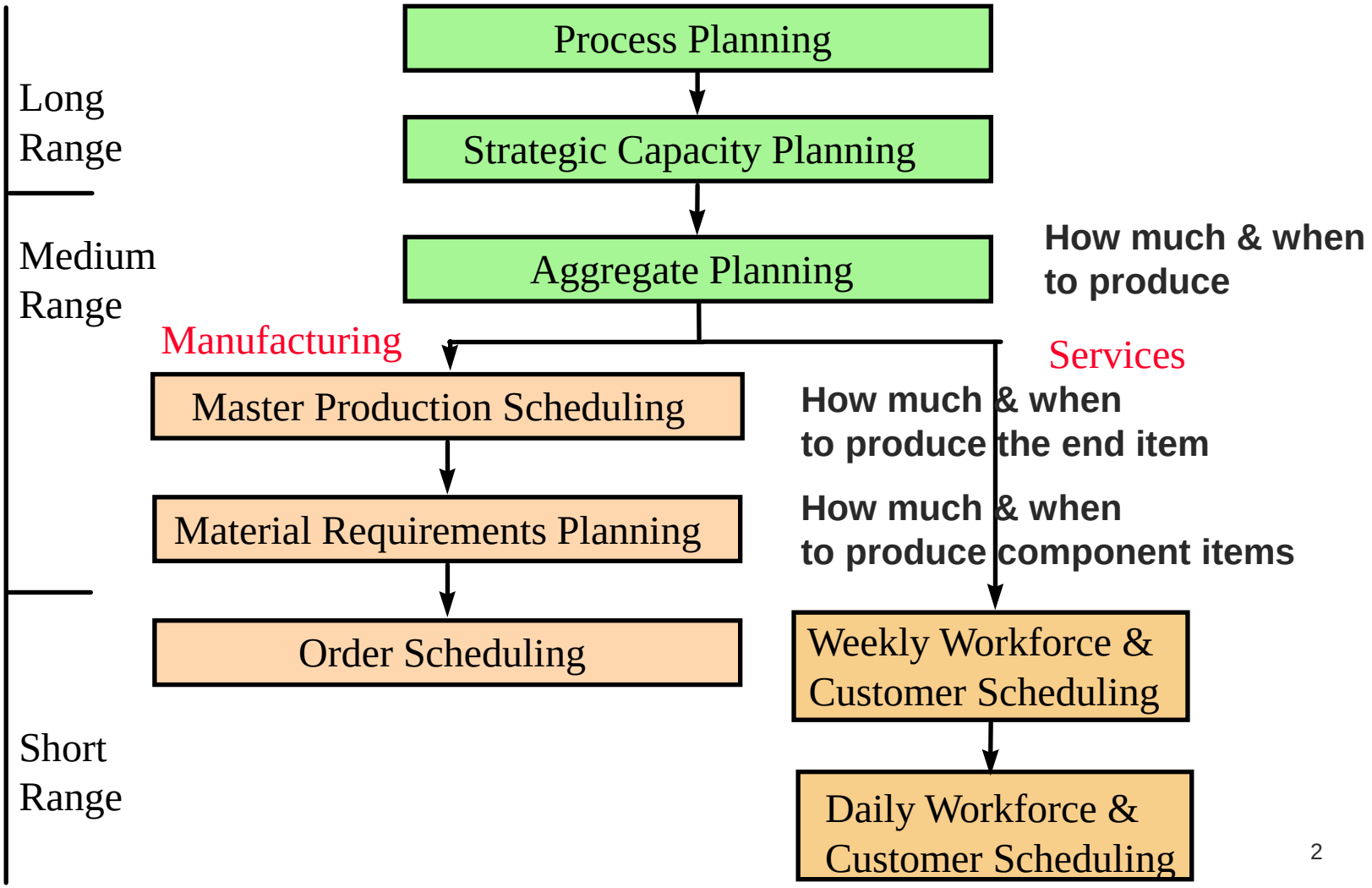
Operations Scheduling

Production Planning Process



Outline

- Scheduling
  - ✓ What is it?

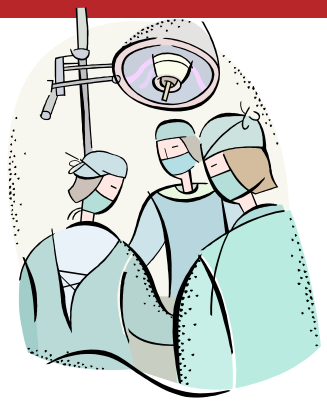
Scheduling involves fixing the priorities for different jobs and deciding the starting and finishing time (or date) of each job. It specifies when resources are needed to produce a product or provide a service.

  - ✓ Objectives
  - ✓ Sequencing rules
    - Single resource

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

UNCW

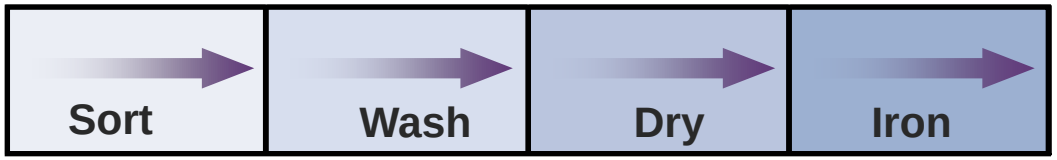
Classroom use

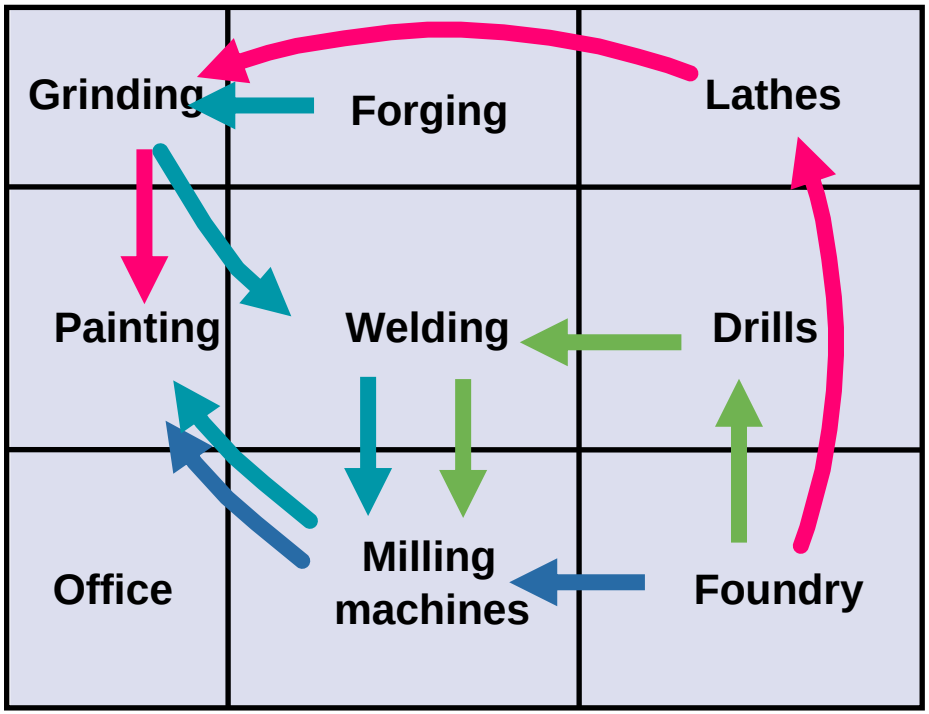
Instructor schedules

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 of jobs that are being processed***
  - ✓***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)

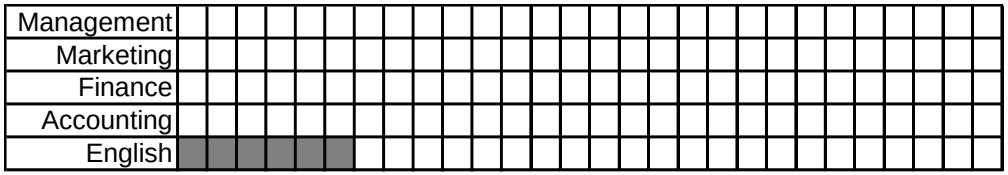
Jobs are processed in order of arrival

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)

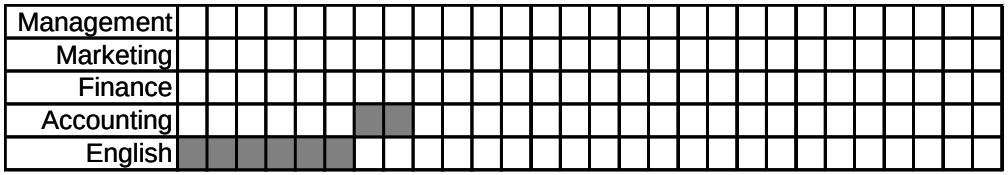


Processing time: 9 3 8 2 6

Time until due: 23 15 18 6 8

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

First Come First Served (FCFS)

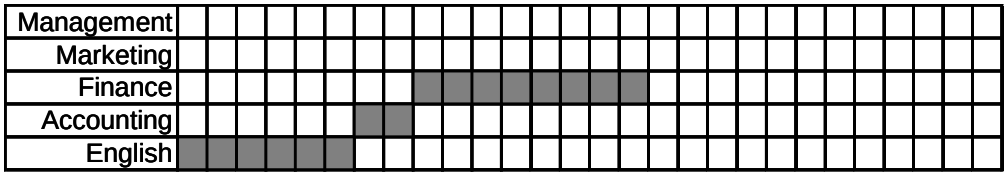


Processing time: 9 3 8 2 6

Time until due: 23 15 18 6 8

Management *Marketing* *Finance* *Accounting*

First Come First Served (FCFS)



Processing time: 9 3 8 2 6

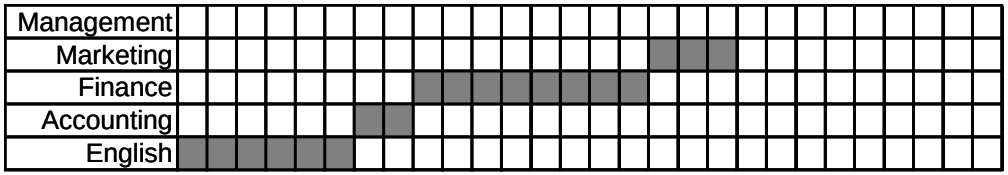
Time until due: 23 15 18 6 8

Management

Marketing

Finance

First Come First Served (FCFS)



Processing time: 9 3 8 2 6

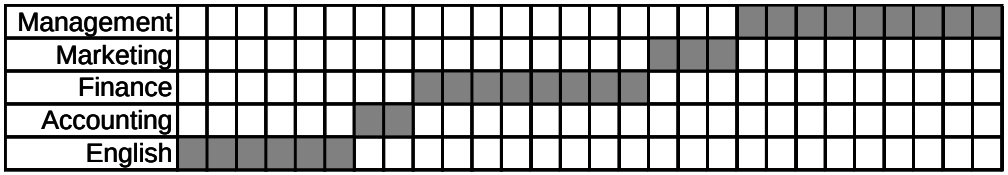
Time until due: 23 15 18 6 8

Management

Marketing

First Come First Served (FCFS)

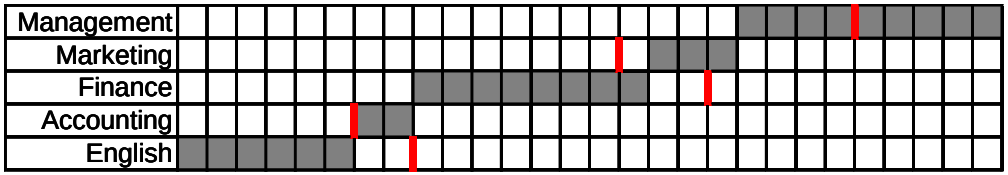
Superimposing due dates…



	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…



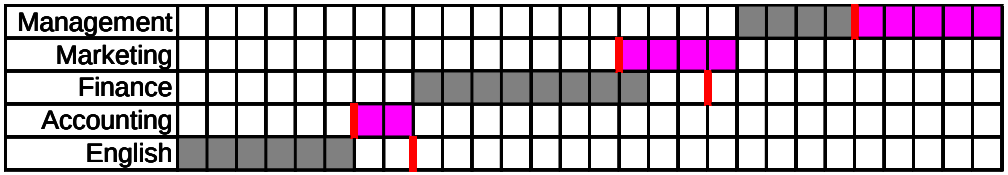
So 3 projects are late!!

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)

Superimposing due dates…

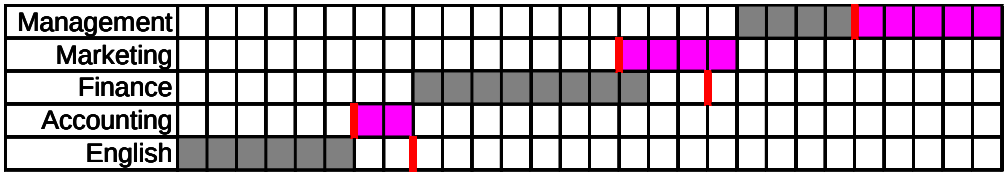


So 3 projects are late!!

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)



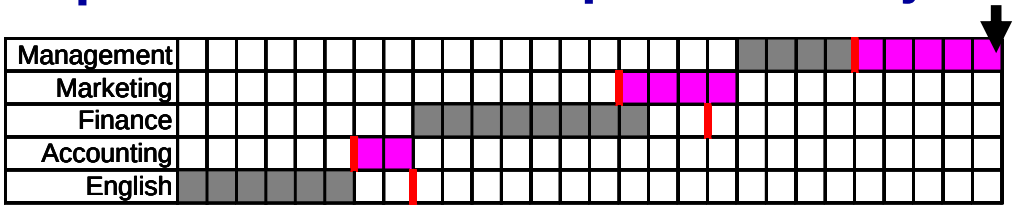
$$\text{Avg. job lateness} = \frac{\text{Total days late}}{\text{Number of jobs}} = \frac{11}{5} = 2.2 \text{ days}$$

	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



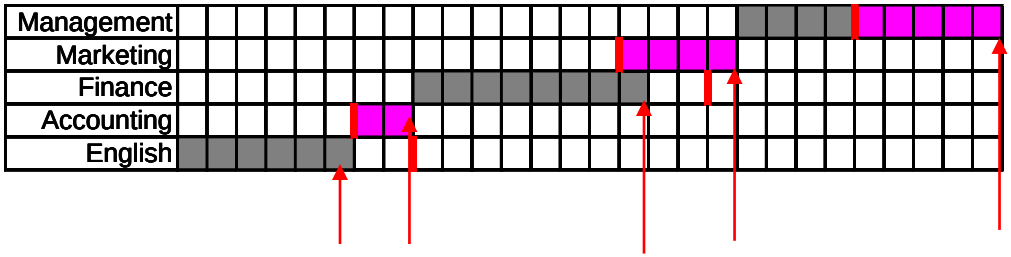
Flow time: Sum of times each job spends in waiting, and being processed

	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



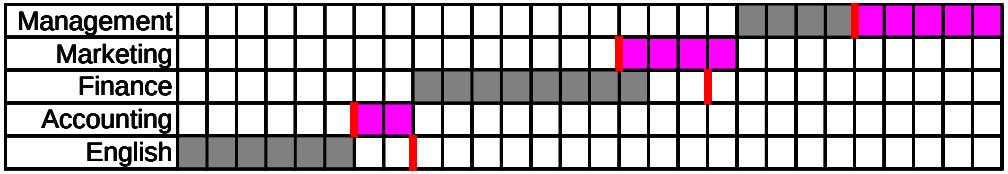
Flow time = 6 + 8 + 16 + 19 + 28 = 77

	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

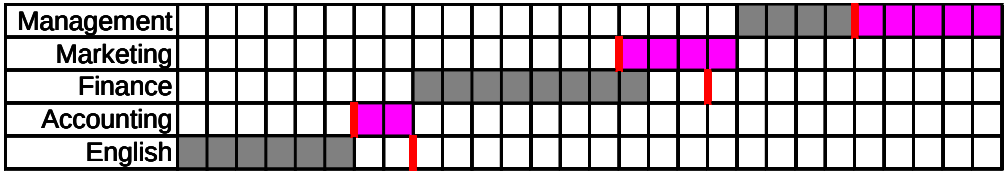
Average flow time = Sum of flow times / # jobs

	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

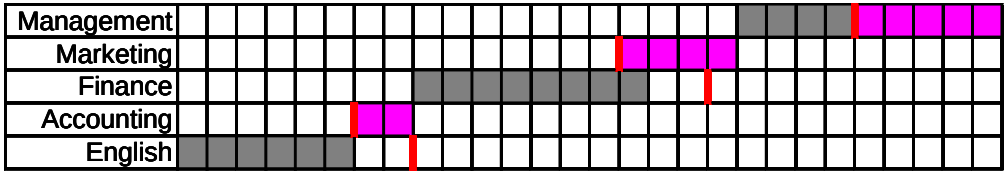
Average flow time = 77 days/5 jobs = 15.4 days/job

	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

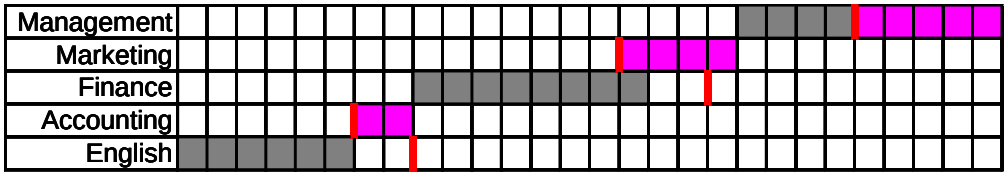
Avg # jobs in system = Sum of flow times / total processing time

	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

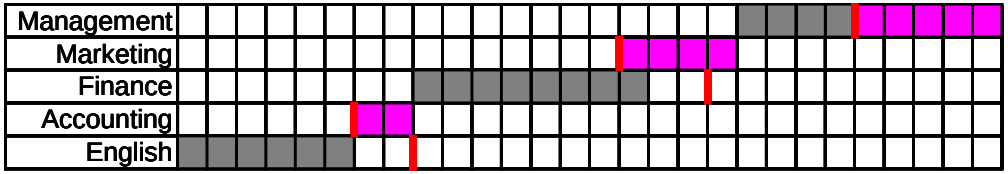
Utilization = Total processing time / sum of flow time

	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)

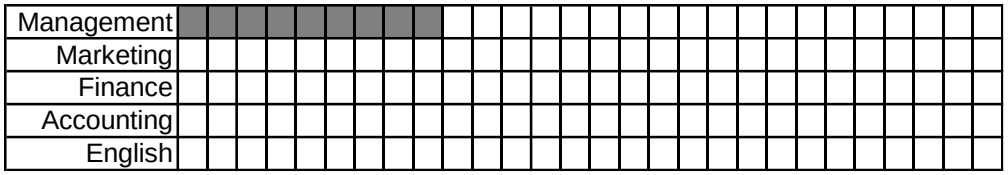
Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

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
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



	Management	Marketing	Finance	Accounting	English
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
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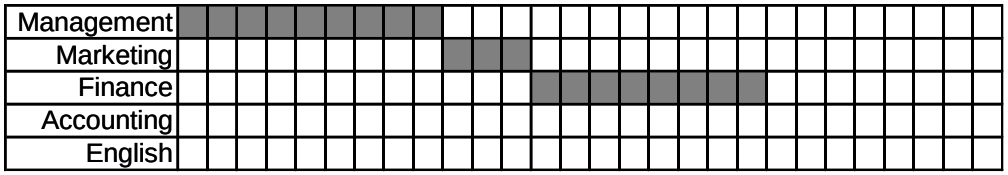
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

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

Marketing *Finance* *Accounting* *English*

Last Come First Served (LCFS)

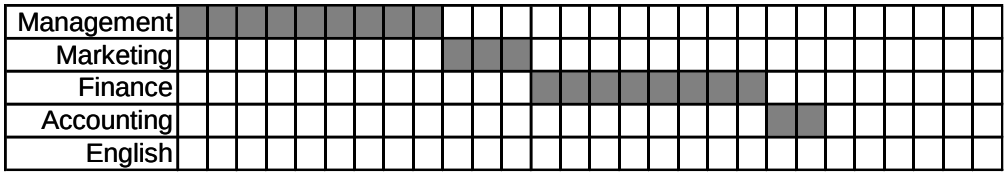
Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes



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



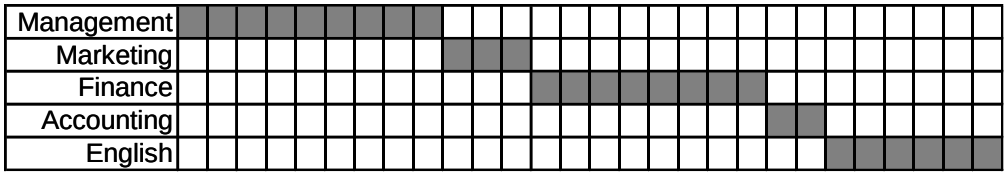
Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**

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…



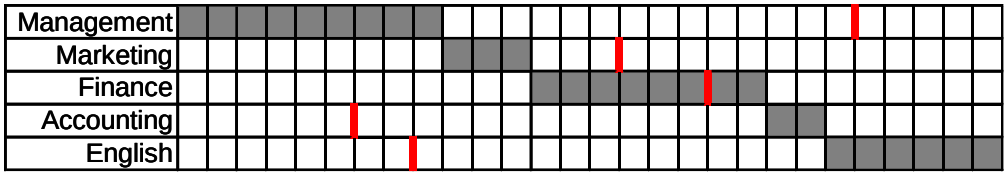
Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**

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…



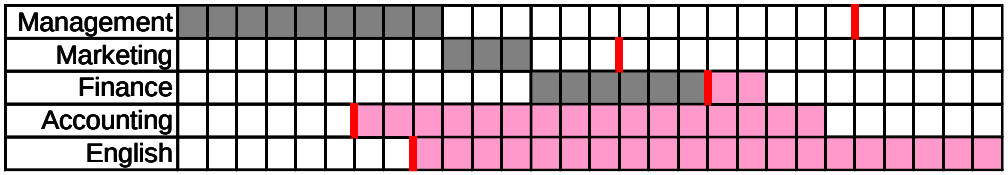
So 3 projects are late!!

Processing time:	**9**	**3**	**8**	**2**	**6**
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…



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

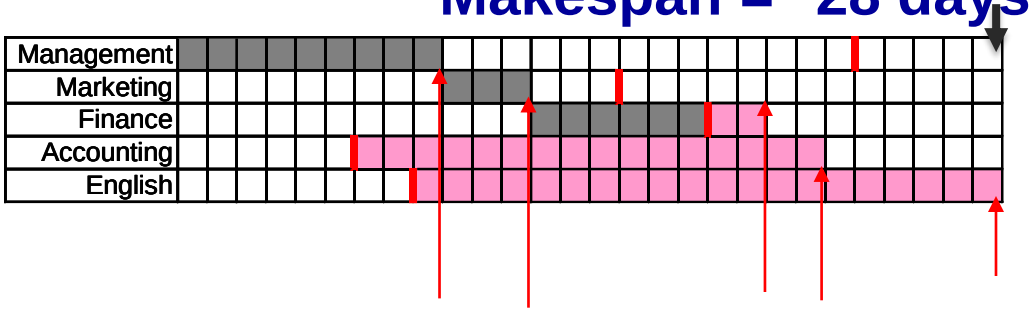
Processing time:	9	3	8	2	6
Time until due:	23	15	18	6	8

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)

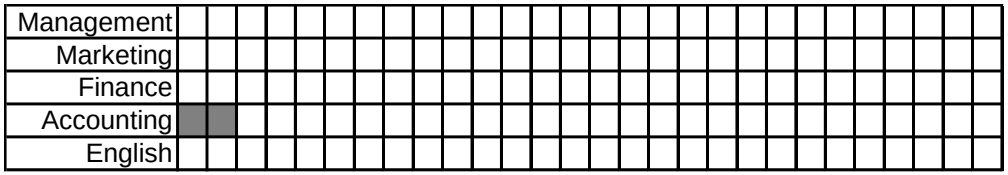
Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

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

Shortest Processing Time (SPT)

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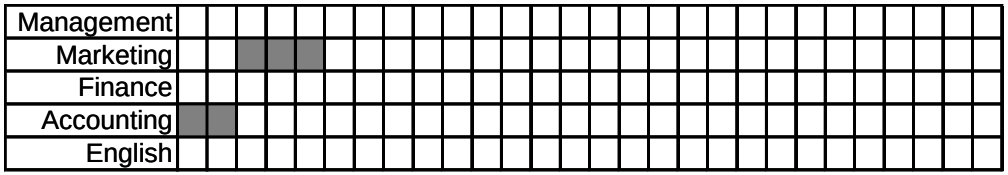


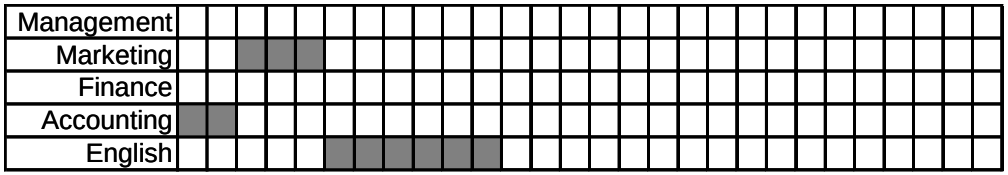
Processing time: 9 3 8 2 6

Time until due: 23 15 18 6 8

Management Marketing Finance English

Shortest Processing Time (SPT)

Avg job lateness =	Total days late / # jobs
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*** ***English***

Shortest Processing Time (SPT)

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Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
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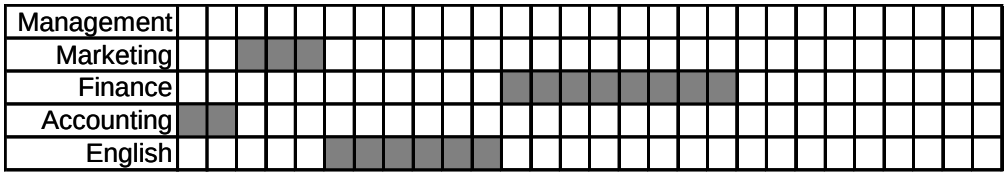


Processing time: 9 3 8 2 6

Time until due: 23 15 18 6 8

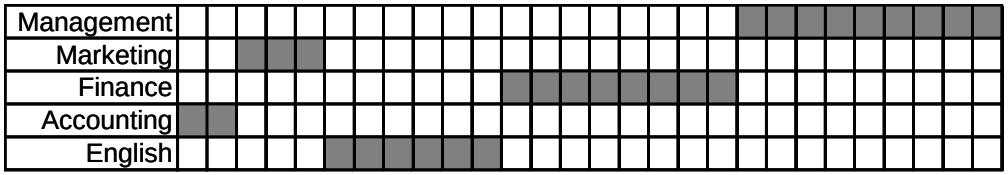
Management

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…



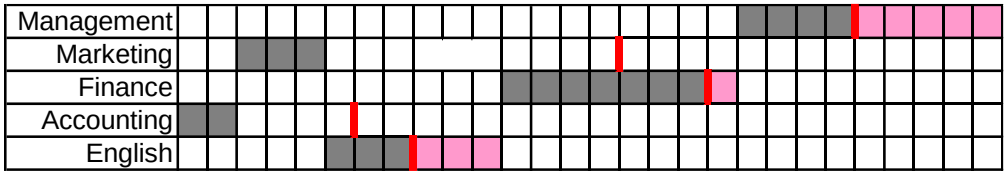
Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**

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…



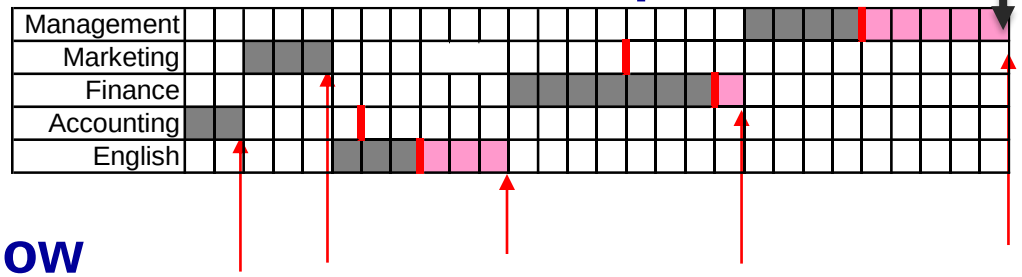
$$\text{Avg. job lateness} = \frac{\text{Total days late}}{\text{Number of jobs}} = \frac{9}{5} = 1.8 \text{ days}$$

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)

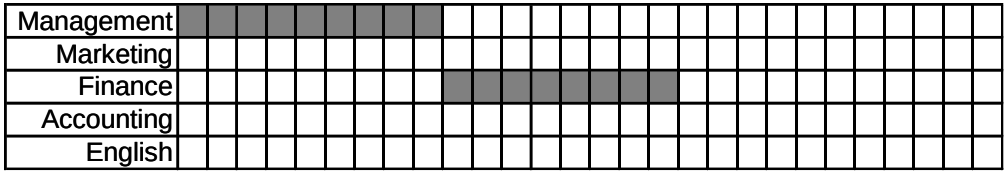
Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Management																									
Marketing																									
Finance																									
Accounting																									
English																									

	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



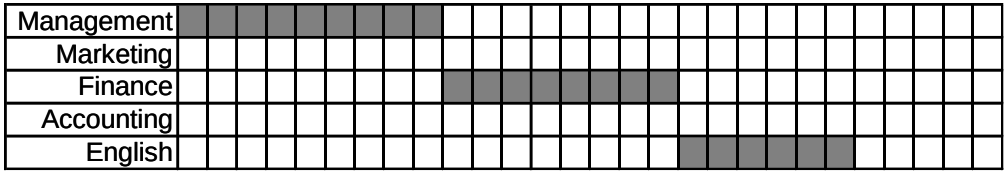
Processing time: 9 3 8 2 6

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



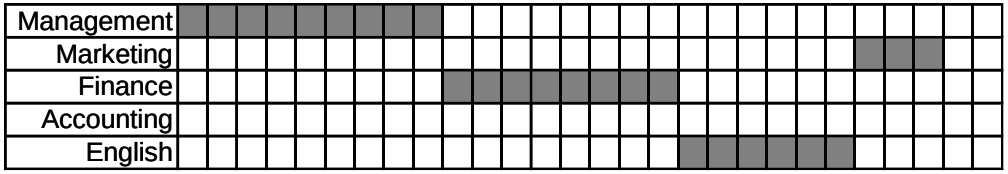
Processing time: 9 3 8 2 6

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**

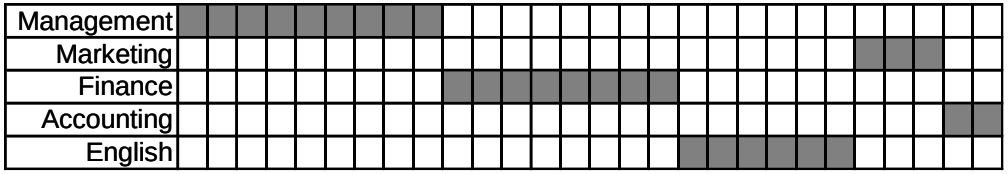
Marketing

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…



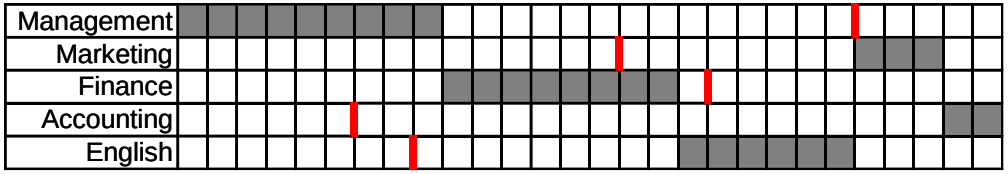
Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**

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

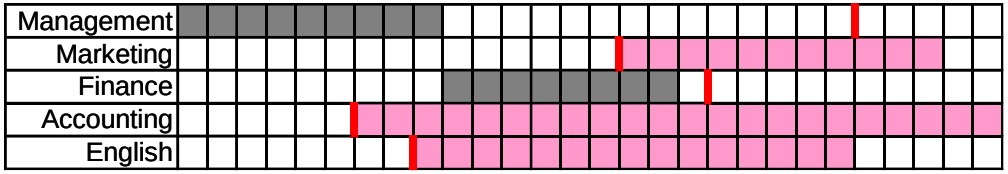
Superimposing due dates…



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



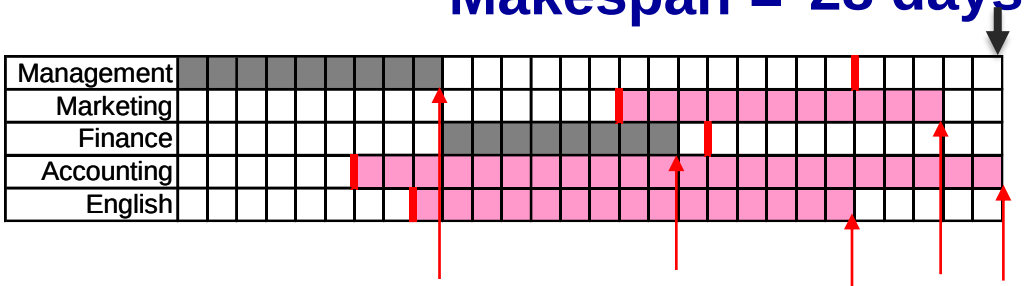
$$\text{Avg. job lateness} = \frac{\text{Total days late}}{\text{Number of jobs}} = \frac{48}{5} = 9.6 \text{ days}$$

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)

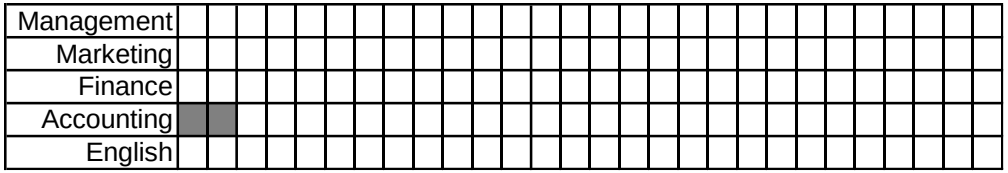
Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

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)

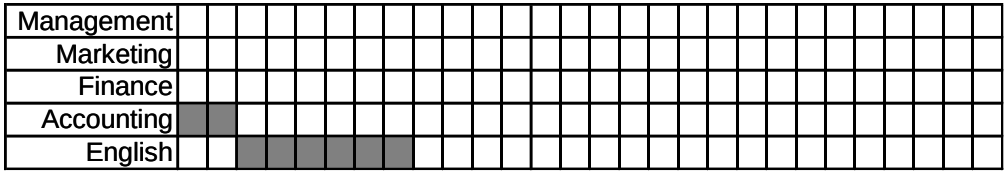
Avg job lateness =	Total days late / # jobs
Avg flowtime =	Sum of flowtimes / # jobs
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes



	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

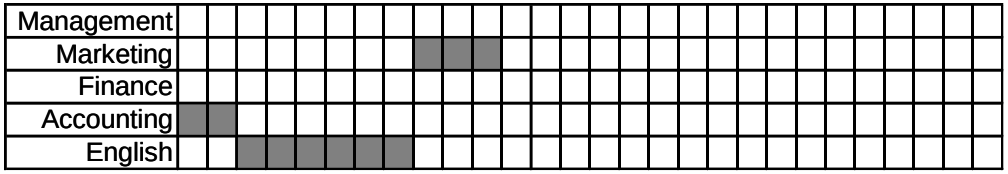


Processing time:	**9**	**3**	**8**	**2**	**6**
Time until due:	**23**	**15**	**18**	**6**	**8**

Management Marketing Finance English

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**
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Management

Marketing

Finance

Earliest Due Date (EDD)

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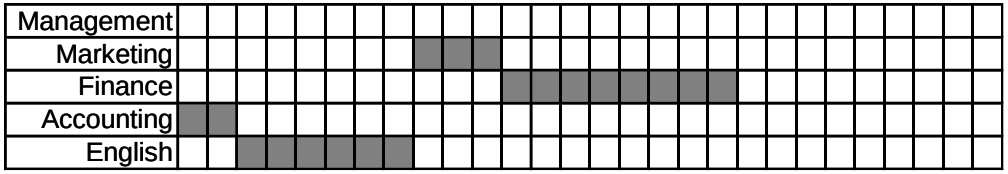

Processing time: 9 3 8 2 6

Time until due: 23 15 18 6 8

Management

Finance

Earliest Due Date (EDD)

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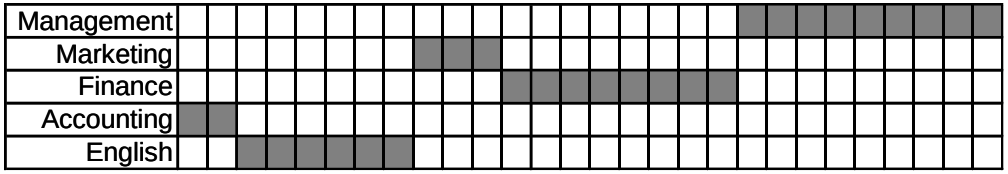
Avg # jobs =	Sum of flowtimes / Total processing time
Utilization =	Total processing time / Sum of flowtimes

Superimposing due dates…



Processing time:	**9**	**3**	**8**	**2**	**6**
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Management

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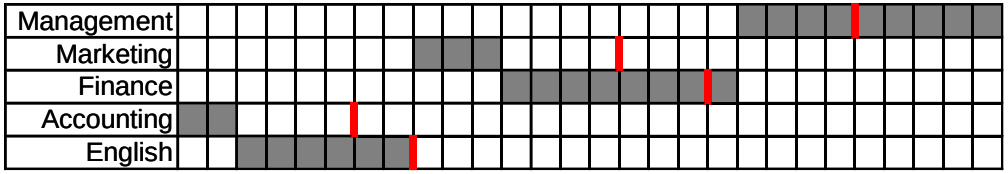
Superimposing due dates…



Processing time:	**9**	**3**	**8**	**2**	**6**
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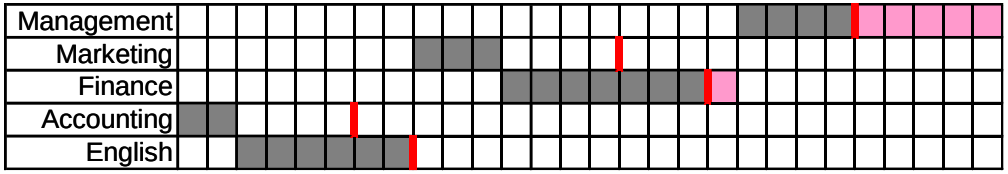
Superimposing due dates…



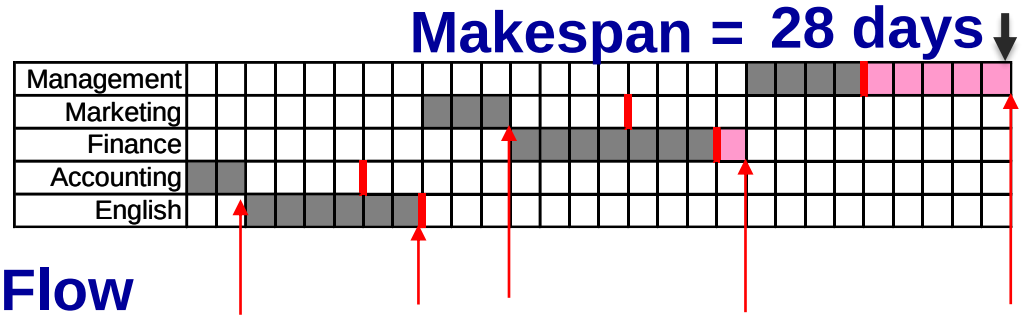
$$\text{Avg. job lateness} = \frac{\text{Total days late}}{\text{Number of jobs}} = \frac{6}{5} = 1.2 \text{ days}$$

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%