Project Control & Management

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Lecture 9

Subjects

Project Management in Engineering Environments

1. Process breakdown for **Delivery**
2. Product **Integrity and Reliability**
3. **Cost** factors and management (Cost Control)
4. **Planning and Scheduling**

Recommended Reading

Project Management, A system approach to planning, scheduling and controlling; 11th Edition, **H. R. Herzner**, Wiley, 2013. ISBN: 978-1-118-02227-6

Project Planning

"Planning can be described as the function of selecting the enterprise objectives and establishing the policies, procedures and programmes necessary for achieving them." (Herzner 2013)

Project Mangers need to:

- Plan, integrate and execute the plans
- Prioritisation of resources requires detail planning
- Establish course of action within an uncertain environment

Project plans need to be ***Systematic*, *Flexible*, *Disciplined*, and** capable of incorporating ***multi-functional inputs.***

Project Scheduling

1. Estimating Activity Time
2. Estimating Total Project Time
3. Total PERT/CPM Planning
4. Crash Time
5. Precedence Networks

1. Estimating Activity Time

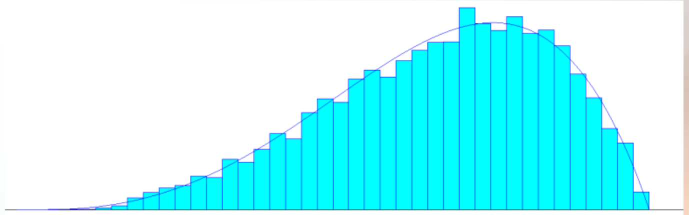
- Determining the elapsed time between events relies heavily on best estimates by the project manager.
- These estimates fall into 3 categories:
  1. **Optimistic Time:** Assuming everything goes as planned and all milestones are achieved in an orderly fashion.
  2. **Pessimistic Time (worst case scenario)**: things could wrong and there will be problems with activities, that would delay the delivery of the milestones.
  3. **Most Likely Completion Time:** The is the time that things normally happen. Requires a good historical knowledge of events, capabilities and performance of contractors etc. *(discuss probability density function and goodness of fit techniques)*

Most Likely Completion Time

According to Herzner (2013):

Provided that:

1. the Standard Deviation σ to be 1/6 of the time requirement range (the end points of the curve being *3σ* from the *mean time*
2. The probability distribution of the time to complete an activity to follow a Beta distribution



Then the expected time between events can be:

$$t_e = \frac{a+4m+b}{6}$$

a: optimistic time, b: pessimistic time, m: most likely time.

Example

If $a = 4\ \ and\ b = 8\ \ and\ m = 5\ then\ t_e = \frac{4+20+8}{6} = 5.3 \rightarrow 6\ \text{time units}$

This value can the be used for activity time in the PERT chart.

2. Estimating total Project Time

For estimating the probability of completion of a project on time

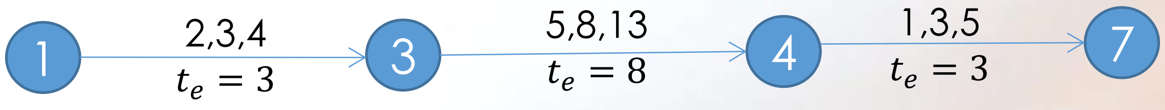
1. the standard deviation of each activity must be known:

$$\sigma_{te} = \frac{b-a}{6}$$

2. Also the variance needs to be known

$$v = \sqrt{\sigma}$$

Assume the critical path of a project to be:



$$\sigma_{te} = \frac{4-2}{6} = 0.33 \qquad \sigma_{te} = \frac{13-5}{6} = 1.33 \qquad \sigma_{te} = \frac{5-1}{6} = 0.67$$

The total STDev of the path:

$$\sigma_{total} = \sqrt{{\sigma^2}_{1-3} + {\sigma^2}_{3-4} + {\sigma^2}_{4-7}} = 1.525$$

Estimating project Time continued

- Assuming that the spread of project completion follows a normal distribution we can estimate with high confidence interval that the project will:
  - With 68% probability finish within one σ
  - With 95% probability finish within 2σ
  - With 99.7% probability finish within 3σ

Example

Assume the Critical Path of a project to be:

Activity	Optimistic Time	Most Likely Time	Pessimistic Time	t_e	σ	σ^2
A	3	4	5	4	2/6	1/9
B	4	4.5	8	5	4/6	16/36
C	4	6	8	$\underline{6}$	4/6	$\underline{16/36}$
				$\sum_{te} = 15$		1.0

Length of critical path = 15, the STDev $\sqrt{\sigma^2} = 1$

Therefore, the probability of completing the project within 1σ or 16 weeks = 50%+(1/2)(68%)=84%
within 2σ or 17 weeks = 50% +(1/2)(95%)= 97.5%
Within 3σ or 18 weeks = 50% + (1/2)(99.73%) = 99.87%
With -1σ or 14 weeks = 50% -(1/2)(68%)= 16%
Within -2σ 13 weeks = 50% -(1/2)(95%) = 2.5%

Recall Total PERT/CPM Planning (Lecture 8)

The continuous monitoring and adjusting resources and time factors for the purpose of delivery the project milestones in the:

- Best time
- Least cost
- Least risk
- Understanding alternatives and their practicability
- Optimum schedules
- Effective use of resources
- Effective and efficient communication
- Effective project control

Within the constraints of:

Contractual obligations, availability of cash, limited resources, and meeting company's objectives.

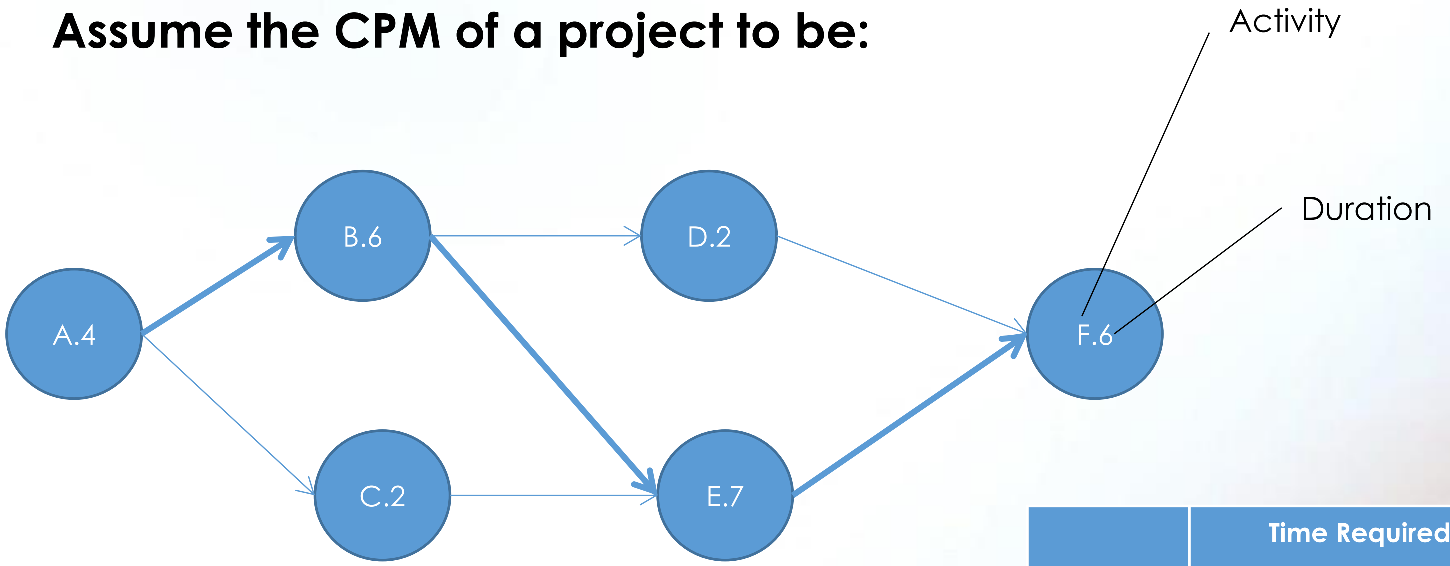
Crash Times

- PERT is event oriented (completion of activities) and there is no possibility to use percentage of activity completion
- CPM on the other hand is activity-based allowing for measuring the percentage of completion.
- CPM is normally used for process industry, construction or single project activities.
- Using CPM project managers can assess the cost of speeding or crashing (shortening activity time by allocation of further resources), certain stages of the project.
- By using CPM diagrams project manager can visualise the cost of crashing.
- Crash time is the minimum required time to complete an activity (normally requires increase in capacity/resources)
- Crash times are only possible with activities that can logically be done quicker by allocating extra resources (**Not all activities can be crashed)**

Example on CPM Crashing Cost

(see Herzner 2013, pp 620-626)

Assume the CPM of a project to be:

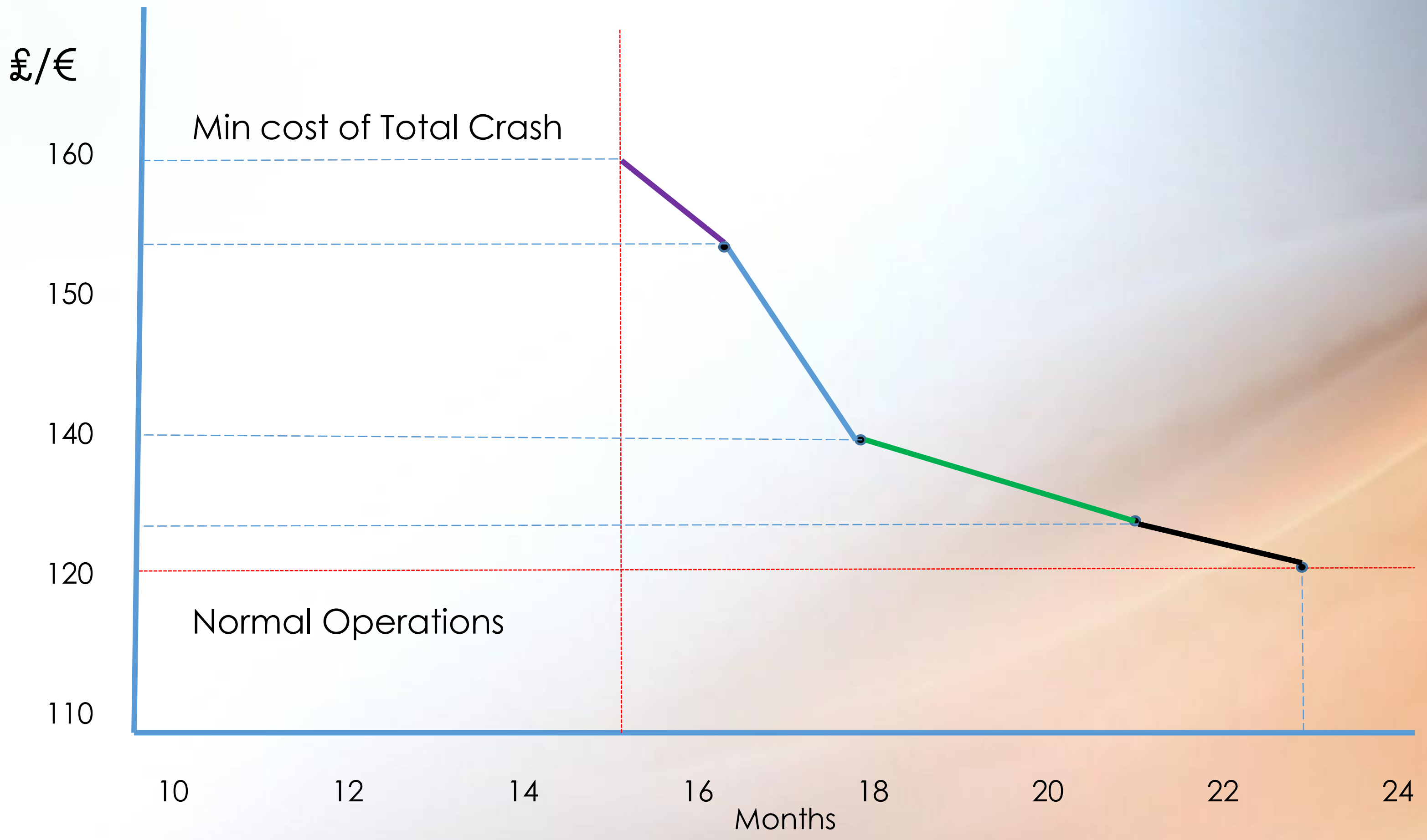


	Time Required		Cost (1000)		Crashing Cost/Per Time Unit (1000)
Activity	Actual	Crash	Normal	Crash	
A	4	2	10	14	2
B	6	5	30	42	12
C	2	1	8	9.5	1.5
D	2	1	12	18	6
E	7	5	40	52	6
F	6	3	20	29	3

Consider Crashing the Critical Path

- CP: A-B-E-F
- CP Normal Time = 23
- Potential Crash for CP = 2+1+2+2+3 = 8 new CP could be 15
- In this case even with crashing critical path, the critical path does not change.
- Start Crashing with the lowest cost
- Total Cost of Activity A Crash = $(2 \times 2000) = 4{,}000$
- Activity C is not considered because it is not on the CP
- Total Cost of Activity F Crash = $(3 \times 3000) = 9{,}000$
- Total Cost of Activity E Crash = $(2 \times 6000) = 12{,}000$
- Total Cost of Activity B Crash = $(1 \times 12000) = 12{,}000$
- Total Cost of Crashing CP = 37000
- The total project cost can range from 120,000 to 157,000.

CPM Crashing Costs Plot (see Herzner 2013, pp 620-626)

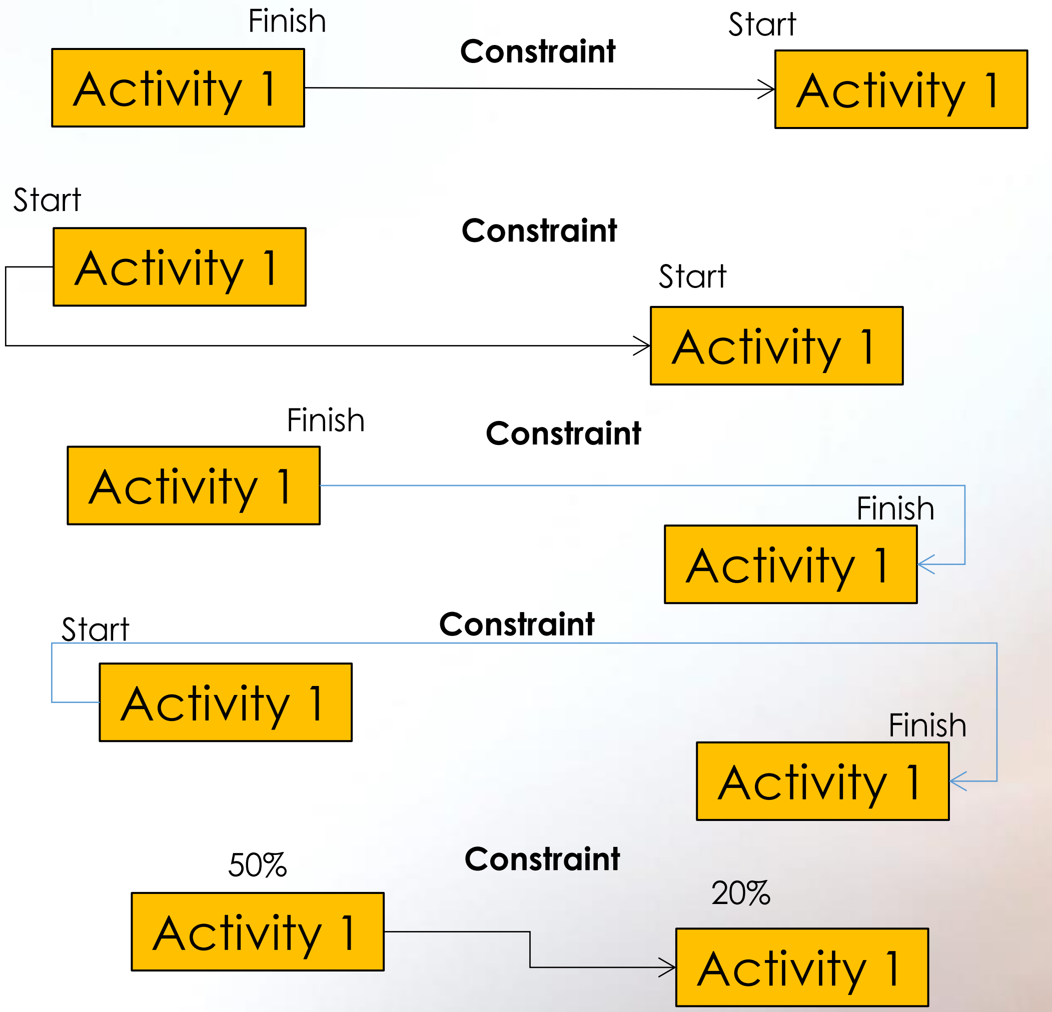


Precedence Network

Project management packages provide precedence networks in various formats, but all ae designed to include:

- The limitations of resources and its effect on the project
- What happens if a change occurs to the requirements during the projects?
- The cash flow situation
- Is there any cash repercussions if there are overtime?
- What additional resources are required to mitigate against constraints?
- How changes in priority of a Work Breakdown Structure (WBS) affect the total project?

Precedence Network Presentation



Finish to Start

Start to Start

Finish to Finish

Start to Finish

Percent Completed

The Teaser

- Line Balancing Example
- A Heuristic Method to Balance Tasks, Resource, with respect to Precedence Network
- Designed for Assembly Lines (imagine your project is an assembly line of activities or physical products!

Challenges of Line Balancing

- Each workstation and operator is given equal amount of work
- Prevent bottlenecks
- Divide the total content into minimum rational work elements
- Sequence of work needs to be satisfied

Work Content Time

$$T_{wc} = \sum_{k=1}^{n_e} T_{ek}$$

Where T_{ek} time for each work element e.g. mounting wheel on wheel hub engaging bolts and tightening bolts with pneumatic tool

$$T_{si} = \sum_{k \in i} T_{ek}$$

Where T_{si} is the total time available to station i

And

$$T_{wc} = \sum_{i=1}^{n} T_{si}$$

n is the total number of stations

Example [Groover 2001]

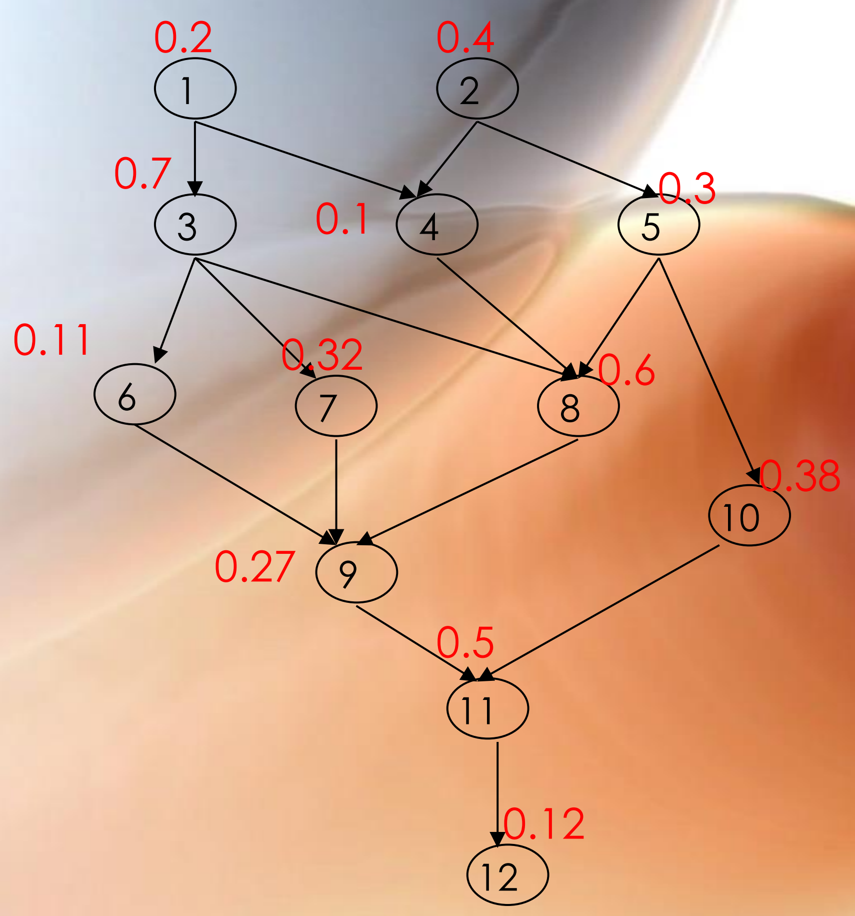
- A small manufacturing line for electronic appliance is a single model assembly line
- The work content and the sequence of each task is shown in the table 1 and diagram 1
- The line needs to be balanced for annual order of 100,000 units
- 50 weeks per year, 5 shift week and each shift 7.5 hrs.
- Manning level is 1 operator per station
- The uptime of line is 95%
- Repositioning time i.e. time lost per cycle 0.07 min.
- *Find: Total work content time T_{wc}? Required hourly production rate R_p to meet the demand? Cycle time T_c? Theoretical minimum number of **workers for the line**? **Service Time** for the balanced line?*

Example cont.

Table 1

Task No.	Work element Time(min.)	Must be Proceeded
1	0.2	
2	0.4	
3	0.7	1
4	0.1	1,2
5	0.3	2
6	0.11	3
7	0.32	3
8	0.6	3,4
9	0.27	6,7,8
10	0.38	5,8
11	0.5	9,10
12	0.12	11

Diagram 1



Solution

$$T_{wc} = \sum T_{ek} = 0.2 + 0.4 + 0.7 + 0.1 + 0.3 + 0.11 + 0.32 + 0.6 + 0.27 + 0.38 + 0.5 + 0.12 = 4.0$$

$$R_p = \frac{100000}{50 \times 5 \times 7.5} = 53.33 \textbf{ units/hr}$$

$$T_c = \frac{60(E)}{R_p} \Rightarrow T_c = \frac{60(0.95)}{53.33} = 1.07 \textbf{ min}$$

$$w = \left(\textbf{min } Int \geq \frac{T_{wc}}{T_c} \right) = \frac{4}{1.07} = 3.74 \textbf{ or 4 operators}$$

$T_s = 1.07 - 0.07 = 1.0$ minimum available time for each station

Conclusions: A line with 4 stations, 1 operator at each, available Time for each station 1 min with respect to task sequence and production rate.

Line Balancing Algorithms

The objective of line balancing is to:

$$\textbf{Minimise } (wT_s - T_{wc}) \textbf{ or Minimise } (\sum_{i=1}^{w} T_s - T_{si})$$

subject to :

$$\sum_{k \in i} T_{ek} \leq T_{wc}$$

- Largest Candidate Rule
- Kilbridge and Wester Method
- Ranked Positional Weights Method

Largest Candidate Rule (LCR)

1. Sort work elements (tasks) in descending order of their *Tek*
2. Assign the tasks to the first work station according to precedence (sequence of tasks) ensure that Total *Tek* is not greater than *Ts*
3. Start back from the top once a task is assigned
4. Proceed to next station
5. Repeat steps 1 & 2 until all tasks are assigned to the stations.

Solution

Task No.	Work element Time(min.)	Must be Proceeded
3	0.7	1
8	0.6	3,4
11	0.5	9,10
2	0.4	
10	0.38	5,8
7	0.32	3
5	0.3	2
9	0.27	6,7,8
1	0.2	
12	0.12	11
6	0.11	3
4	0.1	1,2

Solution cont.

Station	Task No.	Work element Time(min.)	Must be Proceeded	Station Time
1	2	0.4		
	5	0.3	2	
	1	0.2		
	4	0.1	1,2	1
2	3	0.7	1	
	6	0.11	3	0.81
3	8	0.6	3,4	
	10	0.38	5,8	0.98
4	7	0.32	3	
	9	0.27	6,7,8	0.59
5	11	0.5	9,10	
	12	0.12	11	0.62

Station 1	Station 2	Station 3	Station 4	Station 5
2,5,1,4	3,6	8,10	7,9	11,12

$$\text{Balance Efficiency} = \frac{\text{Total Work Content Time}}{\text{No. Stations} \times \text{max. service available time}} \frac{T_{wc}}{wT_s} = \frac{4}{5(1.0)}$$

Do you Think you Can Use it for Balancing your Project Activities?