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Determining the Critical Path of a Hydrologic & Hydraulic (H&H) Modeling Project

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March 15, 2018

Critical Path

- It is the path thru a network with the longest total duration.

Outline

Part 1: History & Simple Example

Part 2: Arrow Diagram Method (ADM): Critical Path by Manual Approach:

- Activity-On-Arrow (AOA)
- Terminology
- Small Network

Part 3: Precedence Diagram Method (PDM): Critical Path by Computer Program:

- Activity-On-Node (AON)
- H&H Project Network

Outline

Part 1: Introduction:

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- Simple Example

Part 2: Arrow Diagram Method (ADM): Critical Path by Manual Approach:

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- H&H Project

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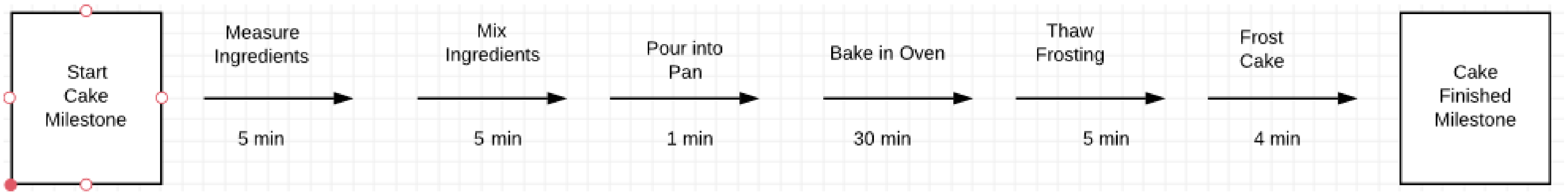
History

- Program Evaluation and Review Technique (PERT)
  - Program developed in 1950's to schedule the Polaris Missile project for the United States Navy.
  - Over 3,000 contractors and agencies working on the Polaris project.

- Critical Path Method (CPM)
  - Referred to as: Arrow Diagram Method (ADM)
    - **Activities are on arrows!**
  - Developed in 1950's by Du Pont to manage projects consisting of new construction and overhauling of its chemical facilities. The implementation of CPM reduced the average time for shutdown from 125 hours to 93, then finally to 74 hours.
- Precedence Diagram Method (PDM)
  - 1980's. Computer programs.
  - **Activities are on nodes, arrow connect the nodes!**
  - Durations – three types.
- Today
  - A schedule is usually a part of the contract documents for construction projects and considered legally binding.

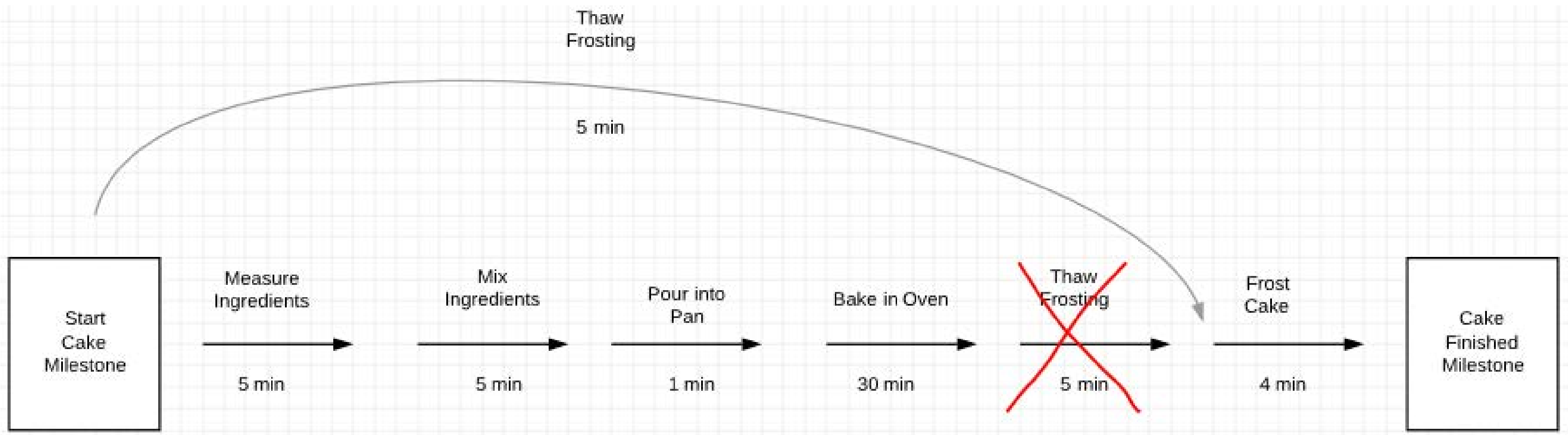
Bake a cake



- Question: How long does it take?
- Organize the activities in a logical sequence for ***1 person***:
  1. Measure ingredients
  2. Mix ingredients
  3. Pour into pan
  4. Bake in oven
  5. Thaw Frosting
  6. Frost Cake
  7. **Calculate project duration.**
  8. What is the critical path?
  9. What activity could be done out of order or started earlier?

SERIES

Bake a cake – Cont'd



- **Improvement** of logical sequence for ***1 person***:
  1. Measure ingredients
  2. Mix ingredients
  3. Pour into pan
  4. Bake in oven
  5. **Thaw Frosting: The head meets the tail of "Frost Cake".**
  6. Frost Cake
  7. Two paths now! Calculate duration of each path. Which one is longer?
  8. **Critical Path?**
  9. **Float?**

Bake a cake – Cont'd

- Improvement of logical sequence for *1 person*:
  1. Increase **duration** for "Thaw Frosting".
  2. Now, which path is longer?
  3. **Critical Path?**
  4. **Float?**

Example Summary

1. Your network should be drawn based on the resources you expect to have to complete the activities. If only you are doing something, then all of the tasks will be pretty much in series.
2. Most activities require action, but some only waiting, e.g.,:
   - "thaw frosting"
   - "bake oven"
   - These are analogous to "cure concrete 7-days" in the construction industry.
3. The "bake oven" activity occurs in logical order, but will not need your time for 30 min, you can do other things while waiting. However, you will need an oven for 30 min. Both the oven and you are resources that need to be managed.
4. If you have more than one person or crew you can break activities out into parallel paths. For example the "thaw frosting" could be "***make frosting from scratch***" and this would be a path for another person in the network.

Why use CPM?

1. Compute a project’s total duration – critical path – and identifies critical activities.
2. Provides a visual presentation of logical connections.
3. A tool for communicating the workflow to all project stakeholders:
   a) Project owner;
   b) Financier(s) (draw schedule);
   c) General Contractor Team (Internal/external);
   d) Subcontractors/Vendors (used to schedule subs and deliver materials);
   e) Road closings. Utility connections/turning off.
   f) State and Municipal Agencies providing regulatory oversight/inspections;
4. Potential to reveal insights into details that otherwise might not of been noted until too late (e.g., special ordering of a certain item/service may require ordering in advance months or years).
5. A tool for progress recording and reporting.
6. A tool for shortening the project’s completion time.
7. Can make workflow more efficient, saving time and money!

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References

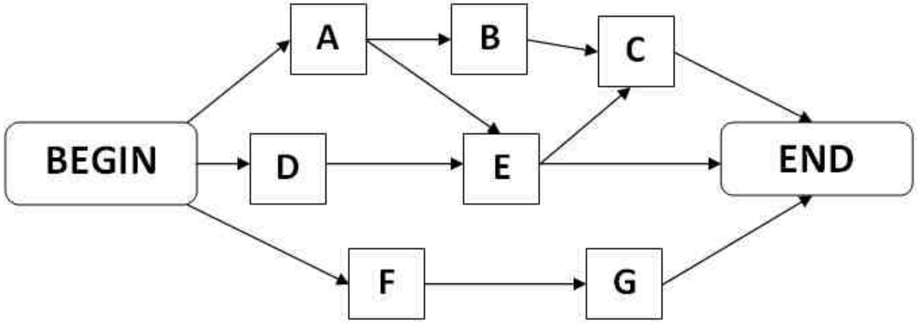
- James J. O'Brien, P.E. and Fredric L. Plotnick, Esq., P.E. ***CPM in Construction Management***, 5th Edition. 1999.
- James J. O'Brien, P.E., **CPM in Construction Management (Project Management with CPM**), 2nd Edition. 1971.

Network Diagrams

- <u>Two Types:</u>

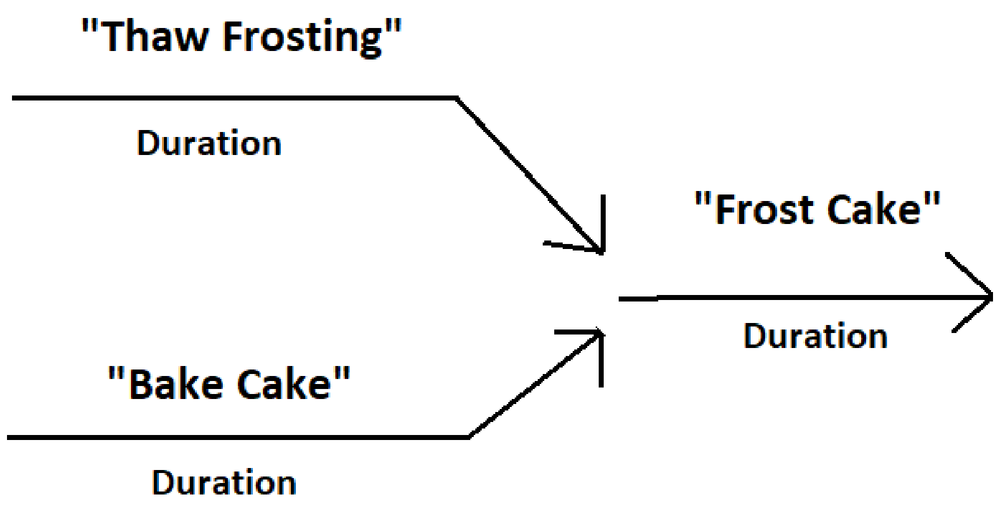
1. Arrow Diagram Method (ADM):
   a) Activity-On-Arrow (AOA)
      i. Better for learning manual computations because it is easier to visualize

2. Precedence Diagram Method (PDM):
   a) Activity-On-Node (AON)
      i. Computer programs



Network Logic: Arrow Diagram Method (ADM)

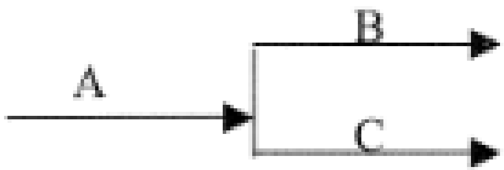
- Determine Predecessors/Successors:
  1. What activities must precede this one?
  2. What activities can be concurrent with this one?
  3. What activities must follow this one?



Network Logic: Arrow Diagram Method (ADM)

If activities A, B & C occur in **series**, their network representation is:

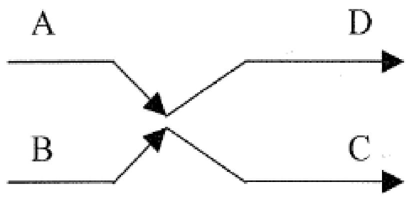
If B & C follow A:



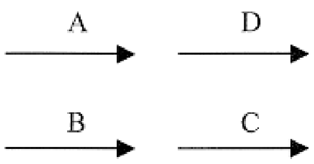
Citation: O'Brien and Plotnick. ***CPM in Construction Management****, 5th Edition. 1999.*

Network Logic: Arrow Diagram Method (ADM)

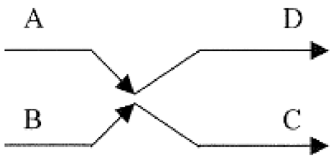
If activity C follows B and activity D follows A, you might expect:



However, no relation was expressed between C and A or B and D. Therefore, the correct relation is:



Now, if both A and B precede both C and D, the network becomes:



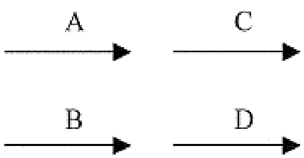
O'Brien and Plotnick. ***CPM in Construction Management****, 5th Edition. 1999.*

Network Logic: Arrow Diagram Method (ADM)

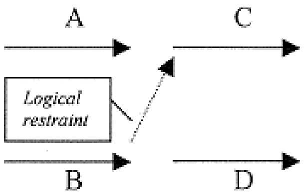
LOGICAL CONNECTIONS

Logical Restraints

If we have the case where activity A and B precede C, but only B precedes D, we might expect something similar to the following:



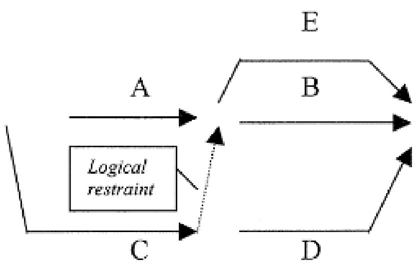
In order to make both A and B precede C, but allow only B to precede D, we need to add a logical connection from B to C. An activity (which is represented by a ***solid*** arrow) cannot be broken up or split. This is solved by use of a logical connection which allows the logical flow of work to occur, but does no work itself. A dashed-line arrow is used to represent this logical connection. In this case (as shown below) it is used as a ***logical restraint***:



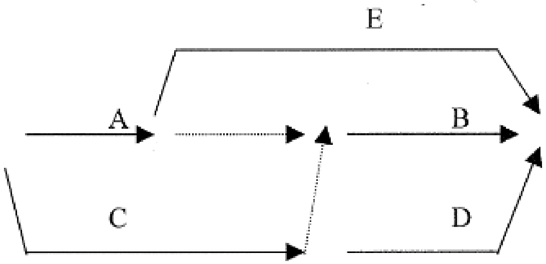
O'Brien and Plotnick. ***CPM in Construction Management****, 5th Edition. 1999.*

Network Logic: Arrow Diagram Method (ADM)

Now add terminal activity E, which follows A, but is independent of C, is not correct by:



The above network is not correct, because Activity E is suppose to be independent of C, but rather is shown dependent on C. To make activity E independent of C, we add in a ***logic splitter*** or ***spreader***:



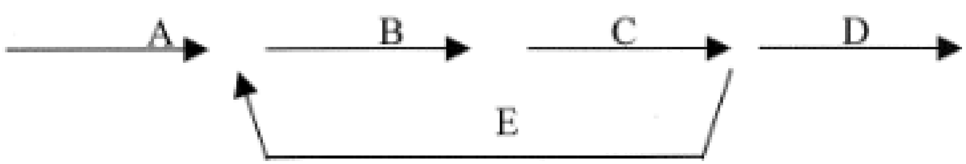
Logic cannot back up from B against the arrowhead, which functions as a check valve.

O'Brien and Plotnick. ***CPM in Construction Management,*** *5th Edition. 1999.*

Network Logic: Arrow Diagram Method (ADM)

Logical Loop

If activities A, B, C and D are in series and activity E following C precedes B, we then have:



The segment B, C and E is a logical loop. Since a loop is illogical, it has no place in a logical network. It is common to inadvertently insert loops in large networks.

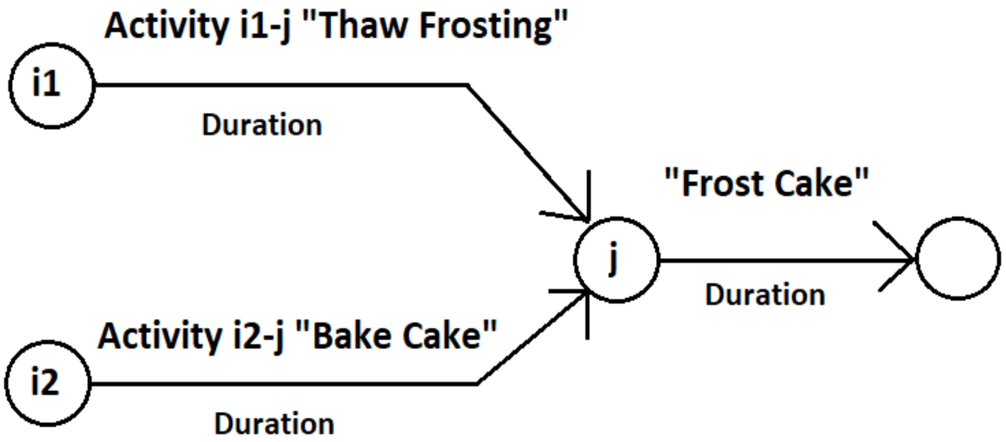
Check for loops: you have a loop when the project duration is greater than the total duration of all the project activities added together.

O'Brien and Plotnick. ***CPM in Construction Management****, 5th Edition. 1999.*

Activity on Arrow

Events:

- An Event is the intersection of two or more activity arrows (e.g., node “j”).
- Identification of an Event by number:
  - i = starting event
  - j = ending event
- Zero time duration.
- All activities leading into an event must be completed before any of the activities leading out of the event can be started.
- Each Activity is bounded by an event



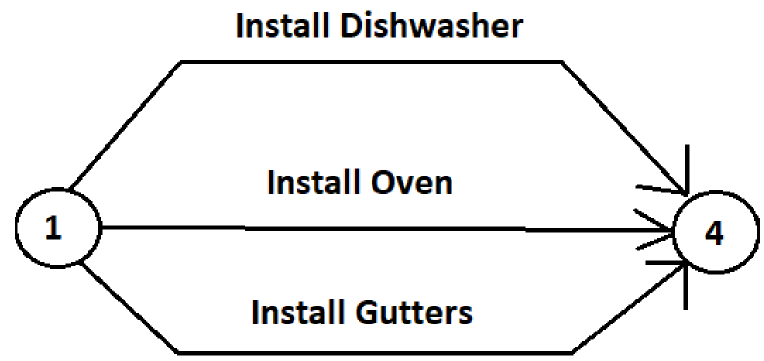
- Random numbering is allowed by programs
- Following the rules for event numbering helps us do the following:
  - J > I makes it easier to locate events in the diagram.
  - Identification of logical loops.

Activity on Arrow

Events:

- Rule 1: The i-j number for each activity should be unique; however it is common for multiple activities to span between two events.

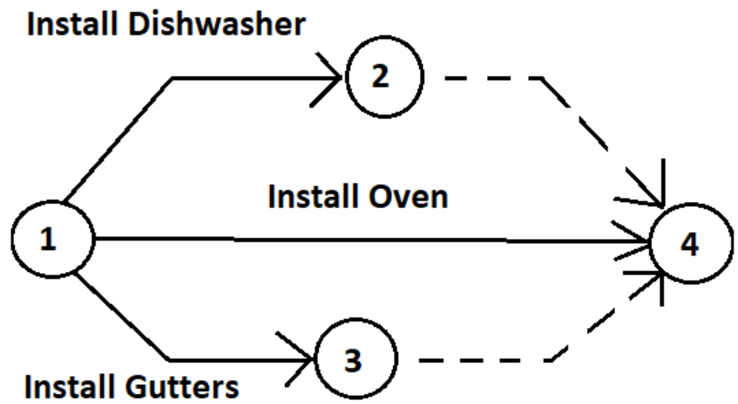
Incorrect: Activity list by common activity



Activity List

i-j	Description
1-4	Dishwasher
1-4	Oven
1-4	Gutters

Correct: Activity list by Unique Numbers



Activity List

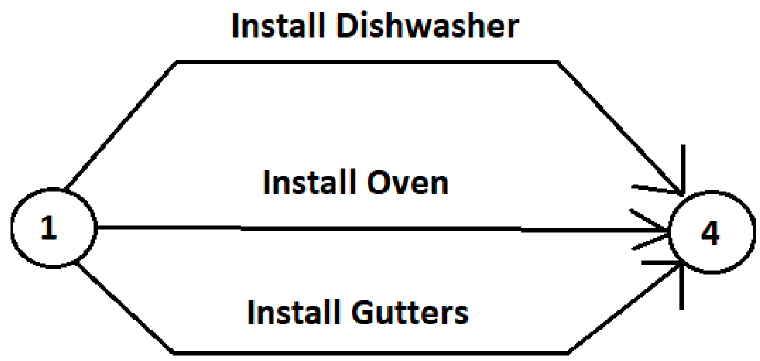
i-j	Description
1-2	Diswasher
1-3	Gutters
1-4	Oven
2-4	Restraint
3-4	Restraint

Activity on Arrow

Events:

- Rule 2: While assigning event numbers, the number at the head (j-end) of the arrow should be greater than at the tail (i-end). So, j > i.

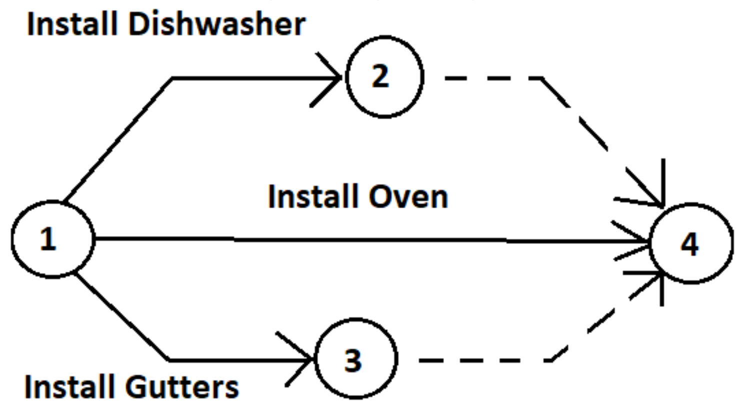
Incorrect: Activity list by common activity



Activity List

i-j	Description
1-4	Dishwasher
1-4	Oven
1-4	Gutters

Correct: Activity list by Unique Numbers



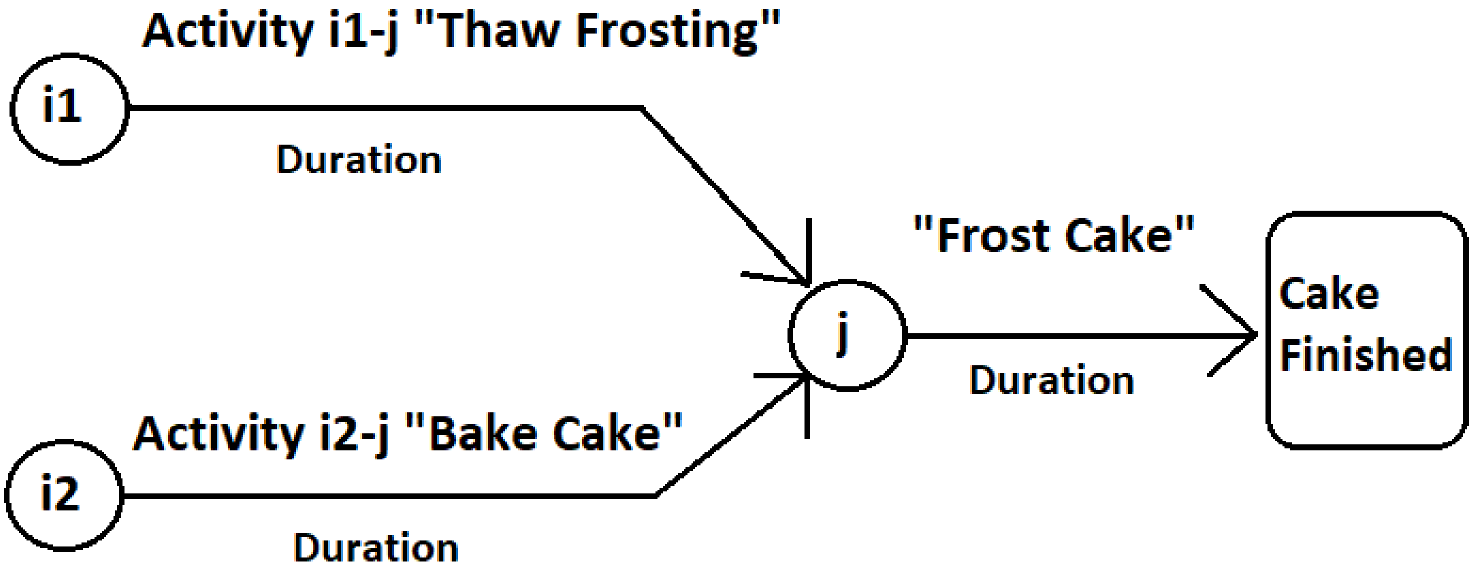
Activity List

i-j	Description
1-2	Diswasher
1-3	Gutters
1-4	Oven
2-4	Restraint
3-4	Restraint

Activity on Arrow

Milestones:

Key events that represent important intermediate goals within the network.
Milestone Example = “Cake Finished”.

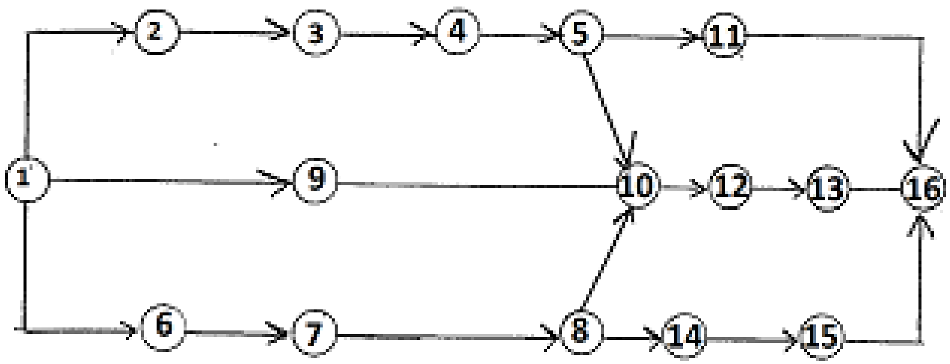


Activity on Arrow

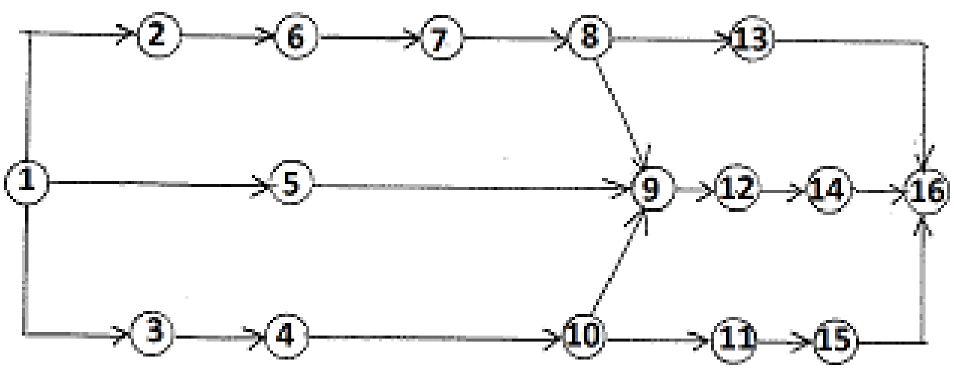
Rules for assigning Event numbers to a network:

- Horizontal Method
- Vertical Event Method

Horizontal Method for Event Numbering



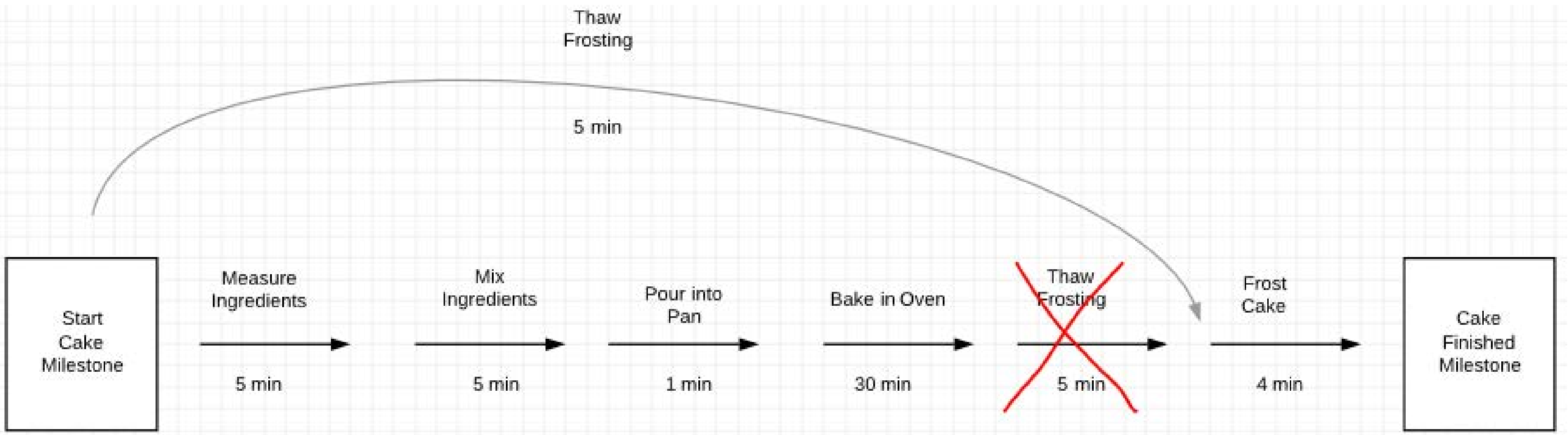
Vertical Method for Event Numbering



O'Brien and Plotnick. ***CPM in Construction Management****, 5th Edition. 1999.*

Event Time Computations

- Preparation of the Arrow Diagram doesn't portray the aspect of time.
- Use of PDM by computer programs allows for a bar or Gantt chart to be created portraying the aspect of time.
- Consistent Time Units:
  - Days are typically used, but any unit is ok as long as it is consistent throughout the project.
  - Short-term projects:
    - Shifts or half-shifts
- Estimating Activity Time Duration:
  - Per individual (man-hours).
  - Per normal crew size (e.g., 5-man crew)

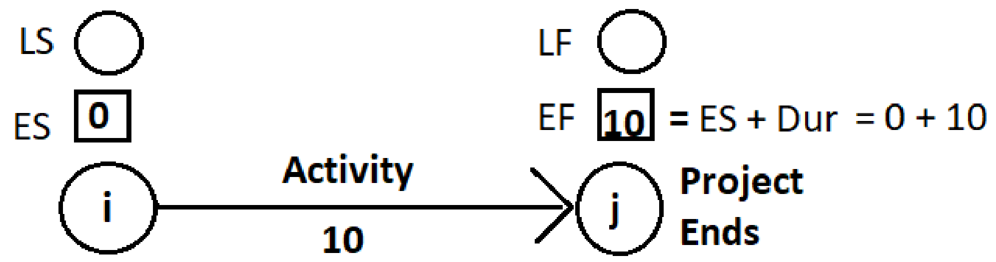


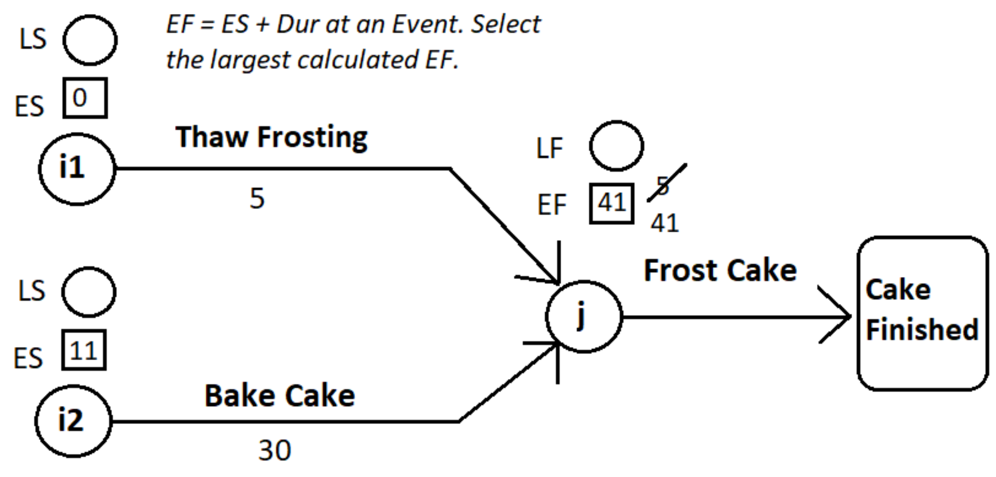
Thaw
Frosting
5 min
Start
Cake
Milestone
Measure
Ingredients
5 min
Mix
Ingredients
5 min
Pour into
Pan
1 min
Bake in Oven
30 min
Thaw
Frosting
5 min
Frost
Cake
4 min
Cake
Finished
Milestone

Event Time Computations – Cont'd

Early Event Times, T_E:

1. The early event time is the latest of the possibilities at a convergence of arrows (head end).
2. The ***early Start*** (ES) of the first activity is defined as zero.
3. The ***early finish*** (EF) of any activity is the ES + duration (D).
4. The ES of any other activity is the ***latest*** of the EF's of all predecessors to that activity. T_E is always the larger value when there is a choice between two or more values.
5. **Forward Pass**: Place early event times in square boxes. Add the Duration to the ES for each activity. The ES in the Forward Pass in the top Figure went from 0 days to a final project duration of 10 days.
6. When you come to a junction (event) of two or more activity arrow heads, the larger value of ES is always chosen. Write down both values and cross out the earlier value. Continue this until the end. The resulting number of days (project duration) is the shortest time in which this work can be completed (critical path). In other words, the shortest project time is the result of the longest path, which is the critical path.



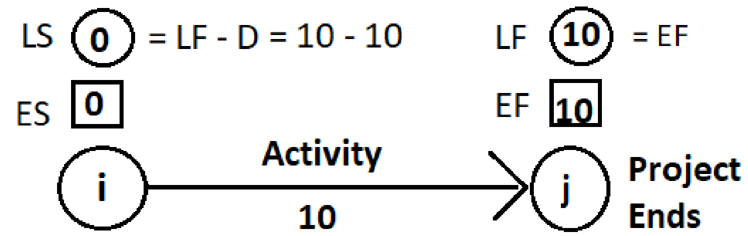


O'Brien and Plotnick. ***CPM in Construction Management****, 5th Edition. 1999.*

Event Time Computations – Cont'd

<u>***Late*** Event Times:</u>

1. The late event TL is the earliest of the possibilities at a convergence of arrows (tail end). The late event time is the latest time at which an event can be reached without delaying the computed project duration.
2. The ***late finish*** (LF) of the last activity is defined as equal to the EF.
3. The ***late start*** (LS) of any activity is the LF – D.
4. The LF of any other activity is the earliest of the LS's of all successors to that activity.
5. Define: the latest time at which an event may be reached without delaying the computed project time.
6. T_L is determined by calculating backwards through the network.
7. T_L is defined as the smaller value when there is a choice between two or more values.
8. ***Backward Pass.*** Place late event times in circles. On the forward pass we found that the project duration was 10 days (EF). (**1rst Figure**): For the backward pass, start by making the LF = EF of the finishing event (i.e., last event of the network). To calculate LS, work backwards from the finish by subtracting the duration from the LF. **(2nd Figure):** Continue this backwards along each path until you reach a junction where two or more arrow tails converge, such as the four arrows A, B, C, & D. At the junction event, write down all of the LS values calculated for each path. TL is always the earlier value whenever there is a convergence of 2 or more arrow tails. Cross out the later values. Highlight or double-hatch the critical path. When working the backwards pass and you come to junction event where two or more arrow tails converge, if CP goes thru this event, then the earlier value will be due to the CP.



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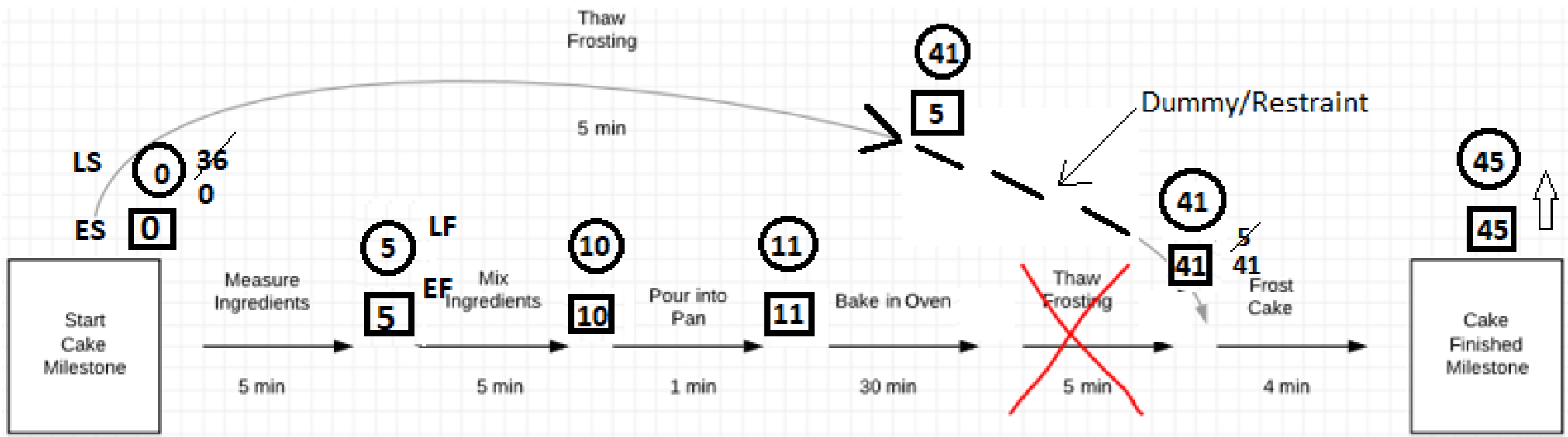
Event Time Computations – Cont'd



1) Main Path: Float = 0 for all activities; therefore they are on the CP.
2)Frosting Path: Float = LF - EF = 41 - 5 = 36 min. If Float > zero, non-critical path.

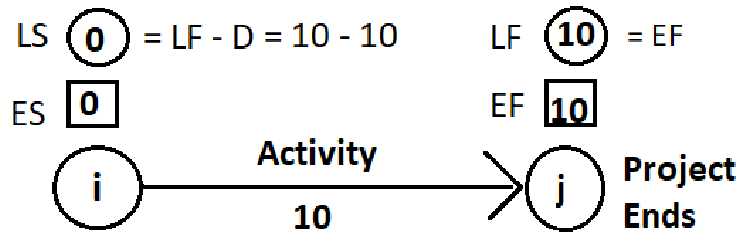
Late Event Times:

1. The ***late finish*** (LF) of the last activity is defined as equal to the EF.
2. The ***late start*** (LS) of any activity is the LF – D.

Event Time Computations – Cont'd

<u>Float Times:</u>

- The *total float* (TF) of any activity is equal to the LS – ES, which is also equal to the LF – EF.



Critical Path

- Longest path into the last event, since it establishes the latest T_E for that last event.
- Three conditions that each critical activity must meet:

1. The early and late event times at the activity start must be equal:
2. The early and late event times at the activity completion must be equal:
3. The difference between the ES and LF must equal the duration.
4. Delaying an activity on the critical path will directly delay the project by that amount. Delaying a non-critical activity may or may not delay the project, depending on how much float that path has.

Example

1. Note there are four paths but there are two main ones.
2. Workflow is set up for two persons (or crews) in the beginning, then at event 8 there is a split and workflow is setup for an additional 2 persons/crews. If only one person/crew was to do all of the work, then all of the activities would be in sequence located along one path and the total project duration would substantially increase.
3. Highlight the critical path red.

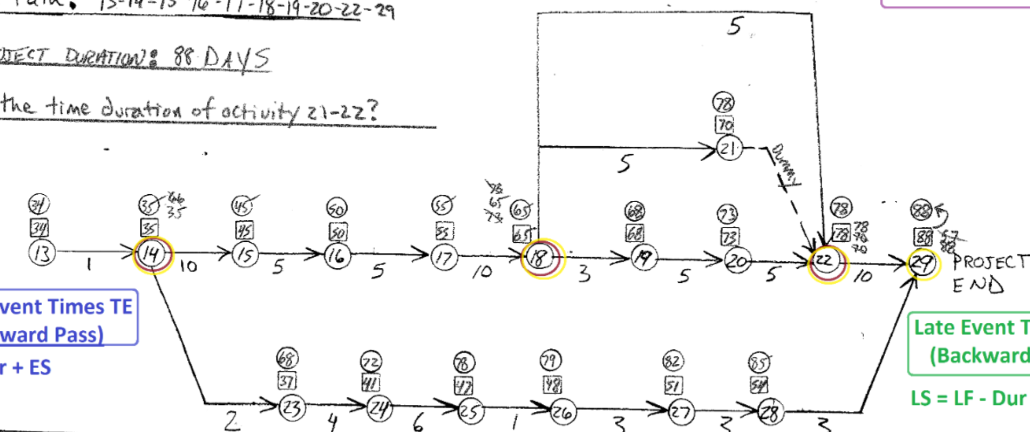
Perform Forward & Backward passes to determine Critical Path of this network. Calculate the early and late events in table below. Also, write the events for the Critical Path. Dont forget Crossouts.

Float = LS - ES or LF - EF

Critical Path: 13-14-15-16-17-18-19-20-22-29

TOTAL PROJECT DURATION: 88 DAYS

What is the time duration of activity 21-22?

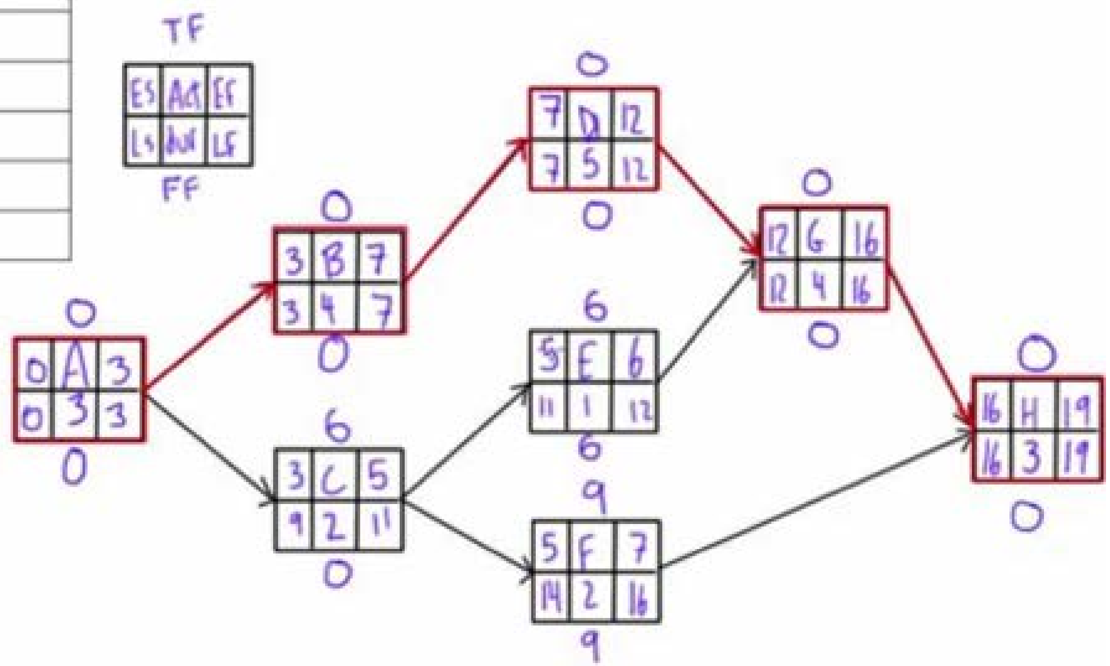


i-j	Duration	ES	EF =ES+D	LS =LF-D	LF	Total Float
13-14	1	34	35	34	35	0
14-15	10	35	45	35	45	0
15-16	5	45	50	45	50	0
16-17	5	50	55	50	55	0
17-18	10	55	65	55	65	0
18-19	3	65	68	65	68	0
19-20	5	68	73	68	73	0
20-22	5	73	78	73	78	0
22-29	10	78	88	78	88	0
18-21	5	65	70	73	78	8
21-22	0	70	70	78	78	8
18-22	5	65	70	73	78	8

i-j	DURATION	ES=	EF=ES+D	LS (LS=LF-D)	LF	TOTAL Float
14-23	2	35	37	66	68	31
23-24	4	37	41	68	72	31
24-25	6	41	47	66	78	31
25-26	1	47	48	78	79	31
26-27	3	48	51	79	82	31
27-28	3	51	54	82	85	31
28-29	3	54	57	85	88	31

PDM Network

Activity	Predecessor	Duration (days)
A	-	3
B	A	4
C	A	2
D	B	5
E	C	1
F	C	2
G	D,E	4
H	F,G	3

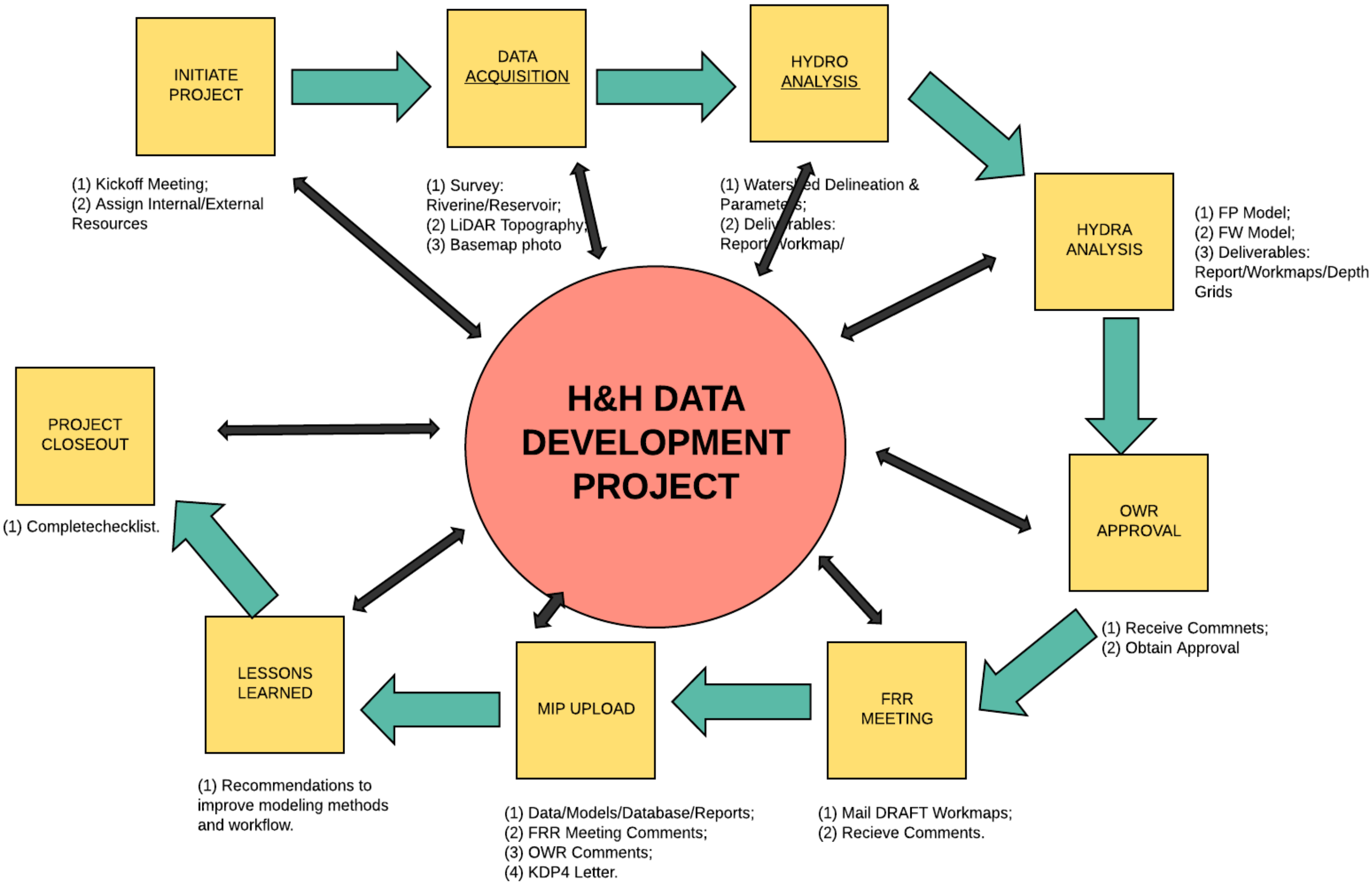


https://www.google.com/search?q=activity+on+node+diagram&tbm=isch&source=iu&ictx=1&fir=ZT1g9rbL32dtZM%253A%252CO_s3w4gfU5HWtM%252C_&usg=__hilqs4BHrcR6YfBOEH3LJnTE3Lc%3D&sa=X&ved=0ahUKEwim1KPq5ezZAhURM6wKHS7PDAoQ9QEIODAI#imgdii=jC8DiCKFHhuyOM:&imgrc=ZT1g9rbL32dtZM:

Hydrologic & Hydraulic Project Outline

1. Workflow of Modules
2. Work Breakdown Structure (with or without predecessors/successors?)
3. PDM Network with Gantt Chart

CIRCULAR FLOW MODEL
DATA DEVELOPMENT PROJECT

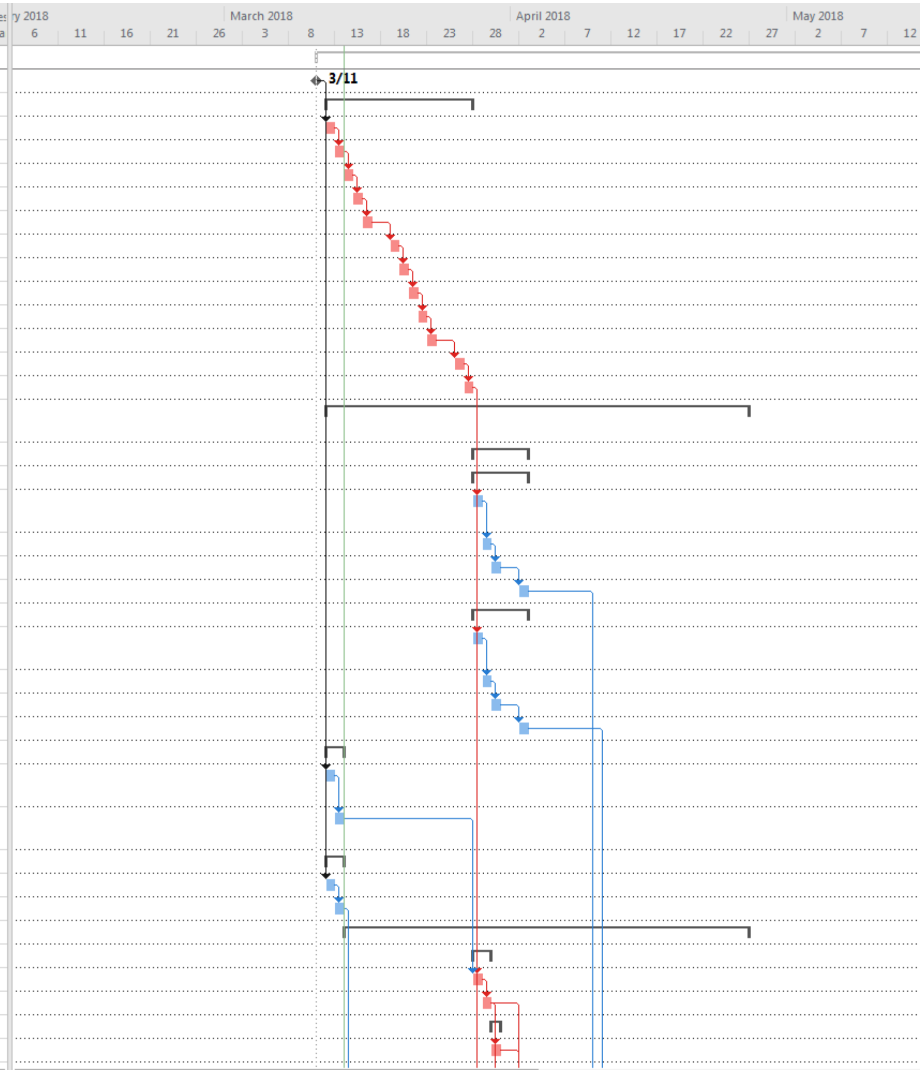


Network Creation

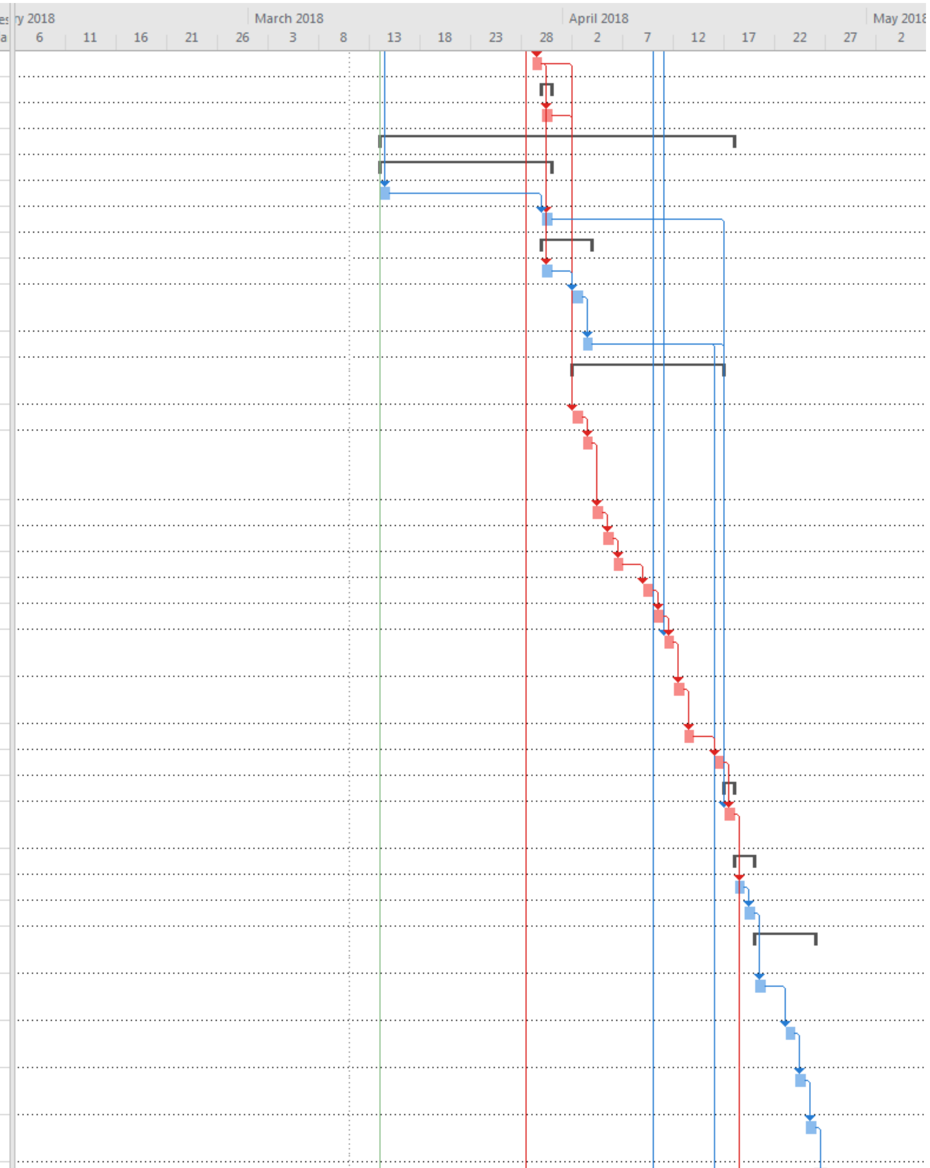
- Step 1 : Start simple and create outline of modules/milestones.
- Step 2: Develop tasks for each module.

1. Modules
2. Summary Tasks
3. Predecessors/Successors

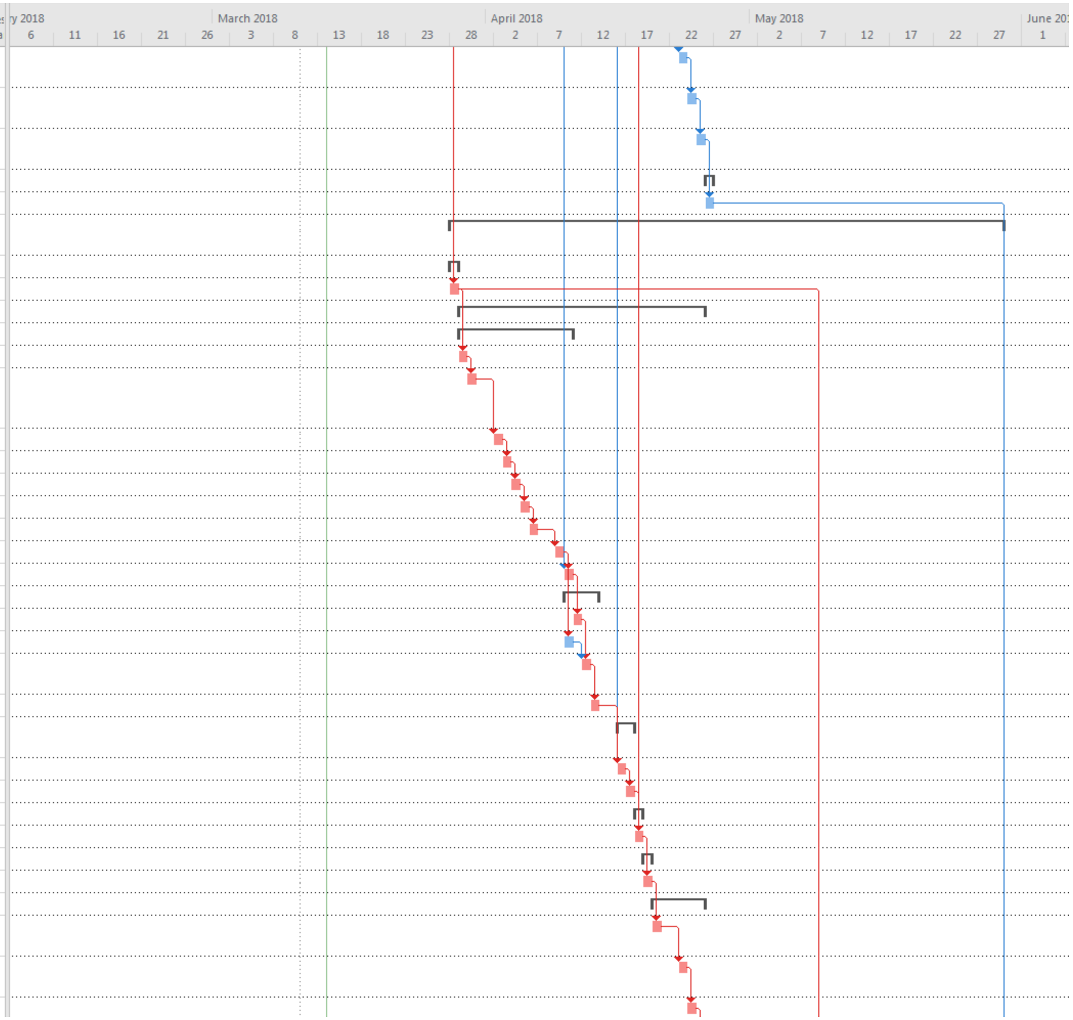
ID	Info	Task Mode	Outline Number	Task Name	Duration	Start	Finish	Predecessors	Successors	Resource Names
0			0	**H&H Modeling Project 1**	**159 da**	**Sun 3/1**	**Thu 1**			
1			1	Start Project	0 days	Sun 3/11	Sun 3,		3,28,31	
2			2	**Project Initiation**	**12 days**	**Mon 3/1**	**Tue 3,**			
3			2.1	Review WBS, RACI & Resources	1 day	Mon 3/1	Mon :	1	4	
4			2.2	Setup Folder Structure	1 day	Tue 3/13	Tue 3,	3	5	
5			2.3	Read MAS	1 day	Wed 3/1	Wed :	4	6	
6			2.4	Define Budgeted Hours	1 day	Thu 3/15	Thu 3,	5	7	
7			2.5	Create Project Timeline	1 day	Fri 3/16/	Fri 3/:	6	8	
8			2.6	Setup Timesheets Lite	1 day	Mon 3/1	Mon :	7	9	
9			2.7	Setup Base MXD	1 day	Tue 3/20	Tue 3,	8	10	
10			2.8	Setup Report Template	1 day	Wed 3/2	Wed :	9	11	
11			2.9	Create Communication Plan	1 day	Thu 3/22	Thu 3,	10	12	
12			2.10	Contact List	1 day	Fri 3/23/	Fri 3/:	11	13	
13			2.11	Check for Study Requests	1 day	Mon 3/2	Mon :	12	14	
14			2.12	Project Kickoff Meeting	1 day	Tue 3/27	Tue 3,	13	18,23,35,	
15			3	**Data Acquisition**	**34 days**	**Mon 3/12/18**	**Thu 4/26/**			
16			3.1	**Survey**	**4 days**	**Wed 3/2**	**Mon**			
17			3.1.1	**Survey Riverine**	**4 days**	**Wed 3/2**	**Mon**			
18			3.1.1.	Send Surveyors Survey Locations	1 day	Wed 3/28/18	Wed 3/28/	14	19	
19			3.1.1.	Start Survey XSs & Structures	1 day	Thu 3/29	Thu 3,	18	20	
20			3.1.1.	Surveyors Process Data.	1 day	Fri 3/30/	Fri 3/:	19	21	
21			3.1.1.	Receive Survey Data	1 day	Mon 4/2	Mon	20	84	
22			3.1.2	**Survey Reservoir(s)**	**4 days**	**Wed 3/2**	**Mon**			
23			3.1.2.	Send Surveyors Survey Locations	1 day	Wed 3/28/18	Wed 3/28/	14	24	
24			3.1.2.	Start Reservoir Survey	1 day	Thu 3/29	Thu 3,	23	25	
25			3.1.2.	Surveyors Process Data.	1 day	Fri 3/30/	Fri 3/:	24	26	
26			3.1.2.	Receive Survey Data	1 day	Mon 4/2	Mon	25	55	
27			3.2	**Watershed Topographic Data**	**2 days**	**Mon 3/1**	**Tue 3,**			
28			3.2.1	Request Topo Data/Metadata Watershed Delineation.	1 day	Mon 3/12/18	Mon 3/12/	1	29	
29			3.2.2	Aquire Topo: Watershed Delineation	1 day	Tue 3/13/18	Tue 3/13/	28	35	
30			3.3	**Gage Data**	**2 days**	**Mon 3/1**	**Tue 3,**			
31			3.3.1	Request Gage Data	1 day	Mon 3/1	Mon :	1	32	
32			3.3.2	Acquire Gage Data	1 day	Tue 3/13	Tue 3,	31	41	
33			3.4	**Hydrology**	**32 days**	**Wed 3/1**	**Thu 4,**			
34			3.4.1	**Start Hydrology**	**2 days**	**Wed 3/2**	**Thu 3,**			
35			3.4.1.	Start Hydrology	1 day	Wed 3/2	Wed :	14,29	36	
36			3.4.1.	Determine Flow Locations	1 day	Thu 3/29	Thu 3,	35	42,38,44,	
37			3.4.2	**Perform Geo-HMS**	**1 day**	**Fri 3/30/**	**Fri 3/:**			
38			3.4.2.	Perform Geo-HMS	1 day	Fri 3/30/	Fri 3/:	36	48	



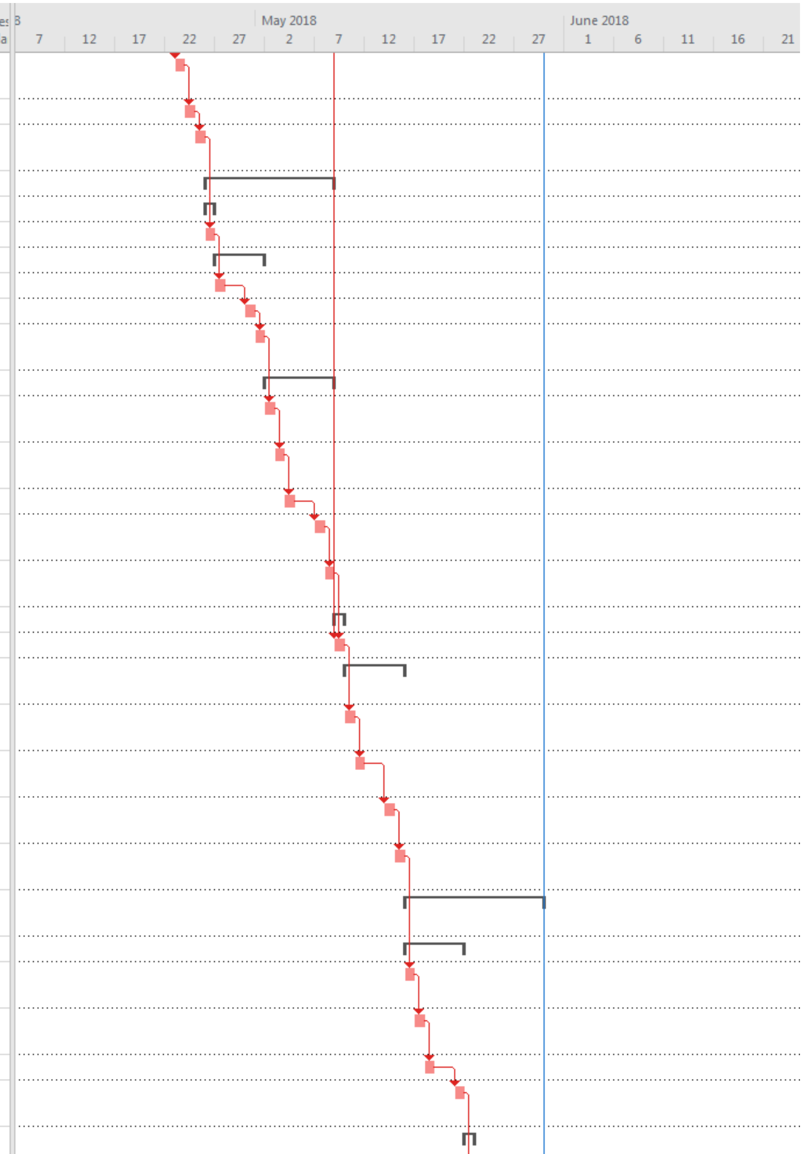
I	Ta M	Ou Nu	Task Name	Durat	Start	Fin	Predec	Succes	Res Na
36		3.4.1.	Determine Flow Locations	1 day	Thu 3/29	Thu 3,	35	42,38,44,	
37		**3.4.2**	**Perform Geo-HMS**	**1 day**	**Fri 3/30/**	**Fri 3/:**			
38		3.4.2.	Perform Geo-HMS	1 day	Fri 3/30/	Fri 3/:	36	48	
39		**3.4.3**	**Flow Analysis**	**25 days**	**Wed 3/1**	**Tue 4,**			
40		**3.4.3.**	**Gage Analysis**	**13 days**	**Wed 3/1**	**Fri 3/:**			
41		3.4.3.	Receive Gage Data	1 day	Wed 3/1	Wed :	32	42	
42		3.4.3.	Perform Gage Analysis	1 day	Fri 3/30/	Fri 3/:	36,41	60	
43		**3.4.3.**	**Regression Analysis**	**3 days**	**Fri 3/30/**	**Tue 4,**			
44		3.4.3.	Assign Streamstats Pour Poi	1 day	Fri 3/30/	Fri 3/:	36	45	
45		3.4.3.	Perform Regression Analysis	1 day	Mon 4/2/18	Mon 4/2/1	44	46	
46		3.4.3.	QAQC Streamstats Results	1 day	Tue 4/3/	Tue 4,	45	91,60	
47		**3.4.3.**	**Rainfall-Runoff Model Analysis**	**11 days**	**Mon 4/2/18**	**Mon 4/16/**			
48		3.4.3.	Setup HEC-HMS Project	1 day	Mon 4/2,	Mon 4	36,38	49	
49		3.4.3.	Import Geo-HMS Watershed Delineation & Parameters	1 day	Tue 4/3/18	Tue 4/3/1	48	50	
50		3.4.3.	Perform Flow Analysis	1 day	Wed 4/4	Wed 4	49	51	
51		3.4.3.	Setup rainfall depths.	1 day	Thu 4/5/	Thu 4,	50	52	
52		3.4.3.	Perform Loss method.	1 day	Fri 4/6/1	Fri 4/	51	53	
53		3.4.3.	Perform Transformation	1 day	Mon 4/9,	Mon 4	52	54	
54		3.4.3.	Perform Reach Routing	1 day	Tue 4/10	Tue 4,	53	55	
55		3.4.3.	Perform reservoir storage modeling	1 day	Wed 4/11/18	Wed 4/11/	26,54	56	
56		3.4.3.	Perform Critical Duration Analysis	1 day	Thu 4/12/18	Thu 4/12/	55	57	
57		3.4.3.	Perform Calibration	1 day	Fri 4/13/	Fri 4/:	56	58	
58		3.4.3.	Perform Verification	1 day	Mon 4/1	Mon 4	57	60	
59		**3.4.3.**	**Compare Flows**	**1 day**	**Tue 4/17**	**Tue 4,**			
60		3.4.3.	Compare Flows: Effective/Gage/Regress/R-R	1 day	Tue 4/17/18	Tue 4/17/	42,58,46	62,94	
61		**3.4.4**	**Hydro DRAFT Report**	**2 days**	**Wed 4/1**	**Thu 4,**			
62		3.4.4.	Start Hydro DRAFT Report	1 day	Wed 4/1	Wed 4	60	63	
63		3.4.4.	Finish Hydro DRAFT Report	1 day	Thu 4/19	Thu 4,	62	65	
64		**3.4.5**	**Independent QA/QC (Hydro Models & Report)**	4 days	**Fri 4/20/18**	**Wed 4/25/**			
65		3.4.5.	Start Independent QA/QC Hydro	1 day	Fri 4/20/18	Fri 4/20/	63	66	
66		3.4.5.	Send Results Independent QA/QC To Engineer.	1 day	Mon 4/23/18	Mon 4/23/	65	67	
67		3.4.5.	Engineer Revises Hydro Model and Report.	1 day	Tue 4/24/18	Tue 4/24/	66	68	
68		3.4.5.	Engineer Sends Hydro Model To GIS-Workmaps.	1 day	Wed 4/25/18	Wed 4/25/	67	70	



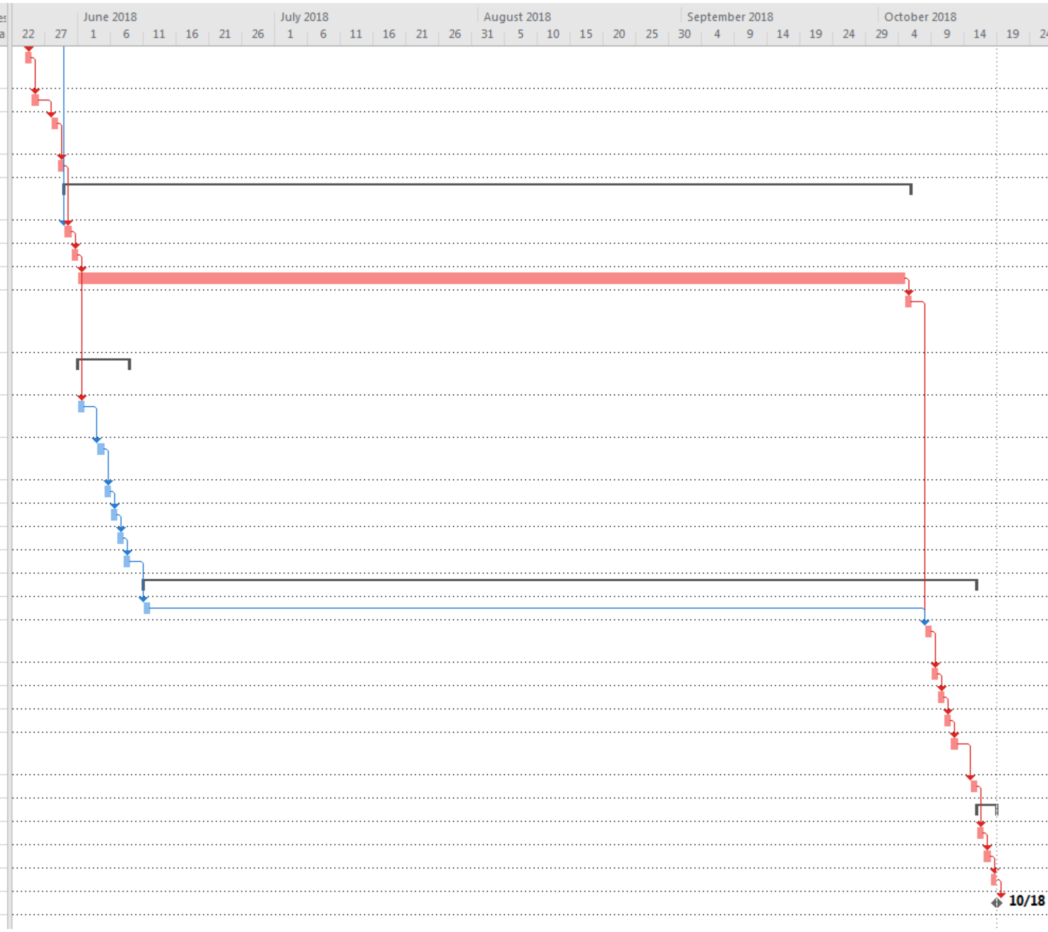
I		Ta M	Ou Nu	Task Name	Durat	Start	Fin	Predec	Succes	Res Na
66			3.4.5.	Send Results Independent QA/QC To Engineer.	1 day	Mon 4/23/18	Mon 4/23/	65	67	
67			3.4.5.	Engineer Revises Hydro Model and Report.	1 day	Tue 4/24/18	Tue 4/24/	66	68	
68			3.4.5.	Engineer Sends Hydro Model To GIS-Workmaps.	1 day	Wed 4/25/18	Wed 4/25/	67	70	
69			**3.4.6**	**Hydro DRAFT Workmap**	**1 day**	**Thu 4/26**	**Thu 4**			
70			3.4.6.	Start Hydro DRAFT Workmap	1 day	Thu 4/26	Thu 4	68	137	
71			**4**	**Hydraulics**	**45 days**	**Wed 3/28/18**	**Tue 5/29/**			
72			**4.1**	**Start Hydraulics**	**1 day**	**Wed 3/2**	**Wed**			
73			4.1.1	Start hydraulics	1 day	Wed 3/2	Wed	14	116,76	
74			**4.2**	**Floodplain Model**	**20 days**	**Thu 3/29**	**Wed**			
75			**4.2.1**	**GeoRAS (GIS_To_RAS) Geometry**	**9 days**	**Thu 3/29**	**Tue 4**			
76			4.2.1.	Digitize 250 ft stream spacing	1 day	Thu 3/29	Thu 3	73	77	
77			4.2.1.	Digitize XS and structure locations, bank lines and flowpath lines.	1 day	Fri 3/30/18	Fri 3/30/	76	78	
78			4.2.1.	QAQC XS	1 day	Mon 4/2	Mon	77	79	
79			4.2.1.	Build DEM	1 day	Tue 4/3/	Tue 4	78	80	
80			4.2.1.	Run GeoRAS	1 day	Wed 4/4	Wed	79	81	
81			4.2.1.	Add GeoRAS to Base MXD	1 day	Thu 4/5/	Thu 4	80	82	
82			4.2.1.	Setup HEC-RAS Project	1 day	Fri 4/6/1	Fri 4/	81	83	
83			4.2.1.	Setup HEC-RAS Geometry	1 day	Mon 4/9	Mon	82	87,84	
84			4.2.1.	Incorporate Surveyed Sections	1 day	Tue 4/10	Tue 4	21,83	86	
85			**4.2.2**	**Structure Geometry**	**4 days**	**Tue 4/10**	**Fri 4/**			
86			4.2.2.	Create Structure (Survey Data)	1 day	Wed 4/1	Wed	84	88	
87			4.2.2.	Create Structure (As-Builts)	1 day	Tue 4/10	Tue 4	83	88	
88			4.2.2.	Create Ineffective Flow Stations & Obstructions.	1 day	Thu 4/12/18	Thu 4/12/	86,87	89	
89			4.2.2.	QAQC HEC-RAS Geometry	1 day	Fri 4/13/	Fri 4/	88	91	
90			**4.2.3**	**Apply Temporary StreamStats Flows**	**2 days**	**Mon 4/16/18**	**Tue 4/17/**			
91			4.2.3.	Assign Flows in HEC-RAS	1 day	Mon 4/1	Mon	46,89	92	
92			4.2.3.	Run HEC-RAS	1 day	Tue 4/17	Tue 4	91	94	
93			**4.2.4**	**Apply Final Flows**	**1 day**	**Wed 4/1**	**Wed**			
94			4.2.4.	Apply Final Flows	1 day	Wed 4/1	Wed	60,92	96	
95			**4.2.5**	**QA/QC FP Model_1**	**1 day**	**Thu 4/19**	**Thu 4**			
96			4.2.5.	QAQC HEC-RAS (FP Model)	1 day	Thu 4/19	Thu 4	94	98	
97			**4.2.6**	**GIS FP Creation**	**4 days**	**Fri 4/20/**	**Wed**			
98			4.2.6.	Extract HEC-RAS results and bring into GIS	1 day	Fri 4/20/18	Fri 4/20/	96	99	
99			4.2.6.	Run Floodplain Autodelineation Tool	1 day	Mon 4/23/18	Mon 4/23/	98	100	
100			4.2.6.	QAQC Autodelineation Results	1 day	Tue 4/24	Tue 4	99	101	



I	Ta M	Ou Nu	Task Name	Durat	Start	Fin	Predec	Succes	Res Na
99		4.2.6.	Run Floodplain Autodelineation Tool	1 day	Mon 4/23/18	Mon 4/23/	98	100	
100		4.2.6.	QAQC Autodelineation Results	1 day	Tue 4/24	Tue 4,	99	101	
101		4.2.6.	Extend XS for Final Floodplain Autodelineation	1 day	Wed 4/25/18	Wed 4/25/	100	104	
102		**4.3**	**Floodway Model (Version 1)**	**9 days**	**Thu 4/26**	**Tue 5,**			
103		**4.3.1**	**Extract RAS XSs For MXD**	**1 day**	**Thu 4/26**	**Thu 4,**			
104		4.3.1.	Extract RAS XSs For MXD	1 day	Thu 4/26	Thu 4,	101	106	
105		**4.3.2**	**Create FW Model (Version 1)**	**3 days**	**Fri 4/27/**	**Tue 5,**			
106		4.3.2.	Perform Floodway.	1 day	Fri 4/27/	Fri 4/:	104	107	
107		4.3.2.	QAQC HEC-RAS (FW Model)	1 day	Mon 4/3	Mon 4	106	108	
108		4.3.2.	Send FW model to GIS for floodway mapping (version 1).	1 day	Tue 5/1/18	Tue 5/1/1	107	110	
109		**4.3.3**	**Floodway Mapping (Version 1)**	**5 days**	**Wed 5/2**	**Tue 5,**			
110		4.3.3.	Extract HEC-RAS results and bring into GIS	1 day	Wed 5/2/18	Wed 5/2/1	108	111	
111		4.3.3.	Add Engineers XS comments to XXXX feature class.	1 day	Thu 5/3/18	Thu 5/3/1	110	112	
112		4.3.3.	Draw Floodway	1 day	Fri 5/4/1	Fri 5/	111	113	
113		4.3.3.	GIS send FW mapping back to Engr for review.	1 day	Mon 5/7/18	Mon 5/7/1	112	114	
114		4.3.3.	Engineer blesses FW. Ready for QA/QC.	1 day	Tue 5/8/18	Tue 5/8/1	113	116	
115		**4.4**	**Hydra DRAFT Report**	**1 day**	**Wed 5/9**	**Wed**			
116		4.4.1	Write Hydra Report	1 day	Wed 5/9	Wed :	114,73	118	
117		**4.5**	**Independent QA/QC (FW Models & Report)**	**4 days**	**Thu 5/10/18**	**Tue 5/15/**			
118		4.5.1	Start Independent QA/QC FW Model & Report	1 day	Thu 5/10/18	Thu 5/10/	116	119	
119		4.5.2	Send Results Independent QA/QC To Engineer.	1 day	Fri 5/11/18	Fri 5/11/	118	120	
120		4.5.3	Engineer Revises FW Model and Report.	1 day	Mon 5/14/18	Mon 5/14/	119	121	
121		4.5.4	Engineer sends revised FW model to GIS- Workmaps.	1 day	Tue 5/15/18	Tue 5/15/	120	124	
122		**4.6**	**DRAFT Hydraulic & FP Comparison Workmaps**	**10 days**	**Wed 5/16/18**	**Tue 5/29/**			
123		**4.6.1**	**Floodplain Mapping (Version 2)**	**4 days**	**Wed 5/1**	**Mon !**			
124		4.6.1.	Extract HEC-RAS results and bring into GIS	1 day	Wed 5/16/18	Wed 5/16/	121	125	
125		4.6.1.	Run Floodplain Autodelineation Tool	1 day	Thu 5/17/18	Thu 5/17/	124	126	
126		4.6.1.	QAQC Autodelineation Results	1 day	Fri 5/18/	Fri 5/:	125	127	
127		4.6.1.	Extend XS for Final Floodplain Autodelineation	1 day	Mon 5/21/18	Mon 5/21/	126	129	
128		**4.6.2**	**Quality Review 'Floodplain**	**1 day**	**Tue**	**Tue**			



I	Info	Ta M	Ou Nu	Task Name	Durat	Start	Fin	Predec	Succes	Res Na
132			4.6.3.	Add Engineers XS comments to XXXX feature class.	1 day	Thu 5/24/18	Thu 5/24/	131	133	
133			4.6.3.	Draw Floodway	1 day	Fri 5/25/	Fri 5/:	132	134	
134			4.6.3.	GIS send FW mapping back to Engr for review.	1 day	Mon 5/28/18	Mon 5/28/	133	135	
135			4.6.3.	Engineer blesses FW.	1 day	Tue 5/29	Tue 5,	134	137	
136			**5**	**Submit to OWR for Approval**	**93 days**	**Wed 5/30/18**	**Fri 10/5/**			
137			5.1	Prepare OWR Submittal Package	1 day	Wed 5/3	Wed :	135,70	138	
138			5.2	Submit to OWR	1 day	Thu 5/31	Thu 5,	137	139,142	
139			5.3	Wait on OWR review	90 days	Fri 6/1/1	Thu 1	138	140	
140			5.4	Document OWR comments and required model/mapping changes and re-mip.	1 day	Fri 10/5/18	Fri 10/5/	139	150	
141			**6**	**Flood Risk Review (FFR) Meeting**	**6 days**	**Fri 6/1/18**	**Fri 6/8/1**			
142			6.1	Schedule Internal FRR Kickoff Meeting	1 day	Fri 6/1/18	Fri 6/1/1	138	143	
143			6.2	Schedule FRR Meeting (30 days after maps mailed)	1 day	Mon 6/4/18	Mon 6/4/1	142	144	
144			6.3	Prepare for FRR Meeting	1 day	Tue 6/5/	Tue 6,	143	145	
145			6.4	Attend FRR Meeting	1 day	Wed 6/6	Wed (	144	146	
146			6.5	30-Day Comment Period	1 day	Thu 6/7/	Thu 6,	145	147	
147			6.6	Receive and Package Up Comments	1 day	Fri 6/8/1	Fri 6/:	146	149	
148			**7**	**MIP**	**91 days**	**Mon 6/1**	**Mon :**			
149			7.1	Prepare MIP Upload	1 day	Mon 6/1	Mon (	147	150	
150			7.2	Check to see if OWR Approval has been obtained.	1 day	Mon 10/8/18	Mon 10/8/	149,140	151	
151			7.3	Complete Transition Spreadsheet	1 day	Tue 10/9	Tue 1	150	152	
152			7.4	Draft FIS Text	1 day	Wed 10/	Wed :	151	153	
153			7.5	Format Final GIS DB Results	1 day	Thu 10/1	Thu 1	152	154	
154			7.6	Copy Final Products to MIP Submittals Folder	1 day	Fri 10/12/18	Fri 10/12	153	155	
155			7.7	MIP Uploads	1 day	Mon 10/	Mon :	154	157	
156			**8**	**Project Closeout**	**3 days**	**Tue 10/1**	**Thu 1**			
157			8.1	CNMS	1 day	Tue 10/1	Tue 1	155	158	
158			8.2	Project Wrap up Meeting	1 day	Wed 10/	Wed :	157	159	
159			8.3	Finalize Project Closeout	1 day	Thu 10/1	Thu 1	158	160	
160			9	PROJECT COMPLETE	0 days	Thu 10/1	Thu 1	159		



Conclusion

- The critical path is the longest path but it may be longer than another path by say only one day! And so, in a way, you really have two critical paths! The amount of float/slack in the 2nd path indicates how close to being "critical" it is.
- In reality, an activity may often be able to start before the predecessor activity is 100% complete. For example, one could start mixing the cake ingredients as they are measured and not wait until all of the ingredients are measured.
- For each activity, look backwards for predecessor activities and forwards for successor activities!

References

- James J. O'Brien, P.E. and Fredric L. Plotnick, Esq., P.E. ***CPM in Construction Management***, 5th Edition. 1999.

- James J. O'Brien, P.E., **CPM in Construction Management (Project Management with CPM**), 2nd Edition. 1971.