CB 516
Construction Project Management

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Fall - 2019

Resume

Dr. Mohamed Saeid Eid

- BS and MS in construction Engineering, AAST (2008, and 2012, respectively)
- PhD in Civil and Environmental Engineering, Construction focus, University of Tennessee, Knoxville (2017)

Teaching Statement

- Interactive STEM teaching approach
- Multi-disciplinary teaching topics
- Problem-based learning

Research Interest

- Multi-objective optimization
  - Repetitive Activities Scheduling
  - Site layout

- Simulation
  - Disaster Recovery and Community Vulnerability
  - Traffic Behavior
  - Construction performance

- Game Theory
  - Traffic behavior
  - Construction bidding
  - Collaborative construction projects

Syllabus

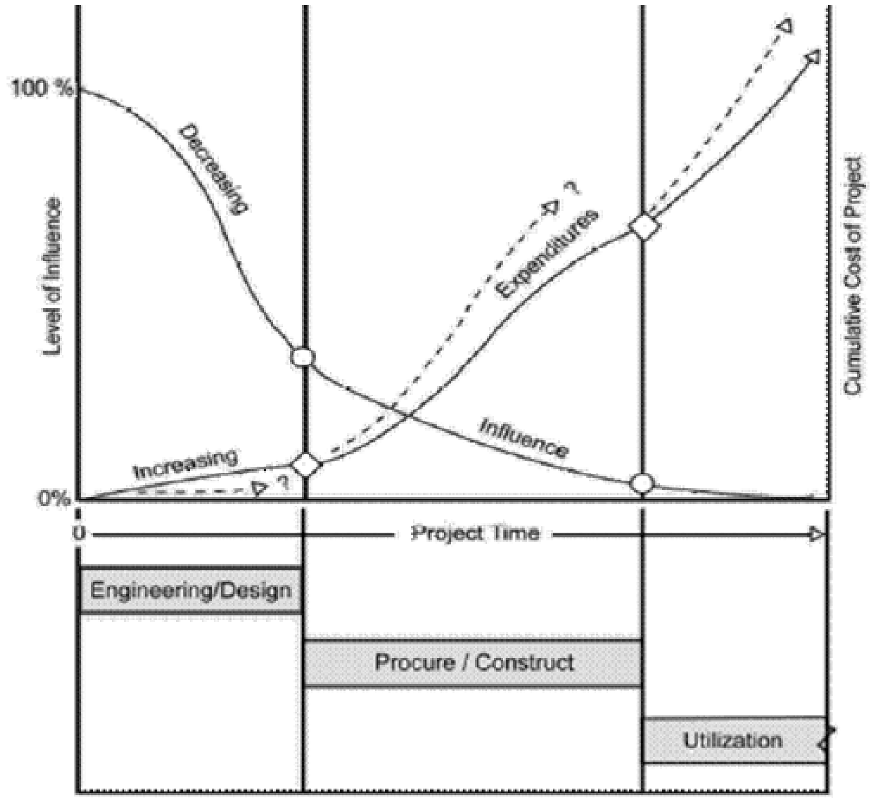
- What do you expect to learn?
  - Developing of a construction plan
  - Scheduling of construction projects
  - Resource management
  - Project monitoring and control
- What will gain from the class?
  - Basic planning and management skills
  - Hands on experience on industry-used tools
- What do I expect from my students?
  - Attention, participation and engagements

Class rules

- Contact
  - No phone calls. Each call worth -5% of your grade.
  - meid@aast.edu
  - Use an appropriate subject title, and English language only
  - Website: Msaeideid.com
- Late assignments
  - No late assignments are accepted beyond due date
- Teamwork
- Class ethics and *Academic Honesty*
- NO CELL PHONES!

Project Management

- What is project?
    - A project is a temporary set of activities with a defined start and end to achieve a specific goal.
    - Control and cost vs. progress



What is planning?

Planning is the process of defining “what” is going to be carried out, “how”, “where” and by “whom”.

Why do we create a plan and a schedule?

- "*He, who every morning plans the transactions of the day, and follows that plan, carries a thread that will guide him through the most busy life*", Victor Hugo

Who creates and needs the construction plan?

- Owner and contractors needs
- Level of details
- Our scope throughout the course

A plan should be S.M.A.R.T

- Specific
- Measurable
- Achievable
- Realistic
- Timely

Life cycle of a plan

1. Study the project
2. Method statement
3. List of activities
4. Dependencies and relationship
5. Calculate duration per activity
6. Determine state and finish date for each activity
7. Get the total project duration
8. Update and fix along the execution phase

Statement of Method

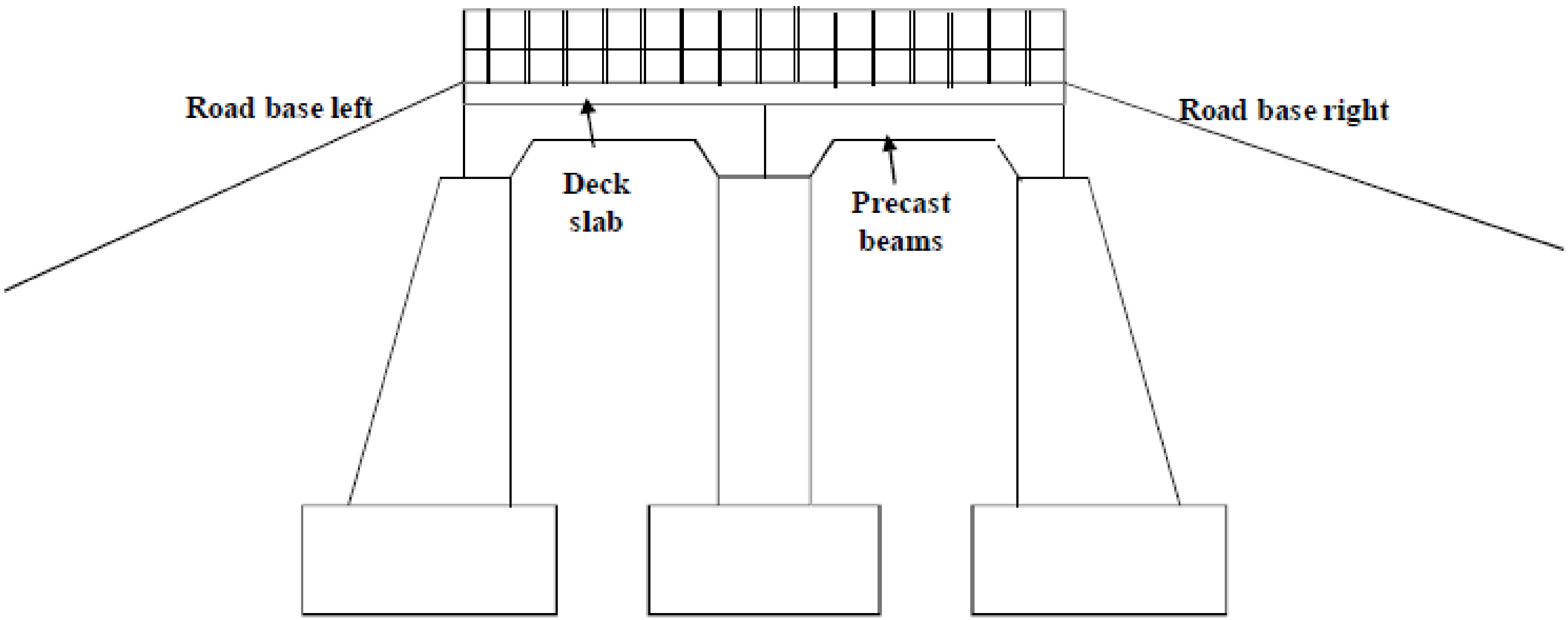
- How would you carry out a project?

- Types of equipment?

- Role of labor?

Example

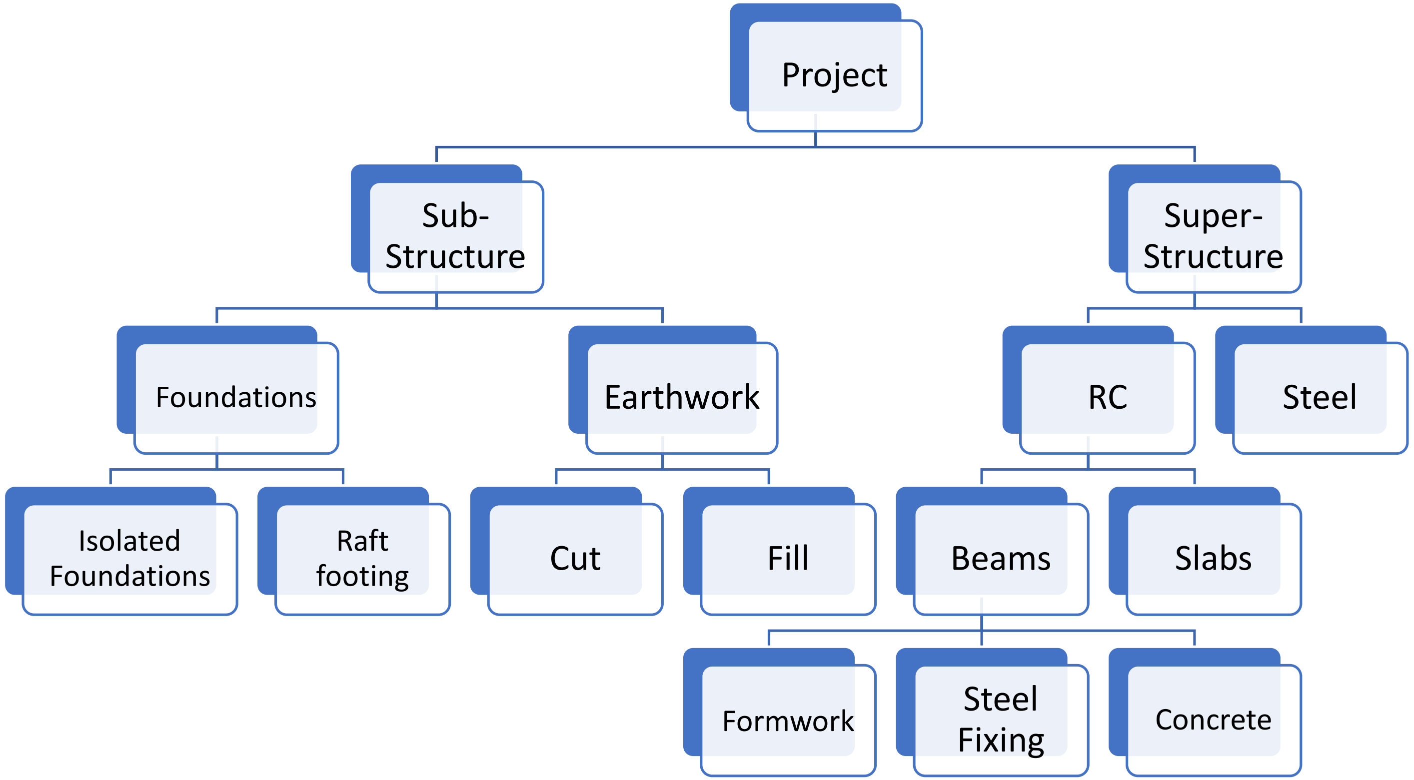
Example (*Double Span Bridge*):



Credit: Prof. Emad Elbeltagi

Work Breakdown Structure (WBS)

- WBS is the hierarchical structure of the project, where we divide it into phases, categories, sections, and activities.



Activities

- Project is divided into packages, packages are divided into activities

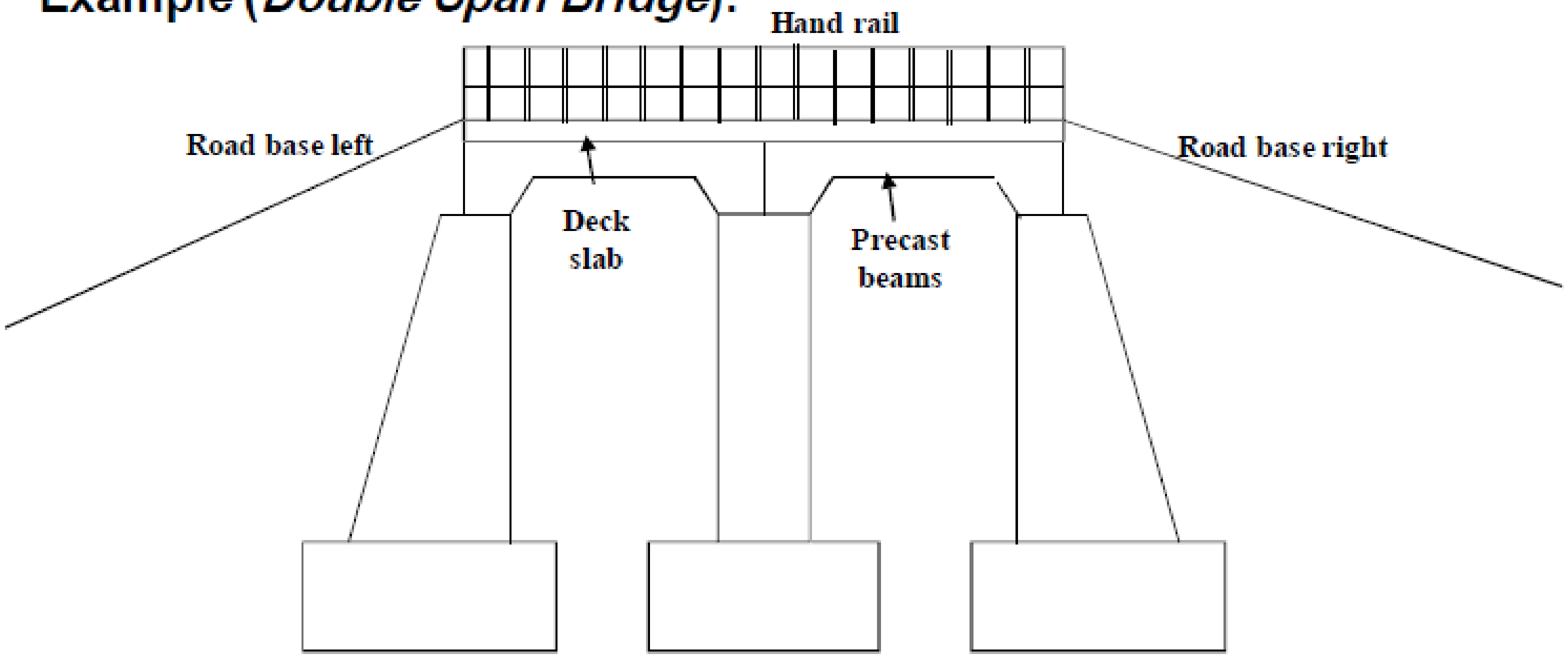
- Activities consume time and resources

- Task/administrative/procurement activities

- Level of detail depends on: planning stage, project size and complexity, etc.

Create a list of activities for this project based on your method statement

Example (*Double Span Bridge*):



Dependencies and Relationships of Activities

Activities dependencies

- The predecessor and successor of activities need to be defined to plan them.

- Predecessors of an activity are the activities that logically and immediately precede it

- Successors of an activity are the activities that logically and immediately follow it.

Relationships

- Four type of activities relationships
  - Finish-Start
  - Start-Start
  - Finish-Finish
  - Start-Finish

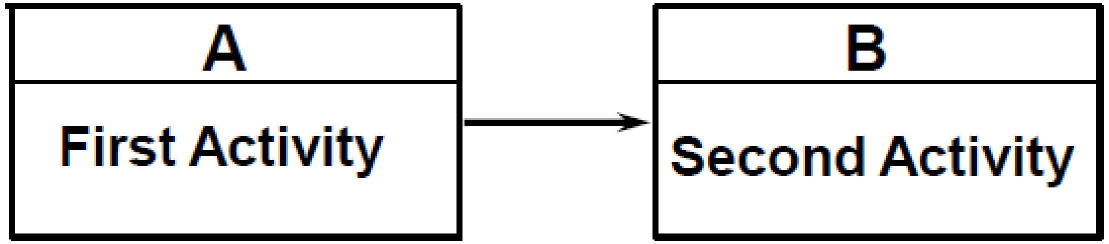
Relationships (Cont'd)

- Finish-Start

Finish-Start

When A finishes, then B can start

Default Relationship



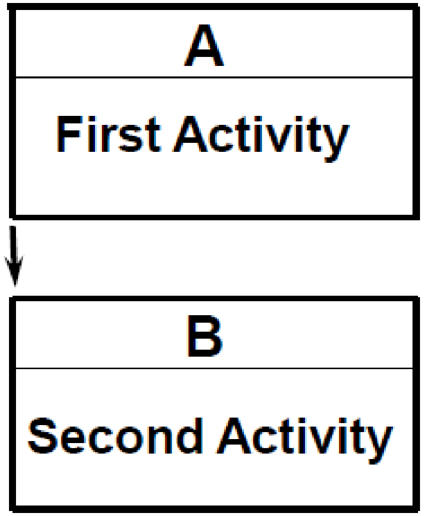
Credit: Prof. Emad Elbeltagi

Relationships (Cont’d)

- Start-Start

Start-Start

When A starts, then B can start



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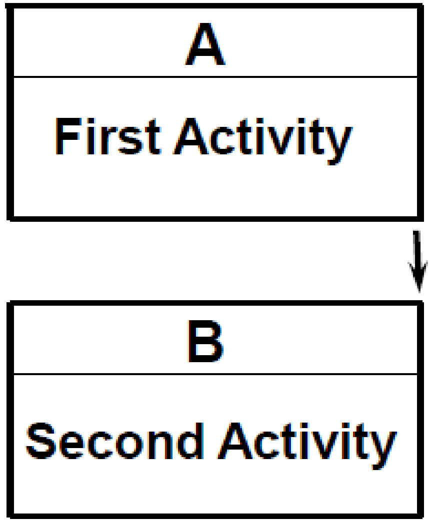
Relationships (Cont'd)

- Finish-Finish

Finish-Finish

When A finishes, then B can finish



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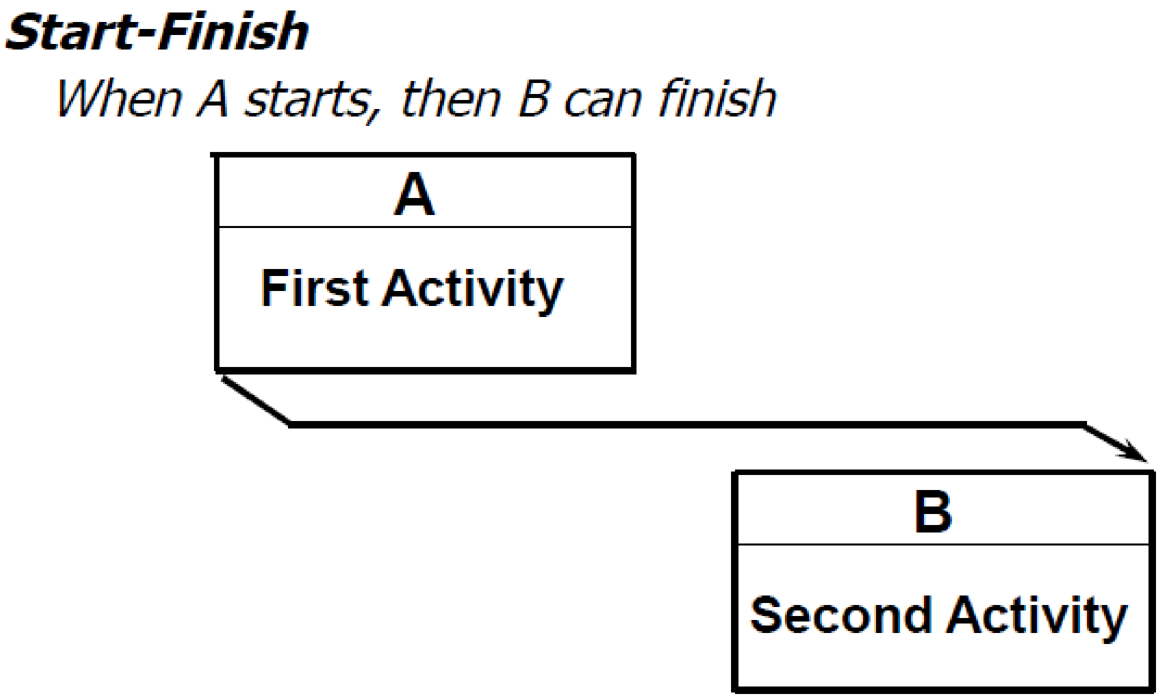
Relationships (Cont’d)

- Start-Finish



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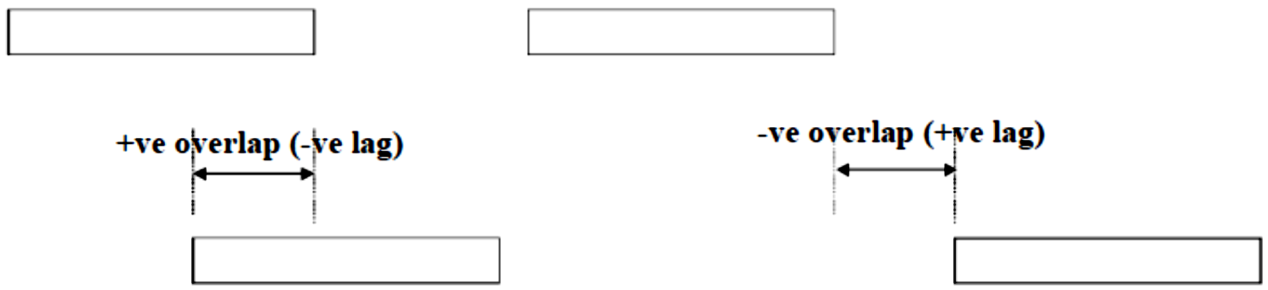
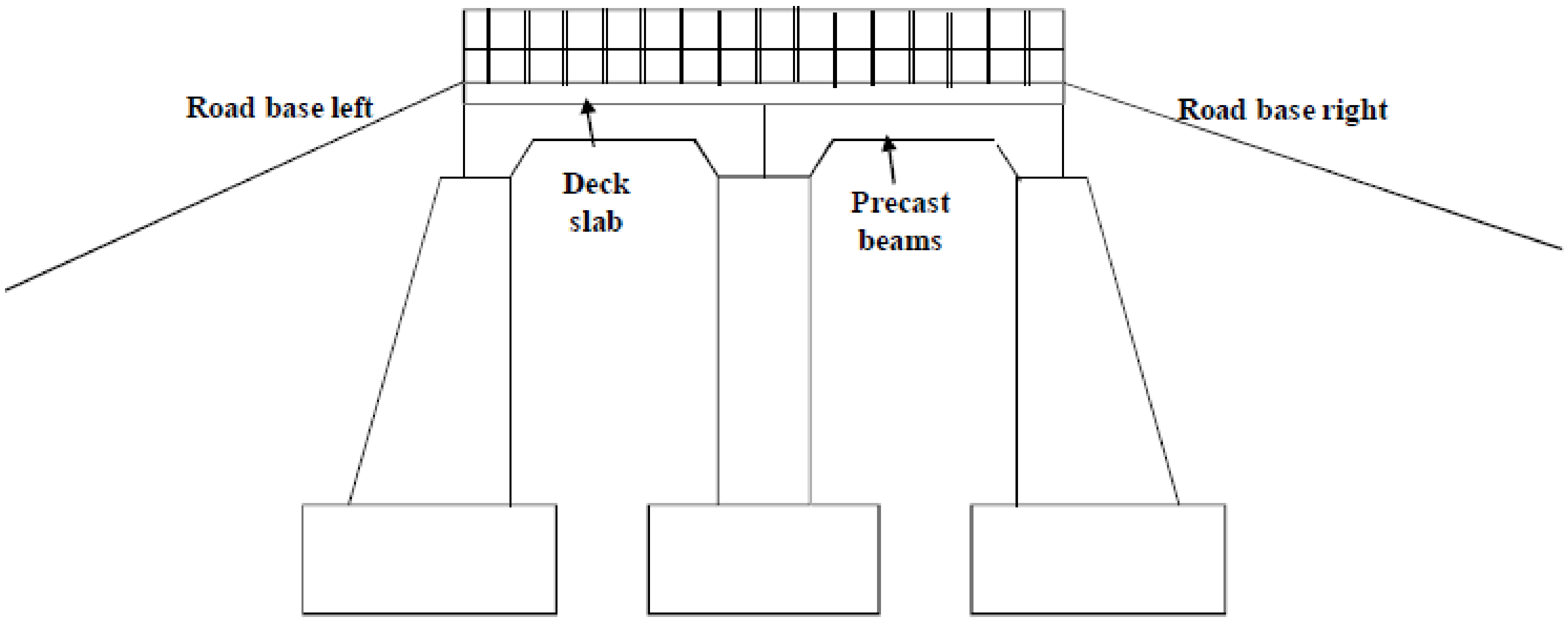
Overlapping and Lag

- Activities can overlap to decrease the project duration or for constructability
- Activities can create a lag between itself and its successor due to constructability or site constraints



Create a full plan for the project.

Example (*Double Span Bridge*):



Code	Description	Predecessor	Code	Description	Predecessor
10	Mobilization and site setup		100	Construct center pier	
14	Procure RFT		110	Erect left precast beam	
16	Procure Precast Beams		120	Erect right precast beam	
20	Excavate left abutment		130	Fill left embankment	
30	Excavate right abutment		140	Fill right embankment	
40	Excavate Center pier		150	Construct deck slab	
50	Foundation left abutment		160	Left road base	
60	Foundation right abutment		170	Right road base	
70	Foundation center pier		180	Road surfacing	
80	Construct right abutment		190	Bridge railing	
90	Construct left abutment		200	Clear site	

What we learned so far

- What is planning
- What do we mean by activities
- Activities predecessors and successors
- Activities relationship, overlap, and lag times

Plan representation

- Activity on Arrow (AOA)
- Activity on Node (AON)
- Bar chart (Gantt chart)
  - We will leave this for later

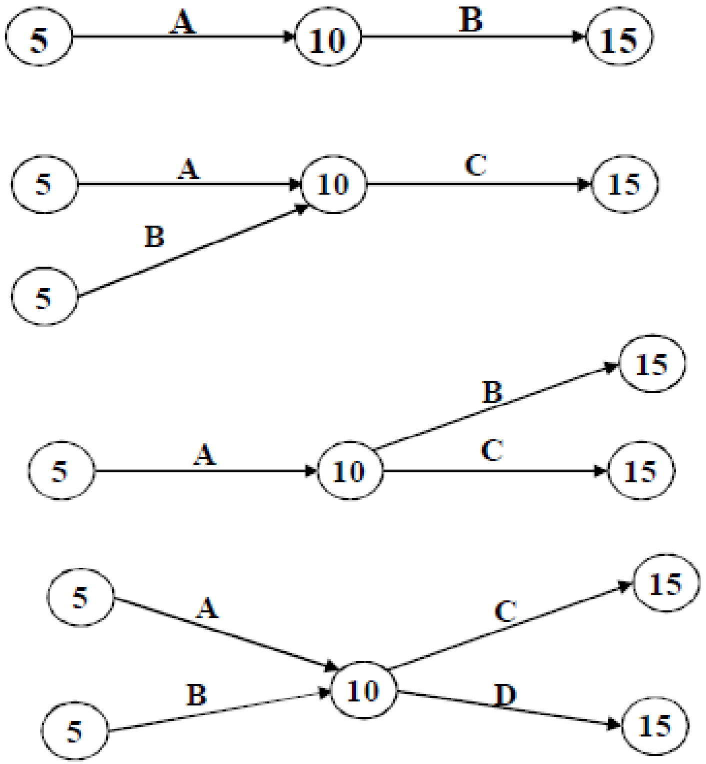
Activity on Arrow

- Each activity is represented by an arrow
- Each arrow is preceded by an event (node), and succeeded by another event
- The event resembles the accomplishment of tasks before starting the following activities

Note: $i < j$

Activity on Arrow (Cont’d)

- Example of different activities representations



B depends on A

C depends on A and B

B depends on A
C depends on A

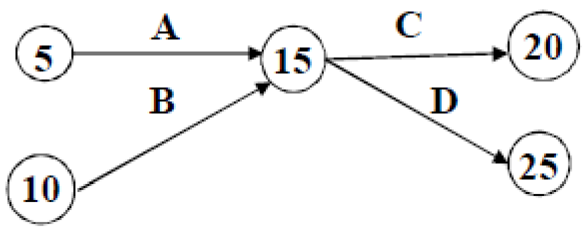
C depends on A and B
D depends on A and B

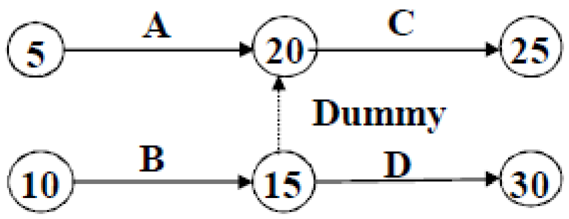
Credit: Prof. Emad Elbeltagi

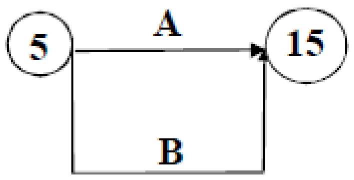
Activity on Arrow (Cont’d)

- Dummy activities

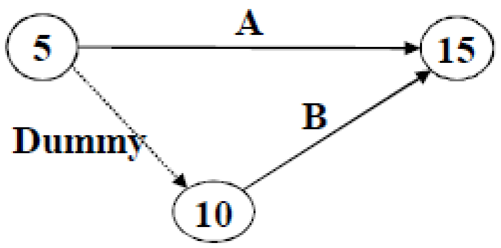
C depends on A and B; D depends on B only







Incorrect representation



Correct representation

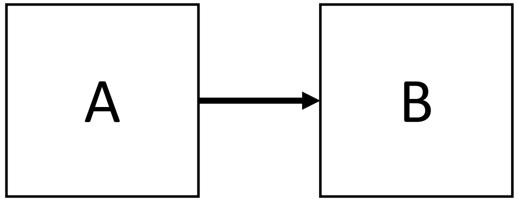
Credit: Prof. Emad Elbeltagi

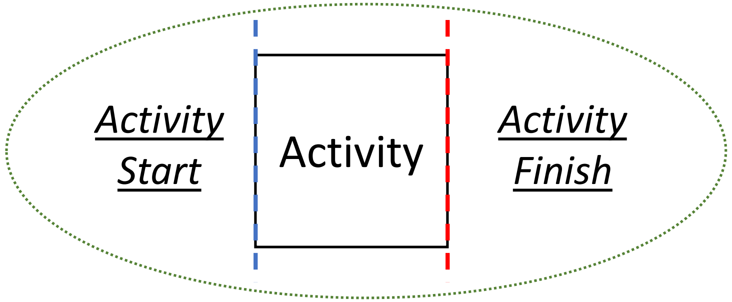
Activity on Arrow (Cont’d)

Activity	Predecessor
A	--
B	A
C	A
D	B,C
E	B
F	D
G	E,F
H	G

Activity on Node

- Activities are represented by nodes
- Arrows connect the activities to represent the relationship between them
- Details of the activities can be shown at the node (more next lecture)





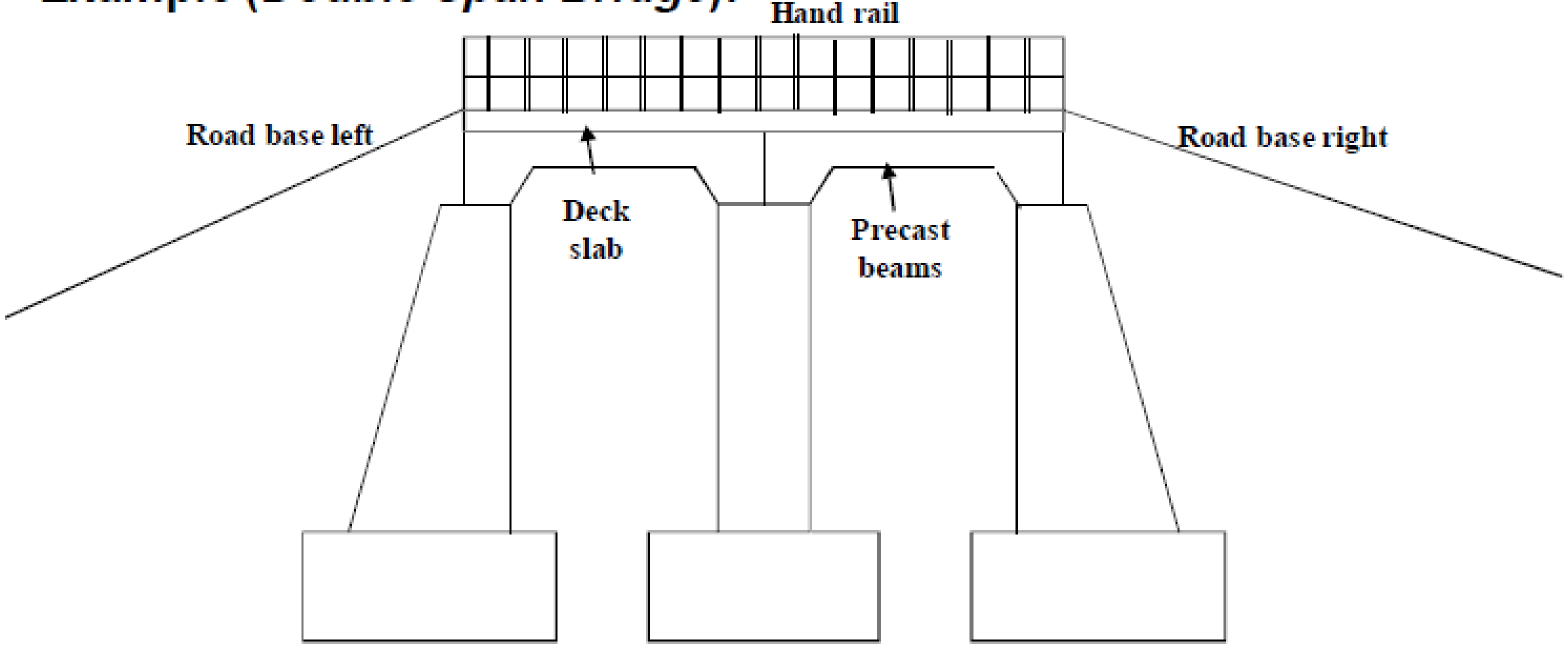
Activity on Node (Cont’d)

Activity	Predecessor
A	--
B	A
C	A
D	B,C
E	B
F	D
G	E,F
H	G

Note: Try to create levels when you represent your plan

Let us represent the example through AoN

Example (*Double Span Bridge*):



Code	Description	Predecessor	Code	Description	Predecessor
10	Mobilization and site setup	NA	100	Construct center pier	70
14	Procure Reinforcement	NA	110	Erect left precast beam	16,80,100
16	Procure Precast Beams	NA	120	Erect right precast beam	16,90,100
20	Excavate left abutment	10	130	Fill left embankment	80
30	Excavate right abutment	10	140	Fill right embankment	90
40	Excavate Center pier	10	150	Construct deck slab	110,120
50	Foundation left abutment	14,20	160	Left road base	130
60	Foundation right abutment	14,30	170	Right road base	140
70	Foundation center pier	14,40	180	Road surfacing	150,160,170
80	Construct left abutment	50	190	Bridge railing	150
90	Construct right abutment	60	200	Clear site	180, 190

Scheduling

Provide a time dimension to your plan

Scheduling

- Scheduling is determining the start and end dates of each activity

- Consequently, a planner can determine the project total duration

Critical Path Method (CPM)

- CPM was developed in the 1950s
- CPM is a simple and systematic algorithm to calculate the start and end dates of the activities, determine the project duration, and define the critical path
- Critical path is a set of activities in the project that cannot be delayed without delaying the project (later on that later)

CPM

- CPM calculation requires
  - ✓ Develop the relationship of activities
  - ✓ Define the overlap and lag of activities
  - ❑ Calculate the duration of each activity ⇨
  - ❑ Carryout the forward path
  - ❑ Carryout the backward path
  - ❑ Calculate floats
  - ❑ Determine the critical path

$$d_i = \frac{q_i}{p_m}$$

Where, *i* is the activity, *d* is the duration of the activity, *q* is the quantity of work in the activity, and *p* is the production rate of construction crew *m*.

CPM – Forward and Backward Paths

- Each activity has early and late dates
  - Early Start (ES)
    - Earliest possible start date of an activity
  - Early Finish (EF)
    - Earliest possible finish date of an activity
  - Late Start (LS)
    - Latest start date of an activity without delaying the project
  - Late Finish (LF)
    - Latest finish date of an activity without delaying the project

ES	Code	EF
LS	Dur	LF

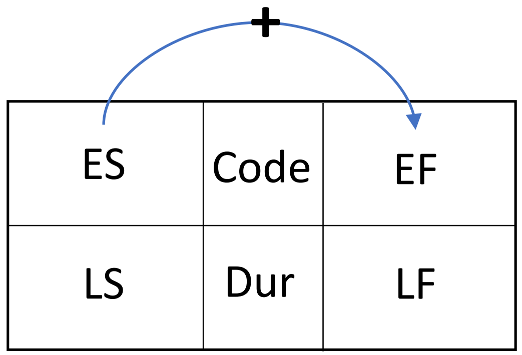
CPM – Forward and Backward paths

- Forward path steps
  - Calculate ES

    ES = max [Predecessors’ EF]

  - Calculate EF

    EF = ES + Duration



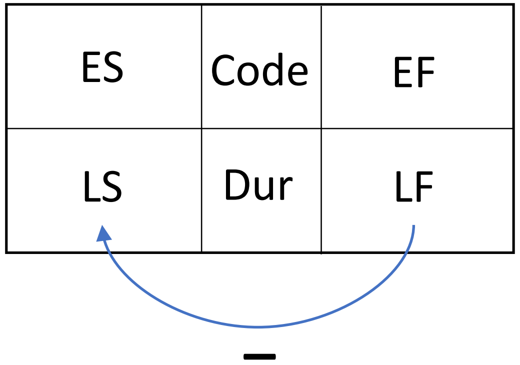
CPM – Forward and Backward paths

- Backward path steps
  - Calculate LF

    LF = min [Successors' LS]

  - Calculate LS

    LS = LF - Duration



Example

Activity	Predecessor	Duration
A	--	5
B	A	3
C	A	2
D	B	7
E	B,C	3
F	D,E	5
G	E	6
H	F,G	2

CPM – Floats

- Free Float (FF)
  - FF is the amount of delay the activity can have without delaying its immediate successors

$$FF = \min [\text{Successors' } ES] - EF$$

- Total Float (TF)
  - TF is the amount of delay the activity can have without delaying the total project

$$TF = LS - ES = LF - EF$$

Note: These equations are for F-S relationship

Critical Activities and Critical Path

- Critical Activities are the activities with Zero TF

- Critical Path is the set of Critical Activities

Note:

Critical path must be continuous

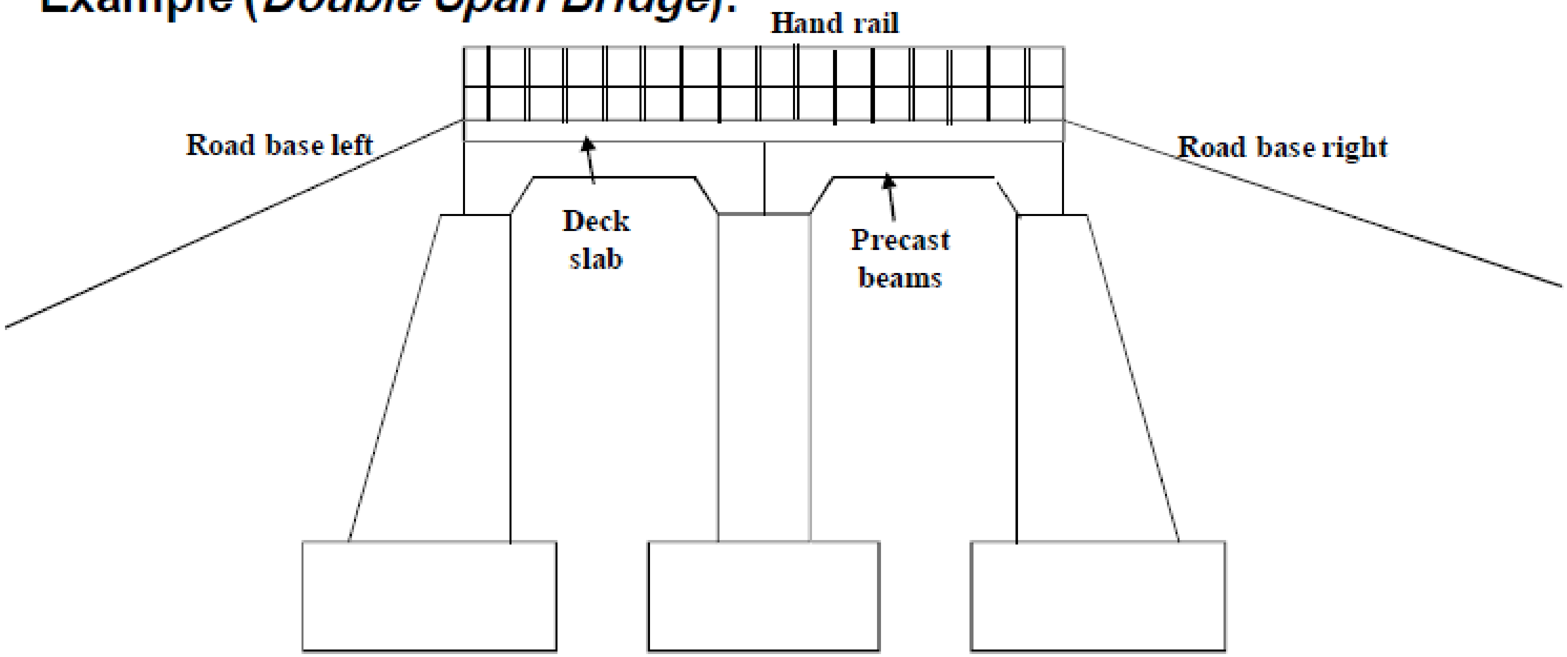
There can exist more than one critical path

If an activity has a TF = 0, then the FF should be = 0

if an activity has a FF = 0, the TF DOES NOT have to be = 0

Let us schedule the project

Example (*Double Span Bridge*):



Code	Description	Predecessor	Duration	Code	Description	Predecessor	Duration
10	Mobilization and site setup	NA	2	100	Construct center pier	70	6
14	Procure Reinforcement	NA	1	110	Erect north precast beam	16,80,90,100	2
16	Procure Precast Beams	NA	1	120	Erect south precast beam	16,80,90,100	2
20	Excavate left abutment	10	5	130	Fill left embankment	80	2
30	Excavate right abutment	10	5	140	Fill right embankment	90	2
40	Excavate Center pier	10	2	150	Construct deck slab	110,120	5
50	Foundation left abutment	14,20	6	160	Left road base	130	3
60	Foundation right abutment	14,30	6	170	Right road base	140	3
70	Foundation center pier	14,40	5	180	Road surfacing	150,160,170	5
80	Construct left abutment	50	8	190	Bridge railing	150	1
90	Construct right abutment	60	8	200	Clear site	180, 190	2

Resource Management

Who is doing what

Resources

- What are resources?
  - Resources are everything that is needed to undertake an activity
  - Resources can be consumable (material and money) and non-consumable (equipment and labors)
  - Resources can be classified as general (used by any activity), key (skilled labor or special equipment)

CPM Drawbacks in Resources

- CMP is a duration-oriented approach
- CPM assumes resources to be unlimited and can be accesses all the time.

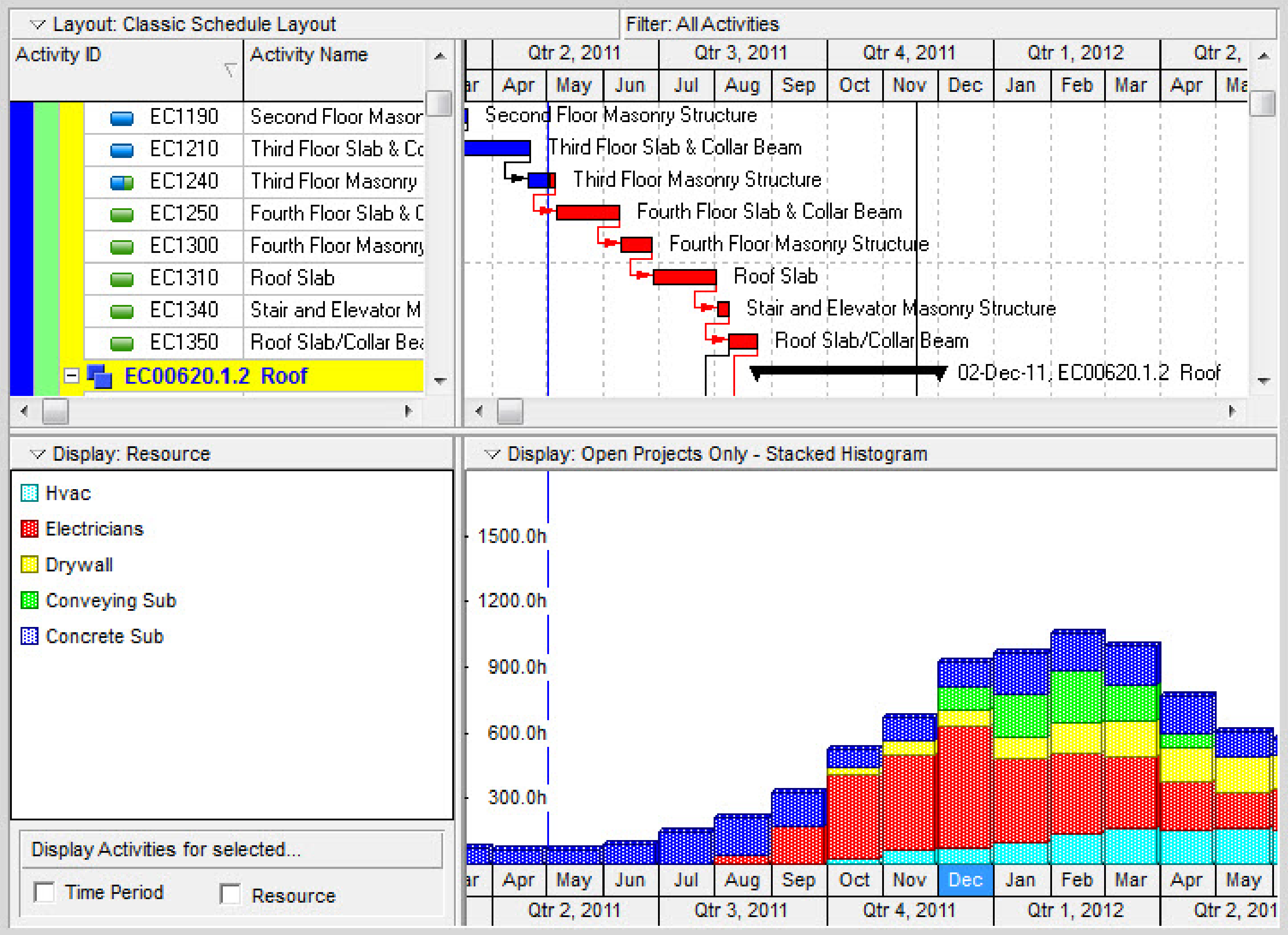
CPM and Resources

- Need to check on resources availability

- Resource loading on CPM

Resource Loading

- After CPM calculation, a planner can allocate (load) the resources on each activity
- The representation can be done graphically through Bar Chart and Histogram



Resource Loading

- Consider the following project and draw a Bar Chart with Resource Histogram

Activity	Predecessor	Duration	Resource
A	--	2	10
B	A (overlap 1 day)	3	8
C	B (overlap 1 day)	2	2
D	B	5	10
E	D (overlap 1 day)	2	6

Resource problems

- Resource fluctuation (firing and hiring)
  - Resource loading profiles need to be smooth
  - Resources unconstrainted
  - Project duration is constrained

- Resource scheduling
  - Resources are constrained
  - Need to schedule start and finish day of each resource
  - Project duration can be changed, but minimally

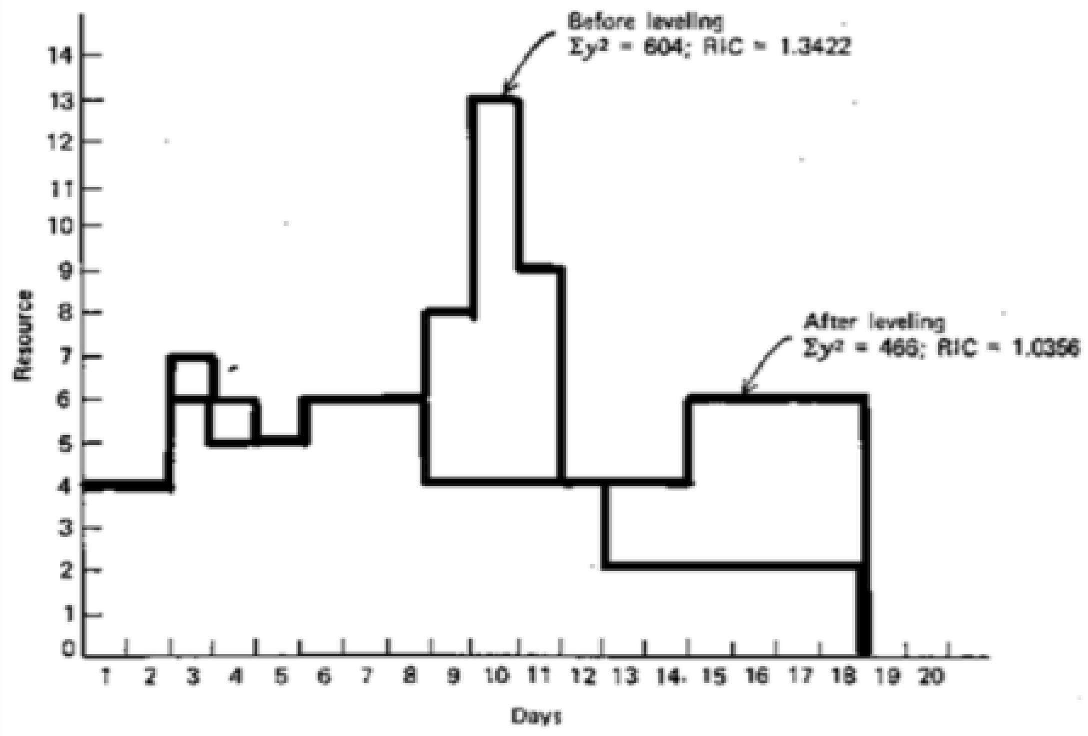
Resource Smoothing

- Solving techniques can include
  - Optimization model (LP, evolutionary, dynamic programming, etc.)
  - Heuristic models (rule of thumb)

Resource Smoothing

- Minimum Moment Heuristic approach

Minimum Moment Algorithm = ∑ Yi * Yi /2



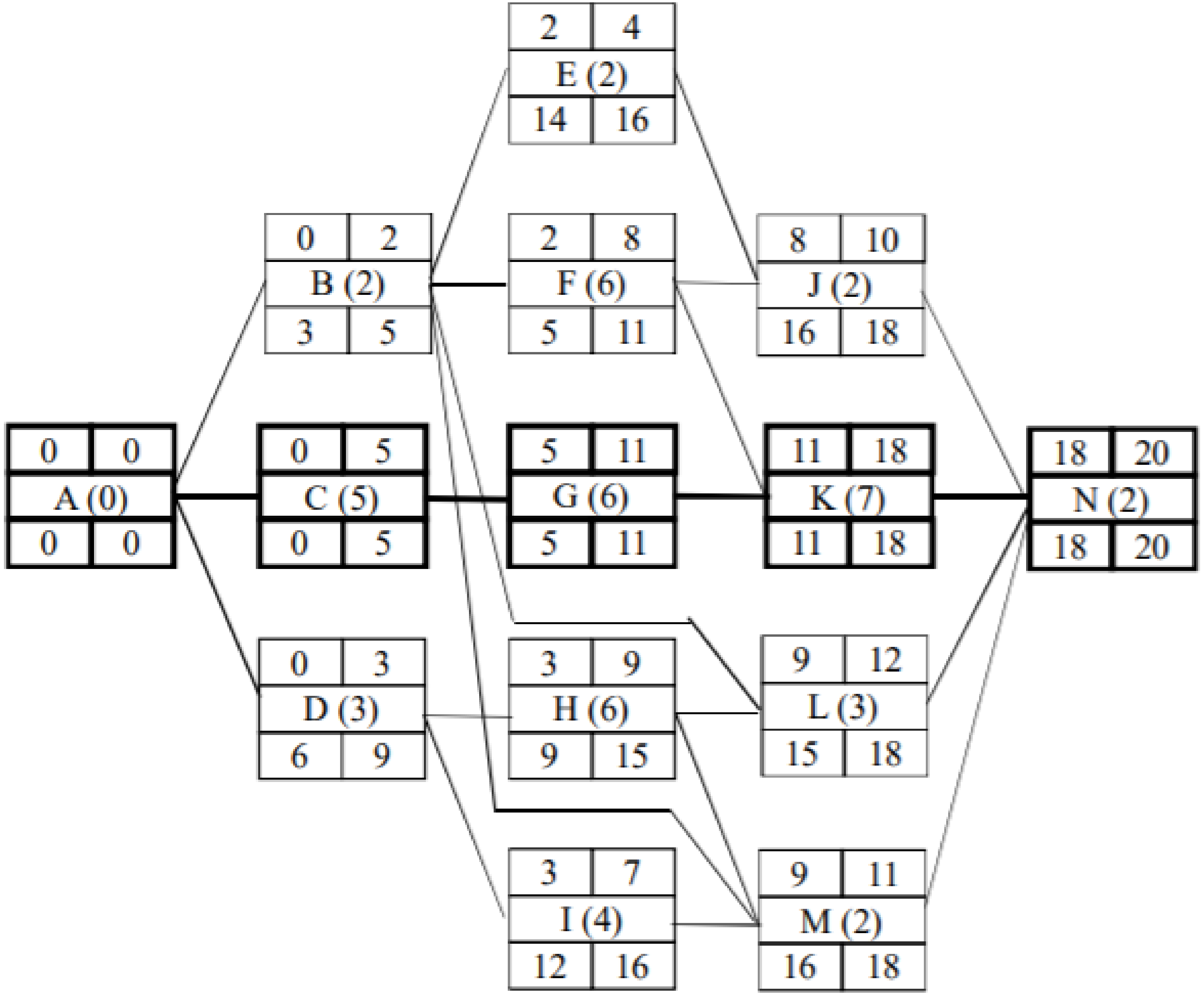
Credit: Prof. Emad Elbeltagi

Resource Smoothing

- Process
  - Draw a bar chart based on CPM’s ES timings
  - Draw critical activities alone so as not to be changed
  - Draw FF and TF on the bar chart
  - Load the resources on each activity
  - Add all resources per period at the bottom of the bar chart
  - Calculate total needed resources
  - Calculate the average resource usage
  - Shift non-critical activities based on their FF then their TF to decrease the resources peaks and raise the resource valleys
  - Revise floats, and repeat till smoothing is achieved

Activity	Duration (Weeks)	Predecessors	Resource (units/week)
A	0	-	0
B	2	A	0
C	5	A	2
D	3	A	2
E	2	B	1
F	6	B	2
G	6	C	3
H	6	D	1
I	4	D	0
J	2	E,F	4
K	7	F,G	2
L	3	B,H	2
M	2	B,H,I	4
N	2	J,K,L,M	0

Credit: Prof. Emad Elbeltagi



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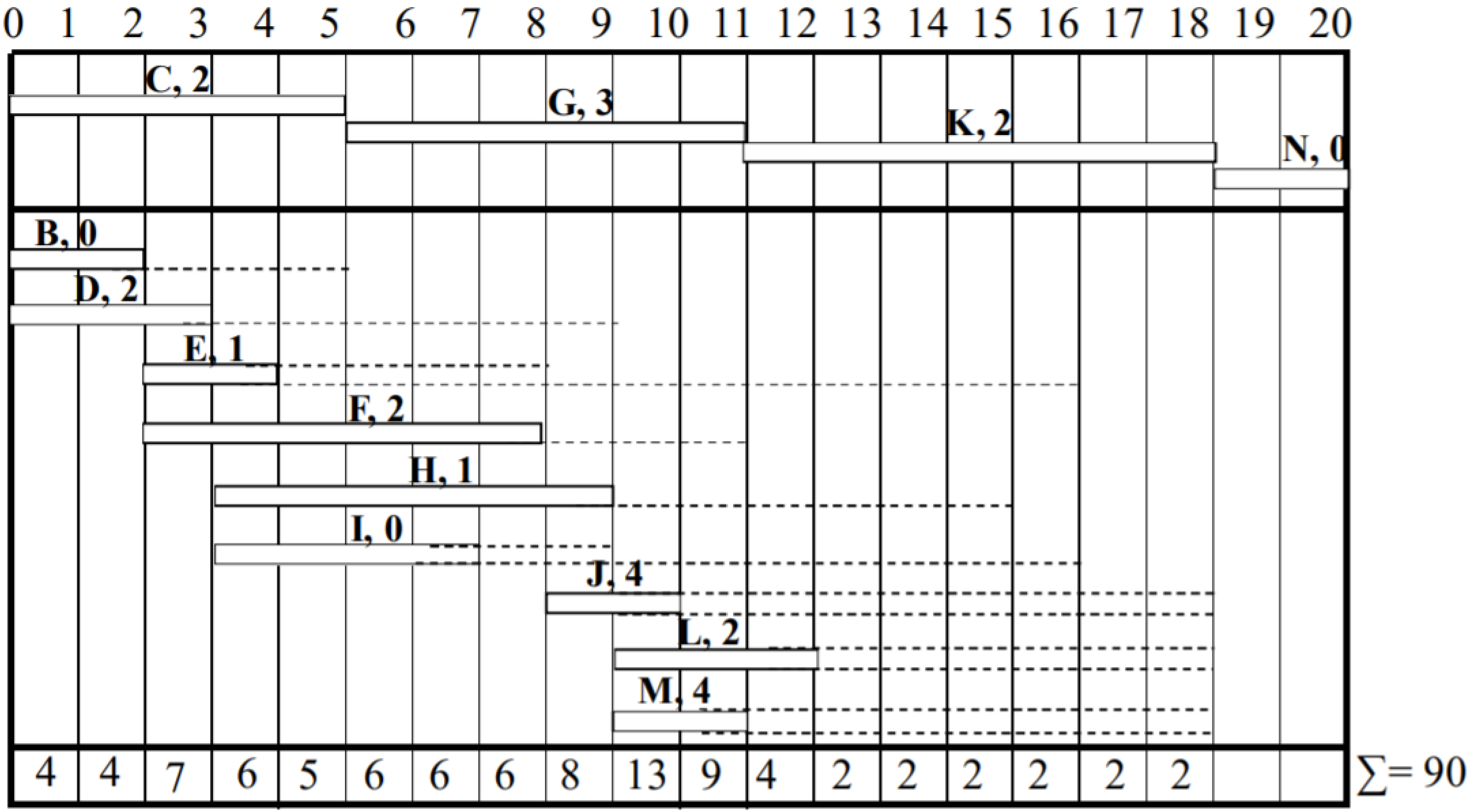

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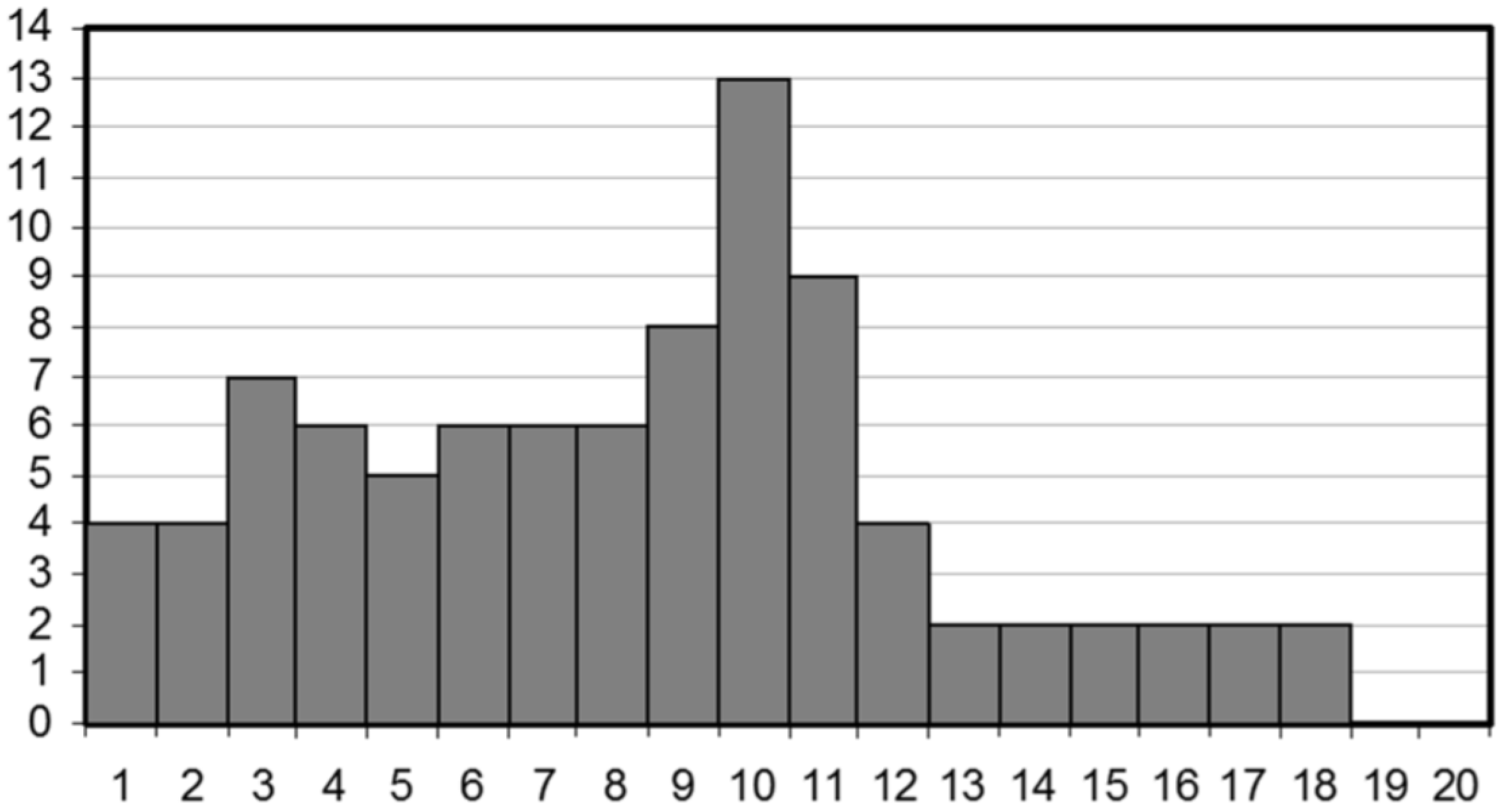

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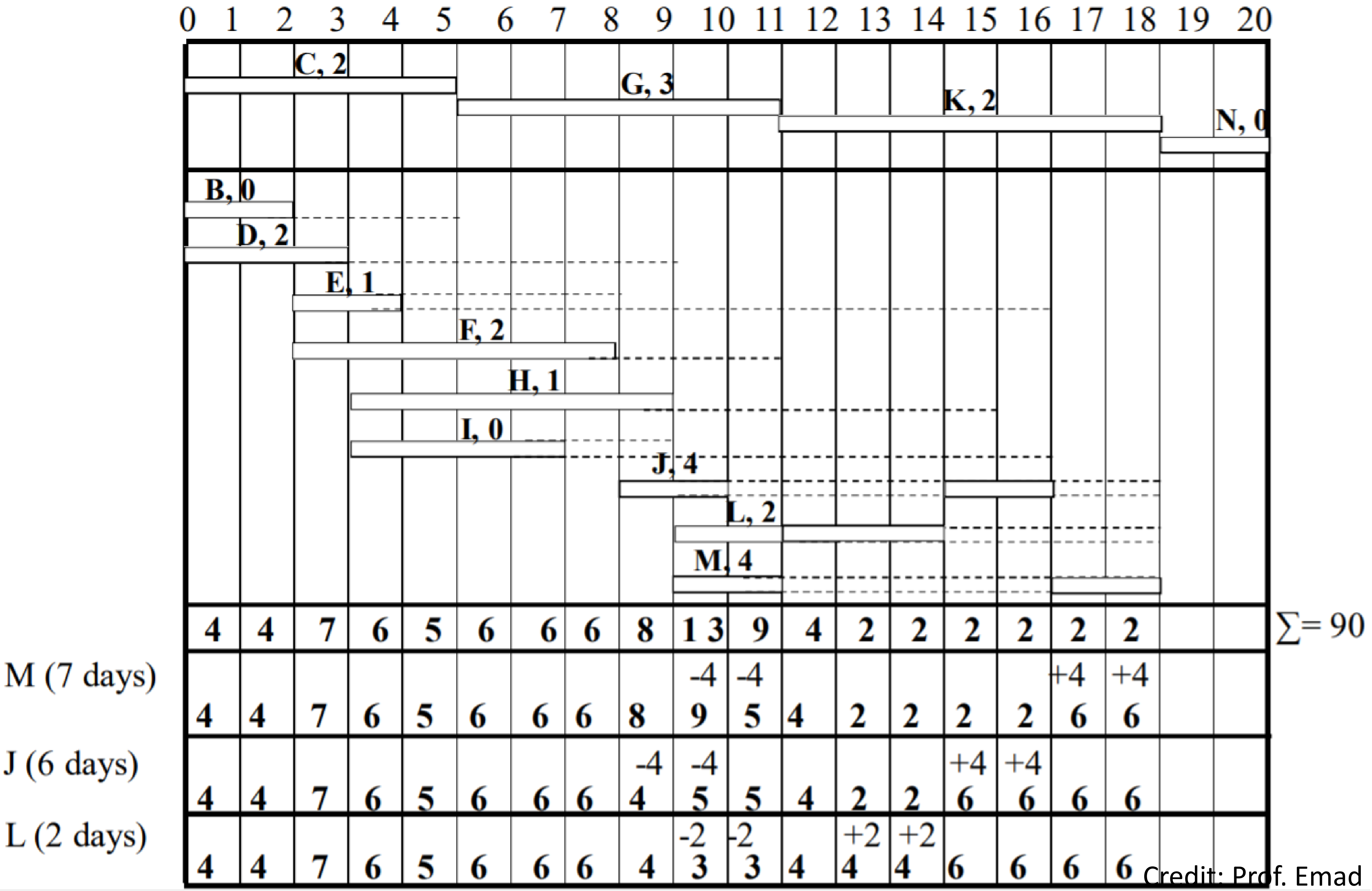

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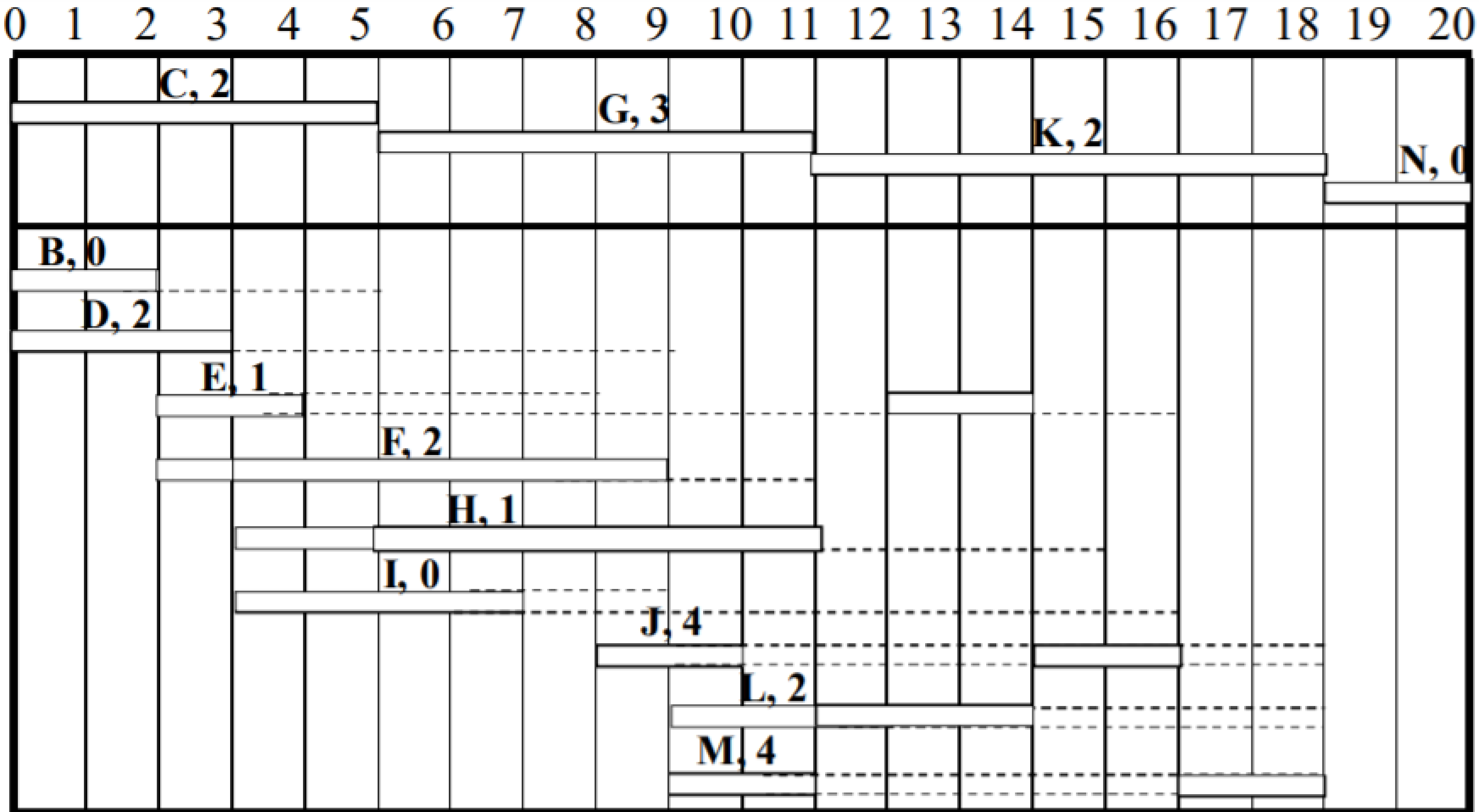
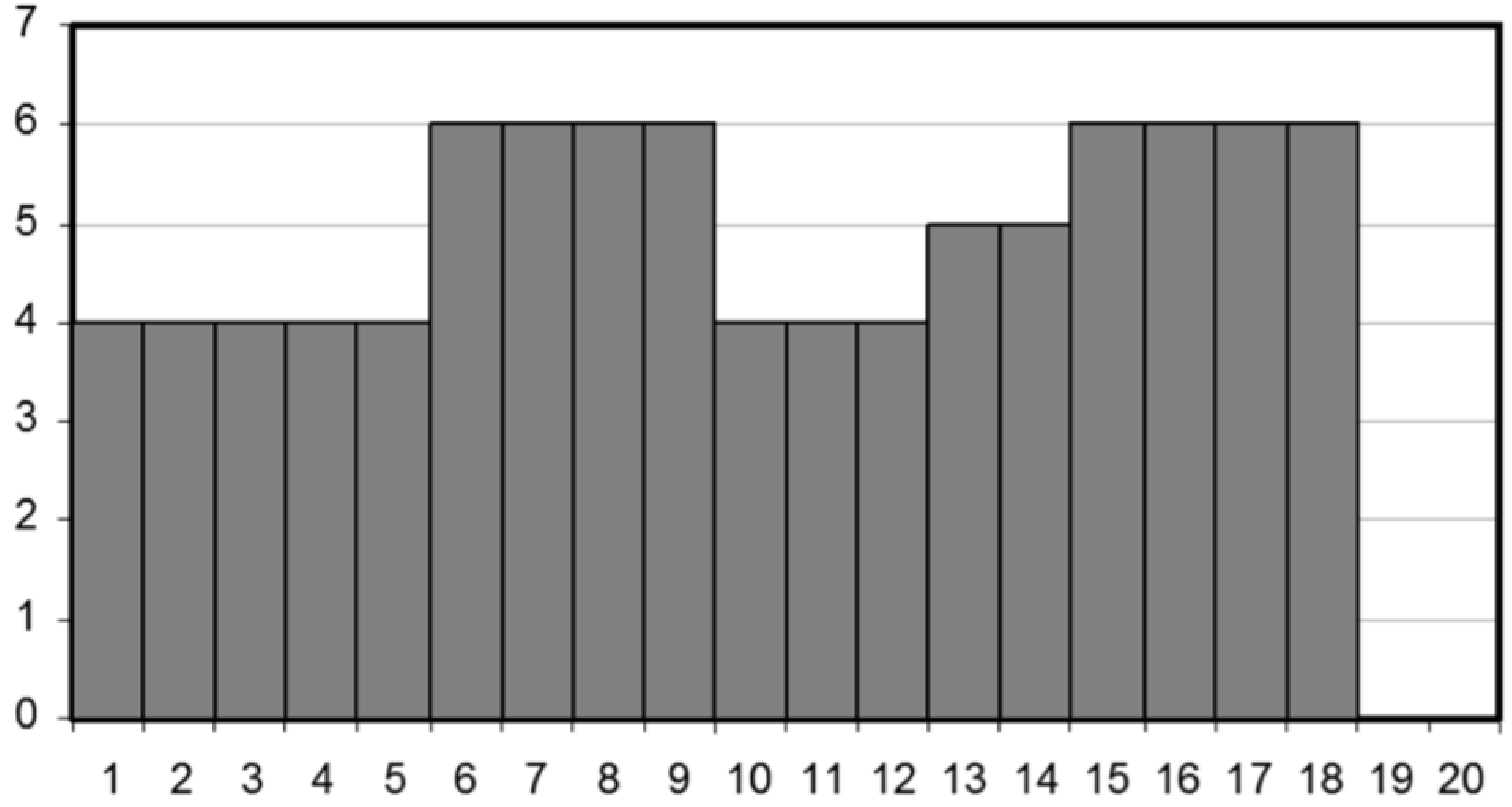


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
	4	4	7	6	5	6	6	6	4	3	3	4	4	4	6	6	6	6			∑= 90
E (10 days)	4	4	-1 6	-1 5	5	6	6	6	4	3	3	4	+1 5	+1 5	6	6	6	6			
H (2 days)	4	4	6	-1 4	-1 4	6	6	6	4	+1 4	+1 4	4	5	5	6	6	6	6			
F (1 days)	4	4	-2 4	4	4	6	6	6	+2 6	4	4	4	5	5	6	6	6	6			

Credit: Prof. Emad Elbeltagi



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Resource problems

- Resource fluctuation (firing and hiring)
  - Resource loading profiles need to be smooth
  - Resources unconstrained
  - Project duration is constrained
- Resource scheduling
  - Resources are constrained
  - Need to schedule start and finish day of each resource
  - Project duration can be changed, but minimally

Prioritizing Activities Competing on Resources

- The objective is to determine the start and finish date of an activity based on the resources undertaking them.
- The main obstacle here is to determine which activity to prioritize if both activities are scheduled to work in parallel.

Prioritizing Activities Competing on Resources

- There are number of optimizing models (LP, evolutionary algorithms, etc.)
- We are going to use a heuristic approach that allows us achieve minimal increase in duration while respecting the limitation in resources.

Can you figure out a rule?

Prioritizing Activities Competing on Resources

- We can prioritize the activities depending on their TF
  - Not really a great idea!
- We can prioritize the activities depending on the LS
  - This means that activities with earlier LS, are more critical than others.

Resource Scheduling Process – CPM approach

- Prepare a complete CPM
- Calculate daily needed resources
- If demand is greater than available resources, determine the activities competing on the resources.
- Prioritize the activities’ start date (and delay of some activities) depending on their LS.
- Tabulate your results

Activity	Duration (Weeks)	Predecessors	Resource (units/week)	
			R1≤8	R2 ≤1
A	4	-	3	0
B	6	-	6	1
C	2	-	4	0
D	8	A	0	1
E	4	D	4	1
F	10	B	0	1
G	16	B	4	0
H	8	F	2	0
I	6	E, H	4	1
J	6	C	5	1
K	10	G, J	2	0

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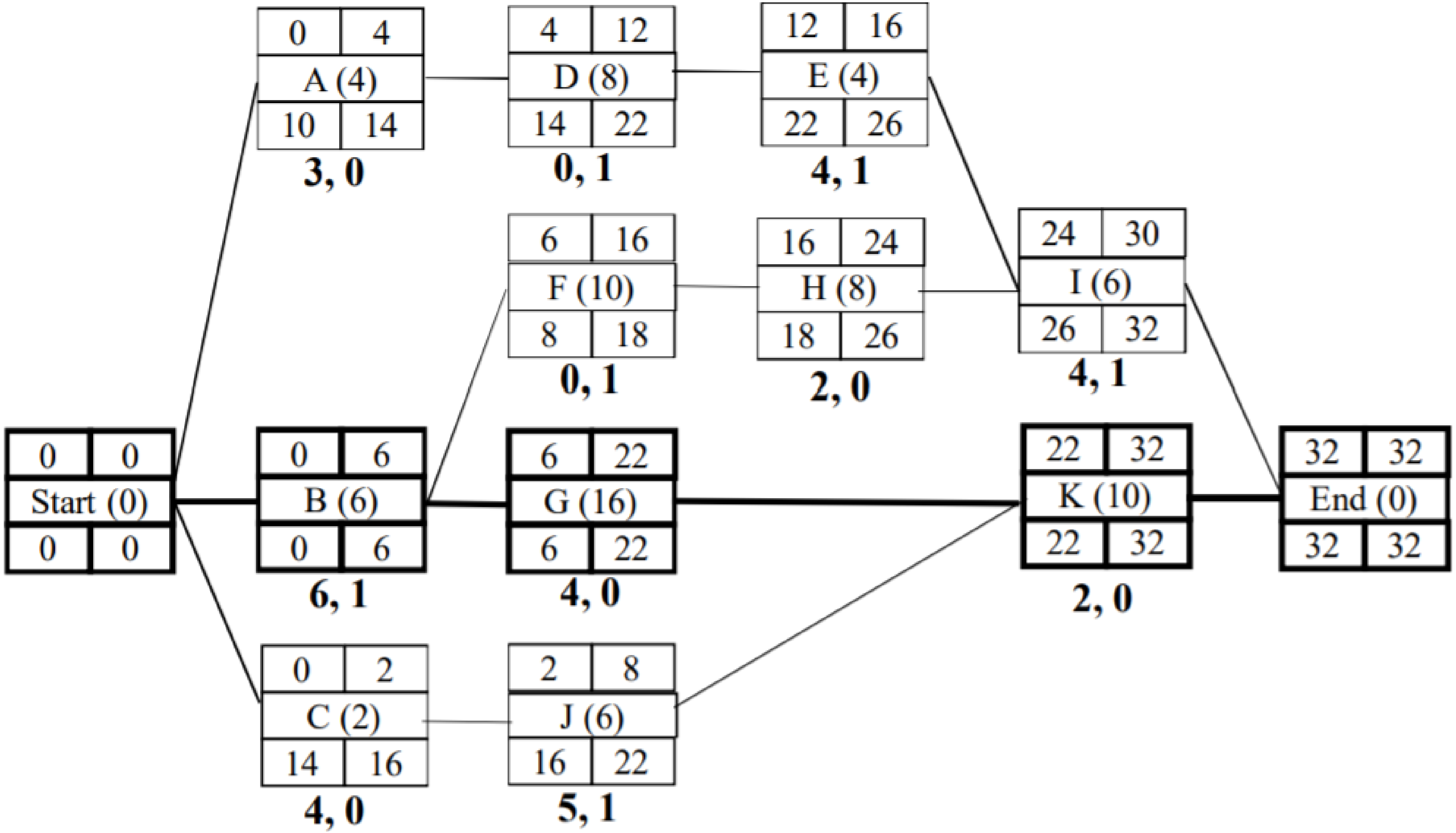

0 4 A (4) 10 14
3, 0
4 12 D (8) 14 22
0, 1
12 16 E (4) 22 26
4, 1
6 16 F (10) 8 18
0, 1
16 24 H (8) 18 26
2, 0
24 30 I (6) 26 32
4, 1
0 0 Start (0) 0 0
0 6 B (6) 0 6
6, 1
6 22 G (16) 6 22
4, 0
22 32 K (10) 22 32
2, 0
32 32 End (0) 32 32
0 2 C (2) 14 16
4, 0
2 8 J (6) 16 22
5, 1

Example

Current Date	Eligible Activities	Resources		Duration	LS	Decision	Finish Date
		R1 ≤ 8	R2 ≤ 1				

Example

Current Time	Eligible Activities	Resources		Duration	Earliest LS	Decision	Finish Time
		R1≤8	R2 ≤1				
0	B	6	1	6	0	Start	6
	A	3	0	4	10	Delay	-
	C	4	0	2	14	Delay	-
6	G	4	0	16	6	Start	22
	F	0	1	10	8	Start	16
	A	3	0	4	10	Start	10
	C	4	0	2	14	Delay	-
10	G	4	0	16	-	Continue	22
	F	0	1	10	-	Continue	16
	C	4	0	2	14	Start	12
	D	0	1	8	14	Delay	-
12	G	4	0	16	-	Continue	22
	F	0	1	10	-	Continue	16
	D	0	1	8	14	Delay	-
	J	5	0	6	16	Delay	-
16	G	4	0	16	-	Continue	22
	D	0	1	8	14	Start	24
	J	5	1	6	16	Delay	-
	H	2	0	8	18	Start	24

Example

Current Time	Eligible Activities	Resources		Duration	Earliest LS	Decision	Finish Time
		R1≤8	R2 ≤1				
22	D H J	0 2 5	1 0 1	8 8 6	- - 16	Continue Continue Delay	24 24 -
24	J E	5 4	1 1	6 4	14 22	Start Delay	30 -
30	E K	4 2	1 0	4 10	22 22	Start Start	34 40
34	K I	2 2	0 0	10 6	- 26	Continue Start	40 40