Marketing

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan

You
Kim

Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20

	Management	Marketing	Finance	Accounting	English
Processing time (you):	2	6	3	5	1
Processing time (Kim):	4	3	5	4	2

Sequence

English

Management

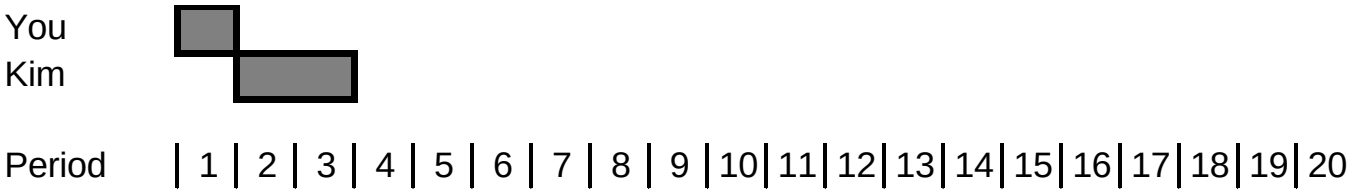
Finance

Accounting

Marketing

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan



Processing time (you):	**2**	**6**	**3**	**5**	**1**
Processing time (Kim):	**4**	**3**	**5**	**4**	**2**
	Management	*Marketing*	*Finance*	*Accounting*	*English*

Sequence

English

Management

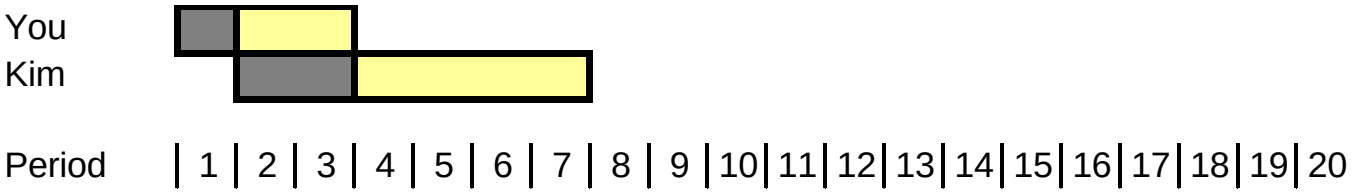
Finance

Accounting

Marketing

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan



Processing time (you):	**2**	**6**	**3**	**5**	**1**
Processing time (Kim):	**4**	**3**	**5**	**4**	**2**
	Management	*Marketing*	*Finance*	*Accounting*	*English*

Sequence

English

Management

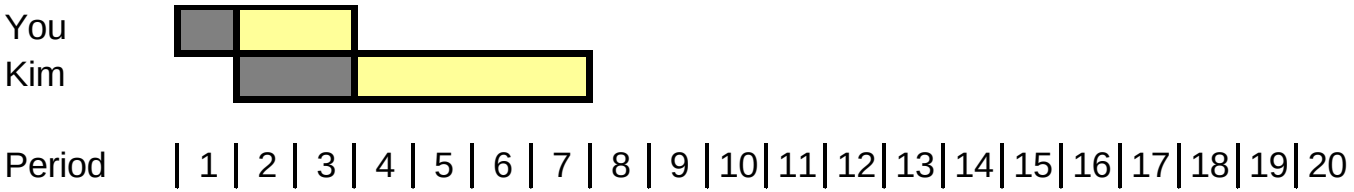
Finance

Accounting

Marketing

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan



Processing time (you):	**2**	**6**	**3**	**5**	**1**
Processing time (Kim):	**4**	**3**	**5**	**4**	**2**
	Management	*Marketing*	*Finance*	*Accounting*	*English*

Sequence

English

Management

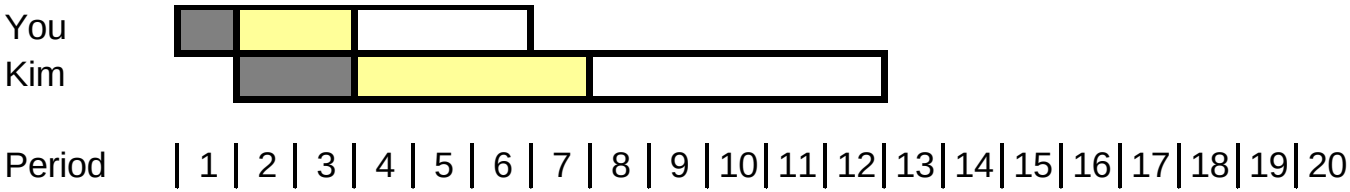
Finance

Accounting

Marketing

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan



Processing time (you):	**2**	**6**	**3**	**5**	**1**
Processing time (Kim):	**4**	**3**	**5**	**4**	**2**
	Management	*Marketing*	*Finance*	*Accounting*	*English*

Sequence

English

Management

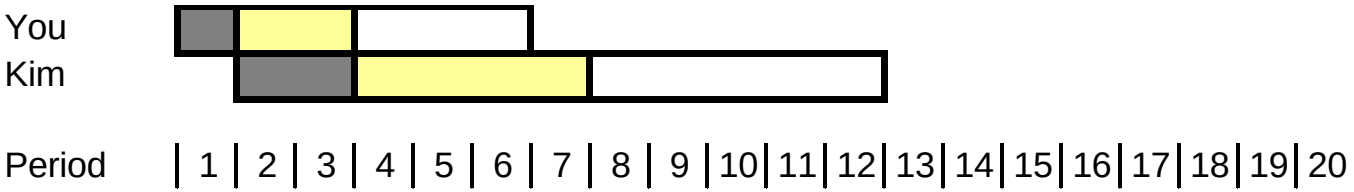
Finance

Accounting

Marketing

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan



Processing time (you):	**2**	**6**	**3**	**5**	**1**
Processing time (Kim):	**4**	**3**	**5**	**4**	**2**
	Management	*Marketing*	*Finance*	*Accounting*	*English*

Sequence

English

Management

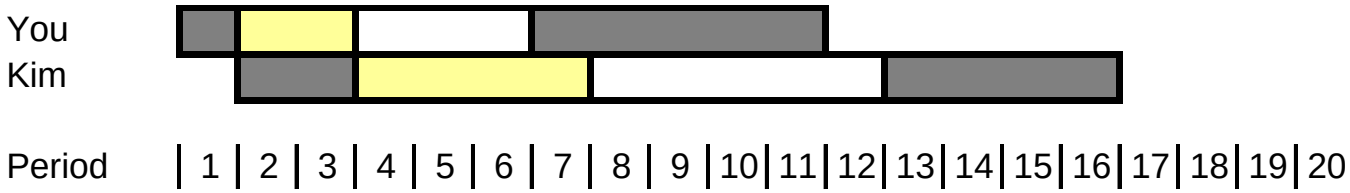
Finance

Accounting

Marketing

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan



Processing time (you):	**2**	**6**	**3**	**5**	**1**
Processing time (Kim):	**4**	**3**	**5**	**4**	**2**
	Management	*Marketing*	*Finance*	*Accounting*	*English*

Sequence

English

Management

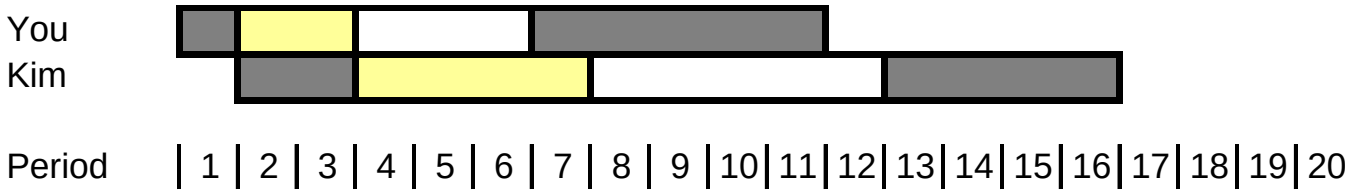
Finance

Accounting

Marketing

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan



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Management *Marketing* *Finance* *Accounting* *English*

Sequence

English

Management

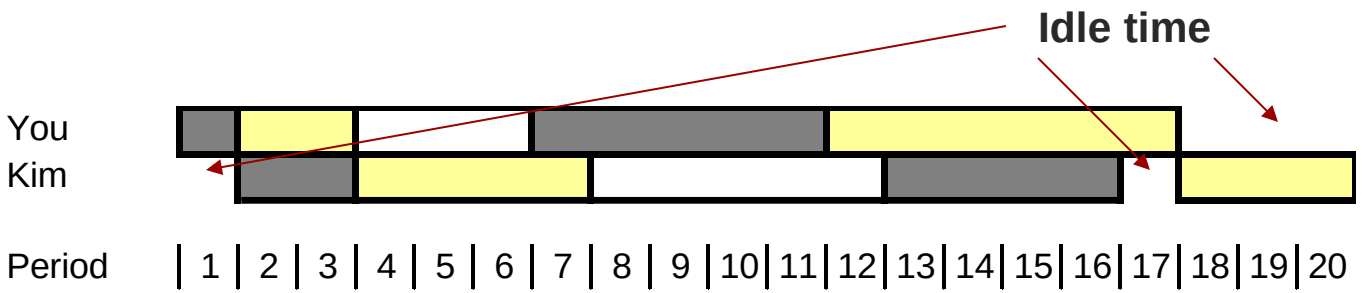
Finance

Accounting

Marketing

Two resource problems

Johnson's Rule Sequences tasks to minimize makespan



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Processing time (Kim):	**4**	**3**	**5**	**4**	**2**
	Management	*Marketing*	*Finance*	*Accounting*	*English*

Sequence

English

Management

Finance

Accounting

Marketing

Employee Scheduling

- ✓ *Labor is very flexible resource*
- ✓ *Scheduling workforce is complicated repetitive task*
- ✓ *Heuristics commonly used*

We'll cover one simple one today…

Employee Scheduling Heuristic

Let N = no. of workers available
D_i = demand for workers on day i

1. ***Assign the first N - D_1 workers day 1 off.***
   Assign the next N - D_2 workers day 2 off.
   Continue in a similar manner until all days are scheduled.

2. ***If number of workdays for full time employee < 5, assign remaining workdays so consecutive days off are possible.***
   - ***Assign any remaining work to part-time employees.***

3. ***If consecutive days off are desired, consider switching schedules among days with the same demand requirements.***

Example

DAY OF WEEK	M	T	W	TH	F	SA	SU
MIN NO. OF WORKERS REQUIRED	3	3	4	3	4	5	3

Taylor

Smith

Simpson

Allen

Dickerson

X = *day working*

O = *day off*

1. *Assign the first N - D1 workers day 1 off.*
   Assign the next N - D2 workers day 2 off.
   Continue in a similar manner until all days are have been scheduled.

DAY OF WEEK	M	T	W	TH	F	SA	SU
MIN NO. OF WORKERS REQUIRED	$D_1 = 3$	$D_2 = 3$	$D_3 = 4$	$D_4 = 3$	$D_5 = 4$	$D_6 = 5$	$D_7 = 3$

N = 5

- Taylor
- Smith
- Simpson
- Allen
- Dickerson

$$N - D_1 = 5 - 3 = 2$$

1. *Assign the first N - D1 workers day 1 off.*
   Assign the next N - D2 workers day 2 off.
   Continue in a similar manner until all days are have been scheduled.

DAY OF WEEK	M	T	W	TH	F	SA	SU
MIN NO. OF WORKERS REQUIRED	3	3	4	3	4	5	3
Taylor	O						
Smith	O						
Simpson							
Allen							
Dickerson							

$$N - D_2 = 5 - 3 = 2$$

2. If number of workdays for full time employee < 5, assign remaining workdays so consecutive days off are possible.

DAY OF WEEK	M	T	W	TH	F	SA	SU	
MIN NO. OF WORKERS REQUIRED	3	3	4	3	4	5	3	Work days
Taylor	O	X	X	O	X	X	X	5
Smith	O	X	X	O	X	X	X	5
Simpson	X	O	X	X	O	X	X	5
Allen	X	O	X	X	X	X	O	5
Dickerson	X	X	O	X	X	X	O	5

3. *If consecutive days off are desired, consider switching schedules among days with the same demand requirements.*

DAY OF WEEK	M	T	W	TH	F	SA	SU
MIN NO. OF WORKERS REQUIRED	3	3	4	3	4	5	3
Taylor	O	X	X	O	X	X	X
Smith	O	X	X	O	X	X	X
Simpson	X	O	X	X	O	X	X
Allen	X	O	X	X	X	X	O
Dickerson	X	X	O	X	X	X	O

Completed schedule satisfies requirements but has no consecutive days off.

3. *If consecutive days off are desired, consider switching schedules among days with the same demand requirements.*

DAY OF WEEK	M	T	W	TH	F	SA	SU
MIN NO. OF WORKERS REQUIRED	3	3	4	3	4	5	3
Taylor	O	X	X	O	X	X	X
Smith	O	X	X	O	X	X	X
Simpson	X	O	X	X	O	X	X
Allen	X	O	X	X	X	X	O
Dickerson	X	X	O	X	X	X	O

3. *If consecutive days off are desired, consider switching schedules among days with the same demand requirements.*

DAY OF WEEK	M	T	W	TH	F	SA	SU
MIN NO. OF WORKERS REQUIRED	3	3	4	3	4	5	3
Taylor	O	O	X	X	X	X	X
Smith	O	O	X	X	X	X	X
Simpson	X	X	X	O	O	X	X
Allen	X	X	X	O	X	X	O
Dickerson	X	X	O	X	X	X	O

The revised schedule satisfies requirements with consecutive days off for most employees.

Service Management; Queuing (WAITING LINE)

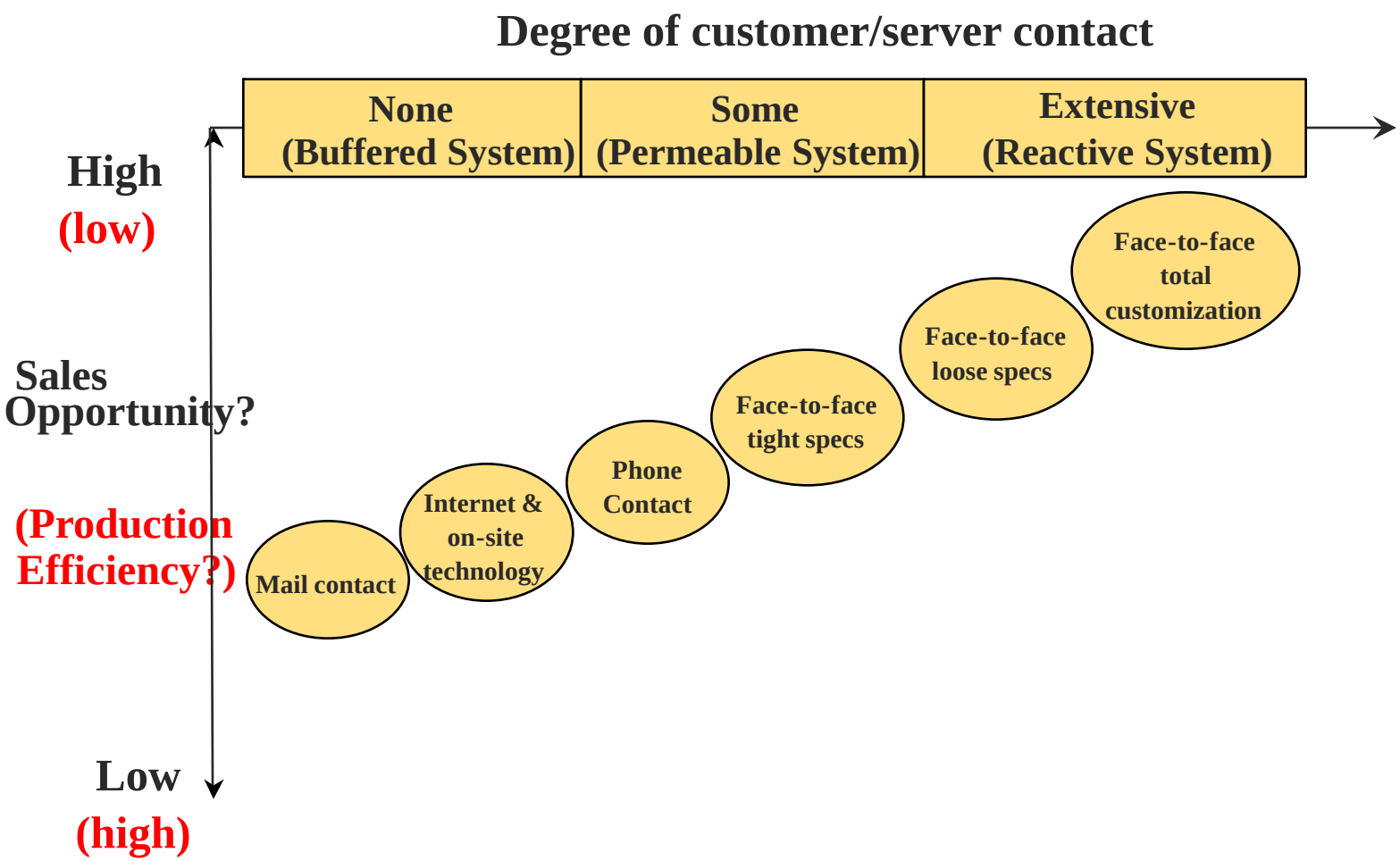
Overview

- Nature of services
- Service system design
- Service queues
  - ✓ Components
  - ✓ Examples (analysis)

Nature of Services

- Everyone is an expert
- Idiosyncratic
  - ✓ what works for one may not others
- Quality of work is not quality of service
- Mix of tangible and intangible attributes
- High contact services are “experienced”
- Need to understand marketing & personnel
- Cycles of encounters

Service System Design Matrix



Designs for On-Site Service

- Production Line Approach
  - ✓ McDonald's
- Self-Service Approach
  - ✓ Salad bar, **ATMs, gas stations**
- Personal Attention Approach
  - ✓ Ruth's Steakhouse

Disney World

- Waiting in lines does not add enjoyment
- Waiting in lines does not generate revenue
- Waiting lines are Non-Value Adding!

Implications of Waiting Lines

- 1. Cost and congestion from waiting space
- 2. Loss of immediate business
- 3. Loss of long term goodwill
- 4. Reduction in customer satisfaction

Queuing (Waiting Line) Systems

- The familiar "waiting in line" situation
- Frustrating, annoying
- Managing well is key
  - ✓ Objectives - depend on situation
  - ✓ Balance service with productivity




You've Been There Before!

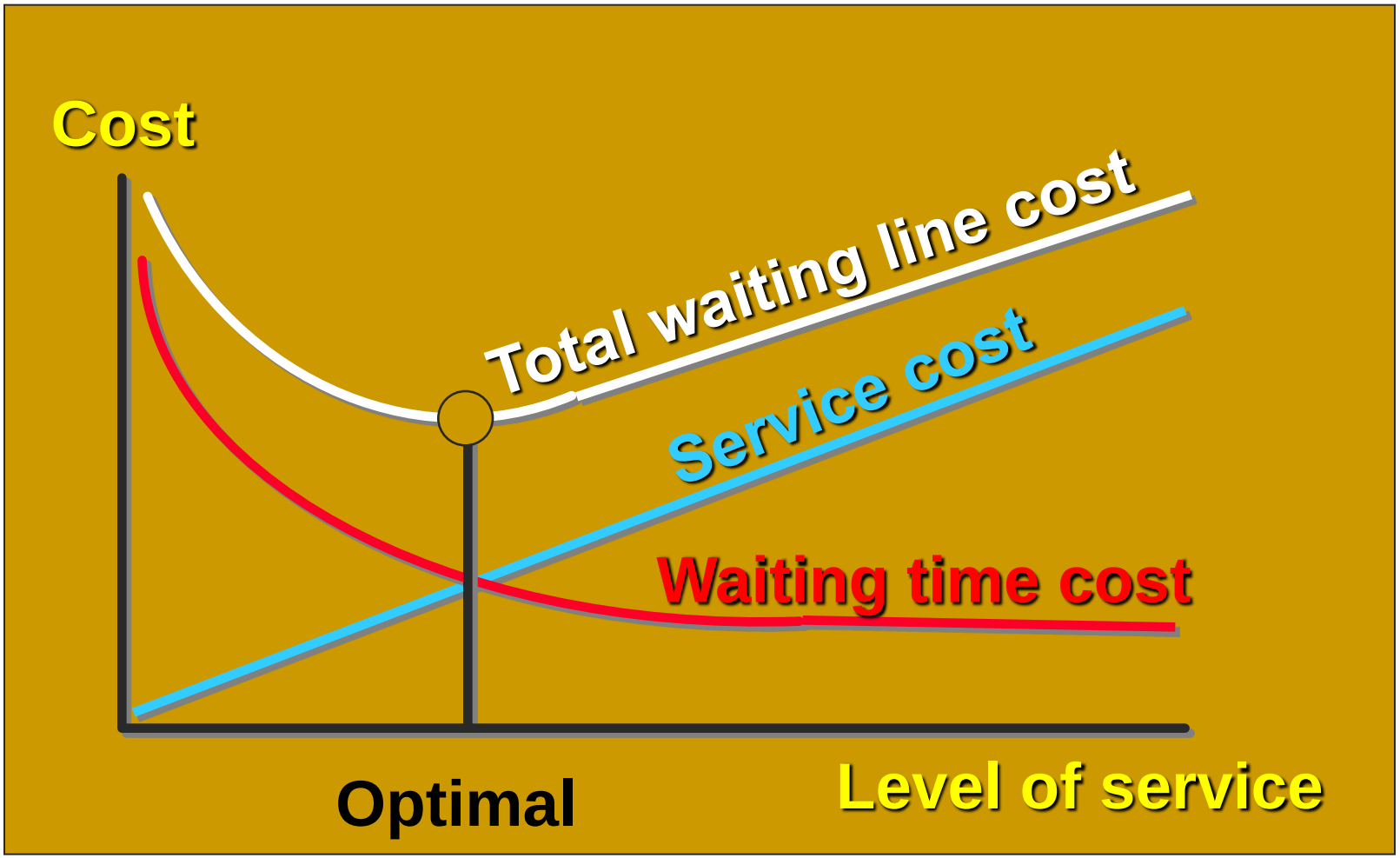
'The other line always moves faster.'

'If you change lines, the one you left will start to move faster than the one you're in.'

Waiting Line Examples

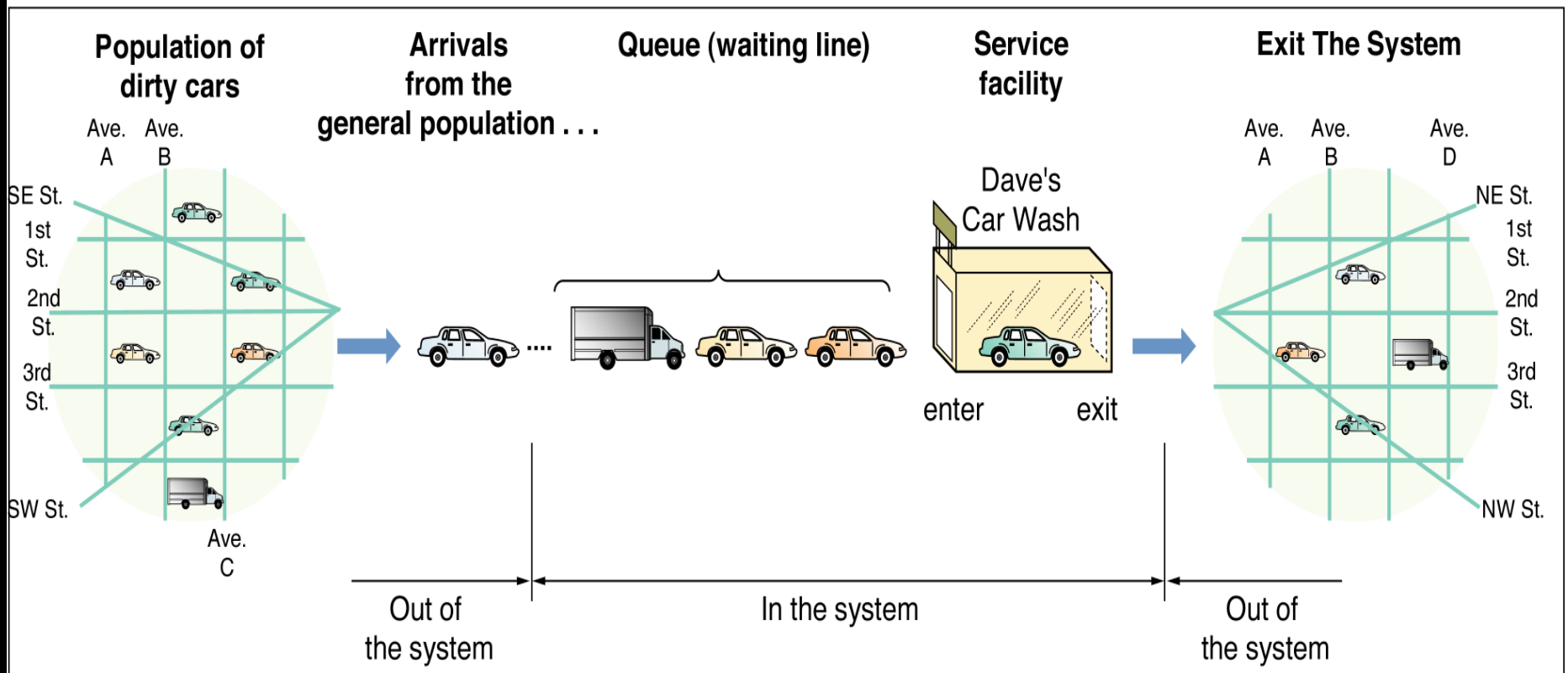
Situation	Arrivals	Servers	Service Process
Bank	Customers	Teller	Deposit etc.
Doctor's office	Patient	Doctor	Treatment
Traffic intersect.	Cars	Light	Controlled passage
Assembly line	Parts	Workers	Assembly
Tool crib	Workers	Clerks	Check out/in tools

Waiting Line Costs



Waiting Line Terminology

- Queue: Waiting line
- Arrival: 1 person, machine, part, etc. that arrives and demands service
- Queue discipline: Rules for determining the order that arrivals receive service
- Channel: Number of waiting lines
- Phase: Number of steps in service



Arrival Characteristics

- ❑ Size of arrival population
- ❑ Behavior of arrivals
- ❑ Statistical distribution of arrivals

Waiting-line Characteristics

- ❑ Limited vs. Unlimited
- ❑ Queue Discipline

Service Characteristics

- ❑ Service design
- ❑ Statistical distribution of service

Input Characteristics

Input Source (Population)

Size

Infinite

Input Characteristics

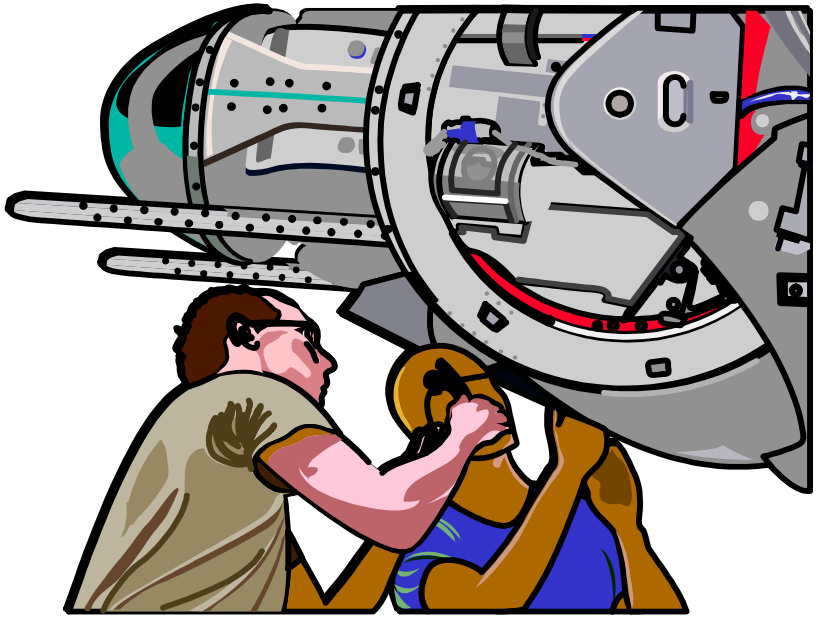
Input Source (Population)

Fixed number of aircraft to service

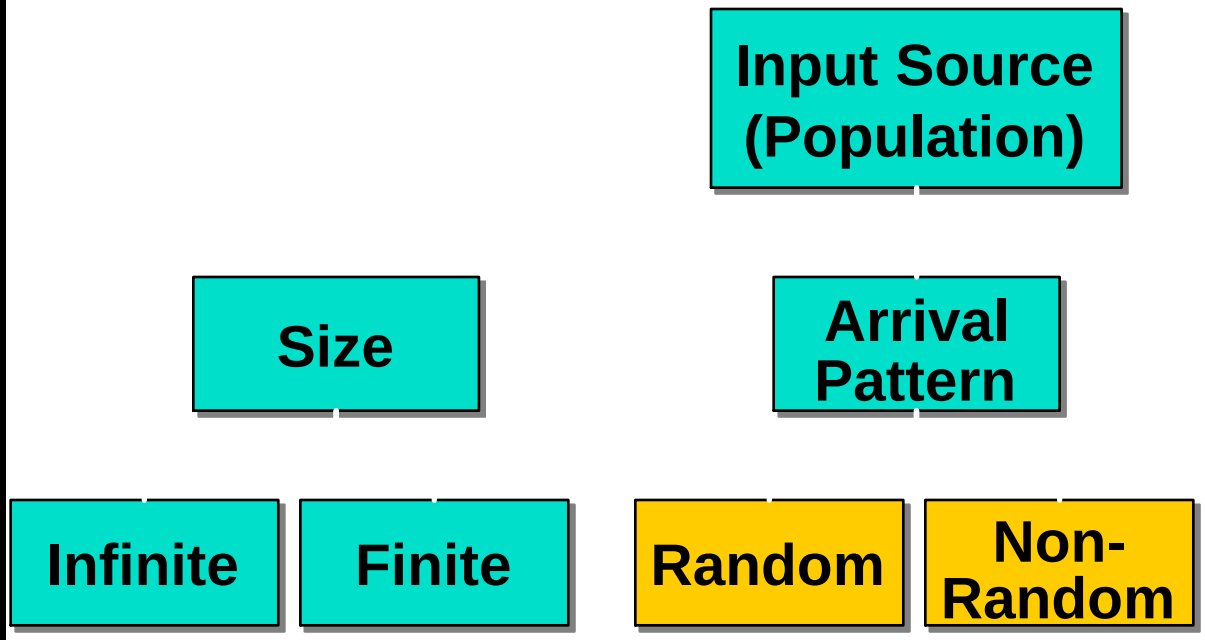
Size

Infinite

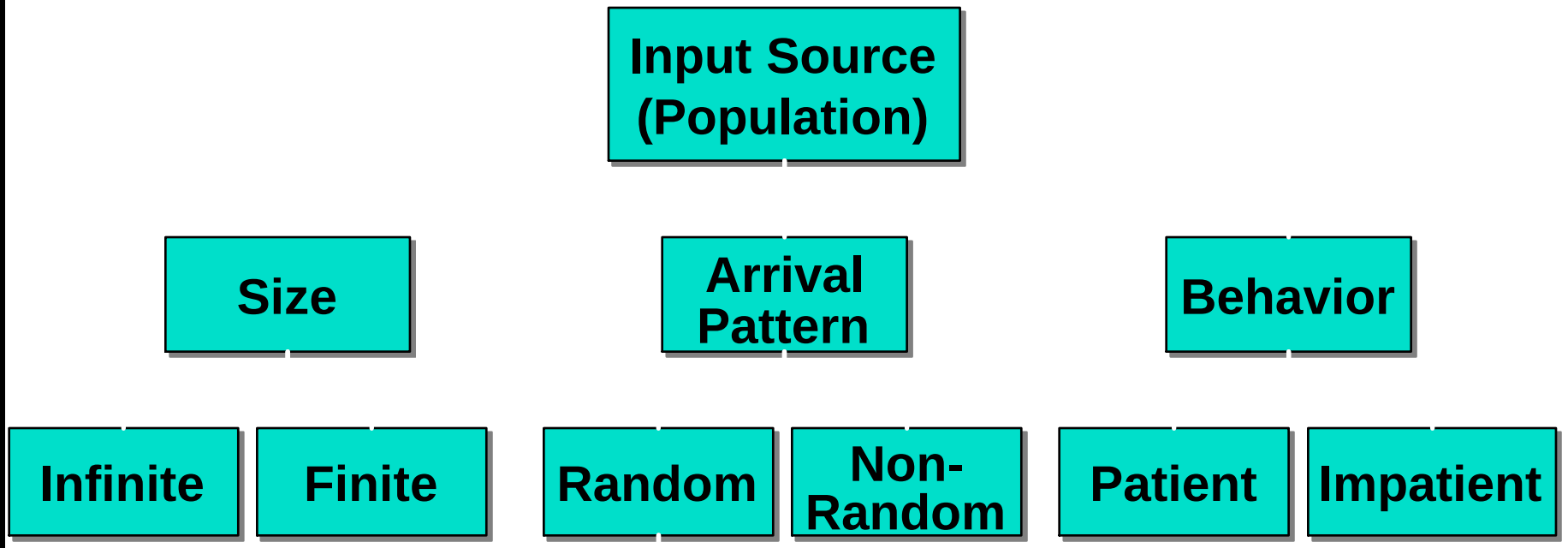
Finite



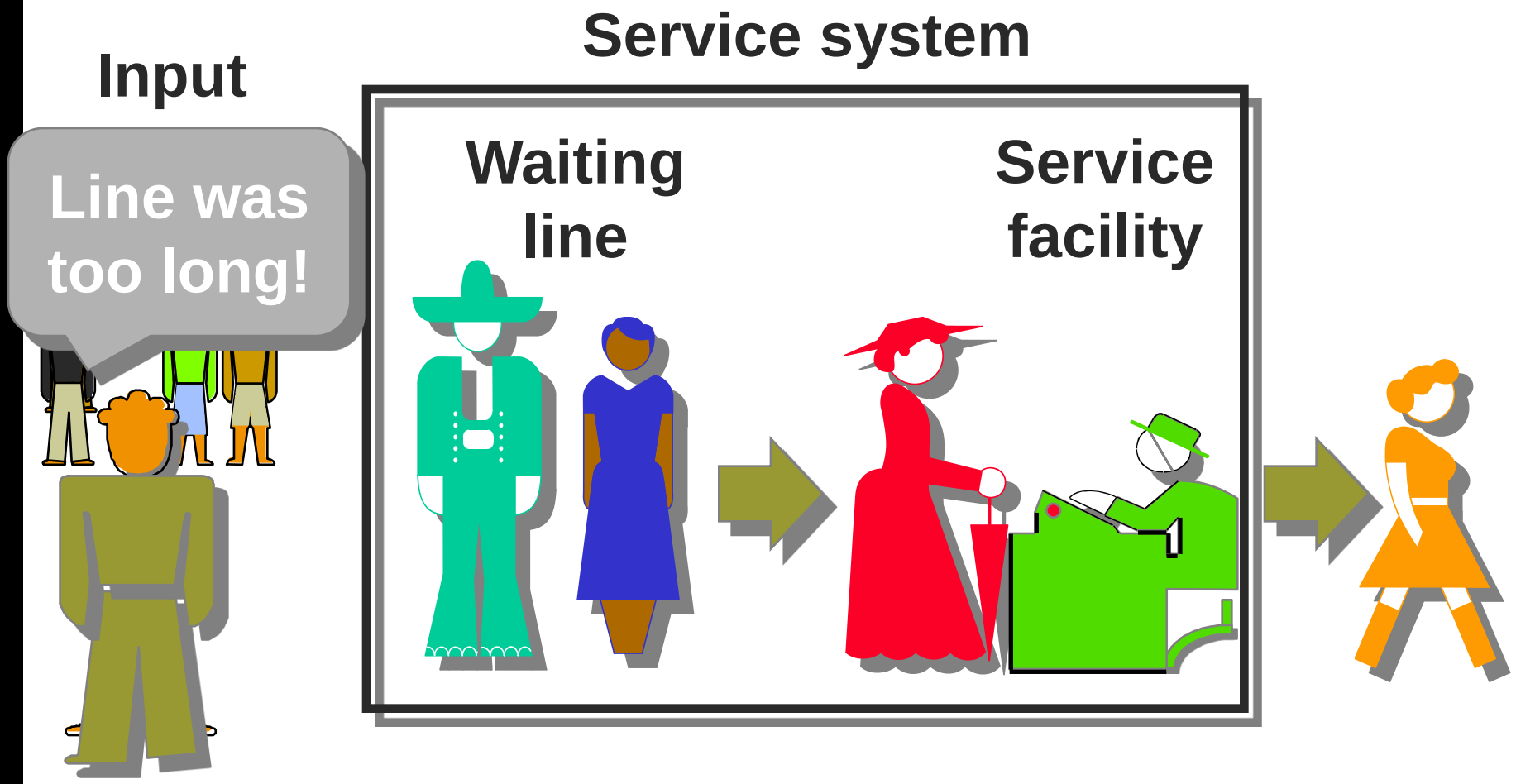
Input Characteristics



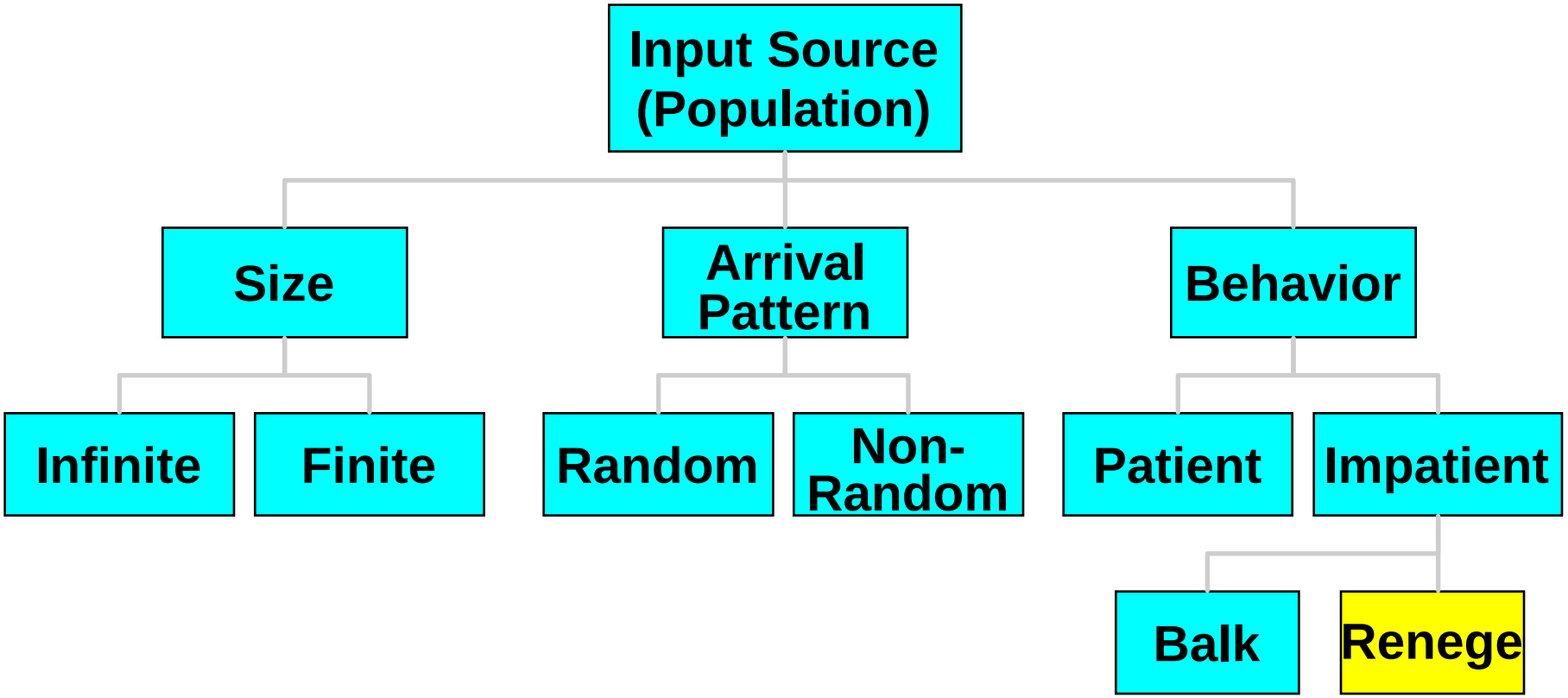
Input Characteristics



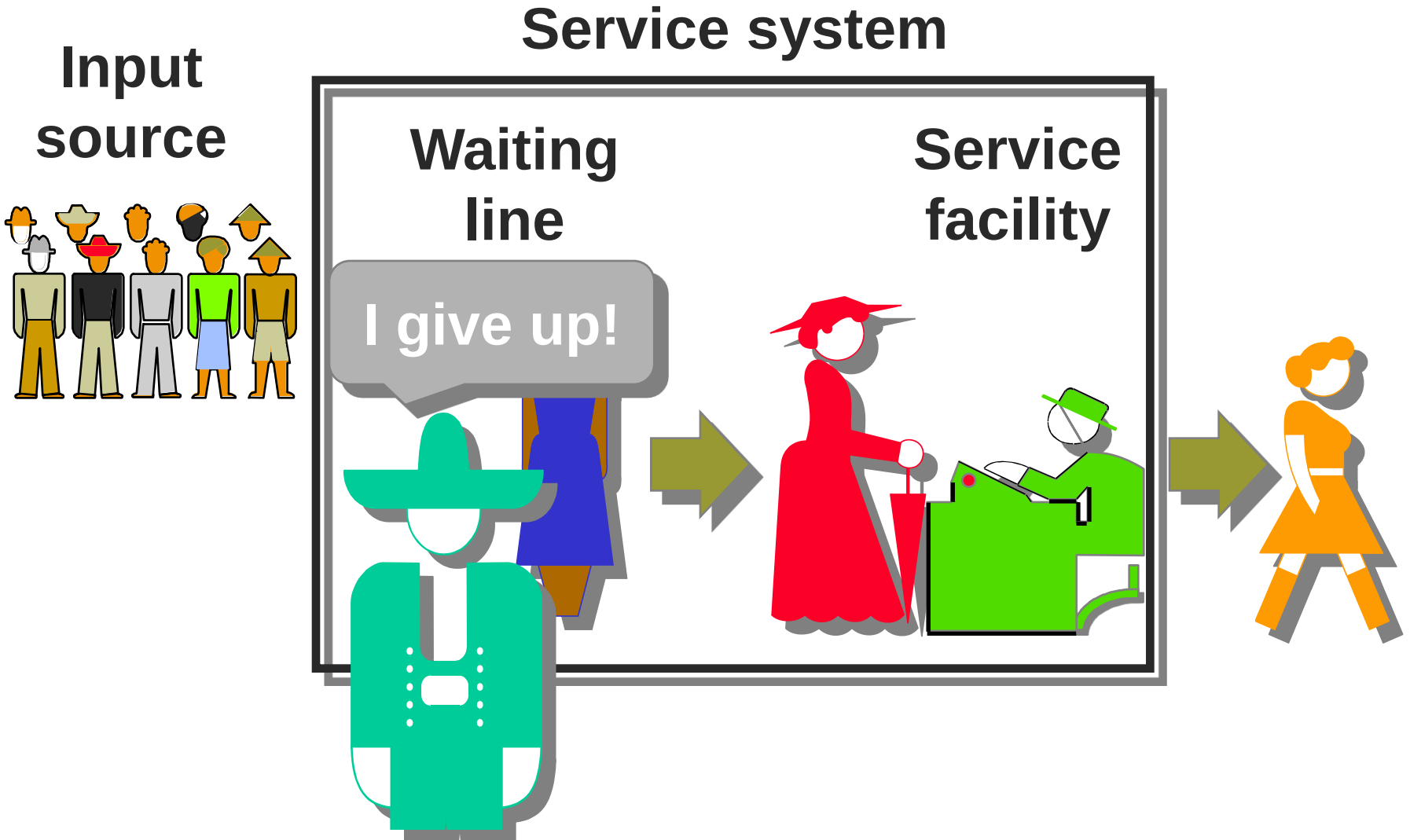
Balking


Input
Service system
Line was too long!
Waiting line
Service facility

Input Characteristics



Reneging

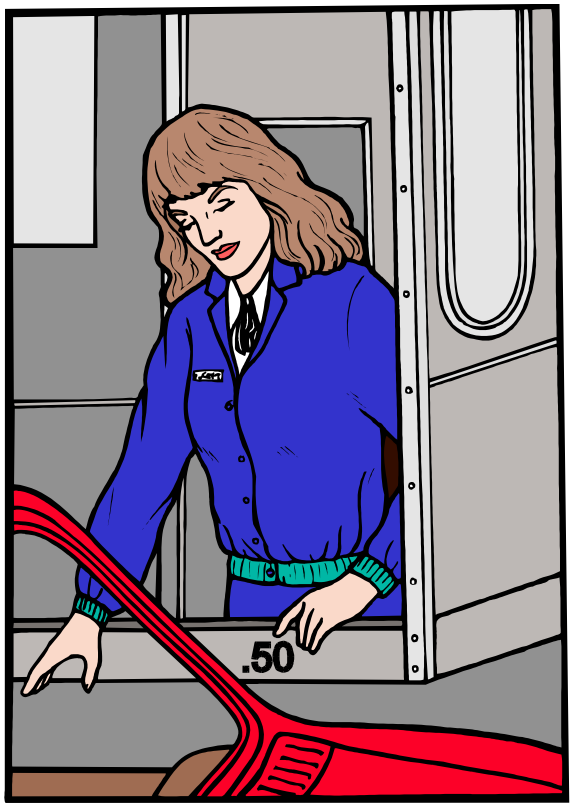

Input source
Service system
Waiting line
Service facility
I give up!

Waiting Line Characteristics

Waiting Line

Length

Unlimited



Waiting Line Characteristics

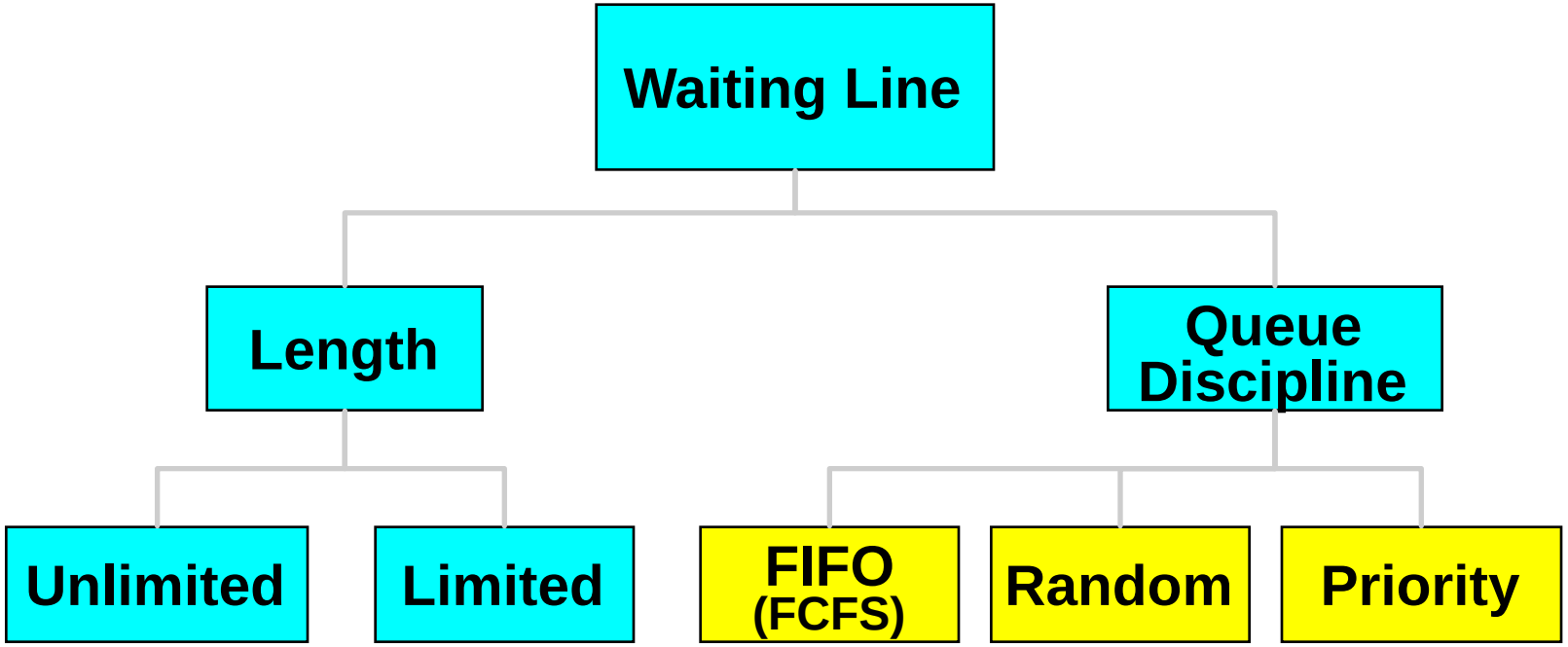
Waiting Line

Length

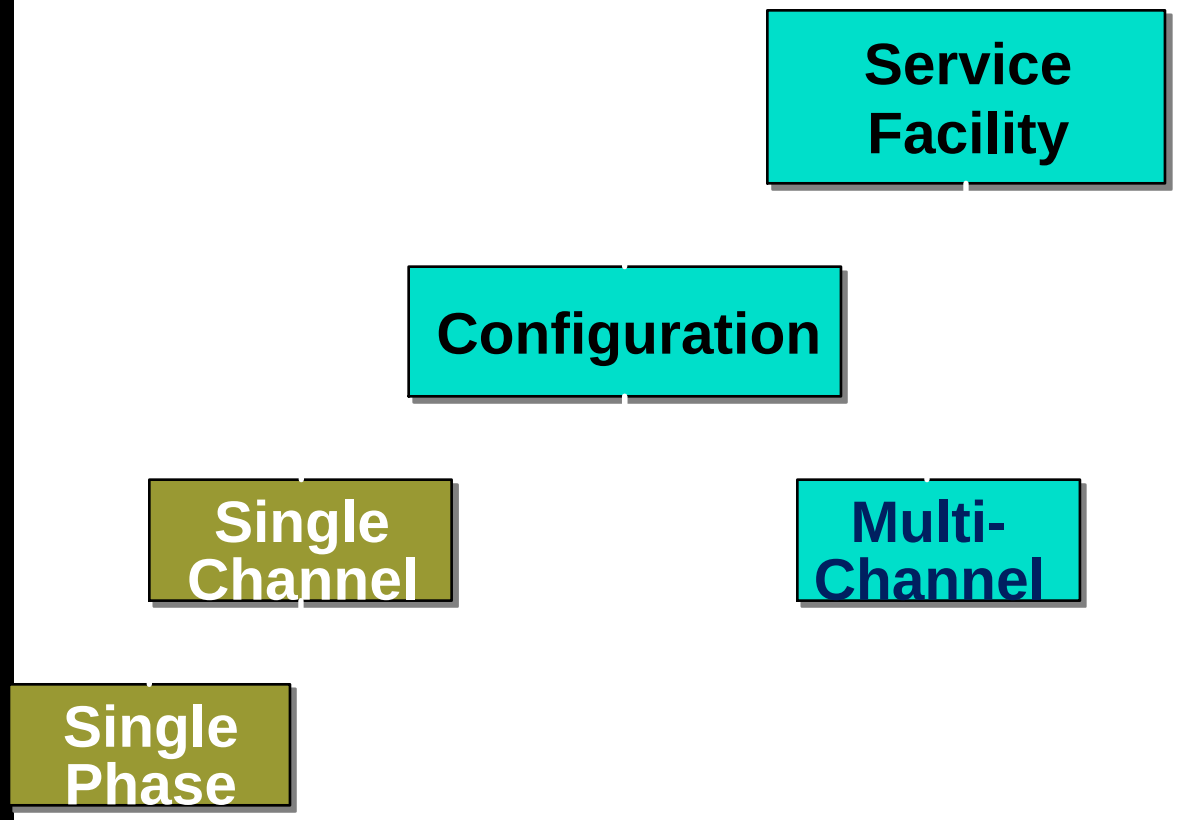
Unlimited

Limited

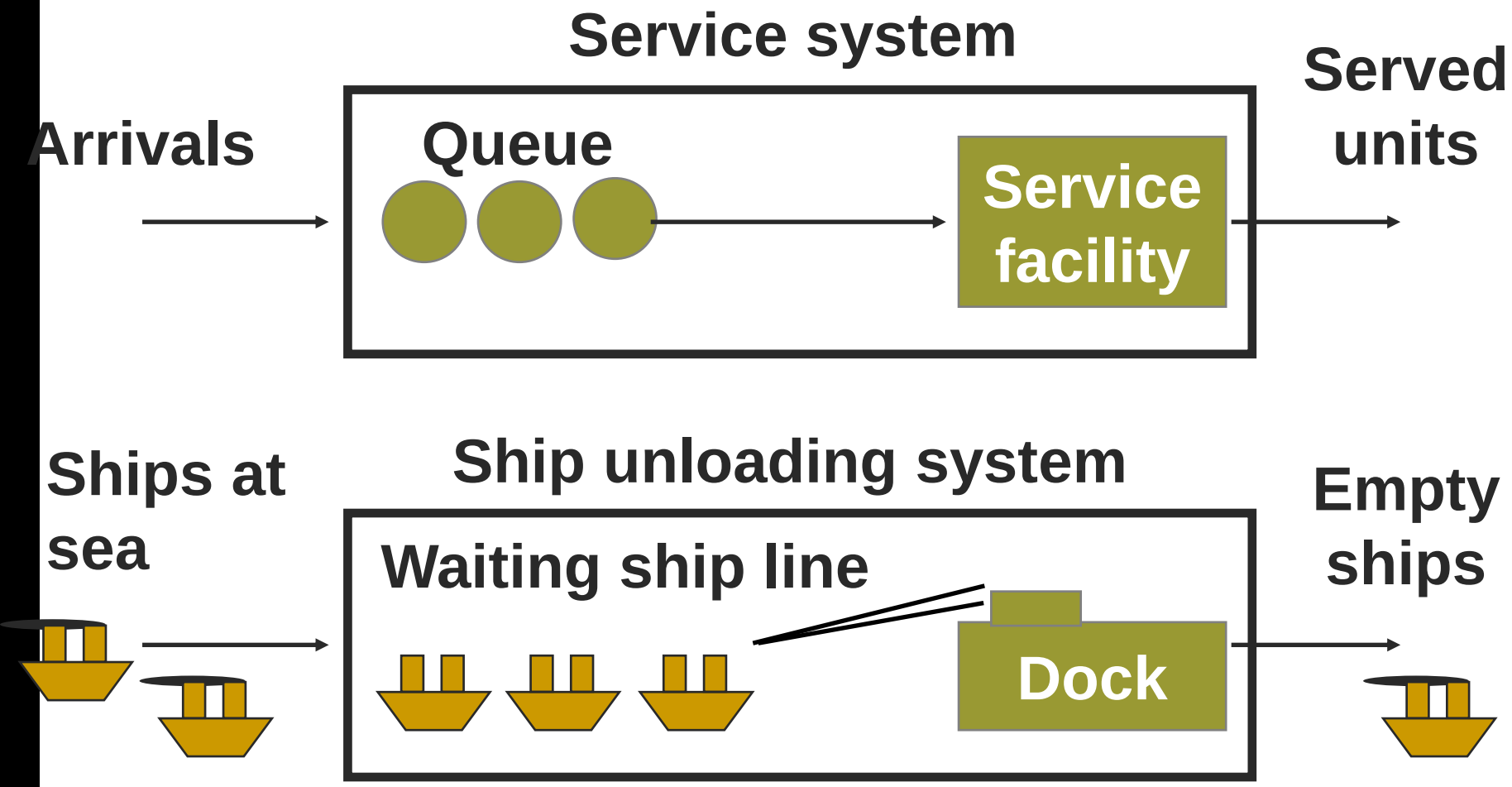
Waiting Line Characteristics



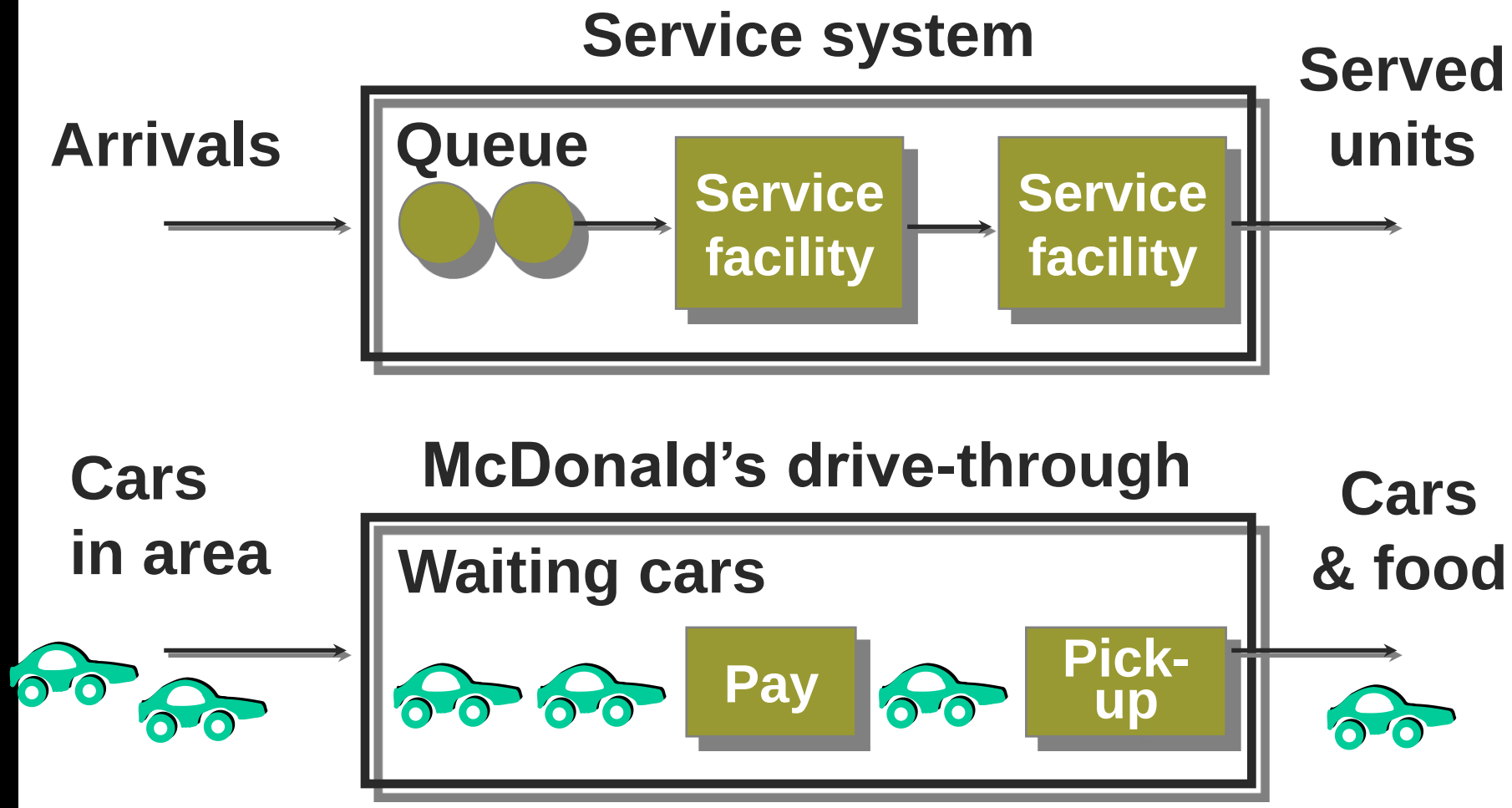
Service Facility Characteristics



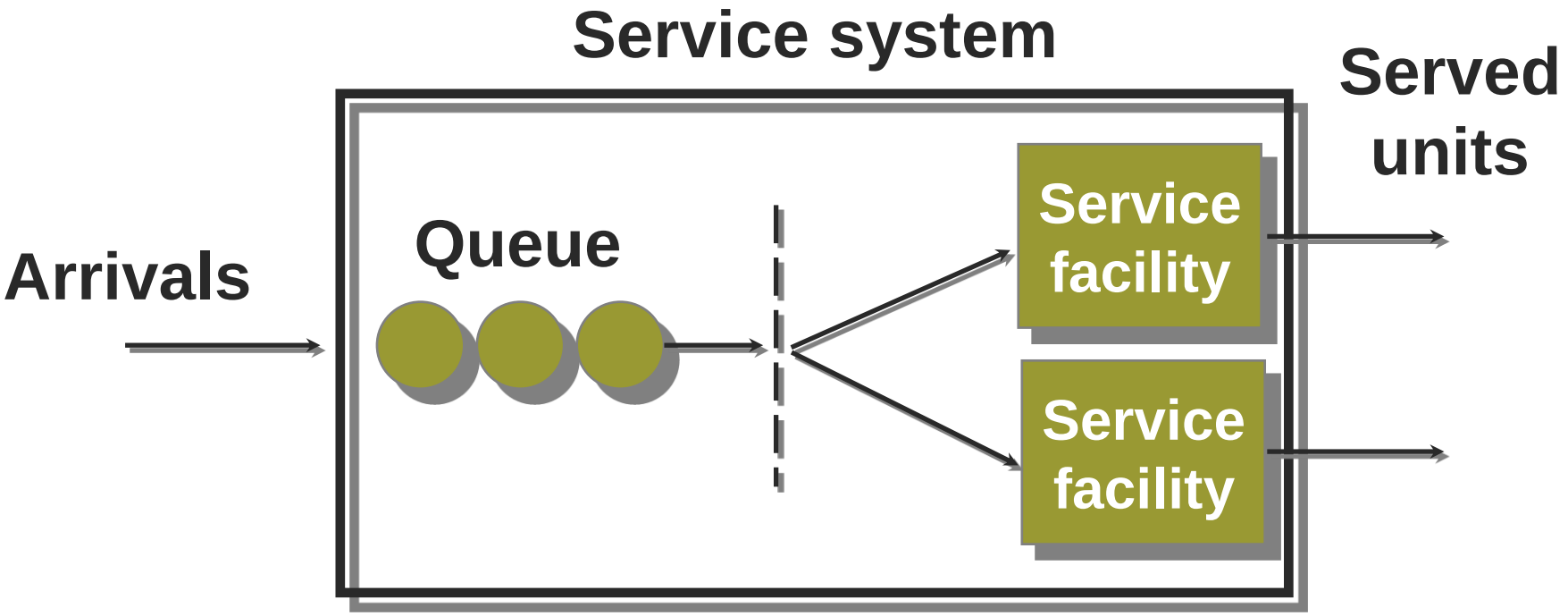
Single-Channel, Single-Phase System



Single-Channel, Multi-Phase System

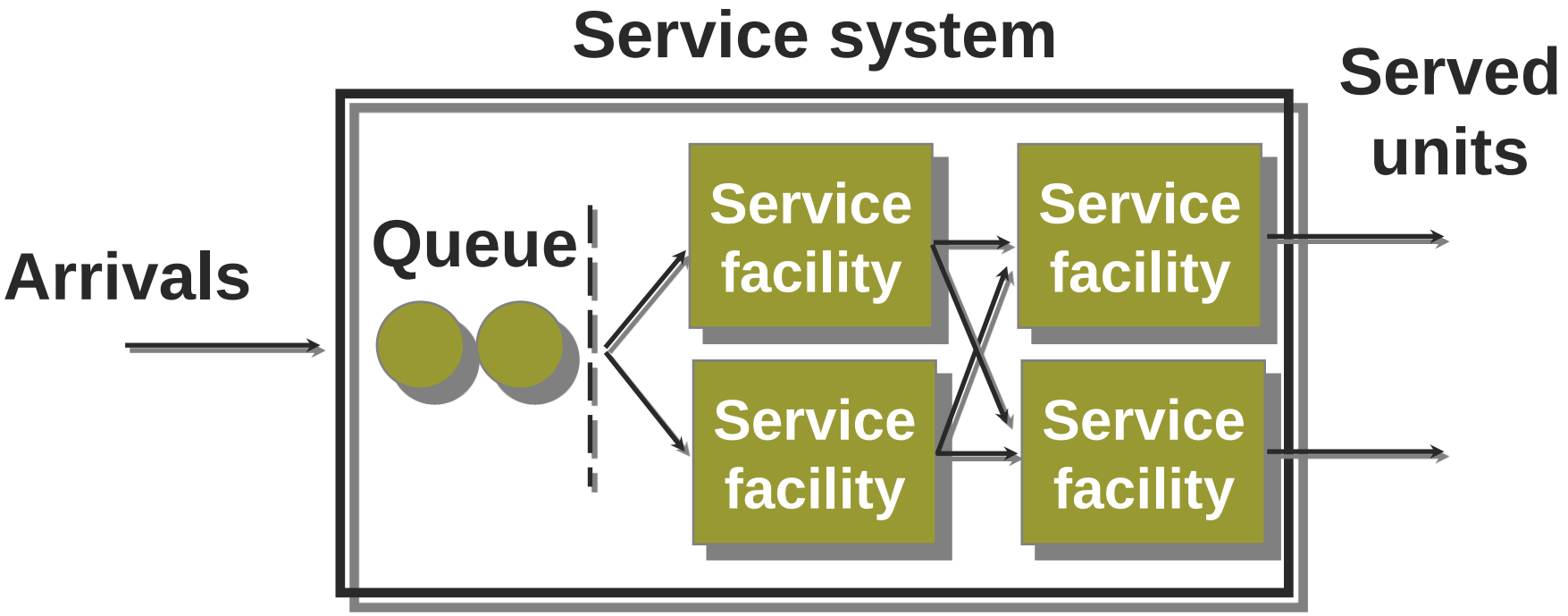


Multi-Channel, Single Phase System



Example: Bank customers wait in single line for one of several tellers.

Multi-Channel, Multi-Phase System



Example: At a laundromat, customers use one of several washers, then one of several dryers.

Waiting Line Priority Rules

- 1. First come, first served
- 2. Best customers first (reward loyalty)
- 3. Highest profit customers first
- 4. Quickest service requirements first
- 5. Largest service requirements first
- 6. Earliest reservation first
- 7. Emergencies first

Queue Psychology

- Unoccupied time vs. occupied time
- Pre-process wait vs. in-process wait
- Uncertain waits vs. certain waits
- Unexplained waits vs. explained waits
- Unfair waits vs. equitable waits
- Willingness to wait related to value
- Solo waits vs. group waits

Changing System Performance

- 1. Customer Arrival Rates
  - ✓ Ex: Try to smooth demand through non-peak discounts or price promotions
- 2. Number and type of service facilities
  - ✓ Ex. Increase or decrease number of servers, or dedicate specific servers for certain tasks (e.g., express line for under 10 items)
- 3. Change Number of Phases
  - ✓ Ex. Can use multi-phase system instead of single phase. This spreads the workload among more servers and may result in better flow (e.g., fast food restaurants having an order phase, pay phase, and pick-up phase during busy hours)

Changing System Performance

- 4. Server efficiency
  - ✓ Ex: Add resources to each phase (e.g., bagger helping a checker at the grocery store)
  - ✓ Ex: Use technology (e.g. price scanners) to improve efficiency
- 5. Change priority rules
  - ✓ Ex: implement a reservation protocol
- Change the number of lines
  - ✓ Ex: Reduce multiple lines to single queue to avoid jockeying
  - ✓ Ex: Dedicate specific servers to specific transactions

Summary

- What is scheduling
- Basic sequencing options
- Johnson’s rule
- Nature of Services
- Waiting Line Terminology
- Changing Service Performance