Chapter 3. Project Management

Session 1. WBS and AON Graph

Most of you are about to finish your undergraduate. Who wants to start his/her own company?

Suppose you have a very rich family, after graduation, you want to launch your own company. What is the most popular thing now? The internet. I have one idea for a long time, but I am not that rich so I am not going to take risk to quit my PhD program.

I remember when I was in my third year. I launched this program with several friends. We do develop one website. party.com/ Patent number/ CV/ similar hobbies

We want to launch a project, and it is a huge staff. When you see such a big thing, you may fear it. How should I start? What should I first do? You need to first break down the project into pieces.

WBS (Work Breakdown Structure)

WBS is a hierarchical and incremental decomposition of the project into phases, deliverables and work packages. It is a tree structure, which shows a subdivision of effort required to achieve an objective.
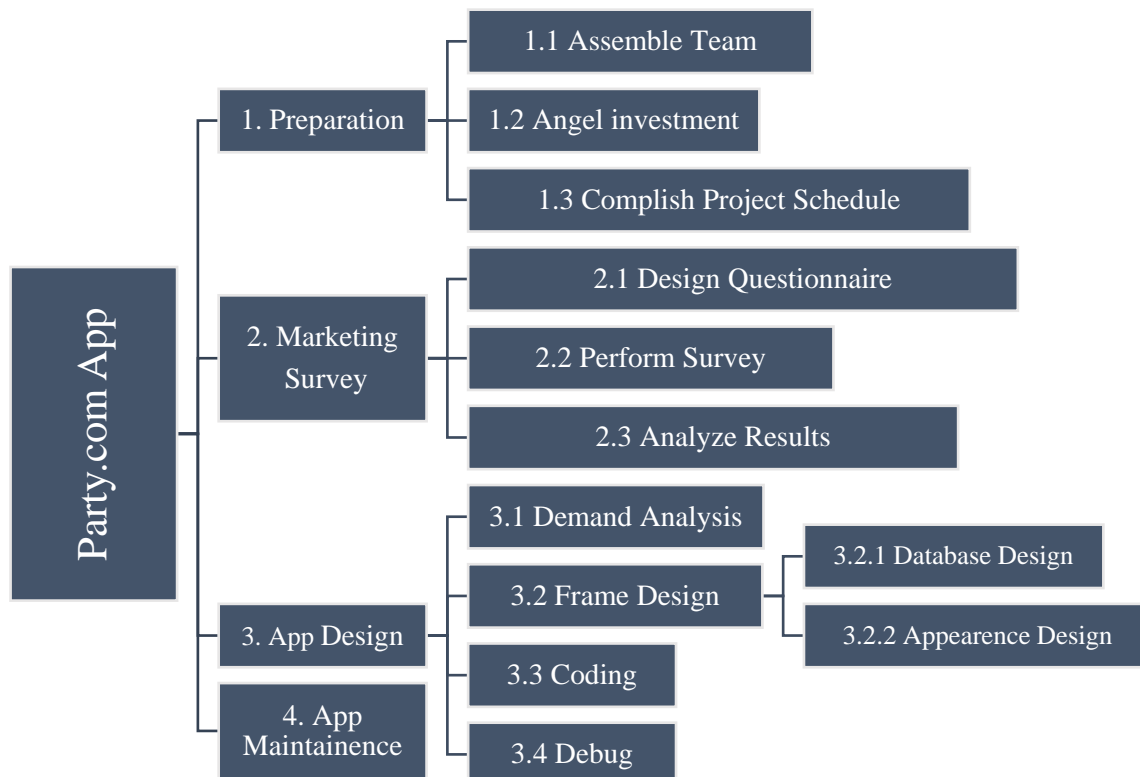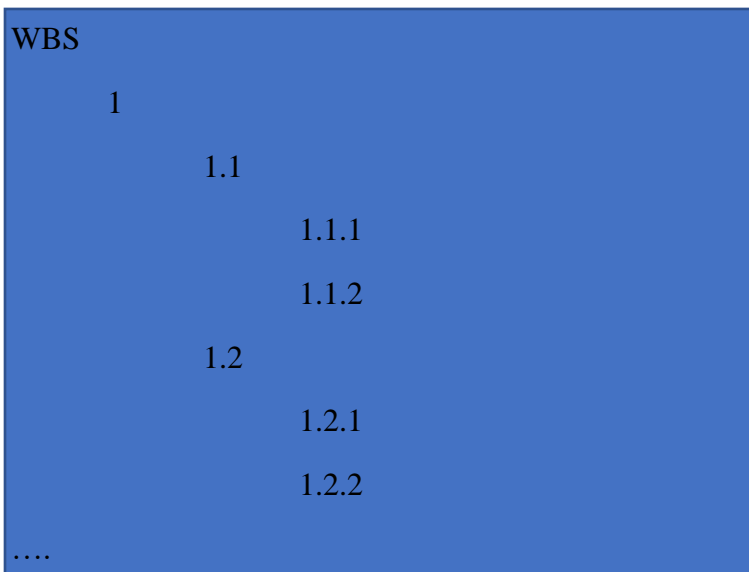
Practice:

Table Version

Level 0	Level 1	Level 2	Level 3
WBS	1	1.1	1.1.1
			1.1.2
		1.2	1.2.1
			1.2.2
	2	2.1	-
		2.2	-
	3	3.1	-
		3.2	3.2.1
			3.2.2

Convert this table to figure

Text version

WBS

   1

      1.1

         1.1.1

         1.1.2

      1.2

         1.2.1

         1.2.2

….

Several important things for a project:

1. Each step and how long each will take

2. The order of these steps

Important Question: How long to complete

Usually we summarize one project in the following table (activity (capital letter), description, predecessors, time)
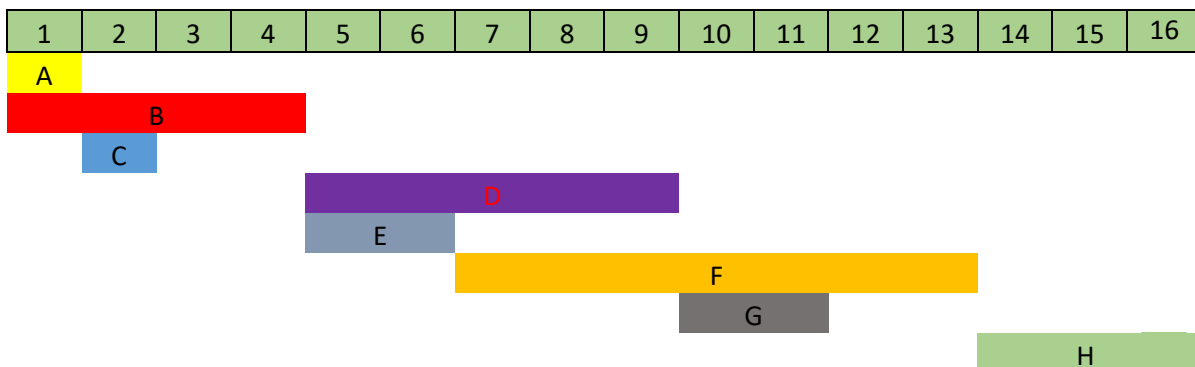
Activity	Description	Predecessors	Time
A	Assembling Team		1
B	Market Survey		4
C	Task Arrangement	A	1
D	App Design	B	5
E	Purchase facilities	B	2
F	App propaganda	C,E	7
G	App Coding	D	2
H	App Improvement	F,G	3

Activity-on-Node (AON) Graph

Can you draw a graph based on this table?
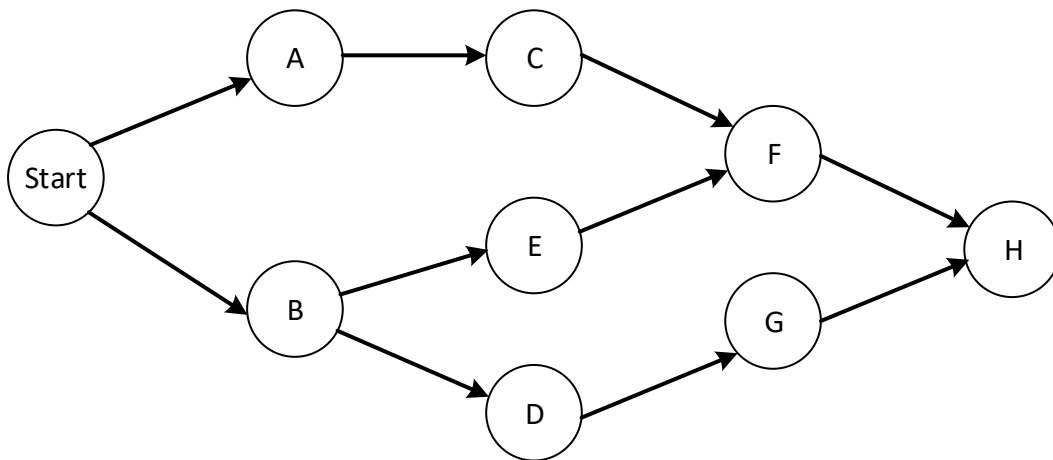
Klotski-Gantt charts

Gantt charts: planning charts used to schedule resources and allocate time.

Can you determine at least how long the project can be finished?

Can you move any rectangle without changing the total time of this project? Find by **backward**
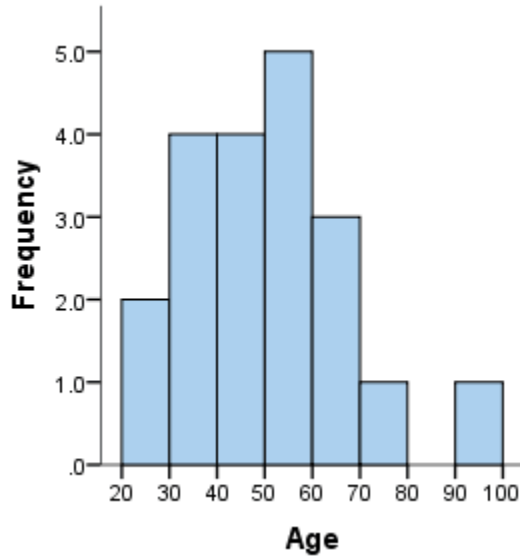
Review on Normal Distribution

Histogram

Age of 20 People

36	25	38	46	55	68	72	55	36	38
67	45	22	48	91	46	52	61	58	55

Age	Frequency	Scores Included in Bin
20-30	2	25,22
30-40	4	36,38,36,38
40-50	4	46,45,48,46
50-60	5	55,55,52,58,55
60-70	3	68,67,61
70-80	1	72
80-90	0	-
90-100	1	91

Suppose we are interested in all human beings' heights. Let's draw an extremely "fine" histogram. It will be very similar to a normal distribution graph.

Shape of normal distribution: Bell curve; Extreme points are few, and most points are in the "normal" range.

What is distribution?

Random variable X has different possibilities/status/situations with corresponding probabilities.

E.g. <u>Discrete random variable</u>, rolling a die, X is the number of the top side. (equal to a specific number) <u>Continuous random variable</u>, tomorrow's temperature (probability is meaningful only for range, larger than, smaller than, between)

Normal distribution

Normal distribution is very common; intuitively, extreme things happen rarely, general things happen a lot.

Animals' height/weight; Launch time of your computers

Rule of Thumb:

1 Something is effected by multiple factors

2 These factors will not influence each other

3 No factor dominates

There are two important things about Normal distribution, the mean and the variance. As long as we know these two parameters, we can draw a normal curve.

Normal Curve can help us understand the density of the probability:

Calculus and Area – Probability – between X-axis and normal curve

In this class, we concern how to calculate the probability, if we know the mean and variance of the normal curve.

Calculate Probability of **Standard** Normal Distribution: N (0, 1)

Transform to Standard Normal Distribution

The defect of a small part (screw) of a car is normal (average 0 millimeter (mm), Var 1 mm^2) ~ N (0, 1)

What is the probability the defect larger than 3 mm, 6mm?

Height ~ N (170, 12^2) How to calculate the probability of height larger than 180?

$\Phi(z) = p$

Given z, we can use the following formula to get p: p = NORM.S.DIST(z,TRUE)

Given p, we can use the following formula to get z: z = NORM.S.INV(p)

Assumption: Total project completion time ($\equiv$X) follows a normal distribution

$X \sim N(\mu, \sigma_p)$

Define $Z = \frac{X-\mu}{\sigma_p} \sim N(0,1)$

Calculate the probability that total project completion time (X) is less than a certain number t:

$P(X \leq t) = P\left(\frac{X-\mu}{\sigma_p} \leq \frac{t-\mu}{\sigma_p}\right) = P\left(Z \leq \frac{X-\mu}{\sigma_p}\right) = \Phi(\frac{X-\mu}{\sigma_p})$

$\Phi(\cdot)$ is the distribution function of standard normal distribution, which we can calculate by Excel.

The formula in Excel 2016

$= $ NORM.S.DIST($\frac{X-\mu}{\sigma_p}$,TRUE) (case insensitive)

The formula used here to calculate the DPMO is thus

$$DPMO = 1000000 \times (1 - \phi(level - 1.5))$$

(defects per million opportunities or DPMO)

Session 2. Critical Path Method (CPM)

A path is a sequence of connected activities running from start to end node in network,

The critical path is the path with the longest duration in the network.

Project cannot be completed in less than the time of the critical path.

(1. The critical path is the path with the longest duration in the network.

2. Project cannot be completed in less than the time of the critical path.

3. Activities will delay the entire project if they are late.

4. The shortest completion time of the project is the length of the critical path.)

Find the critical path

Assumption; project starts from the 0th day.

Earliest Start (ES): Earliest time at which an activity can start, assuming all predecessors have been completed

$$ES = Max \{EF \ of \ all \ immediate \ predecessors\}$$

Earliest Finish (EF): Earliest time at which an activity can be finished

$$EF = ES + Activity \ Time$$

$$Slack = LF - EF, \; or \; Slack = LS - ES$$

$$Earliest \; Finish = Latest \; Finish$$

Latest Start (LS); Latest Finish

$$LF = Min \,\{LS \; of \; all \; immediate \; following \; activities\}$$

$$LS \; = \; LF - \; Activity \; Time$$

Activity	Predecessors	Immediate Following	Time	Followers	ES	EF	LS	LF	Slack
A		C	1	C	0	1	4	5	4
B		D,E	4	D, E	0	4	0	4	**0**
C	A	F	1	F	1	2	5	6	4
D	B	G	5	G	4	9	6	11	2
E	B	F	2	F	4	6	4	6	**0**
F	C,E	H	7	H	6	13	6	13	**0**
G	D	H	2	H	9	11	11	13	2
H	F,G	-	3		13	16	13	16	**0**
					Project	**16**			
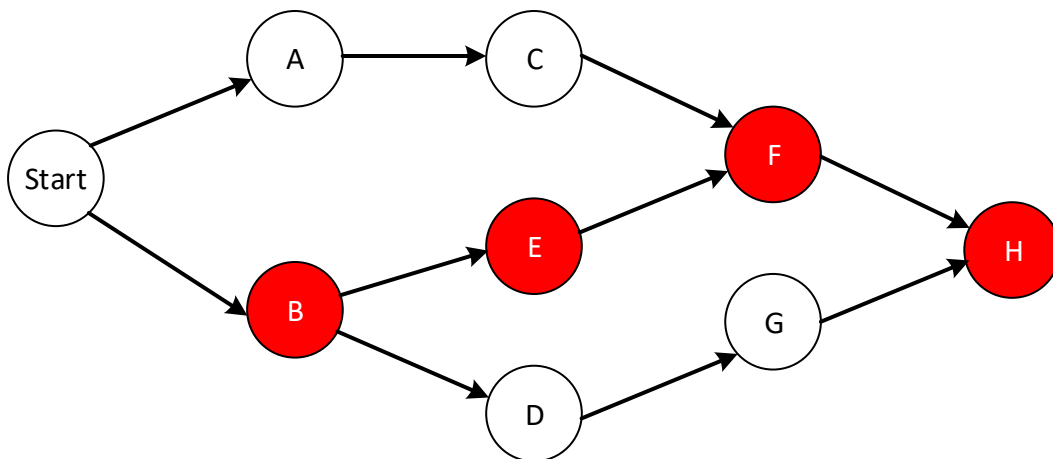
Slack: Free time for an activity.

Session 3. Program Evaluation and Review Technique (PERT)

CPM and PERT:

1 Both of them were developed in 1950s to help managers schedule, monitor and control large and complex projects.

2 CPM arrived first, as a tool to assist in the building and maintenance of chemical plants at DuPont.

3 Independently, PERT was developed in 1958 for U.S. Navy.

4 The main difference between this two is that:

PERT employs three time estimates for each activity, enabling us to compute the probability that we can complete the project by a target date.

CPM makes assumption that activity times are known with certainty and hence requires only one time factor for each activity.

Three times estimates:

Optimistic Time (a) = time an activity will take if everything goes as planned.

Pessimistic Time (b) = time an activity will take assuming very unfavorable conditions.

Most likely Time (m) = most realistic estimate of the time required to complete an activity.

Activity	Expected Time	Optimistic (a)	Most Likely (m)	Pessimistic (b)	Variance
A	1	0.5	1	1.5	0.028
B	4	1	4	7	1.000
C	1	0.5	1	1.5	0.028
D	5	4	5	6	0.111
E	2	1	2	3	0.111
F	7	5	6	13	1.778
G	2	1	2	3	0.111
H	3	1	2	9	1.778

μ = expected project completion time = $\sum expected\ time\ of\ critical\ path$

Expected Time: $t = (a + 4m + b)/6$

Variance: $[(b - a)/6]^2$

Project Variance:

$\sigma_p^2 = \sum variances\ of\ activities\ on\ critical\ path$

$\sigma_p^2 = 1.000 + 0.111 + 1.778 + 1.778 = 4.667$

Project Standard deviation

$\sigma_p = \sqrt{project\ variance}$

$\sigma_p = \sqrt{4.667} = 2.160$

The critical path analysis determines the expected project completion time.

μ = expected project completion time

Assumption: Total project completion time ($\equiv$X) follows a normal distribution

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Define $Z = \frac{X-\mu}{\sigma_p} \sim N(0,1)$

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Organization Culture / Enterprise Culture / Corporate Culture

お誕生日プレゼント

"You" is considered impolite.

Siemens & China Northern Locomotive & Rolling Stock Industry (Group) Corporation

incorporate yourself into that group/

Session 4. Project Crashing

A review on critical path:

1. The critical path is the path with the longest duration in the network.

2. Project cannot be completed in less than the time of the critical path.

3. Activities will delay the entire project if they are late.

4. The shortest completion time of the project is the length of the critical path.

Two ways to find critical path:

1. Gantt Charts

2. Slack Time

An alternative way to find critical path using AOA graph (textbook example):

Activity	Activities Details	Time	Pred 1	Pred 2
A	Build Internal Components	2		
B	Modify Roof/Floor	3		
C	Construct Stack	2	A	
D	Pour Concrete/Install Frame	4	A	B
E	Build Burner	4	C	
F	Install Controls	3	C	
G	Install Pollution Device	5	D	E
H	Inspect/Test	2	F	G
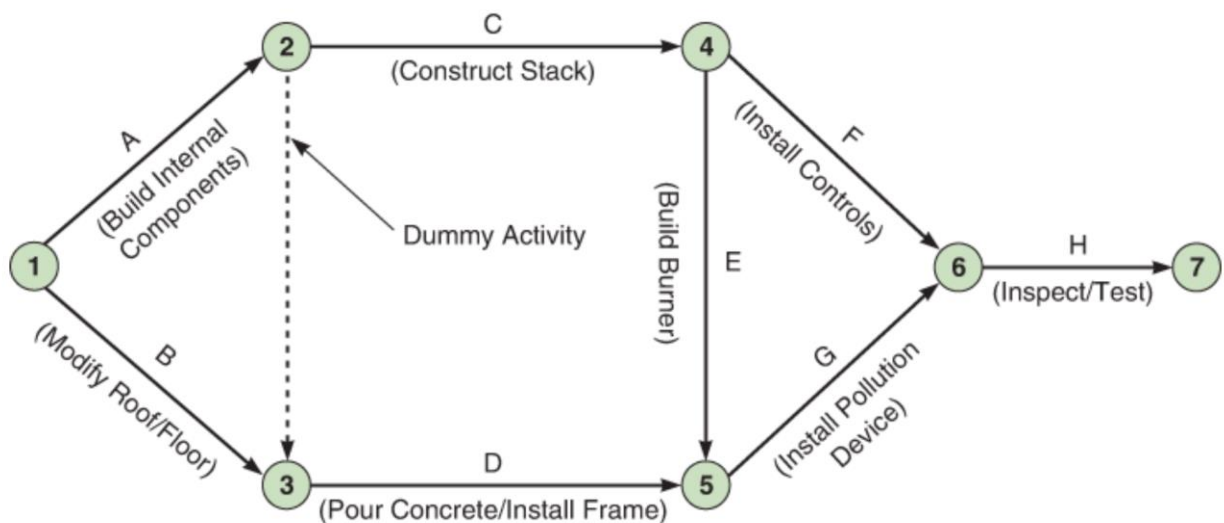
The dummy activity consumes no time, but note how it changes the precedence. Now activity D cannot begin until both B and A are complete.

Find the path with the longest duration:

A-C-F-H: 2+2+3+2 = 10

A-C-E-G-H: 2+2+4+5+2 = 15

A-D-G-H: 2+4+5+2 = 13

B-D-G-H: 3+4+5+2 = 14

Can one project have multiple critical path?

E.g.

Activity	Time	Pred 1	Pred 2
A	1		
B	3		
C	2	A	
D	4	A	B
E	4	C	
F	3	C	
G	5	D	E
H	2	F	G

Normal Time/Standard Time

CPM: The time of each activity in CPM is fixed

PERT: Expected time

Define cost of each activity: normal cost, resource (equipment, people)

Motivation:

(1) The project is behind the schedule

(2) The scheduled project completion time has been moved forward

Crashing: Shorten activity time in a network to reduce time on the critical path so total completion time is reduced. (by adding extra resource such as equipment people)

Crash time: shorter than normal time

Crash cost: higher than normal cost

	Time (Weeks)		Cost ($)			
Activity	Normal	Crash	Normal	Crash	Predecessors	Crash Cost Per Period
A	2	1	22,000	22,750		750
B	3	1	30,000	34,000		2000
C	2	1	26,000	27,000	A	1000

D	4	3	48,000	49,000	A, B	1000
E	4	2	56,000	58,000	C	1000
F	3	2	30,000	30,500	C	500
G	5	2	80,000	84,500	D, E	1500
H	2	1	16,000	19,000	F, G	3000

We want to crash the project down to 13 weeks.

Step1: Compute crash cost per period.

$$\text{Crash Cost per Period} = \frac{Crash\ Cost - Normal\ Cost}{Normal\ Time - Crash\ Time}$$

Step2: Using current activity times, find the critical path (s)

Step3:

 -1) If there is only one critical path, select the critical activity that a) can still be crashed and b) has the smallest crash cost per period. Crash this activity by one period.

 -2) If there are more than one critical paths, then select one activity from each critical path such that a) each selected activity can still be crashed and b) the total crash cost per period of all selected activities is the smallest. Crash each activity by one period.

Note that the same activity may be common to more than one critical path.

Step 4: Update all activities times. If the desired due date has been reached, stop. If not, return to Step 2.

Answers:

1. To crash the project down to 13 weeks, we should crash Activity A by 1 week and activity G by 1 week.

2. The total additional cost will be 2250. (This is important because many contracts for the projects include bonuses or penalties for early or late finishes.)

Suppose, finishing this project in 13 weeks will get a 2000 bonus, what will be the manager's decision?